Workshop on "High-resolution climate modeling"
ICTP, 12 Aug 2009

Two flavors of El Niño and its role on the forecast of MJO and tropical cyclone

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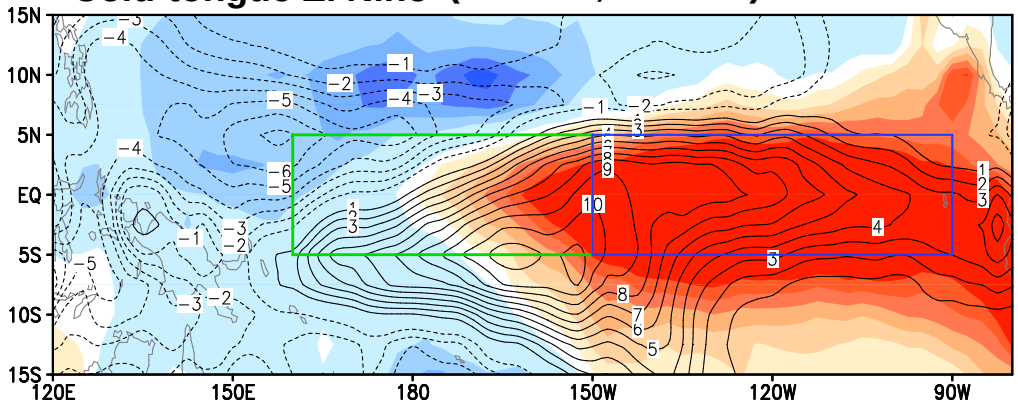
Thanks to J. Shukla, J.-S. Kug, F.-F. Jin

COLA/GMU KORDI Univ. of Hawaii

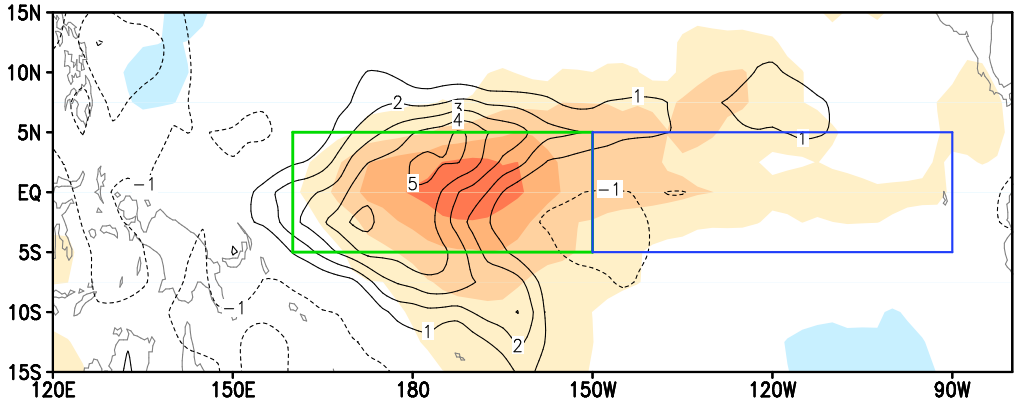
Observed Two Types of El Nino

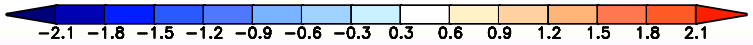
Composite of SST (Shading) and Rainfall (Contour)

Cold-tongue El Nino (1982/83, 1997/98)



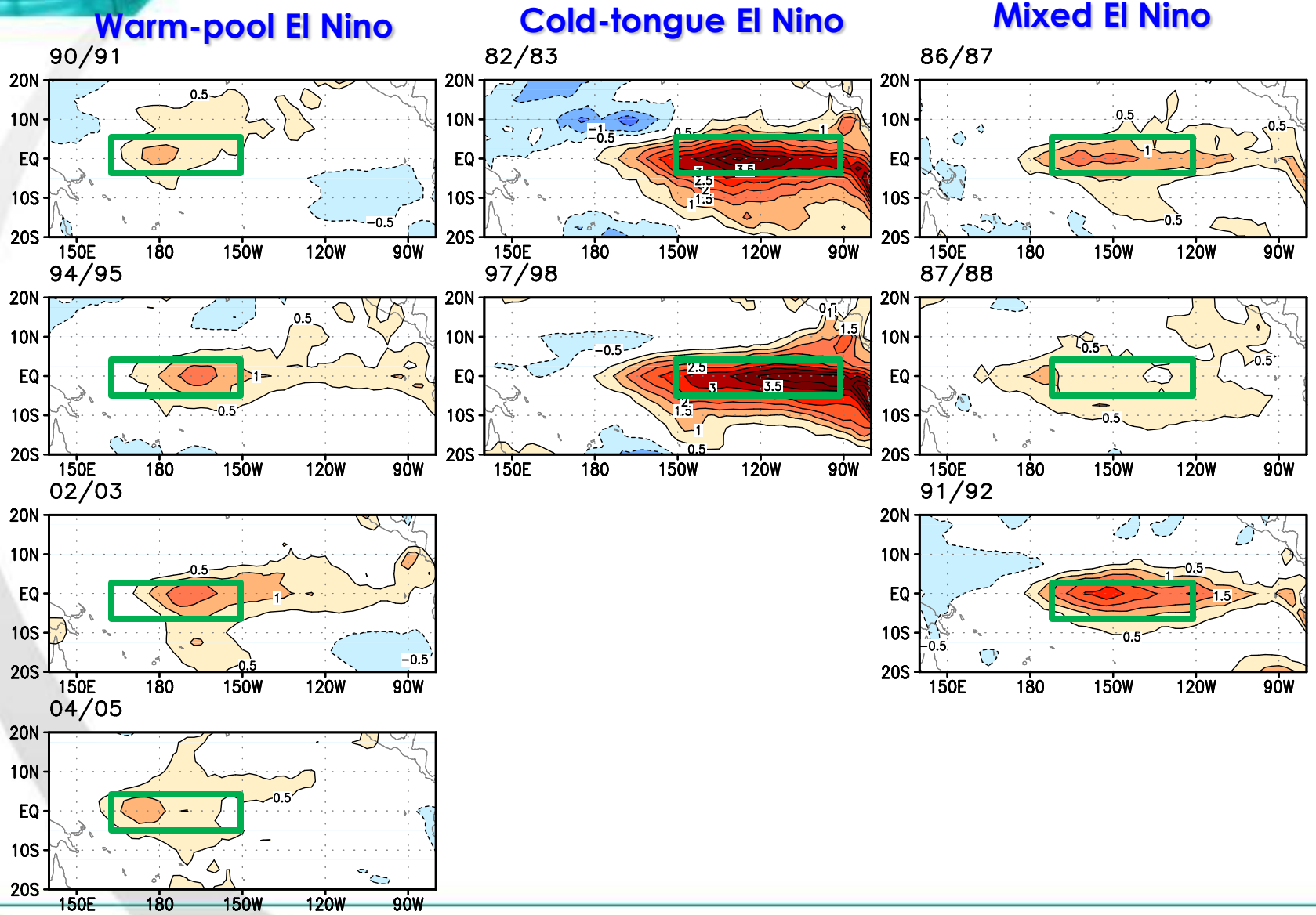
Warm-pool El Nino (1990/91, 1994/95, 2002/03, 2004/05)





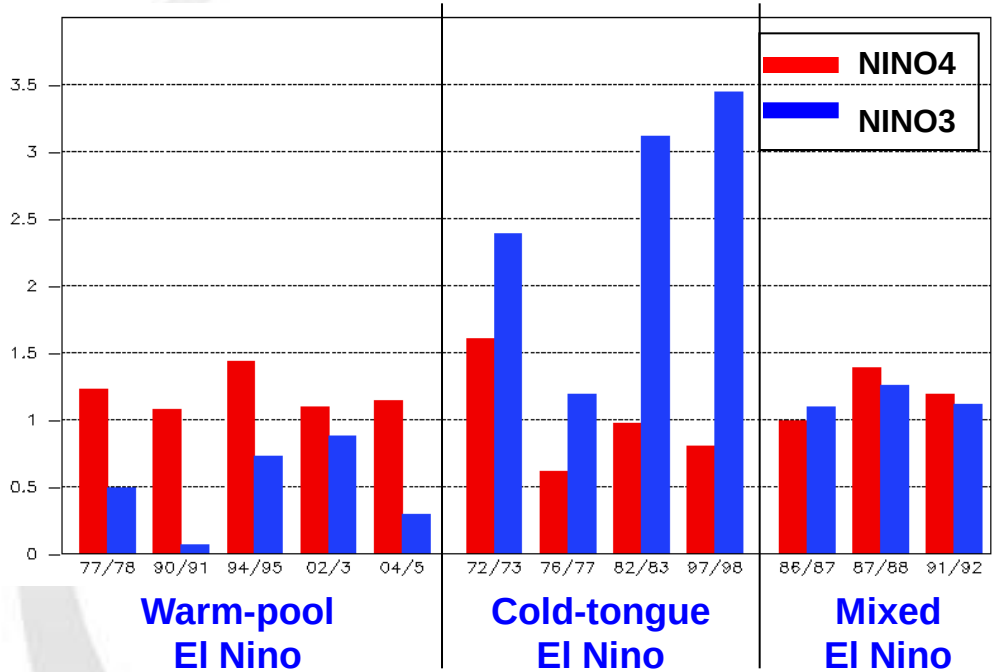
Kug et al. 2009

Observed DJF SST Anomalies



Observed Two Types of El Nino

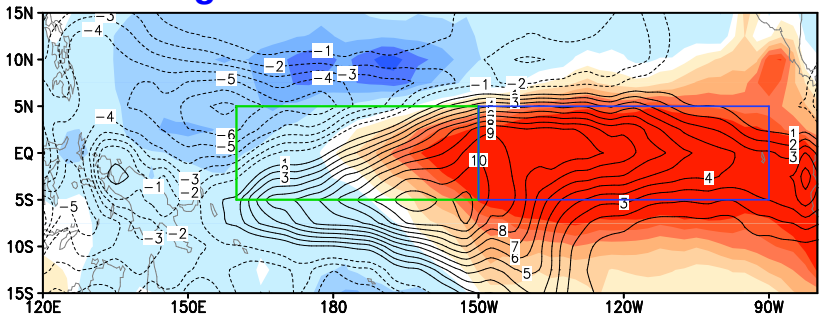
Normalized NINO3 and NINO4 SST



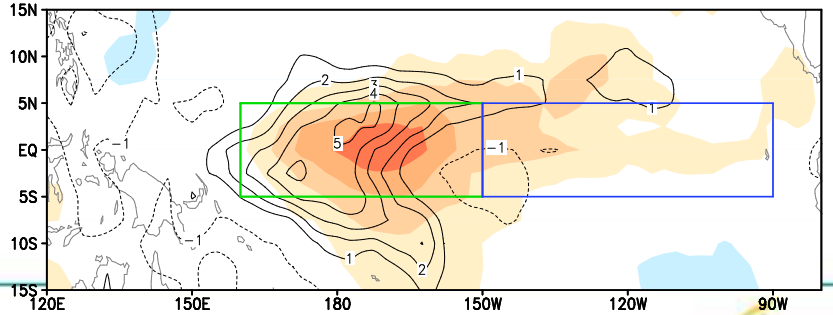
*** Either NINO3 SST or NINO4 SST is greater than their standard deviation**

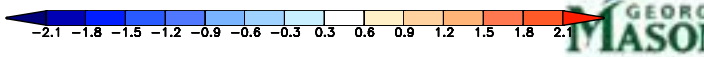
Composite of SST (Shading) and Rainfall (Contour)

Cold-tongue El Nino



Warm-pool El Nino





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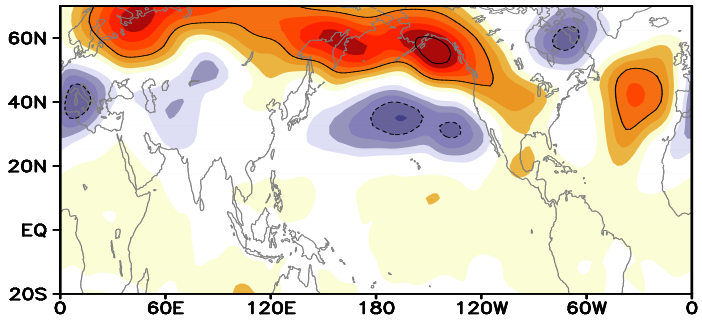
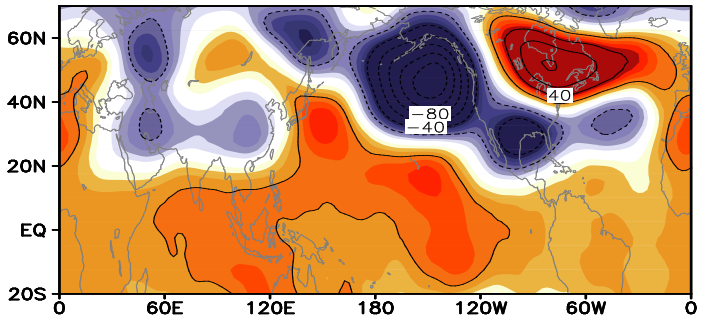
Composite of Anomalies

