The Venus Climate Database

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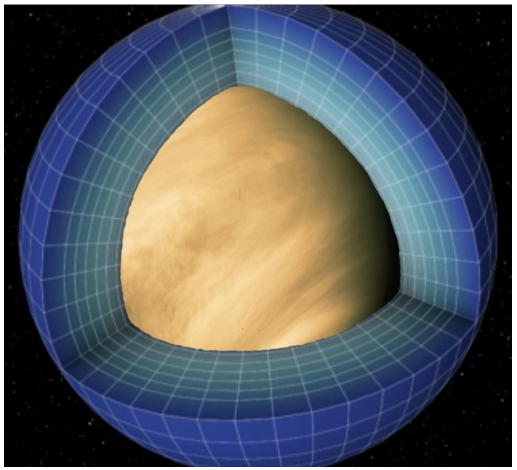
Direct use in users' codes

Various langage interfaces

The IPSL Venus GCM

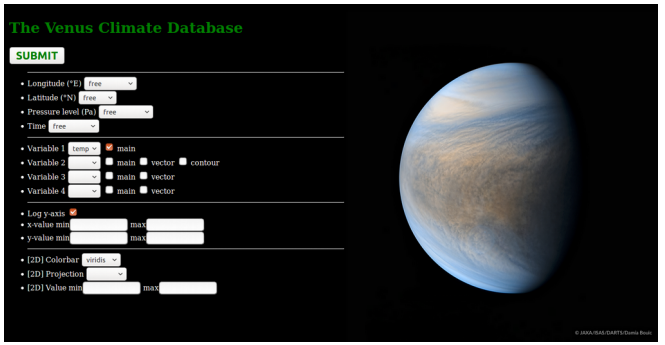


From surface to 250 km

VCD

routine suite

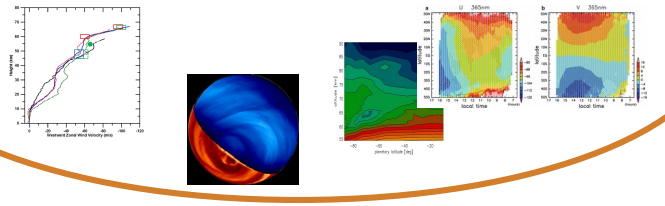
call_vcd(*z_key,z,lon,lat,…,*
T,p,dens,zonwind,...)

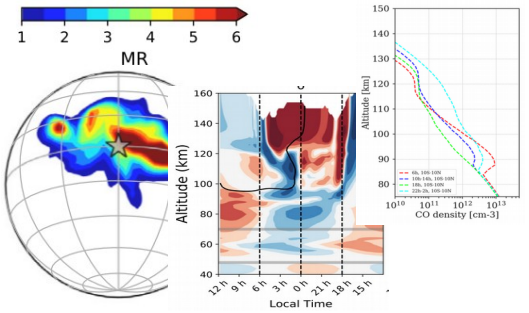


Simple web interface use

Validation

Observational datasets





see Martinez et al.,
same session

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)

The Venus Climate Database

- Based on the same principles as the well-known Mars Climate Database (MCD)
- The Venus Climate Database (VCD) is a database **derived from Global Climate Model** (GCM) **simulations**, using the IPSL Venus GCM.
- **ESA is funding the project**, in relation with the EnVision candidate M5 mission
- The VCD is intended to be useful for engineering applications (e.g. Aerobraking studies, Entry Descent & Landing studies) and scientific work which require accurate knowledge of the Venusian atmosphere (e.g. analysis of observations).
- The VCD will be freely available (public release in september 2021), either via light online access for moderate needs (web interface), or a full version which includes advanced post-processing software (Fortran subroutine call_vcd; examples of C, C++, IDL, MATLAB, SCILAB, Python interfaces are provided).

