

Modélisation méso-échelle de l'atmosphère de Vénus

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LATMOS

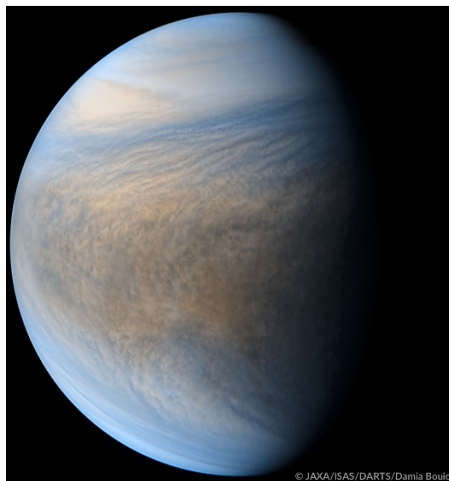
1/2 journée IPSL



Small-scale Dynamics

Venus cloud top (70 km) and lower cloud (50 km)

Akatsuki UVI camera

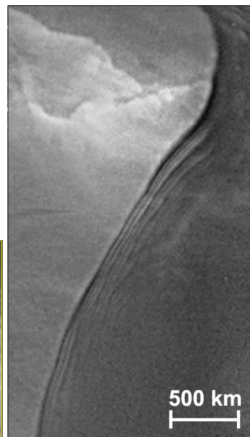
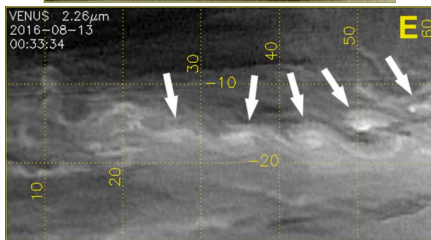
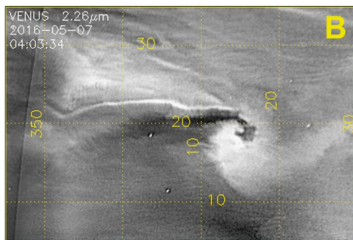


Akatsuki IR2 camera



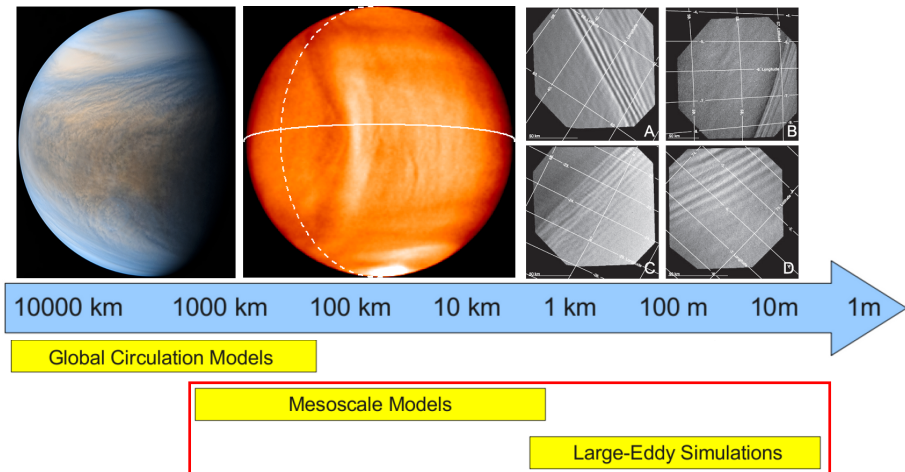
Small-scale Dynamics

Venus Night side lower cloud (50 km)