Warm-pool El Nino

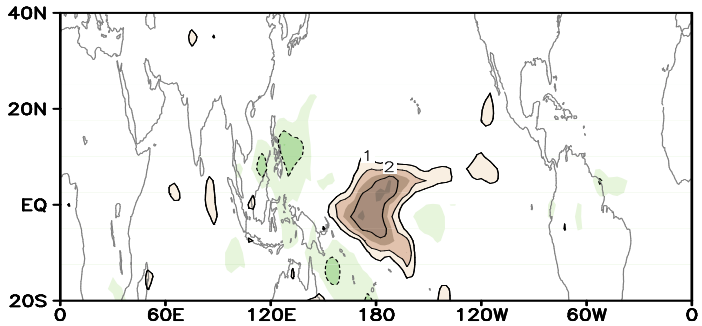
Cold-tongue El Nino

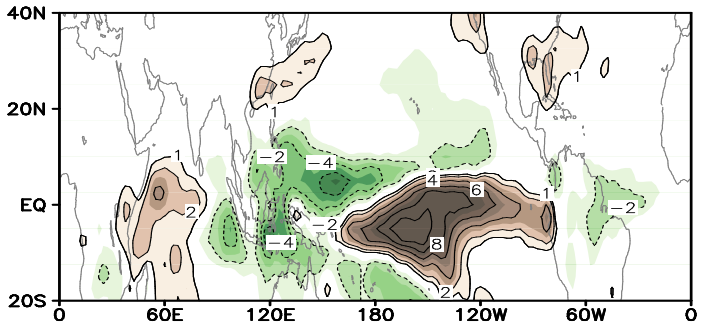
H500



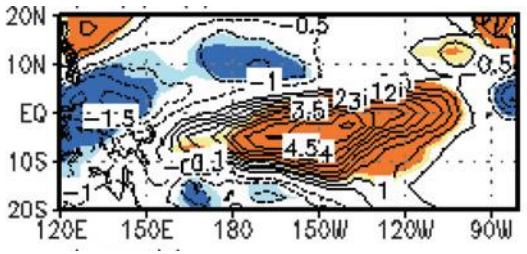


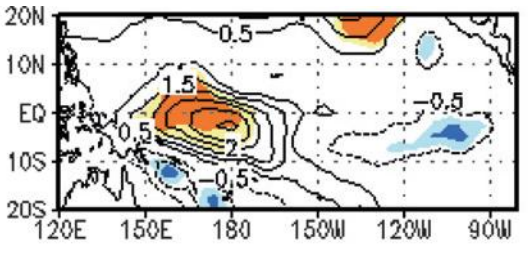
Rainfall





925 hPa Zonal wind

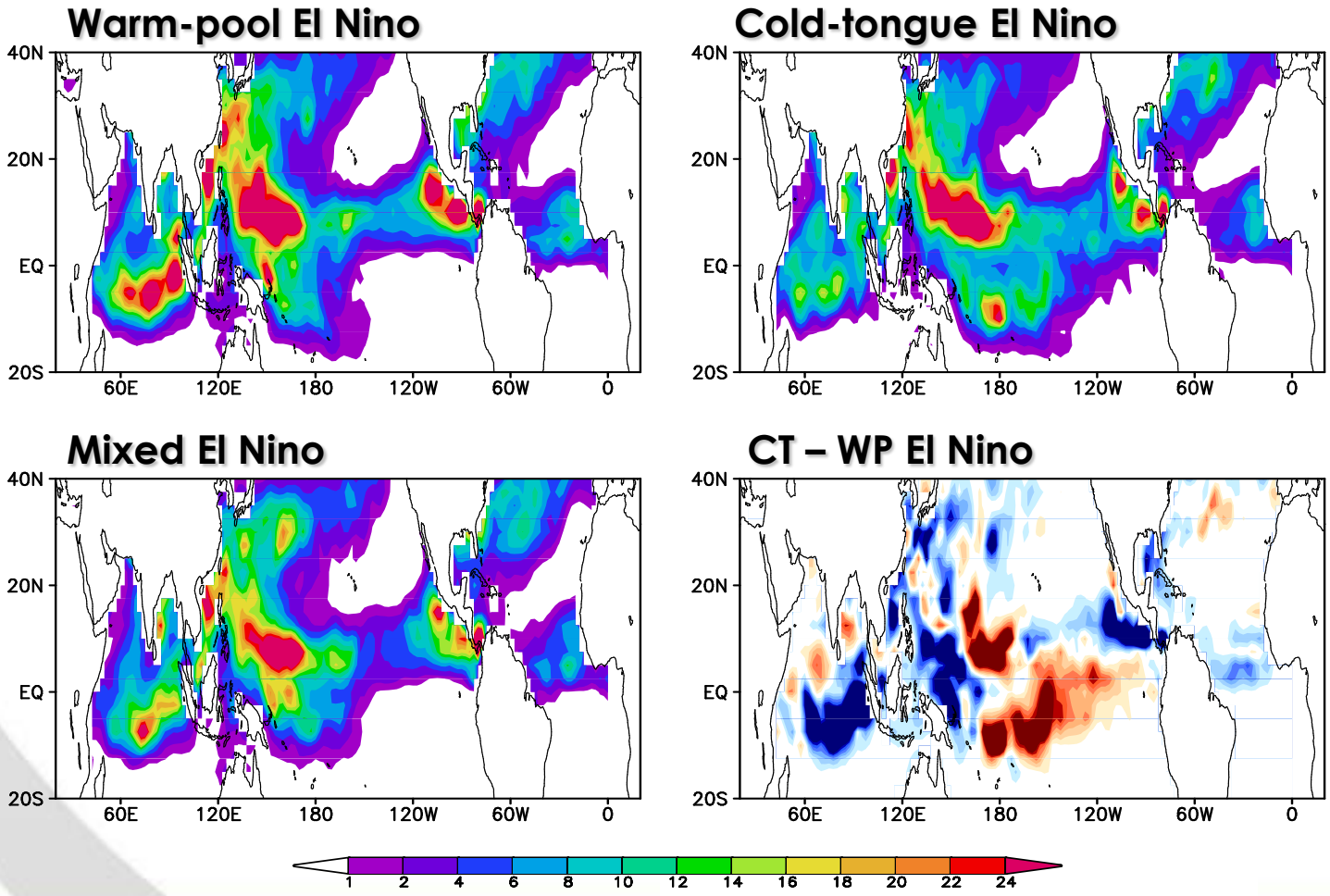




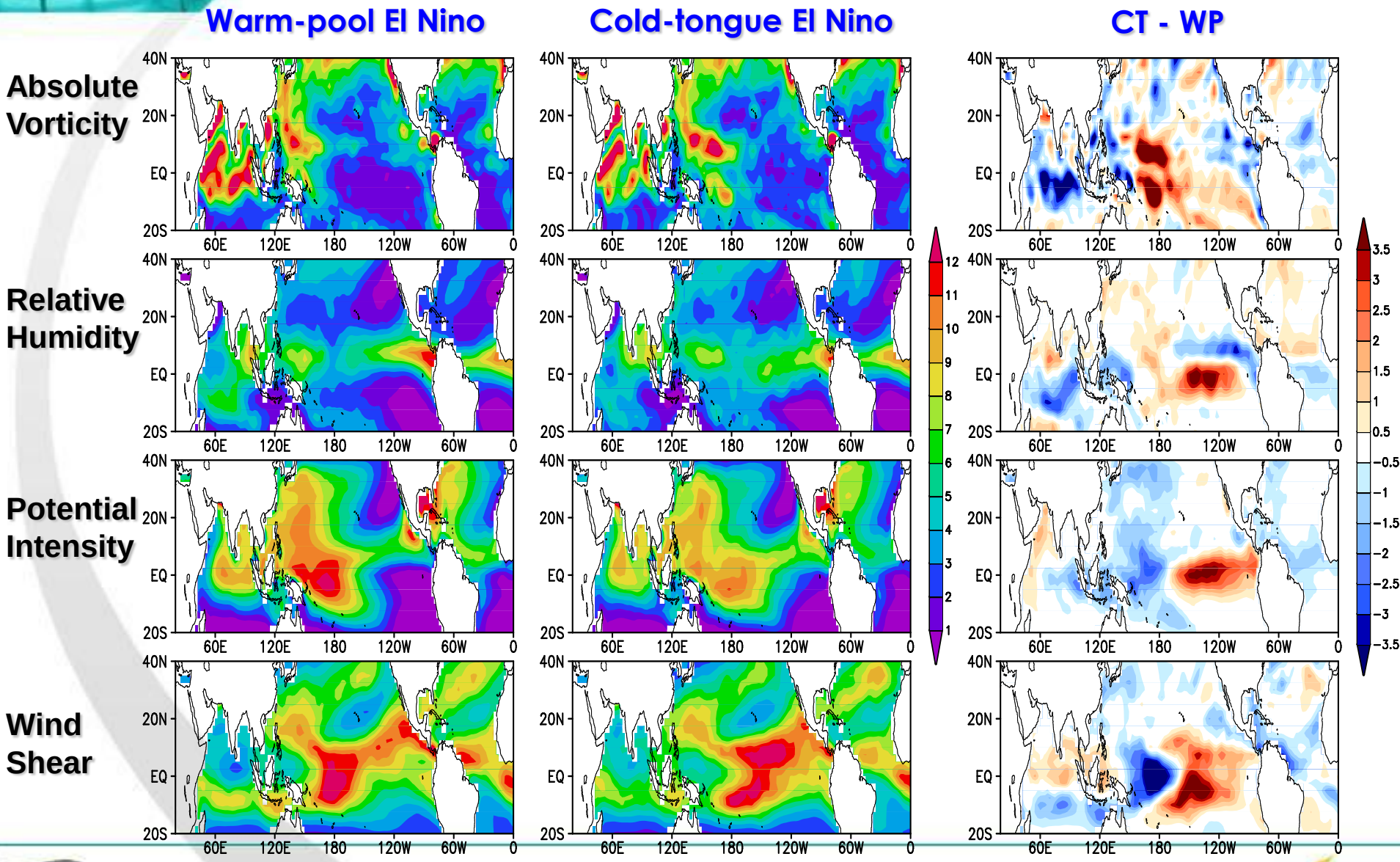
Composite of GPI (Jun-Nov)

Genesis Potential Index (Emanuel and Nolan 2004, Camargo et al. 2007):

GPI=Absolute vorticity * Relative humidity * Potential Intensity * Wind shear



Composite of GPI (Jun-Nov)



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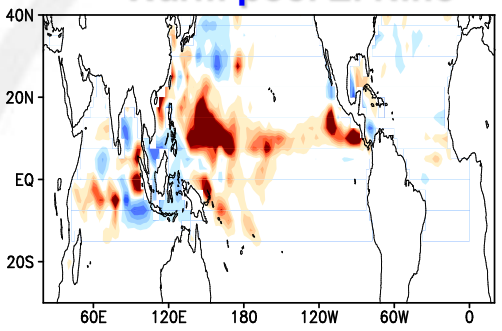
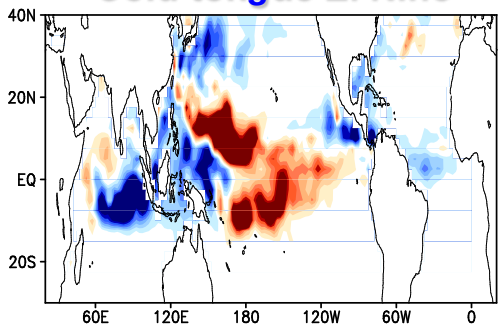
Composite of GPI Anomalies (Jun-Nov)

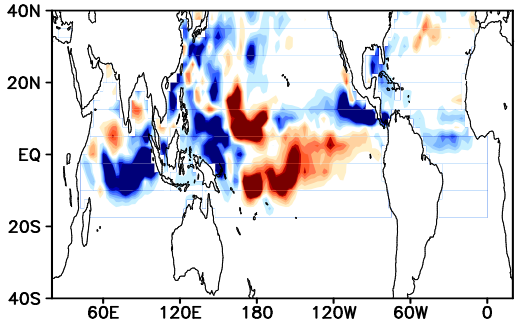
Warm-pool El Nino

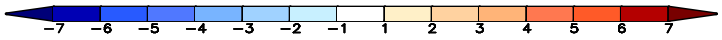


Cold-tongue El Nino

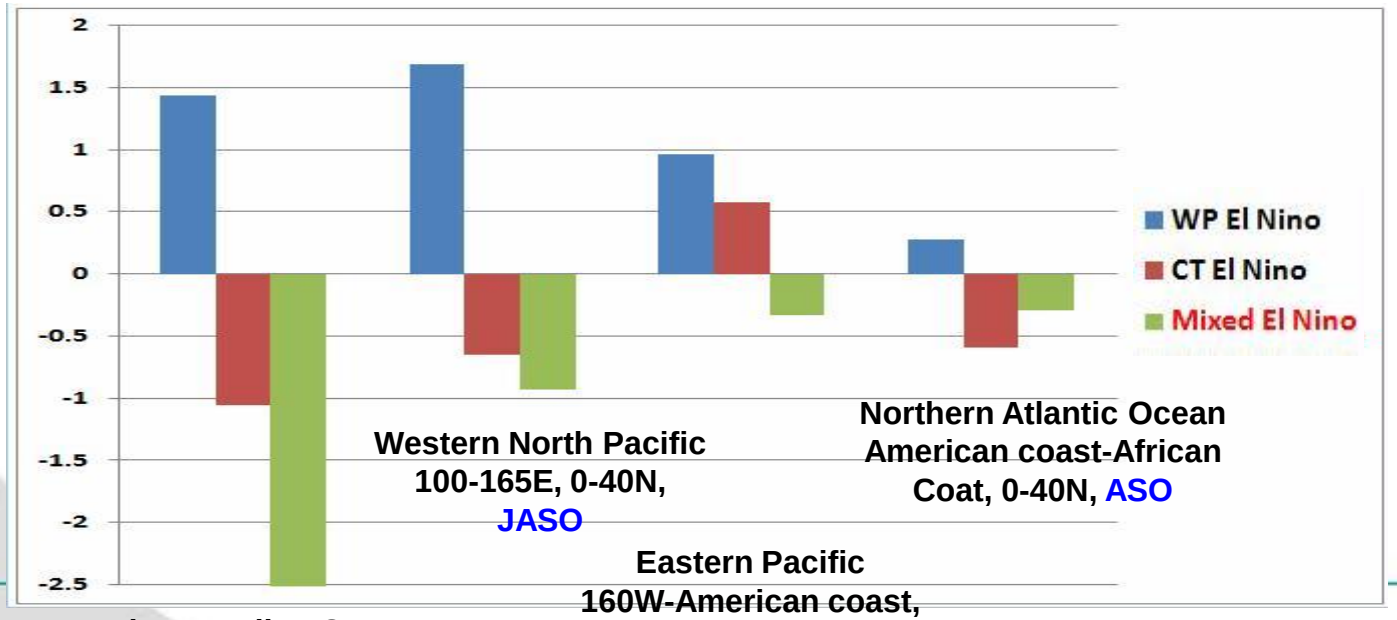


CT – WP El Nino





Area mean seasonal mean GPI anomalies (peak season)



