Asian and Indo-Pacific Monsoon Climate in the NCEP Climate Forecast System

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Topics to Cover

Summer monsoons*

East Asian winter monsoon

Mei-yu, Baiu & Changma (mid-summer East Asian rain bands)

Emphasis of the Impacts of

ENSO

Model resolutions

Atmosphere-ocean coupling

Land surface processes

Main Simulations Used in This Presentation

Hindcasts:

T62: 15 members, 23-26 years & 9-mon integration

T126: 15 members, 20 years & 5-mon integration

Free run:

T126: 100 years

T62: 50 years

Co-authors and References

Gao, H., S. Yang, A. Kumar, Z.-Z. Hu, B. Huang, Y. Li, and B. Jha, 2010: … East Asian Mei-yu ... *J. Climate,* conditionally accepted.

Li, Y., and S. Yang, 2010: A dynamical index for the East Asian winter monsoon. *J. Climate,* in press.

Li, Y., S. Yang, R. Wu, and W. Higgins, 2010: … East Asian winter monsoon …" *Climate Dyn.,* In preparation.

Liang, J., S. Yang, Z.-Z. Hu, B. Huang, A. Kumar, and Z. Zhang, 2009: Predictable patterns of Asian and Indo-Pacific summer precipitation ... *Climate Dyn.,* **32,** 989-1001.

Yang, S., M. Wen, and R. W. Higgins, 2008: Sub-seasonal features ... *ACTA Oceanol. Sinica,* **27,** 88-103.

Yang, S., M. Wen, R. Yang, K. E. Mitchell, W. Higgins, R. Zhang, and J Meng, 2010: … land surface processes … *J. Hydrometeor.,* In preparation.

Yang, S., Z. Zhang, V. E. Kousky, R. W. Higgins, S.-H. Yoo, J. Liang, and Y. Fan, 2008: … Asian summer monsoon ... *J. Climate,* **21,** 3755-3775.

Yoo, S.-H., J. Fasullo, S. Yang, and C.-H. Ho, 2010: … Indian Ocean ... *J. Geophys. Res.,* in press.

Yoo, S.-H., S. Yang, and C.-H. Ho, 2006: … Indian Ocean … monsoons … *J. Geophy. Res.,* **111,** D03108.

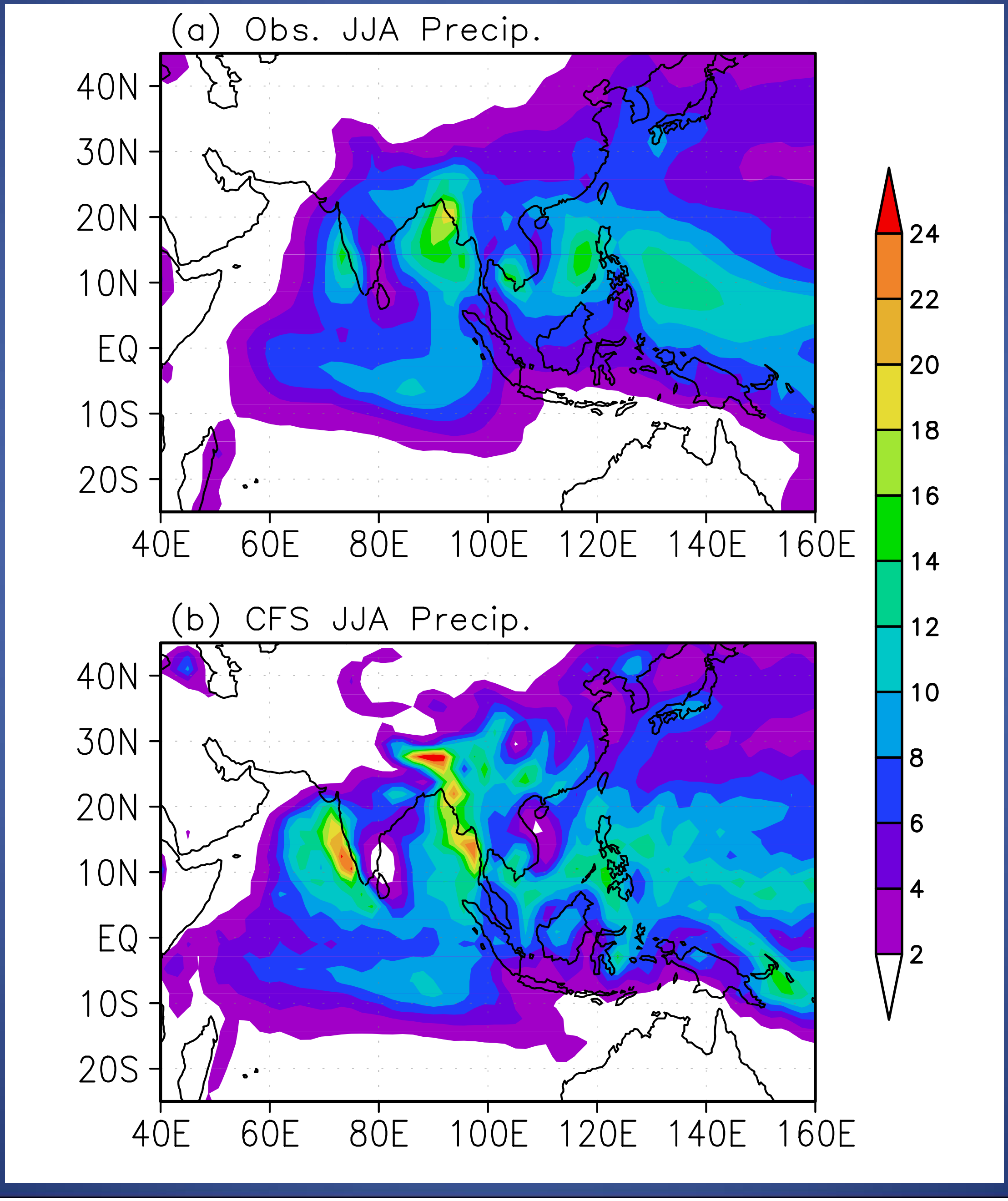
1. Simulation and Prediction of Summer Monsoon

Large-scale monsoons over Asia and Indo-Pacific Oceans

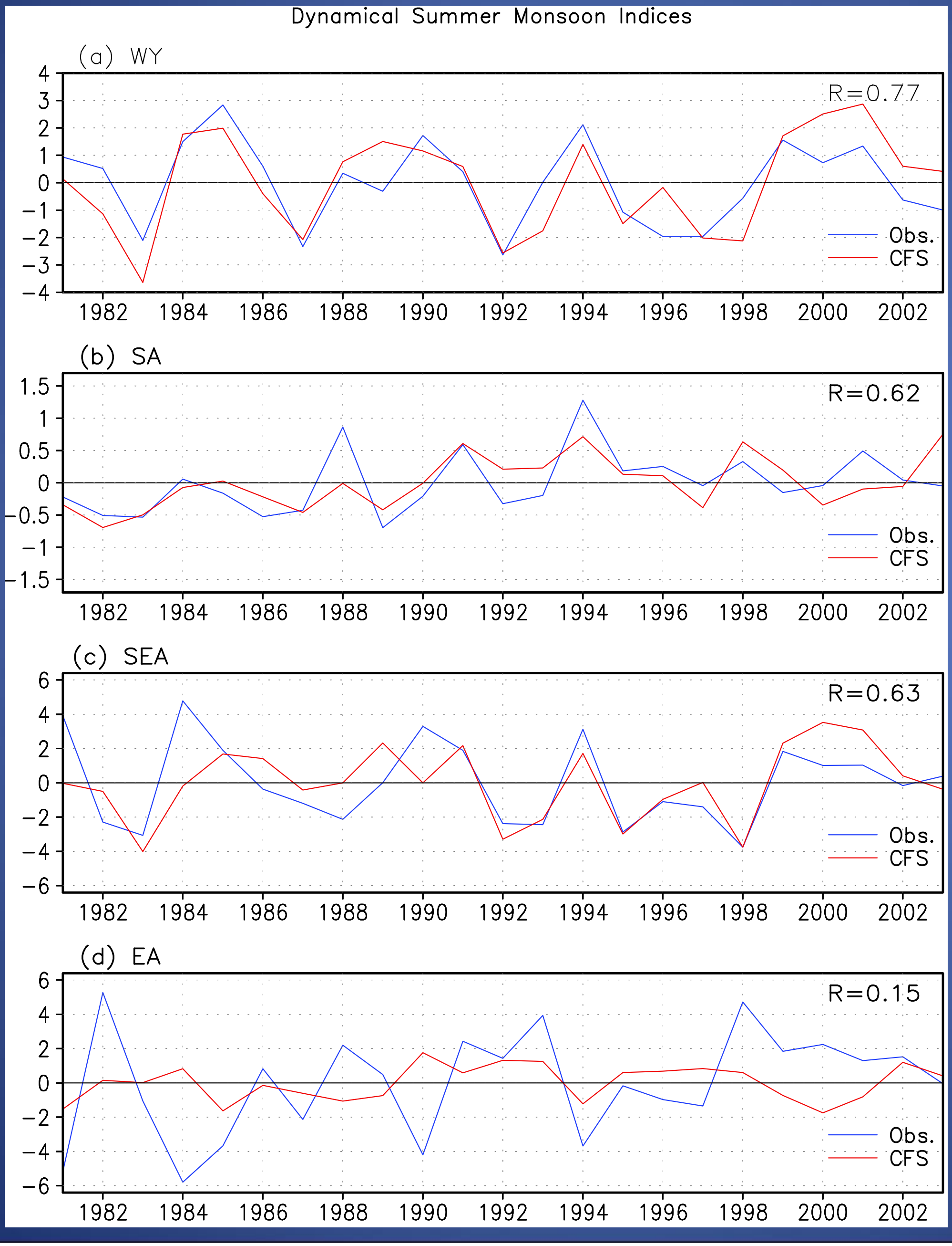
Seasonal-to-interannual timescales

Higher frequency variability

JJA Precip. (CMAP and CFS T62)



Interannual Variability of Various Monsoon Indices



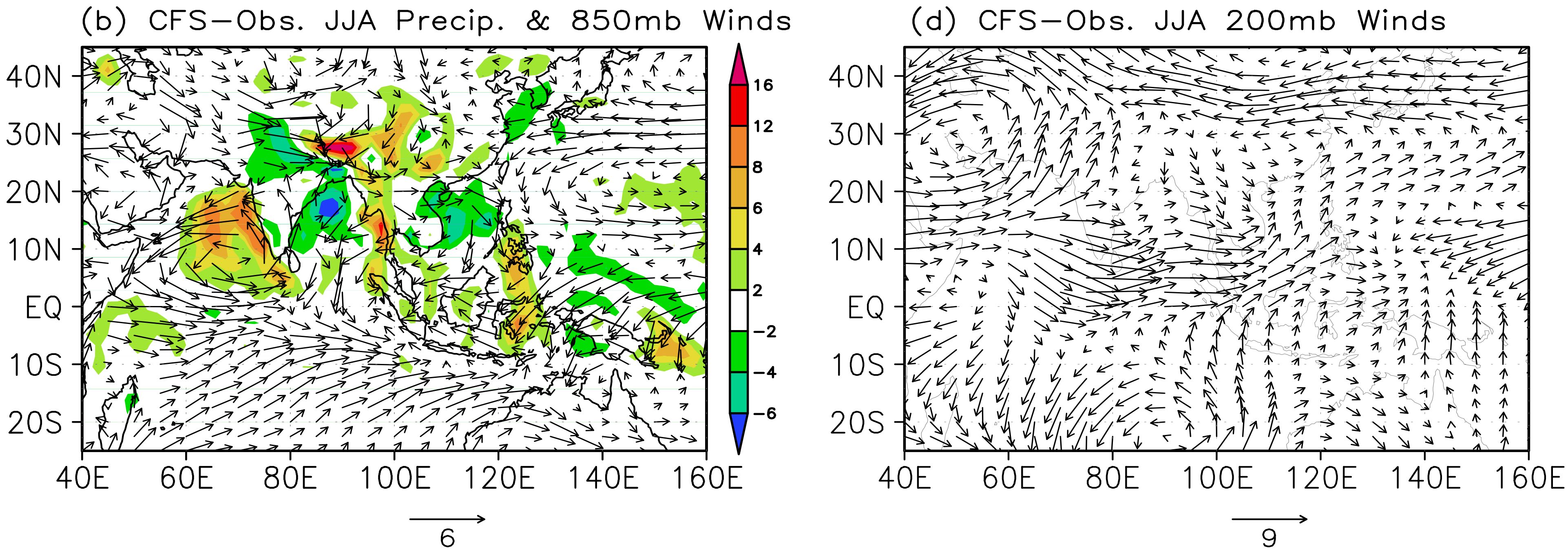
Webster-Yang (Webster and Yang 1992)

South Asia (Goswami et al. 1999)

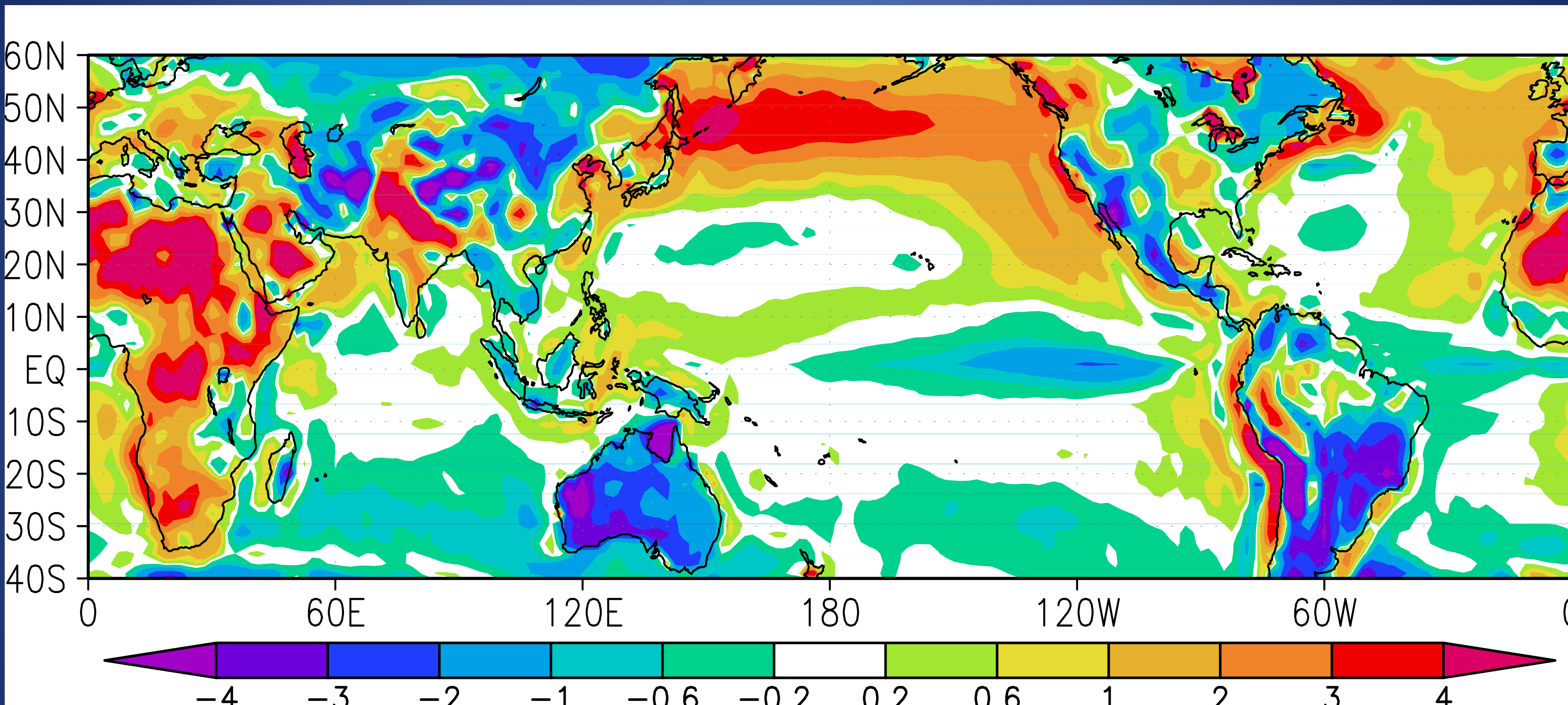
Southeast Asia (Wang and Fan 1999)