VCD content and main features

Main access software (**call_vcd**):

- Primarily composed of a Fortran subroutine (benefit from MCD heritage) 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 will include one full Venus day of computations, sampled at 1/24th of a Venusian day to accurately represent the diurnal cycle

VCD content and main features

- The VCD enables to reconstruct realistic conditions using:
  - day-to-day (i.e. V-hourly) variability of main atmospheric fields
  - adding random small scale perturbations as gravity waves (of user specified wavelength)
  - adding random large scale perturbations (extracted from EOFs of individual GCM runs)
- It also offers a high resolution (wrt GCM resolution) prediction of surface pressure when taking into account a higher resolution topography (Magellan map).

VCD content and main features

Foreseen available VCD scenarios:

The VCD must reflect (include) the impact of forcings over longer scales than a Venusian day, e.g.:

- The Sun's extreme UV input to the upper atmosphere => cases with minimum, average and maximum EUV (E10.7 index) will be included as scenarios.
- Possible long-term evolution of the UV albedo at the cloud top (Lee et al, 2019) => realistic extreme bracketing cases will be included as additional scenarios.

VCD content and main features

call_vcd inputs:

- **z_key:** Enabling the user to choose between different possible vertical coordinates (pressure, altitude above surface or altitude above reference geoid)
- **z:** vertical coordinate value (in m or Pa, depending on z_key)
- **lon:** longitude (in degrees East)
- **lat:** latitude (in degrees North)
- **hires_key:** flag to switch to high resolution mode
- **date_key:** type of input date

0: Earth Julian date (given as input argument juliandate)

1: Venus True Solar Local Time (given as input argument localtime)

- **juliandate:** Earth Julian date (s). Only used if date_key = 0.
- **localtime:** True solar local time (in Venusian hours) at longitude lon. Only used if date_key = 1.
- **dset:** path to the VCD datafiles root directory

VCD content and main features

call_vcd inputs:

- **scena:** VCD scenario number. Valid choices are:

1: standard cloud albedo and average solar EUV input
2: minimum solar EUV input (and mean cloud albedo)
3: maximum solar EUV input (and mean cloud albedo)
4: low cloud albedo and average solar EUV input
5: high cloud albedo and average solar EUV input
6: EUV input as deduced from the input Julian date juliandate
7: EUV input as specified from input argument varE107

- **varE107**: value of the E10.7 factor specifying the solar EUV input.
- **perturb_key:** flag to specify perturbations to add

0: No perturbations
1: Add a small scale perturbation as a gravity wave (of wavelength given as input argument perturb_gw_length and using input argument perturb_seed for randomness generation)
2: Add a large scale perturbations (weather systems) as captured from EOFs of the GCM runs (using input argument perturb_seed for randomness generation)
3: Add both small scale and large scale perturbations (i.e 1+2 above).

- **perturb_seed:** seed for pseudo-random number generation
- **perturb_gw_length:** added gravity wave wavelength (m)
- **extvar_keys:** array (100 elements) of flags, to compute (or not) output variables extvar(i)

VCD content and main features

call_vcd outputs:

- **zon_wind**: zonal wind (m/s)
- **mer_wind**: meridional wind (m/s)
- **vert_wind**: vertical wind (m/s)
- **temp**: atmospheric temperature (K)
- **pres**: atmospheric pressure (Pa)
- **dens**: atmospheric density (kg/m3)
- **extvar**: array (100 elements) of values containing (if requested by corresponding input extvar_keys(i); unused extvar(i) are set to zero):
  - Vertical coordinates (distance to planet center, altitude above reference sphere, above local surface, orographic height)
  - Orbital elements of Venus (if Earth date is an input)
  - Local true solar time at specified longitude and at lon=0 (Universal solar time)
  - Unperturbed winds, temperature, pressure, density
  - Surface pressure and temperature

  (...)

