Organization of the convection in the Venus cloud layer

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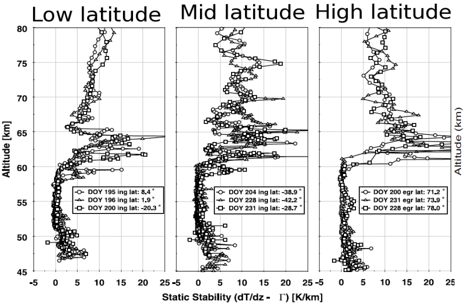
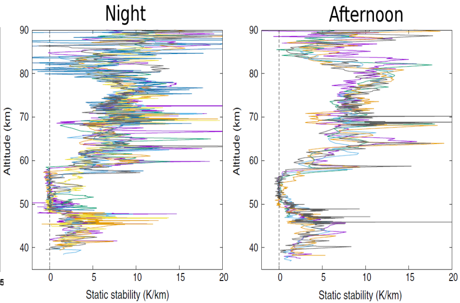
Introduction : Convective layer

VeRa radio occultation variability with latitude



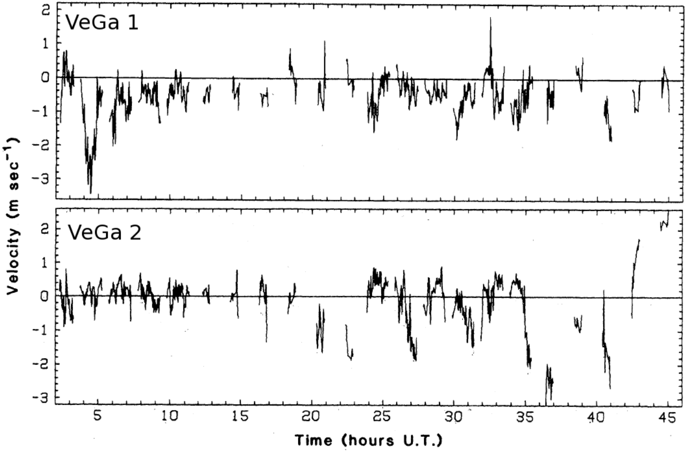
Tellmann et al., 2009

Akatsuki radio occultation (40N-40S) variability with local time



Imamura et al., 2017

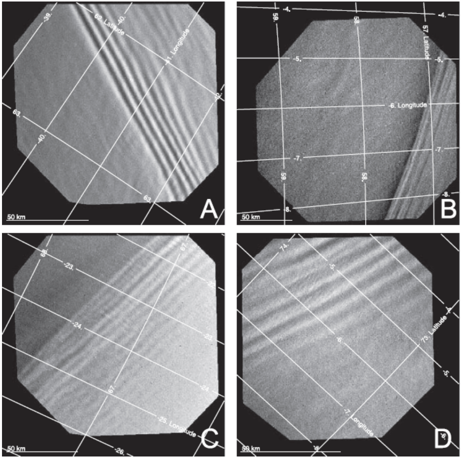
VeGa Balloon vertical wind measurement $\sim \pm$ 3 m/s at $\pm$ 7°



Linkin et al., 1986

Introduction : Gravity waves

Venus Express observations at cloud top ($\sim$ 70 km)

