FINAL REPORT PROGRAM LEFE

Program LEFE/ action(s) Interactions Multiples dans l'Atmosphère, la Glace et l'Océan (IMAGO)	**Project Title :** **Robustness Of the Self-Aggregation of convection to Large-scale forcing, and implications for precipitation over tropical Islands (ROSALI)**	**Years : 2018 – 2020**
PI : Caroline MULLER, carolinemuller123@gmail.com, Laboratoire de Météorologie Dynamique (LMD) Participating Laboratories :Laboratoire de Météorologie Dynamique (LMD)	Contribution to Other funding sources : PhD funding from Marie-Sklodowska Curie Actions (MSCA) under the European Union's Horizon 2020 research and innovation programme (Grant Agreement No. 675675) to cover the PhD salary of Sara Shamekh.	

Context

Self-aggregation refers to the spectacular ability of tropical deep clouds to spontaneously organize in space in idealized simulations. Self-aggregation is associated with a dramatic change in the large-scale properties, including extremely dry mean conditions and enhanced rainfall rates.

Objectives / scientific questions

The goal of this project is to investigate whether large-scale (mesoscale) inhomogeneities in the ocean surface conditions, as well as the inclusion of the Coriolis force associated with the Earth rotation, can impact the self-aggregation of convection at mesoscale and synoptic scales, and the relevant feedbacks identified in idealized settings.

Main results

We investigate how a circular ocean-surface hot spot helps organize deep convection, and how self-aggregation feedbacks modulate this organization. One key result is that the hot spot significantly accelerates aggregation, particularly for warmer/larger hot spots (Shamekh et al 2019), and extends the range of sea-surface temperatures for which aggregation occurs (Shamekh et al 2020; Shamekh 2020). Indeed, Figure 1a shows that a small hotspot does not lead to significant aggregation, while Figure 1b shows strong aggregation with a larger hotspot, a response which can be quantified using an aggregation index (Figure 1c).

We also show that self-aggregation feedbacks play a leading-order role in the spontaneous genesis of tropical cyclones in cloud-resolving simulations (Figure 2). Those feedbacks accelerate the cyclogenesis process by a factor of two, and the feedbacks contributing to the cyclone formation show qualitative and quantitative agreement with the self-aggregation process.

Once the cyclone is formed, WISHE (Wind Induced Surface Heat Exchange, a feedback due to enhanced surface fluxes in regions with stronger winds, notably in the eyewall) effects dominate, though we find that self-aggregation feedbacks have a small but non negligible contribution to the maintenance of the mature cyclone. Our results suggest that self-aggregation, and the framework developed for its study, can help shed some new light into the physical processes leading to cyclogenesis and cyclone intensification. In particular, our results point out the importance of the longwave radiative cooling outside the cyclone (Muller Romps 2018).

Our results also highlight the importance of this process for the hydrological cycle (Risi et al 2021), notably for precipitation extremes (Muller Takayabu 2020).

Future of the project :

The funding from LEFE has allowed to clarify the relevance of idealized self-aggregation, to clouds organization in more realistic conditions. This work led to the successful application to an ERC starting grant by the PI on this topic, in order to pursue this research avenue.

