Respective Roles of Shallow-Convection and Stratiform Rainfall on the Simulation of Madden-Julian Oscillation

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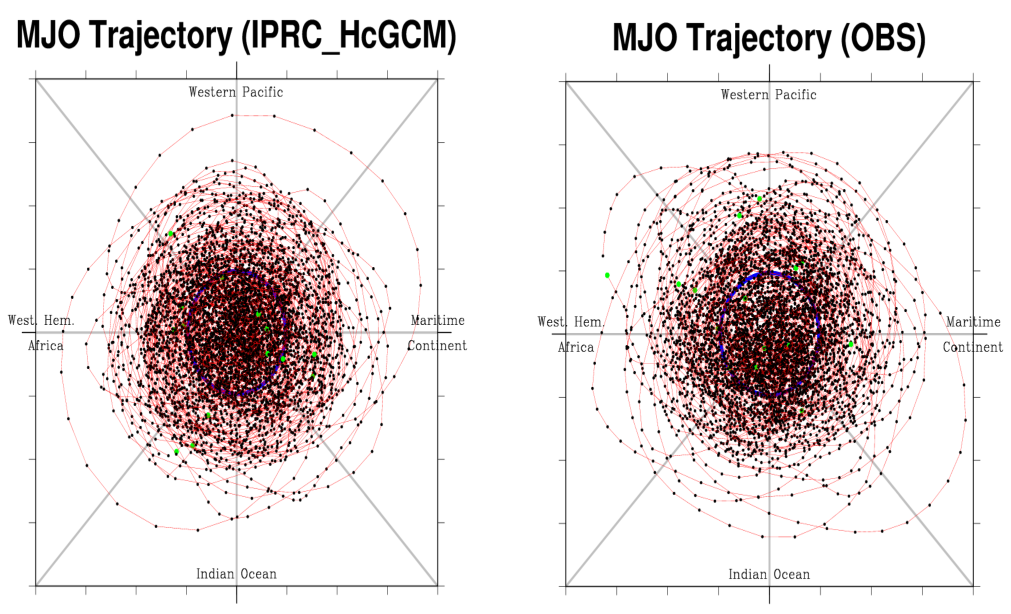
Simulation of MJO



Phase space (RMM1, RMM2) diagram of the simulated (left panel) and observed (right panel) MJO. The simulation is from a 15-year coupled integration with IPRC/UH Hybrid-coupled GCM (IPRC_HcGCM). The observations (OBS) are derived from NOAA OLR and NCEP U850 and U200 between 1991 and 2005.

Introduction and Objective

The IPRC/UH Hybrid-coupled GCM (HcGCM), which combined ECHAM-4 AGCM with UH intermediate ocean model, produces robust Tropical Intra-Seasonal Oscillations including the boreal-winter MJO (left panels) and boreal-summer Monsoon Intra-Seasonal Oscillation.

In this study, two sets of sensitivity experiments [(I): Short-term retrospective forecast of one MJO event observed during TOGA COARE and (II): Long-term free integrations] have been carried out to understand the respective roles of shallow-convection and stratiform rainfall on the simulation of MJO.

