Modelling of Jupiter tropospheric dynamics

Alexandre Boissinot

Laboratoire de Météorologie Dynamique

Supervisor : Aymeric Spiga
Advisor : Sandrine Guerlet

March 28, 2018

Introduction

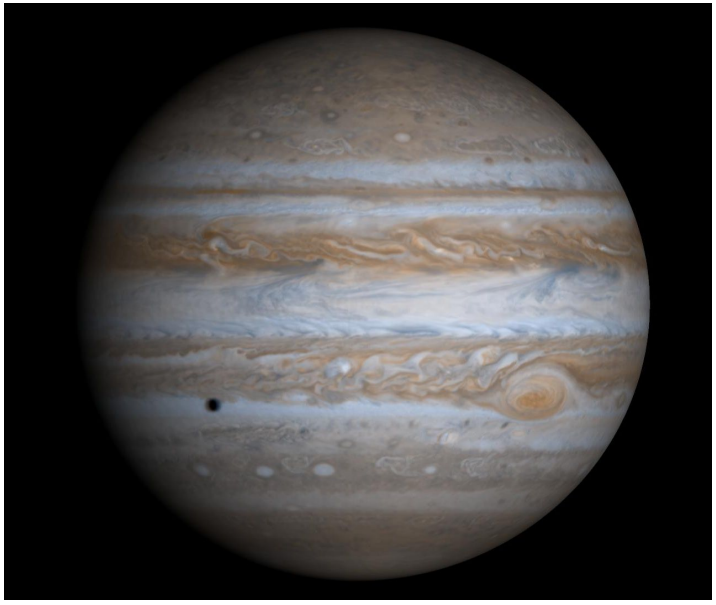
During my PhD about the *modelling of Jupiter atmosphere dynamics*, I will focus on the troposphere.

- What is the superrotation driving force ?
- How maintain large and long-duration anticyclones on Jupiter ?
- Why Jupiter poles are turbulent unlike Saturn ones ?

Framework:

- I. Observations
- II. Model and context
- III. Reference simulation
- IV. Discussion

Jupiter orbital constants



- Masse: $1.9\ 10^{27}$ kg
- Radius: $7\ 10^{7}$ m
- Solar constant: 50 W m^{-2}
- Obliquity: 3.13°
- Day length: 9.9 hours
- Year length:
  10475.5 jovian days or
  4333.4 terrestrial days

Jupiter interior and composition

- No surface
- Atmospheric composition: H_2 (86.3%), He (13.4%), CH_4, NH_3, H_2O and H_2S (percentages are mole fractions as determined by the Galileo probe, *cf.* Niemann *et al.* 1998).

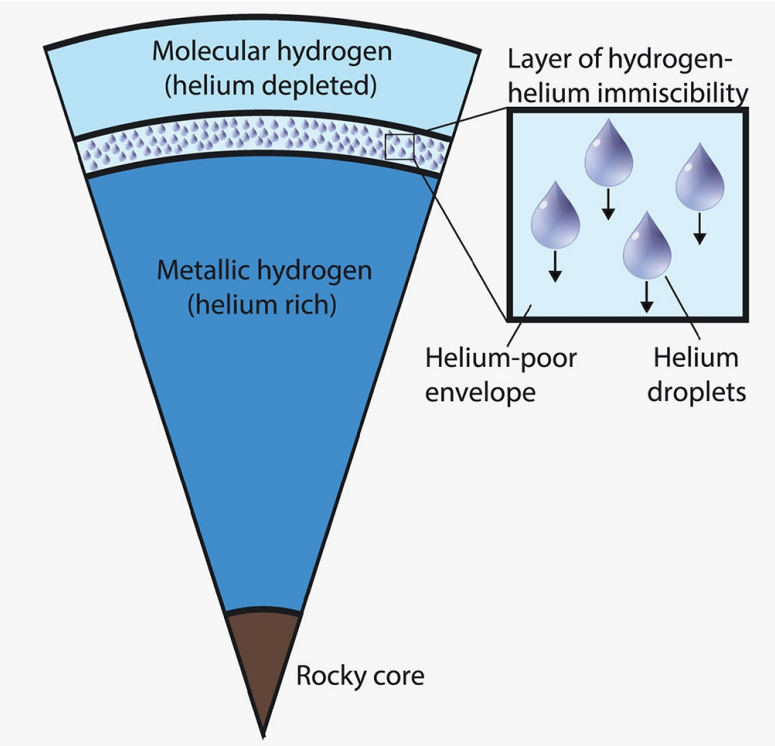


Figure : Jupiter interior structure (Militzer *et al.* 2016)

ATMOSPHERE OBSERVATIONS

Bands and Jet-streams

- Equatorial superrotation
- Jets alternately prograde and retrograde

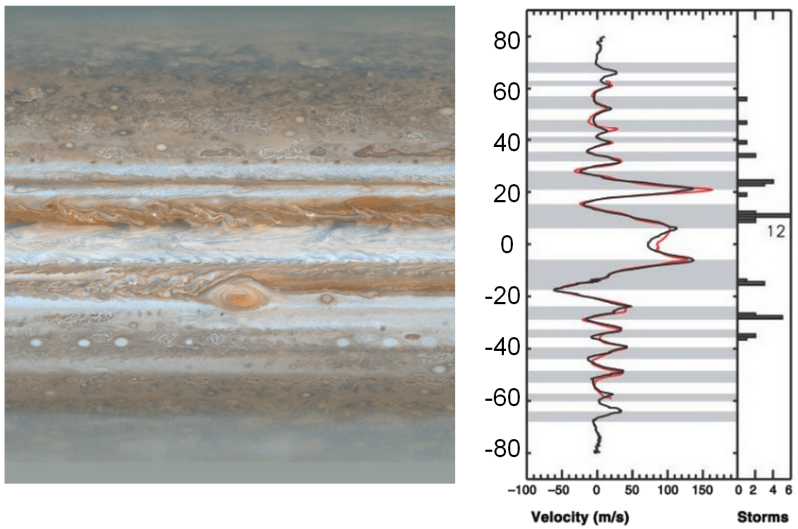


Figure : Jupiter bands and zonal wind zonal mean profile

Cyclones and anticyclones

Figure : Juno image of the Great Red Spot (GRS)