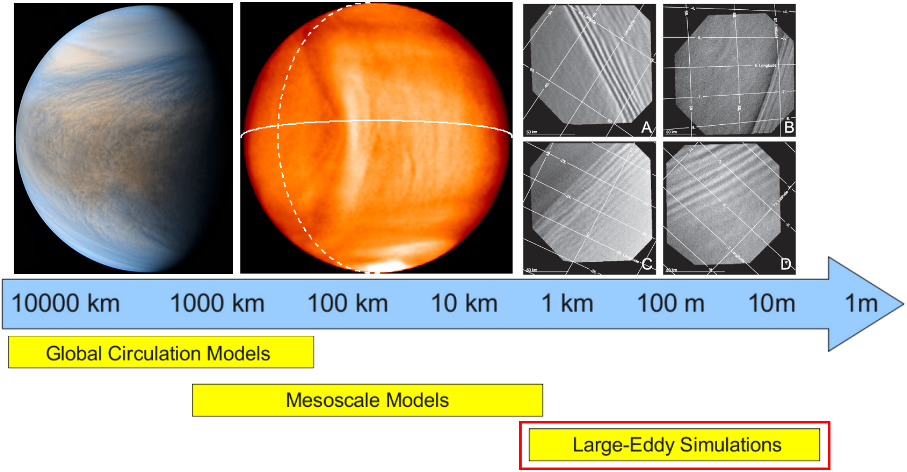


Piccialli et al., 2014

Atmospheric Modeling

Atmospheric Modeling

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



First 3D coupled LES model

Model description

Heating rates decomposed in 3 different contributions :

-2 radiative ones : Solar and IR

- Dynamics: associated with global dynamics : Hadley cell (Adiabatic warming/cooling)

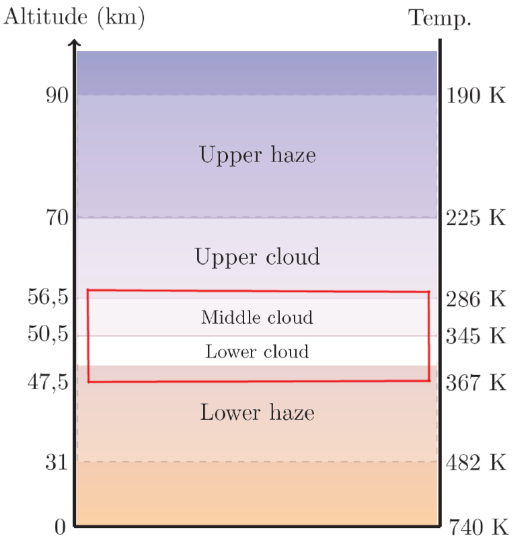
	Off-line (Lefèvre et al., 2017)	**On-line** (Lefèvre et al., 2018)
Solar	Constant	LMD Venus radiative transfer
IR	Constant	LMD Venus radiative transfer
Dynamics	Constant	Constant
Resolution	200 m	400 m
horizontal domain	36x36 km	60x60 km
vertical level	181	300
vertical domain	40 to 70 km	surface to 100 km

Cloud model (Haus et al.) is fixed during the simulation

No wind shear is imposed

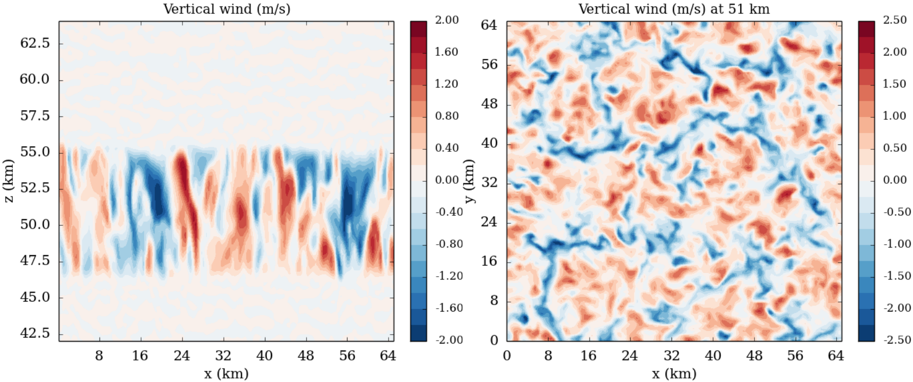
Input from LMD GCM Simulations (Garate-Lopez and Lebonnois, 2018)