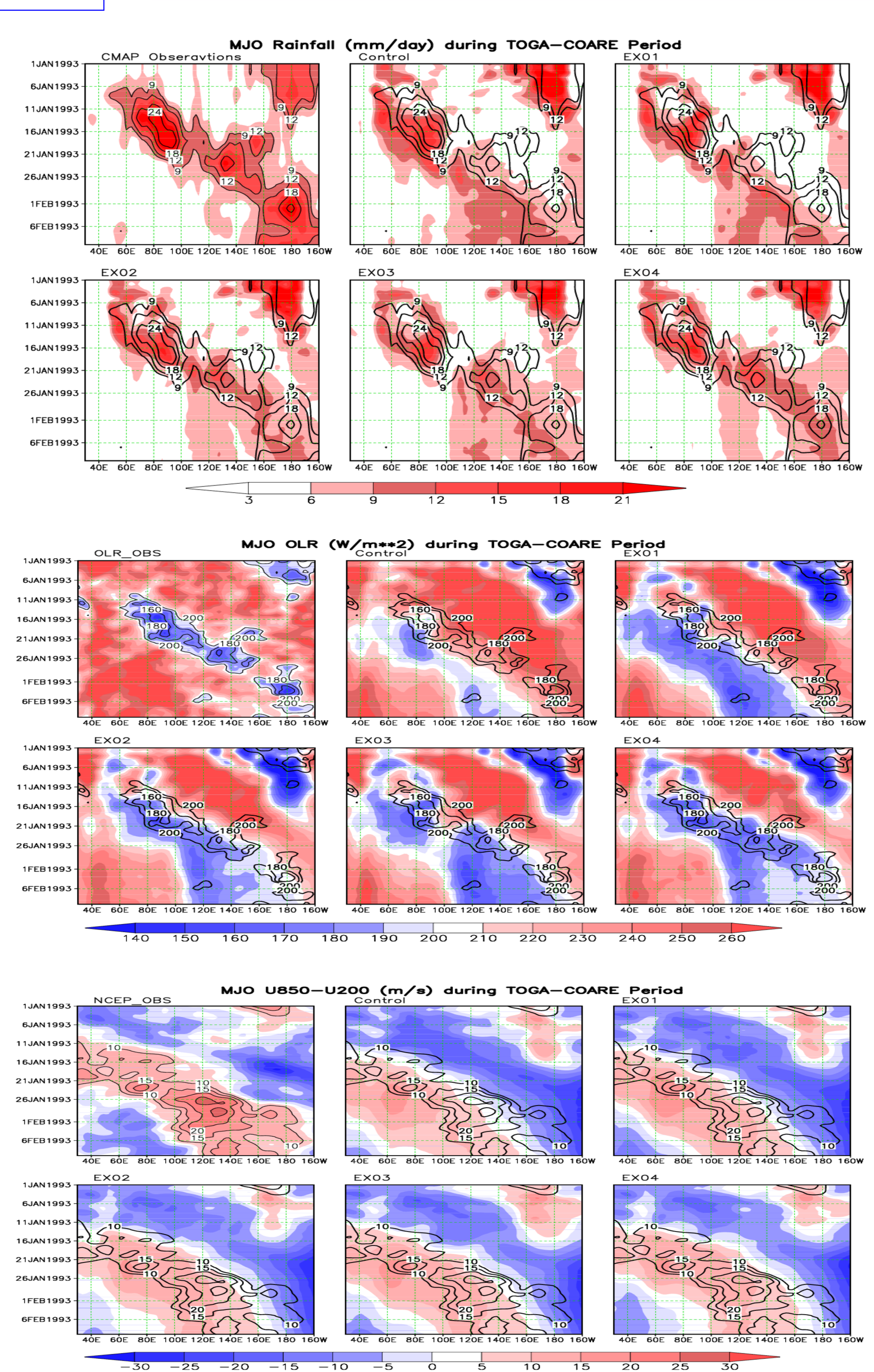
Forecast Experiment Design*

Exp.	Description
EX01	Double the convective downdrafts.
EX02	Increase shallow-convection entrain./detrain. rate to a value derived from cloud-resolving-model experiment.
EX03	Double the CAPE lapse time.
EX04	Combine all changes made in EX01, EX02 and EX03.

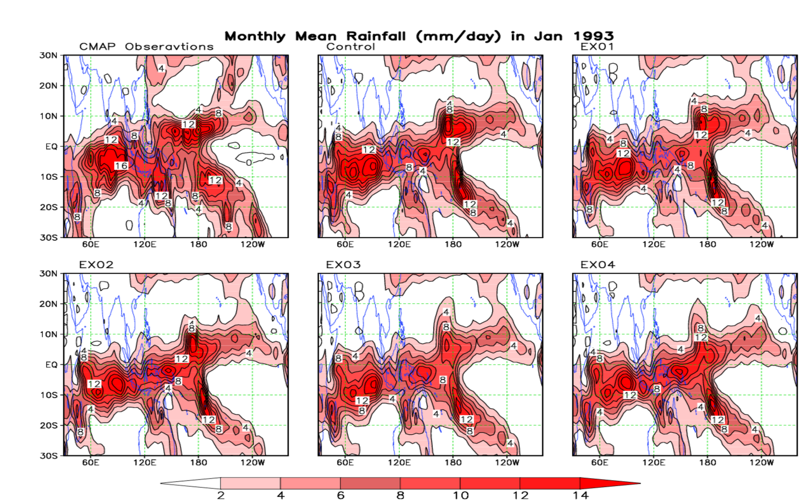
* ECHAM-4 uses the mass flux scheme of Tiedtke (1989) for shallow, midlevel, and deep convection with CAPE closure (Nordeng 1995).