- Size: from 1000 to 20000 km
- Duration: from a few days to several years (almost 400 for the Great Red Spot)

Jupiter poles

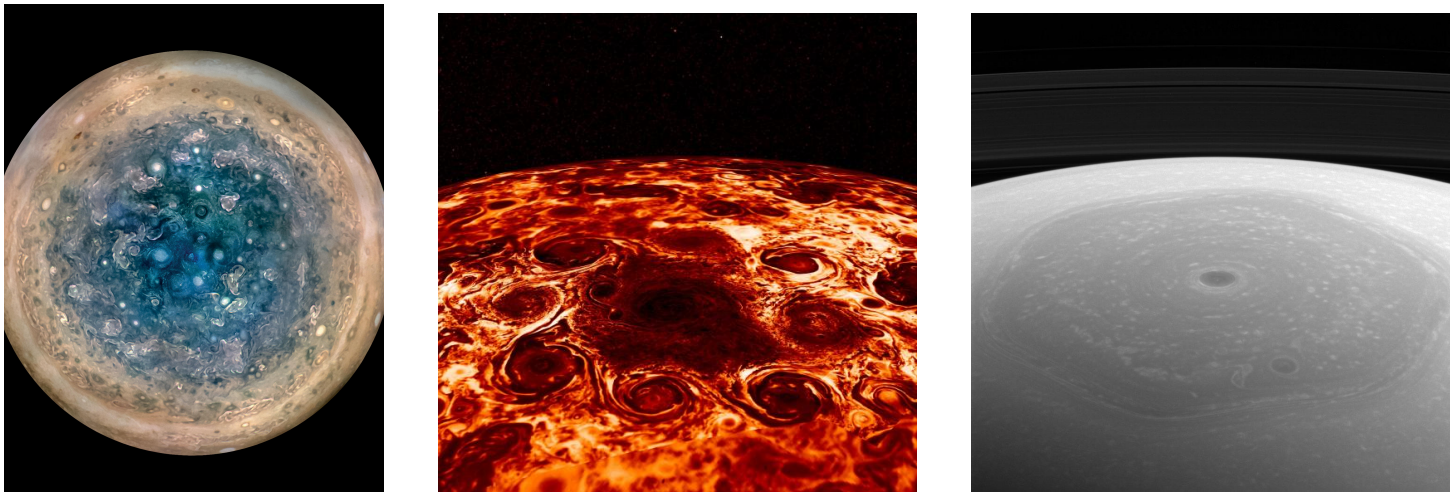


Figure : Left and center: respectively Jupiter South and North poles as seen by JIRAM and JUNOCAM. Left: Saturn North pole (Cassini)

- Jupiter poles seem to be more turbulent than Saturn ones.
- Anticyclones collars around South and North polar vorticies which include 5 and 8 vorticies repectively.

Cloud structure

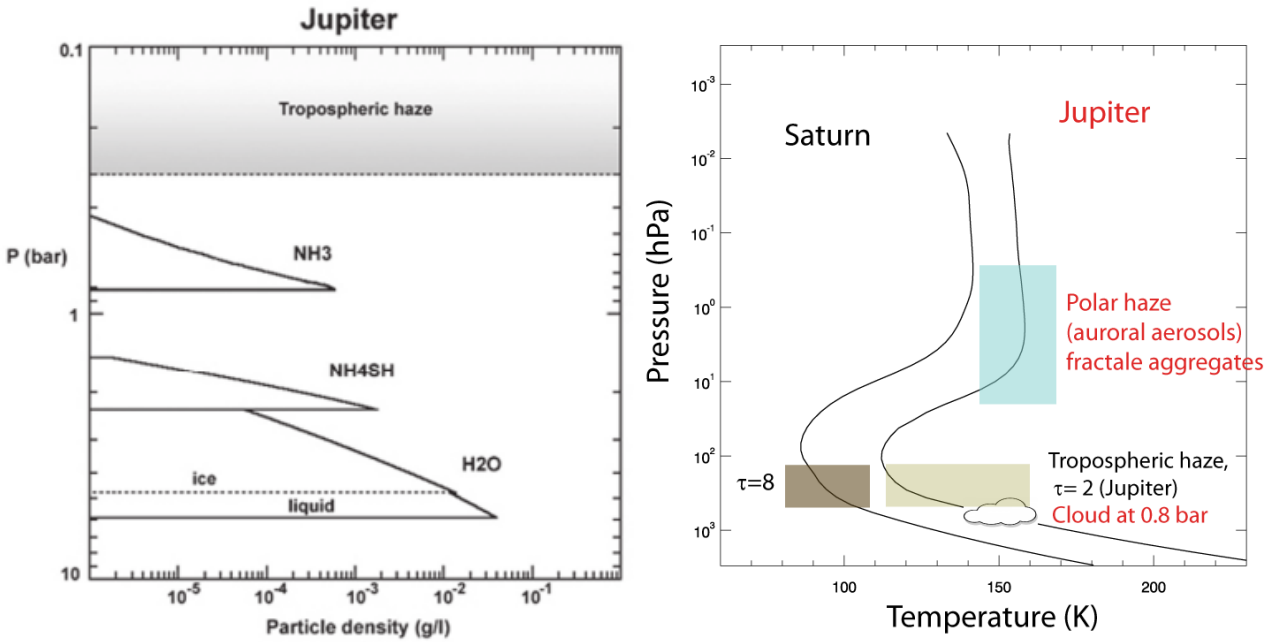


Figure : Jupiter clouds vertical structure (left) and Jupiter vertical temperature profile

- Three layers: water (10 to 2 bar), ammonium hydrosulfide ($\approx$ 2 bar) and ammonia (0.8 to 0.4 bar)

Convective activity

- Large storms () mainly occuring in belts
- Field of small convective clouds in zones

Figure :

MODEL USED

Deep and shallow models

Two kinds of models try to explain the previously mentionned atmospheric features: deep models and shallow models.

