Investigations below the clouds of Venus with the IPSL Venus GCM

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Below the clouds of Venus

Tool for these studies

IPSL Venus GCM

Radiative transfer in deep atmosphere

Strong impact on dynamics

Wave activity

Impact on angular momentum transport and zonal wind profile

Near-surface behavior

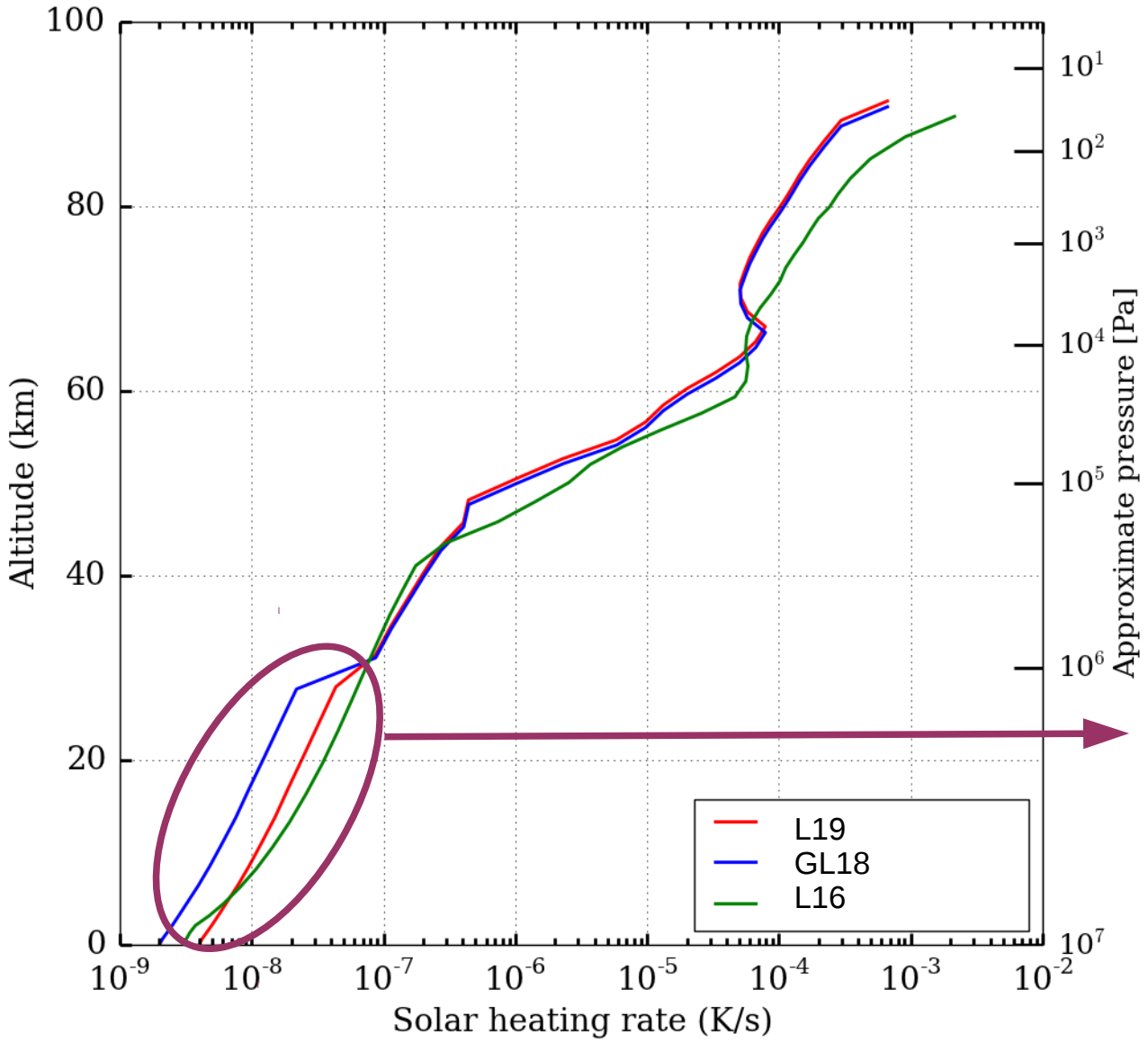
Planetary boundary layer (PBL) structure,
slope winds and mountain waves

IPSL Venus GCM

- Three-dimensional: 96x96x50 (0~95 km)
- Vertical coordinates: hybrid (sigma/pressure)
- Dynamical core, transport of tracers
- Specific physics:
  - **radiative transfer:** Infrared Net Exchange Rates matrix
    Solar heating rates: tables
  - parameterizations of sub-grid processes:
    boundary layer (Mellor&Yamada 1982), convection
  - Topography
  - Photochemistry implemented (PhD of Aurélien Stolzenbach)
  - clouds microphysics, to be tested (PhD of Sabrina Guilbon)
- **Recent simulations:**
  - Lebonnois et al. 2016 (L16)
  - Garate-Lopez & Lebonnois (GL18)
  - New simulation, ongoing analysis (L19)

Radiative transfer sensitivity

Tuning solar heating in the deep atmosphere...



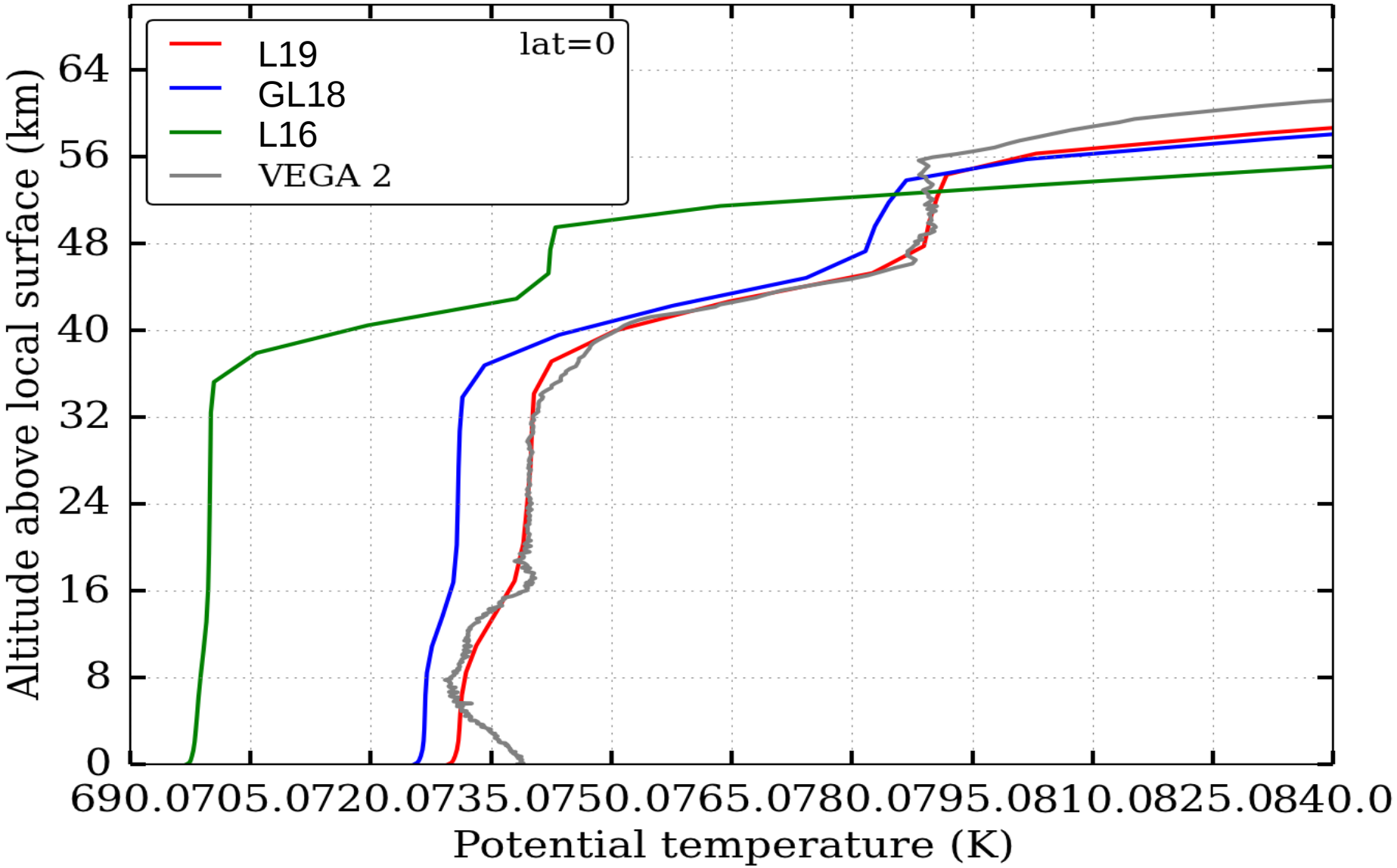
Red : New tuning (L19)
Green : Crisp, 1986 (used in L16)
Blue : Haus et al, 2015
+ additional heating (30-48 km)
(used in GL18)

