Tropical Pacific impacts of convective momentum transport (CMT) in the SNU coupled GCM

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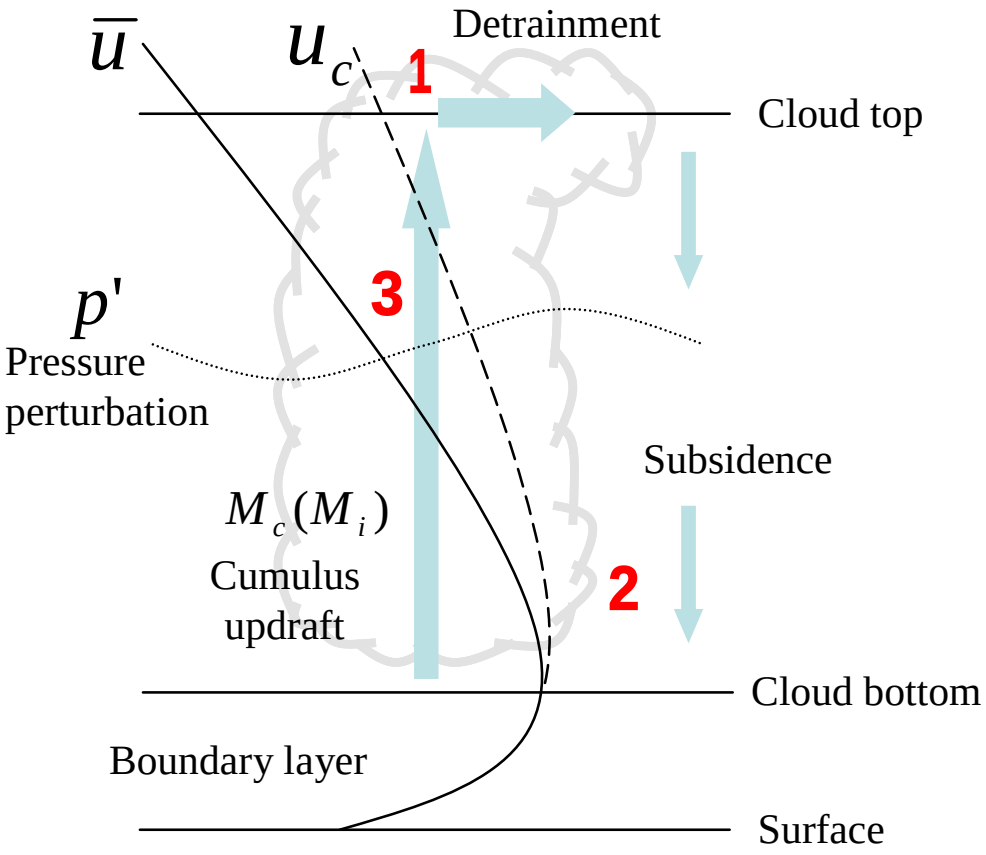
CMT Equations (Wu and Yanai 1994)



$$F_c = \sum_i \delta_i (\rho \bar{v}_{Di} - \rho \bar{v}) - M_c \frac{\partial \rho \bar{v}}{\partial p} + \sum_i \gamma M_i \frac{\partial \rho \bar{v}}{\partial p}$$

① ② ③

Equations (Wu and Yanai 1994)

Cumulus effects on the environmental flow

$$F_c = \sum_i \delta_i (\vec{v}_{Di} - \vec{v}) - M_c \frac{\partial \vec{v}}{\partial p} + \sum_i \gamma M_i \frac{\partial \vec{v}}{\partial p}$$

① ② ③

1. The effect of horizontal momentum detrained from cumulus clouds

2. The vertical advection of mean horizontal momentum by the part of environmental vertical motion that compensates the convective mass flux (**Vertical Advection Term**)

3. The effect of the convective-scale horizontal pressure gradient force on the environment (**Pressure Gradient Term**)

$$\gamma = 0.55$$

(Wu and Yanai, 2003 CRM result)

Questions

1) What is impact of Convective Momentum Transport (CMT) on ENSO simulation in AGCM and CGCM?

2) How can the CMT alter ENSO characteristics?

Experimental Design

- **SNUAGCM : T42, 20 levels**
  - Simplified AS convection scheme - Perpetual simulation with boreal winter condition.

- Climatological SST Run/ El Nino SST Run

CTLa : without CMT
CMTa : with CMT

- **SNUCGCM : SNUAGCM + MOM2.2**
  - Ocean mixed layer scheme (Noh and Kim, 1999)
  - No flux correction

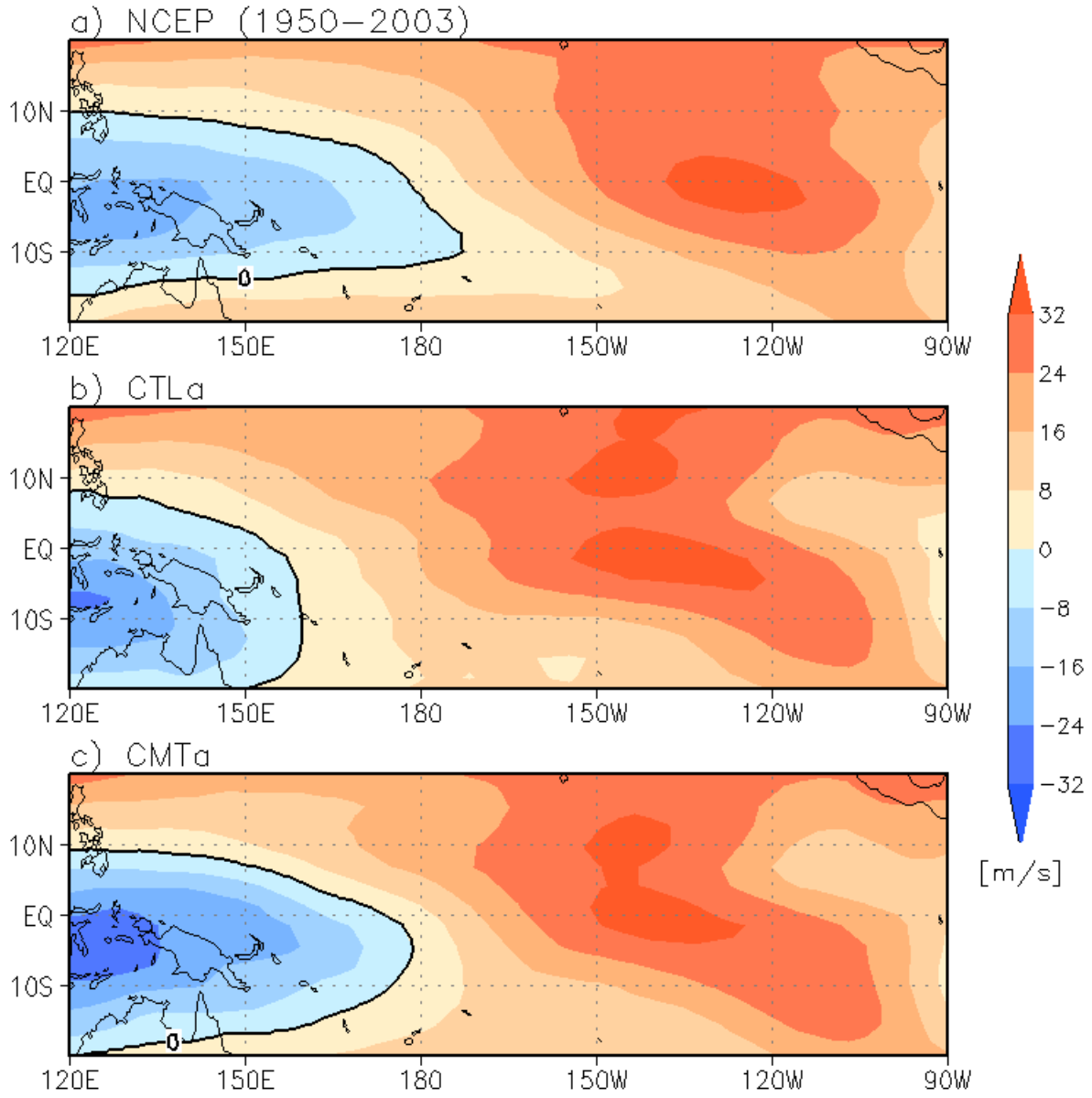
CTLc : without CMT (200 years)
CMTc : with CMT (50 years)