Model and Dataset

Retrospective Forecast

- **Initial condition cases of 12 calendar months are analyzed.**
- **As observational counterparts, OISST, CMAP rainfall, and NCEP/NCAR reanalysis data are used.**

Model	Lead month	Ensemble Member	Period	AGCM	OGCM
NCEP CFS	9	15	1981-2006	GFS T62 L64	MOM 3 1/3x5/8 L27
FRCGC SINTEX	12	9	1982-2006	ECHAM 4 T106 L19	OPA 8.2 2x2 L31

- **In this study, forecast data is reconstructed with respect to lead time (monthly forecast composite).**

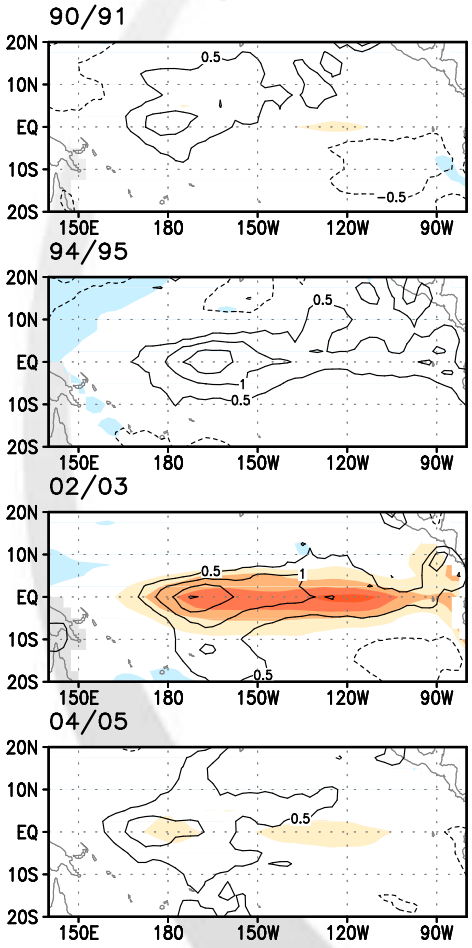
Courtesy of *NCEP EMC* and *J.-J. Luo, T. Yamagata*

Simulated DJF SST Anomalies

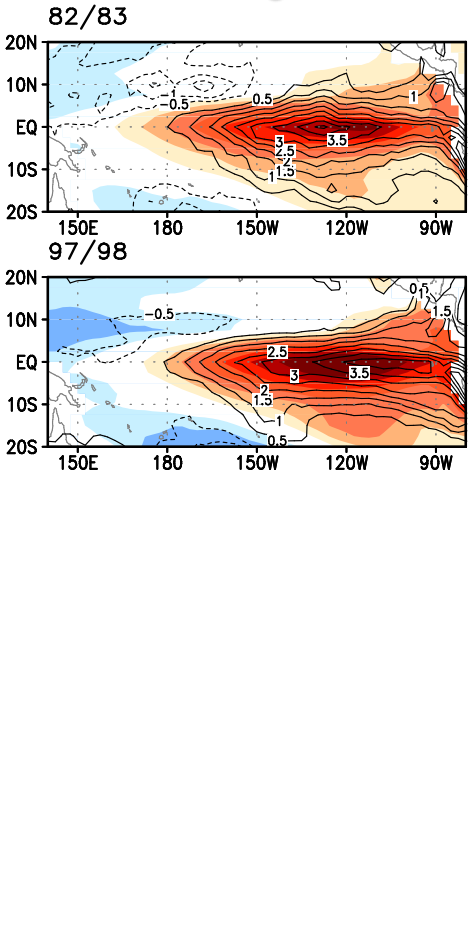
Forecast lead month 6

CFS

Warm-pool El Nino

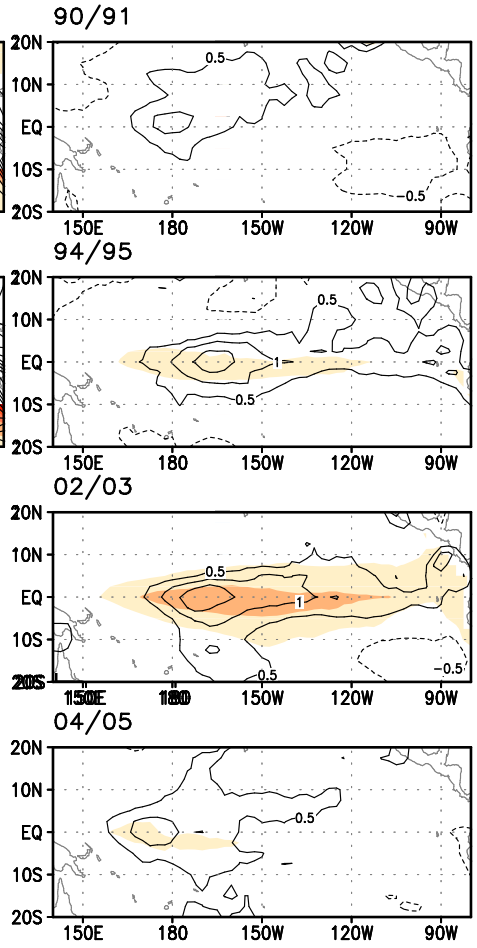


Cold-tongue El Nino

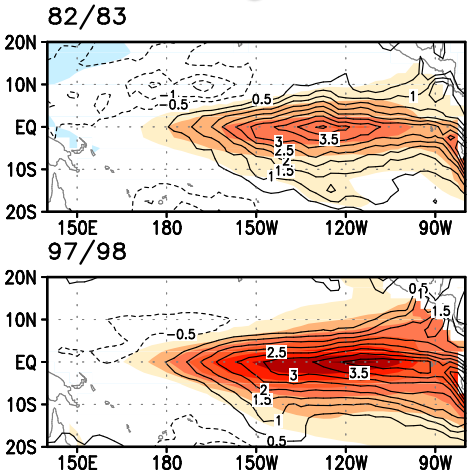


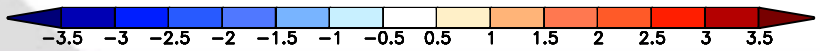
SINTEX

Warm-pool El Nino



Cold-tongue El Nino





Note: loss of predictability in the Warm Pool El Nino cases

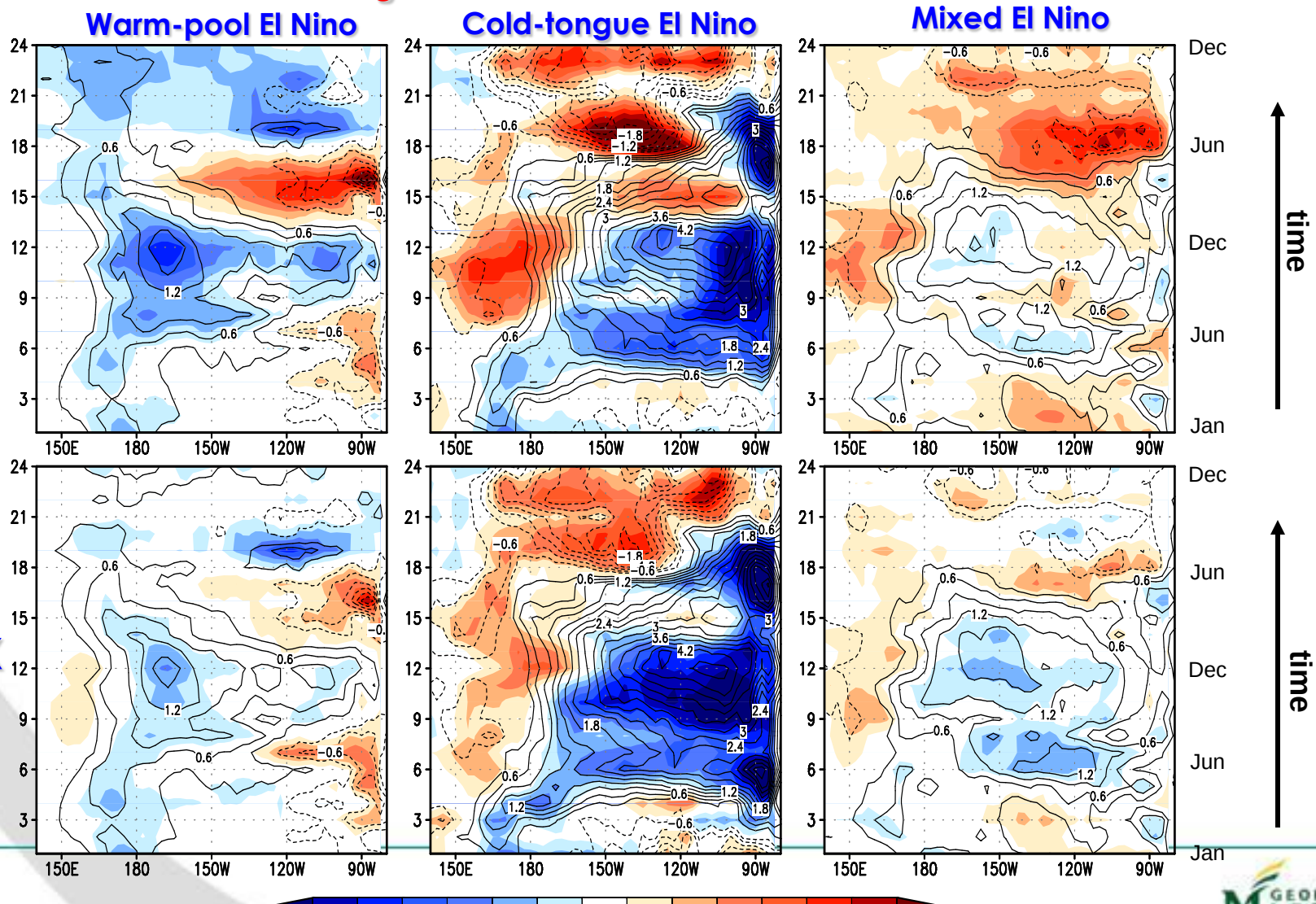
Shading is for model, and contour is for observation

