Three-dimensional turbulence-resolving modeling of tidally locked exoplanetary atmosphere.

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Abstract

The role that convection play in cloud feedback on Earth is still not fully understood [1]. Numerous observed exoplanets are in synchronous rotation with its host star. To understand the impact on climate of such extreme insolation Global Circulation Model (GCM) are used. The representation of turbulence require in such model a subgrid parametrization that are based on Earth convection. The extreme insolation on those exoplanets could lead to different convective activity. This difference in the turbulence could change the height and thickness of the cloud layer and lead a change in the stability of the surface liquid water [2, 3]. Zhang et al [4] model for the first time the convective activity around M Dwarfs star. We propose here to revisit the study of the convection regime of such extreme environment using turbulent-resolving model with a realistic radiative transfer and microphysics (Figure 1).

2. Earth Test-case

To ensure the performance of the model in extreme exoplanetary environment the model has been tested in Earth tropics condition. Vertical profiles from TOGA-COARE measurement campaign [7] are used as input. The emission spectrum of the Sun is used to compute shortwave heating rate with 24h cycle. The width of the mesh is 1 km over 151 km on the horizontal and the vertical domain extends from the ground to 25 km over 65 layers.

Figure 2 shows a snapshot of the vertical cross-section of the liquid/ice water content (kg/kg) for the TOGA-COARE case. There is formation of cumulonimbus cloud associated with deep convective activity. The characteristics in terms of vertical wind, cloud fraction and precipitation are consistant with observations. The model is therefore able to reproduce convective activity and rain precipitation comparable to mean tropics behaviour with realistic radiative transfer and a general water microphysics.
TOGA-COARE case. Deep convection is visible with associated vertical transport of water but the vertical extent of the clouds is smaller compared to the earth case.

Simulations with a flux ranging from 850 W m$^{-2}$ to 3000 W m$^{-2}$ were performed to quantify the effect of incoming flux. The sensitivity to the surface temperature is also taken into account by varying the greenhouse gas content. Moreover the impact of the rotation rate of the planet is quantified.

### References