Climatological Simulation in AGCM

Results/ Climatological Vertical Wind Shear

Without CMT

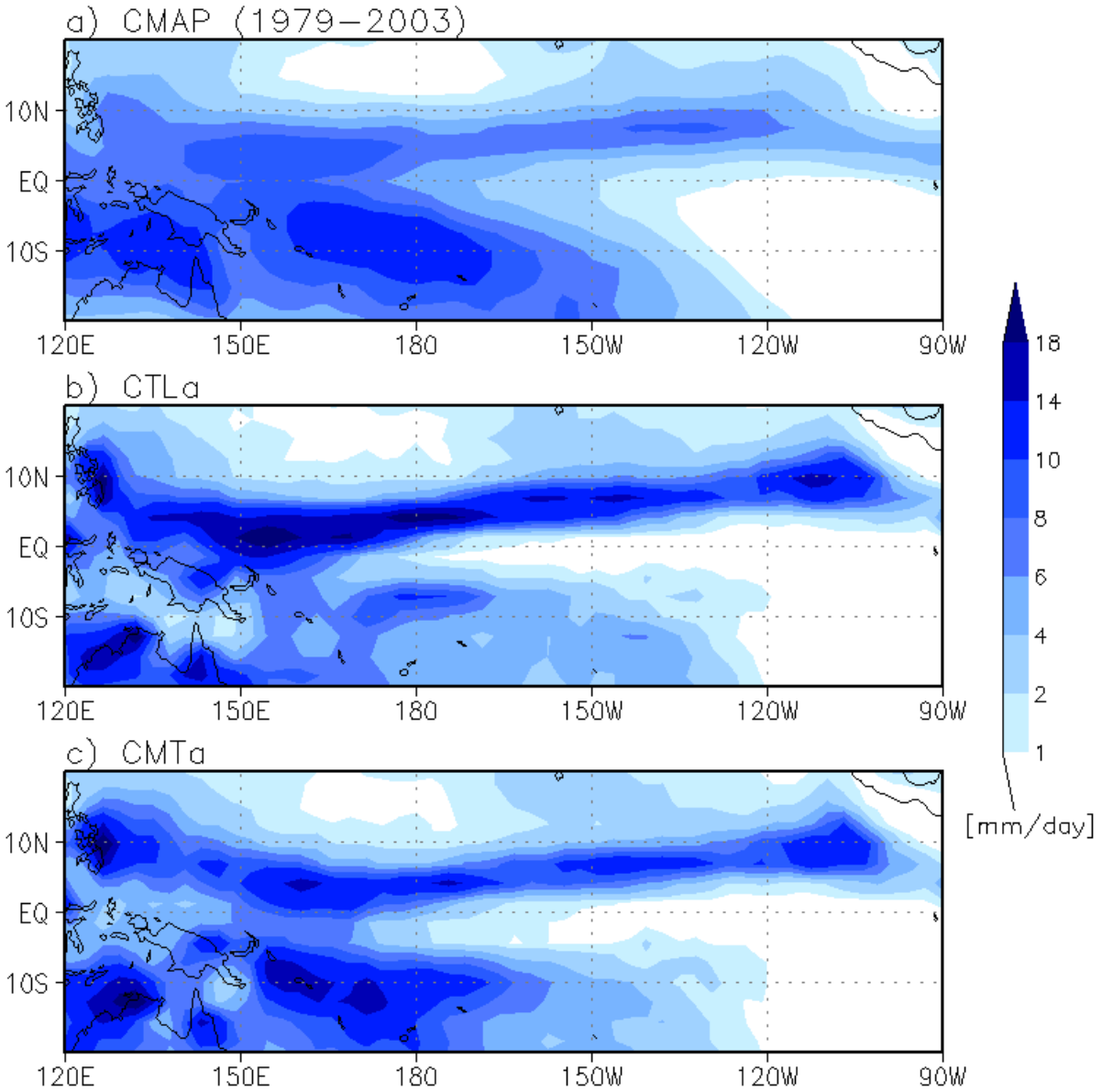
With CMT



Results/ Precipitation Climatology

Without CMT

With CMT



Results/ RMSE and Pattern Correlation

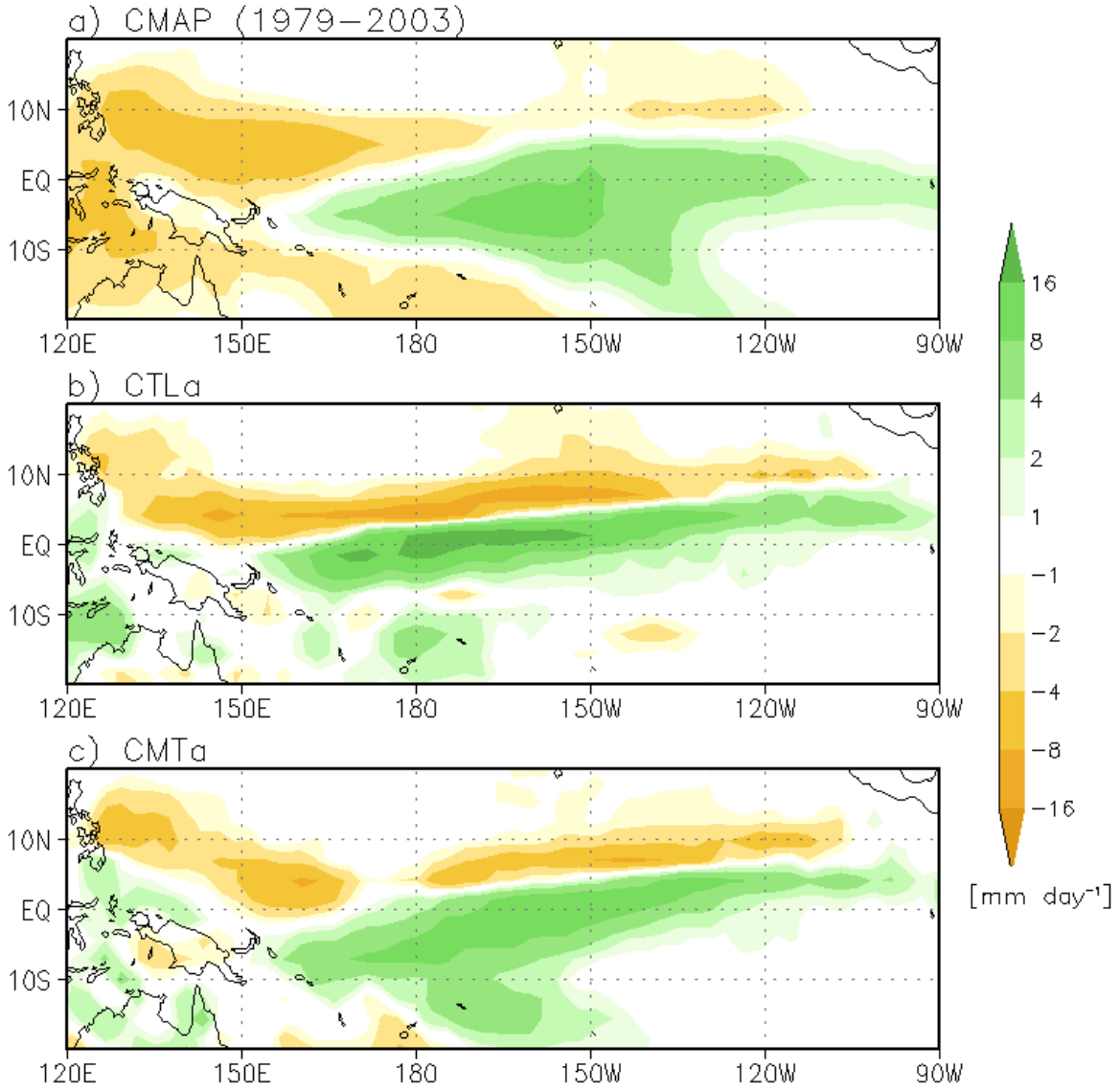
- DJF climatology simulation

The CMT has a positive impact on the DJF climatology simulation

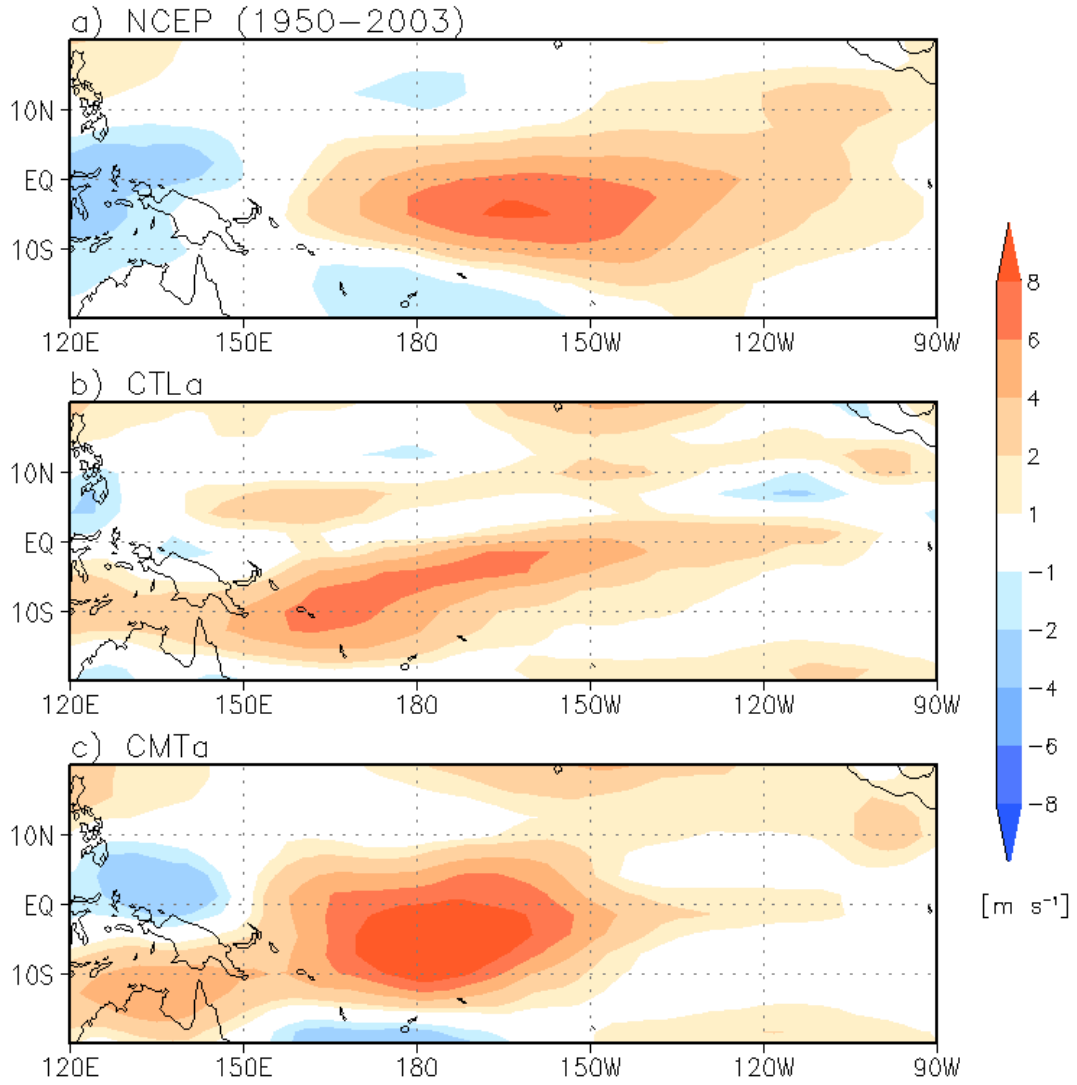
		RMSE		Pattern Correlation	
		Pacific	Global	Pacific	Global
SHEAR	CTL	8.01	5.87	0.85	0.91
	CMT	5.51	4.99	0.94	0.94
PRCP	CTL	3.73	2.23	0.60	0.69
	CMT	2.73	1.86	0.78	0.77