East Asia (Lau et al. 2000)

Differences in JJA Precip and Winds (CFS-Obs)

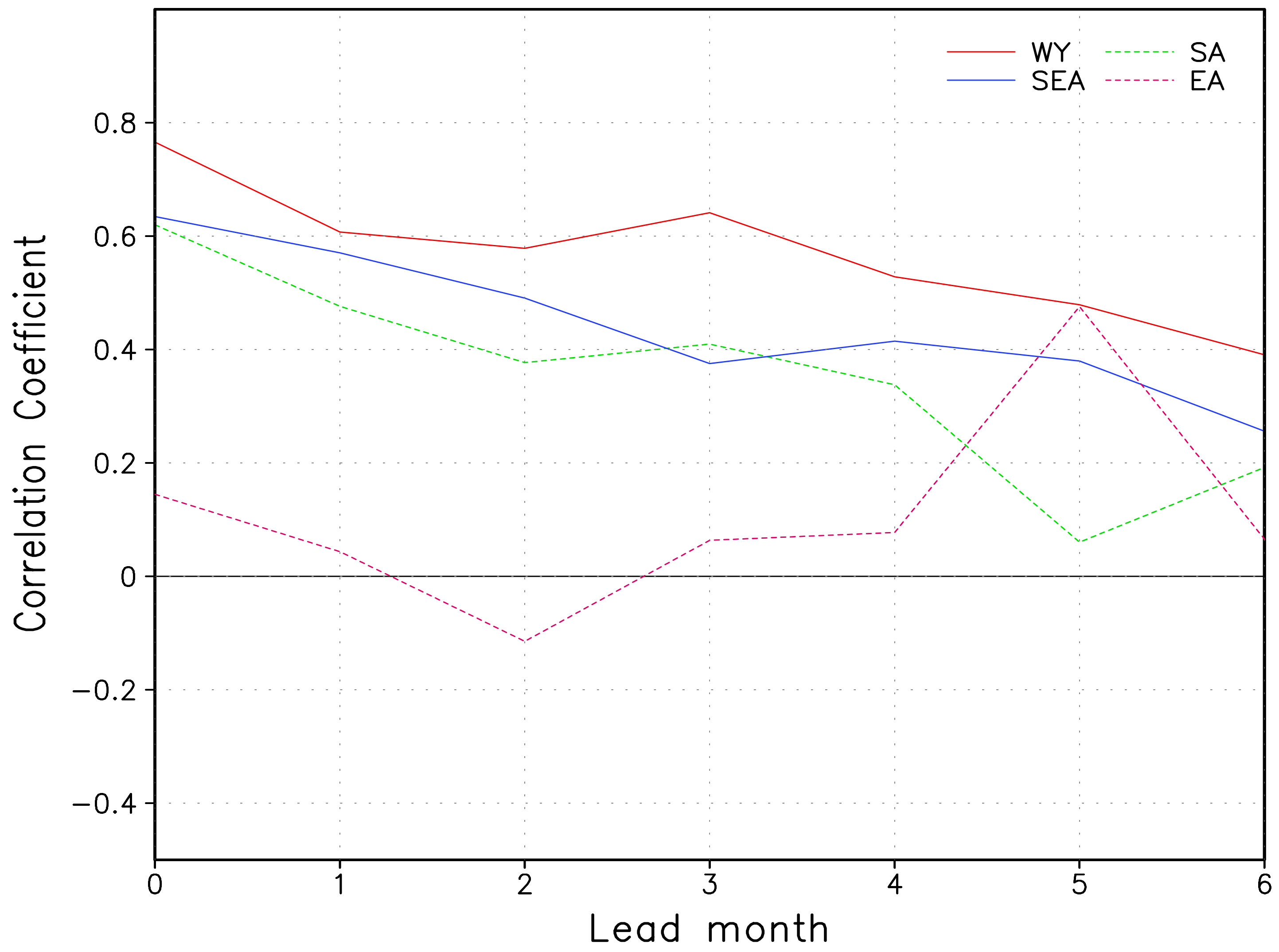


Difference in JJA Surface Temperature (CFS-Obs)

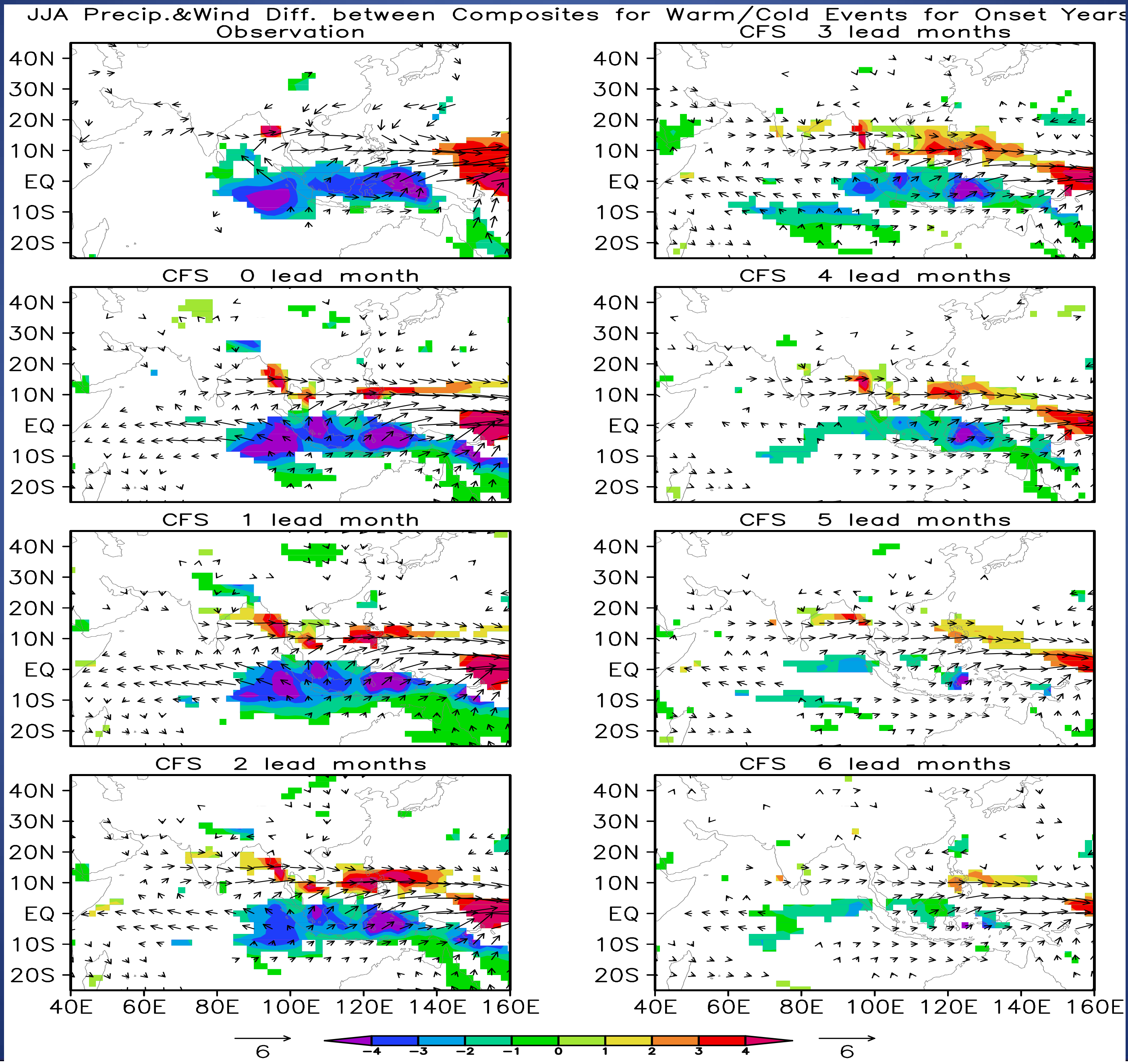


Corr between Obs Indices and CFS Indices at Various Leads

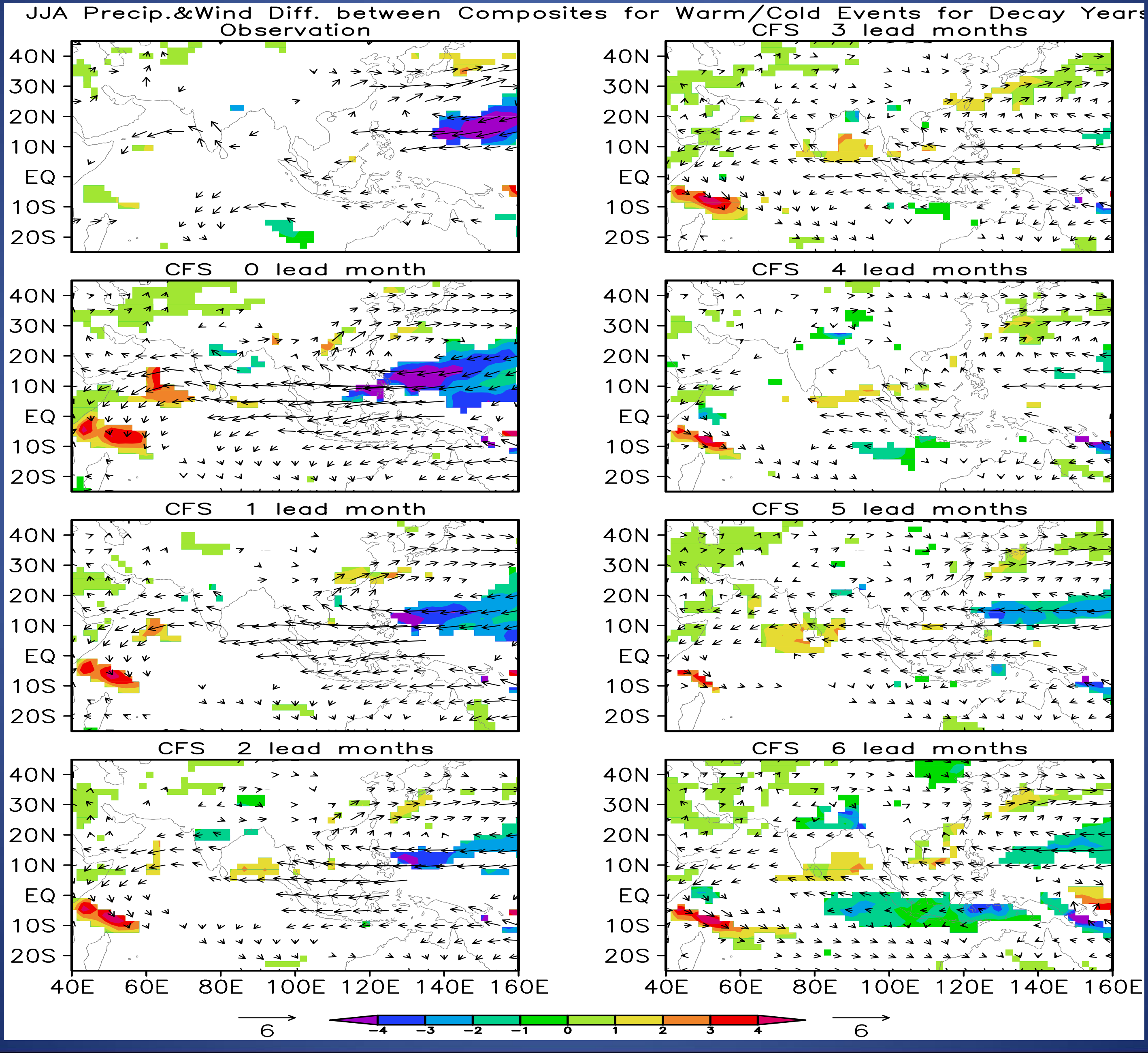
Webster-Yang index (WY 1992), South Asia (Goswami et al. 1999), Southeast Asia (Wang and Fan 1999), East Asia (Lau et al. 2000)