Main convective layer



On-line mode

Equator noon

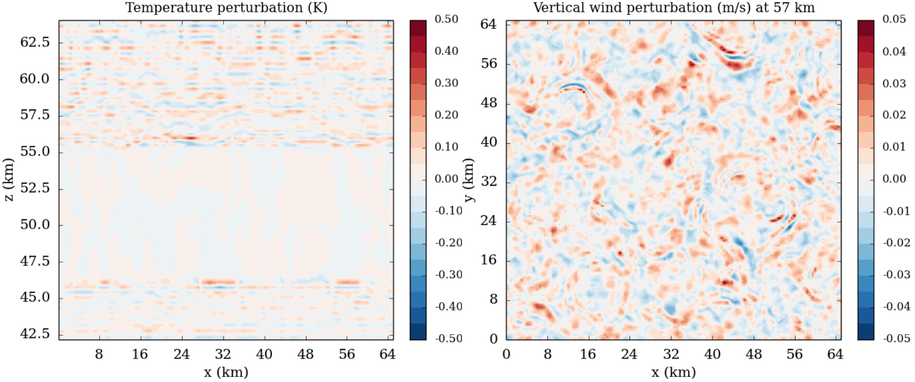


Lefèvre et al, 2018

Vertical wind between ± 2.5 m/s, consistent with observations

Convective cell of 20 km of diameter

Equator noon: : Gravity waves



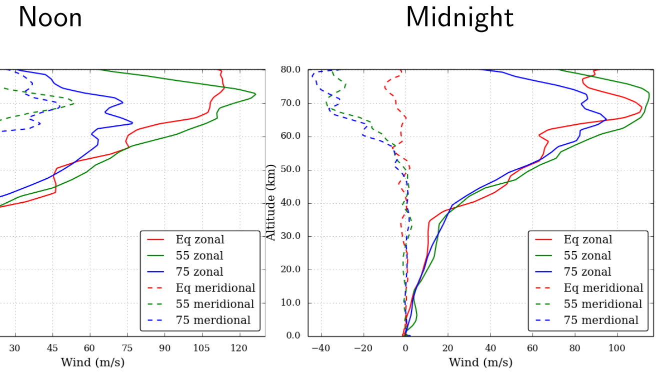
Amplitude of GWs ±0.5 K, smaller than the observations
Circular wavefront, not consistent with observations.

Impact of the wind shear

Wind shear

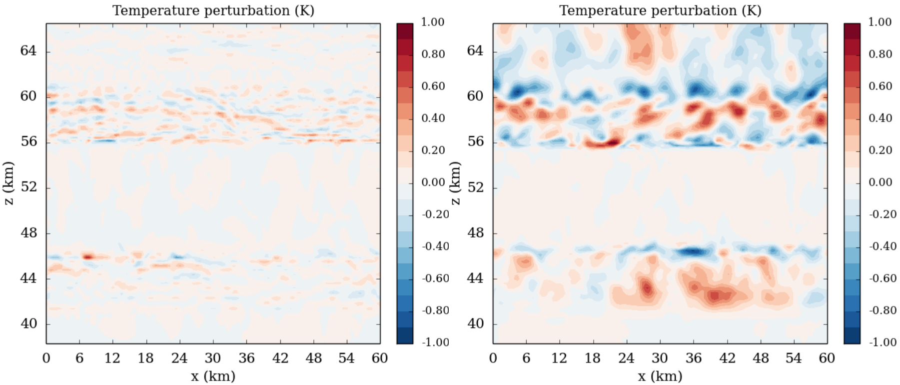
Prescribed wind from the LMD Venus GCM

Noon | Midnight



Comparison : the Equator midnight

No wind shear | Wind shear



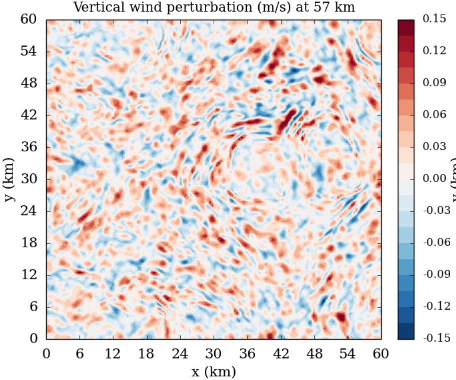
Few impact on convection but strong on GWs
Stronger amplitude with the wind shear : obstacle effect