Composite of SST Anomalies along the Equator

Forecast lead month 7

Note: Positive anomaly and negative bias in the Warm Pool and Cold Tongue

Shading is for model bias, Contour is for observed composite

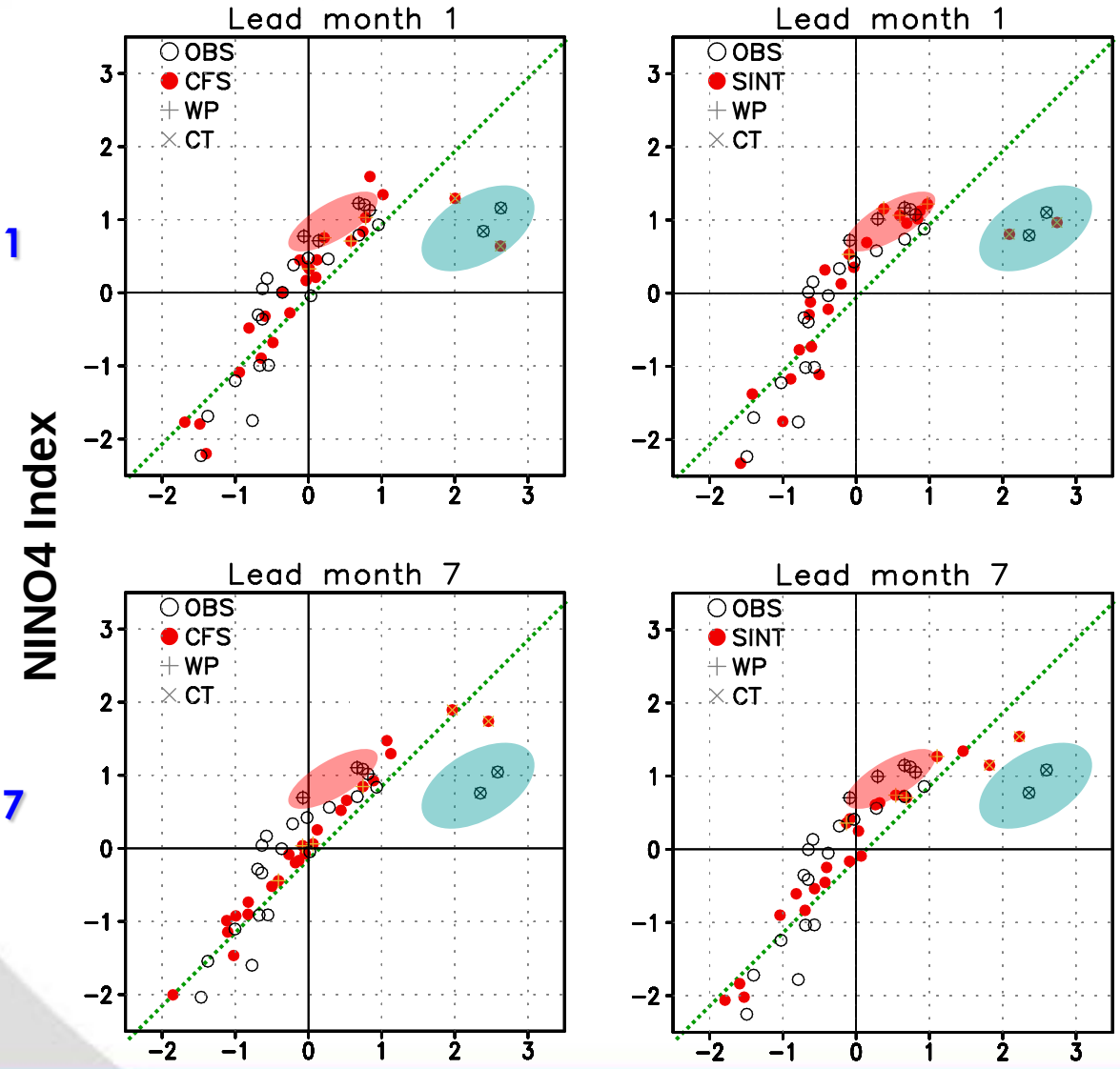


Scatter Diagram of Normalized DJF NINO3 vs. NINO4

CFS | **SINTEX**

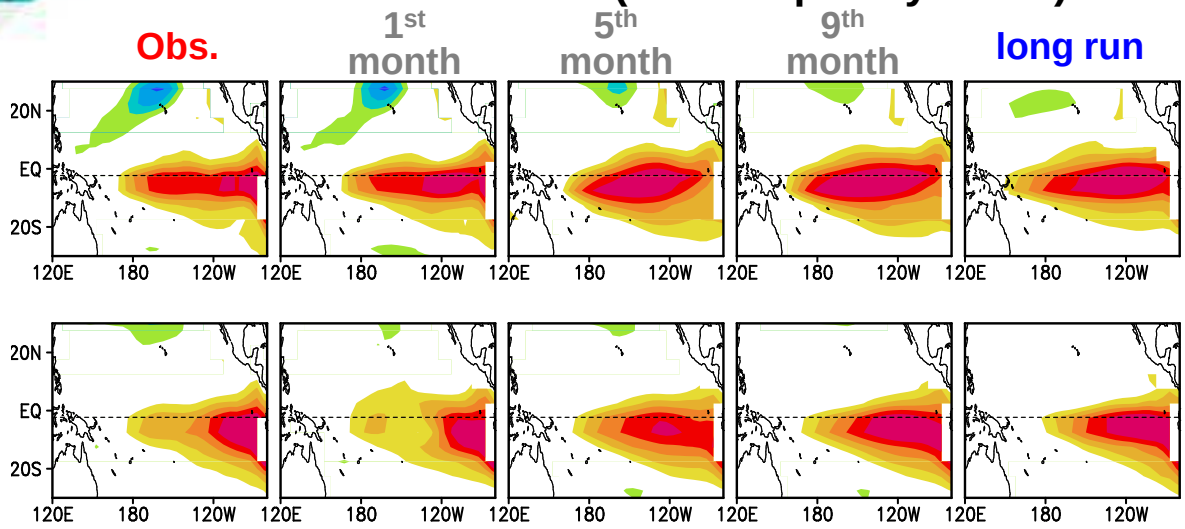
Lead month 1

Lead month 7



Impact of Couplde Model Error on Predictability

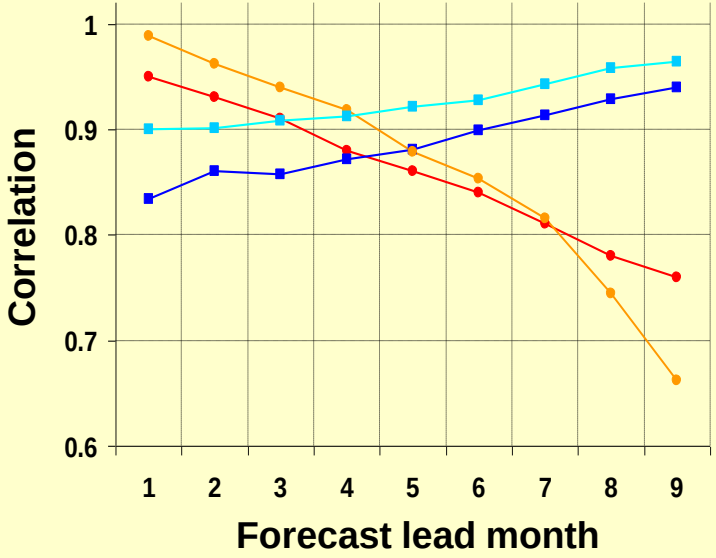
1st mode SEOF of SST (Low frequency mode)



→ **Model Flaw: Slow coupled dynamics of CGCM**

Jin and Kinter, 2009 Climate Dynamics

Correlation coefficients with respect to lead month



SINTEX-F
NCEP CFS
Temporal correlation of PC timeseries with observation

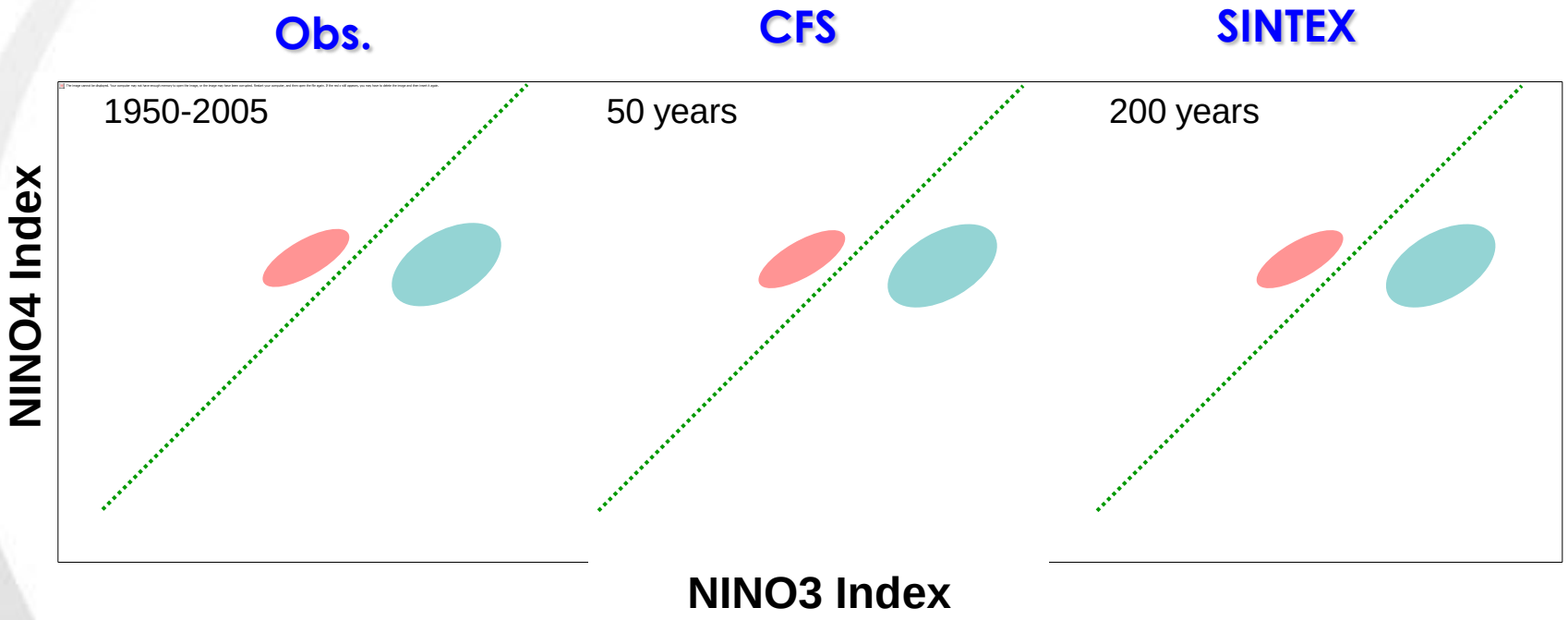
SINTEX-F
NCEP CFS
Pattern correlation of eigenvector with free long run

✓**The forecast error of model in the long lead month is also shown in the model error in the free long run.**

✓ With increase of the lead month, the forecast ENSO mode progressively approaches to the model intrinsic mode in free coupled run and departs from the observed.

Scatter Diagram of Normalized DJF NINO 3 vs. NINO 4

From free long run of two CGCMs



COR=(NINO3, NINO4)	0.69	0.82	0.86

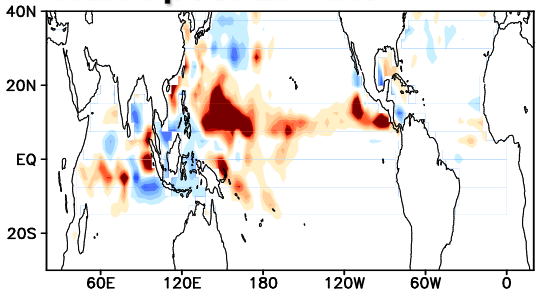
Shading: Observed; models do not capture observed behavior

→ Model Flaw: One Flavor of El Nino

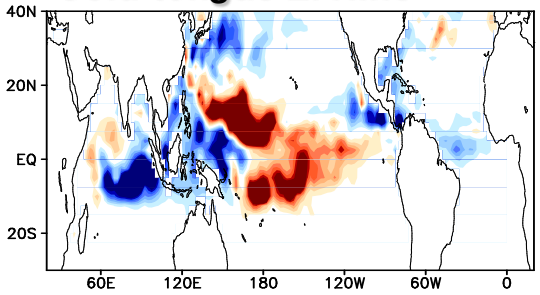
Data from *K. Pegion, J.-J. Luo, T. Yamagata*

Composite of GPI Anomalies (Jun-Nov)

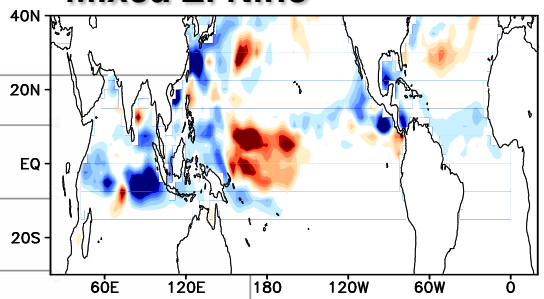
Warm-pool El Nino



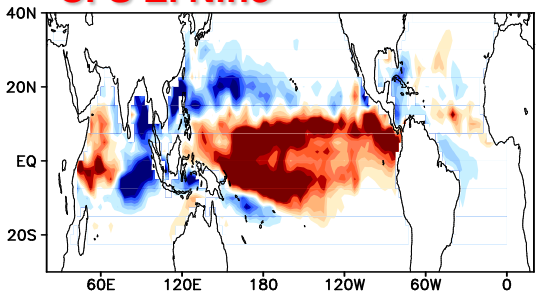
Cold-tongue El Nino

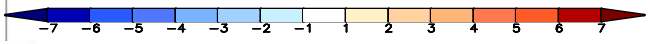


Mixed El Nino

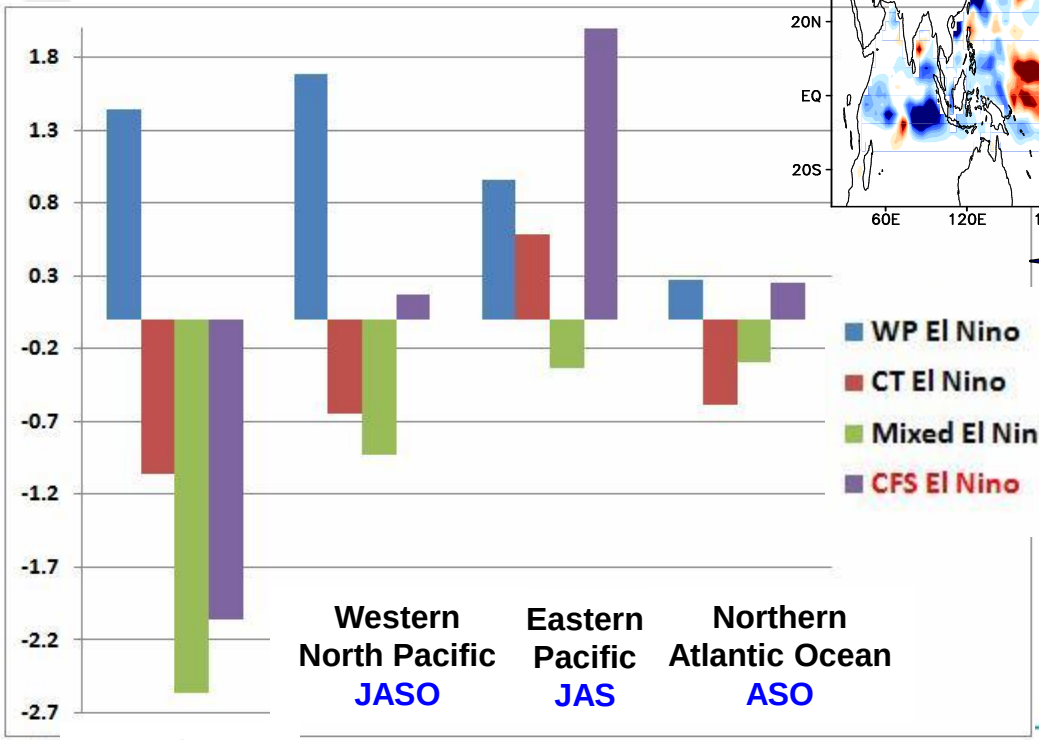


CFS El Nino

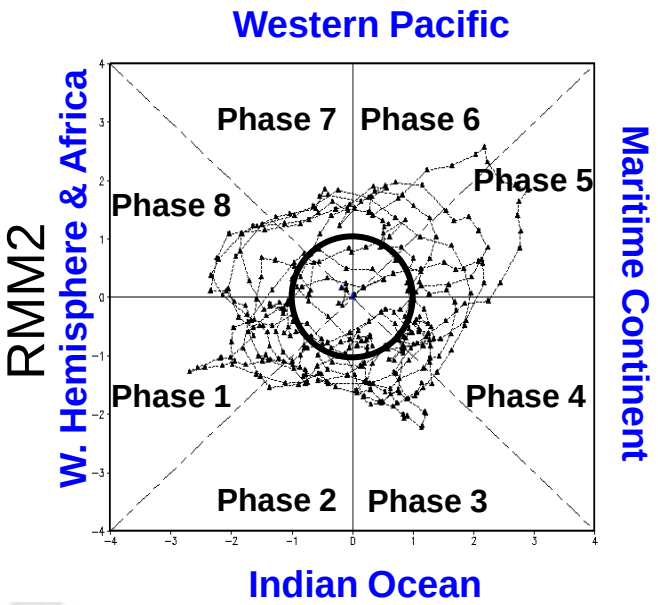




Area mean seasonal mean GPI anomalies (peak season)