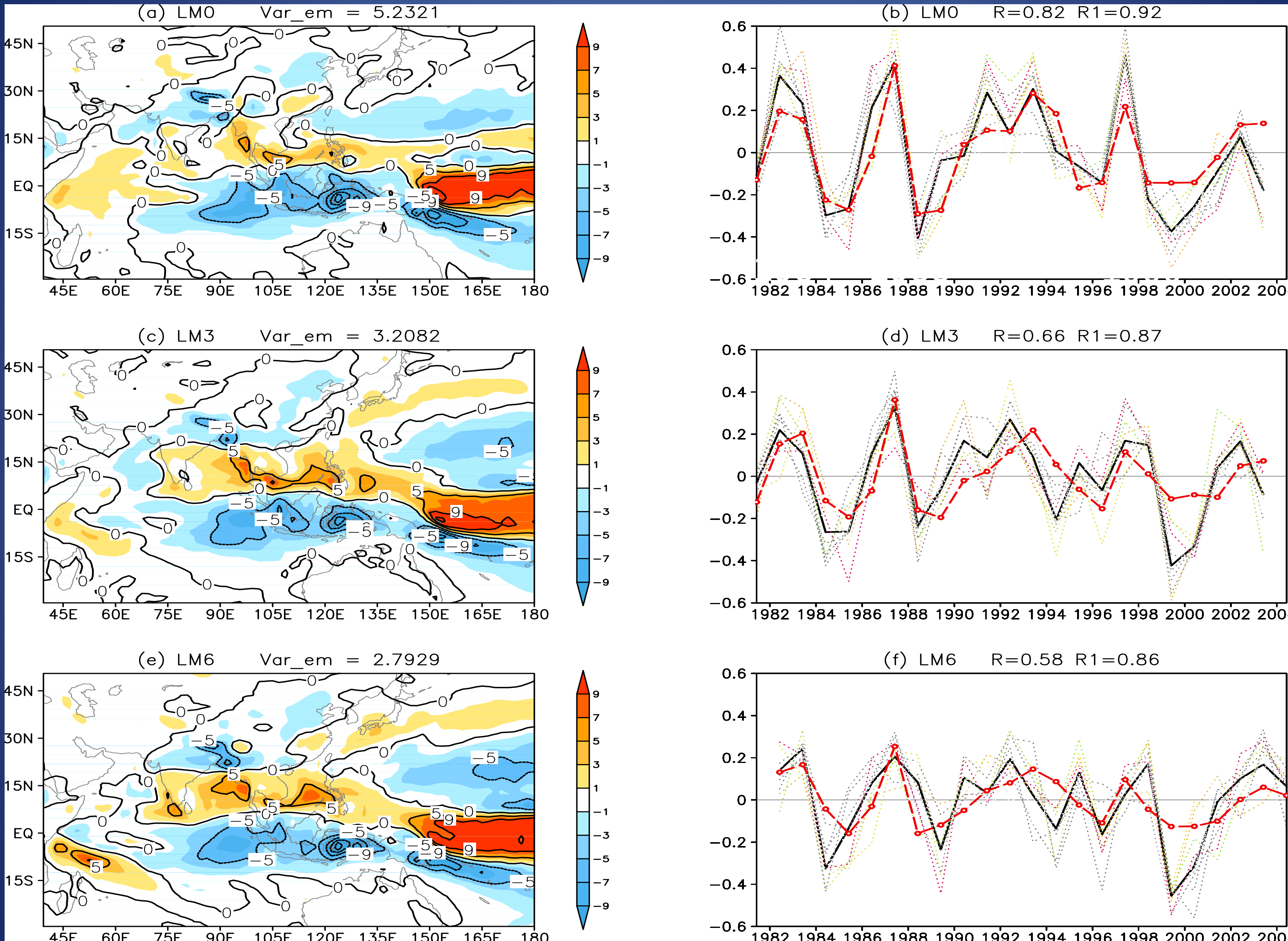
Diff in Precip and 850-mb Winds (E-L); ENSO Onset Years



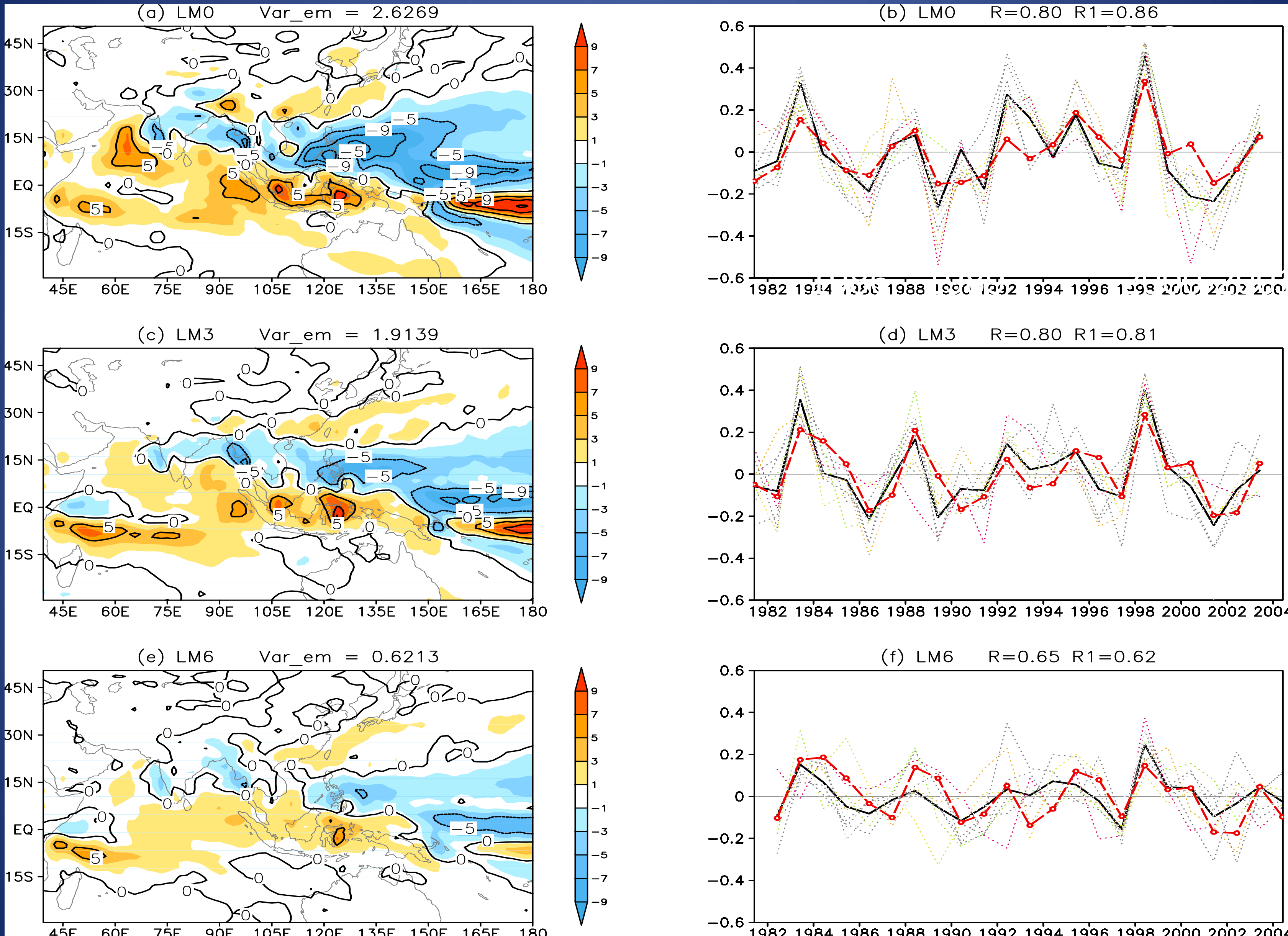
Diff in Precip and 850-mb Winds (E-L); ENSO Decay Years



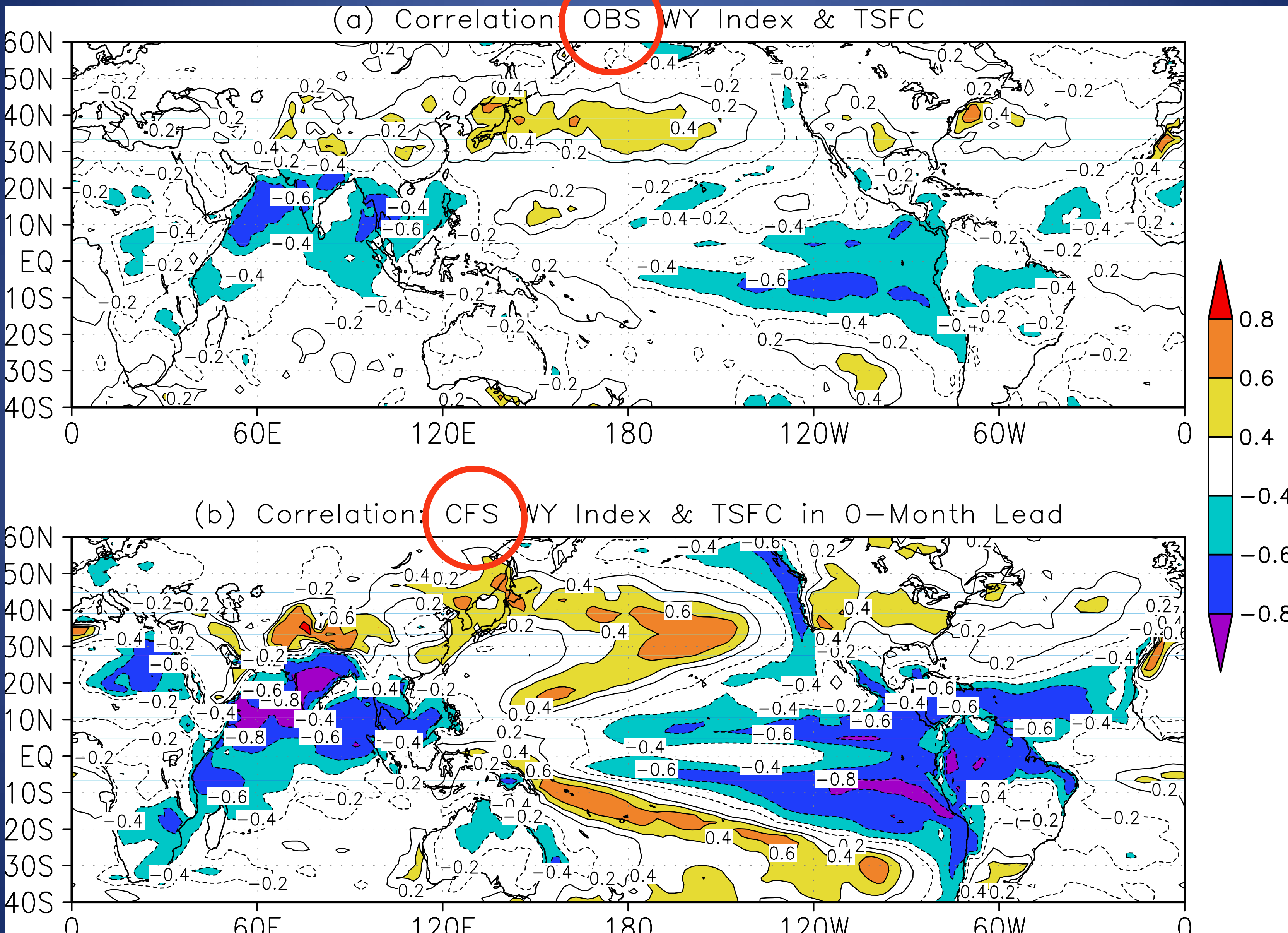
Maximum Signal-to-Noise EOF-1 of CFS JJA Precipitation



