Diagnosing MJO and convection behaviour in SP-CAM and CAM simulation

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1. Introduction

Rather than conduct sensitivity experiments with a single convection parameterization, we will make use of two simulations from the same GCM but with two very different treatments of convection and very different resultant simulations of the MJO. Our focus will be on the local control of tropical convection as resolved on the GCM grid, which is thus naturally comparable to observed behaviour as resolved, for instance, by global satellite products. The aim of this analysis is to provide a better understanding of those aspects of convective behaviour that are essential for proper simulation of the MJO.

2. CAM and SP-CAM model

Our analysis will be based on AMIP-style runs of the standard version of the Community Atmosphere Model (CAM), version3) and the "superparameterized" version (SP-CAM). The standard CAM simulation uses the Zhang and McFarlane (1995) method for convective parameterization, in which closure is based on the assumption that convection consumes large-scale available potential energy (CAPE), returning the atmosphere toward a neutrally buoyant state over a given convective adjustment time scale. The SP-CAM is based on the multi-scale modelling framework (MMF), which is a new approach to climate modelling (Khairoutdinov 2001) in which cloud processes are treated more explicitly by replacing the cloud and radiation parameterizations of a GCM with a 2D cloud system resolving model.

3. Results

Wavenumber-frequency spectrum analysis show that there is strong MJO power with a pronounced spectral peaks in both precipitation (See Fig. 1) and U850 fields in the SP-CAM, but MJO is completely absent in

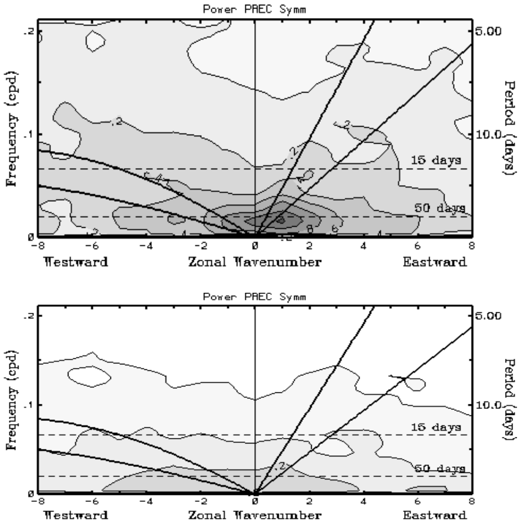

Fig. 1: Power Spectra plot of precipitation for SP-CAM (a) and CAM (b).

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CAM simulation. In this paper, we compared the different convection behaviours in SP-CAM and CAM simulations, aiming at understanding what aspect of moist convection in GCM are important to improve model MJO simulation.

We concluded that the following different features associated with convection in the two models contribute to the differences in MJO simulation:

1) In SP-CAM, an exponential relationship is exhibited between precipitation and column integrated relative humidity (See Fig. 2), with more rainy events for high precipitable water in the atmospheric column, consistent with "re-charge" process; In CAM, the model tends to rain for low column relative humidity indicating that the model can't sustain high column humidity, and instead tends to rain prematurely, which is part of the limitation with CAPE closure.

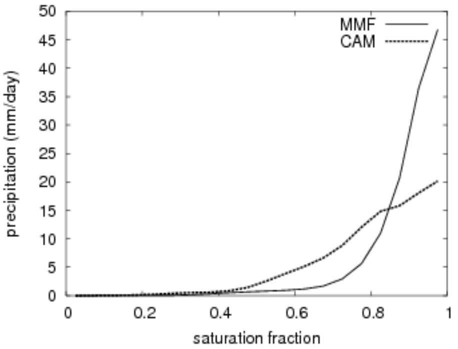

Fig. 2 Mean daily precipitation in 5 % bins of saturation fraction in CAM and SP-CAM.

2) In SP-CAM, the precipitation is solely related with an upper-level moisture anomaly, and humidity increases substantially over an increasingly deep layer with increasing rainfall; In CAM, there is relatively dry region in the lower troposphere associated with deep convection, and the precipitation is not only related with upper level moisture anomaly, but also strongly correlated with the boundary layer moisture anomaly.

3) In SP-CAM, heavy precipitation is associated with top heavy (stratiform) heating profile, which should project onto slower modes and also increase the strength of intraseasonal oscillations; in CAM simulation, convective-dominated heating profile should project onto fast modes.

4) In SP-CAM, the latent heat flux increases the boundary layer entropy, and decreases the value of CIN, and therefore is in phase with deep convection and promotes sustained convection; while in CAM, the latent heat flux, not determined by the wind field, reduces sharply during the process of deep convection intensification, and acts to throttle deep convection.

In order to explore the atmospheric dynamics and convection features during the developmental and decaying stages of the MJO, we calculate the lag relationship between different fields related to convection and the MJO-prec. Consistent with the recharge-discharge theory Blade and Hartman (1993), there is a gradual moistening prior to the intense precipitation and afterward drying related to the MJO events. In SP-CAM, the humidity increasing progressively over an increasing deep layer in the recharge process is related to the grid-scale ascending motion. Unlike the observation (Benedict and Randall 200)) that there is asymmetry in terms of time for charge and recharge of the instability, the time for the recharge of the moisture before the rainfall maximum in SP-CAM simulation is similar to that of discharge of the moisture after the rainfall maximum. They emphasized that the important role of the moistening and warming of shallow convection during the recharge phase and re-stabilisation of the column by the immediately drying effect related to the westerly wind-bursts directly after the maximum rainfall. Due to the grid resolution, the warming and moistening effects per-deep convection by shallow convection is not well presented in SP-CAM. Meanwhile, the abrupt drying accompanying transition of the zonal wind are also not captured by SP-CAM simulations.

Our results also confirm that the convection characteristics associated with intensive precipitation are consistent with those of MJO-related convection features.

4. References

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