ENSO Simulation in AGCM

ENSO Anomalies/Precipitation



ENSO Anomalies/Zonal wind at 850hPa



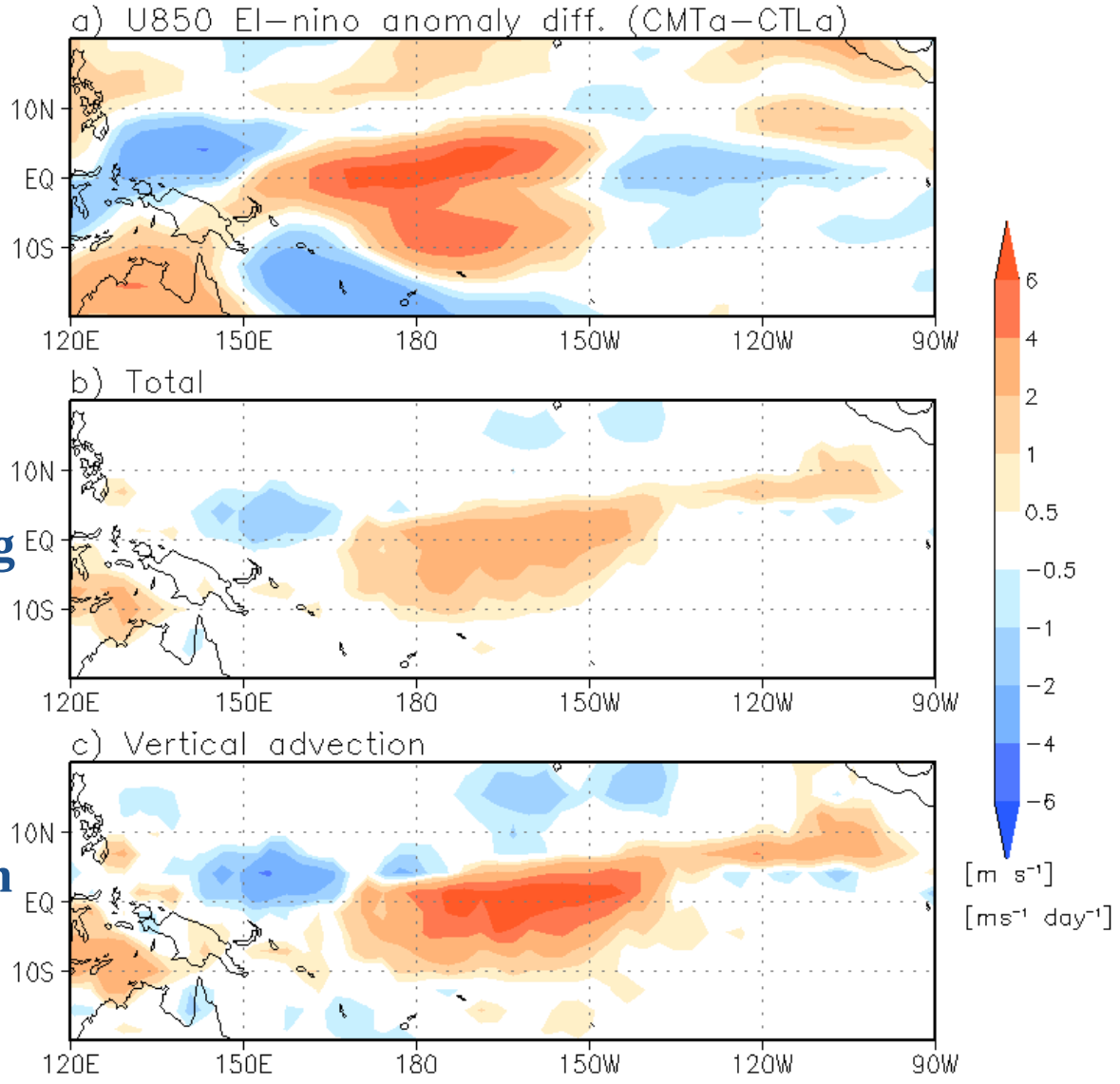
Momentum forcing of CMT

Wind Difference

Total Momentum forcing by CMT

Forcing by vertical advection

$$-M_c \frac{\partial \bar{\theta}}{\partial p}$$



Momentum budget Analysis

Vertical advection term = -convective massflux * environmental wind shear

$$-M_c \frac{\partial \bar{v}^{\theta}}{\partial p}$$

Decomposition

= climatology (C)+ seasonal anomaly (E)+ daily transient(')

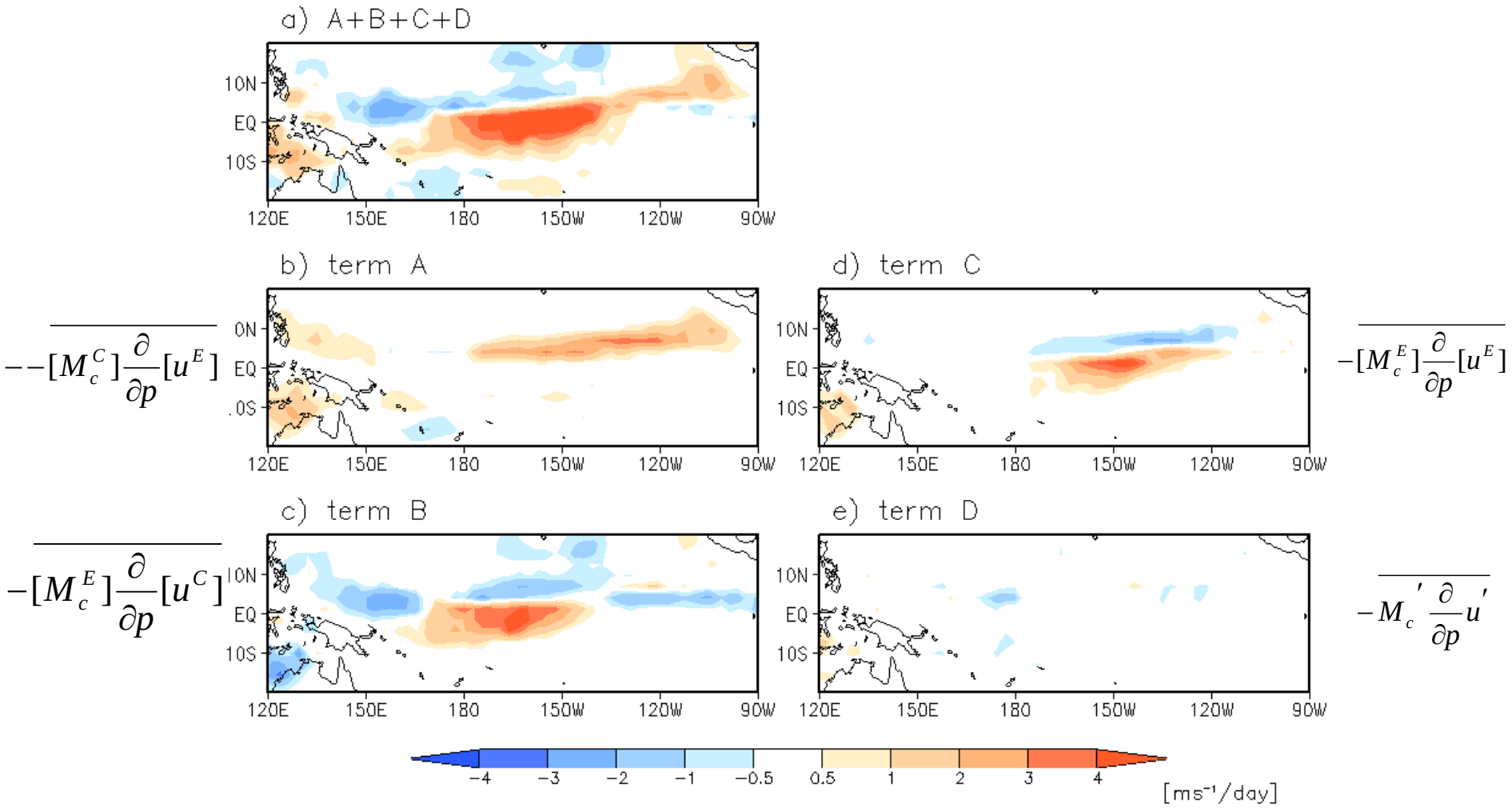
$$A = A^C + A^E + A'$$

Budget Decomposition

$$-\overline{M_c \frac{\partial u}{\partial p}}^{E} = -\overline{[M_c^C]\frac{\partial}{\partial p}[u^E]}^{E} - \overline{[M_c^E]\frac{\partial}{\partial p}[u^C]}^{E} - \overline{[M_c^E]\frac{\partial}{\partial p}[u^E]}^{E}$$

