Proposition de Sujet de thèse 2017

(1 page recto maximum)

Laboratoire (et n° de l'unité) dans lequel se déroulera la thèse :
CNRM - UMR 3589

Titre du sujet proposé :
A conceptual model of the anvil of tropical mesoscale convective system

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Résumé du sujet de la thèse

Convection is a major source of high clouds. Their radiative effects are crucial in the Earth's energy budget and their heating in the atmospheric column has important impacts on the large-scale circulation, especially over the tropics. For instance, Sherwood et al. (1994) found that removing high cloud radiative heating reduces the Hadley circulation strength by about 25% while the Walker circulation completely collapses. The limited understanding of dynamical and microphysical processes in deep convective clouds and their observable signatures poses a significant challenge for weather and climate research.

Deep convective clouds develop precipitating and non precipitating anvils as a result of a converging vertical mass flux close to the tropopause. By mass conservation, air has to diverge horizontally. The spreading anvil is easily detected in satellite observations (in particular by instrument onboard geostationnary satellites) and its expansion rate contains information about the strength of convective updrafts as well as compensating downdrafts within the cloud interior. Tracking from sequential geostationnary infra-red images (Fiolleau and Roca 2013) associated with sampling by orbiting satellites (A-Train, TRMM, GPM-core, Megha-Tropiques) provides observationnal constraints on physical processes involved in the anvil life cycle (e.g., Bouniol et al. 2016).

In general circulation models such as those used for climate projections, clouds associated with deep convection are subgrid-scale and thus need to be represented via a set of equations called parameterizations. Those parameterizations attempt to capture the main processes and factors controlling cloud fraction, occurrence and radiative properties. They involve parameters that can be highly uncertain, such as the fall speed of ice crystals or the variance of the subgrid-scale moisture distribution. Besides, these parameters are often used in the final tuning process of climate models (e.g., Hourdin et al., 2017) in order to simulate a correct radiative balance at the top of the atmosphere. This is often achieved at the price of compensating errors. Therefore, it is necessary to better understand key physical processes driving the formation, life cycle and dissipation of anvil clouds in order to improve their representation in climate models.

Nature du travail attendu

The objective of this thesis is to build a conceptual model able to capture how the cloud shield associated with tropical mesocale convective systems forms, evolves, and decays and to identify the key processes involved in the anvil life cycle. For instance, one seeks to understand the potential role the cloud–radiative interactions plays in the dynamics of the anvil (Hartmann and Berry 2017), the importance of vertical transport within the anvil and how anvil clouds relate to the deep convective towers at the origin of their formation. In particular the relationships between the mass-flux intensity, the expansion rate of the anvil and its life duration and how the convective environment controls it will be explored. Another aim of the proposed work is to evaluate the way anvil clouds are represented in climate models (namely Arpege-Climat and LMD-Z) either in present-day realistic climate simulations or in idealized experiments, to identify the processes that should be incorporated in parameterizations and find ways to better constrain cloud parameterization uncertain parameters using the available observations.

This conceptual model will be built starting from simplified models published in the literature (e.g., Houze 1982 ; Zender and Kiehl 1997 ; Machado and Laurent 2004 ; Senf and Deneke 2017) and will be used to test the importance of a given process on the life-cycle of anvil clouds.

In the same time, the same simplified model will be forced by climate model simulated variables (for instance mass-flux, ice/liquid water content) in order to determine their potential ability in simulating such clouds and associated feedbacks.

Finally, comparisons between similar systematic collections of spaceborne observations (CloudSat, TRMM-PR, GPM Core among others) under different environmental conditions will further improve our understanding of processes involved in the anvil life cycle and guide the model parameterization development based on an approach that connect observations and simplified modeling.

Compétences souhaitées

Good programmation skills including visualisation tools
Data processing
Knowledge in atmospheric physics

Références bibliographiques

Bouniol, D., R. Roca, T. Fiolleau and E. Poan, 2016 : Macrophysical, microphysical and radiative properties of tropical Mesoscale Convective System over their life cycle. *J. Climate*, **29**(9), 3353-3371. DOI: 10.1175/JCLI-D-15-0551.1

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