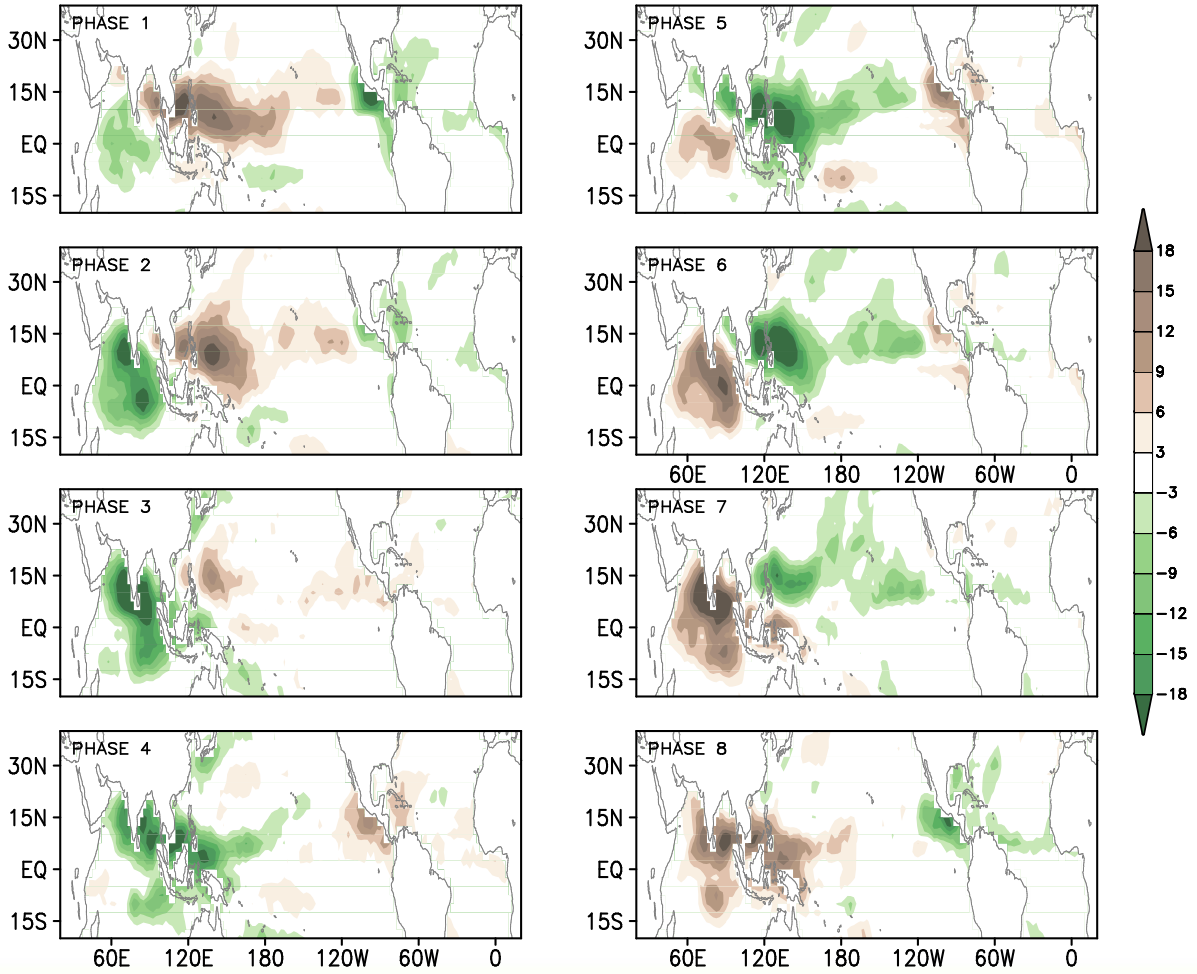


MJO Index



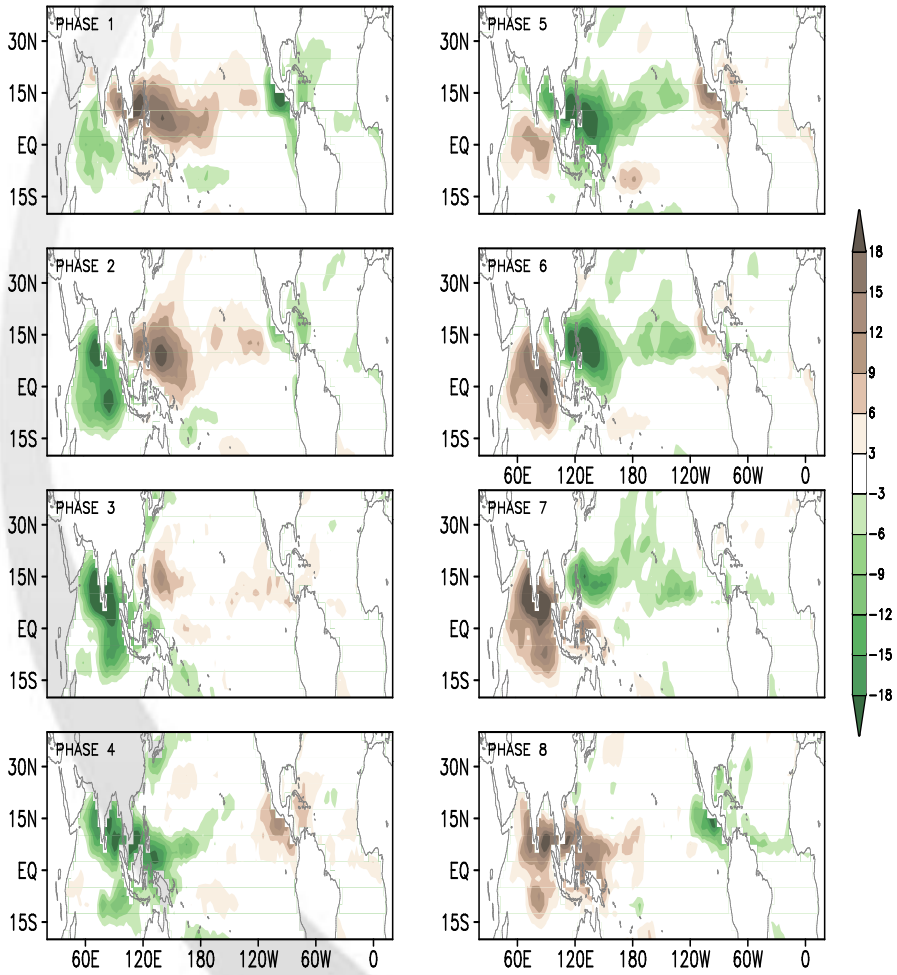
Wheeler and Hendon 2004

Composite of OLR anomalies (JJASON)

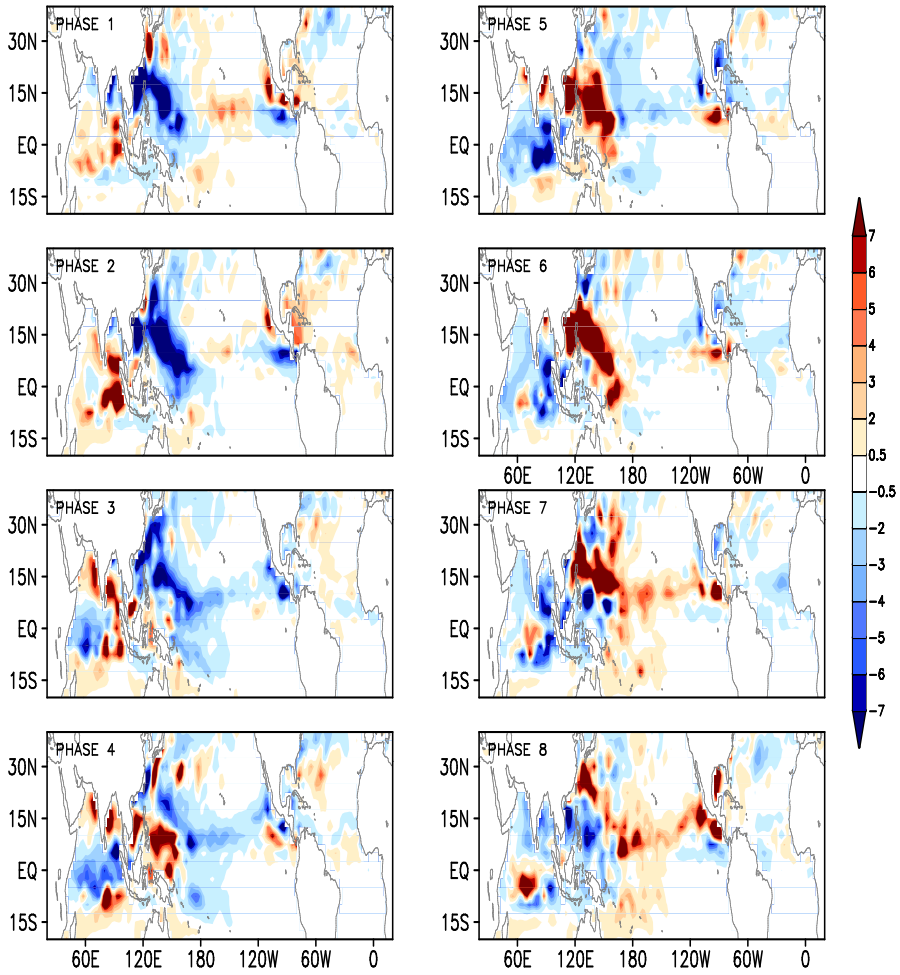


Composite of GPI Anomalies based on MJO Phase (Jun-Nov)