$$-\overline{M_c' \frac{\partial}{\partial p} u'}^{E}$$

Momentum Budget Analysis



$$--[M_c^C]\frac{\partial}{\partial p}[u^E]$$

$$-[M_c^E]\frac{\partial}{\partial p}[u^C]$$

$$-[M_c^E]\frac{\partial}{\partial p}[u^E]$$

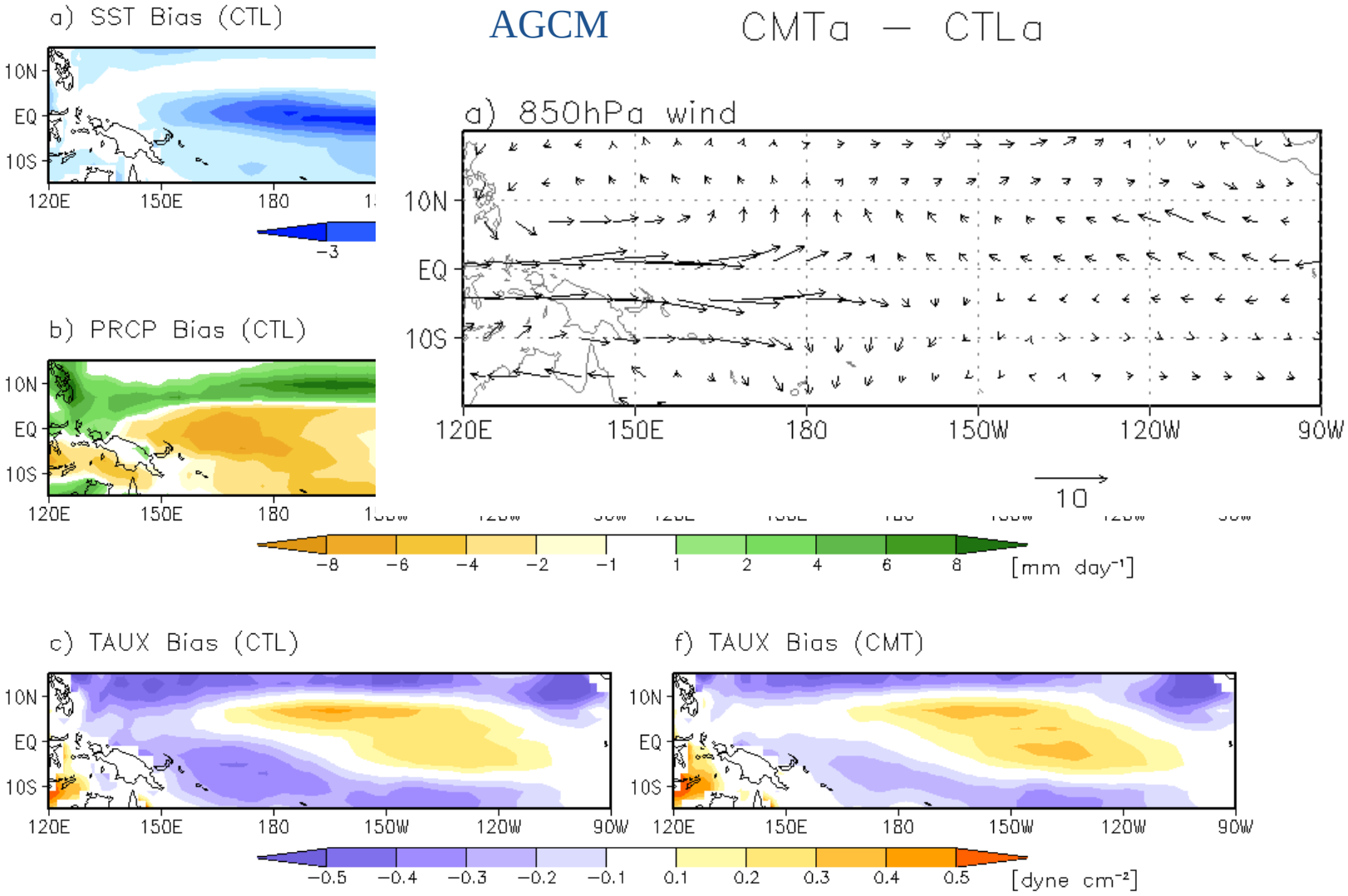
$$-M_c'\frac{\partial}{\partial p}u'$$

SNU CGCM Simulation

Climatological Bias

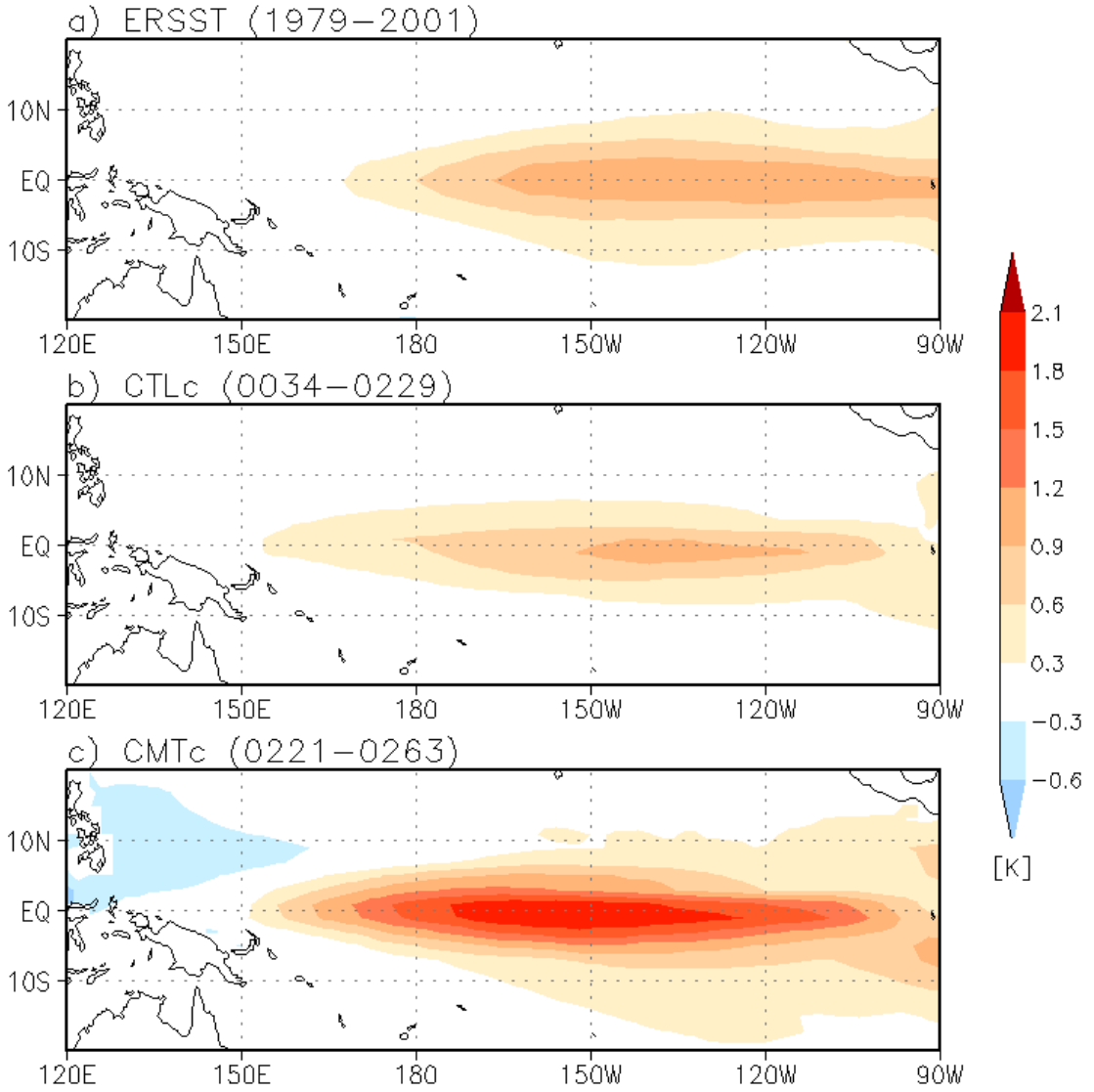
CTLc

CMTc

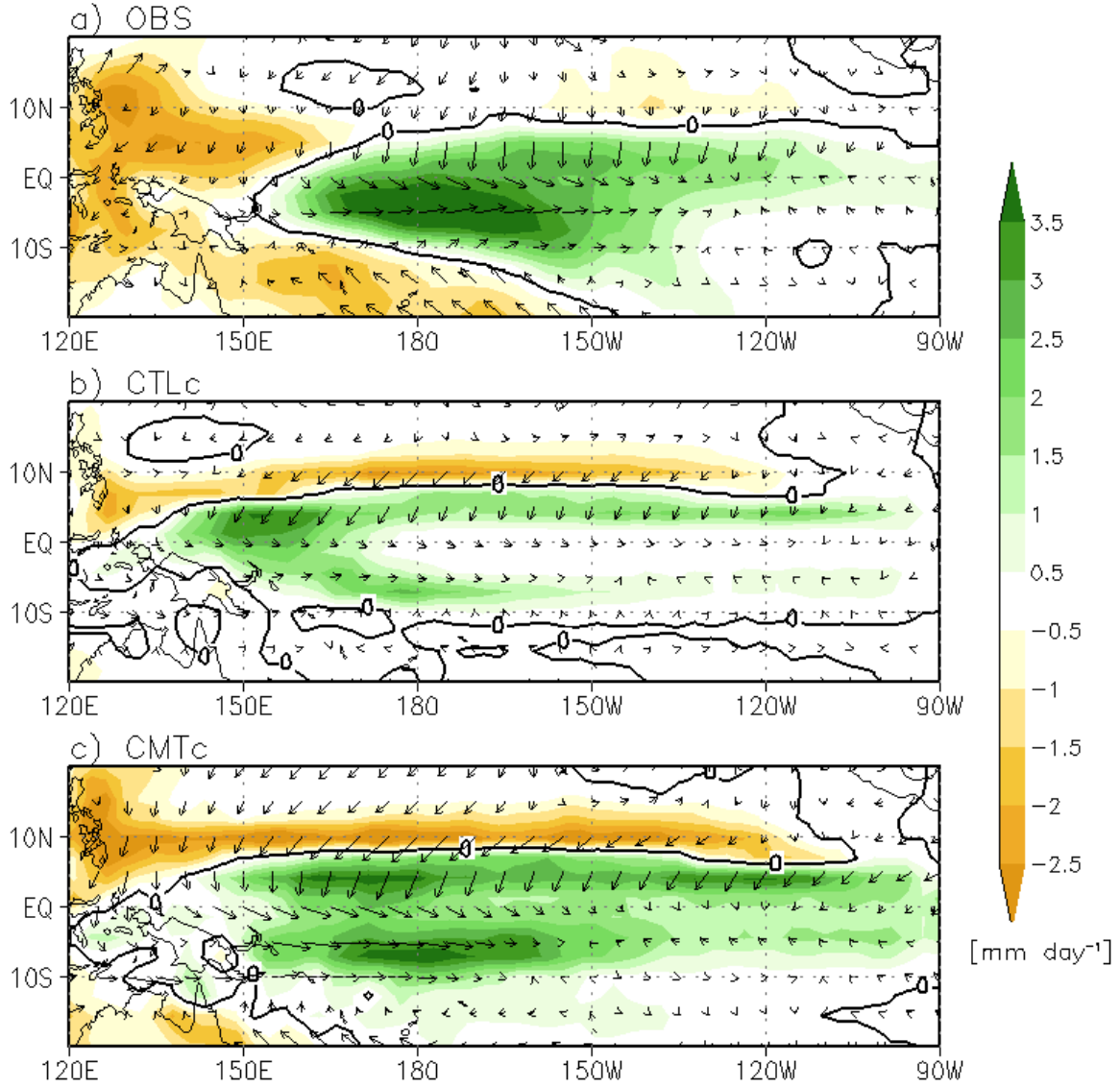


ENSO Amplitude Simulation

Linear Regression
of SST onto
normalized NINO3.4 SST