Additional heating
below 30 km
(closer to Crisp computations)

Need for additional modeling
and confirmation

Radiative transfer sensitivity

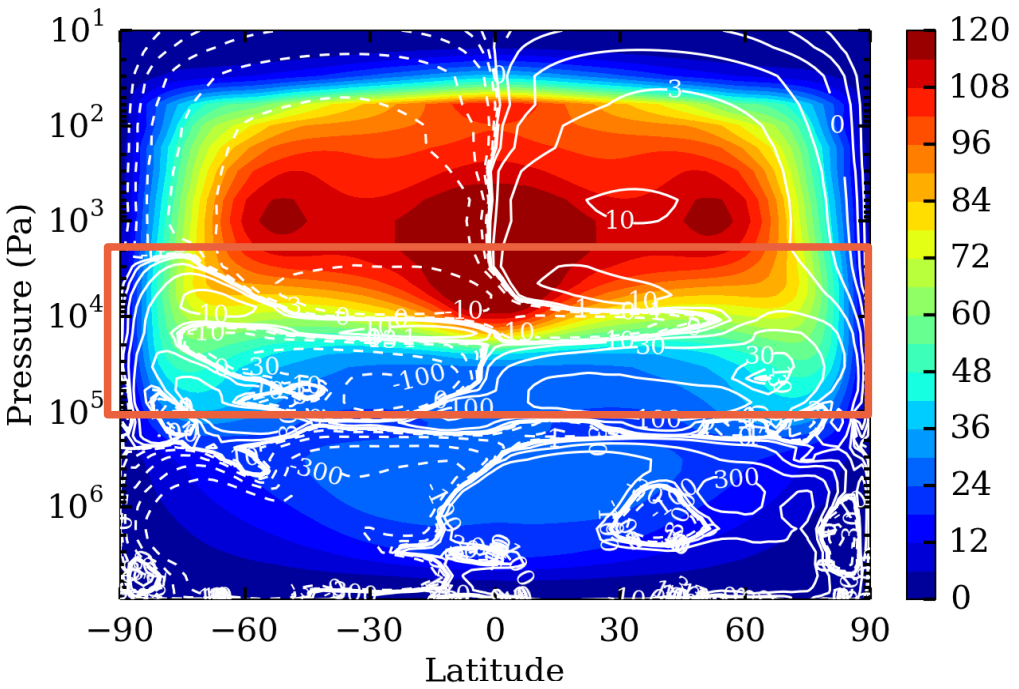
New solar tuning
=> fit of the temperature to Vega 2 profile



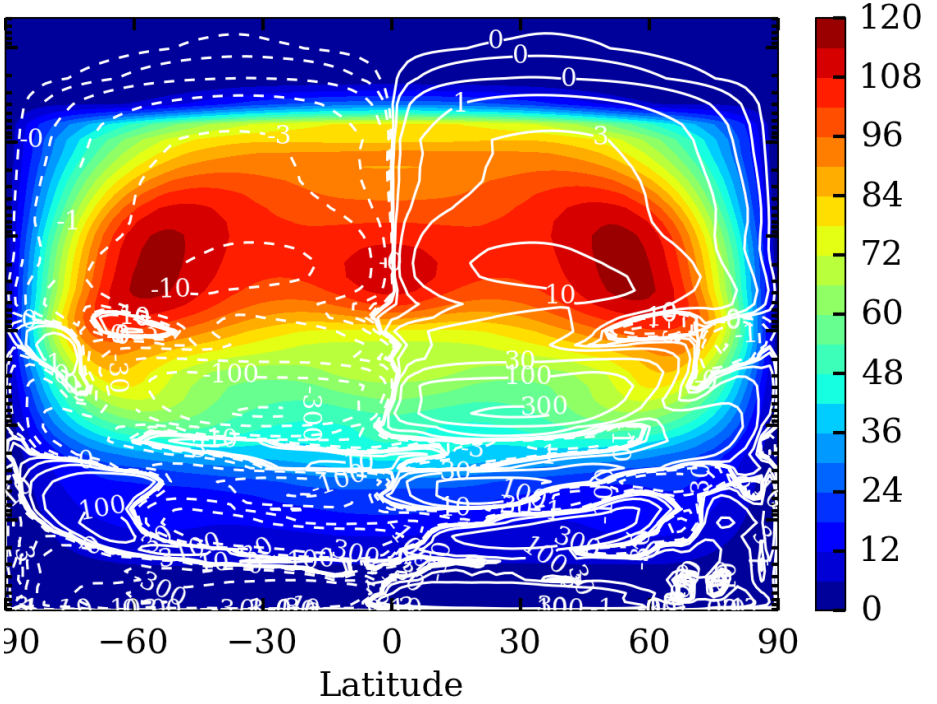
Superrotation

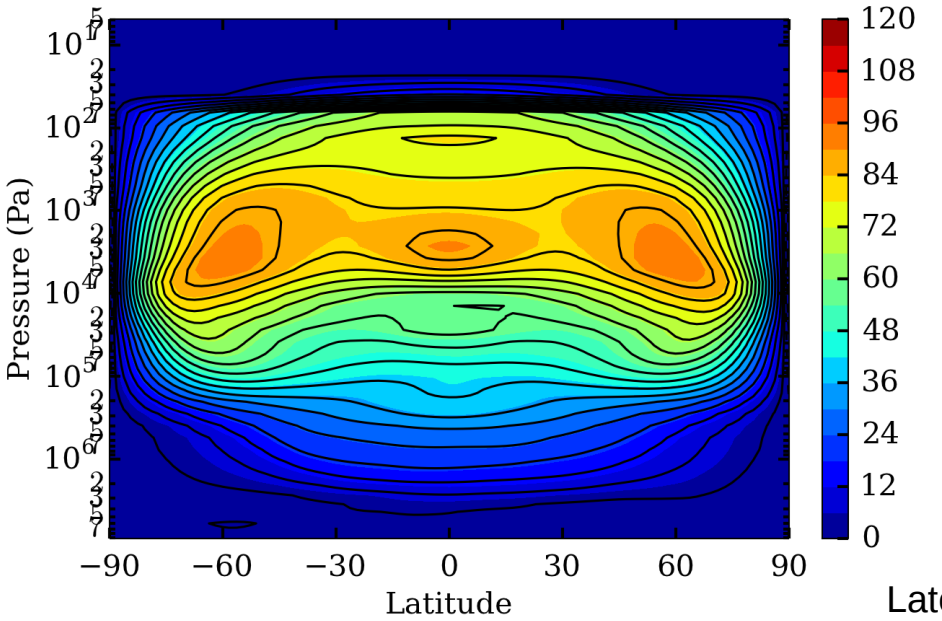
Clouds

Lebonnois et al. (2016)