OLR Anomalies

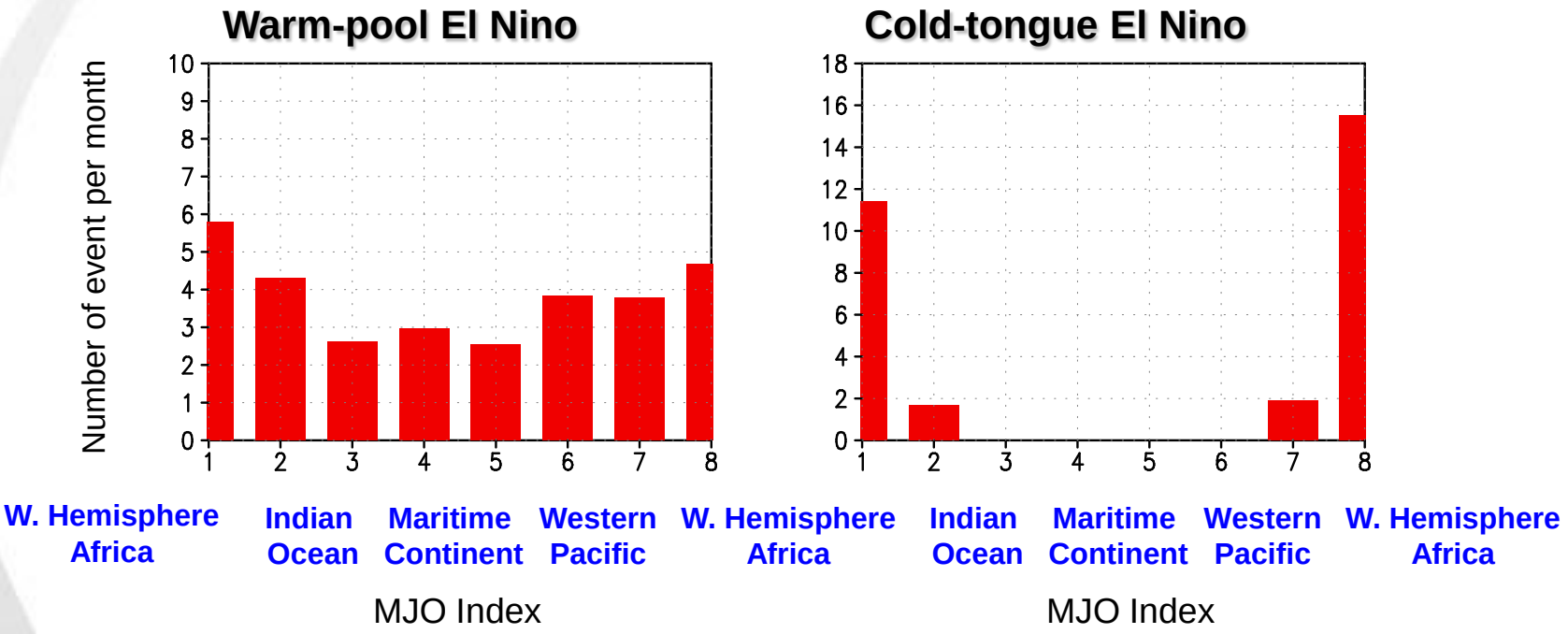


GPI Anomalies



* ENSO related components are removed by linear regression

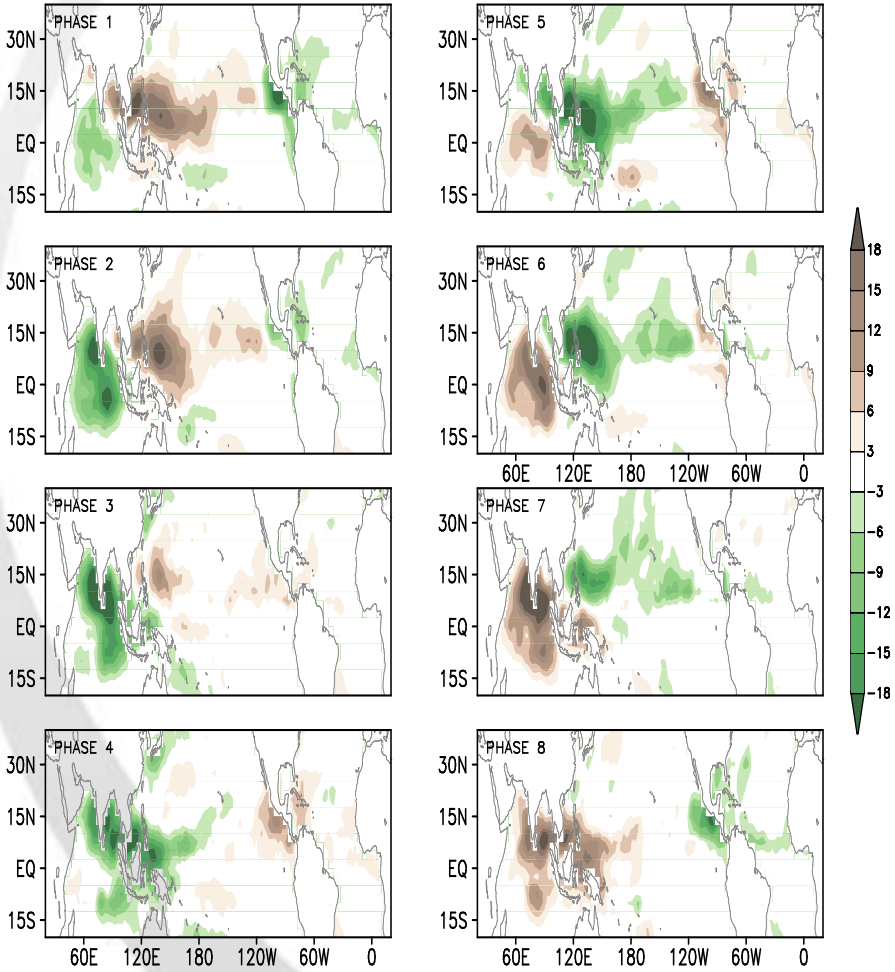
Composite of MJO Phase based on ENSO (June to November)



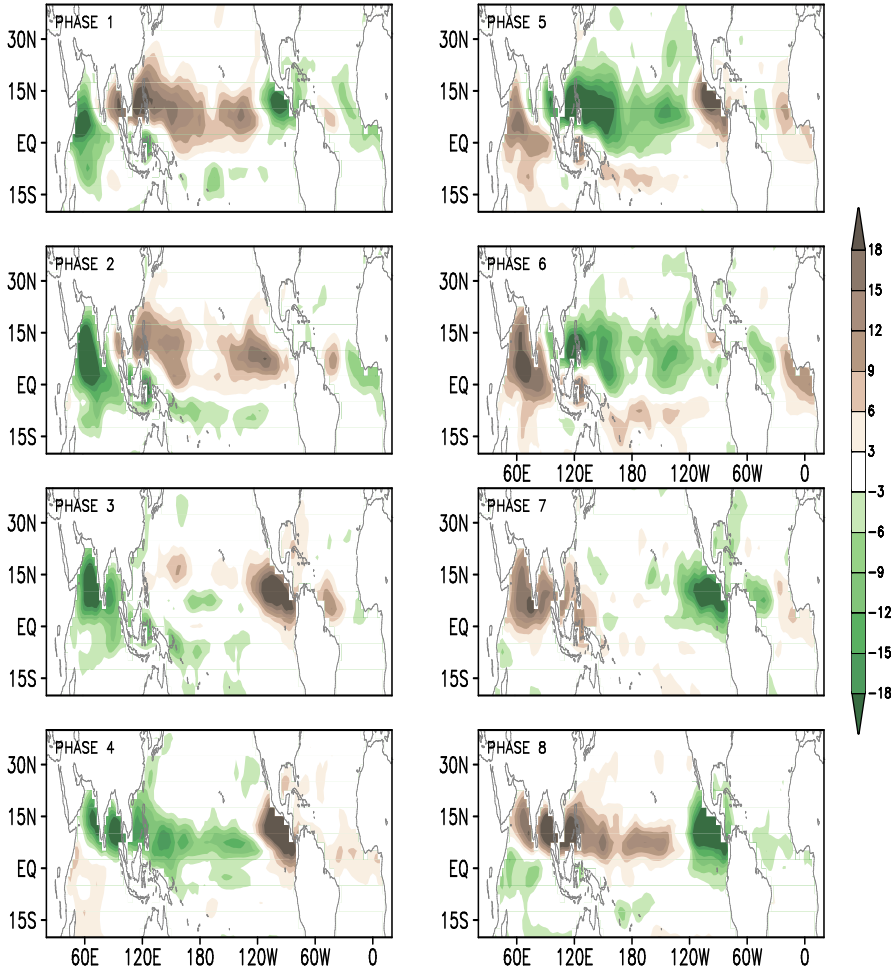
5-day running mean daily data is used for the calculation.

Composite of OLR based on MJO Phase

Observed OLR Anomalies



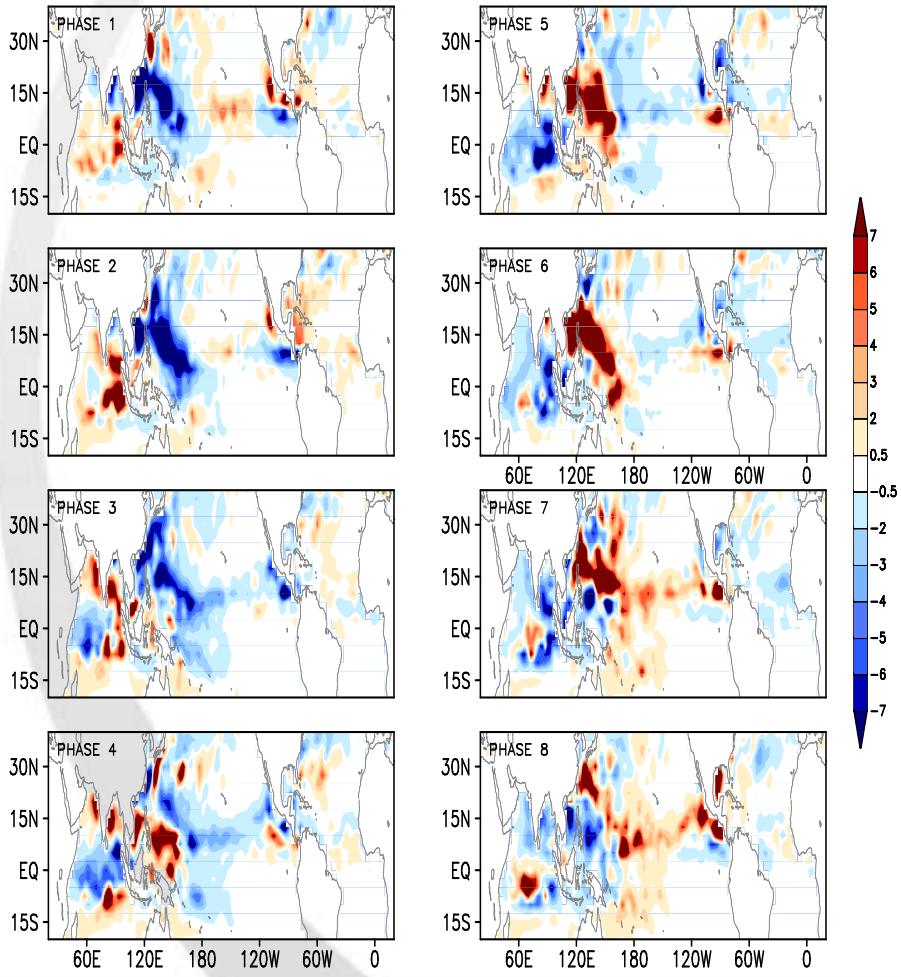
CFS OLR Anomalies



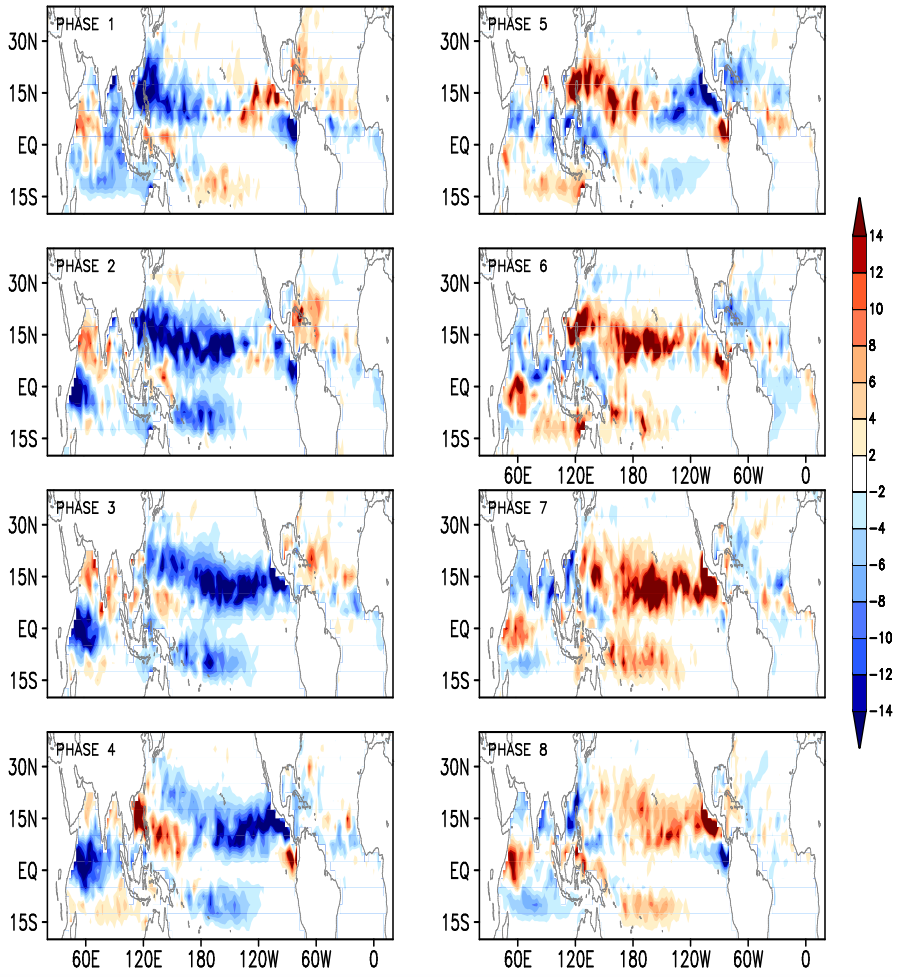
* ENSO related components are removed.

