On the Relative Roles of Circumnavigating Waves and Extratropics on the Madden-Julian Oscillation (MJO)

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1. Background

MJO Mechanisms:

TheMadden-Julian oscillation (MJO) and its initiation are influenced by a variety of factors.
(i) Local thermodynamics (discharge-recharge processes),
(ii) Upstream effects of circumnavigating waves,
(iii) Extratropical influences,
(iv) Stochastic forcing, and
(v) Air-sea interactions, among others.

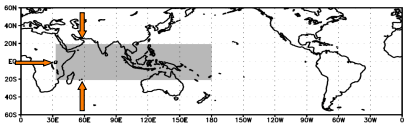

Fig. 1. Schematic diagram showing the influences of the circumnavigating waves and the extratropics.

Motivation:

To investigate the relative roles of the circumnavigating waves and the extratropics on the MJO.

Observations:

More than 50% of the MJO events are influenced by the circumnavigating waves and extratropics (Matthews, 2004)

Modeling:

(a) Standard regional model (Gustafson and Weare 2004a,b).
(b) Tropical Channel Model (Ray et al. 2009, 2011, Ray & Zhang 2010, Ray 2012).
(c) GCM relaxed to reanalysis (Vitart and Jung 2010).

Modeling Issues:

(i) Tropical and extratropical influences cannot be separated.
(ii) No global view possible in regional models.
(iii) Needs boundary conditions. intraseasonal variability present in the reanalysis boundary conditions may be different from the intraseasonal variability generated by the model.

Our approach:

(i) A GCM-based framework is introduced, in which the model boundary conditions come from the parallel simulations of the same model.
(ii) Remove one factor at a time. Influences from the circumnavigating waves and extratropics are separated.
(ii) Global view of the intraseasonal oscillation possible.
(iii) MJO statistics over all seasons.
(iv) Coupling with an ocean model.
(v) Can be used for forecasting.

2. Model and Simulation Design

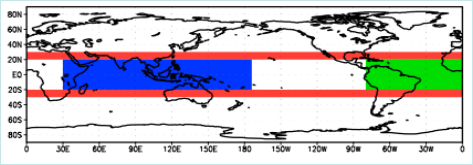

Fig. 2. Schematic diagram of the numerical experiments in which the prognostic variables in 20°-30° latitude zones (red) and the tropical Atlantic region (green) are relaxed toward the "controlled" climatological annual cycle. Blue indicates the coupling to an ocean model.

Exp.	Description	Purpose
Control	ECHAM4 atmosphere only, 20 yrs., monthly SST	MJO evaluation; Provide boundary conditions for other simulations.
EW	Relaxed to the 'controlled' annual cycle the over the tropical Atlantic	To evaluate the role of circumnavigating waves.
NS	Relaxed to the 'controlled' annual cycle over 20°-30° latitude.	To evaluate the role of extratropics.
EWNS	Combination of EW and NS.	To evaluate the combined effects from circumnavigating waves and extratropics.
Coupled	Same as control, but with a slab ocean model over the Indo-Pacific warm pool	To evaluate the role of air-sea interaction
EWNS Coupled	Combination of EWNS and coupled.	To evaluate the combined effects from the circumnavigating waves, extratropics, and air-sea interaction.

Table 1. Description of the simulations using ECHAM4. (EW: East West; NS: North South).

3. Results

Spectrum

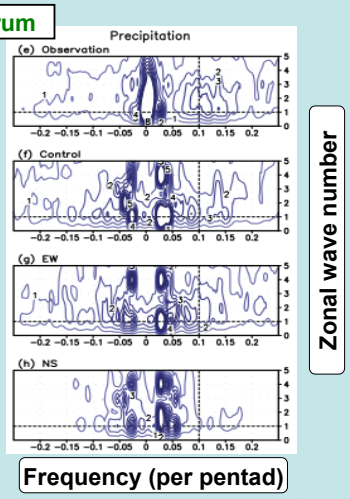

Fig 3. Unfiltered time-space spectra of precipitation.

3. Results Continued…

Var	Obs.	Control	EW	NS
U50	2.8	1.8	1.7	1.1
P	2.4	1.7	1.7	1.0

Table 2. The ratio of eastward to westward propagating power for 850-hPa zonal wind (U850) and precipitation (P) averaged over 10°S-10°N at 20-90 day period.