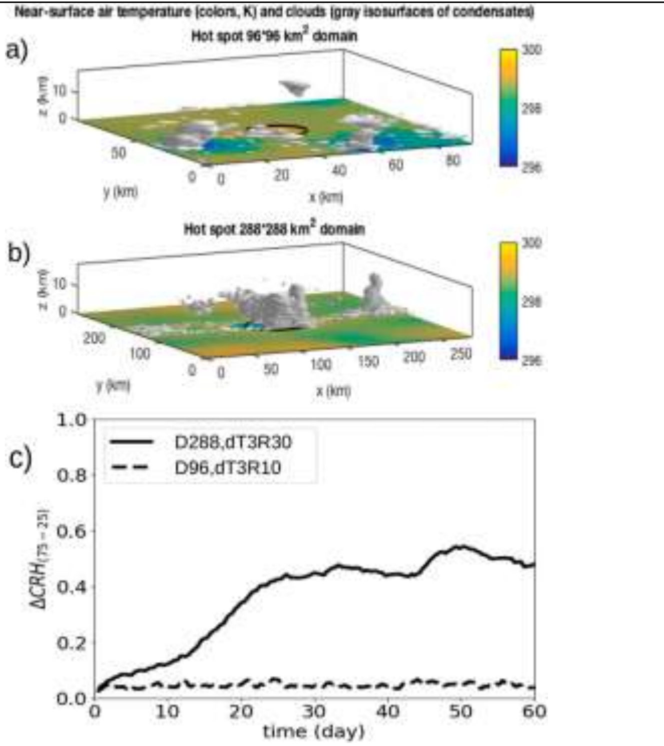

FIG. 1. Snapshots of near-surface air temperature (colors, K) and cloud water (gray shades) from two simulations with a hot spot in the center of the domain (the hot spot is visible as a black circle in the center of the domain, has a temperature anomaly of 3K, and a radius of 10km in the small domain and 30km in the large domain) for (a) a domain size 96 km x 96 km and (b) 288 km x 288 km. (c) Time evolution of the aggregation index (strength of aggregation measured by the interquartile range of precipitable water) for both simulations. As can be seen on panel c, the presence of a large hot spot favors aggregation (Shamekh et al, 2019).

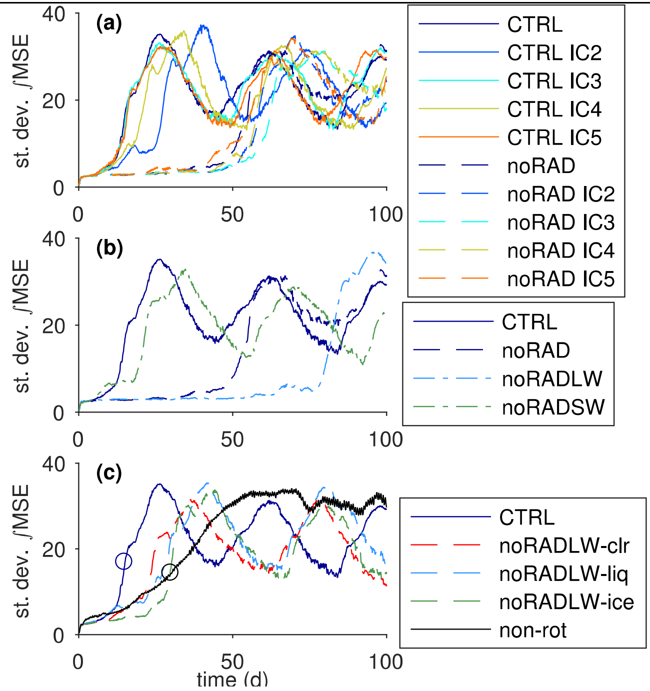

FIG. 2. Time evolution of the standard deviation of the vertically integrated moist static energy (MSE) which is representative of the strength of aggregation (a) for different initial conditions, (b) in sensitivity runs removing separately the SW and LW interactive radiation, and (c) in sensitivity runs removing the LW liquid cloud, ice cloud and clear-sky contributions separately. Open circles in panel c indicate the first 15 days of cyclogenesis and the first 30 days of non-rotating self-aggregation. Radiative feedbacks, crucial for aggregation, are found to significantly accelerate the genesis of tropical cyclones in those simulations. (Muller Romps 2018).

Nombre de publications, de communications et de thèses

Thèse:

Shamekh S., 2020
The Impact of Sea Surface Temperature on the Aggregation of Deep Convective Clouds
PhD thesis, Ecole Doctorale 129

Publications:

Risi C., C. Muller, P. Blossey, 2021
Rain evaporation, snow melt and entrainment at the heart of water vapor isotopic variations in the tropical troposphere, according to large-eddy simulations and a two-column model
Journal of Advances in Modeling Earth Systems, 13, https://doi.org/10.1029/2020MS002381

Shamekh S., C. Muller, J.-P. Duvel, F. D'Andrea, 2020
Self-aggregation of convective clouds with interactive sea surface temperature
Journal of Advances in Modeling Earth Systems, 12, https://doi.org/10.1029/2020MS002164

Muller C., Y. Takayabu, 2020
Response of precipitation extremes to warming: what have we learned from theory and idealized cloud-resolving simulations, and what remains to be learned?
Environmental Research Letters, 15, 035001, https://doi.org/10.1088/1748-9326/ab7130

Shamekh S., C. Muller, J.-P. Duvel, F. D'Andrea, 2019
How do ocean warm anomalies favor the aggregation of deep convective clouds?
Journal of the Atmospheric Sciences, https://doi.org/10.1175/JAS-D-18-0369.1

Muller C., D. Romps, 2018
Acceleration of tropical cyclogenesis by self-aggregation feedbacks
Proceedings of the National Academy of Sciences, 201719967; DOI: 10.1073/pnas.1719967115

Communications:

More than 20 communications in national and international conferences (full list available at https://www.lmd.ens.fr/muller/talks.html)