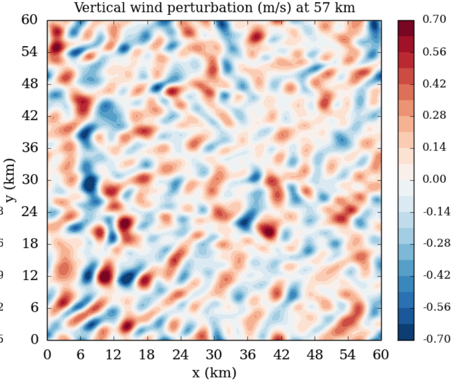
Comparison : the Equator midnight

At 57 km

No wind shear

Wind shear

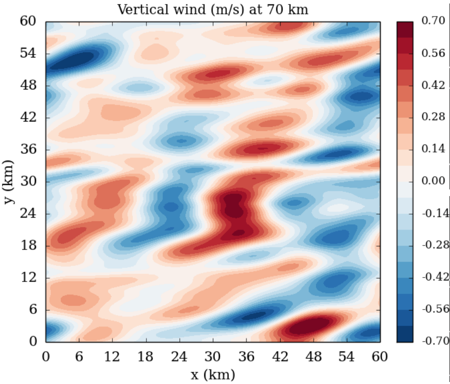


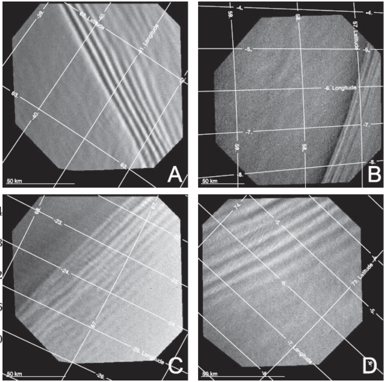


Linear wave front and stronger amplitude

Cloud top gravity waves

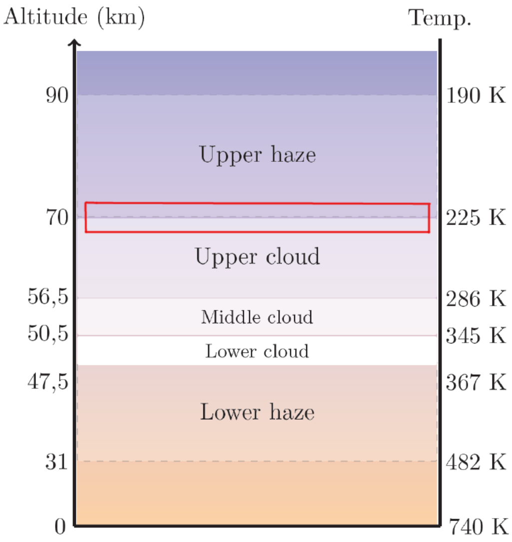
At cloud top





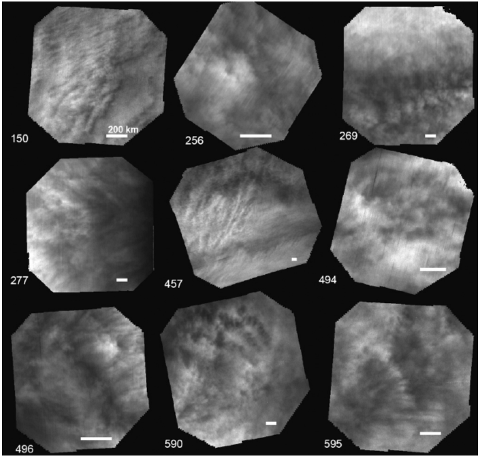
Wavelength up to 20 km. Very close to VMC observations.