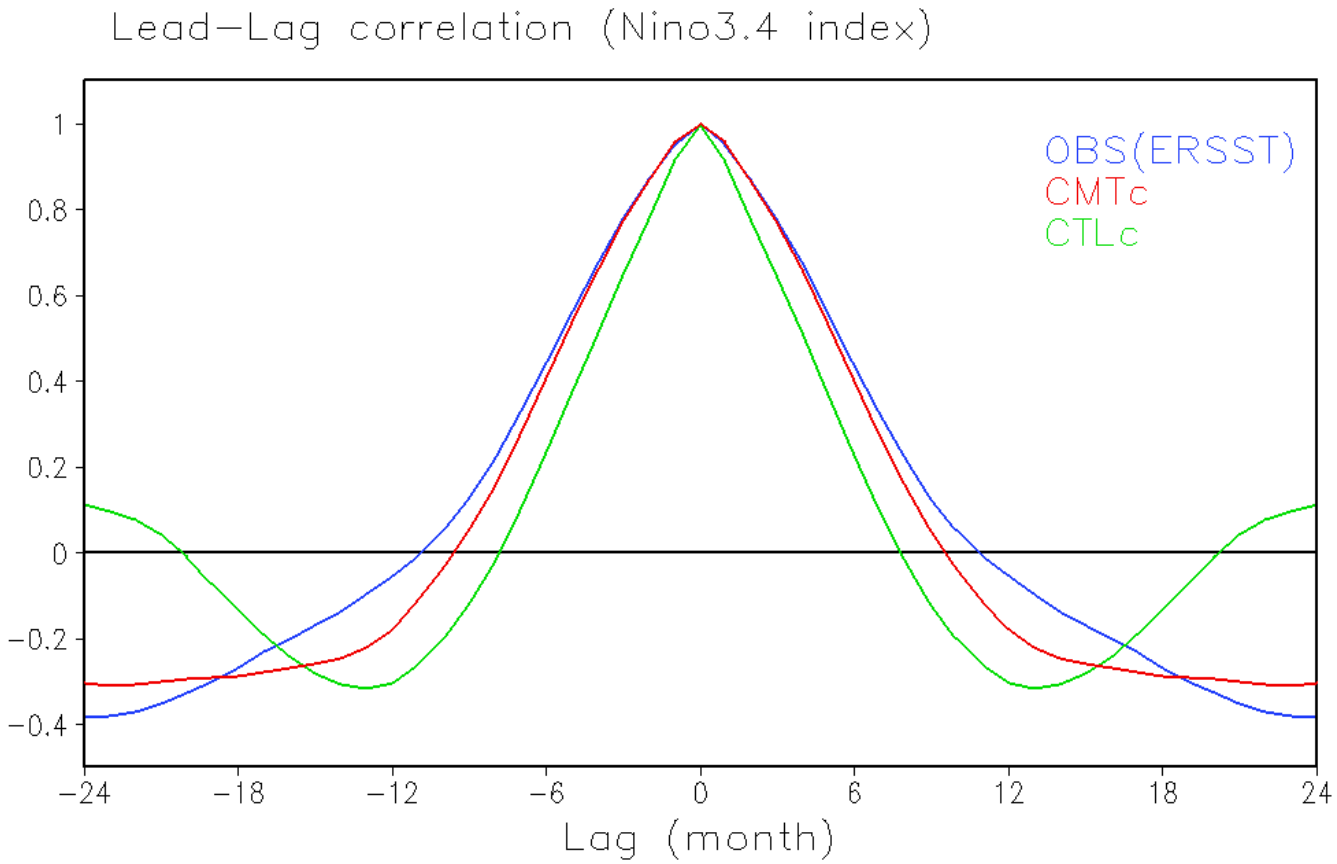


Precipitation and Wind Anomalies (850hPa)



ENSO Period

Autocorrelation of NINO3.4 SST



Longer ENSO period due to eastward shift and meridionally broadening of zonal wind

Background

❖ Previous Studies on ENSO and Atmospheric Noise (MJO/WWB)

- Relation between ENSO and Westerly Wind Bursts (WWB)
  (Luther et al. 1983; Harrison and Vecchi, 1997)

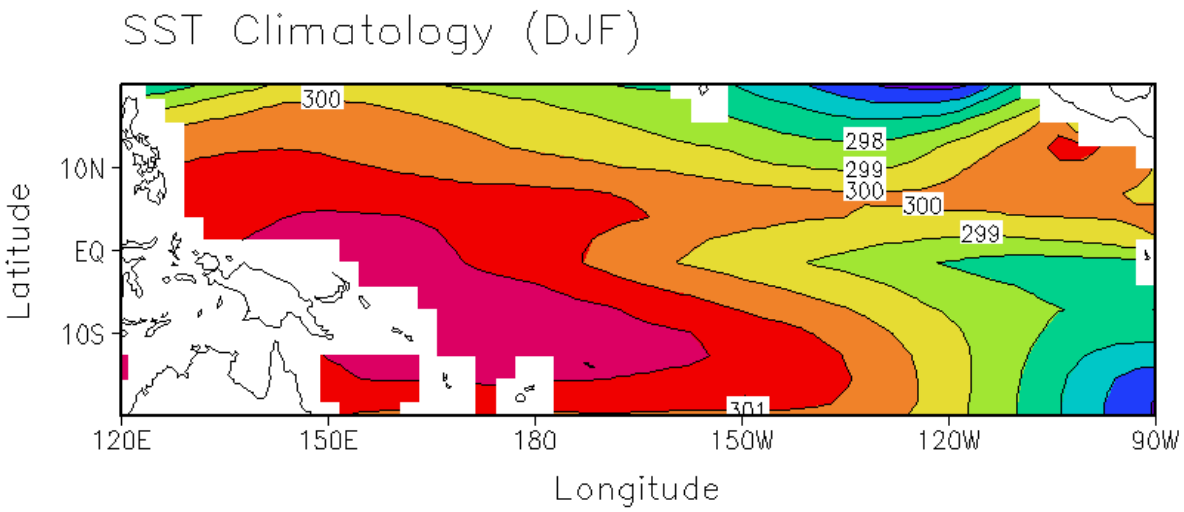
- Relation between ENSO and MJO Variability
  (Gutzler 1991; Hendon et al. 1999; Kessler 2001; Tam and Lau, 2006)

