EPSC Abstracts
Vol. 13, EPSC-DPS2019-1329-1, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

A thermal plume model to investigate convection in Jupiter's troposphere

Alexandre Boissinot, Aymeric Spiga, Sandrine Guerlet and Frédéric Hourdin (alexandre.boissinot@lmd.jussieu.fr)
Laboratoire de Météorologie Dynamique (LMD), Paris, France

1. Introduction

1.1. Observational background

Jupiter's atmosphere contains three condensible species (ammonia, ammonium hydrosulfide and water) what allows for moist convective activity. Storms and lightnings have been observed by Galileo [8], Cassini [3] and Juno [1] missions. Storms are typically few thousands kilometers large but we can also see smaller (∼100 km) convective clouds. Juno mission revealed recently that they unexpectedly occur mainly in polar regions, less often at lower latitudes in belts and hardly ever in zones.

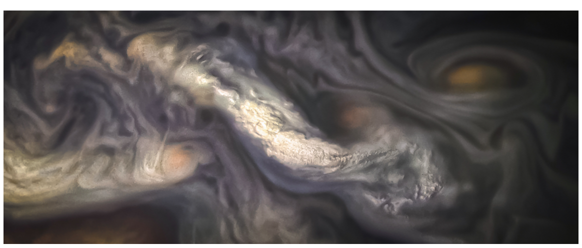

Figure 1: Jupiter's storm (credits: NASA Junocam)

1.2. Modeling context

Convection has already been modeled in Large Eddies Simulations (LES) (for example [5], [10]). In these simulations, vertical speed can reach several tens of m s^{-1} and stronger plumes can range from water condensation level up to ammonia clouds. That is why this activity could impact on the large scale circulation [7] and supply jet streams through inverse cascade of energy.

2. Thermal plume model

We seek to model moist convection in Jupiter's weather layer in order to determine its impact on the large-scale circulation and particularly on the jet streams structure. For that, we adapted a thermal plume model coming from Earth LMD GCM [9] to gas giant. It's a 1D mass flux parametrization which computes a representative plume in an atmospheric column as soon as it detects unstable layers. For each layer penetrated by the plume: vertical speed w, entrainment e, detrainment d and vertical mass flux f (cf. figure 2 for dry case result) are computed thanks to the following equations :

$$\frac{\partial f}{\partial z} = e - d \tag{1}$$

$$\frac{\partial f w}{\partial z} = -dw + \alpha \rho \Gamma \tag{2}$$

Where Γ is an acceleration term due to buoyancy, ρ the density and α the updraft fraction. Then plume properties such as temperature or tracers mass mixing ratios are inferred. This parametrization has the advantage of consistently computing mixing and plume top with a possible overshoot.

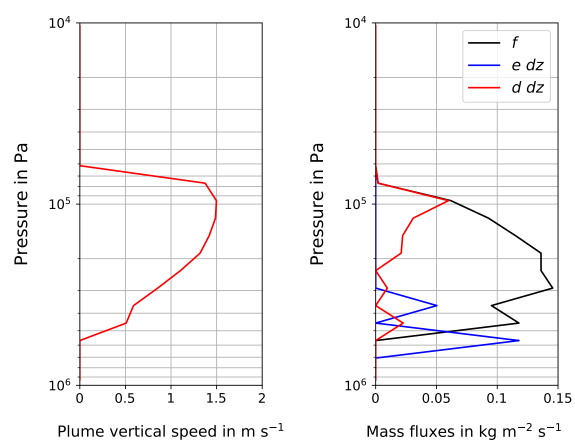

Figure 2: Dry case vertical speed and mass flux ($e\,dz$ and $d\,dz$ are respectively entrained and detrained mass flux)

3. First results

We performed several 1D simulations using a complete radiative transfer scheme ([4]) and the thermal plume model, with and without water. In both cases, we get radiatively entailed plumes but when there is water, competition between latent heat release and molecular weight leads to stronger but less high plumes (cf. figure 3). Moreover, the greater the water abundance is (from 0 to 9 solar abundance), the deeper convection ranges. The thermal plume model was coupled with the 3D GCM Dynamico Jupiter ([2], [4]) and some simulations was also performed.

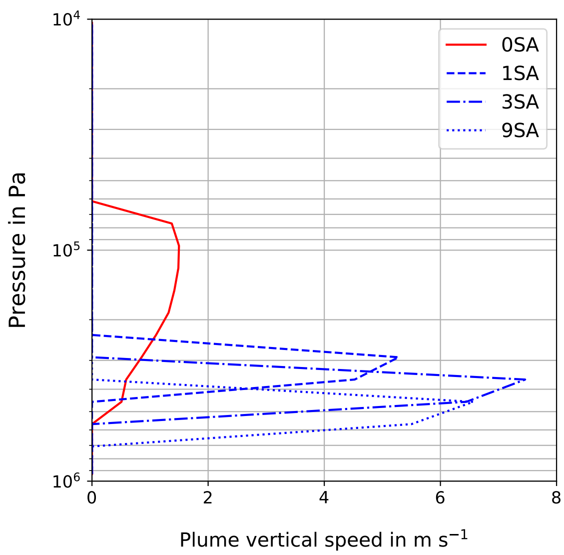

Figure 3: Vertical speed for various water solar abundance (SA)

Conclusion

During the conference, we will present further investigations about convection impact on Jupiter's troposphere and we will compare our results with storm distribution and altitude-latitude map of ammonia [6] measured by Juno.

References

[1] Brown, S., Janssen, M. *et al.*: Prevalent lightning sferics at 600 megahertz near Jupiter's poles, Nature, Vol. 558, pp. 87-90, 2018.

[2] Dubos, T., Dubey, S. *et al.*: DYNAMICO-1.0, an icosahedral hydrostatic dynamical core designed for consistency and versatility, Geoscientific Model Development, Vol. 8, pp. 3131–3150, 2015.

[3] Dyudina, U., Del Genio, A. *et al.*: Lightning on Jupiter observed in the Hα line by the Cassini imaging science subsystem, Icarus, Vol. 172, pp. 24-36, 2004.

[4] Guerlet, S. and Spiga, A.: Radiative and dynamical modeling of Jupiter's atmosphere, EGU General Assembly Conference, 17-22 April 2016, Vienna, Austria, 2016.

[5] Hueso, R., Sánchez-Lavega, A. and Guillot T.: A model for large-scale convective storms in Jupiter, Journal of Geophysical Research, Vol. 107, pp. 5075-5085, 2002.

[6] Ingersoll, A., Adumitroaie, V. *et al*: Implications of the ammonia distribution on Jupiter from 1 to 100 bars as measured by the Juno microwave radiometer, Geophysical Research Letters, Vol. 44, pp. 7676-7685, 2017.

[7] Li, L., Ingersoll, A. and Huang, X.: Interaction of moist convection with zonal jets on Jupiter and Saturn, Icarus, Vol. 180, 113-123, 2006.

[8] Little, B., Clifford, D. *et al.*: Galileo Images of Lightning on Jupiter, Icarus, Vol. 142, pp. 306-323, 1999.

[9] Rio, C., Hourdin, F. *et al.*: Resolved Versus Parametrized Boundary-Layer Plumes. Part II: Continuous Formulations of Mixing Rates for Mass-Flux Schemes, Boundary-Layer Meteorology, Vol. 135, pp. 469-483, 2010.

[10] Sugiyama, K., Nakajima, K. *et al.*: Numerical simulations of Jupiter's moist convection layer: Structure and dynamics in statistically steady states Icarus, Vol. 229, pp. 71-91, 2014.