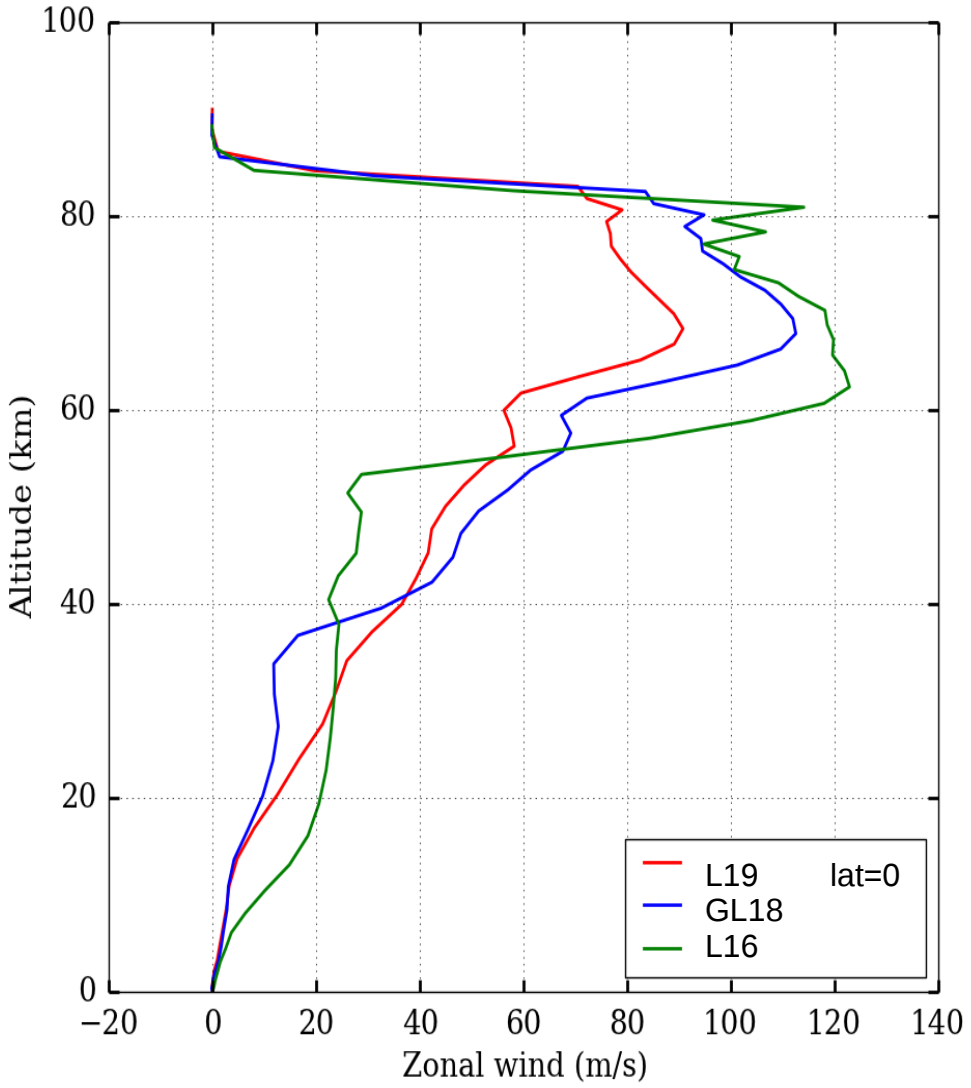
Garate-Lopez & Lebonnois (2018)





Latest simulation (L19)

Superrotation



Zonal wind distribution

↕

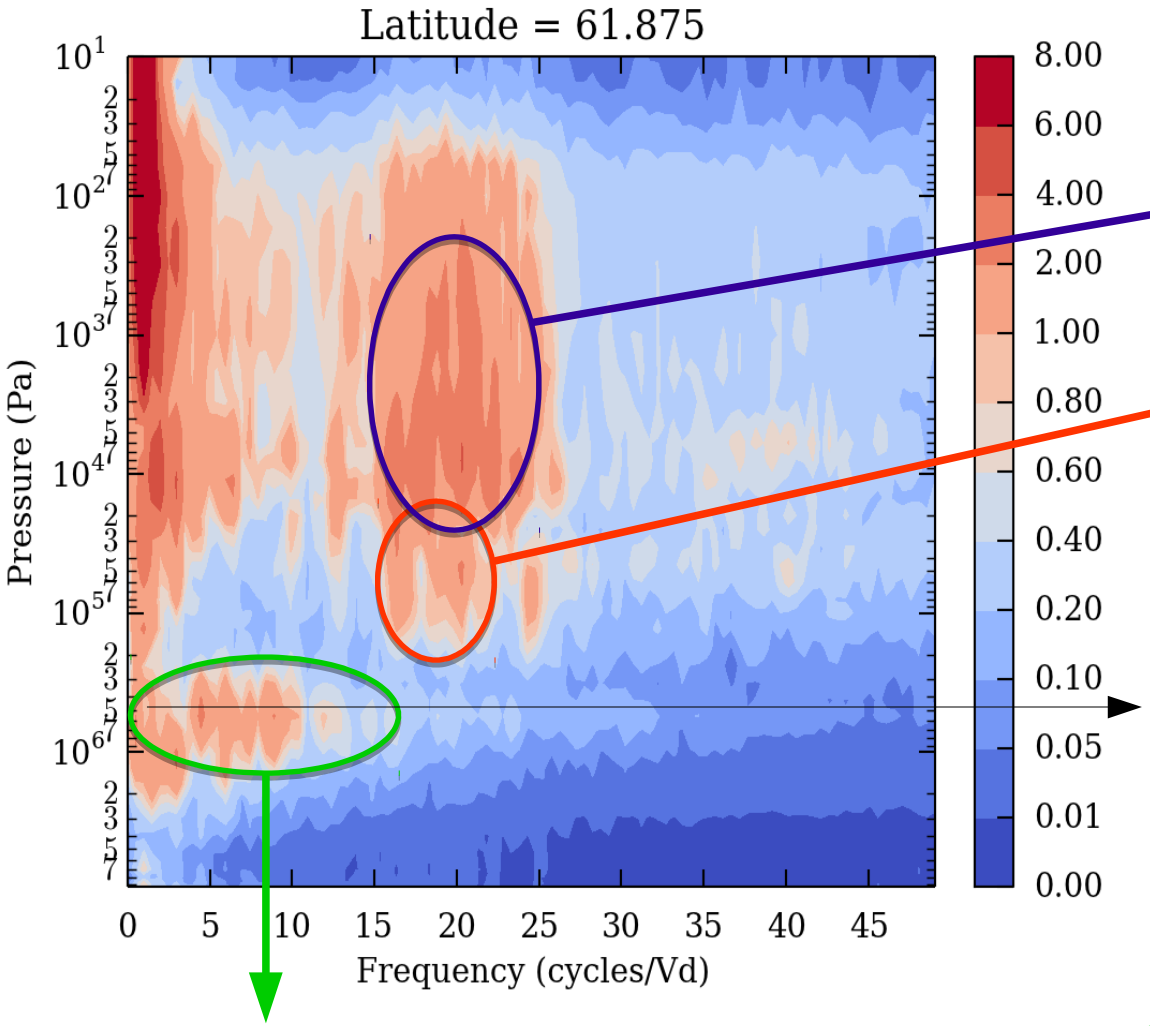
Angular momentum transport

↕

Wave activity

Wave activity

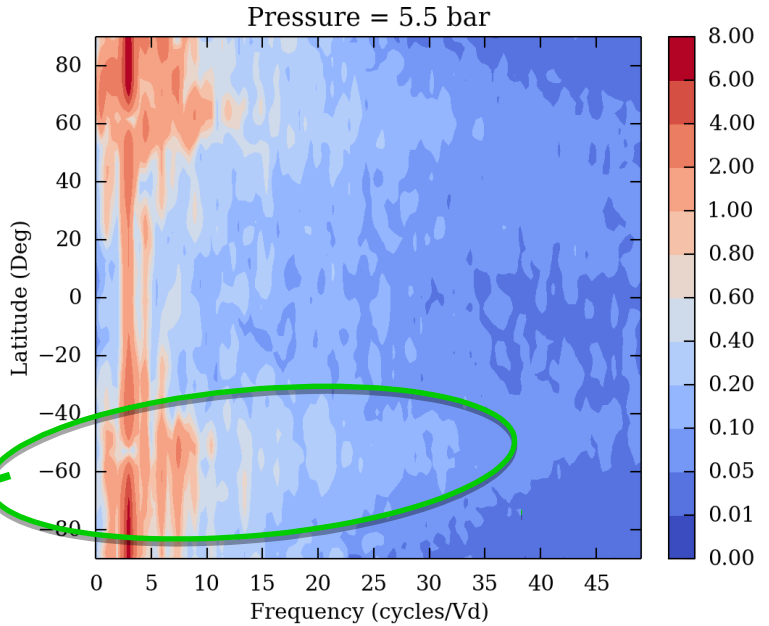
Most recent simulation (L19)