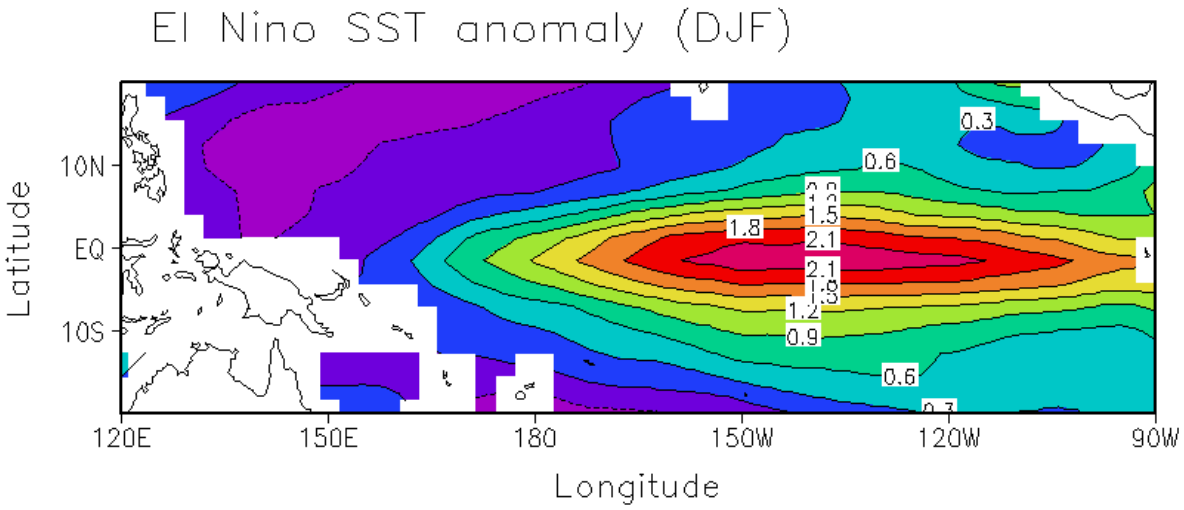
- Interaction between Atmospheric Noise and ENSO
  - Theoretical and modeling work
  (Lengaigne et al. 2004; Eisenman et al. 2005; Perez et al. 2005;
  Zavala-Garay et al. 2005; Jin et al. 2007)

➢ **Observational Evidence for the state-dependent noise is still unclear.**

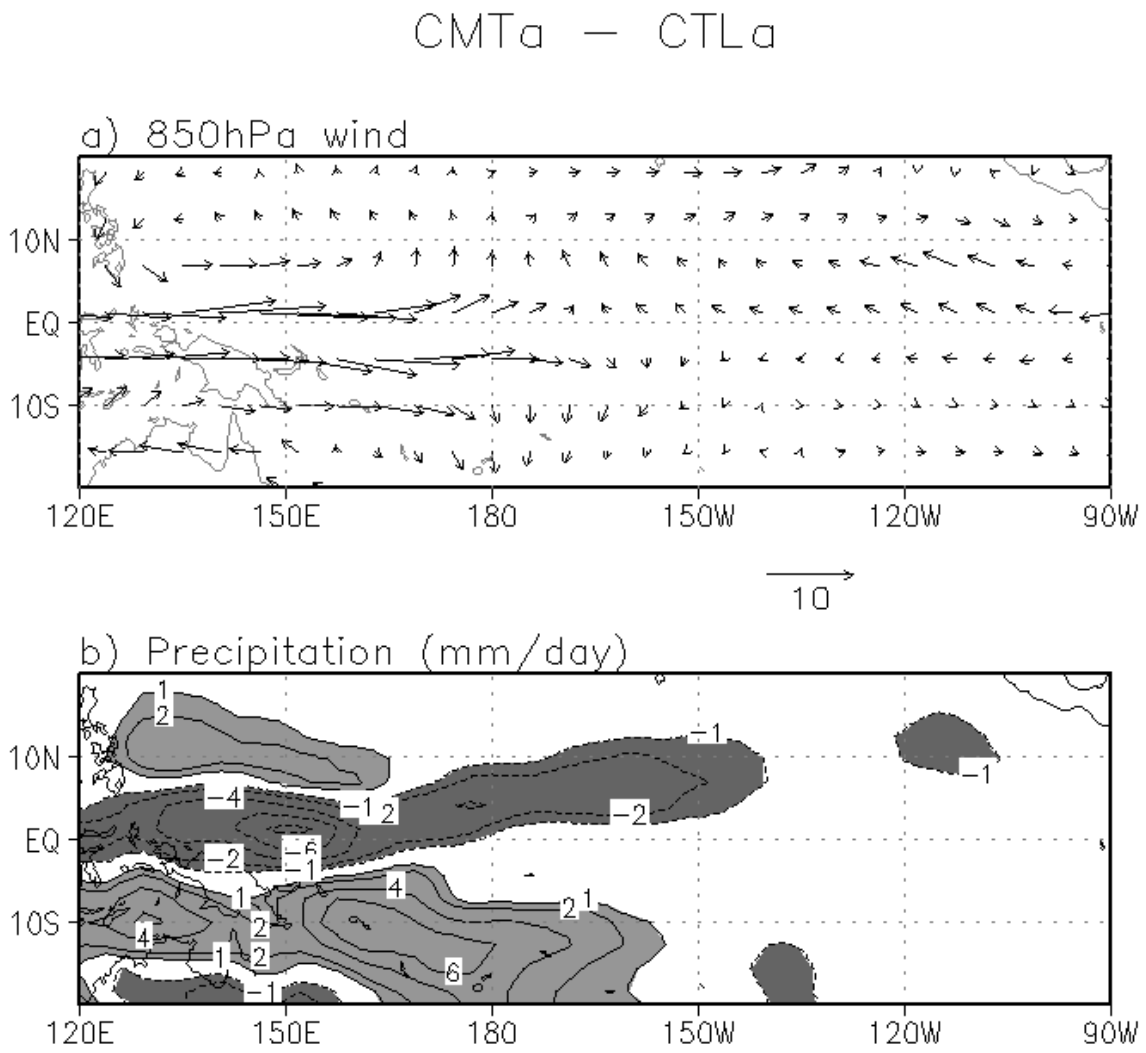
- **Impact of ENSO-noise interaction on ENSO variability**
- **Interdecadal Change of ENSO-atmospheric noise interaction**
- **Projection onto past and future climate**

SST Boundary Condition for AGCM Experiment





Climatology Differences



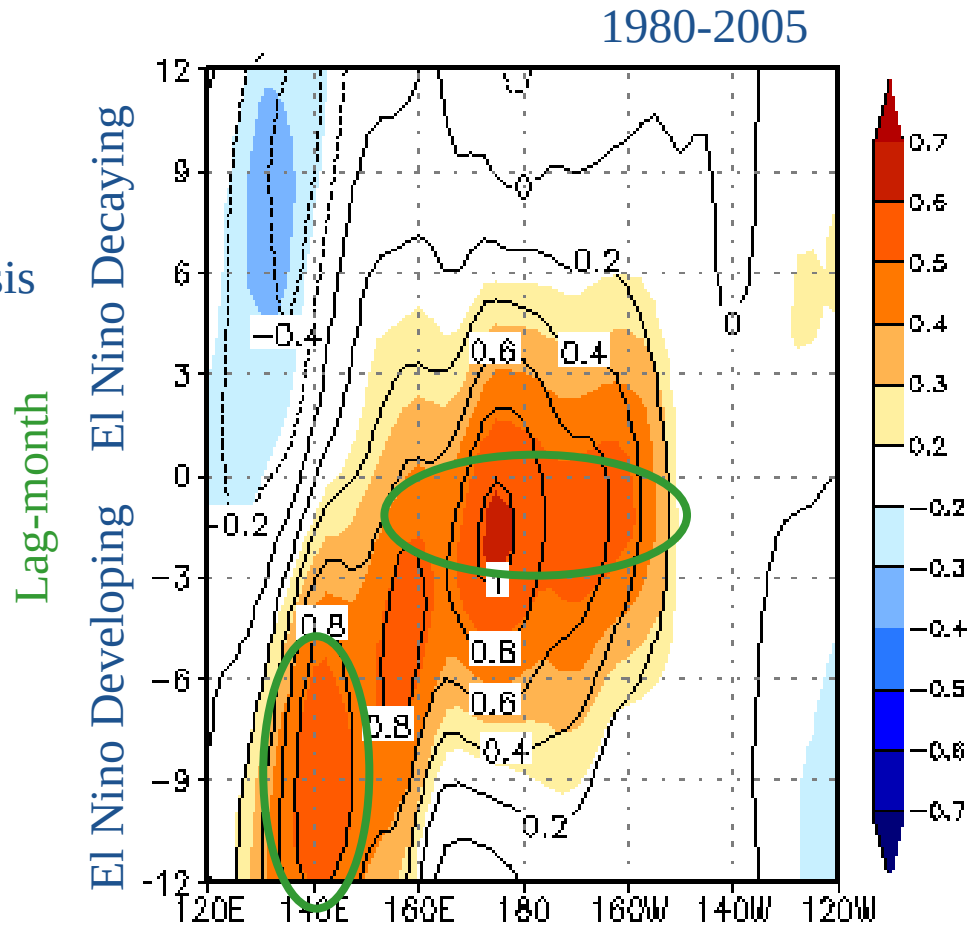
ENSO/MJO Interaction

Kug et al. (2007 a,b), Jin et al. (2007)

ENSO-MJO Interaction / NCEP Reanalysis Data

Lag Correlation (Shaded) and Regression (Contour) between NINO3.4 SST and MJO Activity