Composite of GPI based on MJO Phase

Observed GPI Anomalies

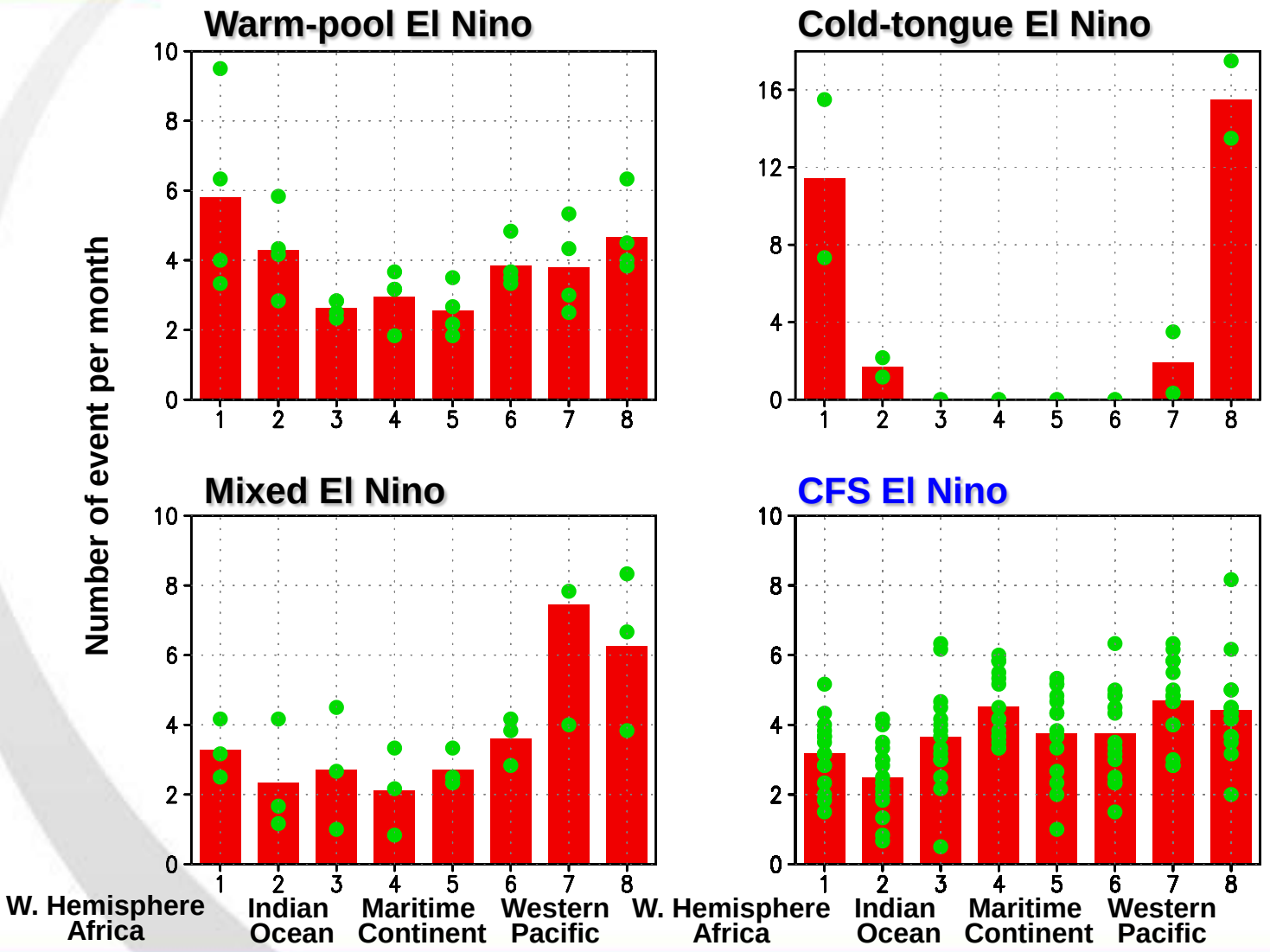


CFS GPI Anomalies



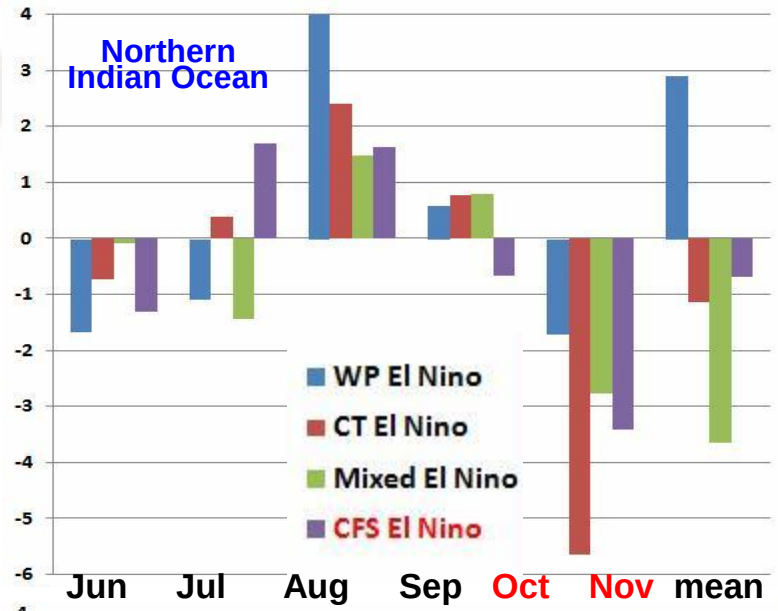
* ENSO related components are removed.

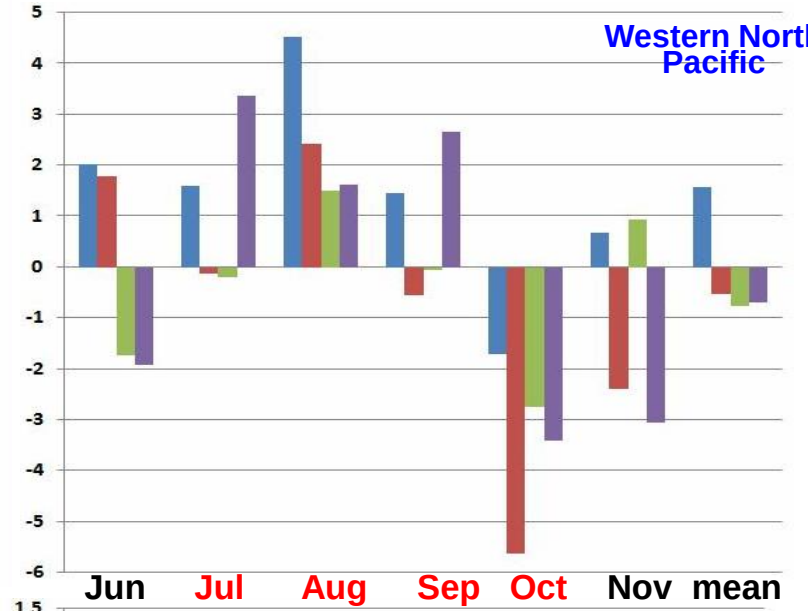
Composite of MJO Phase based on ENSO (Jun-Nov)

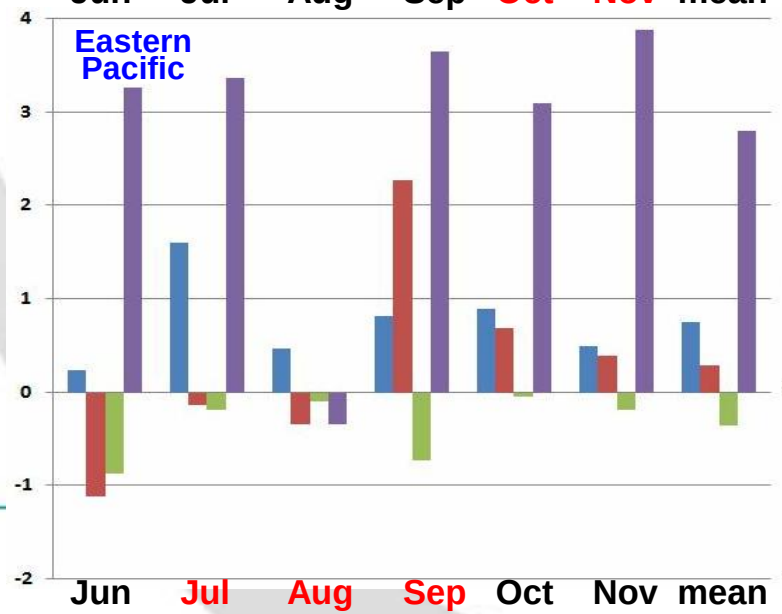


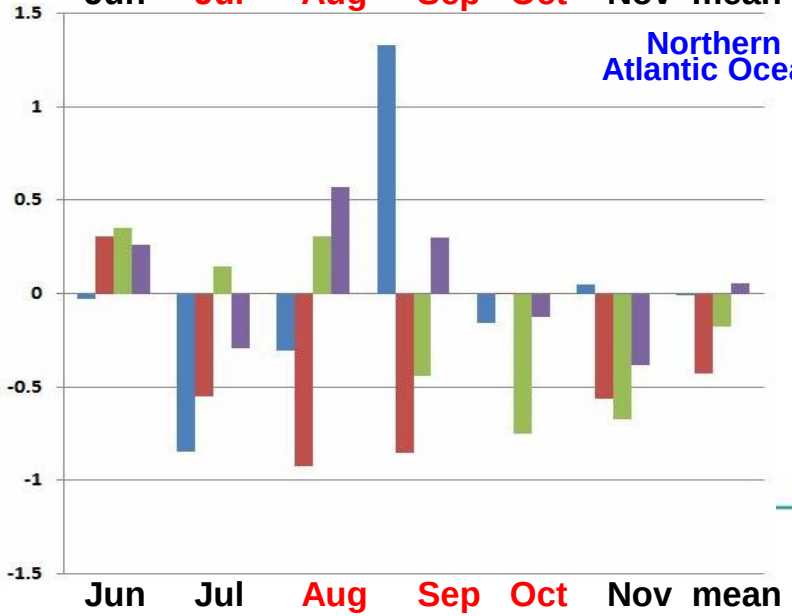
→ Model Flaw: ENSO-MJO relationship

Monthly Area Mean GPI Composite (Jun-Nov)









Summary

- **Two flavors of El Niño are identified in observations: (1) maximum SST anomalies in the warm pool region (2) in the cold-tongue region.**

- **With respect to increase of forecast lead month, CGCMs fail to distinguish between two flavors of El Niño because models tend to simulate the one mixed flavor of El Niño.**

- **CFS GPI is in agreement with warm-pool and mixed-mode El Niño, but not with cold-tongue El Niño.**

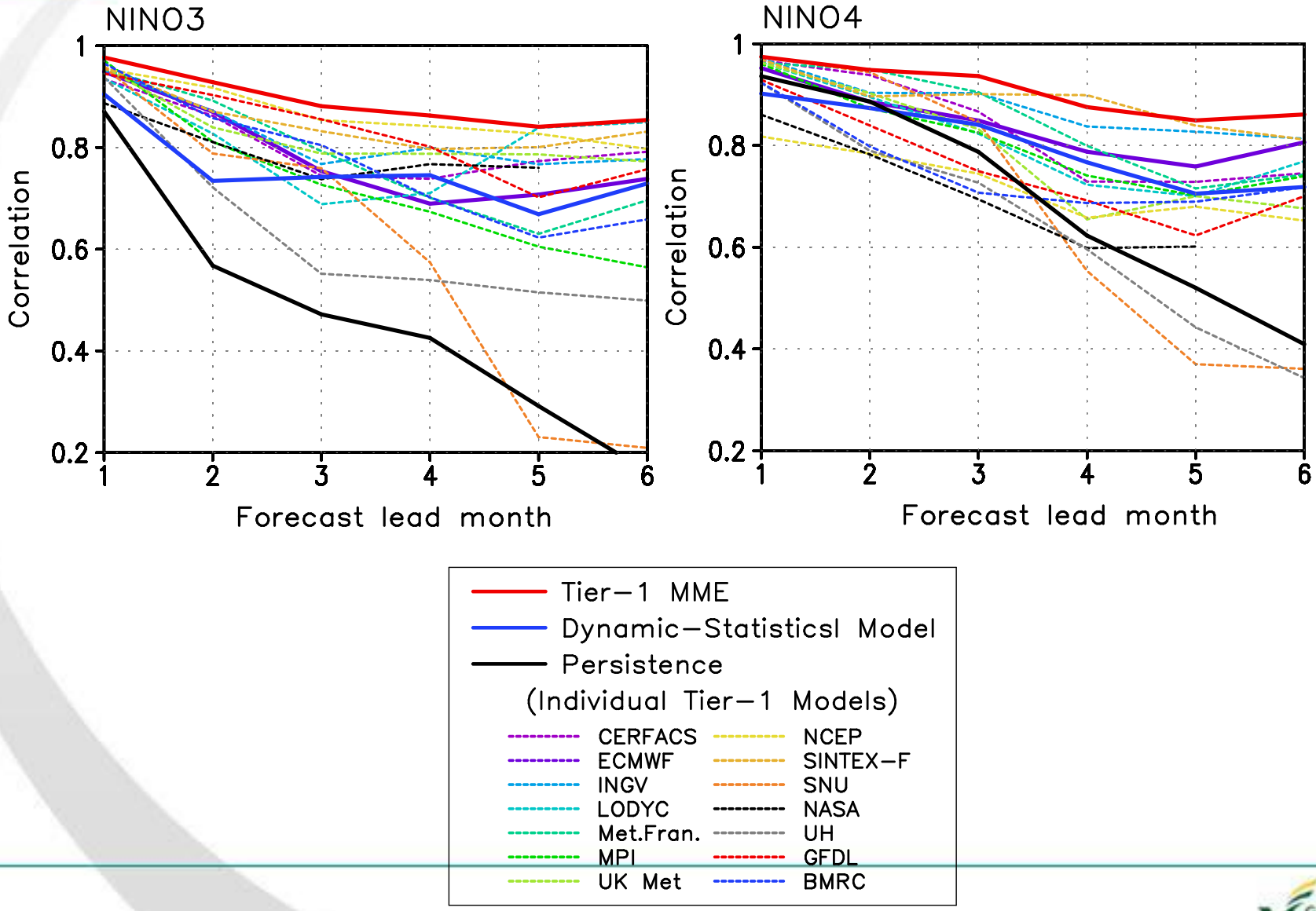
- **CFS can reproduce the realistic MJO-tropical cyclone genesis relationship globally.**

- **However, because of unrealistic ENSO-MJO relationship, the actual prediction of cyclone genesis is not realistic.**

- **Improvement of ENSO, and ENSO-MJO relationship is important to improve the simulation of tropical cyclones in coupled model.**

THANK YOU!

Forecast Skill of NINO Indices



Model Description and Experimental Design

APCC CLIPAS

5 CGCMs

- 1980 – 2004
- 4 case of initial time (Feb, May, Aug, Nov)
- 3-15 member
- 5-9 months duration

DEMETER

7 CGCMs

- 1980 – 2001
- 4 case of initial time (Feb, May, Aug, Nov)
- 9 ensemble member
- 6 months duration

	Lead month	run	Period	AGCM	OGCM
FRCGC SINTEX-F	6	9	82-04	ECHAM 4 T106 L19	OPA 8.2 2x2 L31
NASA	5	3	80-04	NSIPP 1 2x2.5 L34	Poseidon V4 1/3x1 L40
SNU	6	6	60-01	SNU T42 L21	MOM 2.2 1/3x1 L32
UH	6	10	83-03	ECHAM 4 T31 L19	UH Ocean 1x2 L2
NCEP CFS	9	15	81-03	GFS T62 L64	MOM 3 1/3x5/8 L27

	AGCM	OGCM
CERFACS	ARPEGE T63 L31	OPA 8.2 2.0x2.0 L31
ECMWF	IFS T95 L40	HOPE-E 1.4x0.3-1.429 L29
INGV	ECHAM 4 T42 L19	OPA 8.1 2.0x0.5-1.5 L31
LODYC	IFS T95 L40	OPA 8.2 2.0x2.0 L31
Meteo-France	ARPEGE T63 L31	OPA 8.0 192-152, L31
MPI	ECHAM-5 T42 L19	MPI-IM1 2.5x0.5-2.5 L23
UK Met Office	HadAM3 2.5x3.75 L19	GloSea OGCM 1.25x0.3-125 L40

