Analysis of the physical mechanisms responsible for the self-aggregation of convection in a GCM run in Radiative-Convective Equilibrium

David Coppin, Sandrine Bony
Laboratoire de Météorologie Dynamique (LMD), Institut Pierre Simon Laplace (IPSL), UPMC/CNRS, Paris, France

Introduction

Convective self-aggregation is the capacity of the tropical clouds to spontaneously organize itself into mesoscale or large-scale clusters.
Its mechanisms of initiation and effects on the atmosphere have been studied with observations (Tobin et al 2012, 2014 ; Feng et al 2015) and LES/CRM (Bretherton et al 2005, Muller and Held 2012, Wing and Emanuel 2013). Khairoutdinov and Emanuel (2010) emphasized its dependence on sea surface temperatures (SST). Lastly, Shi and Bretherton (2015) looked at it in a rotating Global Circulation model (GCM).

Investigating self-aggregation in GCMs allows us to see if these models used to predict climate are able to represent self-aggregation and if the state of organization impact the simulated climate.

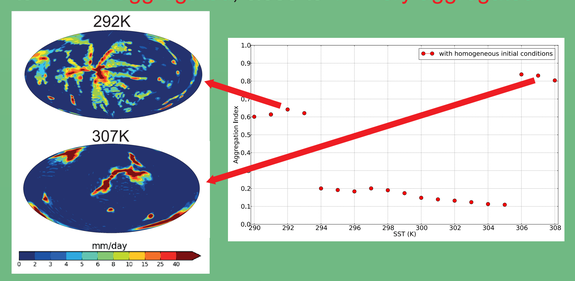
In this poster, we focus on the **mechanisms governing its initiation at low and high sea surface temperatures (SST) in IPSL GCM**.

Methods

LMDZ/IPSL-CM5A GCM run in **radiative convective equilibrium** (RCE) configuration defined as follows:
- aquaplanet with no rotation
- constant and uniform insolation

SSTs fixed and ranging from 290K to 308K.

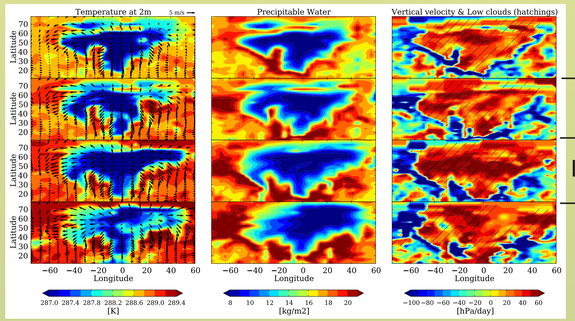
Aggregation Index quantifies self-aggregation: close to 0 = desaggregated, close to 1 = very aggregated



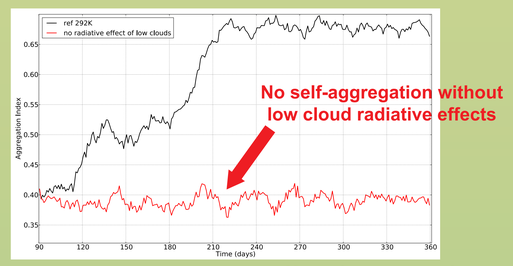
Three different states of aggregation:
- **for SST below 295K, RCE instability and large-scale convective aggregation**
- between 296K and 305K, strong dependence on initial conditions
- **above 306K, strong aggregation**

Mechanisms triggering self-aggregation in the IPSL GCM

292K

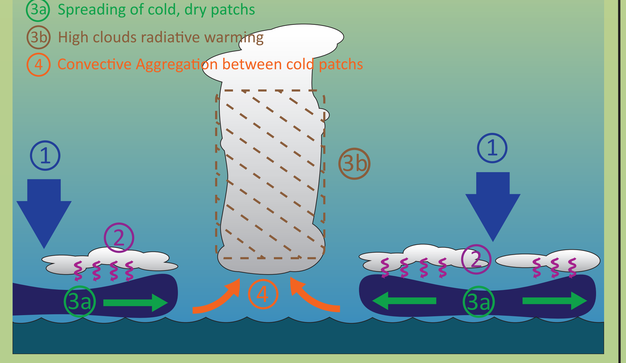


- Cold and dry patchs under a region of subsidence
- Strong humidity and temperature gradients at the edge of the cold/dry patchs
- Low clouds over the whole subsiding region
- Strong wind from the patch to outside with maximum at the edge