15-90 day filter
925hPa Wind
NCEP Reanalysis



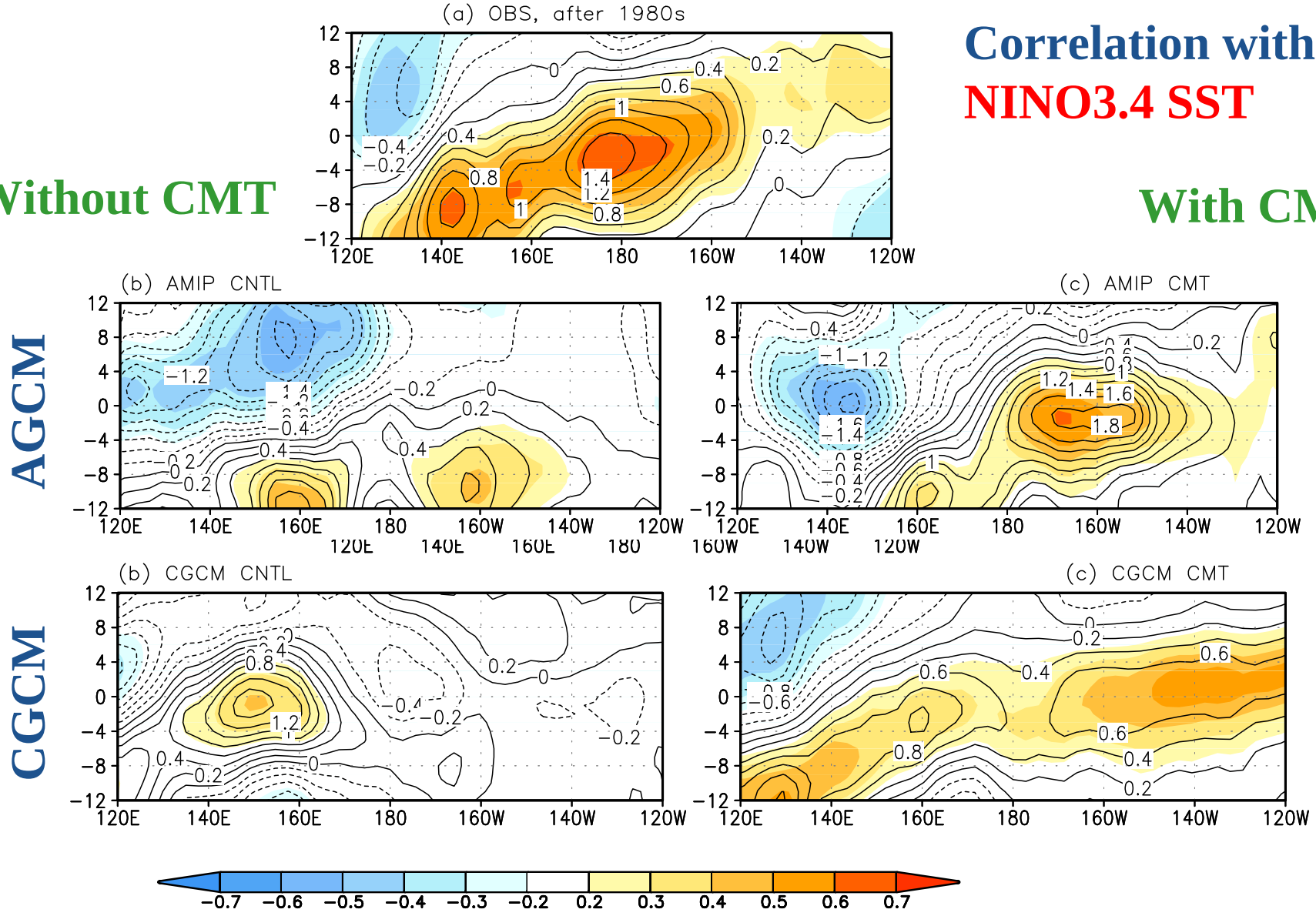
MJO and WWEs are getting stronger at onset phase over WP and peak phase over CP

Kug et al. (2007a)

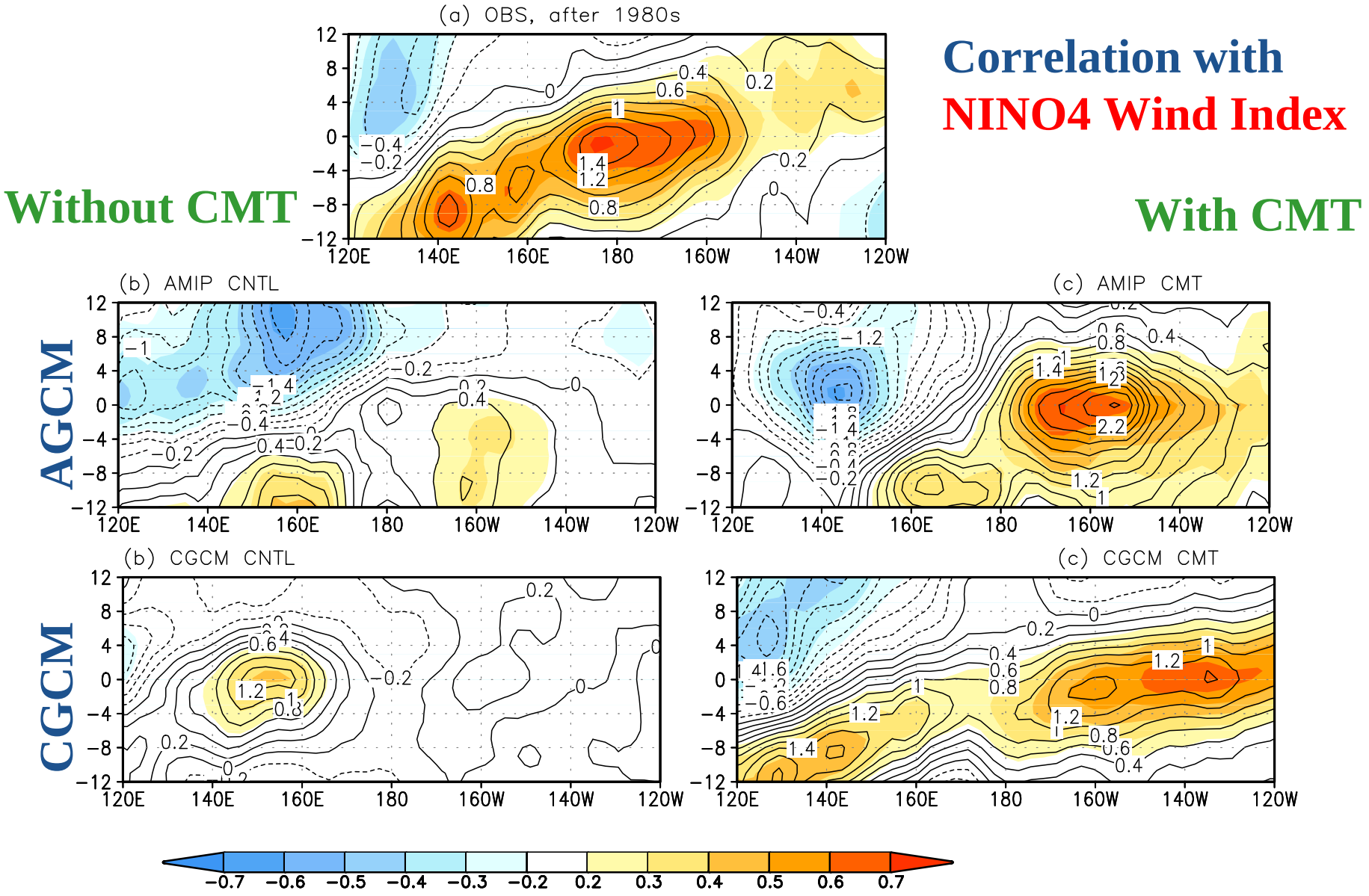
Simulation of ENSO-MJO Interaction

Correlation with NINO3.4 SST

Without CMT **With CMT**



Simulation of ENSO-MJO Interaction



Brief Summary

Impact of CMT on the Tropical Climate in the Coupled GCM

Climatology :

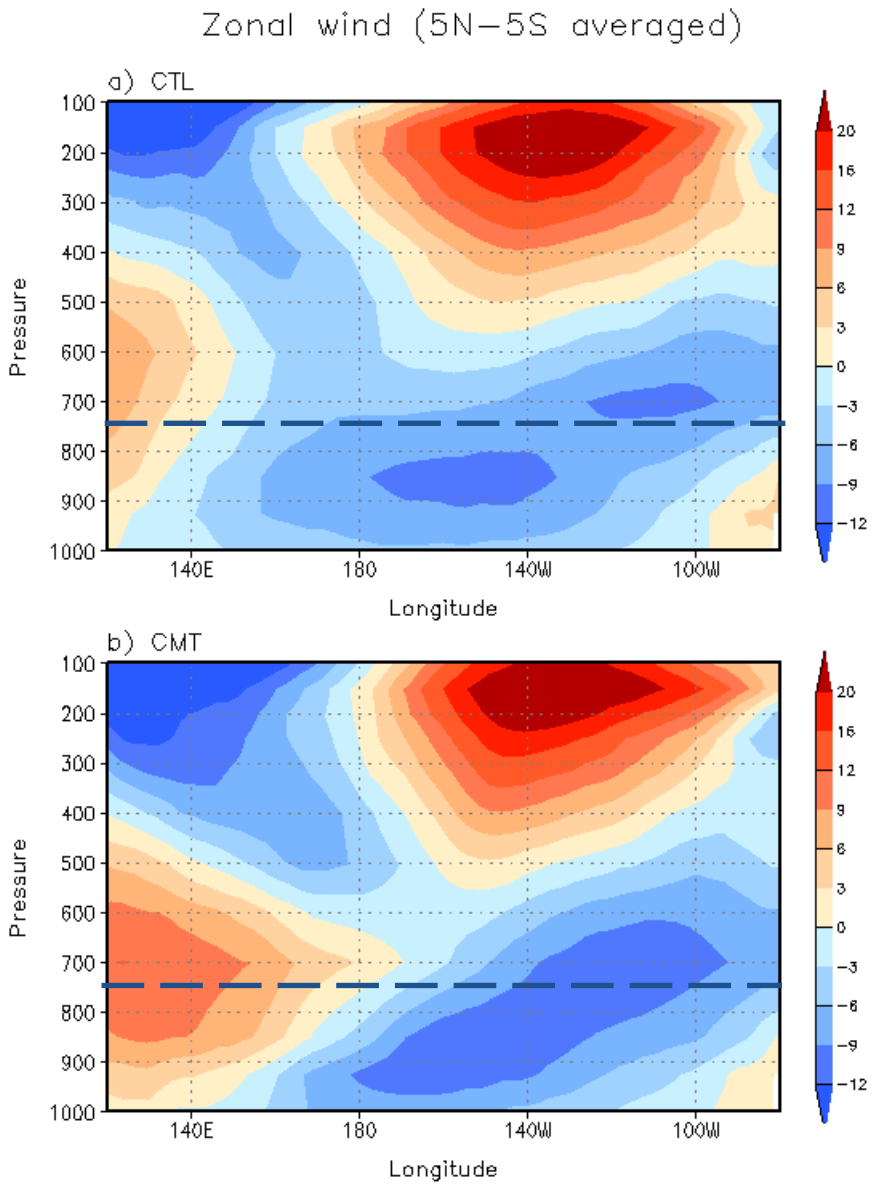
- Reduce climatological bias of most atmospheric and oceanic variables