All retrospective forecasts were initiated with NCEP Reanalysis-I on December 31, 1992. 100 ensembles have been carried out for each forecast. The results presented here are from 100-ensemble means. The control forecast (with original cumulus scheme in ECHAM-4) captures the re-initiation of the MJO in the western Indian Ocean, but propagating too slow comparing to the observations. All four sensitivity experiments tend to speed up the eastward propagation of the forecast MJO.

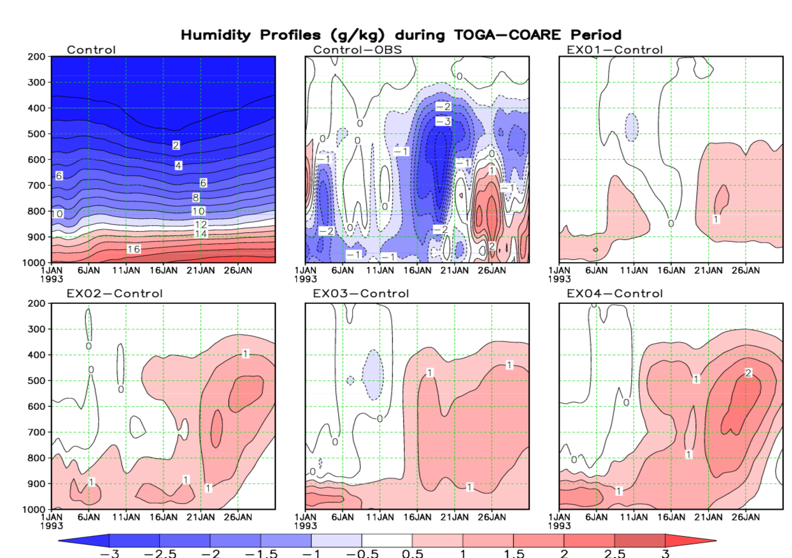
Shallow-Convection Moistening Favors the Eastward-Propagation of MJO



Longitude-time cross-sections of rainfall (upper panel), OLR (middle panel), and U850-U200 (lower panel) from the observations (OBS), control forecast (Control), and four sensitivity experiments (EX01, EX02, EX03, and EX04). All variables are averaged between 10°S and 10°N. For the control forecast and four experiments, the shadings show the respective forecast; the overlaid contours are from the observations.



Monthly-mean rainfall over the tropical Indo-Pacific sector from the observations, control forecast (Control) and four sensitivity forecasts (EX01, EX02, EX03, and EX04).



Height-time cross-sections of specific humidity in control forecast (Control), model biases (Control-OBS), and differences between sensitivity experiments and control forecast. The observation is from the IFA-averaged sounding obtained during TOGA-COARE period. The others are averaged over (150°E-160°E, 5°S-2°N).