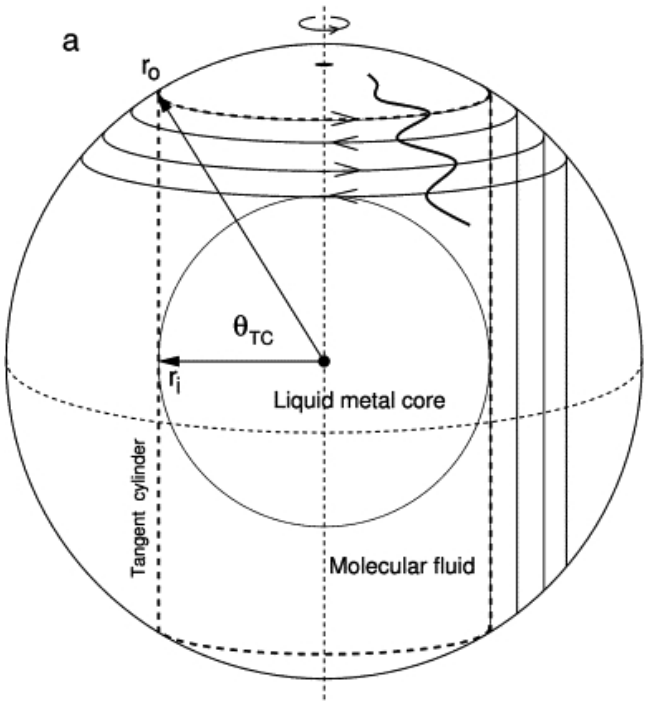


Figure : Deep model illustration (Heimpel & Aurnou 2006)

- Deep models assume that jets result from
- Shallow models assume that jets result from
- In both cases, an inverse cascade transfers energy from small to large scales.

Dynamical core

Dynamico is the dynamical core used here.

- Hexagonal-icosahedral grid
- Assumptions: shallow atmosphere, hydrostatic approximation

Its interest lies in the grid which is adapted for massively parallel computation.

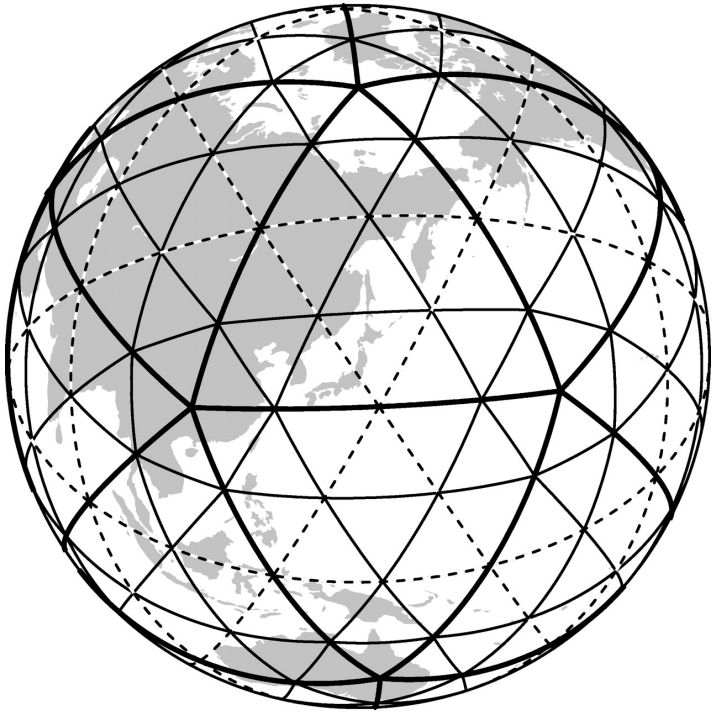


Figure : icosahedral grid – bold line: inscribed icosahedron, solid and dashed line: domain subdivision

Parametrized physics

- Radiative transfer

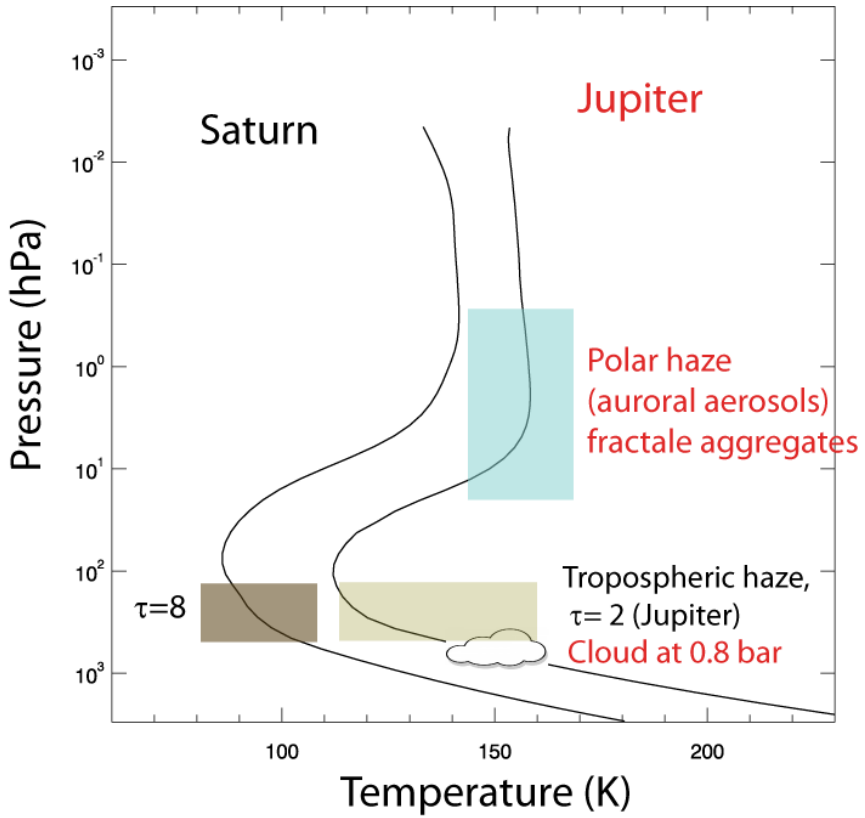


Figure : Jupiter and Saturn vertical temperature profile

– UV-absorbing polar haze

– NH_3 clouds at p=0.8 bar

– NH_3 greenhouse effect in the troposphere

Parametrized physics

- Rayleigh friction (cf. Liu and Schneider 2010)
- Turbulent diffusion
- Dry convective adjustement scheme with relaxation time
- Internal heat flux (constant equal to 6 W m^{-2})