ENSO :

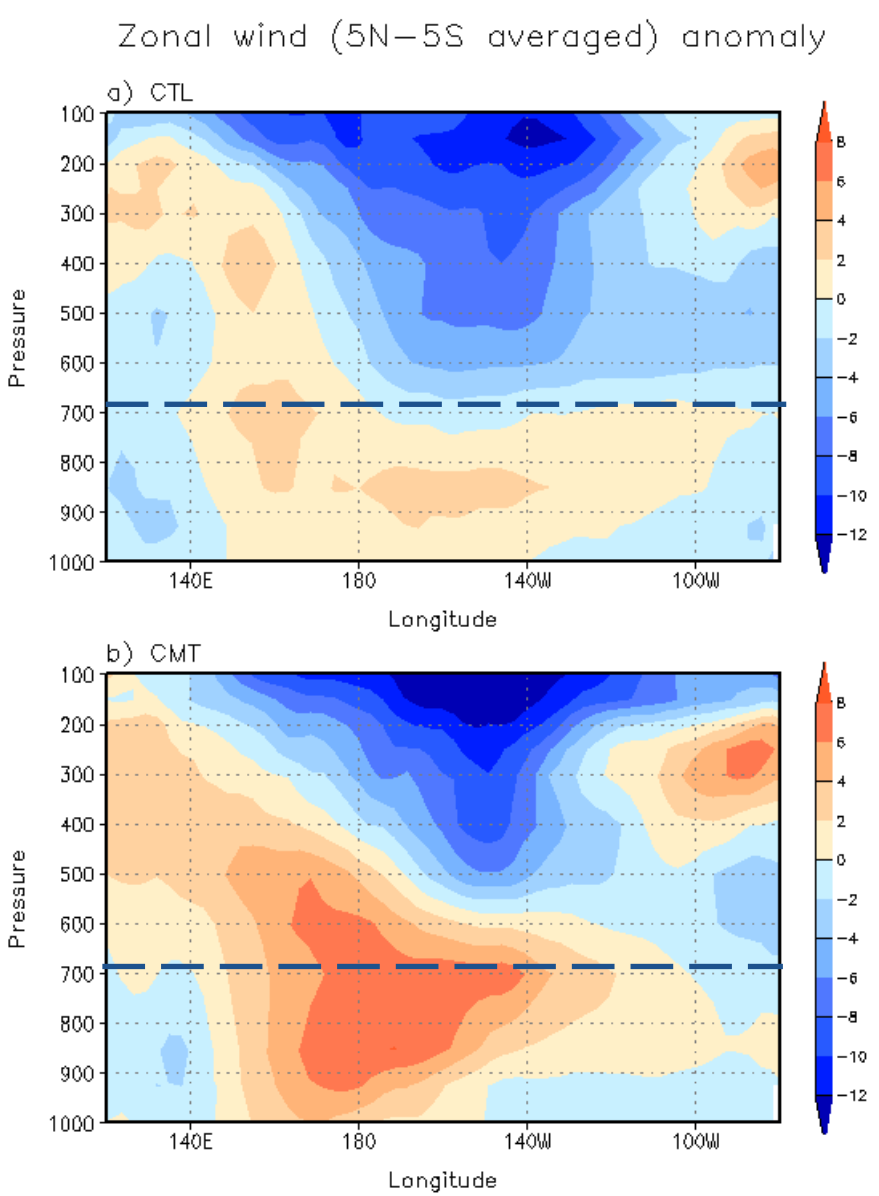
- Larger ENSO Amplitude
- Eastward shift of Atmospheric Responses (closer to observational one)
- Longer ENSO Period
- Better ENSO-MJO Interaction

➢ **All results are consistent with AGCM results**

Climatology



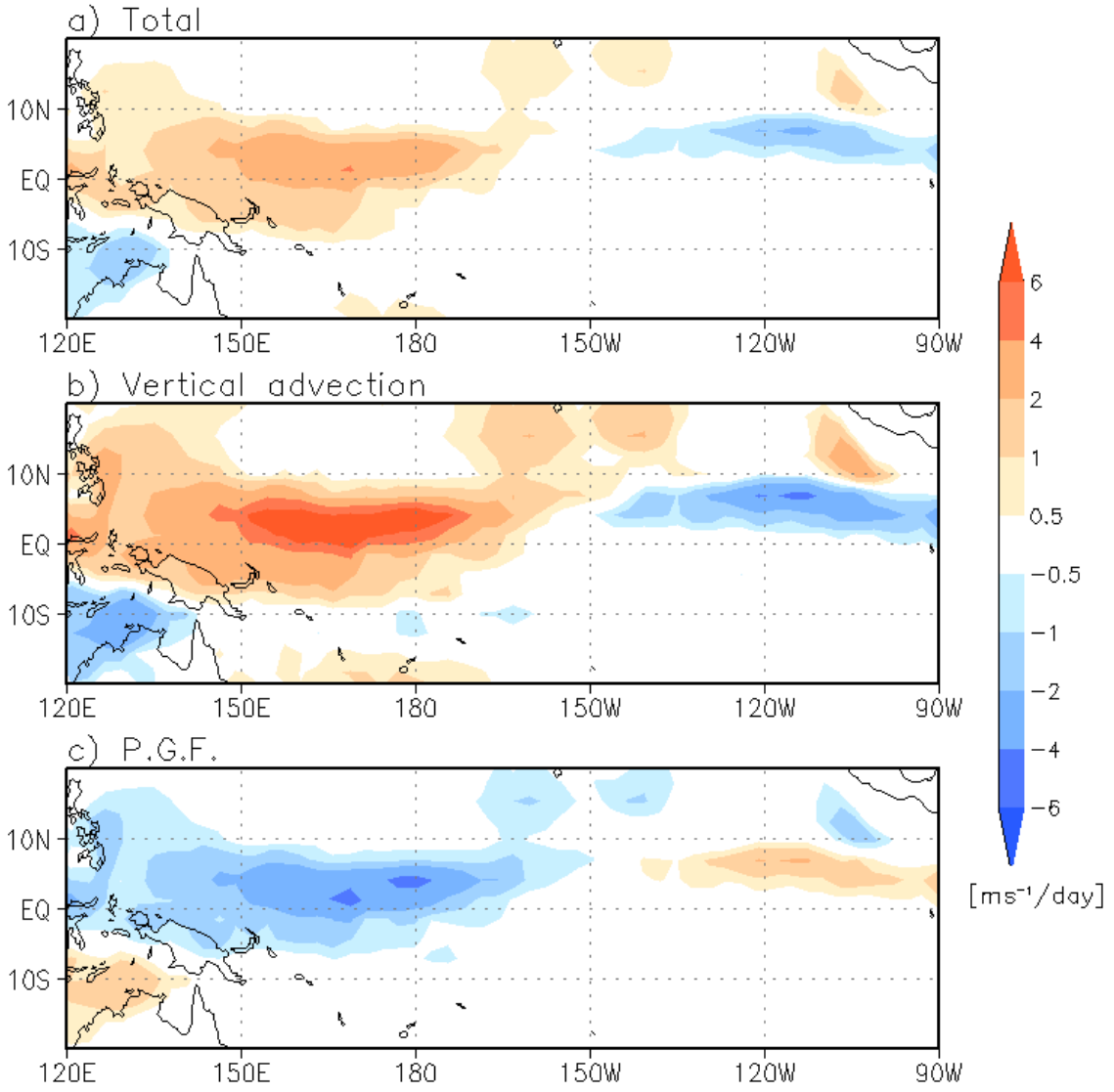
ENSO anomaly



Momentum Forcing of CMT (850hPa)

$$-M_c \frac{\partial \bar{v}^p}{\partial p}$$

$$\sum_i \gamma M_i \frac{\partial \bar{v}^p}{\partial p}$$



Introduction

• Observational evidences : Stevens 1979; Wu and Yanai 1994; Carr and Bretherton 2001; Tung and Yanai 2002a, b; Lin et al. 2005; Dima et al. 2005; Lin and Mapes 2006

• Lin and Mapes (2006) : CMT is important for climatological Walker circulation, both deep and shallow convection regions, a missing component in many GCMs

A role of CMT on various climate phenomena (e.g. ENSO, MJO) in climate models and nature is not yet fully explored

• Numerical representation in climate model : Zhang and Cho 1991; Wu and Yanai 1994; Kershaw and Gregory et al. 1997

• Most of them focused on the role of CMT in mean circulation : Zhang and McFarlane, 1995; Gregory et al. 1997; Tiedke 1989

• Wu et al. (2003) : the seasonal migration of ITCZ across the equator during northern hemisphere winter season (seasonal cycle)