Cloud top convective activity



Observations

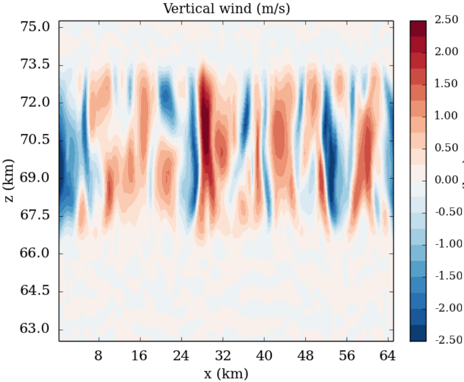
VMC observations

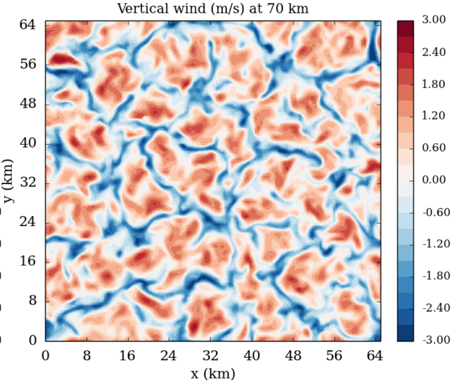


Titov et al., 2012

Puffy clouds at subsollar point at low latitude : convection ?

Cloud top convective activity : Equator noon

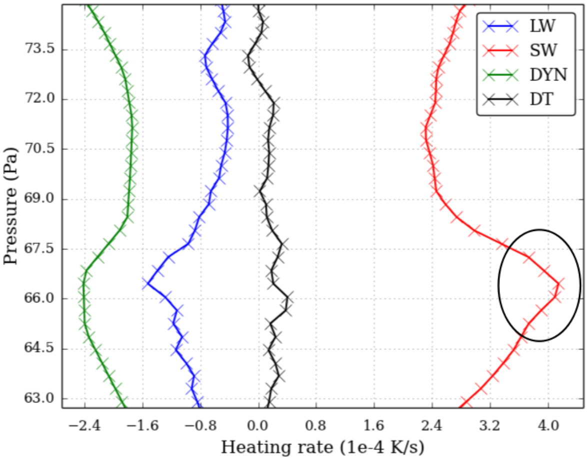




Vertical wind between ± 3 m/s

Convective cell of diameter of 10 km

Cloud top convective activity : Mechanism



Strong solar heating from unknow UV absorber → destabilization.

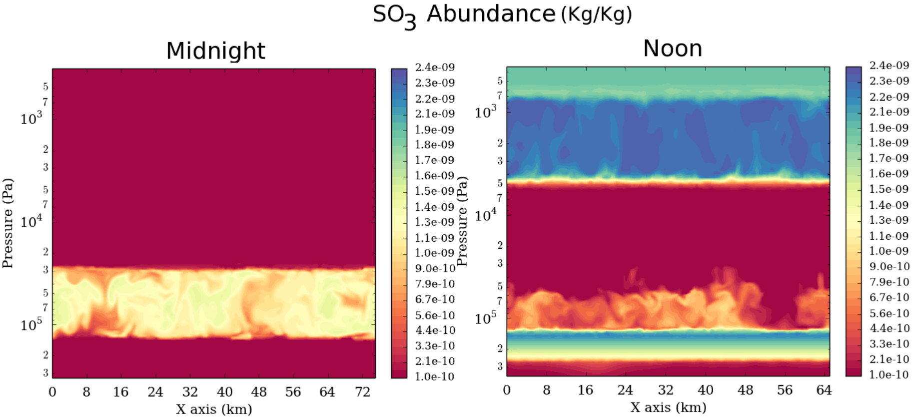
Conclusion

- First 3D coupled LES model for Venus
- Fine vertical resolution radiative transfer for realistic convective layer
- Strong impact of the wind shear : generated waves enhanced by obstacle effect
- Convection activity at cloud top due to UV absorber