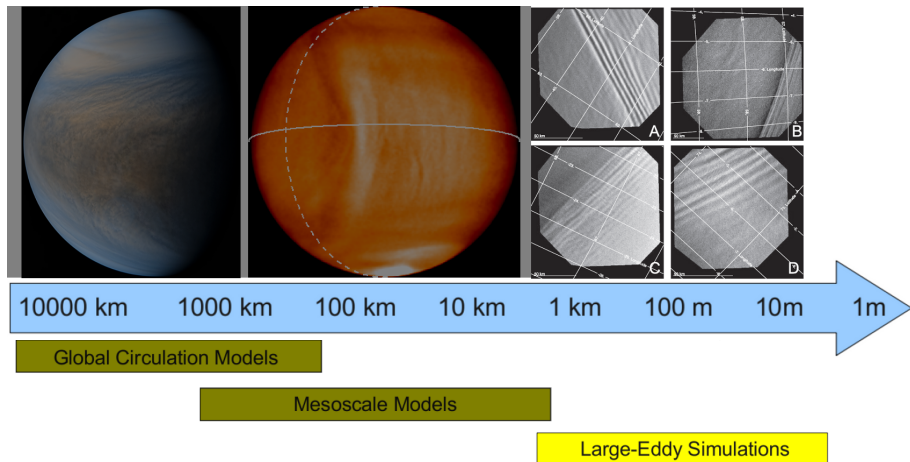
Peralta et al., 2019, 2020

Atmospheric Modeling



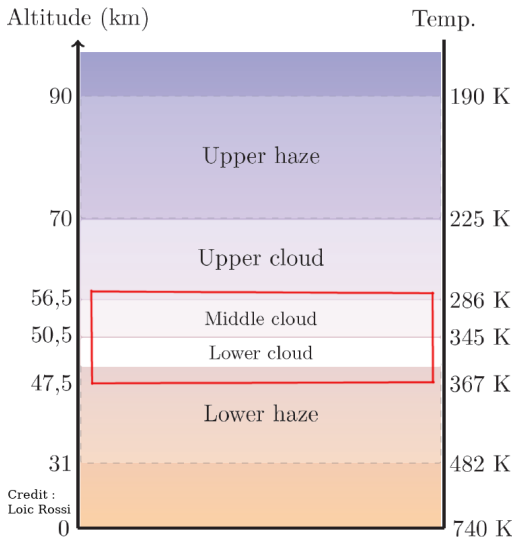
Atmospheric Modeling

Small-scale turbulence → Large-Eddy Simulations (LES) with WRF core



First 3D coupled LES model for Venus

Main cloud convective layer

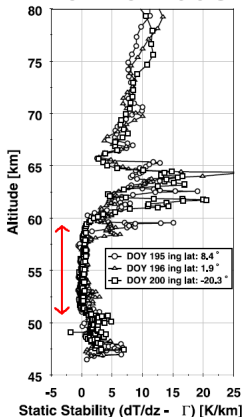


Cloud Convective Layer

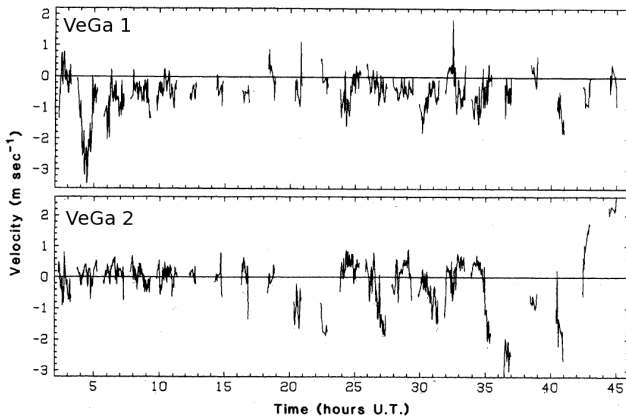
VeRa radio occultation
~ 10 km depth

VeGa Balloons wind measurement around 50 km
 ± 3 m/s

Low latitude



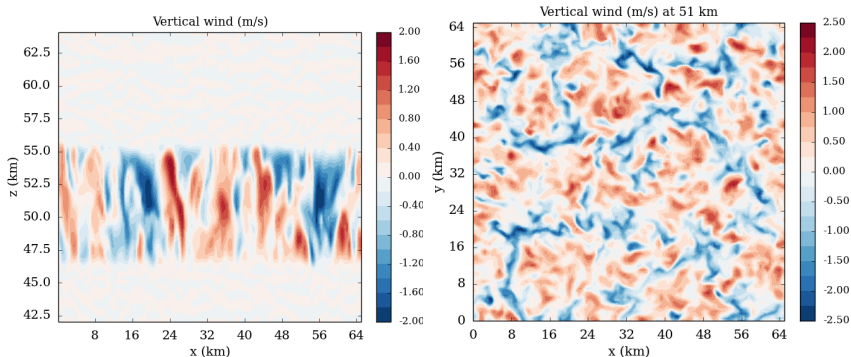
Tellmann et al., 2009



Linkin et al., 1986

Cloud convective layer

First 3D LES model for Venus. Resolution = 400 m
Equator midnight

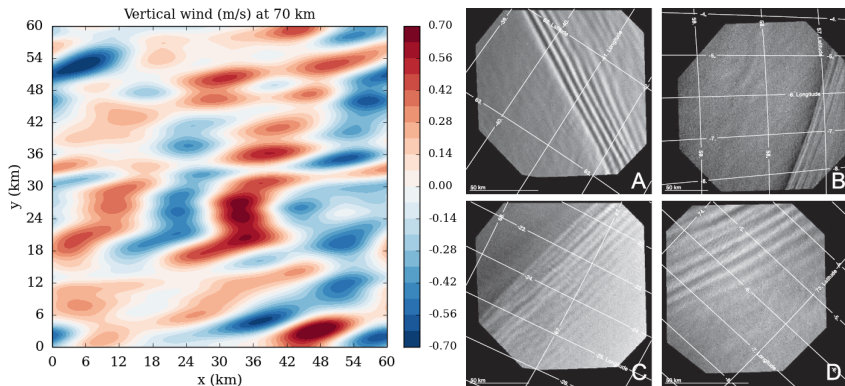


Lefèvre et al, 2018

Vertical wind between ± 2.5 m/s, consistent with observations
Convective cell of 20 km of diameter

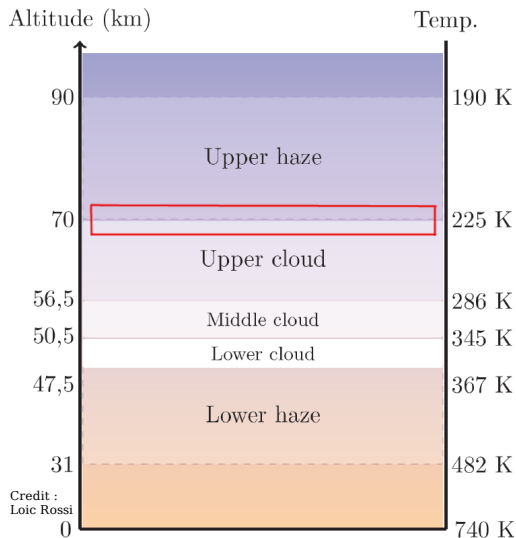
Cloud top gravity waves

At cloud top

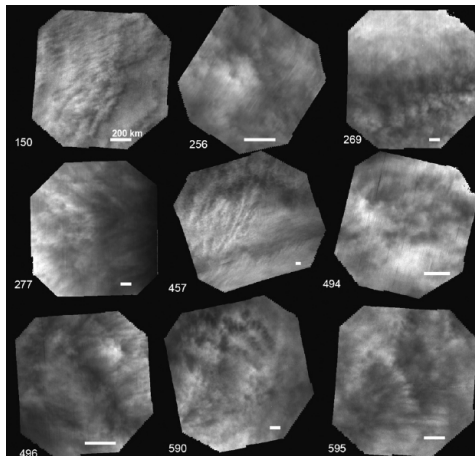


Wavelength up to 20 km. Very close to VMC observations.