FFT of zonal wind time series

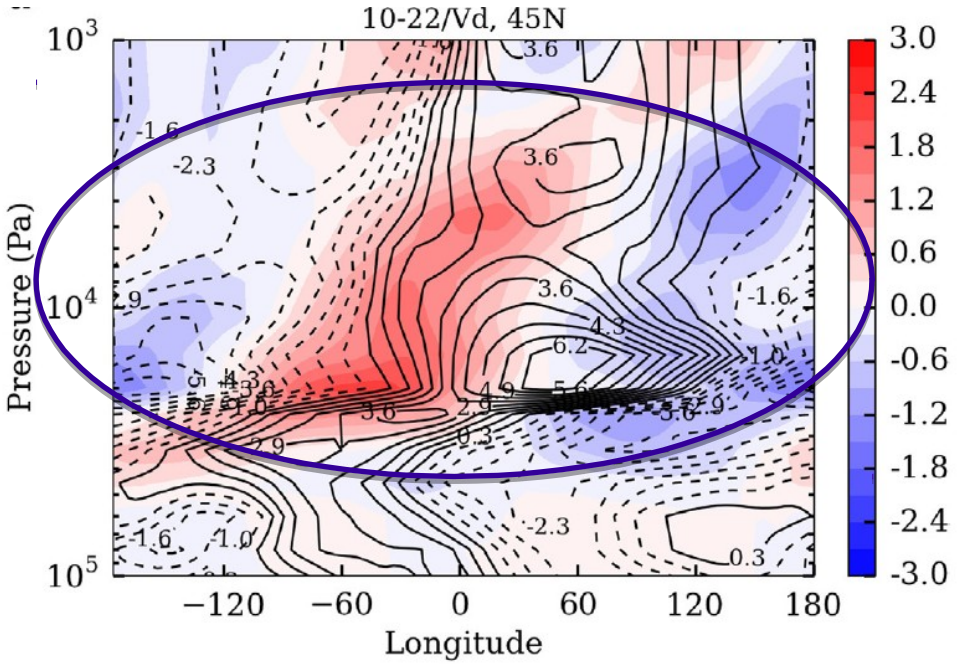
Dominant baroclinic activity,

Wave activity,
contributes to cloud-base
equatorial zonal wind



Inertio-gravity waves,
contributes to deep atmosphere
zonal wind

Angular momentum budget

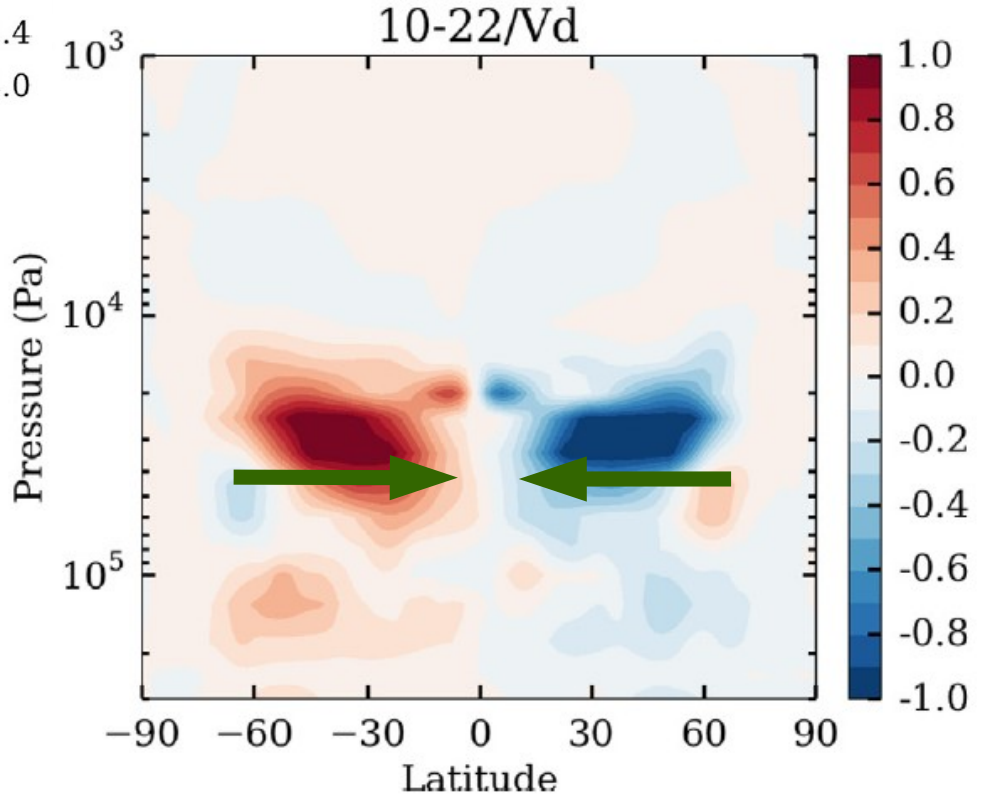


Baroclinic waves

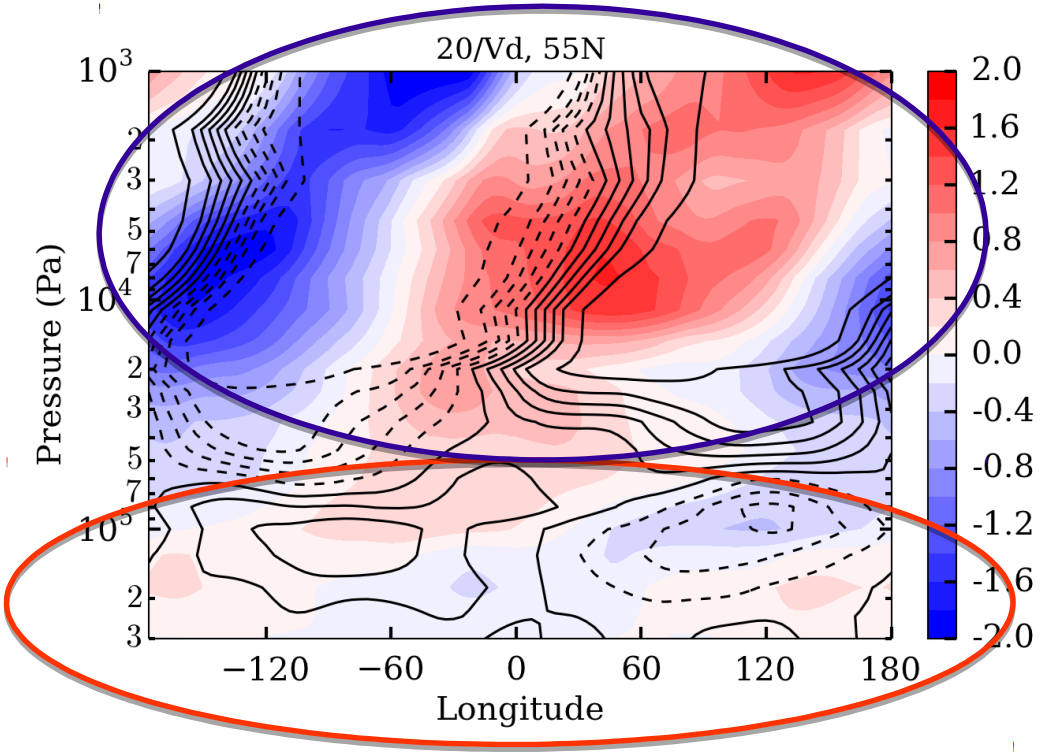
Meridional wind and temperature anomalies

Lebonnois et al (2016)

Horizontal transport of angular momentum



Angular momentum budget

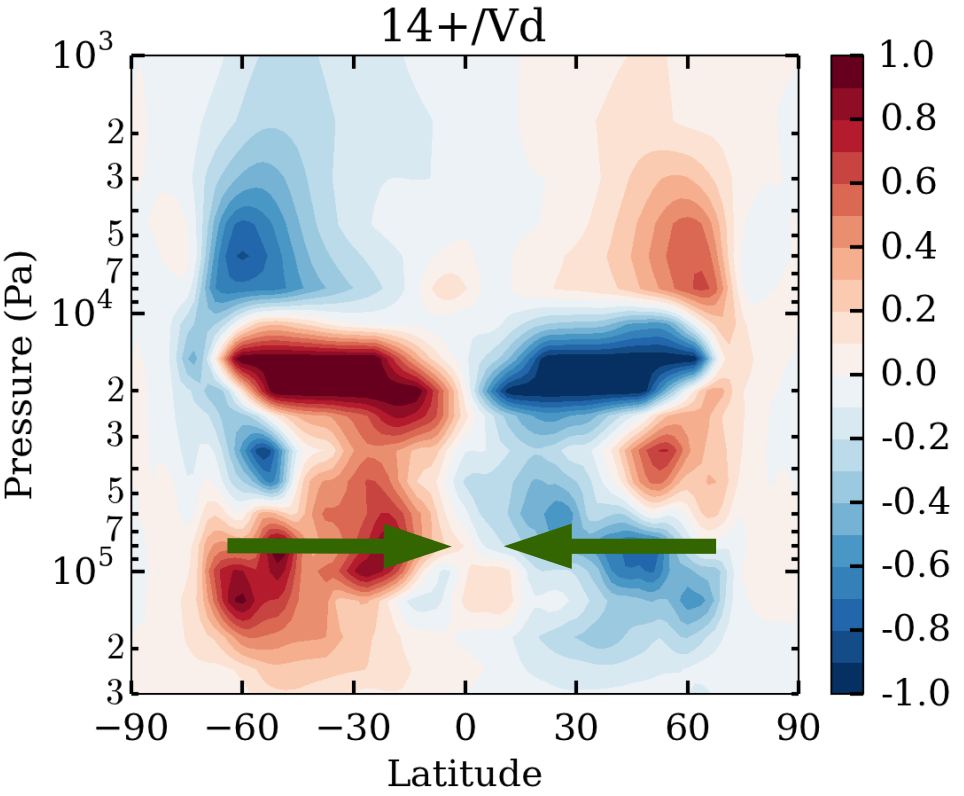


Cloud base waves

Meridional wind and temperature anomalies

Most recent simulation (L19)