	Off-line	On-line	On-line with wind shear
Convection morphology	✓	✓	✓
Convection depth	×	✓	✓
Plumes strength	×	✓	✓
Gravity waves amplitude	×	×	✓
Gravity waves morphology	×	×	✓

Perspectives

- Subgrid parametrization : Thermall Plume model and Gravity waves
- Planetary boundary layer turbulence
- Implementation of Photochemistry and Microphysics scheme

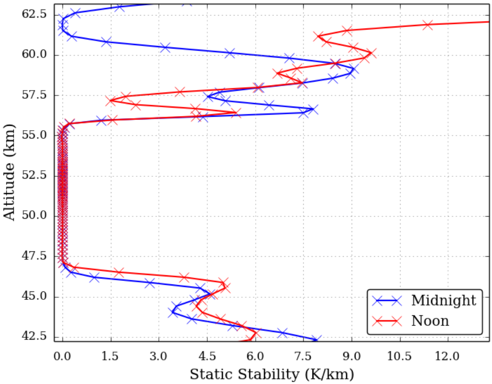


Additional Slide

Main convective layer

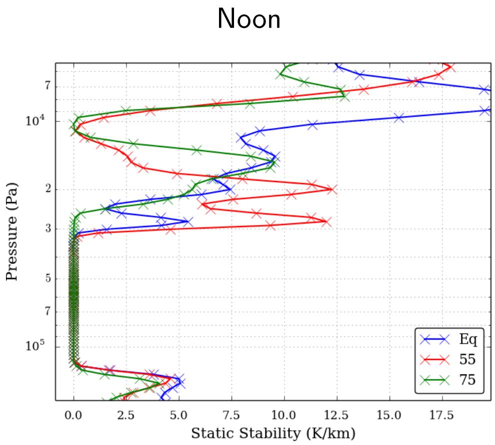
Variability with local time

The Equator



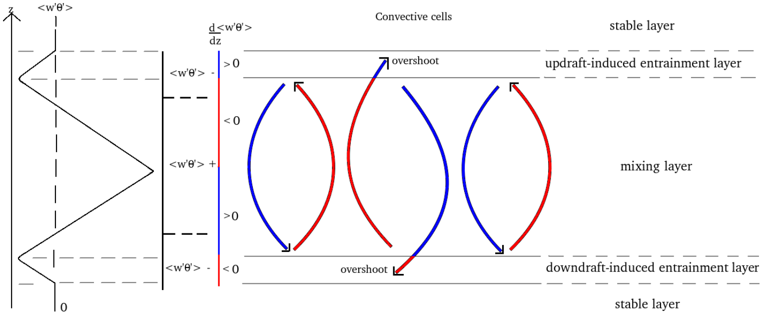
No variation between day and night.
Consistent with VeRa observations.

Variability with latitude



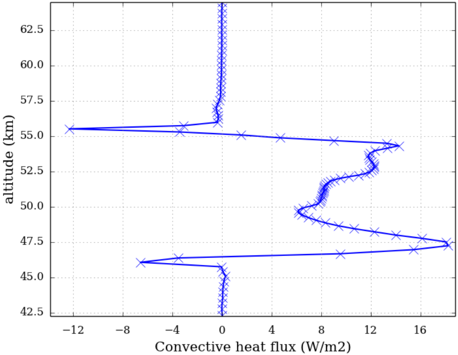
75° thicker than the Equator, consistent with observations
55° : GCM mid-latitude jets are too close to the pole.