VCD content and main features

call_vcd outputs:

- **extvar**: array (100 elements) of values containing (if requested by corresponding input extvar_keys(i); unused extvar(i) are set to zero):
  (...)
  - RMS variability of winds, temperature, pressure, density, surface pressure, surface temperature
  - Net solar flux at top of atmosphere, net solar and infrared fluxes
  - SZA, scale height, mean molar mass, speed of sound, reduced molecular gas constant, Cp, specific heat ratio, viscosity estimation
  - Composition (vmr, column densities):
    CO_2, CO, O_2, O, H, H_2, H_2O, CO_2, SO, OCS, O_3, HCl, N2, He
  - Vertically integrated O_2 nightglow
  - VIRA temperature, pressure, density
- **seed_out**: suggested new seed value for the random number generator
- **ier**: call_vcd status return code

High resolution prediction of surface pressure on Venus

hires_key

Can be derived at a given altitude by combining hydrostatic equilibrium and the adiabatic lapse rate:

$$p = p_0 \, e^{-(g/R)/[\Gamma/2 + T_0/(z-z_0)]}$$

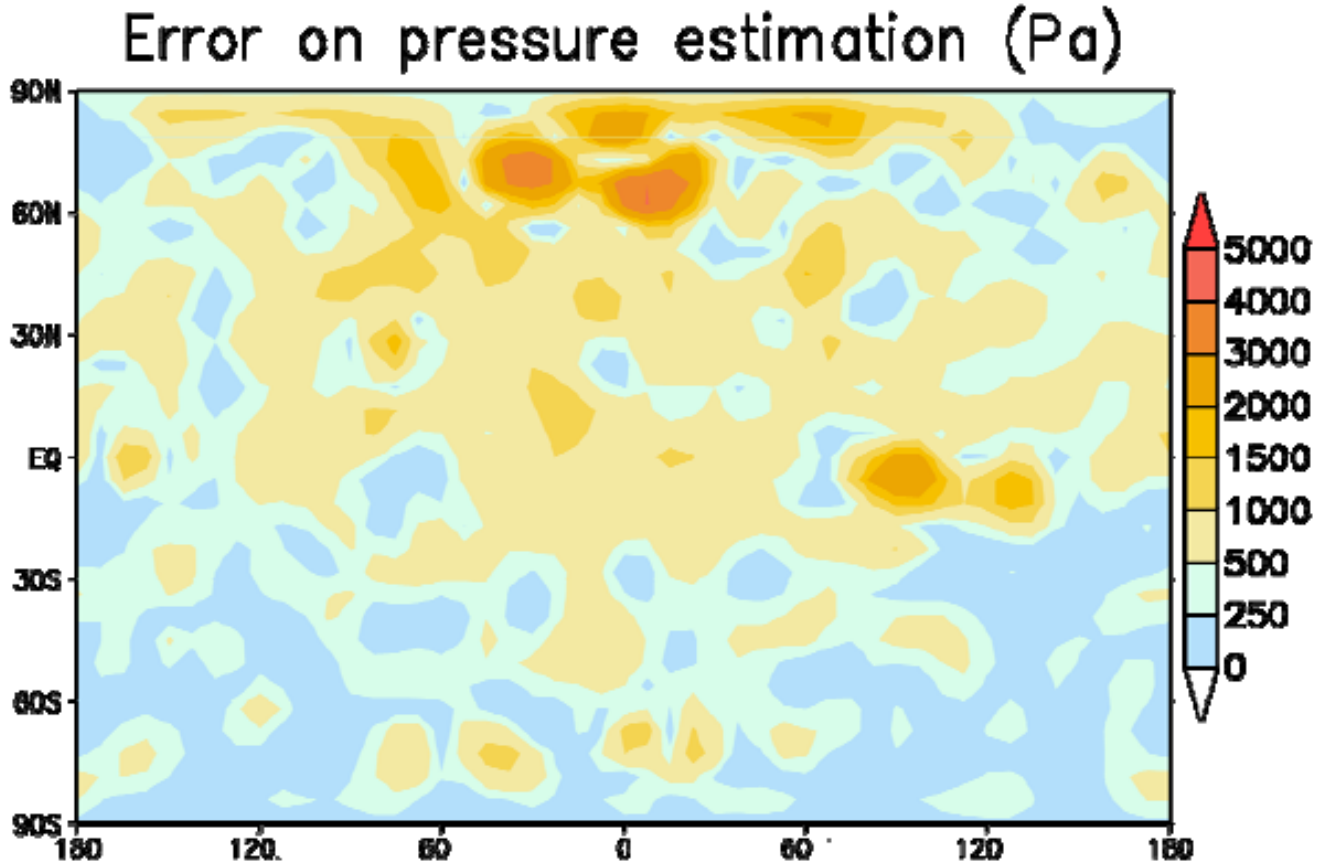
with :