REFERENCE SIMULATION

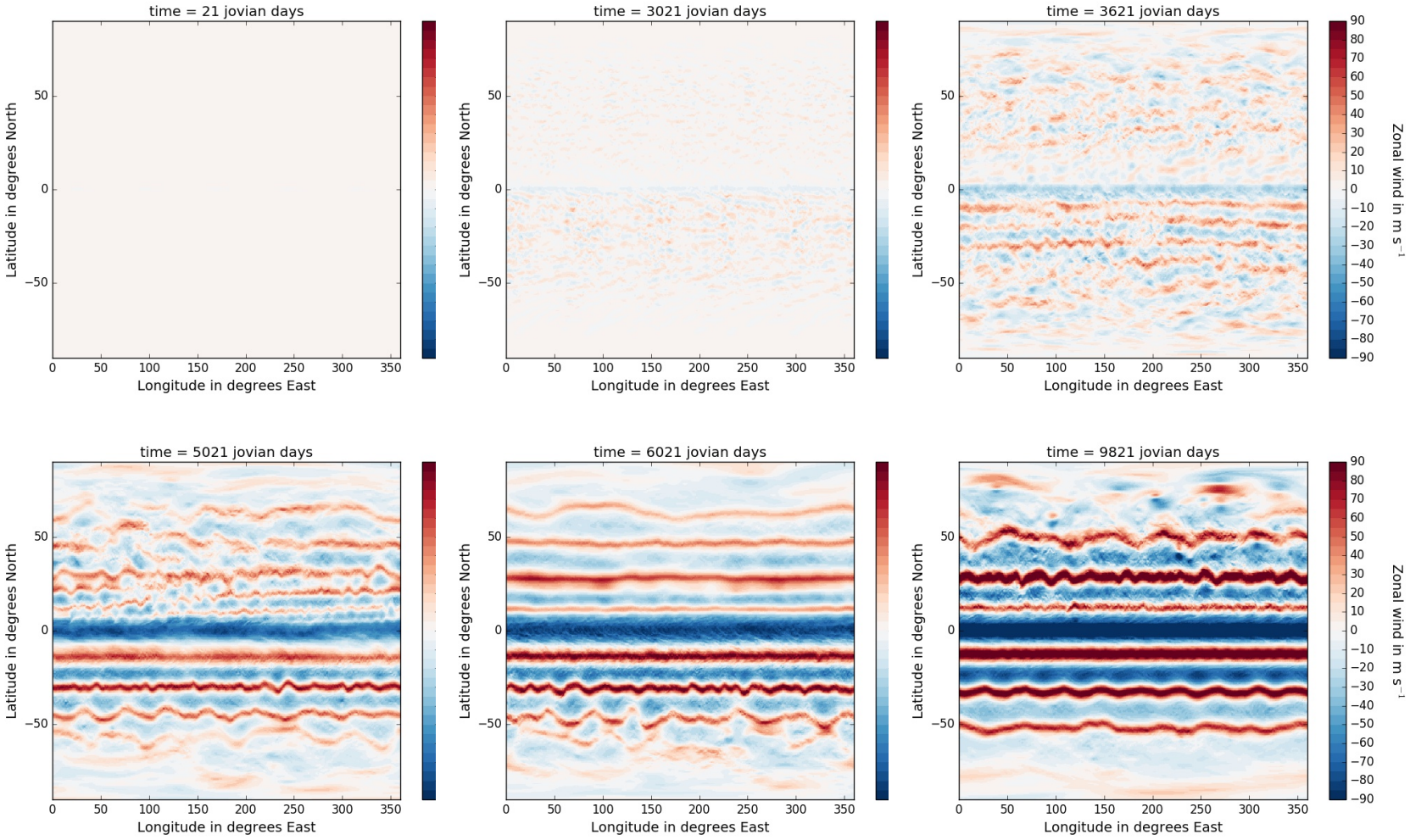
Reference simulation parameters

Parameters:

- Horizontal resolution: 0.5°
- vertical resolution: 32 layers for pressures between 100 mbar and 3.5 bar
- Rayleigh friction: phi=33°and $\tau = 864000$ s
- Dissipation: $n = 1$ and $\tau = 2500$ s

10 jovian years were simulated.