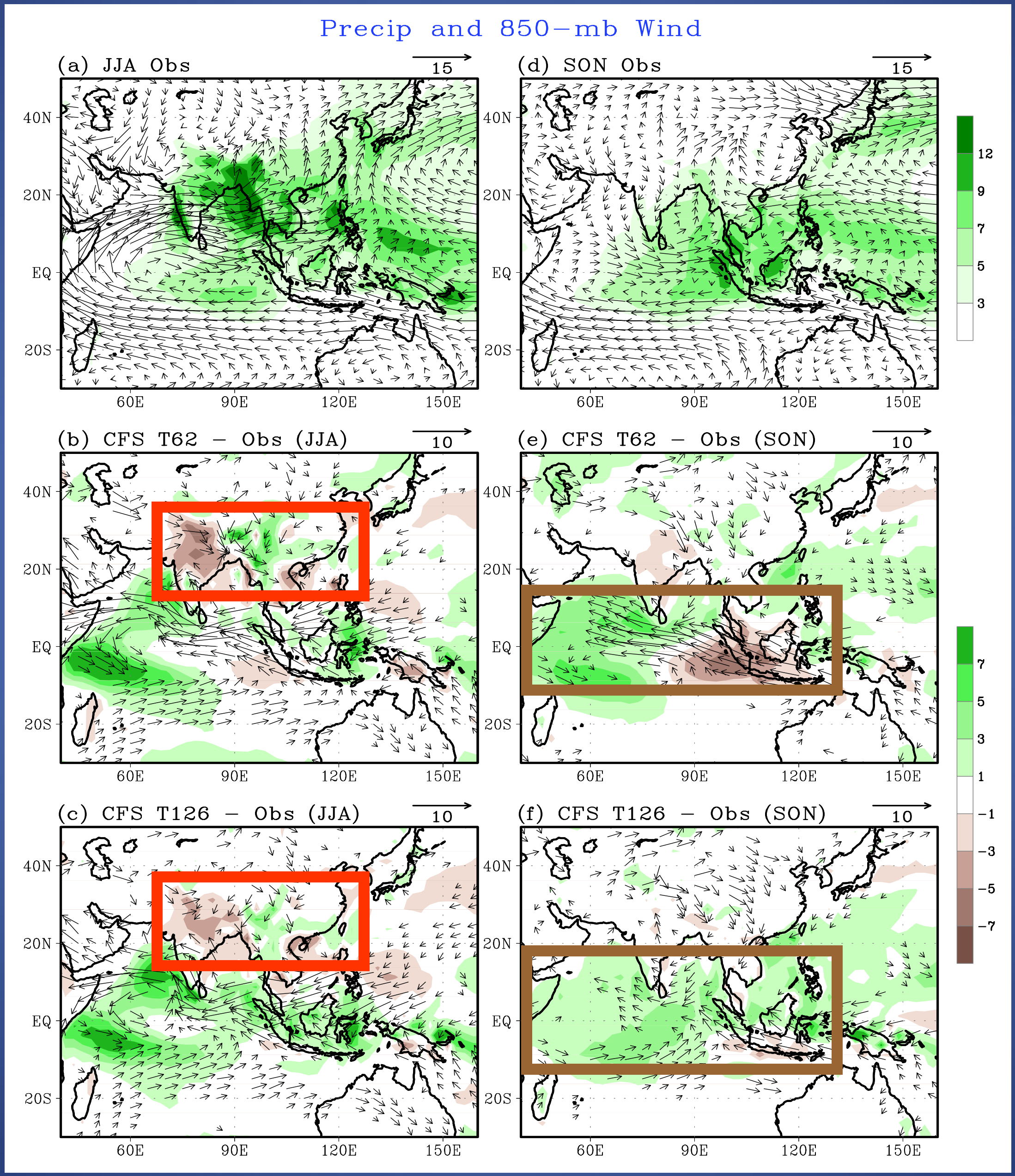
MSN EOF-2 of CFS JJA Precipitation



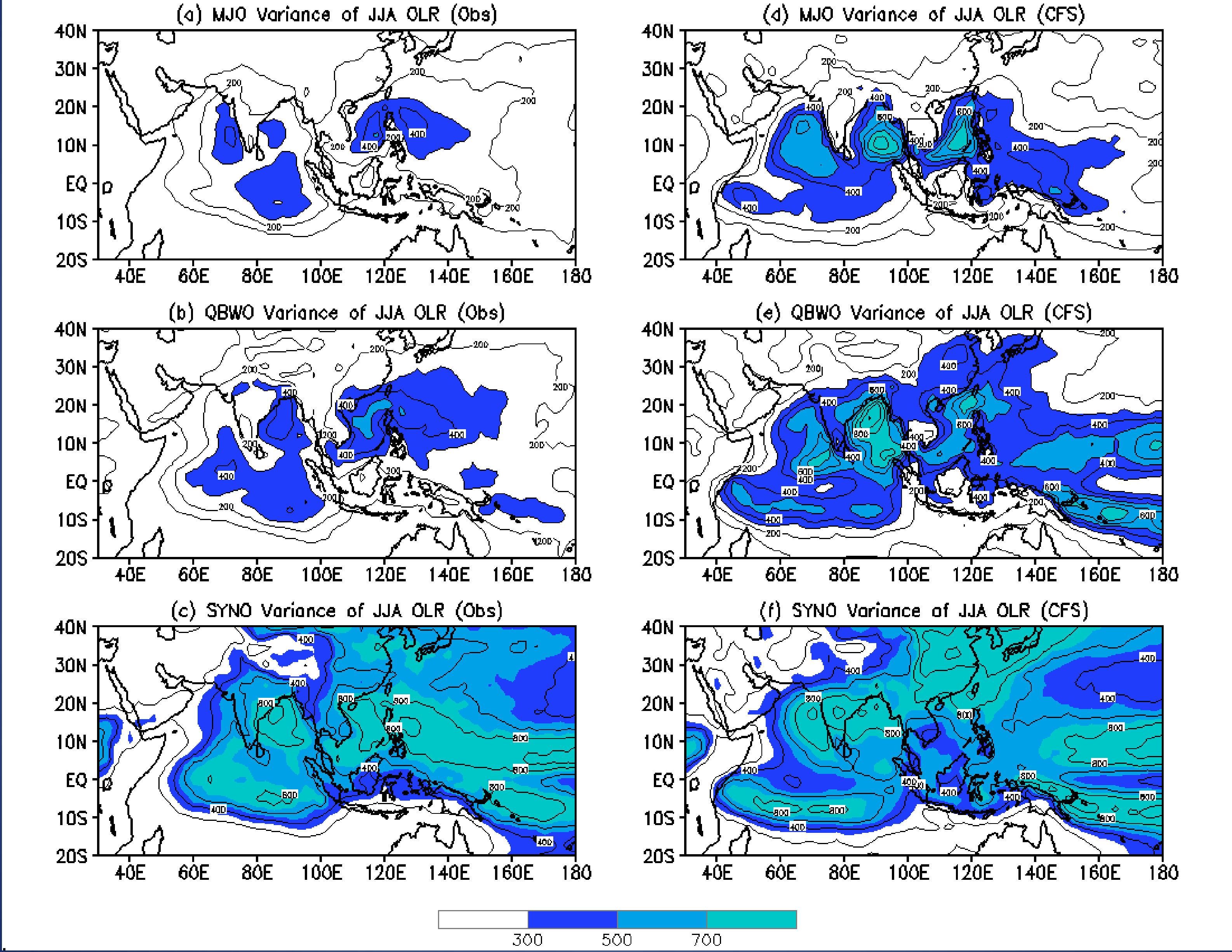
Corr between WY Monsoon Index and Surface Temperature

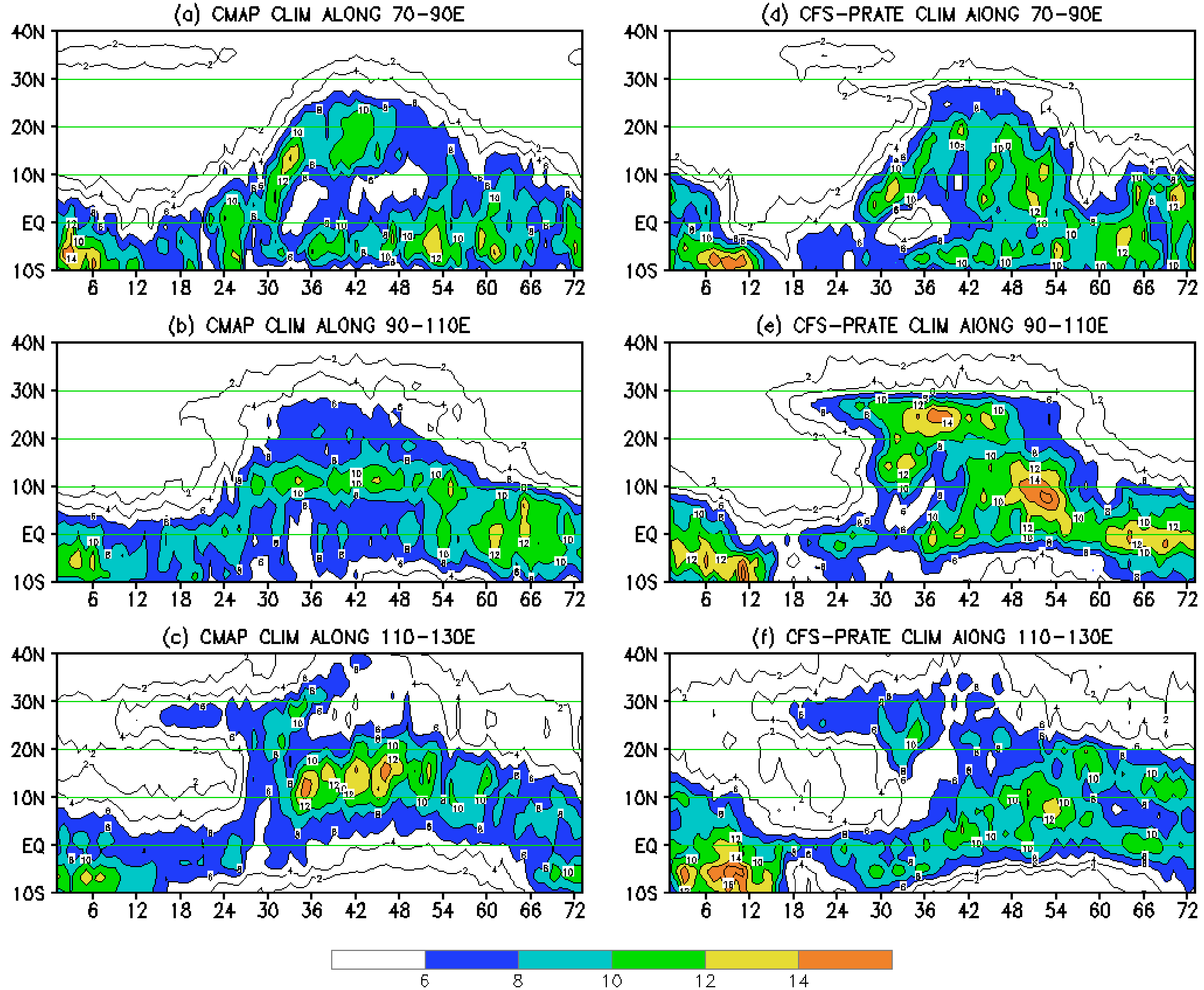


T62 vs. T126


Precip and 850-mb Wind
(a) JJA Obs
(d) SON Obs
(b) CFS T62 – Obs (JJA)
(e) CFS T62 – Obs (SON)
(c) CFS T126 – Obs (JJA)
(f) CFS T126 – Obs (SON)
15
10
40N
20N
EQ
20S
60E
90E
120E
150E
12
9
7
5
3
1
-1
-3
-5
-7

Sub-seasonal Time Scales




(a) CMAP CLIM ALONG 70-90E
(b) CMAP CLIM ALONG 90-110E
(c) CMAP CLIM ALONG 110-130E
(d) CFS-PRATE CLIM AlONG 70-90E
(e) CFS-PRATE CLIM AlONG 90-110E
(f) CFS-PRATE CLIM AlONG 110-130E
40N
30N
20N
10N
EQ
10S
6 12 18 24 30 36 42 48 54 60 66 72
6 8 10 12 14

Indian Ocean SST with Monsoons, ENSO & IO Dipole

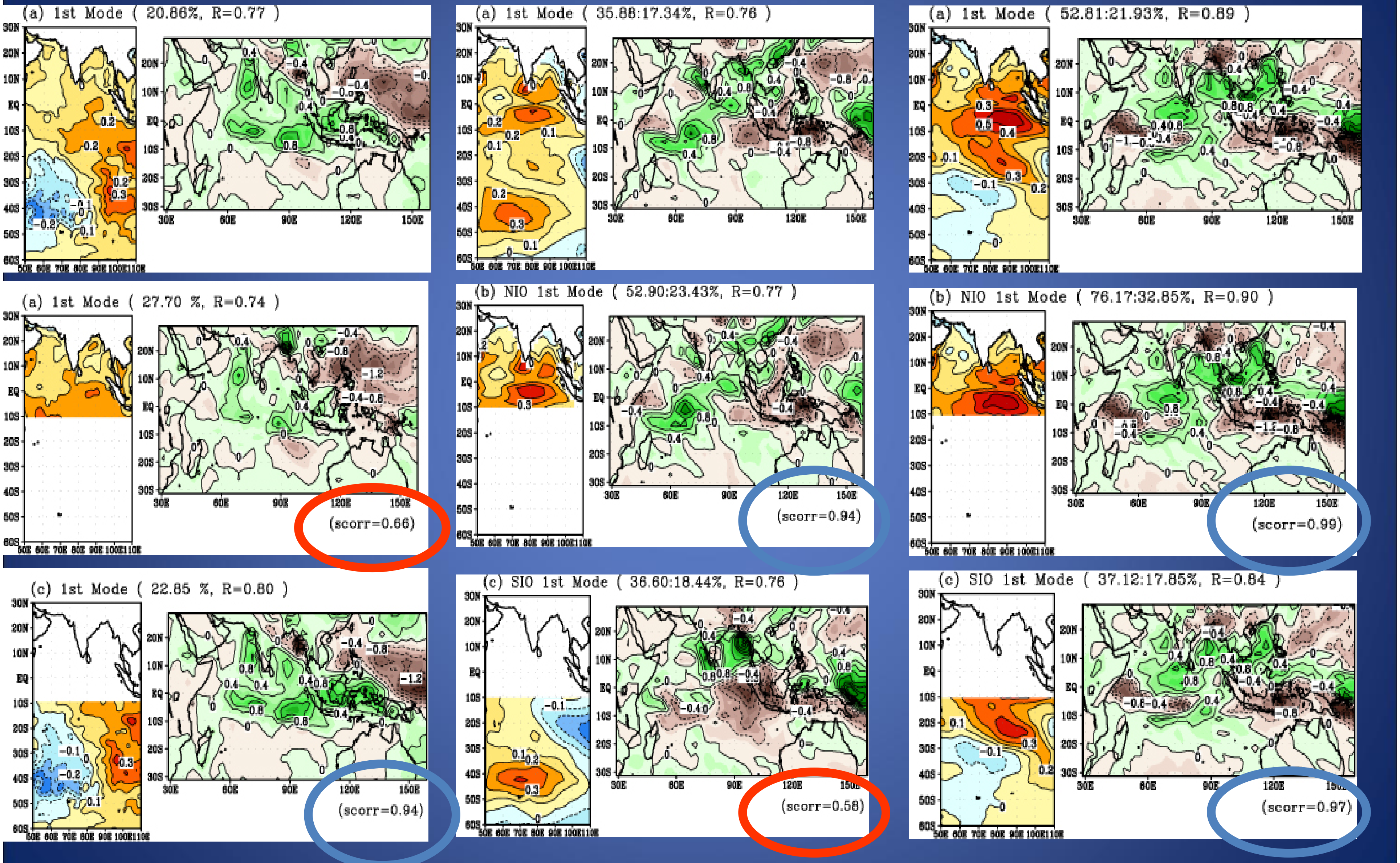
Simultaneous Relationships

	Observation	AMIP	CFS
DJF IO SST	Nino3 SST IO Dipole Australian Monsoon	Nino3 SST	NINO3 IO Dipole Australian Monsoon
MAM IO SST		IO Dipole	Nino3 SST
JJA IO SST	SE Asian Monsoon Webster-Yang		IO Dipole Nino3 SST SE Asian Monsoon Webster-Yang East Asian Monsoon
SON IO SST	IO Dipole Nino3 SST	IO Dipole Nino3 SST	IO Dipole

Lag Relationships between IO SST & Monsoons

	JJA Monsoons					DJF Monsoon
	W-Y	South Asia	East Asia	SE Asia		Australia
Obs MAM SST		+		-	Obs SON SST	-
AMIP MAM SST					AMIP SON SST	
CFS MAM SST		(+)		-	CFS SON SST	-