Cloud top convective activity



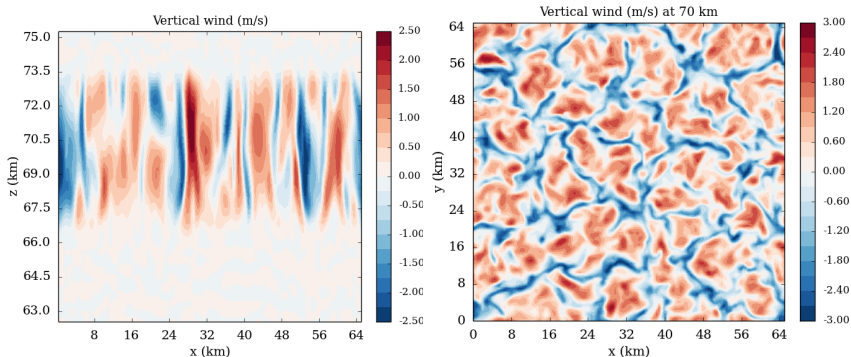
VMC observations



Titov et al., 2012

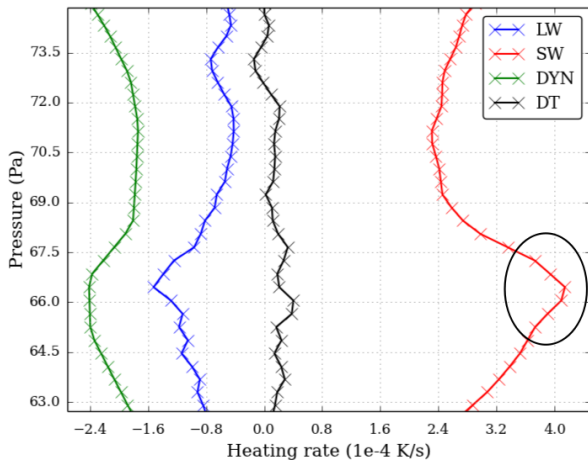
Puffy clouds at subsolar point at low latitude : convection ?

Cloud top convective activity : Equator noon



Vertical wind between ± 3 m/s
Convective cell of diameter of 10 km

Cloud top convective activity : Mechanism

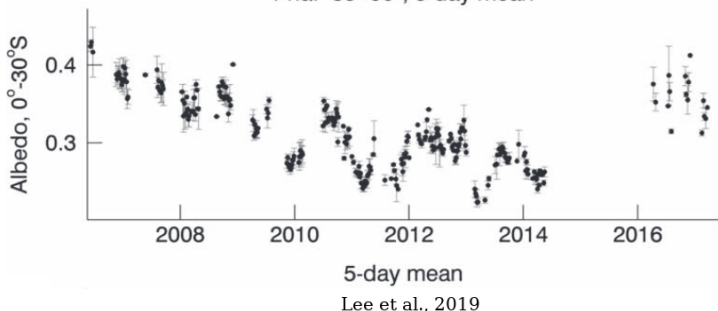


Strong solar heating from unknown UV absorber \rightarrow destabilization

Cloud top convective activity : Mechanism

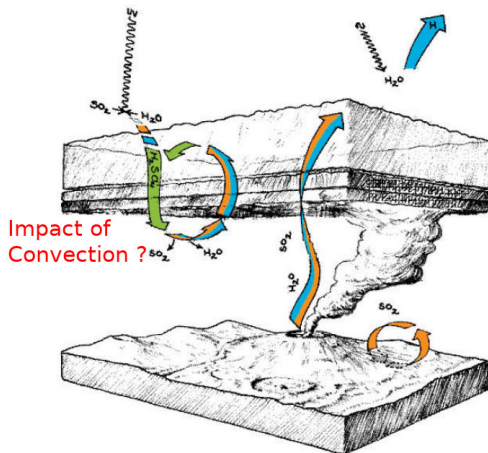
Cloud top albedo

Pha: 85- 90°, 5-day mean

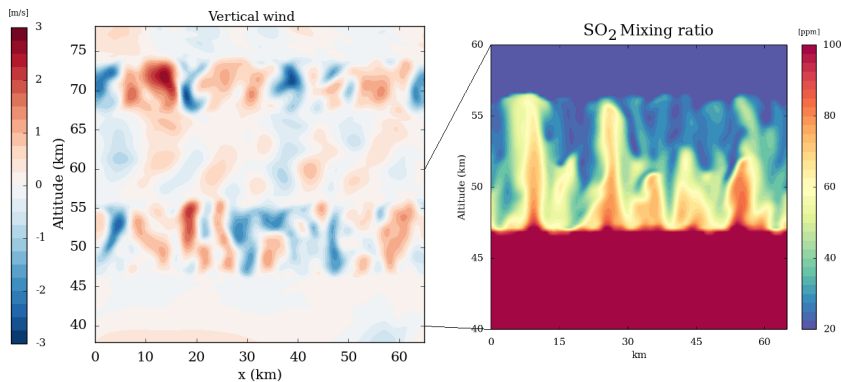


Temporal variation of the albedo → variation of the UV absorber

What is the convective vertical mixing ?