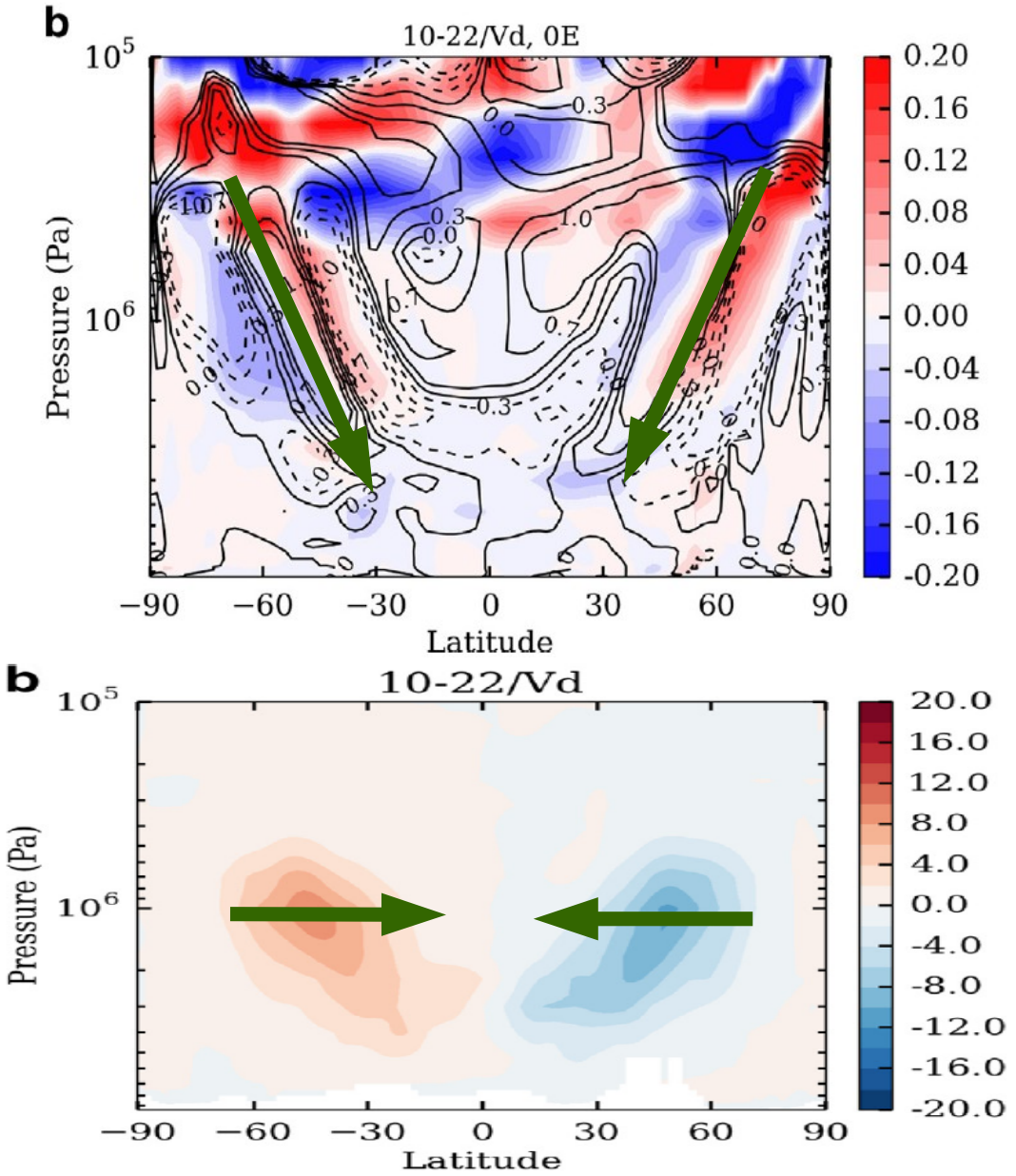
Horizontal transport of angular momentum

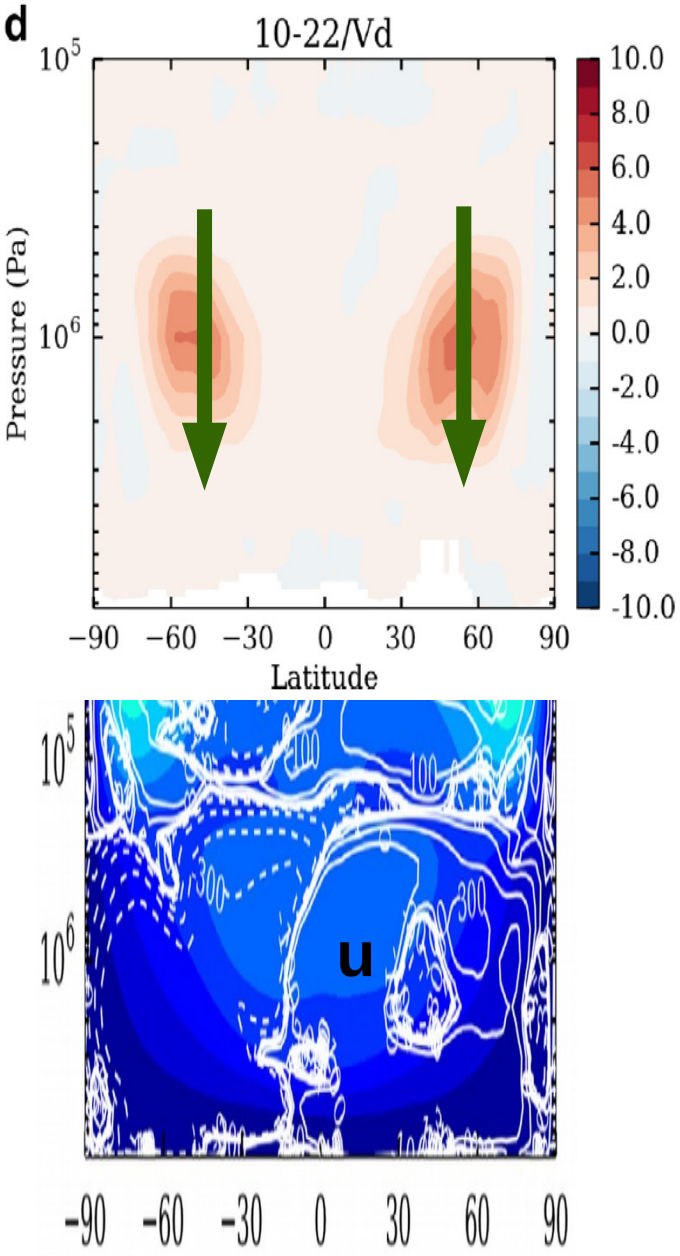


Angular momentum budget

Inertio-gravity waves

Lebonnois et al (2016)

