The Global Circulation Response to Diabatic Heating Associated with the MJO During Northern Winter

Kyong-Hwan Seo

[1]Pusan National University, Department of Atmospheric Sciences, Korea,

*email: khseo@pusan.ac.kr

OBJECTIVES

(1) To investigate the detailed dynamical mechanisms of the global circulation response to MJO convective forcing.

(2) Does an improved simulation of the MJO improve the global circulation response pattern in a GCM?

MODELS

(1) GFDL Dynamical Core GCM: R30L20 (output grids: 96* 80)
Initial State: DJF mean 3-d T, q, winds, Psfc
Initial Forcing: Diabatic Heating Profile with a Peak at 400hPa
Integration : 31 days (integration time step: ~15 min)
8^{th} order horizontal diffusion coefficient: $8.0*10^{37}$

(2) NCEP Coupled high resolution run: CFS T126SAS (64 Vertical Levels)
(=GFS T62 +GFDL MOM3)

(3) NCEP Coupled high resolution run with Relaxed Arakawa-Schubert scheme:
CFS T126 RAS

Simulation Period: 15-20 years

Figure Group 1: Diabatic Forcing Structure and Example of Time Evolution of Streamfunction Anomalies

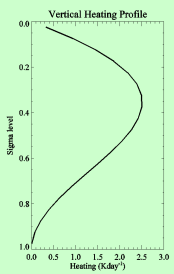


Fig.1. Vertical Heating Profile

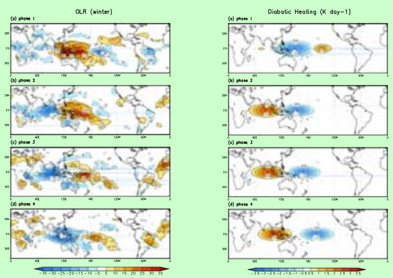


Fig.2. Horizontal Structure of MJO Convection for Phases 1-4

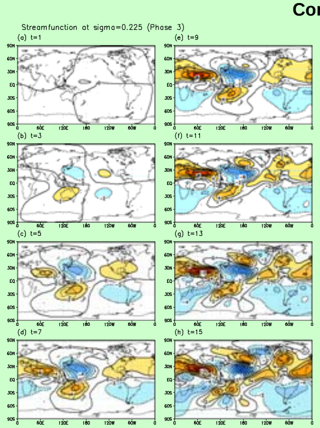


Fig.3. Time Evolution of Streamfunction Anomalies at sigma=0.225 for phase 3

*Equatorial trapped Rossby and Kelvin waves are seen.

*Rossby wave propagation in the NH and SH is seen in midlatitudes

Figure Group 2: Day 15 Streamfunction Anomalies at the Upper and Lower Troposphere

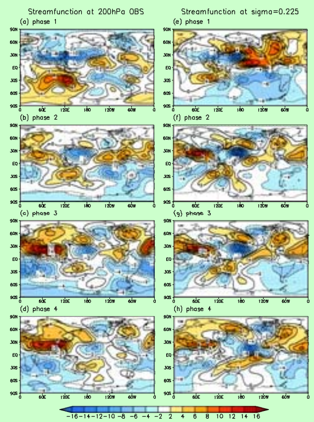
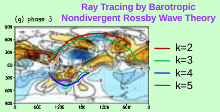


Fig.4. Global (Upper-Level) Streamfunction Anomalies for Obs (left) and Model (right)



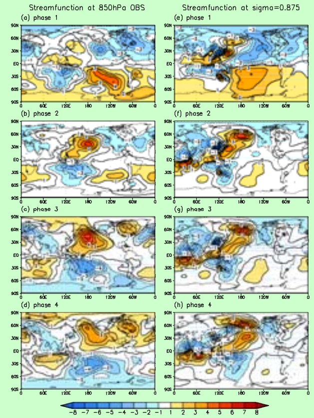


Fig.5. Global (Lower-Level) Streamfunction Anomalies for Obs (left) and Model (right)

Figure Group 4: Global Circulation Response to MJO Heating: NCEP CFS Model Simulation

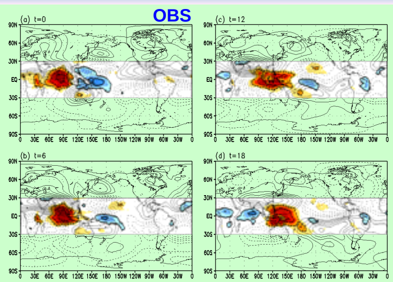


Fig.10. 200hPa Streamfunction regressed onto PC1 & PC2

*Half life cycle

*Tropics: anticyclonic couplet at or west of enhanced convection + tropical westerly anomaly to the east of enhanced convection: Rossby-Kelvin wave response

*PNA-like response

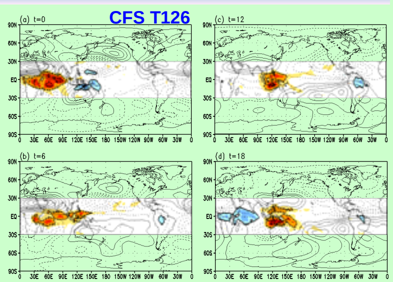


Fig.11. 200hPa Streamfunction regressed onto PC1 & PC2

*CFS T126: convection and streamfunction anomalies are weak

*No significant suppressed convection over the western Pacific at t=6 & t=12 → weaker circulation response