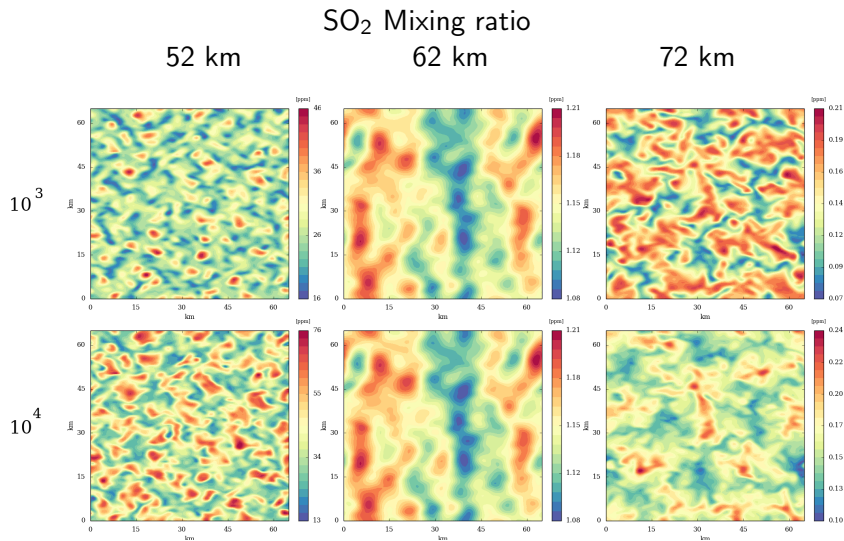


SO₂ passive tracer mixing at noon



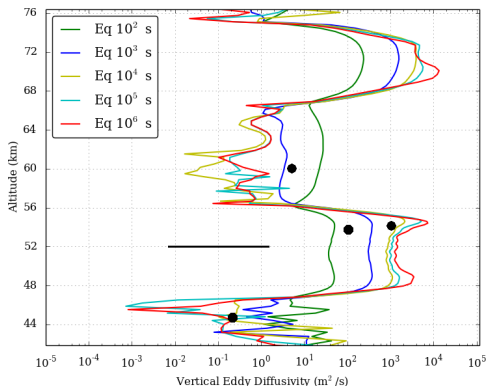
Lefèvre et al. 2022

SO₂ : Equator noon



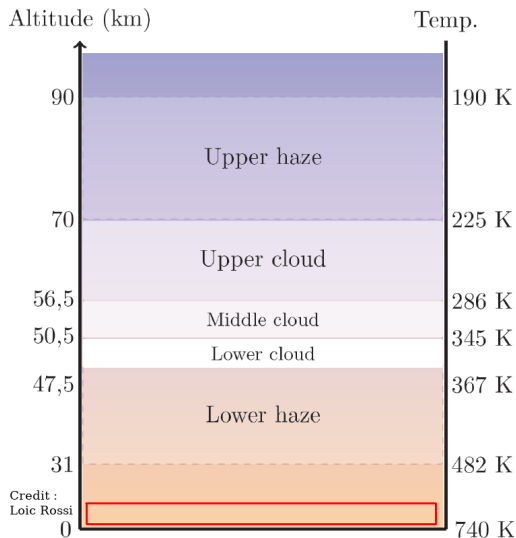
LES model : Resolved convection

$$\text{Vertical Eddy Diffusion} = -\frac{\langle q'w' \rangle}{\partial \langle q \rangle / \partial z}$$



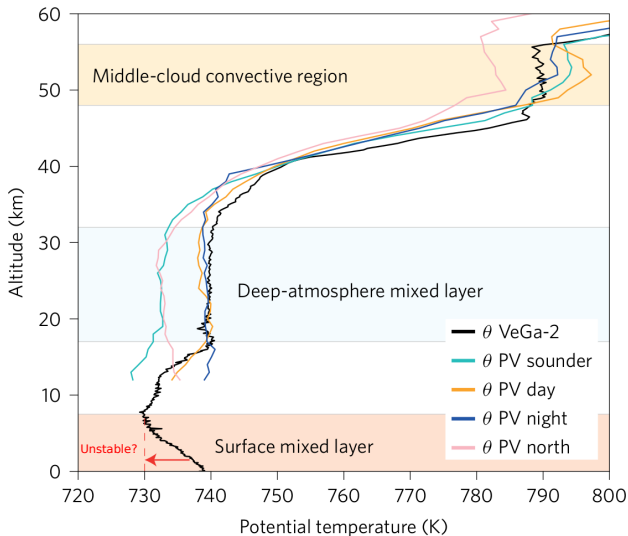
Consistent with in-situ estimations $1-10^3 \text{ m}^2 \text{ s}^{-1}$
Superior to the value in chemical models for the convection