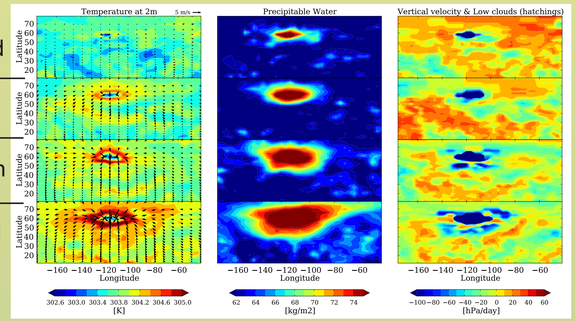


Without low cloud radiative effect (cooling of the boundary layer), no self-aggregation

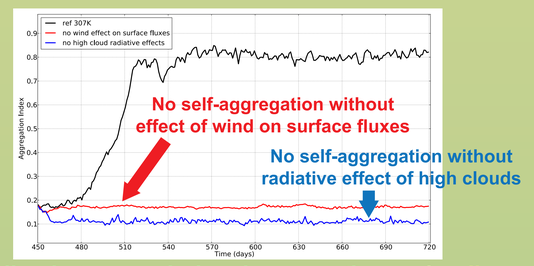
1. Strong subsidence
2. Low clouds Radiative Cooling
3a. Spreading of cold, dry patchs
3b. High clouds radiative warming
4. Convective Aggregation between cold patchs



307K

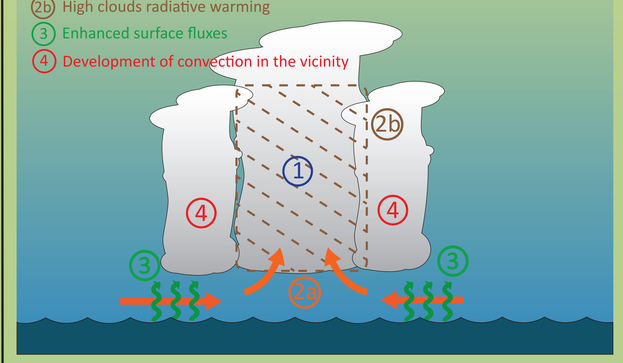


- Intensifying convection in one place
- Increased wind around convection
- New convection generated above wind maximum



Coupling between wind and evaporation and radiative effects of high clouds crucial for initiation

1. Strong isolated convection
2a. Enhanced convergence and surface wind
2b. High clouds radiative warming
3. Enhanced surface fluxes
4. Development of convection in the vicinity



Conclusions

Self-aggregation:
- Spontaneous at low and high SST
- Stronger at high SST

Initiation mechanisms:
- **292K**: **low clouds** control a low-level circulation which, added to decreased radiative cooling by **high clouds,** promotes the clustering of convection at the edge between dry/cold patchs
- **307K**: increased **surface fluxes** and decreased radiative cooling by **high clouds** around areas of strong convection favor the clustering of convection in the vicinity of existing convection

Outlooks

- Why are the mechanisms different between SSTs? What about in observations ?
- What happens for intermediate SSTs ?
- What is the impact on climate in more realistic configurations ?

References

- Bretherton et al, 2005 (*J. Atmos. Sci.*, 62: 674-701)
- Feng et al, 2015 (*J. Adv. Model. Earth Syst.*, 07)
- Khairoutdinov and Emanuel, 2010: paper presented at the 29th Conference on Hurricanes and Tropical Meteorology
- Muller and Held, 2012 (*J. Atmos. Sci.*, 69: 2551-2565)
- Shi and Bretherton, 2014 (*J. Adv. Model. Earth Syst.*, 06: 616-629)
- Tobin et al, 2012 (*J. Clim.*, 25: 6885-6904)
- Tobin et al, 2013 (*J. Adv. Model. Earth Syst.*, 05: 692-703)
- Wing and Emanuel, 2013 (*J. Adv. Model. Earth Syst.*, 05: 611-627)

Contact information

david.coppin@lmd.jussieu.fr
Poster available at:
http://emc3.lmd.jussieu.fr/en/group-members/dcoppin