- p_0 a reference surface pressure at a reference landing site (e.g. Vega 2 or more combination)
- T_0 the reference near-surface atmospheric temperature at the reference site (K)
- z_0 the altitude of the reference site
- g the acceleration of gravity
- R the gas constant on Venus (we use $R = 191.39$ m^2 s^{-2} K^{-1} , corresponding to a mean molecular mass of 43.44 g mol^{-1}).
- Γ the adiabatic lapse rate ($dT/dz = -g/Cp$) in K/m

Study by F. Forget

High resolution prediction of surface pressure on Venus

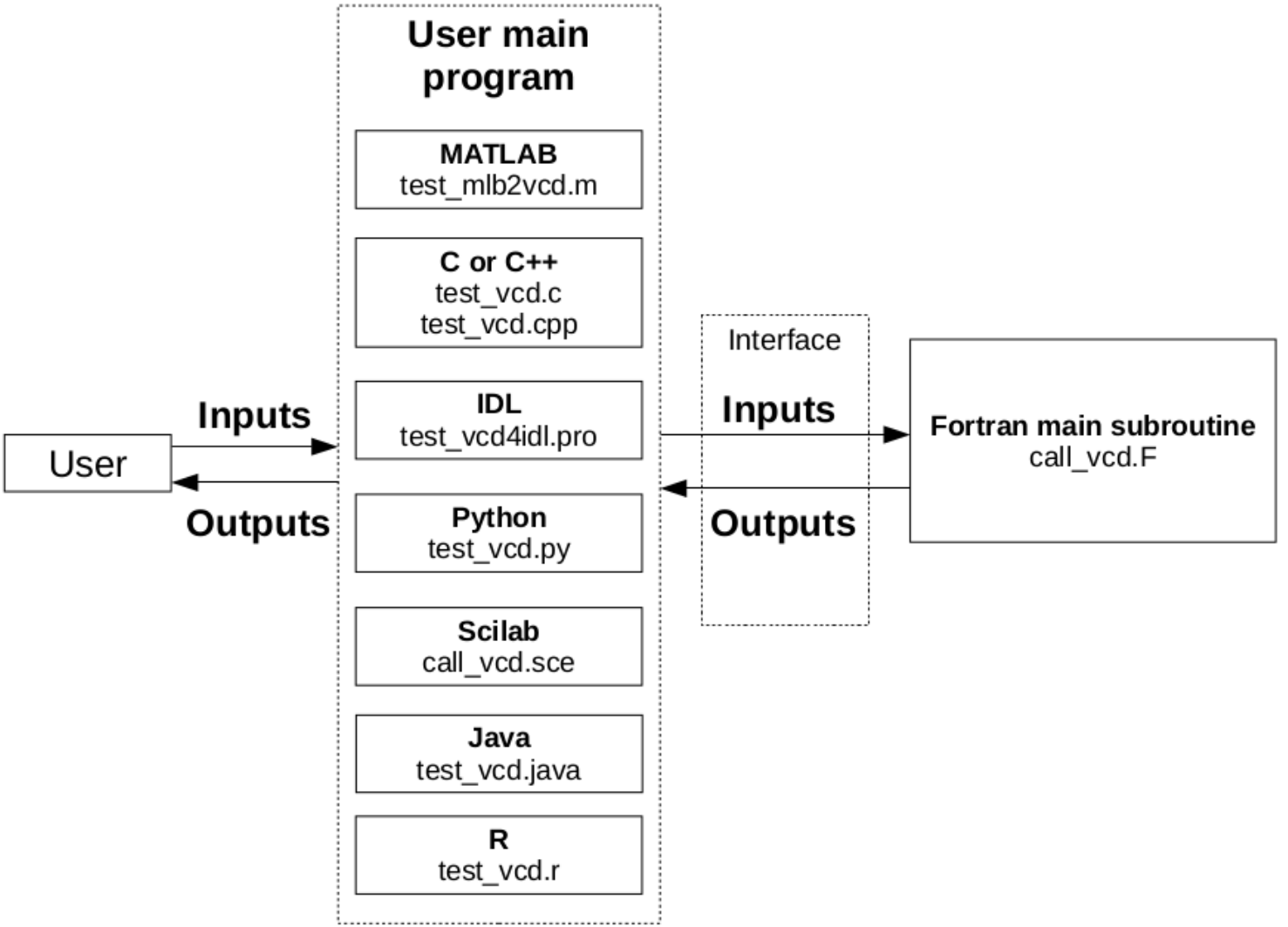
Has been tested with the GCM and yields in most locations a total error below 2000Pa, i.e. less than 0.02% relative error.
This technique could be extended to finer topography.