Mean State

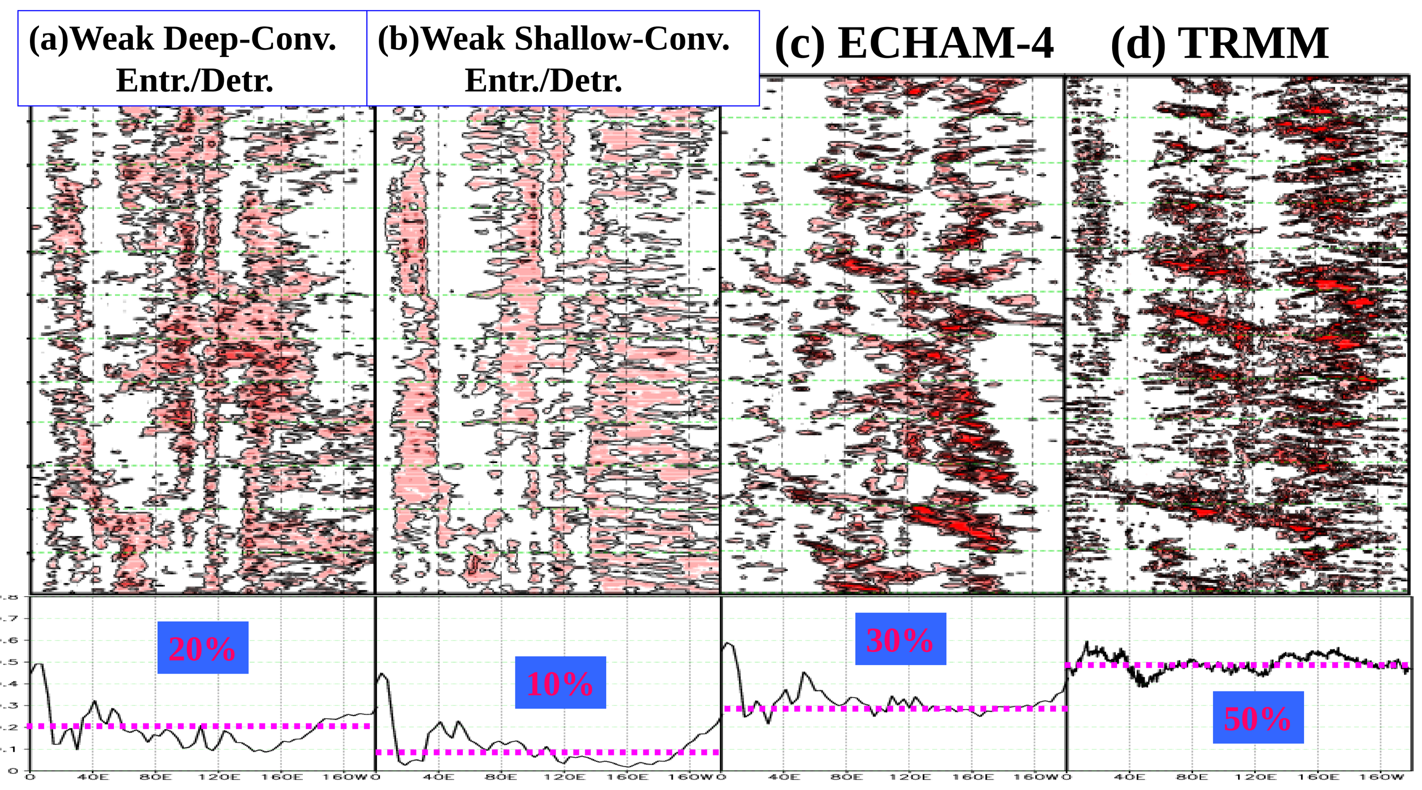
The speed-up of forecast MJO in four sensitivity experiments can hardly be explained with the changes of mean states because they are actually very similar (see left panels).

Preconditioning

In the observational studies (Fu et al. 2006; Tian et al. 2006) using humidity profiles obtained from AIRS onboard Aqua Satellite, it is found that MJO-related deep convection is always led by significant lower-troposphere moistening. This preconditioning is apparently underestimated in the control forecast (left panels). All four sensitivity experiments tend to enhance this preconditioning; particularly with enhanced shallow-convection moistening.

Stratiform Rainfall Sustains Madden-Julian Oscillation

(a)Weak Deep-Conv. Entr./Detr. (b)Weak Shallow-Conv. Entr./Detr. (c) ECHAM-4 (d) TRMM



(Upper Panels) One-year longitude-time cross-sections of rainfall averaged between 10°S-10°N from (a) ECHAM-4 with weaker deep-convection entrainment/detrainment rates; (b) ECHAM-4 with weaker shallow-convection entrainment/detrainment rates; (c) Control ECHAM-4; (d) TRMM observations. (Lower Panels) Corresponding stratiform fraction (Stratiform rainfall vs. Total rainfall).

Stratiform Rainfall

Observations show that large portion (40-70%) of total tropical rainfall is from stratiform (Schumacher and Houze 2003; Lin et al. 2004). The stratiform rainfall sustains MJO through warming-up upper troposphere; generating large-scale eddy available potential energy through the co-variability between warming and heating.

Summary

- Shallow-convection ahead of MJO deep convection moistens the lower-troposphere and preconditions the movement of MJO. Present result suggests that this process is very important to the eastward propagating speed of MJO.
- A significant fraction of stratiform rainfall (~30%; stratiform part vs. total rainfall) is needed for ECHAM-4 to have a robust MJO.
- The above findings suggest that in addition to deep convection, shallow convection and stratiform rainfall needs to be well represented in conventional GCMs to ensure a robust model MJO.

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