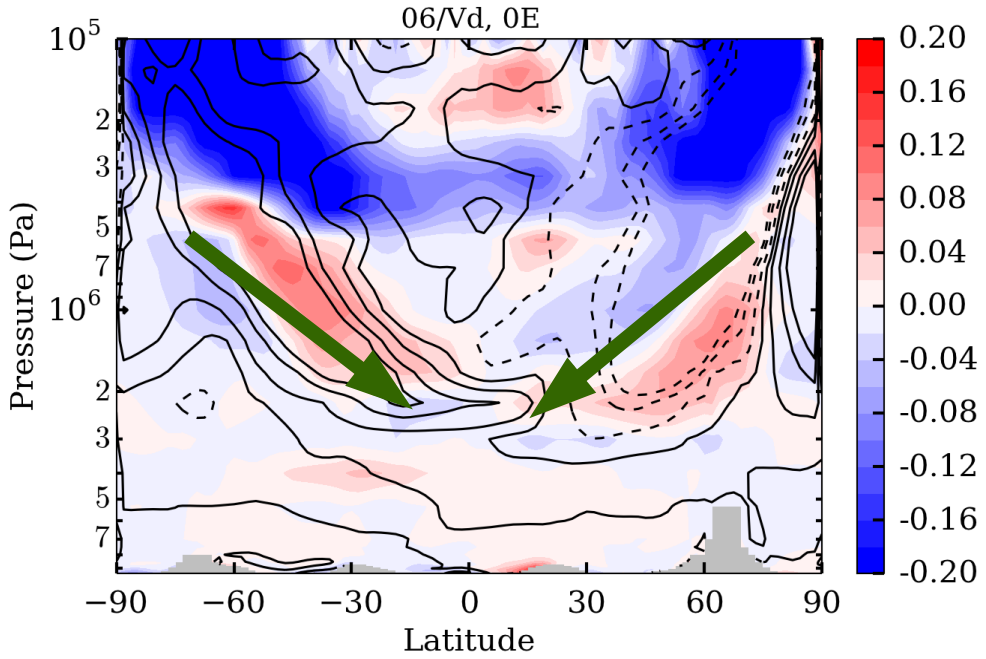


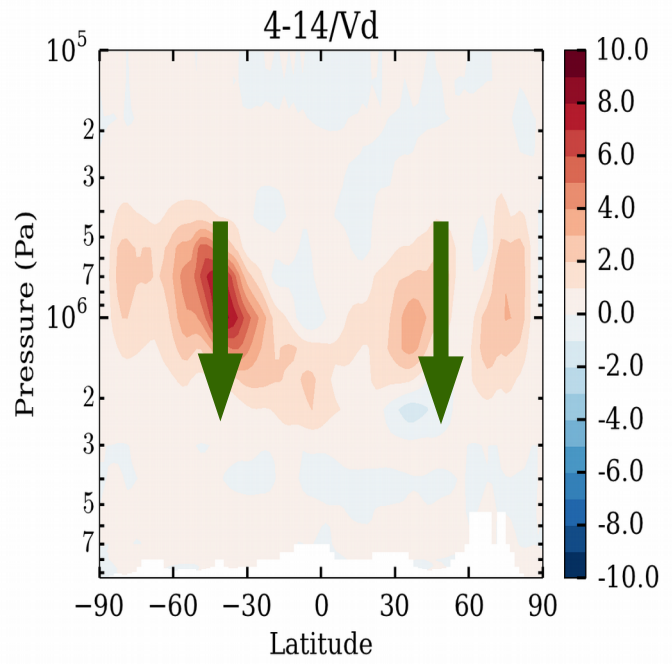


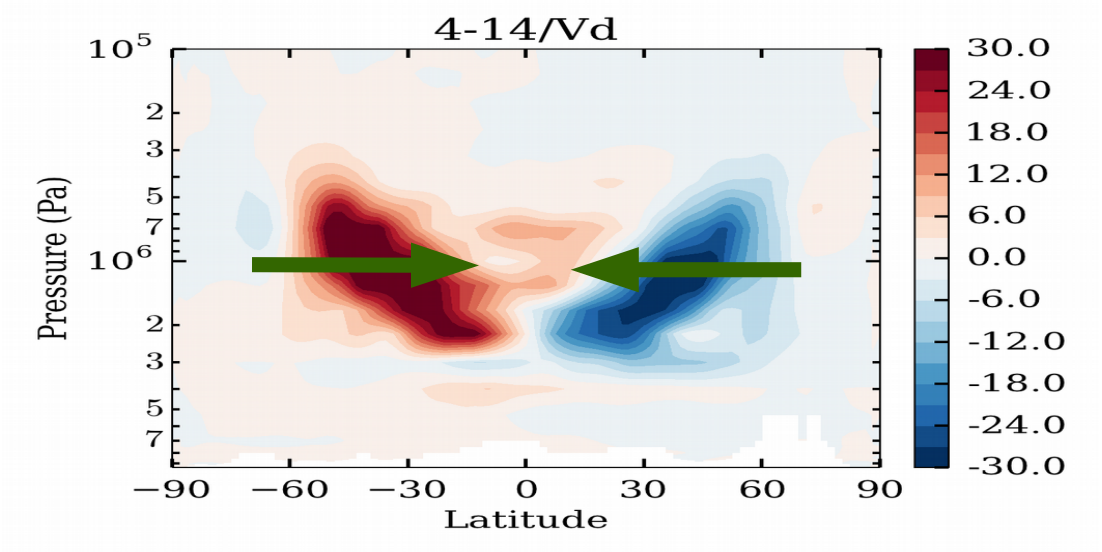
Angular momentum budget

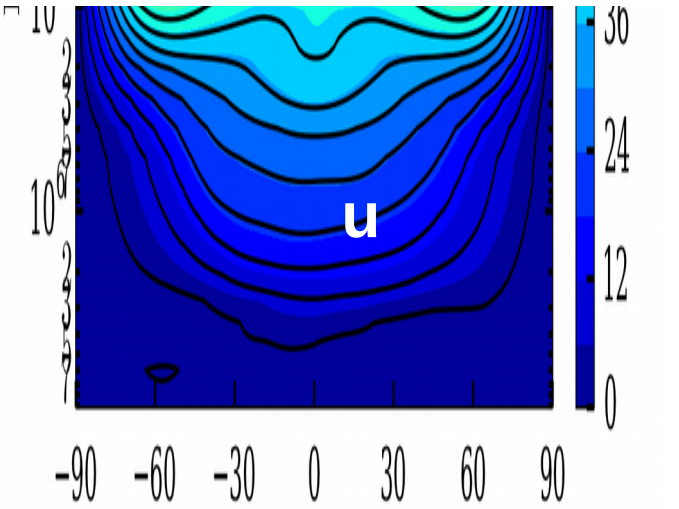
Inertio-gravity waves

Most recent simulation (L19)