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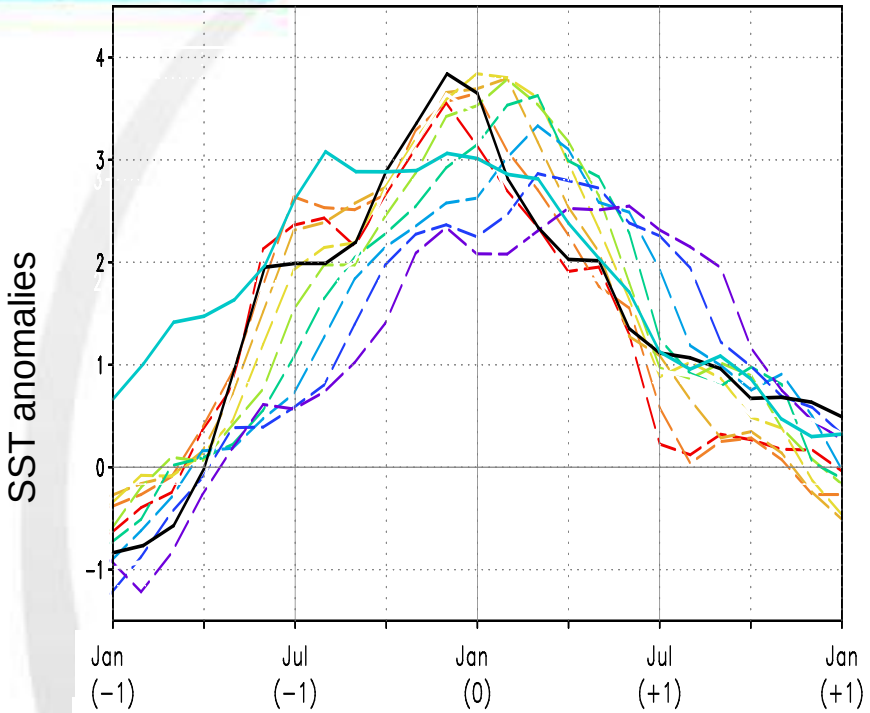
Model and Dataset

	Free long run	forecast	
PRCGC SINTEX	• 202-year simulation • Analyzing last 200 years (200-yr climatology)	• 1982-2004 period • 9 members • 12 calendar months ICs • 12 months lead	Luo *et al*. 2005
NCEP CFS	• 52-year simulation • Analyzing last 50 years (50-yr climatology)	• 1981-2003 period • 15 members • 12 calendar months ICs • 9 months lead	Saha *et al*. 2006

Courtesy of *J.-J. Luo, T. Yamagata, and K. Pegion*

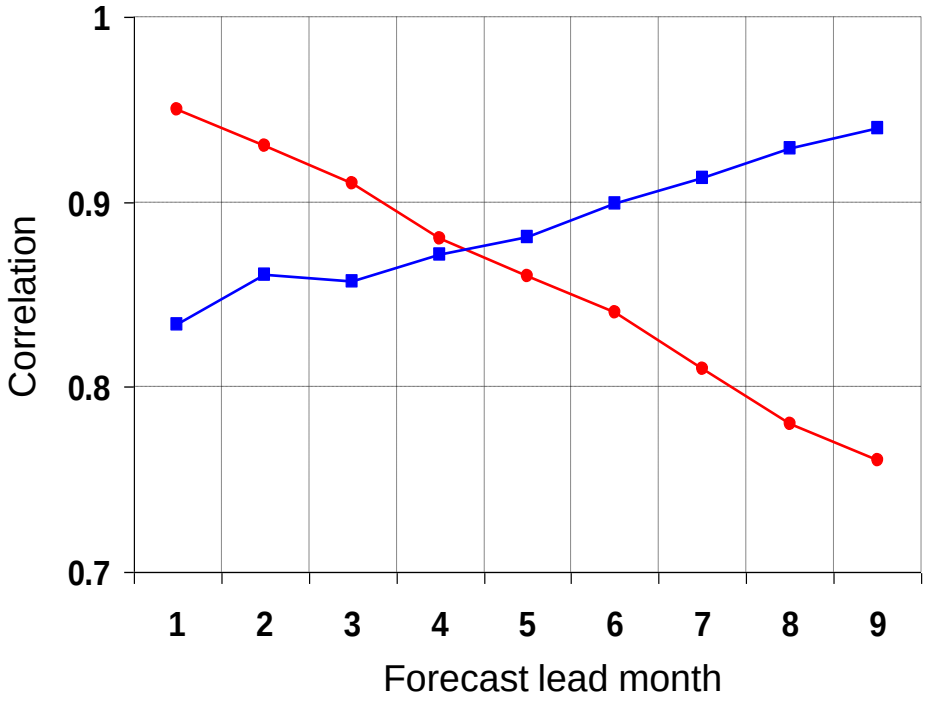
Influence of Systematic Error on CFS Forecast Skill

NINO3: Warm minus Cold composite



- Warm composite (82/83, 86/87, 91/92, 97/98) - Cold composite (84/85, 88/89, 98/99, 99/00)
- Dashed lines denote composite for Hindcasts at different lead times

CORR. with respect to lead month based on 1st SEOF mode of SST



Correlation between 1st PCs based on observation and hindcasts at different lead times

Correlation between 1st PCs based on long run and hindcasts at different lead times

Jin and Kinter. 2009

→ Model Flaw: Slow coupled dynamics of CGCM

Potential Intensity

Variables that enter the definition of the potential intensity (taking into account dissipative heating):

- SST – sea surface temperature
- SLP – sea level pressure
- CAPE – convective available potential energy
- Atmospheric temperature (various pressure levels)
- Mixing ratio (various pressure levels)

K.A. Emanuel, JAS 52, 3969-3976 (1995).
M. Bister and K.A. Emanuel, Meteor. Atm. Phys. 52, 233-240 (1998)

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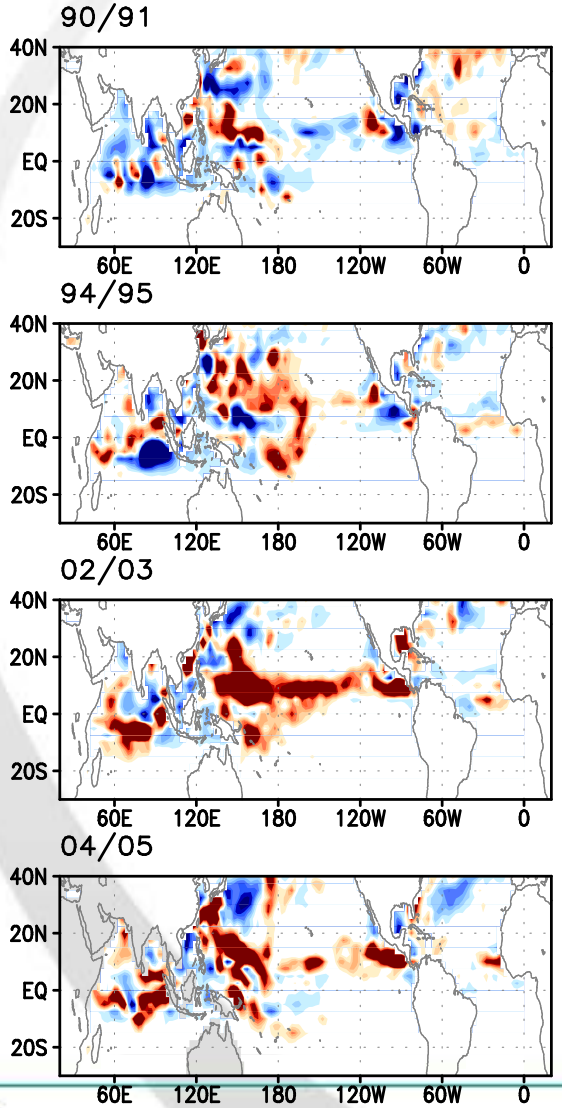
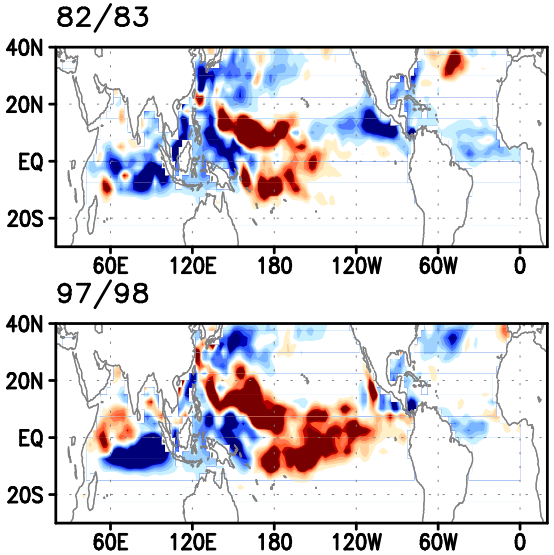
Observed GPI

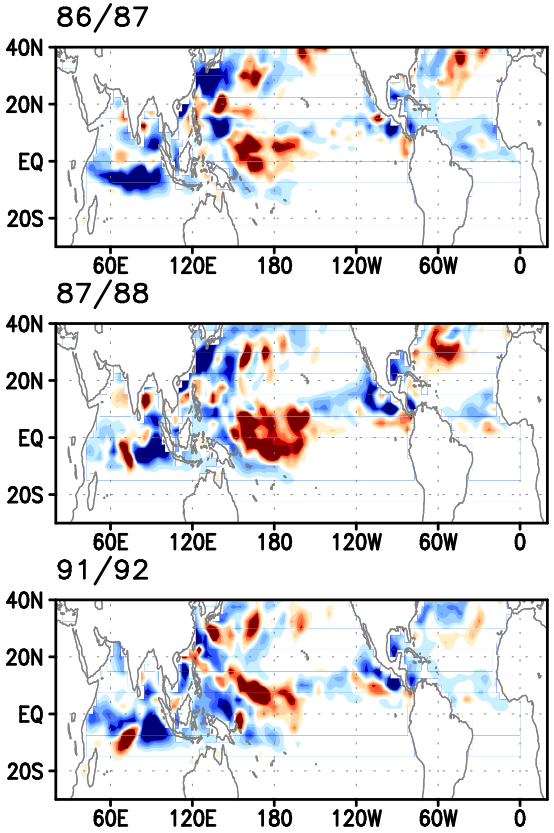
Warm-pool El Nino

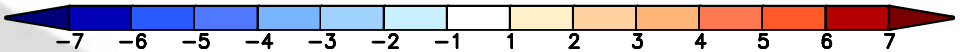


Cold-tongue El Nino

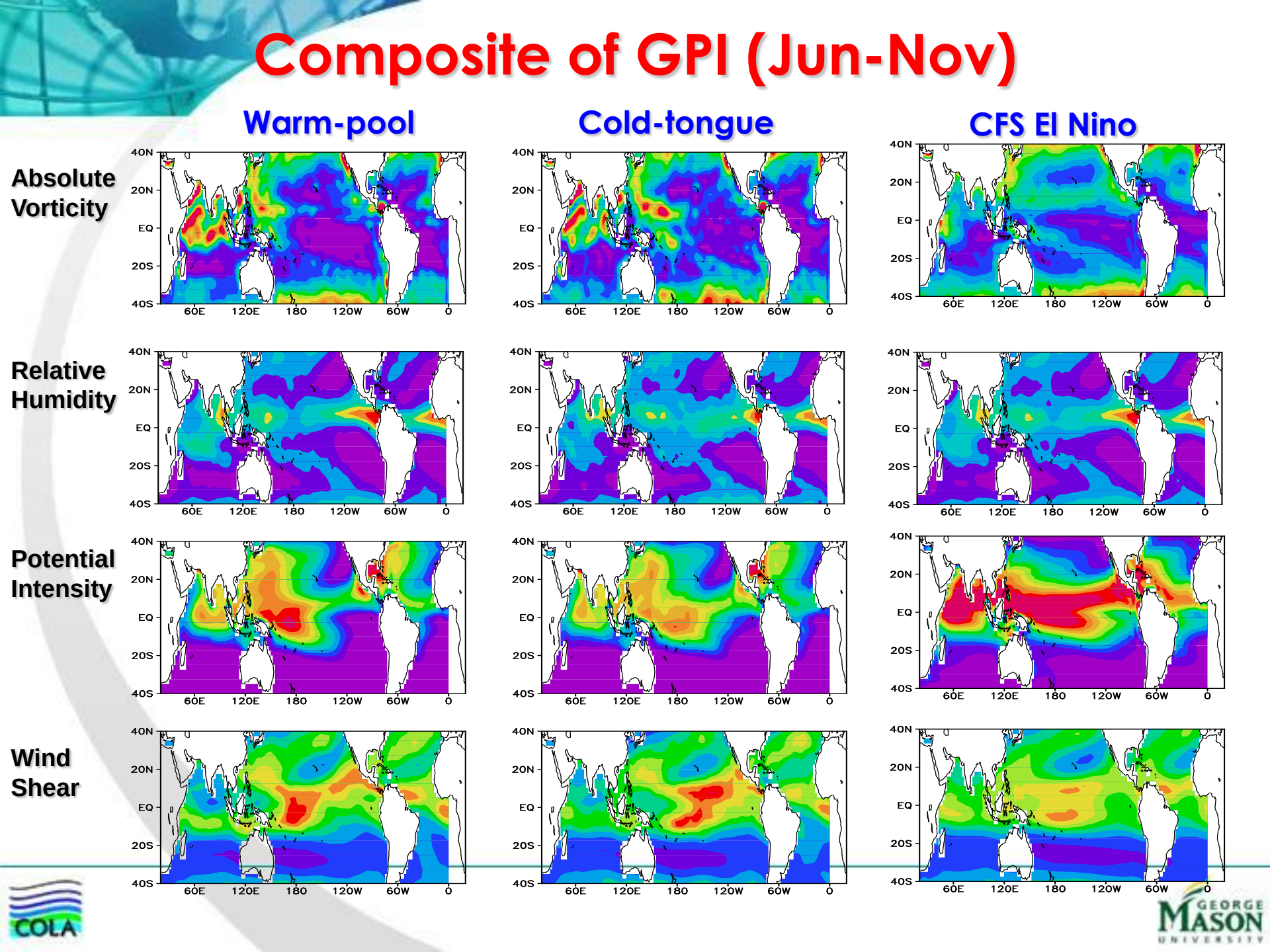


Mixed El Nino





Composite of GPI (Jun-Nov)



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