Simulation convergence



Jets migration

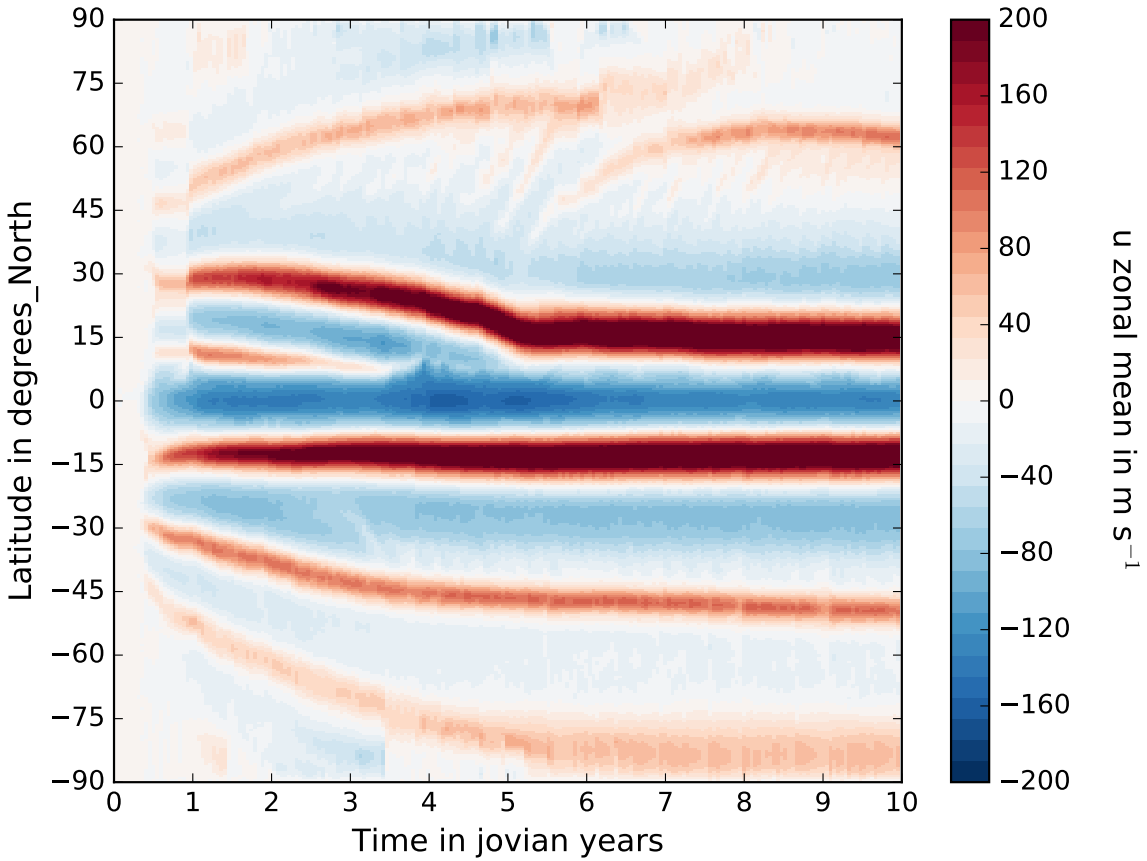


Figure : Zonal mean zonal wind at p=1 bar

Reference simulation

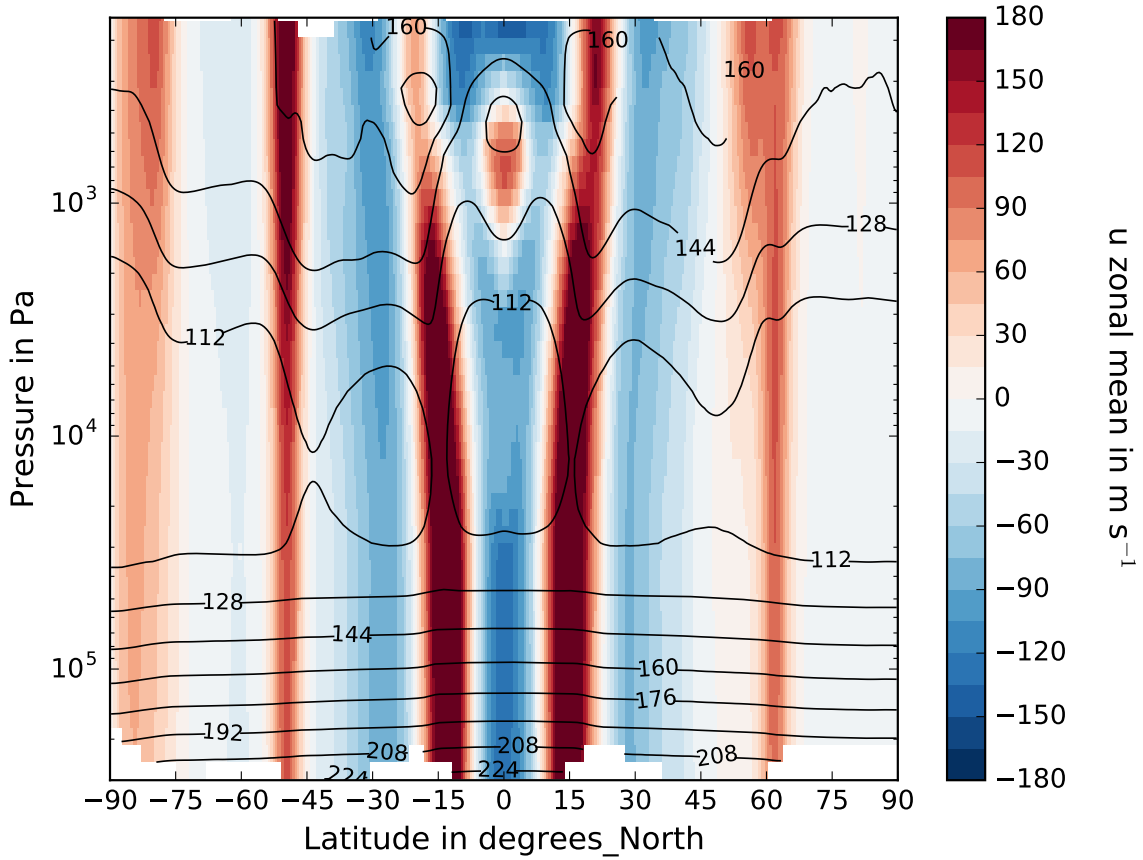


Figure : Zonal wind (colors) and temperature (black lines) at t=104500 jovian days

Reference simulation

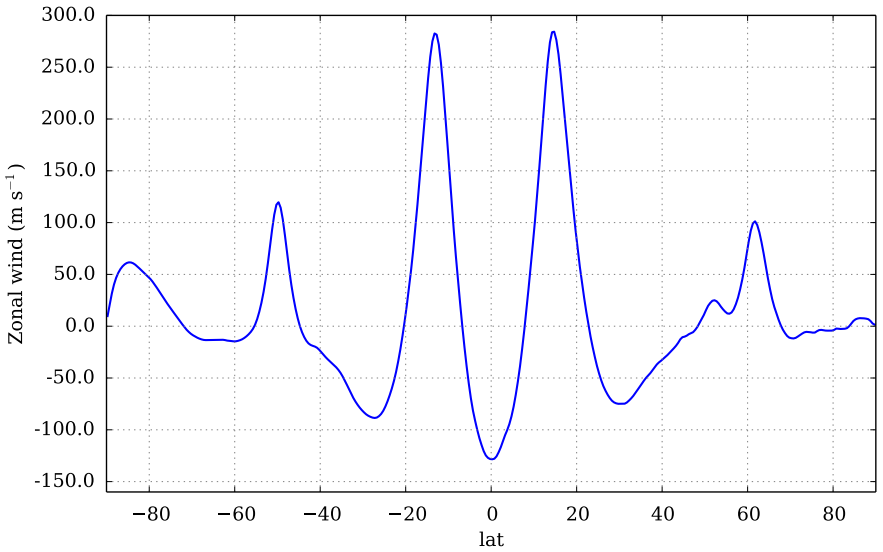


Figure : Zonal wind zonal mean at p=1 bar and t=10 jovian years

- Strong subrotation instead of a superrotation
- Only 7 jets modeled at $t > 4$ jovian years
- Mid-latitude jets faster than observed (up to 280 m s^{-1})