Study by F. Forget

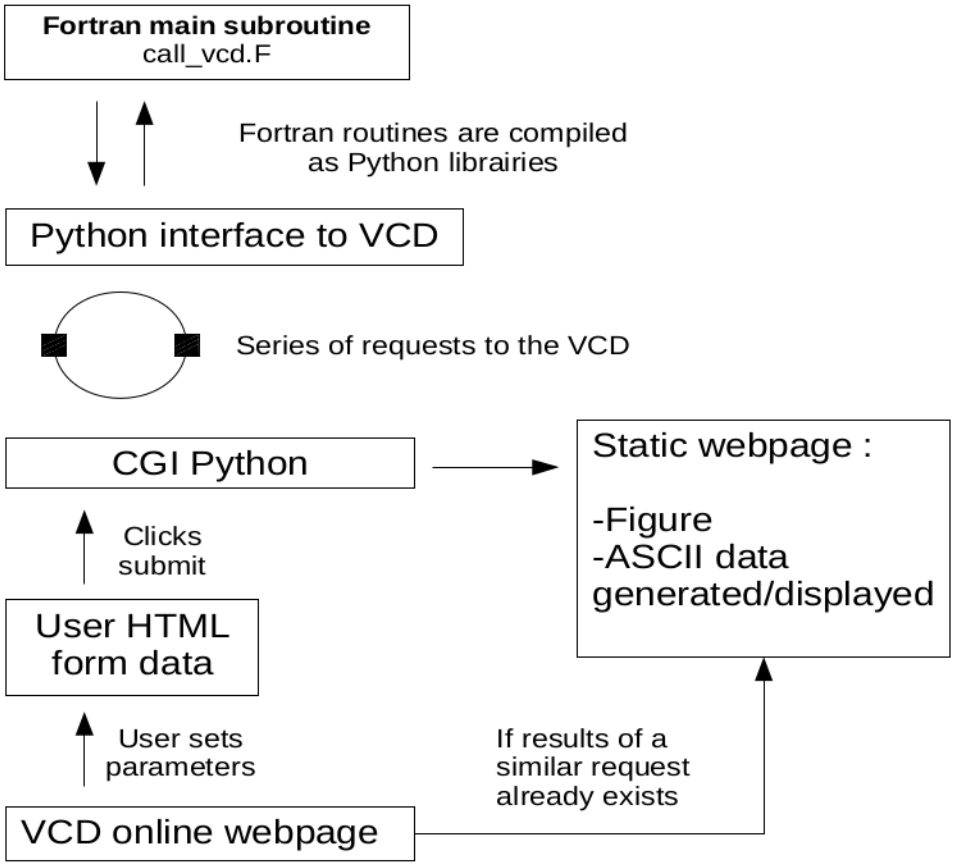
Additional means to access the VCD

Interfaces with other programming languages (e.g. C, C++, IDL, Matlab, Python3, …) will also be provided.



Additional means to access the VCD

A web interface for quick-looks and plots is always very welcome (still on-going work)



We are also very much interested in the possibility of distributing the VCD as a virtual observatory in the frame of the Virtual European Solar and Planetary Access (VESPA) Europlanet 2020 Research Infrastructure program http://www.europlanet-vespa.eu

Schedule :

- alpha version ready
- beta-testing up to september
- public release sometime in september

Suggestions and comments from potential future users are very welcome!

Let us know what you'd like the VCD to provide.