Planetary Boundary Layer



Deep Atmosphere Dynamics

VeGa 2 and Pioneer Venus measurements

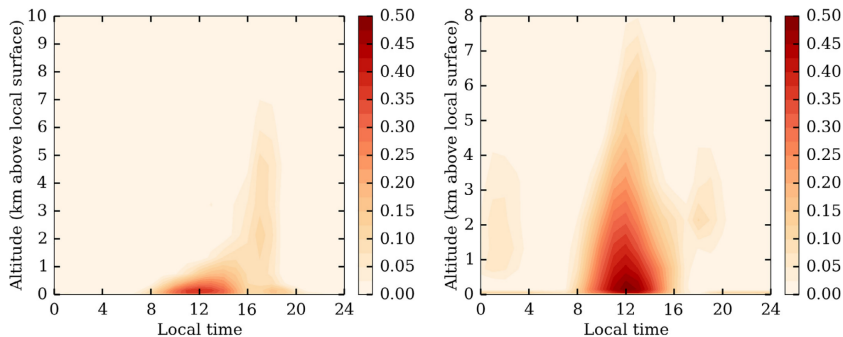


Deep Atmosphere Dynamics

LMDz Venus PCM study : influence of surface wind on the PBL turbulence

Plain

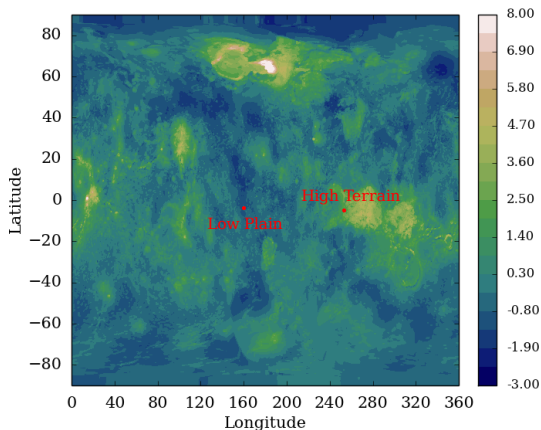
Slope at the Equator



Lebonnois et al., 2018

PBL turbulence

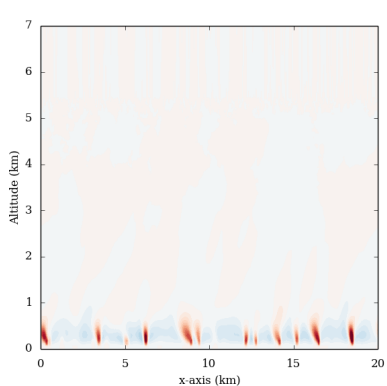
2 sites : plain and slope at the Equator



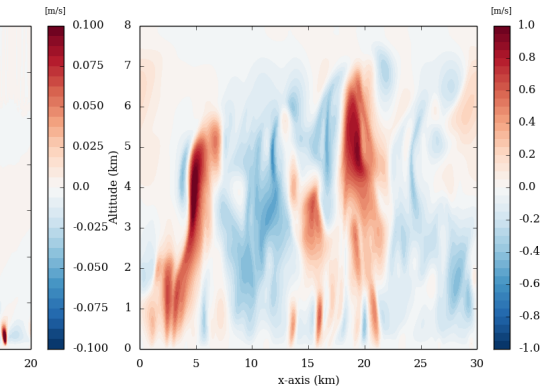
$dx = 50$ m. Heating rates fixed from IPSL Venus GCM (Lefèvre et al., 2017).

Diurnal cycle : High Terrain

Midnight



Noon



Lefèvre et al., 2022

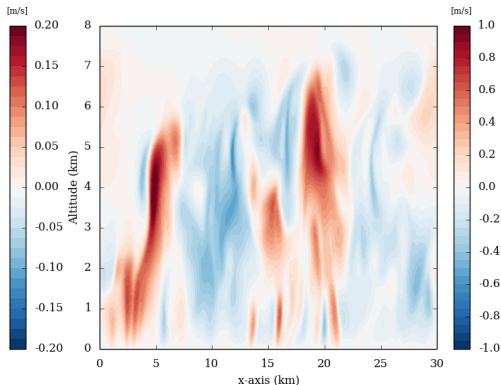
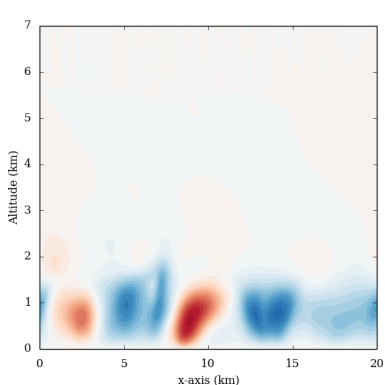
Consistent with Lebonnois et al., 2018