Importance of Southern Indian Ocean

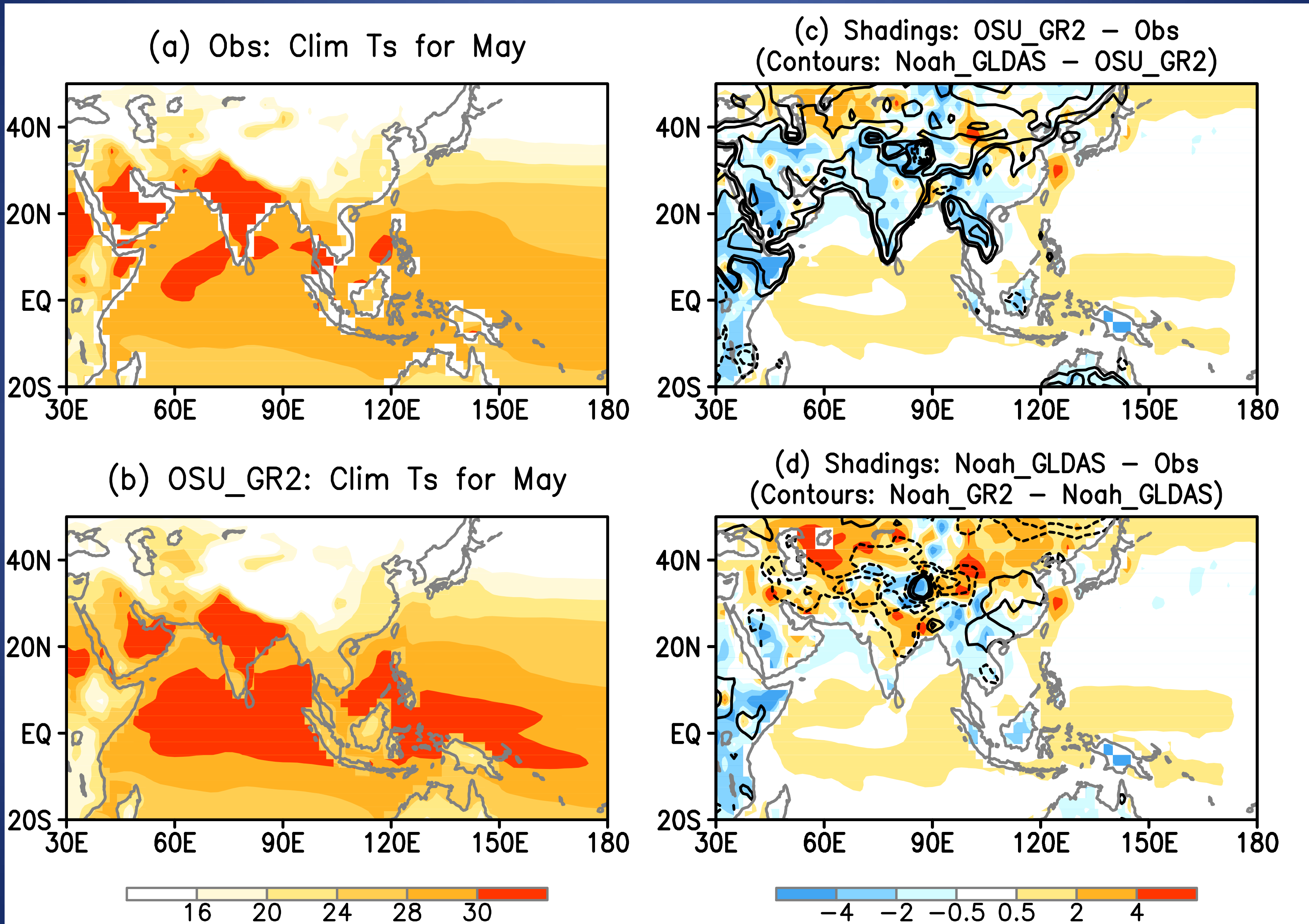


Land Models and Land Surface Processes

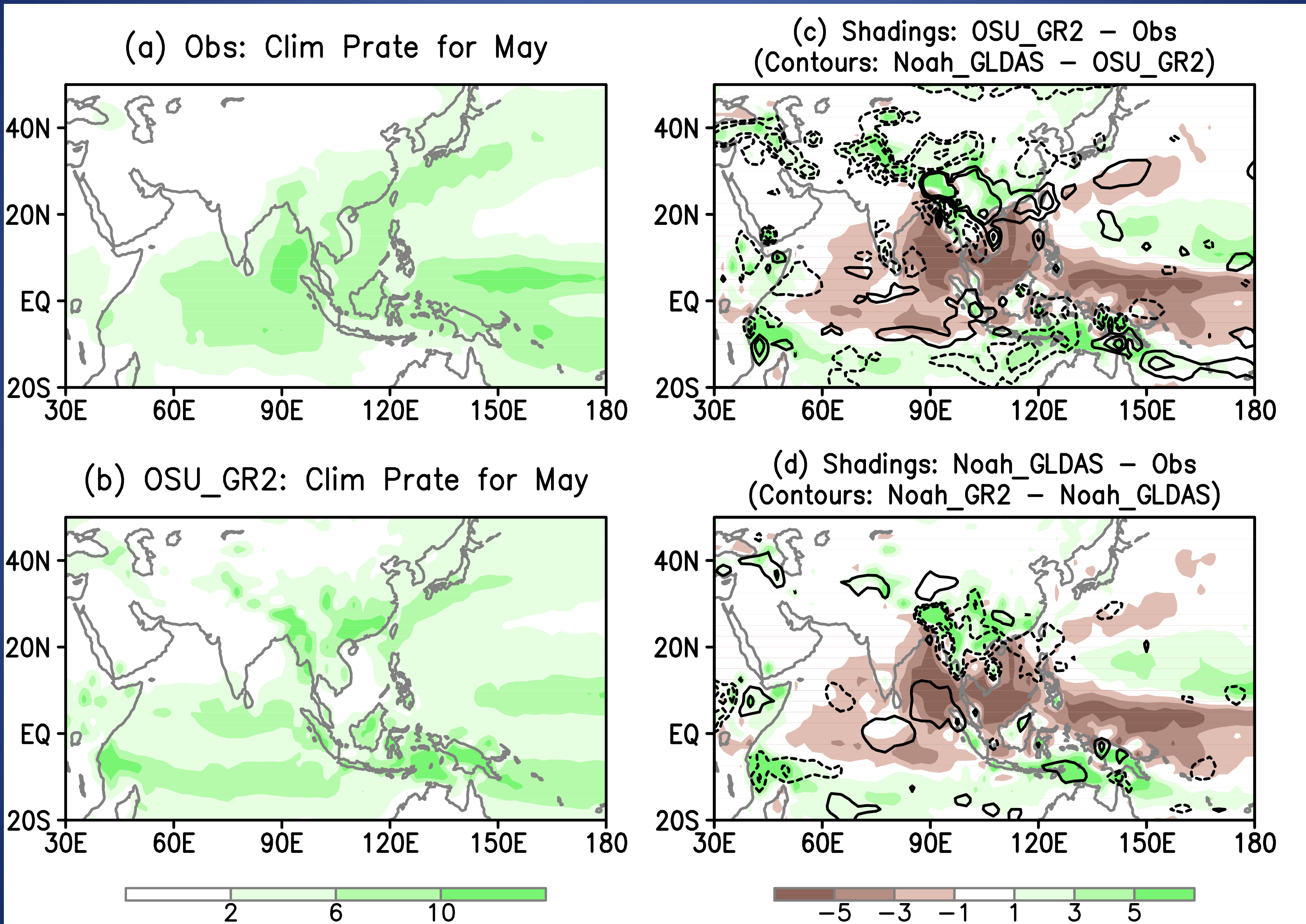
Major improvements from OSU Model to Noah Model

OSU Land Surface Model	Noah Land Surface Model
2 soil layers (0-10 and 10-190 cm)	4 soil layers (0-10, 10-40, 40-100, and 100-200 cm)
No frozen soil physics	Frozen soil physics included
Surface fluxes not weighted by snow fraction	Surface fluxes weighted by snow fraction
Vegetation fraction never less than 50 percent	Improved seasonal cycle of vegetation cover
Spatially constant root depth	Spatially varying root depth
Sub-grid variability of precipitation and soil moisture not accounted for by runoff and infiltration	Sub-grid variability of precipitation and soil moisture accounted for by runoff and infiltration
Poor soil and snow thermal conductivity, especially for thin snowpack	Improved soil and snow thermal conductivity
Higher canopy resistance	

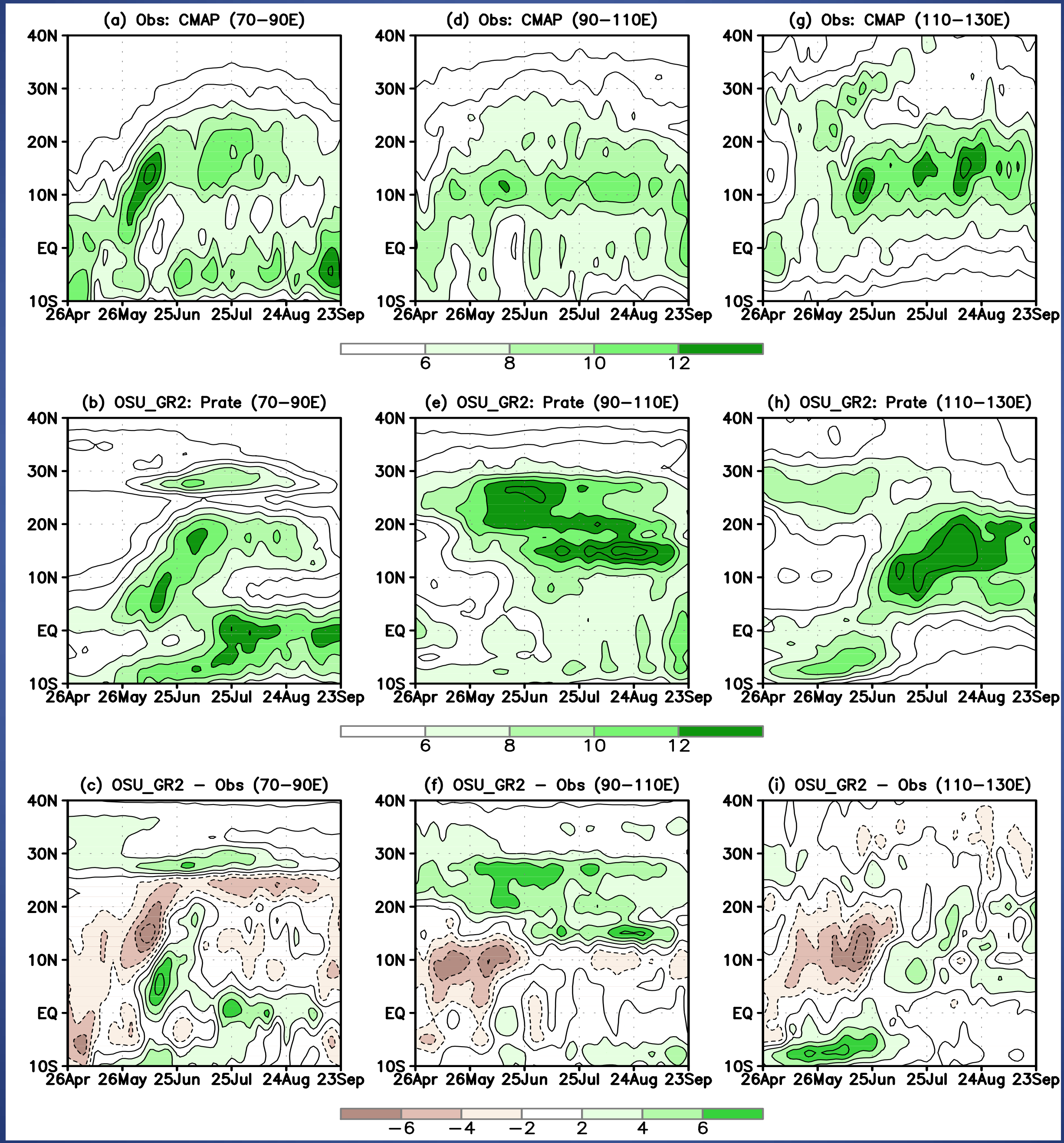
May Surface Temperature in Obs & CFS of Various Configurations: OSU_GR2, Noah_GR2 and Noah_GLDAS



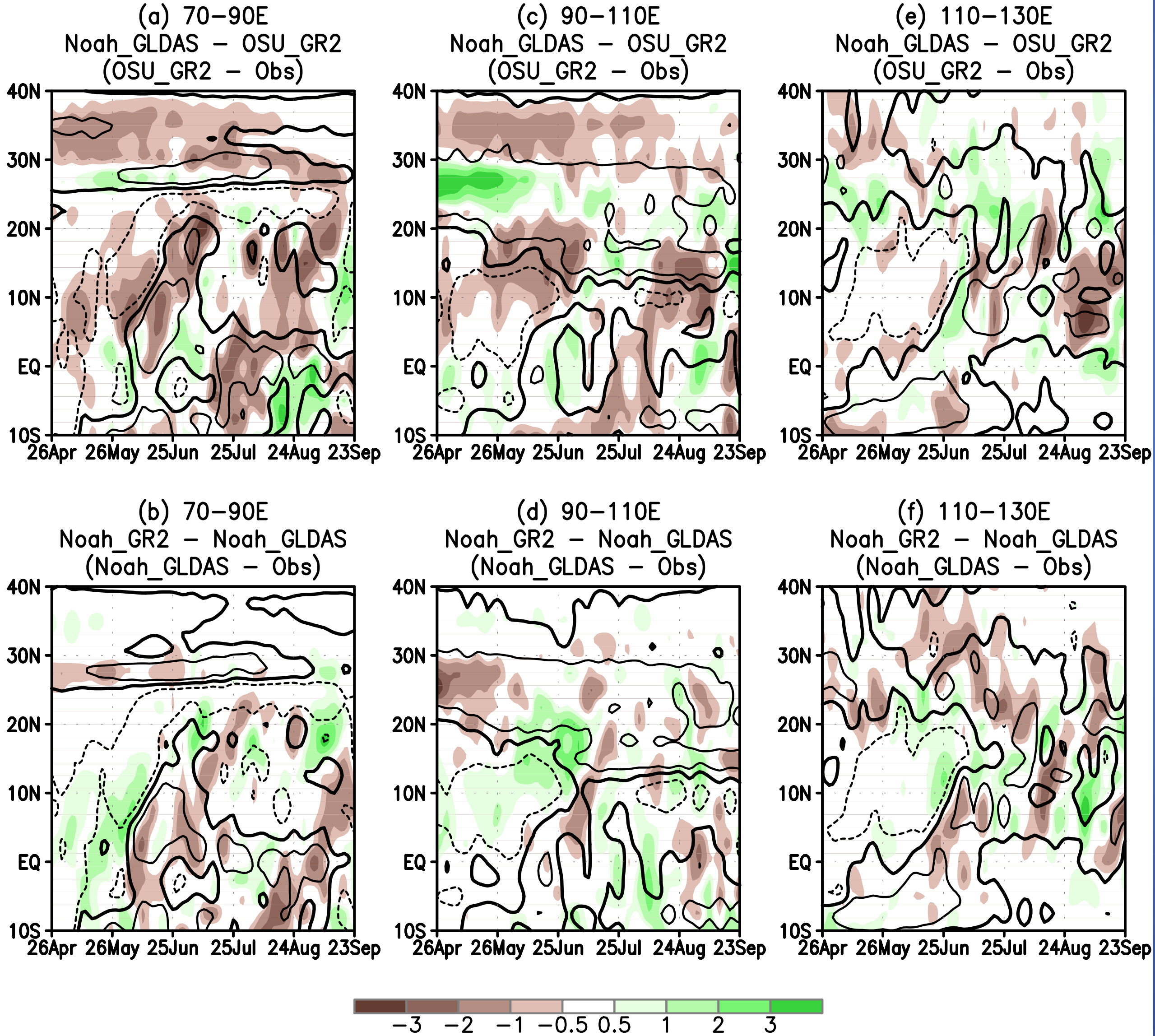
May Precipitation in Obs & CFS of Various Configurations: OSU_GR2, Noah_GR2 and Noah_GLDAS



CMA & OSU_GR2 Pentad Rainfall along Different Longitudinal Bands



Differences in Pentad Rainfall (between Obs and different GSF Configurations)



Contours:

OSU_GR2 – Obs

Shadings:

Noah_GLDAS – OSU_GR2

Contours:

Noah_GLDAS – Obs

Shadings:

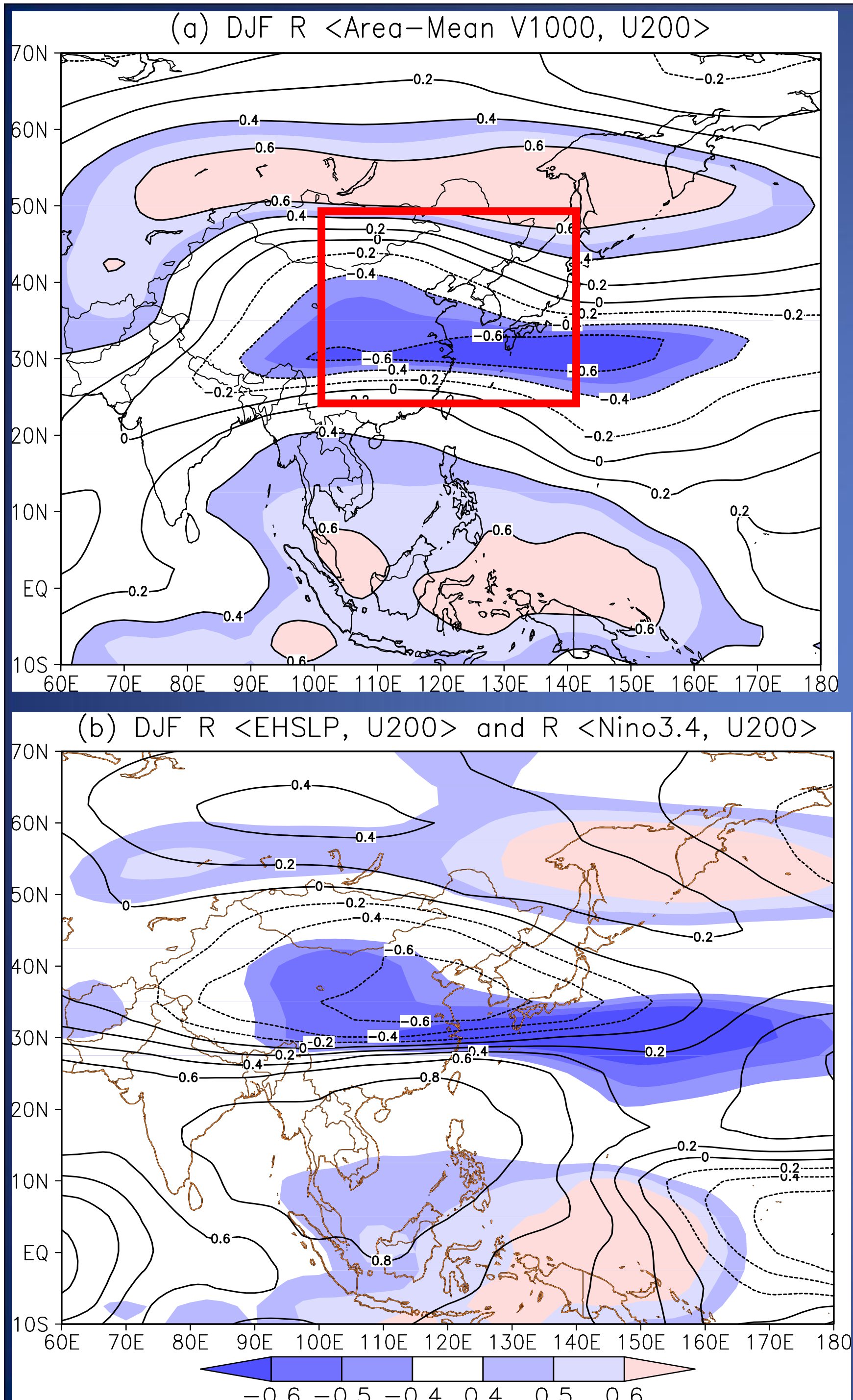
Noah_GR2 – Noah_GLDAS

2. East Asian Winter Monsoon

Two Points to Emphasize

A deep system, prominent at both the lower troposphere and the upper troposphere

Interactive with both tropical and high-latitude systems



Corr <box-averaged V1000, U200>

(V1000: 25-50N/100-145E)

Shadings: significant values

Contours: Corr <EHSLP, U200>

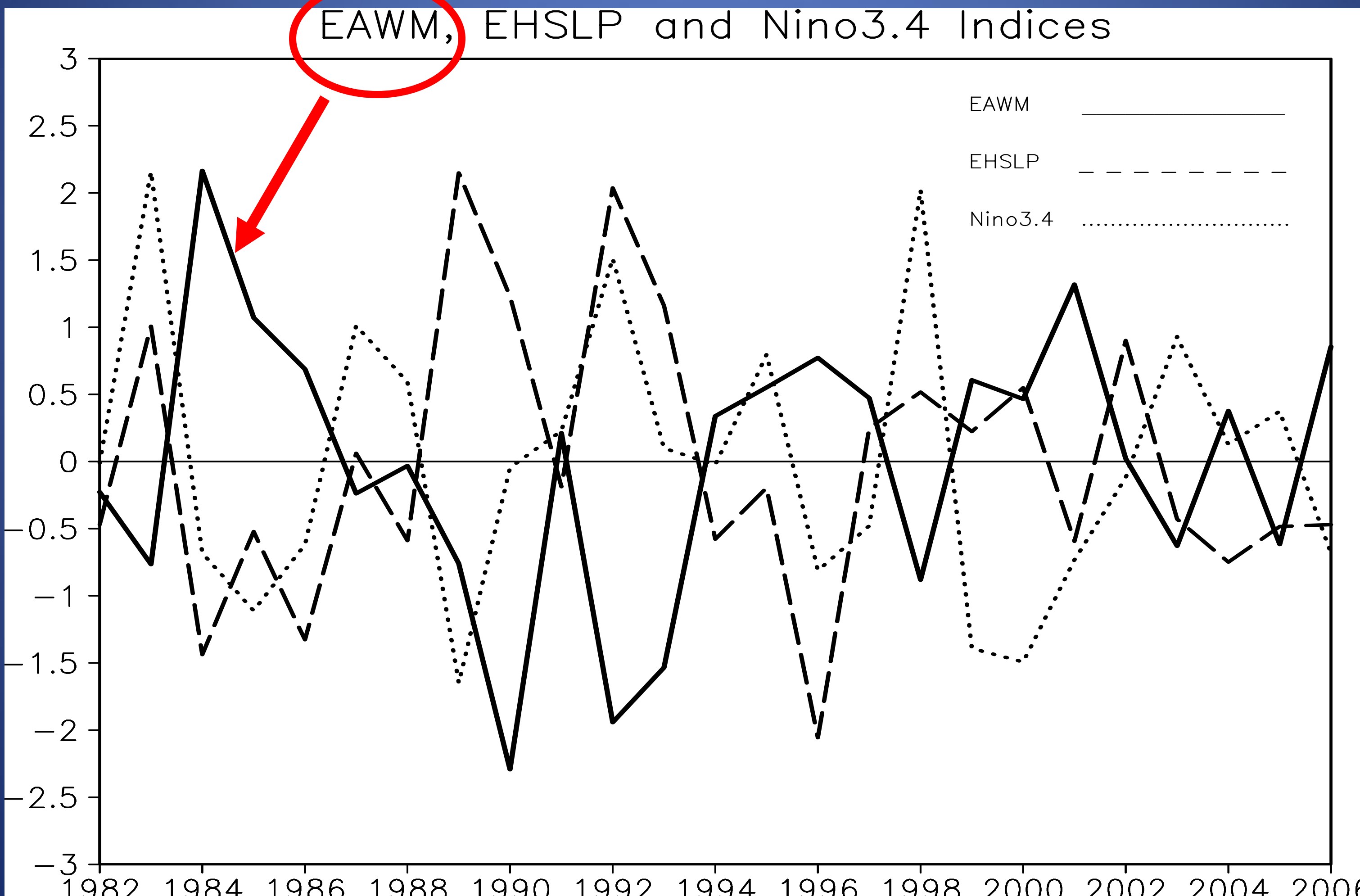
Shadings: Corr <Nino3.4 SST, U200>

EHSLP is computed using the eastern hemisphere SLP. It is highly correlated to AO but better linked to the East Asian winter monsoon.

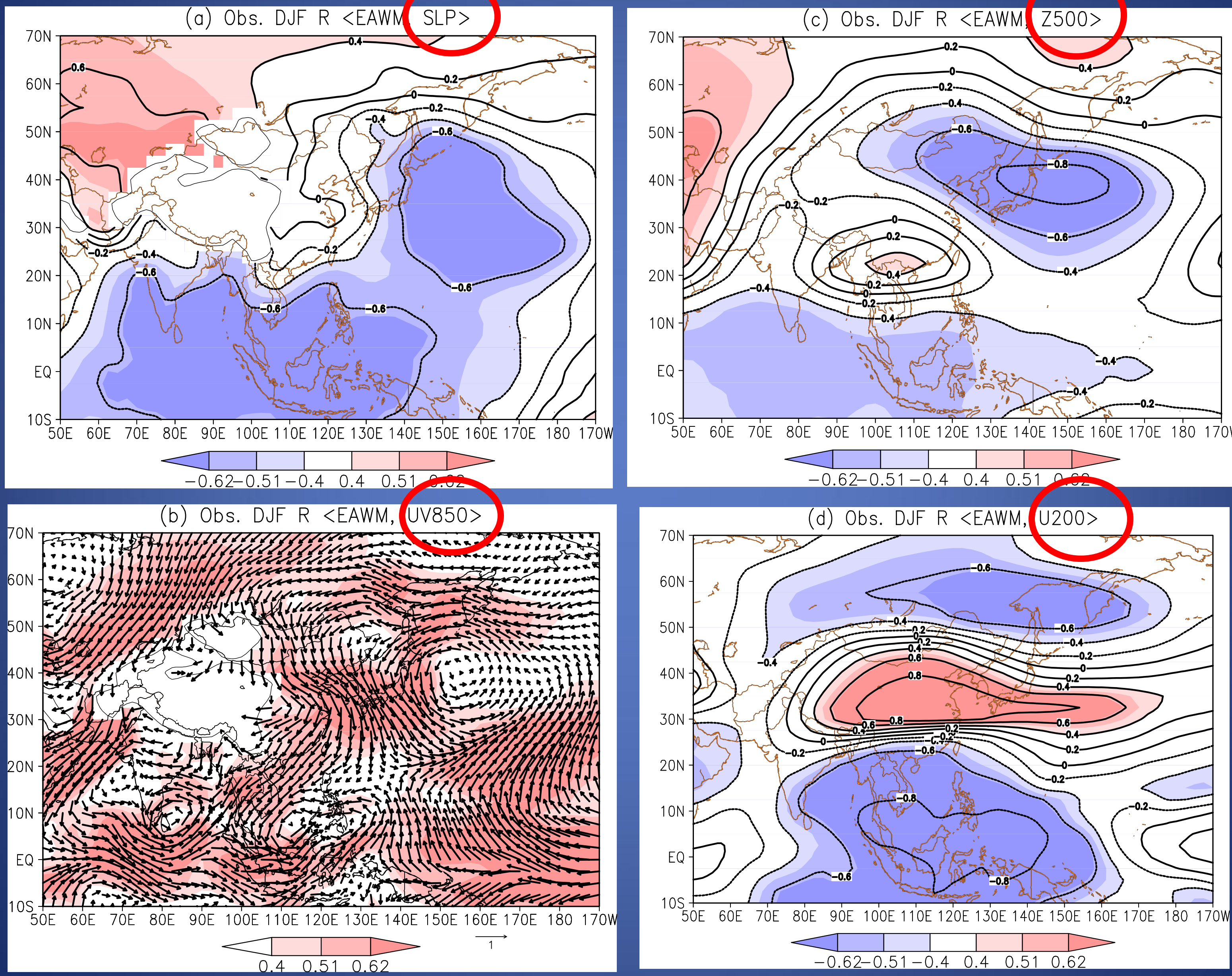
East Asian Winter Monsoon Index (EAWMI):

{[U200(30-35ºN/90-160ºE)-U200(50-60ºN/70-170ºE)]+
[U200(30-35ºN/90-160ºE)-U200(5ºS-10ºN/90-160ºE)]}/2

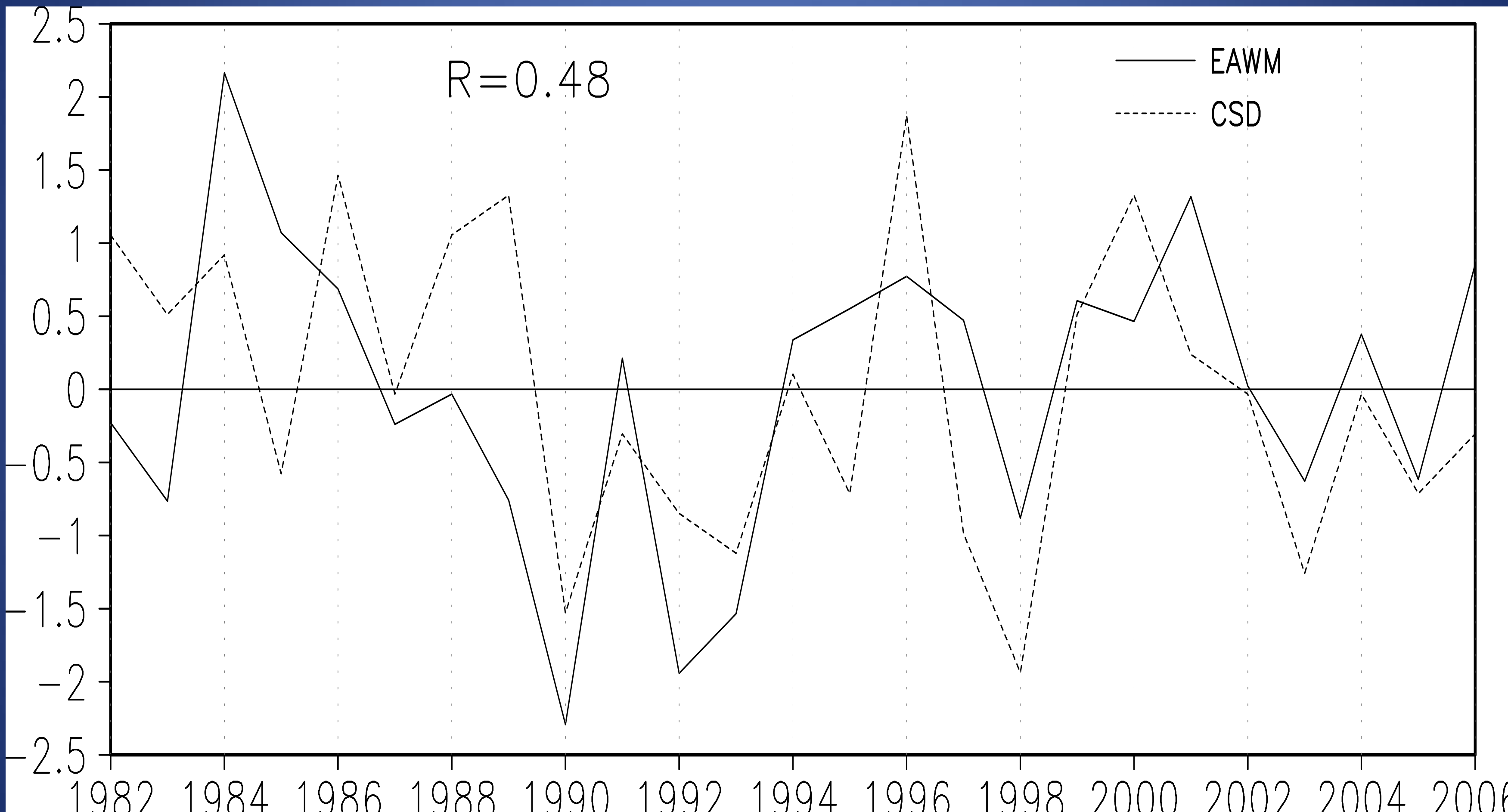
Time Series of EAWMI, EASLP, and Nino3.4 SST



