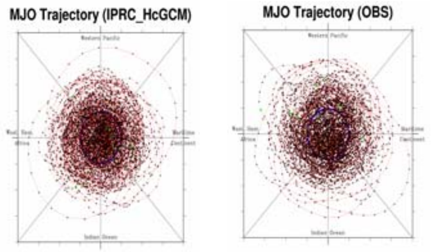
Dynamical MJO Forecast Experiments:

Sensitivity to Cumulus Parameterization and Air-Sea Coupling

Xiouhua (Joshua) Fu and Bin Wang

International Pacific Research Center (IPRC), SOEST, University of Hawaii at Manoa

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-1U850 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, a series of retrospective forecast experiments, targeting a prominent MJO event observed during TOGA-COARE, have been conducted to assess the impacts of cumulus parameterization details and air-sea coupling on the dynamical MJO forecast skill.

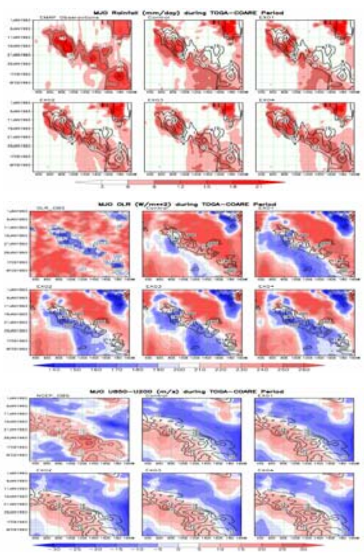
Experiment Design*

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

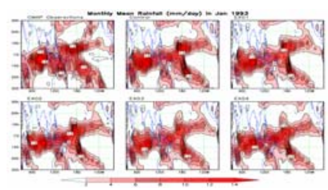
* ECHAM-4 uses the mass flux scheme of Tiedtke (1989) for deep, shallow, and midlevel convection with CAPE closure (Nordeng 1995).

All forecast experiments were initiated with NCEP-1 reanalysis on December 31, 1992. 100 ensembles have been conducted for each experiment. Results presented in the following are from 100-ensemble means. The control forecast (with default cumulus parameterization) 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.

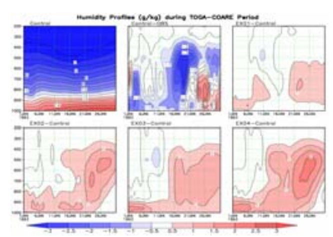
Sensitivity to Cumulus Parameterization



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 sensitivity experiments, the shaded represents the corresponding 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 experiments (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).

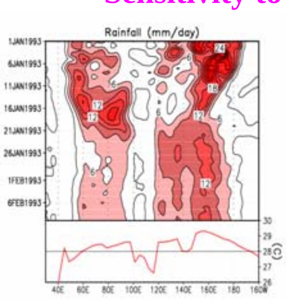
Mean State

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).

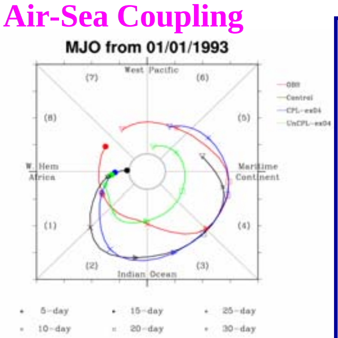
Preconditioning

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 preconditioned with strong boundary-layer (BL) moistening. This preconditioning is apparently underestimated in the control forecast (left panels). All four sensitivity experiments tend to enhance this preconditioning.

Sensitivity to Air-Sea Coupling



Longitude-time cross-section of forecast rainfall from an experiment same as the EX04 but with underlying ocean decoupled (UnCPL-ex04) lies over the SST averaged between 10°S and 10°N.



Phase-space diagram of the observed MJO event (OBS), control forecast (Control), the EX04 (CPL-ex04) and its corresponding atmosphere-only forecast (UnCPL-ex04).

Air-Sea Coupling

When forced with climatological SST instead of interactive coupled SST during forecast integration, the forecast rainfall tends to lock upon high SST regions, resulting in too much stationary rainfall. The traveling portion, which corresponds to MJO, was significantly underestimated comparing to the coupled counterpart and the observations (see left panels).

Summary

- **Dynamical MJO forecast is very sensitive to model cumulus parameterization details. The MJO forecasted by the IPRC_HcGCM with default cumulus scheme is too slow. It is probably a result of underestimated boundary-layer moisture preconditioning. After revising the cumulus scheme accordingly, the forecast MJO speeds up and well tracks the observed MJO beyond one month.**
- **Interactive air-sea coupling plays an essential role in maintaining the intensity of the forecast MJO in this hybrid coupled model .**