Influence of topography

At local noon

Low Plain

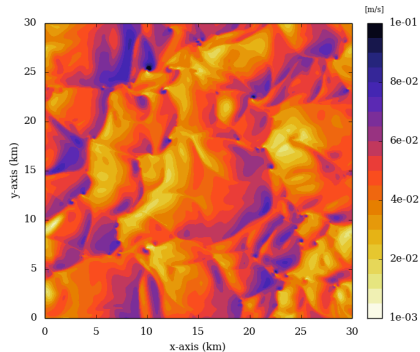
High Terrain



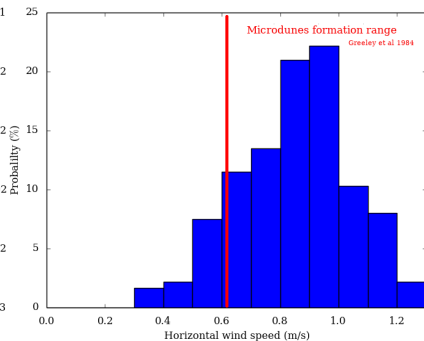
Consistent with Lebonnois et al., 2018

Dust lifting : High Terrain at noon

Friction Velocity u^*

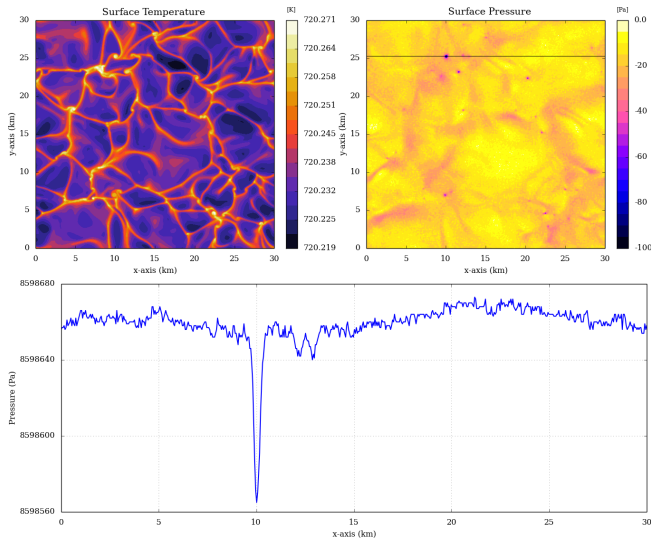


Horizontal wind



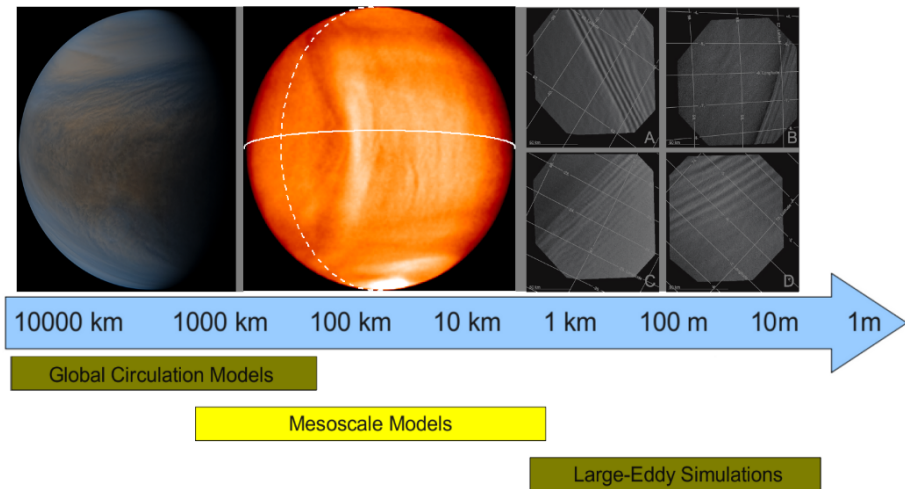
To lift dust $u^* > 2.5 \cdot 10^{-2} \text{ m s}^{-1}$ (Iversen et al., 1976) : OK at noon
Formation of microdunes at noon

Surface condition : High Terrain at noon



Low temperature effect (< 0.1 K) ; Generation of vortices

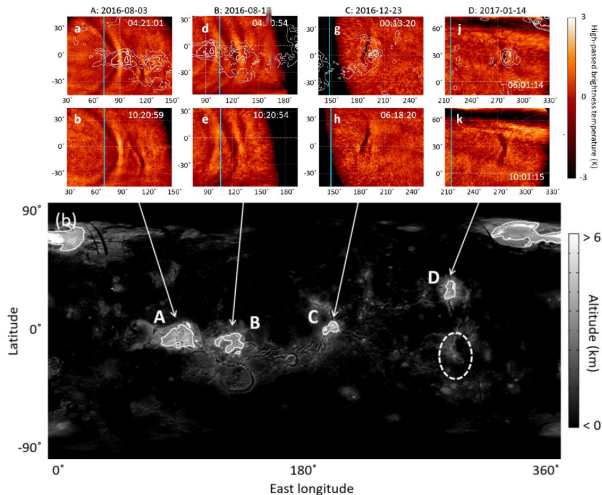
Atmospheric Modeling



First mesoscale model for Venus

Cloud-top Mountain Waves

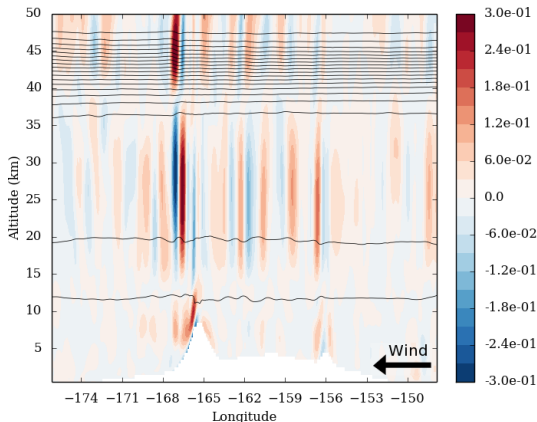
IR2/Akatsuki observations at cloud top (70 km)



Kouyama et al., 2017

LMD Venus Mesoscale Model

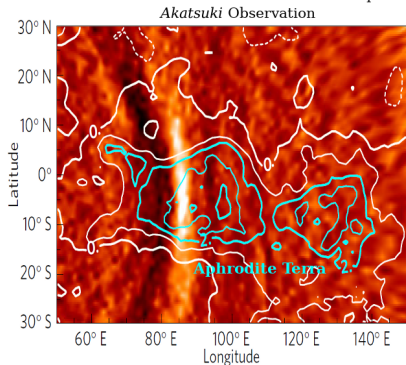
WRF Dynamical core coupled to IPSL Venus GCM radiative transfer