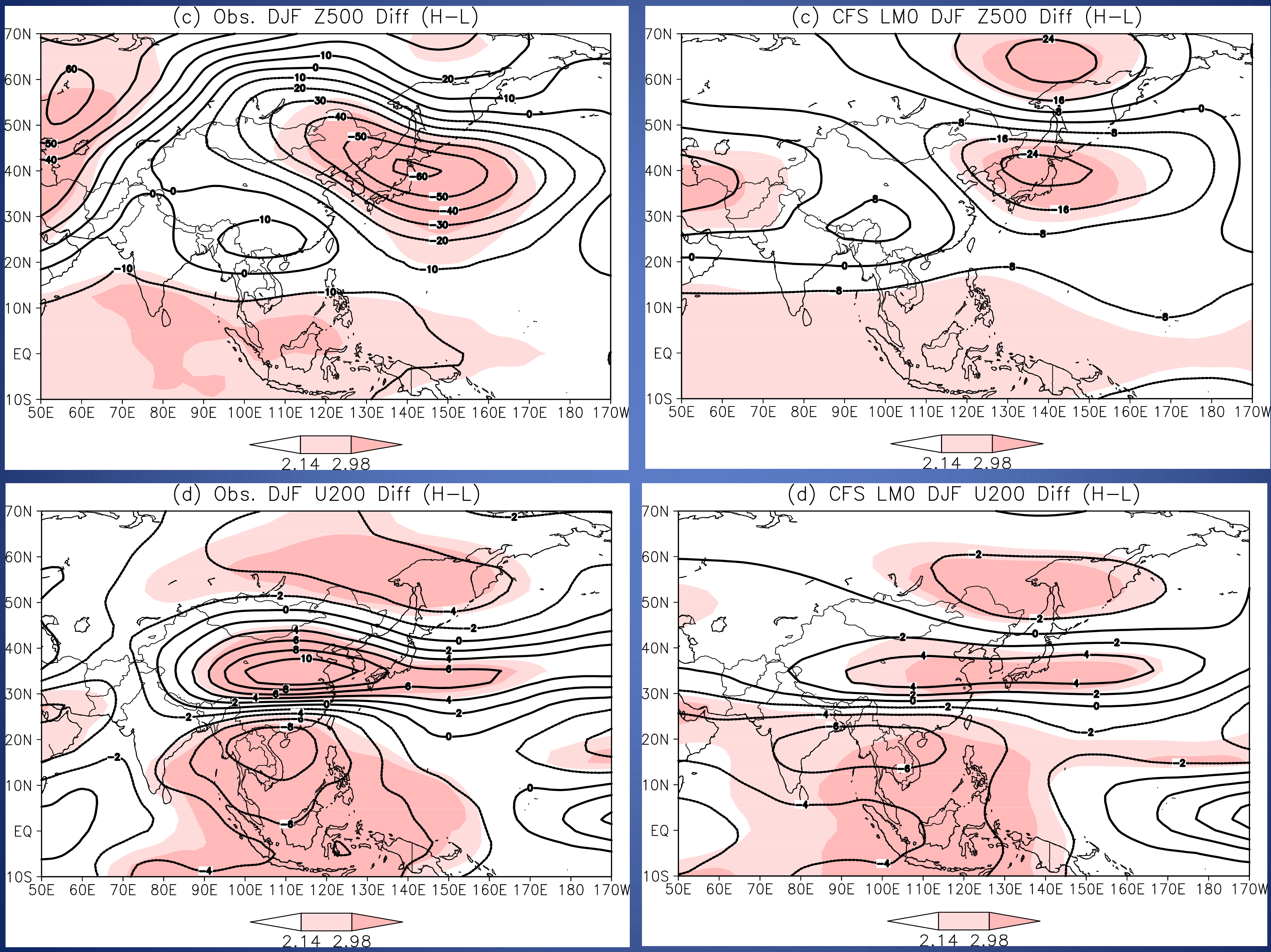
Corr of EAWMI with SLP, 850-mb Winds, Z500, and U200



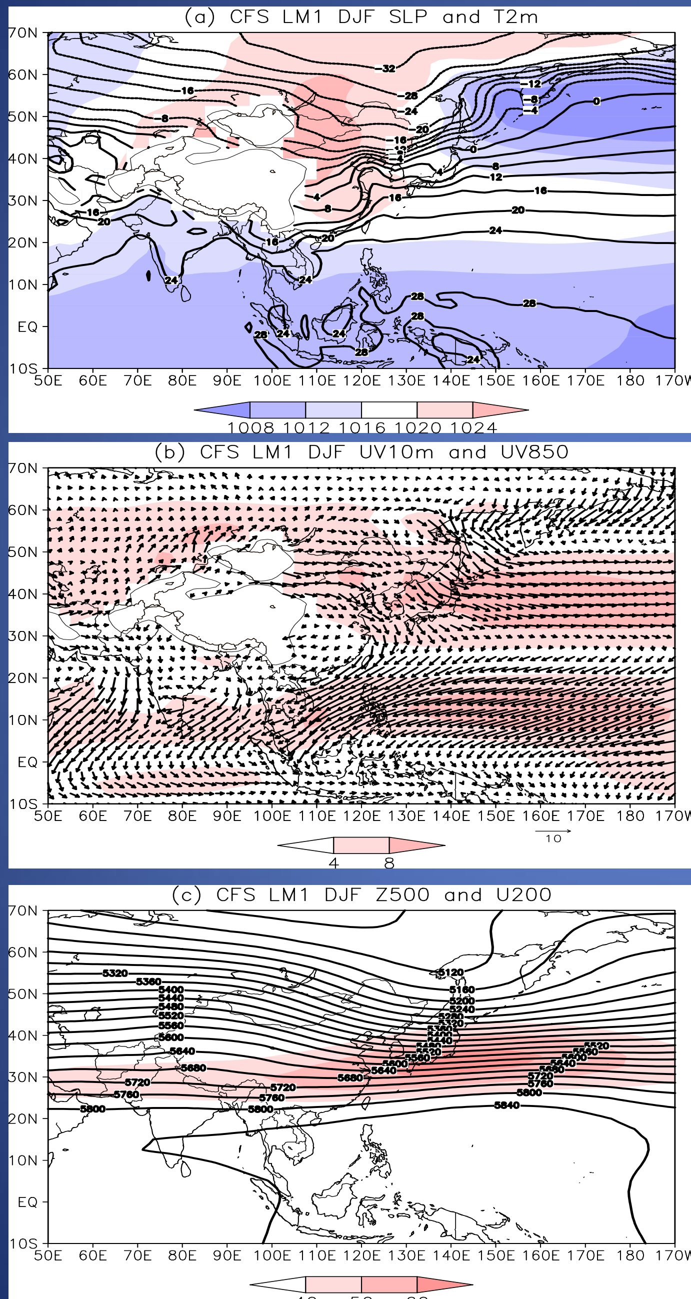
EAWMI and the Days of East Asian and Western Pacific Cold Surges Defined by Chang et al. (2005)



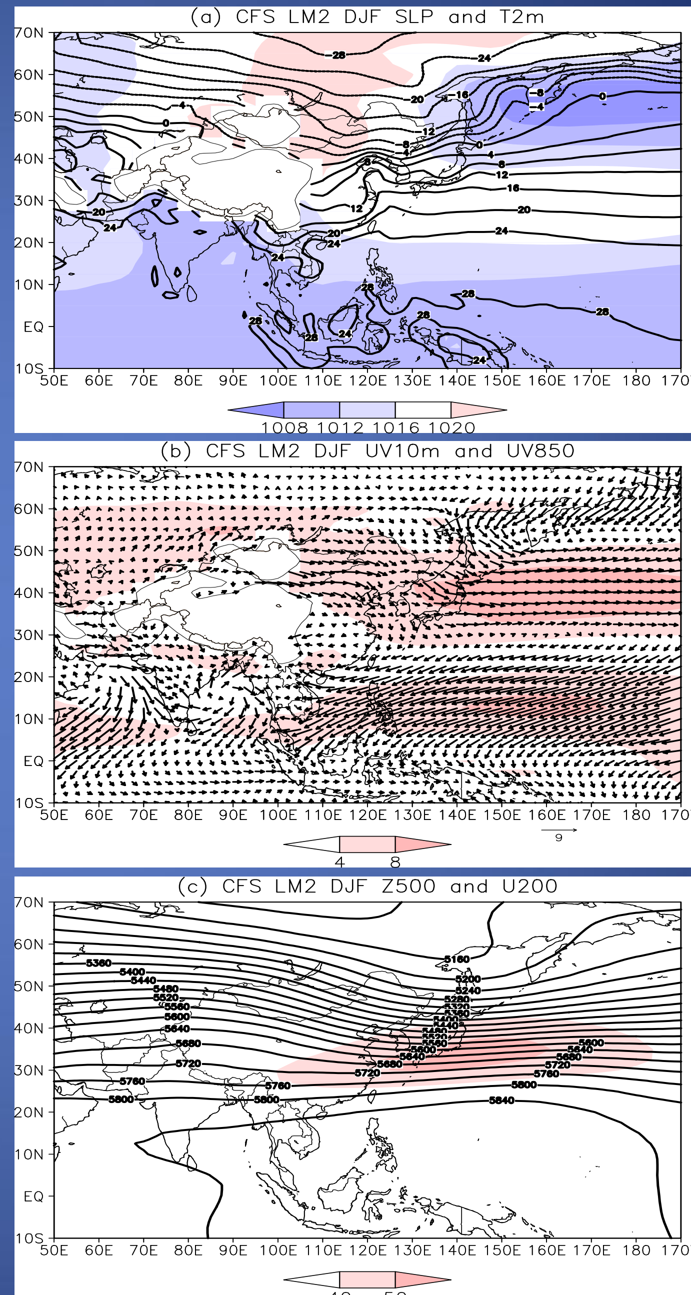
Obs and CFS LM0 Composite Patterns



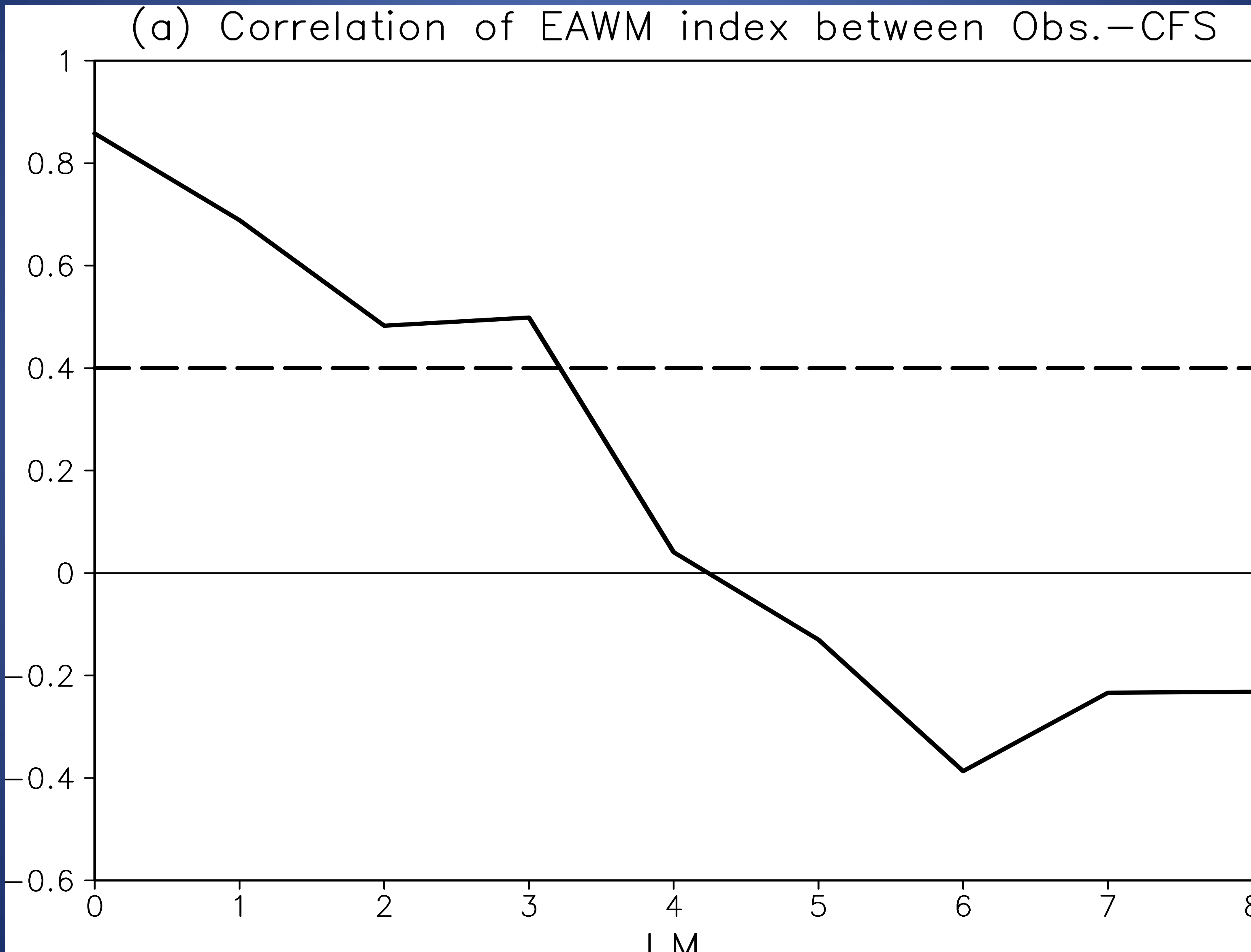
CFS LM1



CFSLM2



Correlations between Observed EAWMI and CFS-Predicted EAWMI at Various Leads



Comparison with Other Indices in Various Leads
Underlined: 99.9%; Italic: 99%; Regular: 95%

	LM0	LM1	LM2	LM3	LM4
EAWMI	**0.86**	**0.69**	0.48	0.50	
Jhun-Lee (JCLI 2004)	**0.81**	**0.69**			
Sun-Li	**0.72**	***0.57***			
Yang-Lau-Kim (JCLI 2002)	**0.65**	***0.53***			
Shi	***0.60***	0.45			
Guo	***0.53***	0.40			