Convective layer



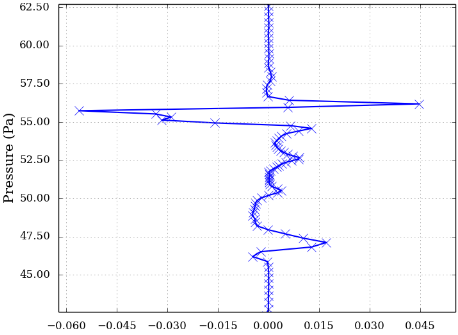
Convective layer

Convective heat flux $\rho\overline{\theta' w'}$



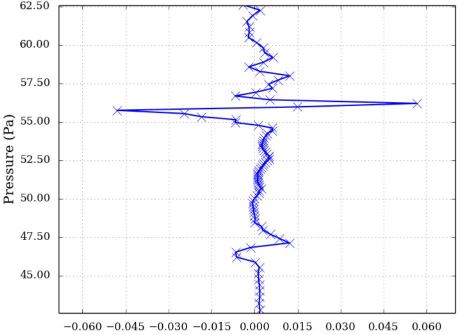
Convective layer

Heating rate form convection $\mathrm{Div}(\overline{\theta' w'})$ (10^{-3} K/s)



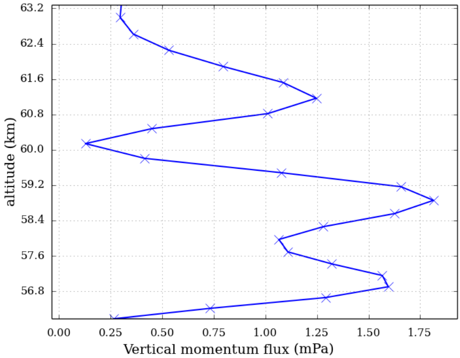
Convective layer

Comparison between radiative HR and convective HR (10^{-3} K/s)



Gravity waves

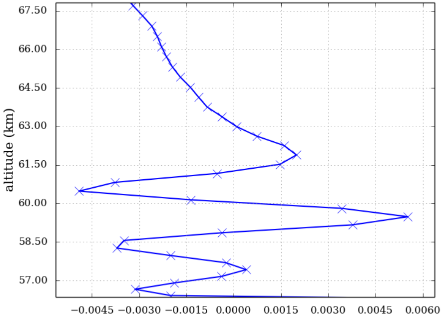
Vertical momentum flux $\rho\overline{u'w'}$



Same order of magnitude that Earth studies (Horinouchi et al, 2002)

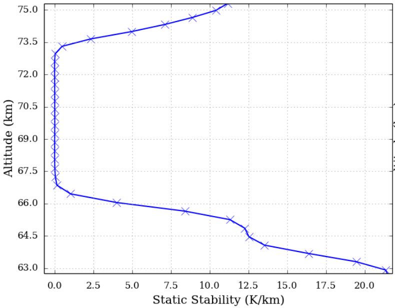
Gravity waves

Acceleration from GWs Div($\overline{u'w'}$) (10^{-3} m/s^{-2})