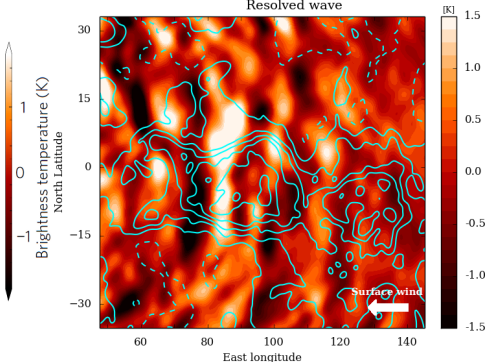
Generation of Trapped Lee waves
Lefèvre et al., 2020

LMD Venus Mesoscale Model

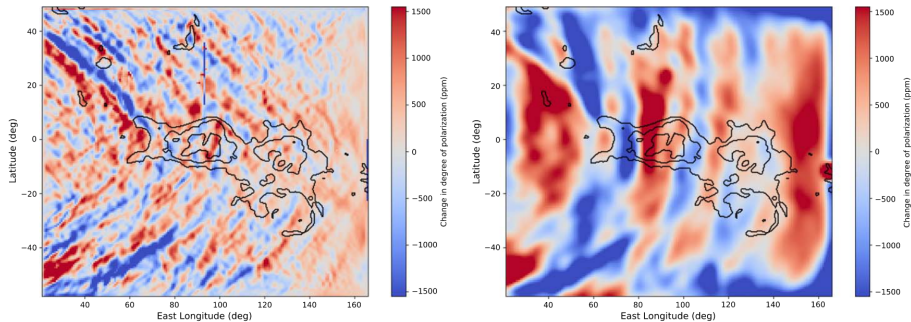
Temperature anomalies at cloud top



Resolved wave

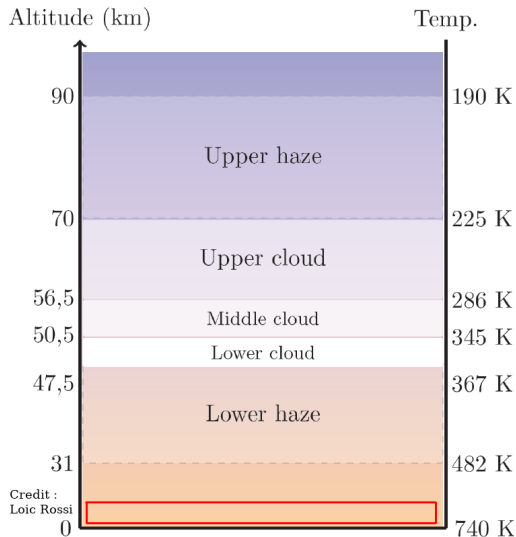


Observability through polarization



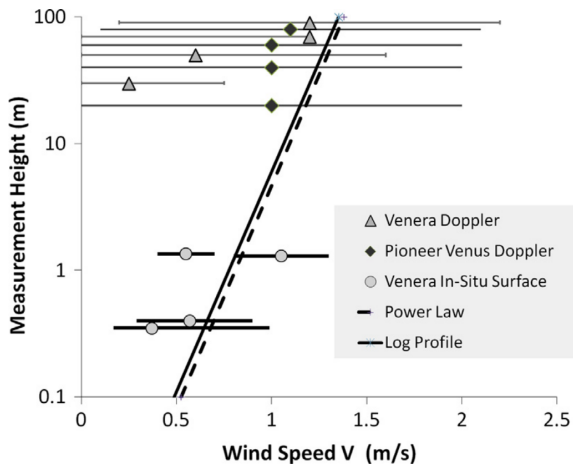
Mahapatra et al., 2021

Near-Surface Dynamics



Deep Atmosphere Dynamics

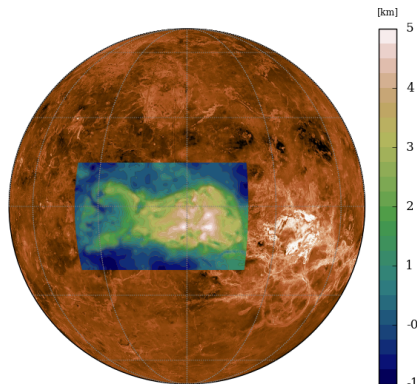
In-Situ and spacecraft measurements



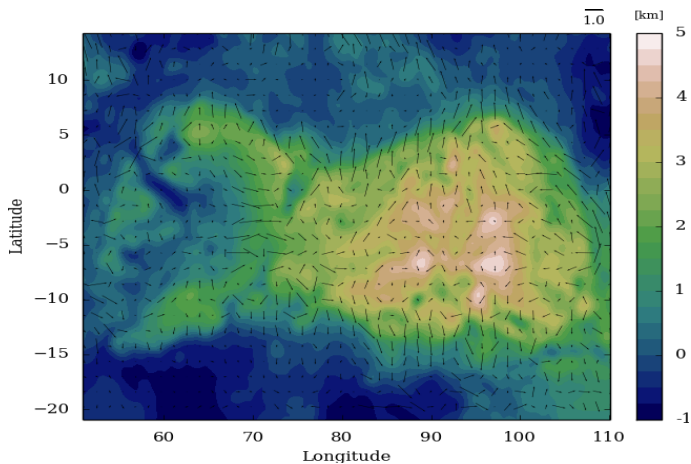
Lorenz, 2016

LMD Venus Mesoscale Model

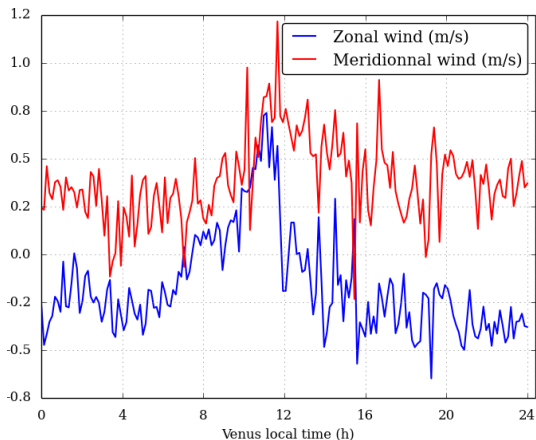
Aphrodite Terra
Horizontal resolution = 20 km



