Proposition de Sujet de thèse 2021

(1 page recto maximum)

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

Titre du sujet proposé :
Radiative impact of tropical deep convective clouds from diurnal to climatic scales

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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.

It is therefore necessary to evaluate and improve the way high clouds detrained from deep convection are represented in climate models in order to get rid of compensating errors and understand their possible impact on the representation of both the convective system life-cycle and the large-scale circulation.

The PhD work will then be organised around three objectives :

1. Evaluate the way high clouds associated with convection are represented in models: It will be first necessary to find a way to identify such clouds in climate model simulations and define relevant process-oriented metrics to allow meaningfull comparisons with

observationall data sets. Several aspects of the cold cloudiness will be documented : macrophysical properties (cloud cover, cloud extent, cloud duration, cloud depth) versus microphysical properties (liquid and ice content), cloud radiative effect and latent and radiave heating rates. Identification of potential relationships between convective variables (mass-flux, vertical velocity) and anvil characteristics will be sought in observationnal data sets or eventually high resolution modeling and used to evaluate the parameterization at the process level.

2. Based on this first step, sensitivity tests on the various existing parameterization components (cloud microphysics, cloud overlap, radiative properties, interactions between the deep convection scheme and the large-scale condensation scheme) will be performed in order to improve the physical consistency among convection, condensation and the radiation codes. To increase the realism of the simulations, inclusion of additional processes may be tested. For instance a degree of memory of the convective life cycle could be considered in the large scale cloud scheme in order to sustain anvil cloud after deep convection has vanished.

3. Understand how errors in the representation of high clouds from convection impact the large-scale circulation, energy budget and precipitation patterns and quantify how a larger consistency benefits to the model simulated climate at different scales.
A particular focus will be given to the impact of an improved representation of the convective system life cycle and related cloudiness to the diurnal cycle, and the intra-seasonal variability. Also, the impact of the cloud representation on the dynamical circulation will be explored.

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

Fiolleau, T. and R. Roca, 2013 : An algorithm for the detection and tracking of tropical mesoscale convective systems using infrared images from geostationary satellite. IEEE Trans. Geosci. Remote Sens., **51**, 4302–4315. DOI:10.1109/TGRS.2012.2227762.

Hourdin, F. and Coauthors, 2017 : The Art and Science of Climate Model Tuning. *Bull. Amer. Meteor. Soc.*, 589-602. DOI :10.1175/BAMS-D-15-00135.1

Sherwood, S.C., V. Ramanathan, T.P. Barnett, M.K. Tyree and E. Roeckner, 1994 : Response of an atmospheric general circulation model to radiative forcing of tropical clouds. *J. Geophys. Res.*, **99**(D10), 20829-20845.