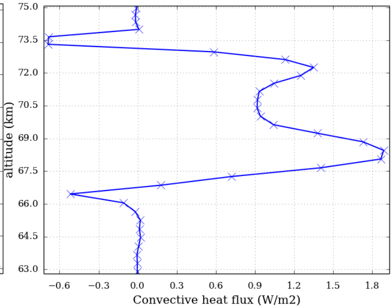


Equator noon

Static stability



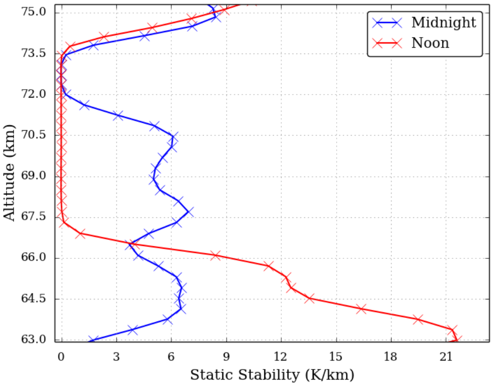
Convective heat flux



Convection between 67 and 73km

Variability with local time

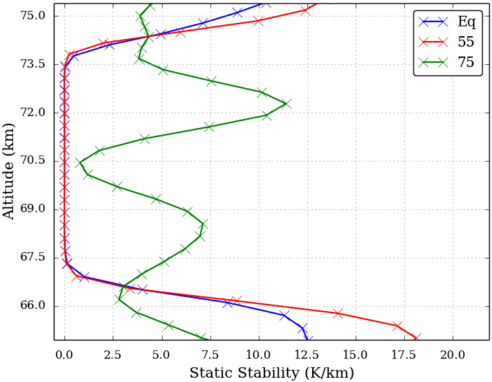
The Equator



Weaker convecive activity at midnight
Destabilization at midnight due to dynamics

Cloud top convective activity : Variability with latitude

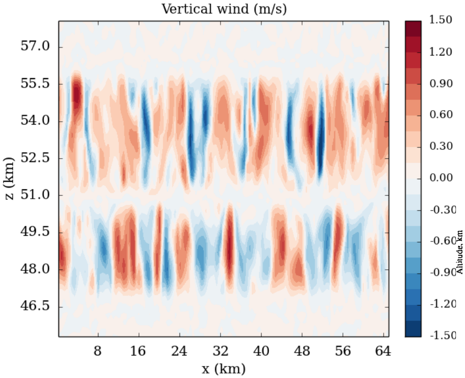
At noon



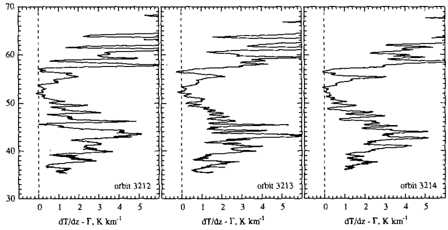
No convection at 75°.

But convective activity present at 55° : GCM jets position.

Large scale dynamics effect

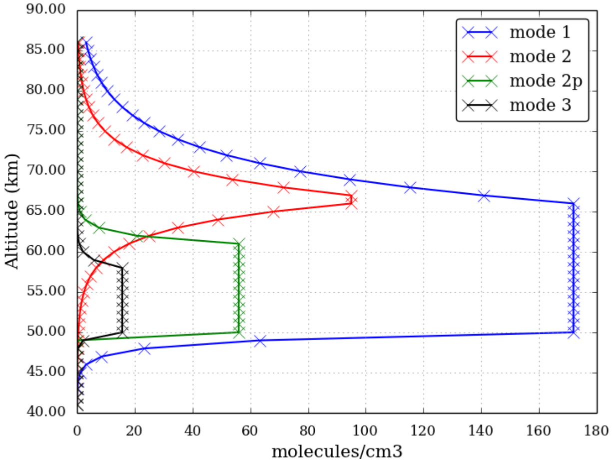


Magellan data

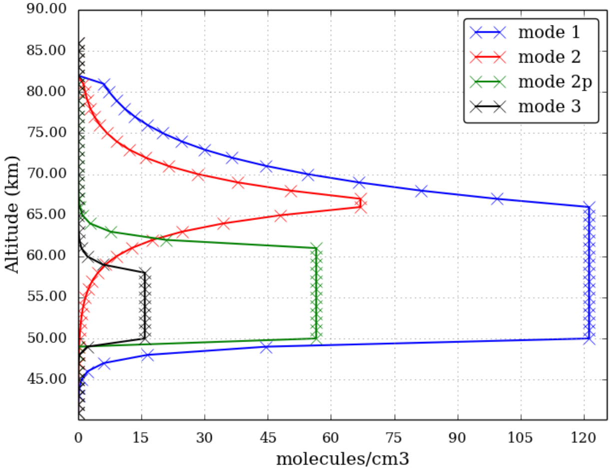


Hinson et al, 1995 Hinson et al, 1995

Cloud model : Equator-50



Cloud model : 50-60



Cloud model : 70-80