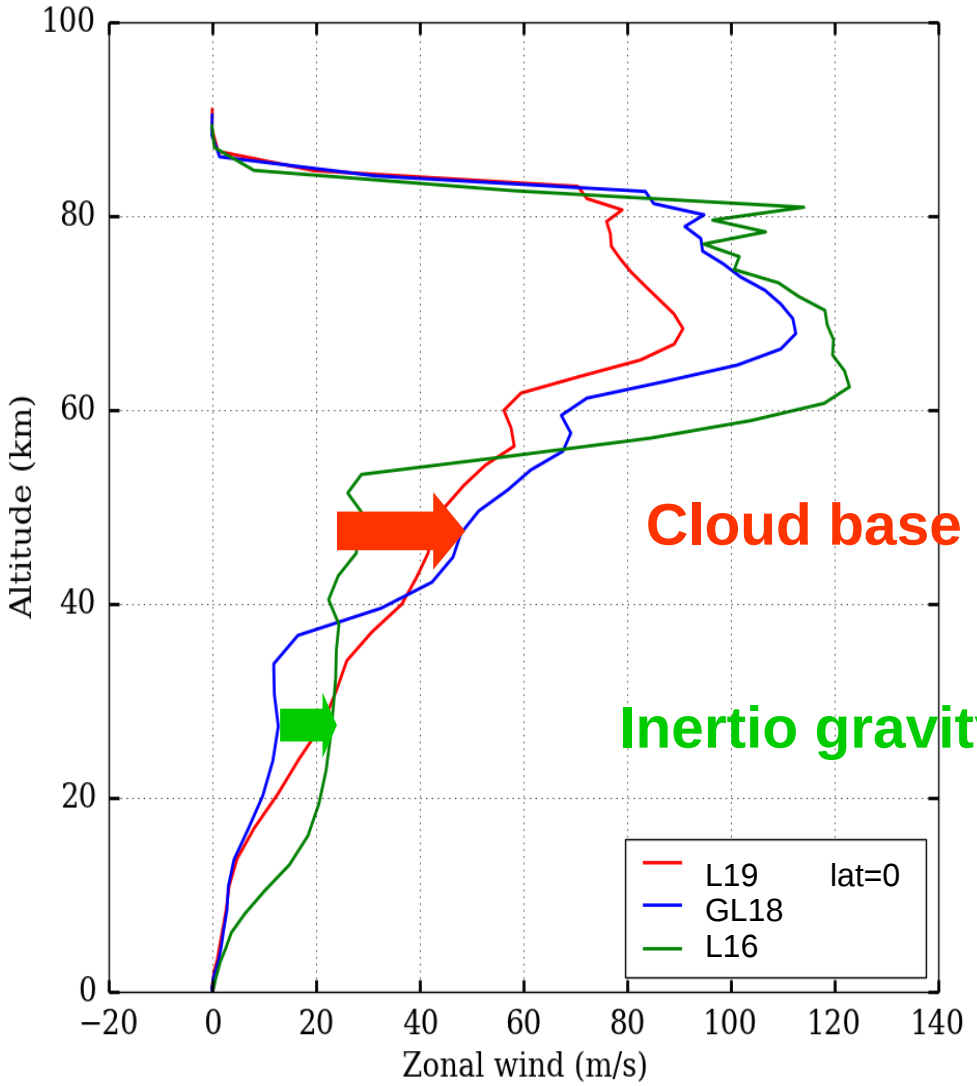








Wave activity below clouds

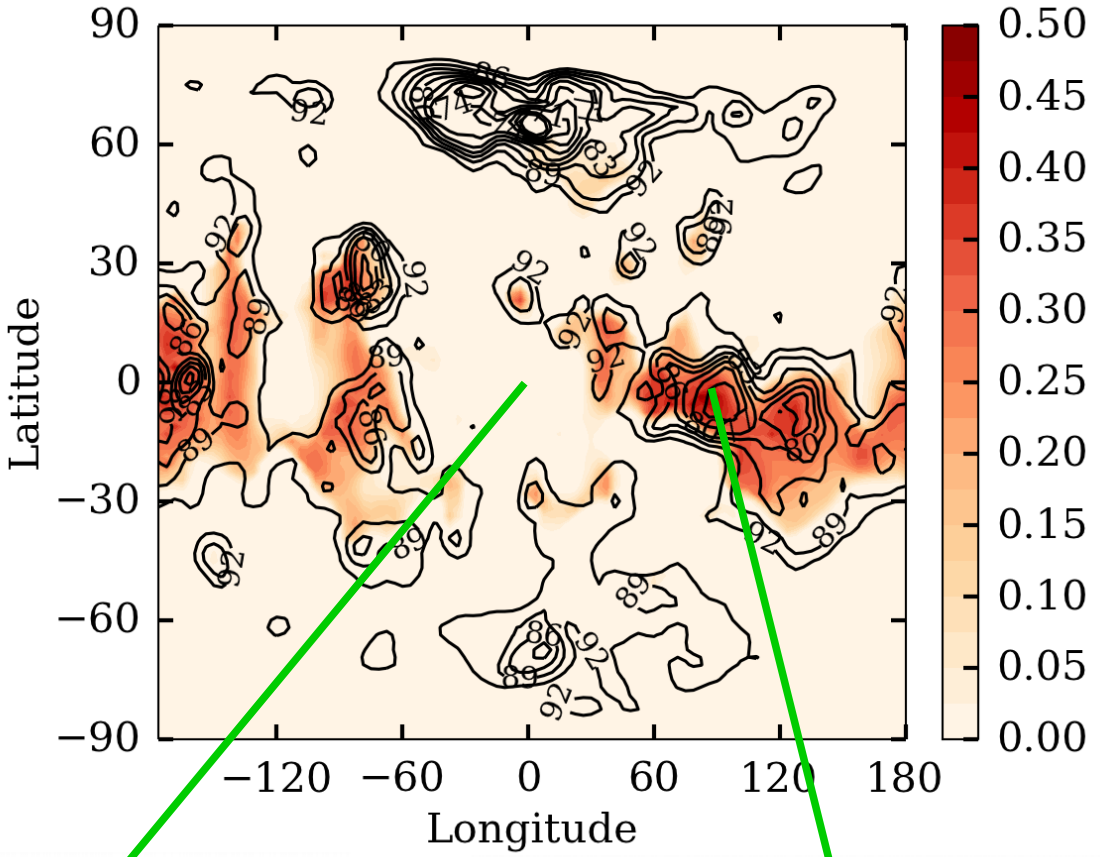


Cloud base wave activity

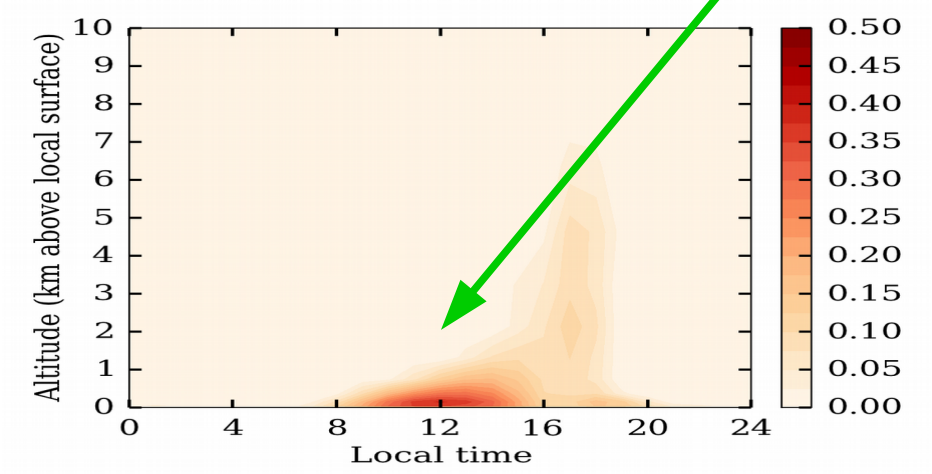
Inertio gravity wave activity

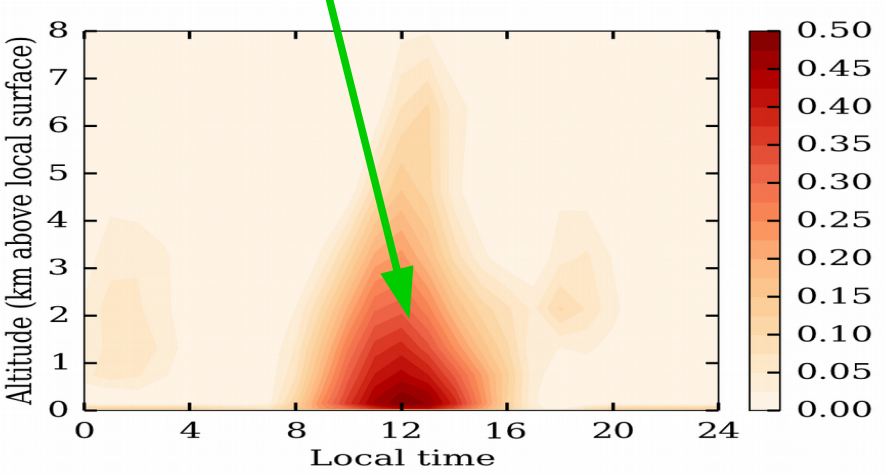
PBL structure

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

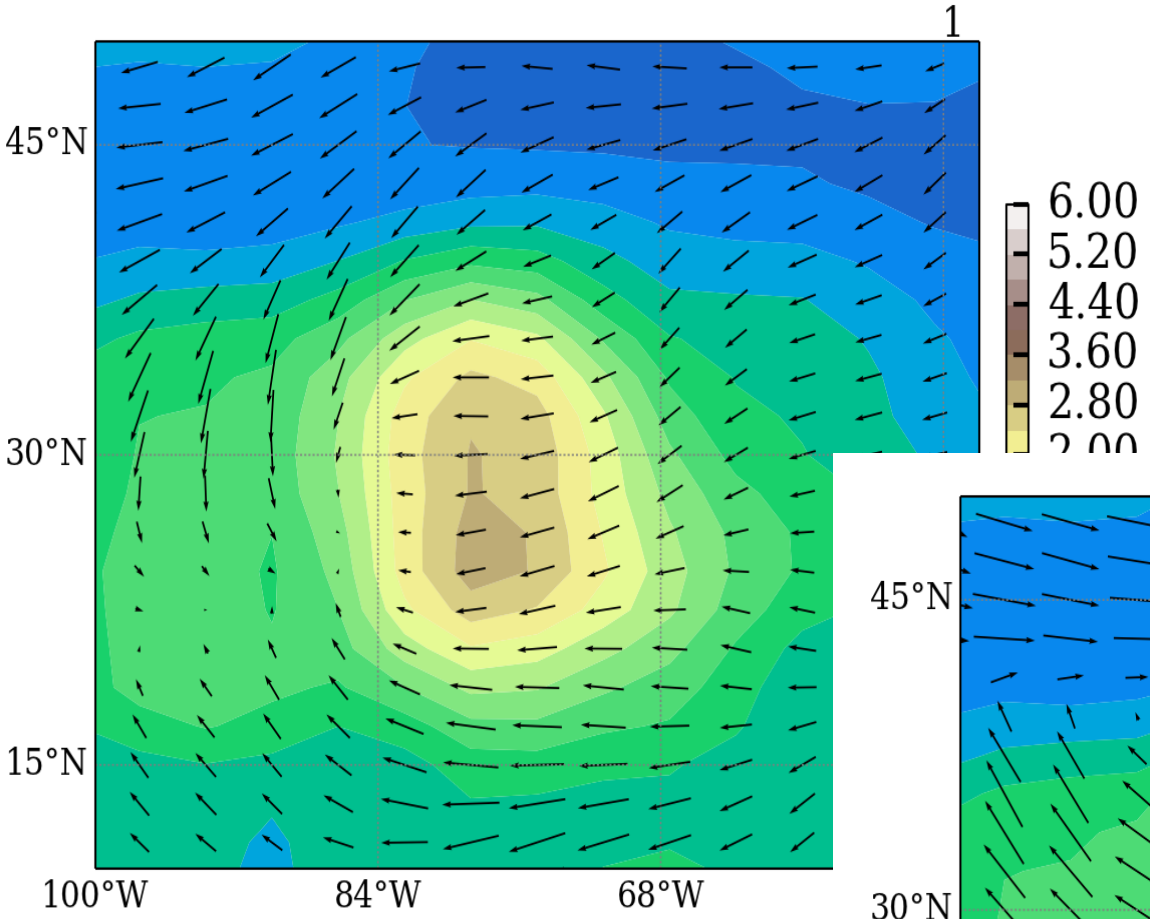


Lebonnois et al., 2018





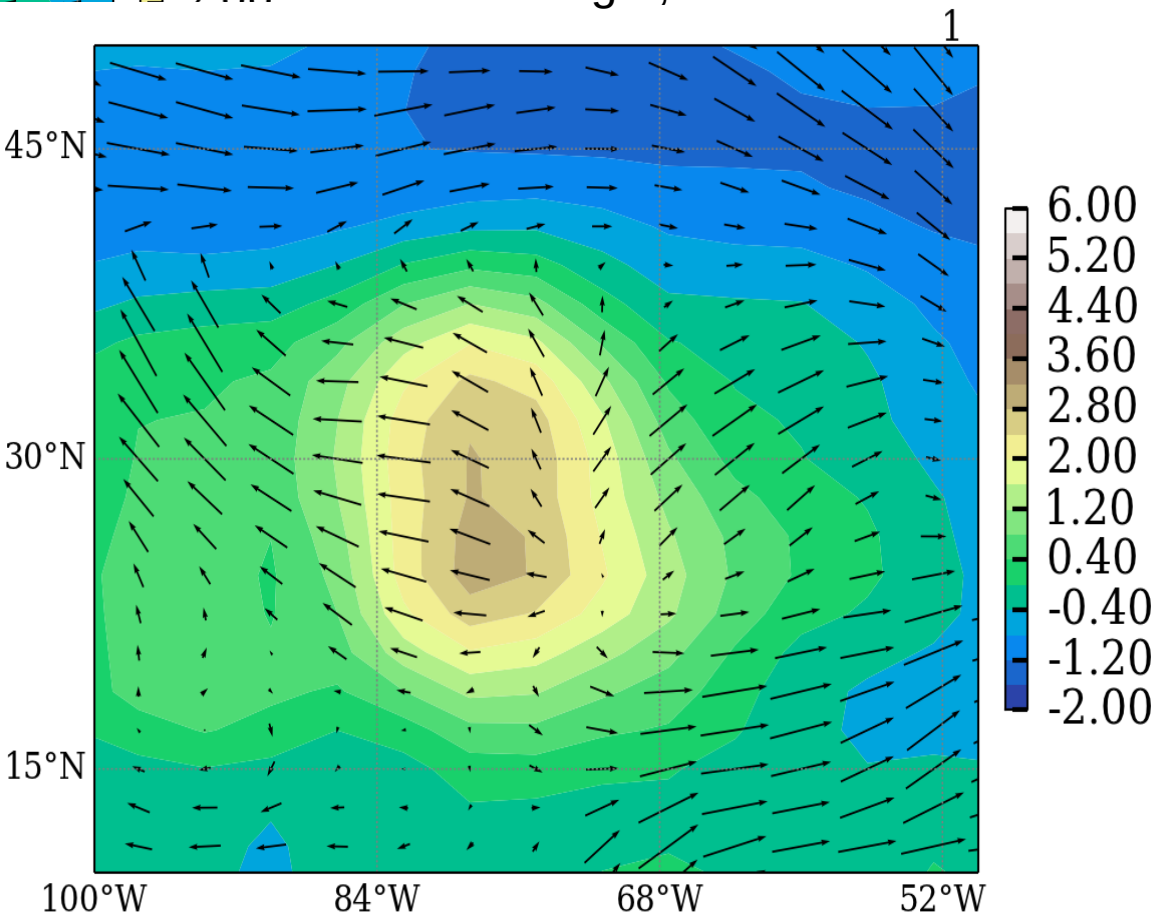
Role of slope winds



Noon, anabatic

winds 150 m above surface
Beta Regio (30N)

Midnight, katabatic



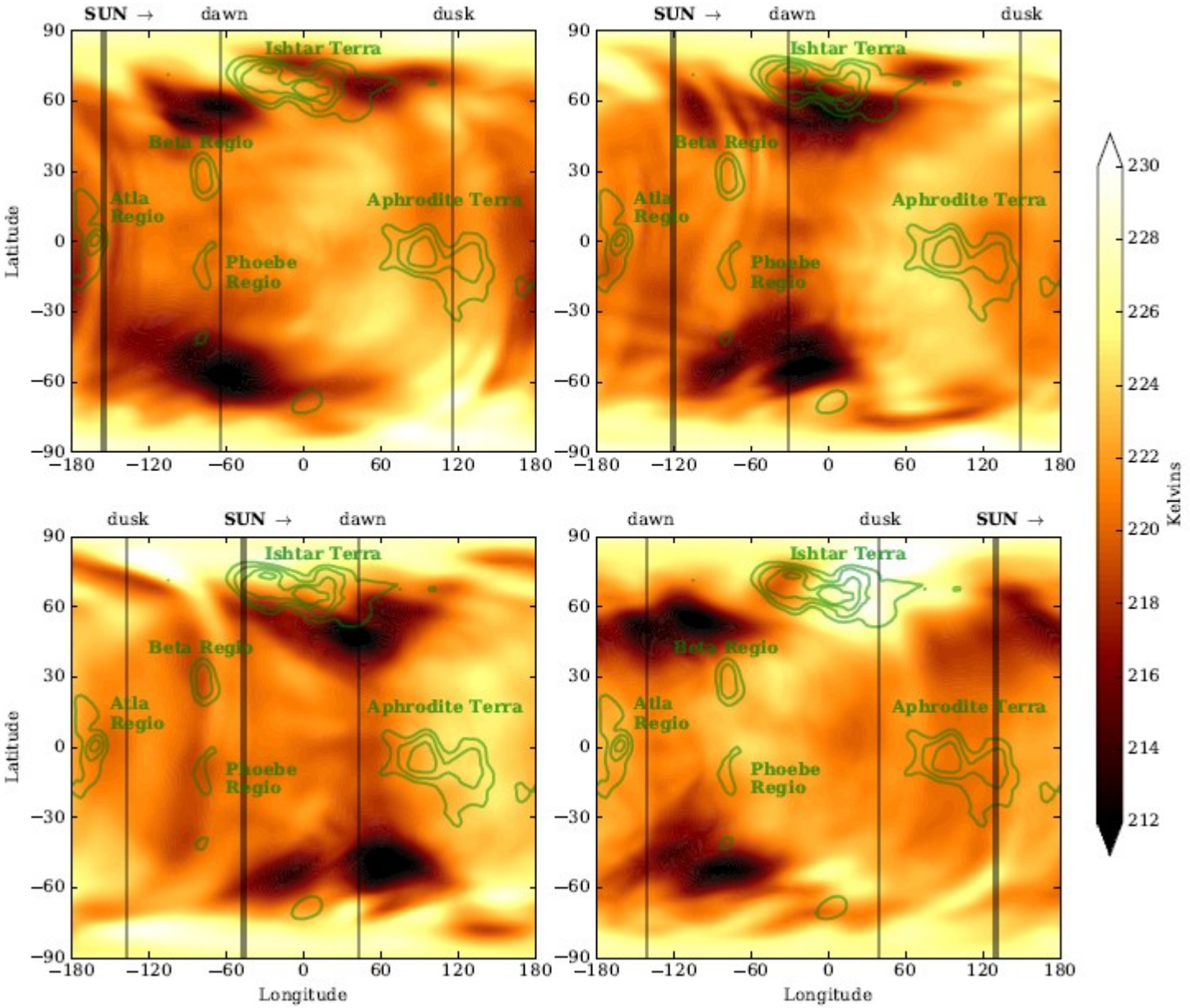
Lebonnois et al., 2018

Mountain waves

Physical parameterization tested in the GCM

GCM

T at 70km
(~cloud-top)



Navarro et al., 2018

Conclusion

Zonal wind field results from subtle balance between mean meridional circulation and wave momentum transport

Wave activity
- plays a crucial role in the redistribution of angular momentum
- is very sensitive to solar heating distribution in the deep atmosphere

Different type of waves can participate to this balance
=> tides, planetary-scale horizontal waves, inertio-gravity waves

Near-surface slope winds affect the stability structure of the PBL, which controls the emission and propagation of mountain waves

Interpretation of the zonal wind distribution needs
- observational constraints on planetary-scale wave activity
- confirmation by comparisons between several GCMs