Wind Map



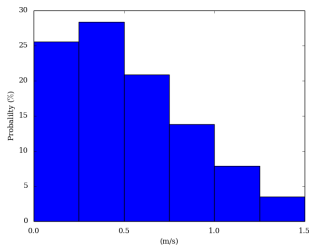
Diurnal cycle



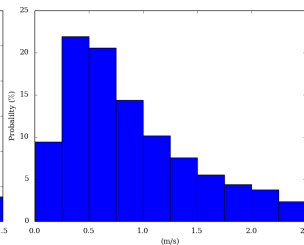
Change of Direction not always present, weaker than Lebonnois et al. 2018

Wind distribution

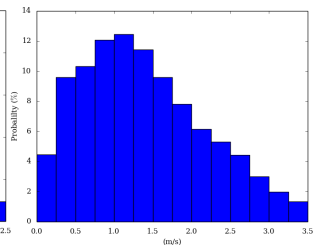
1 m



10 m



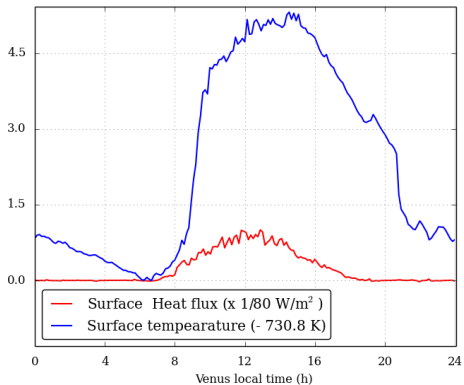
100 m



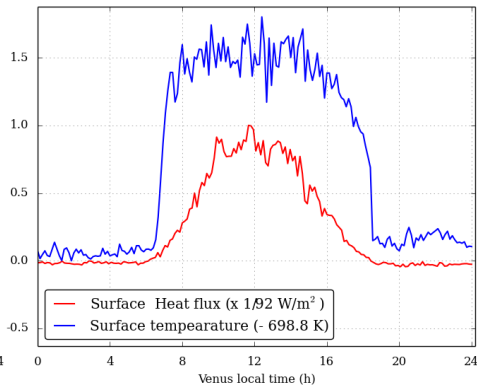
Consistent with in-situ measurements

Temperature variation

Low Plain

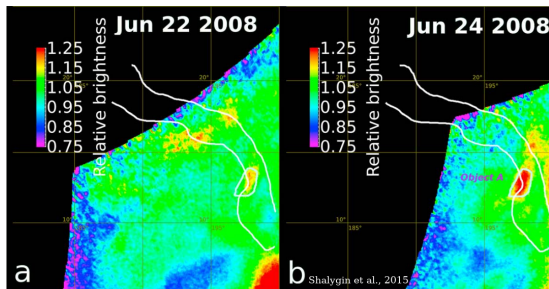
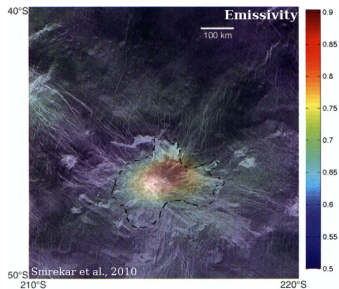


High Terrain



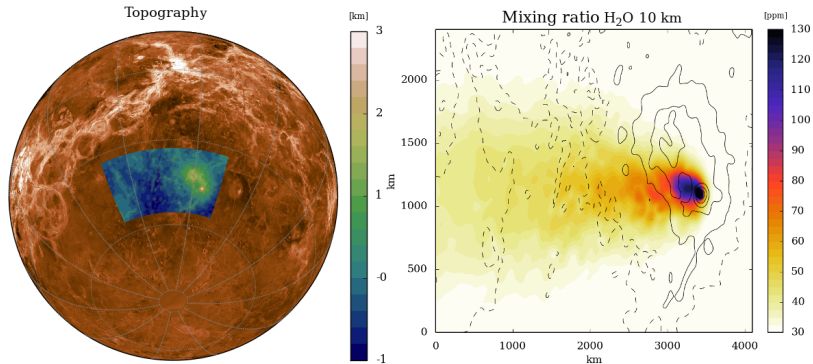
Higher temperature variation at low altitude

Active volcanism ?



LMD Venus Mesoscale Model

Imdr Regio



With passive tracer (SO₂, H₂O, CO) and fixed height plume and abundance.

Perspectives



- Coupling LATMOS chemistry : vertical mixing and sulfur reservoir
- Tropospheric chemistry
- Realistic microphysical scheme
- Parametrization of the convective for the GCM
- Impact of variation of UV absorber on cloud top convection
- Cloud morphologies due to Equatorial jet and others
- Buoyancy of the volcanic plumes
- Extension of the model top to 150 km
- Deep-atmosphere mixed layer