Zonal flow energy spectrum

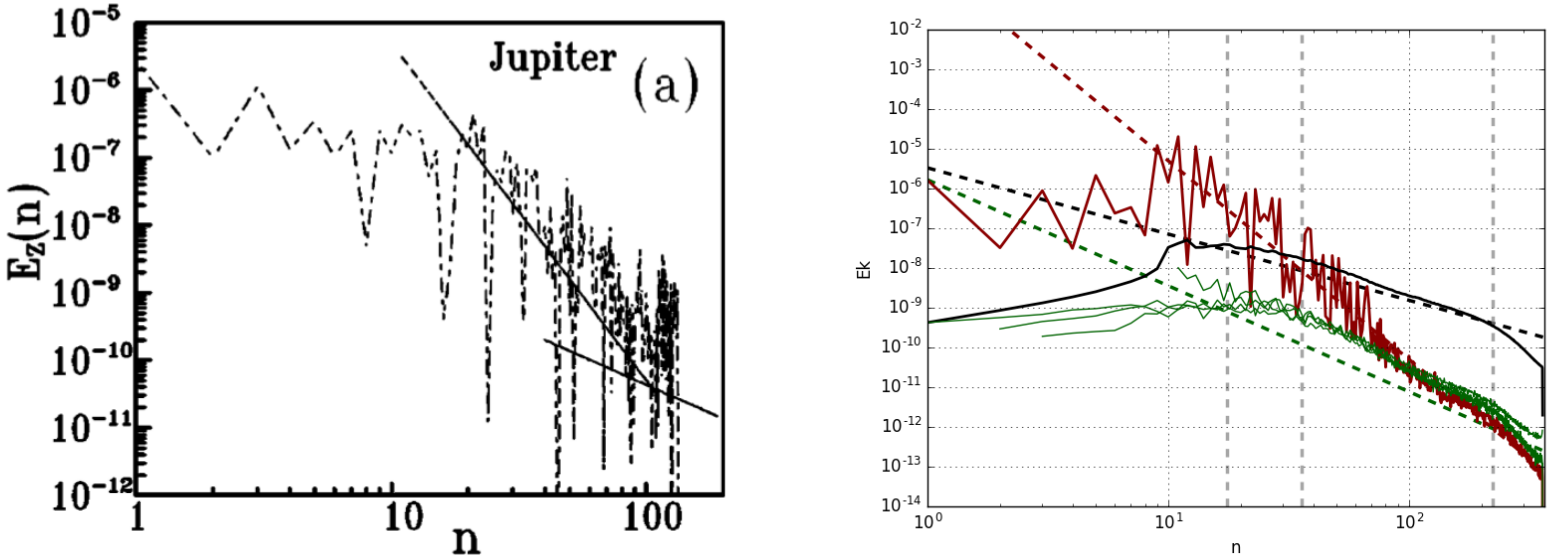


Figure : Jupiter observed (left) and modelled at p=1 bar and t=10 jovian years (right) zonal flow energy spectrum. Red and black dashed lines have respectively -5 and -5/3 slopes.

North pole

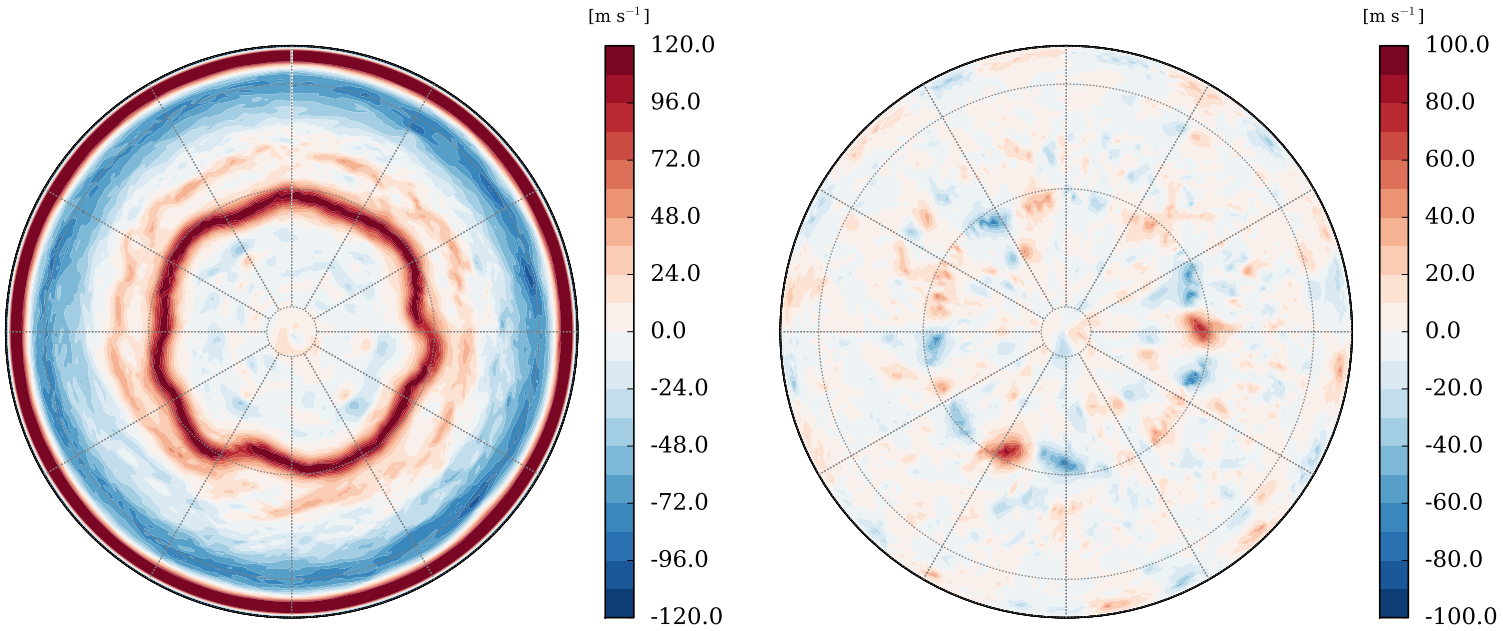


Figure : Zonal (left) and meridional (right) wind at p=1 bar and t=10 jovian days