Mean State

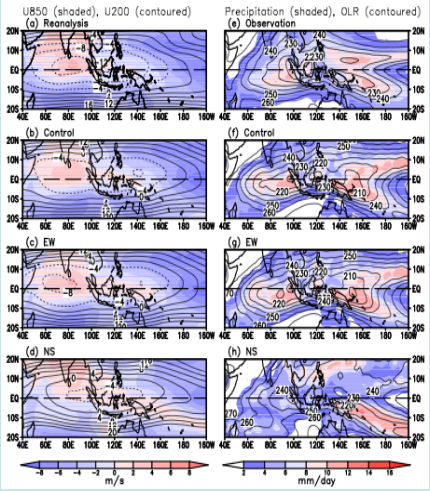

Fig. 4. (left) U850 (shaded) and U200 (contoured). (right) Precipitation (shaded) and OLR (contoured).

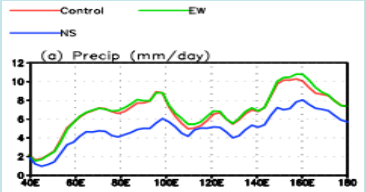

Fig. 5. Mean precipitation (10°S-10°N avg.)

Static Stability

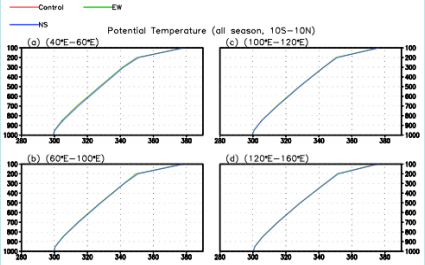

Fig. 6. Potential Temperature (10°S-10°N avg.).

Convective Stability

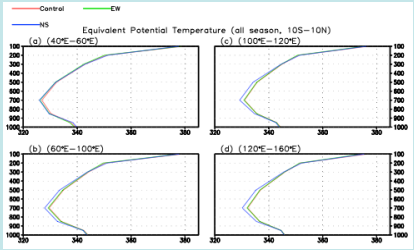

Fig. 7. Equivalent Potential Temperature (10°S-10°N avg.).

Vertical Shear

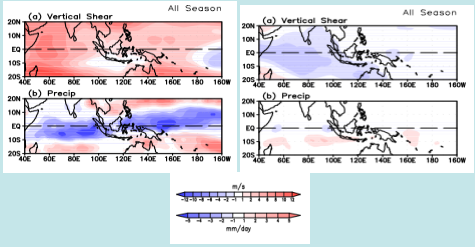

Fig. 8. (left) NS minus control. (right) EW minus control.

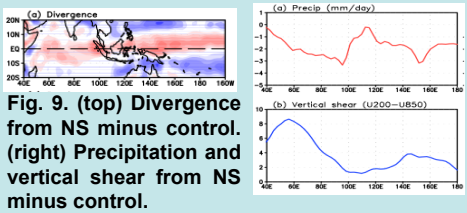

Fig. 9. (top) Divergence from NS minus control. (right) Precipitation and vertical shear from NS minus control.

Easterly shear favors development of convection in the tropics (Wang and Xie 1996).
Low-level convergence is favored under easterly shear (Sooraj et al. 2009).
Idealized AGCM simulation shows that the growth of perturbation kinetic energy is much larger under a constant easterly shear than under a constant westerly shear (Li 2006).

Ongoing work

(i) Role of the scale interactions;
$P = P_{(<20\ day)} + P_{(20\text{-}90\ day)} + P_{(>90\ day)}$
(ii) Seasonal dependence
(iii) Case studies during the YOTC period.

4. Summary and Implications

(i) A problem oriented modeling framework was constructed to explore the relative roles of the tropical internal dynamics and the external influences.
(ii) Extratropics play a major role compared to the circumnavigating waves. However, internal dynamics can produce substantial variance in the absence of extratropical influences.
(iii) Inclusion of a slab ocean model did not improve the simulation.
(iv) Error in the mean state, particularly over the equatorial Indian and west Pacific Ocean, seems to affect the simulated MJO in the absence of extratropical influences.
(v) Vertical shear plays a major role compared to the atmospheric stability.
(vi) Better representation of the extratropical influences in the GCMs may improve the MJO prediction skill in the tropics.

References:

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