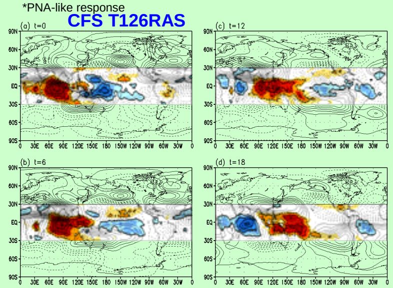
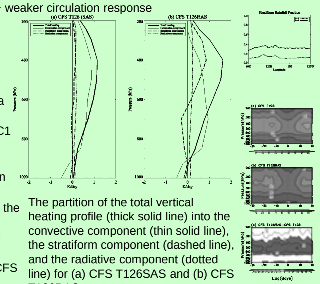


Fig.12. 200hPa Streamfunction regressed onto PC1 & PC2

*CFS T126RAS: stronger circulation response

*Similar pattern to the observation → pattern correlation 0.84-0.91

(vs. 0.47-0.78 in CFS T126)



The partition of the total vertical heating profile (thick solid line) into the convective component (thin solid line), the stratiform component (dashed line), and the radiative component (dotted line) for (a) CFS T126SAS and (b) CFS T126RAS.

Figure Group 3: Sensitivity Test, RWS and MJO-ENSO Interaction

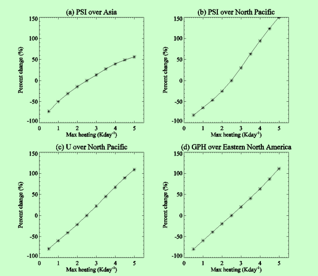


Fig.6. Sensitivity Test

*Quasi-linear relationship between the circulation response and imposed diabatic heating strength

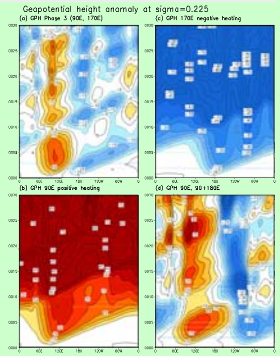
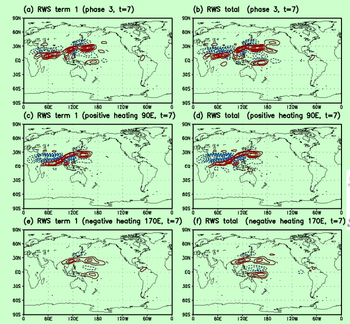
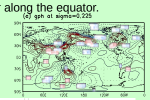


Fig.7. Equatorial Rossby and Kelvin Waves due to Dipole Convection Forcing

*Formation of circulation anomalies by equatorial Rossby and Kelvin Waves

*Rossby and Kelvin Waves of positive and negative signs oppose each other along the equator.





$$\frac{\partial \zeta'}{\partial t} + \overline{V_\psi} \cdot \nabla \zeta' + V'_\psi \cdot \nabla \bar{\zeta} = S' + F'$$

$$S' = -\bar{\zeta}\nabla \cdot V'_\chi - V'_\chi \cdot \nabla \bar{\zeta} - \zeta'\nabla \cdot \overline{V_\chi} - \overline{V_\chi} \cdot \nabla \zeta'$$

Fig.8. Rossy Wave Source at Phase 3

*The first term (the generation of wave vorticity by anomalous divergence) is dominant. The RWS perturbations by the positive heating at 90°E are as much as twice greater than those by the negative forcing at 170°E

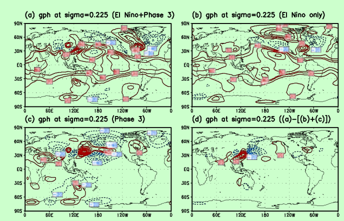


Fig.9. MJO-ENSO Interaction (at Phase 3)

Tthe nonlinear interaction between the MJO and ENSO takes place primarily in the northern extratropics along the jets, and mostly occurs along the Asian-Pacific jet

$$TOT_{MJO} = LN_{MJO} \ \& \ TOT_{ENSO} = LN_{ENSO}$$

$$TOT_{MJO+ENSO} = LN_{MJO+ENSO} + NON_{MJO+ENSO}$$
$$= LN_{MJO} + LN_{ENSO} + NON_{MJO+ENSO}$$

CONCLUSIONS

(1) The global circulation response to the MJO is largely determined by the wintertime large-scale background mean flow and the location of the enhanced and suppressed heating anomalies in the MJO development region.

(1a)"***Extratropical circulation is almost entirely from tropical heating anomalies***": Barotropic Rossby wave trains with zonal wavenumbers 2-4 in the NH and 3-5 in the SH are dominant.

(1b) ***Tropical circulations*** are formed from **opposition/cooperatio**n between negative and positive circulation anomalies due to eastward propagating Kelvin and westward propagating Rossby waves.

(2) The nonlinear interaction takes place preferentially along the NH midlatitude jets when the enhanced convection is located over the Indian Ocean.

(3) The improved MJO simulation in CFS T126RAS improves the simulation of extratropical circulation anomalies

Seo, K.-H., and W. Wang, 2010: The Madden-Julian oscillation simulated in the NCEP Climate Forecast System model: The importance of stratiform heating. *J. Climate*, in print.

Seo, K.-H., 2010: The Global Atmospheric Circulation Response to Tropical Diabatic Heating Associated with the Madden-Julian Oscillation during Northern Winter., J. *Atmos. Sci.*, in prep.