South pole

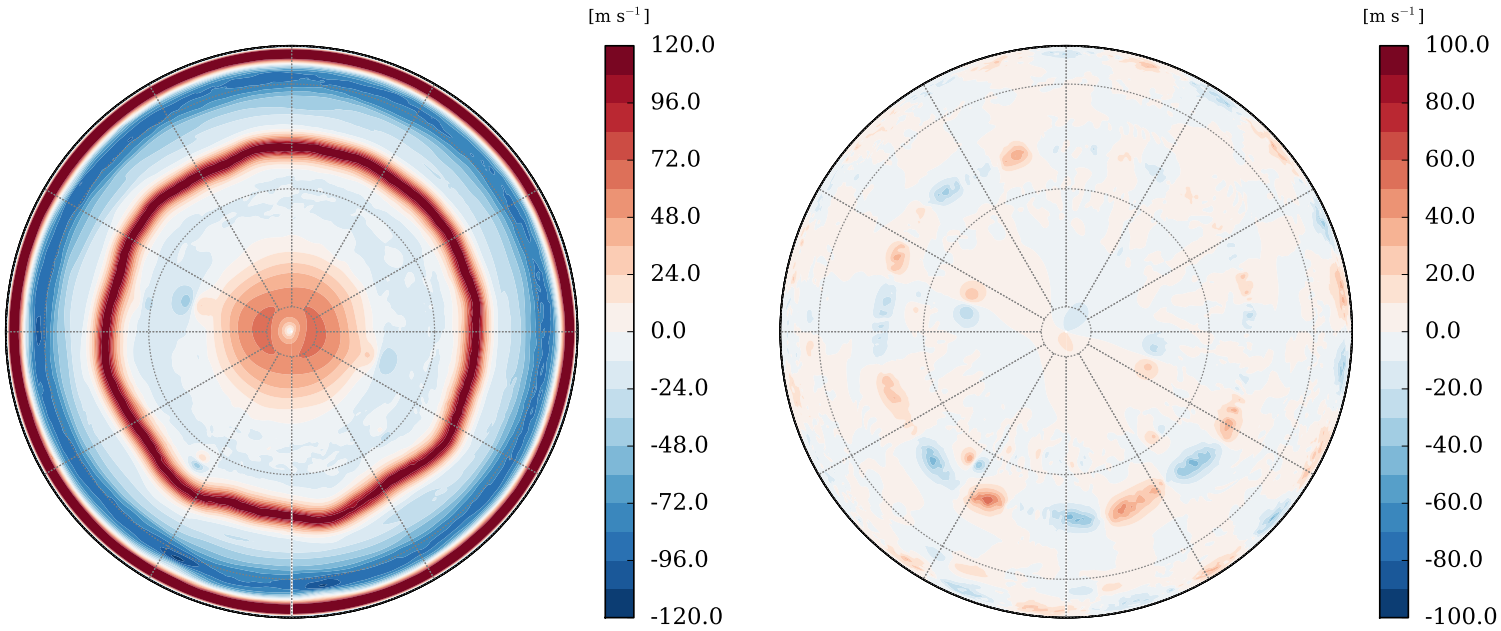


Figure : Zonal (left) and meridional (right) wind at p=1 bar and t=10 jovian days

DISCUSSIONS

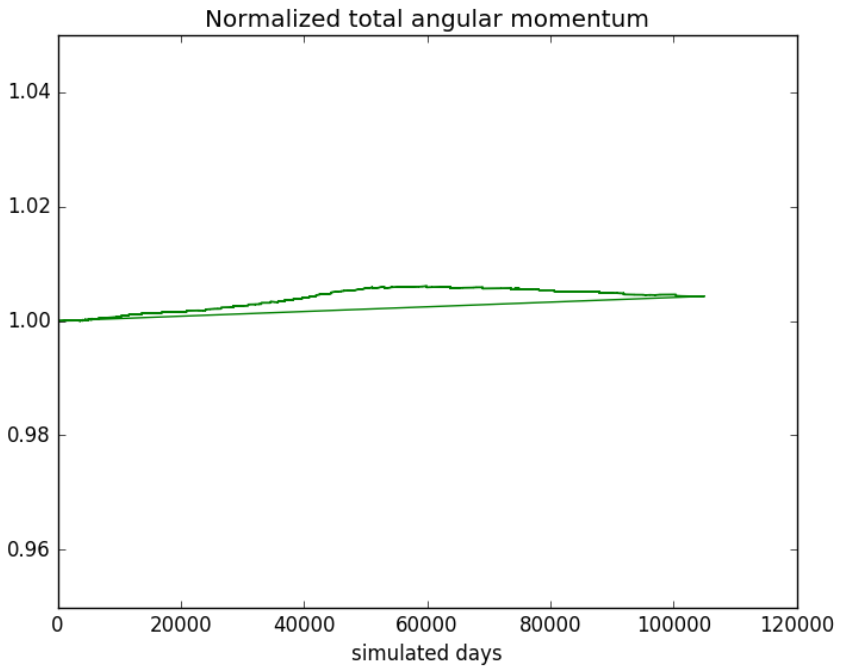
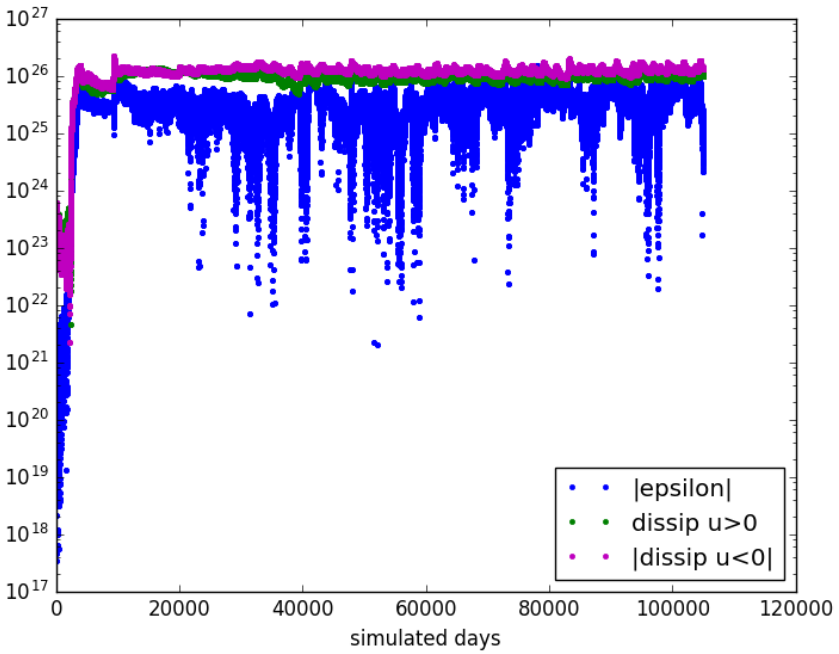
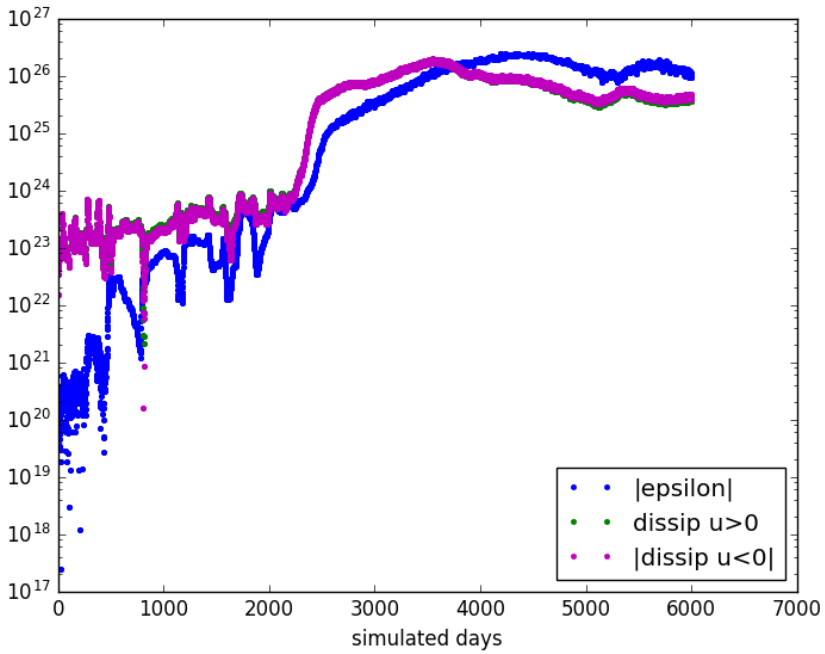


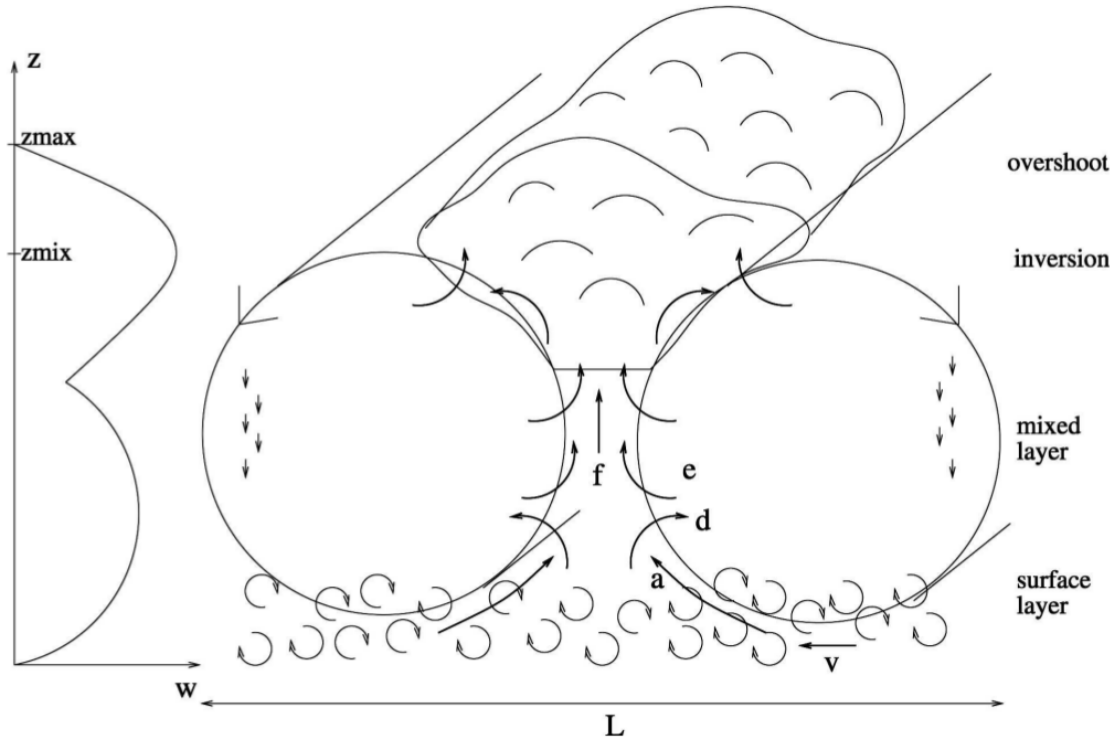
Figure : Normalized total angular momentum in the reference simulation

$$\left(\frac{df}{dt}\right)_{dissip} = \frac{(-1)^{n+1}}{\tau}\nabla^{2n} f$$





Jupiter convective activity modelisation



THANK YOU FOR YOUR ATTENTION

Master degree intership results

Figure :