3. Mei-yu, Baiu and Changma

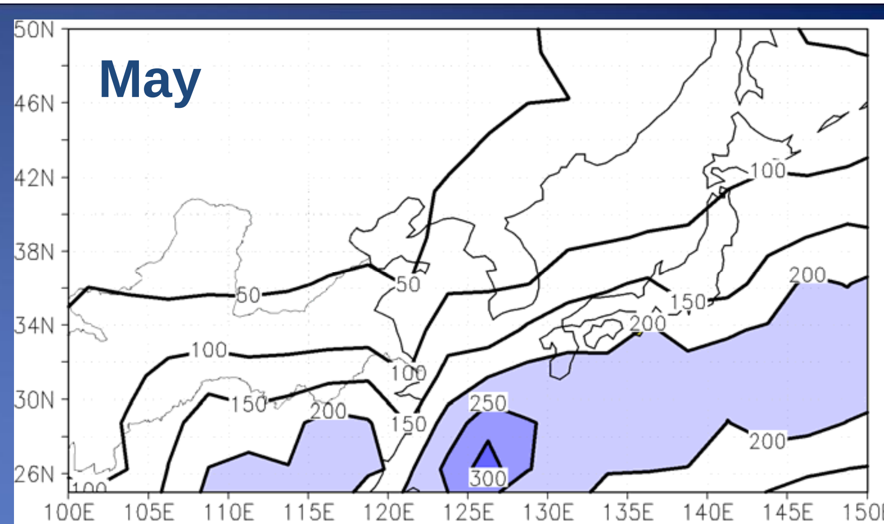
Things to Point Out

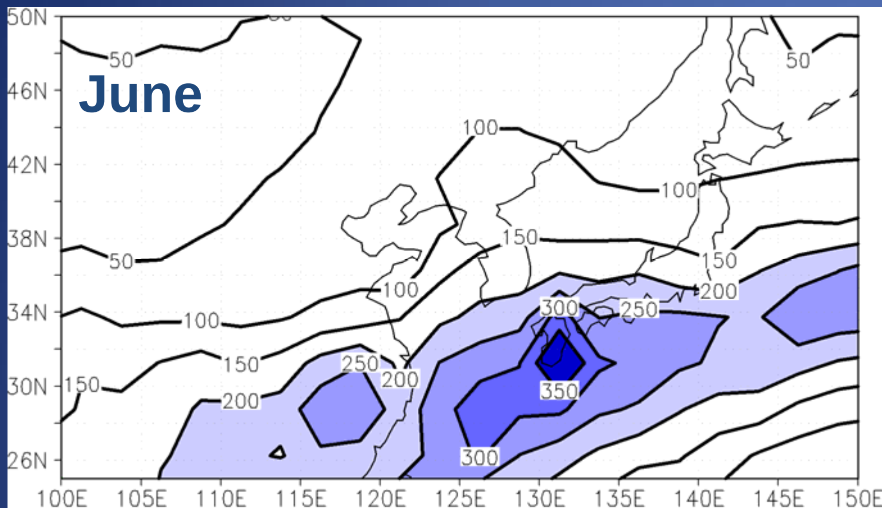
There exist few studies on the climate features of East Asian Mei-yu

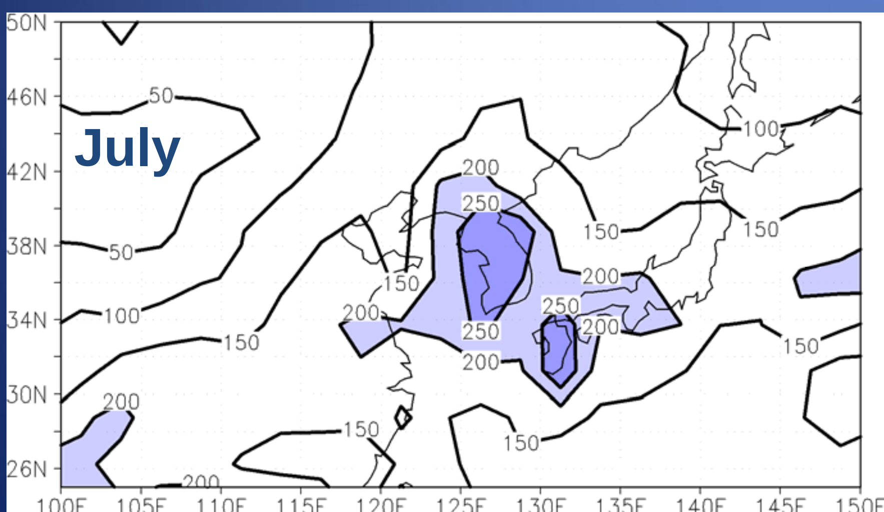
Climate models have poor skill in simulating/predicting the East Asian Mei-yu

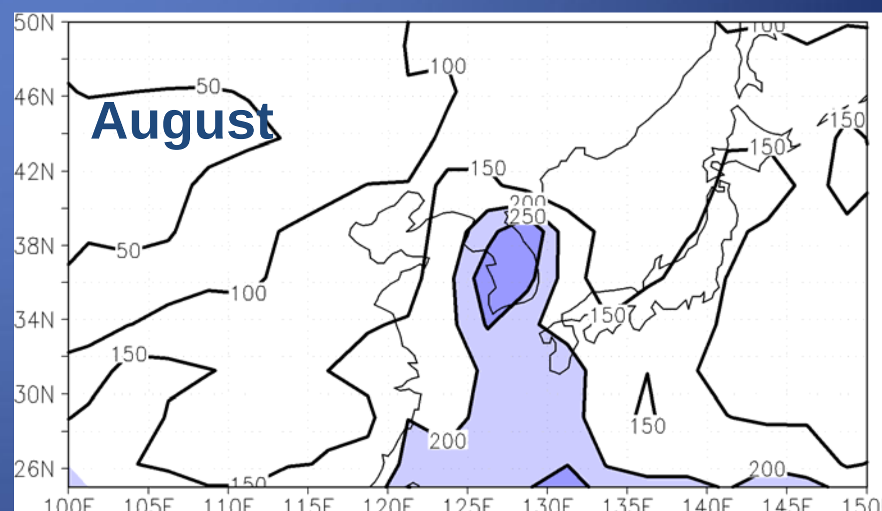
The performance of NCEP CFS in simulating/predicting East Asian Mei-yu is unknown

Monthly Climatology of Observed Rainfall

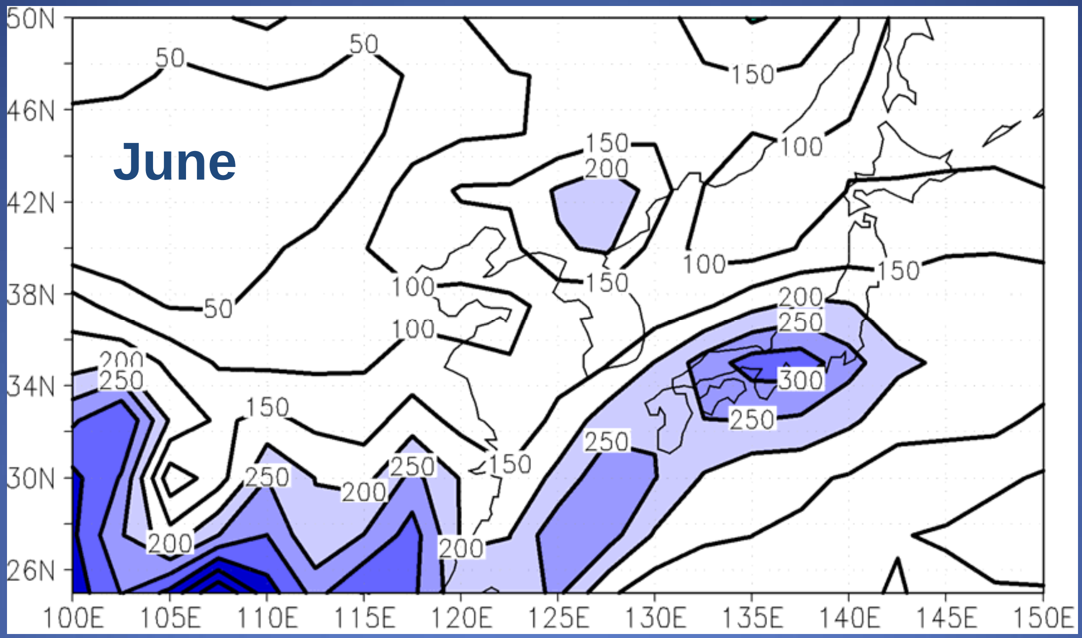


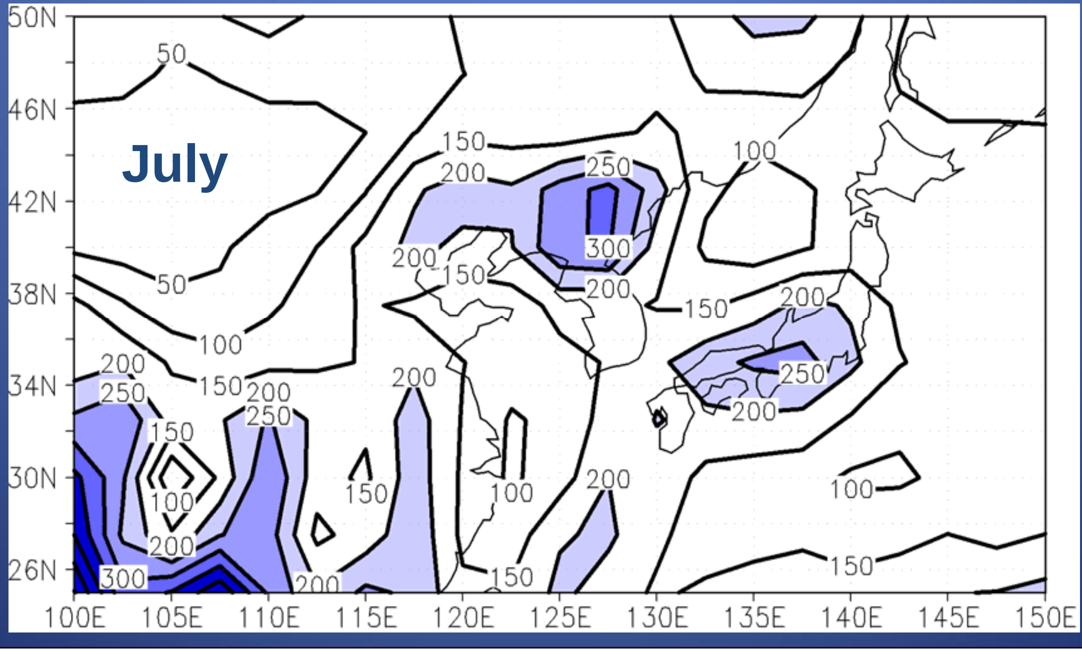






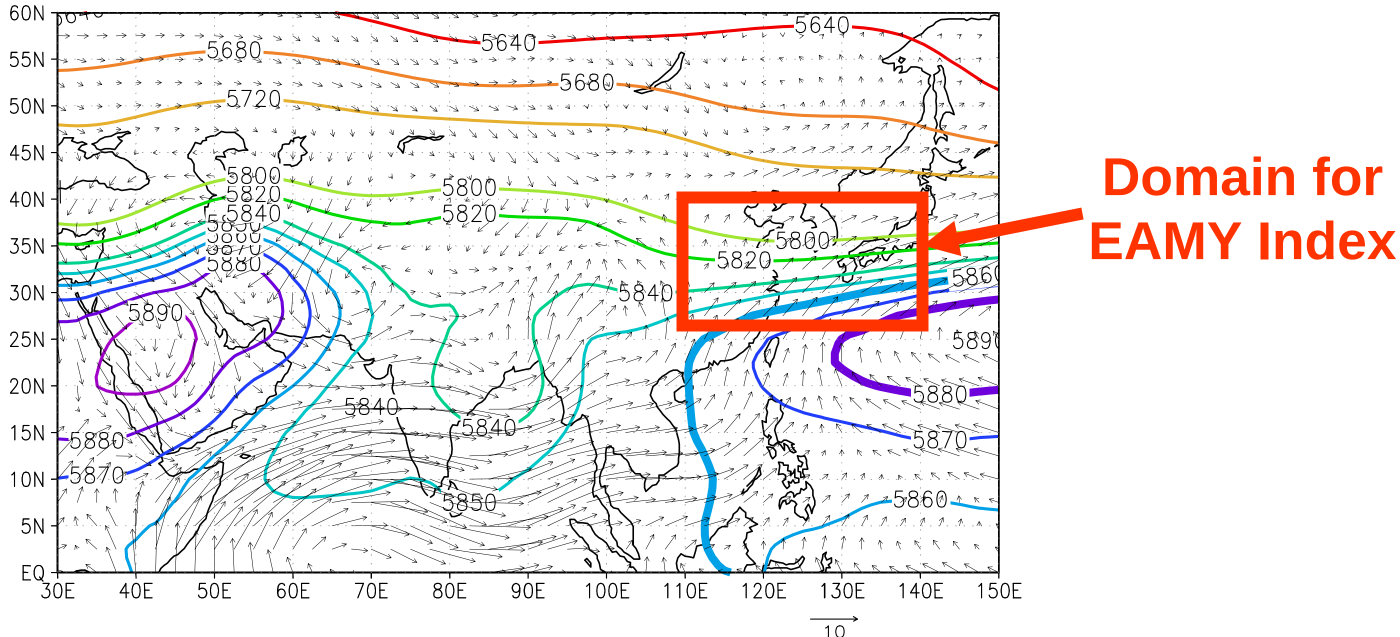
Monthly Climatology of CFS Rainfall



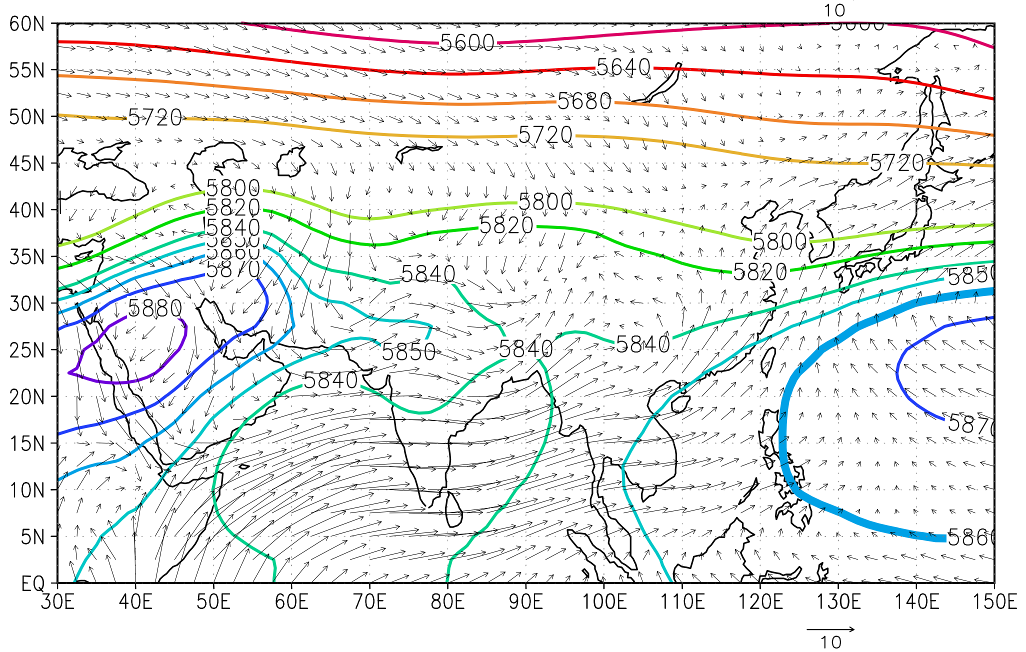


Jun-Jul Climatology of H500 and 850-mb Winds

Obs

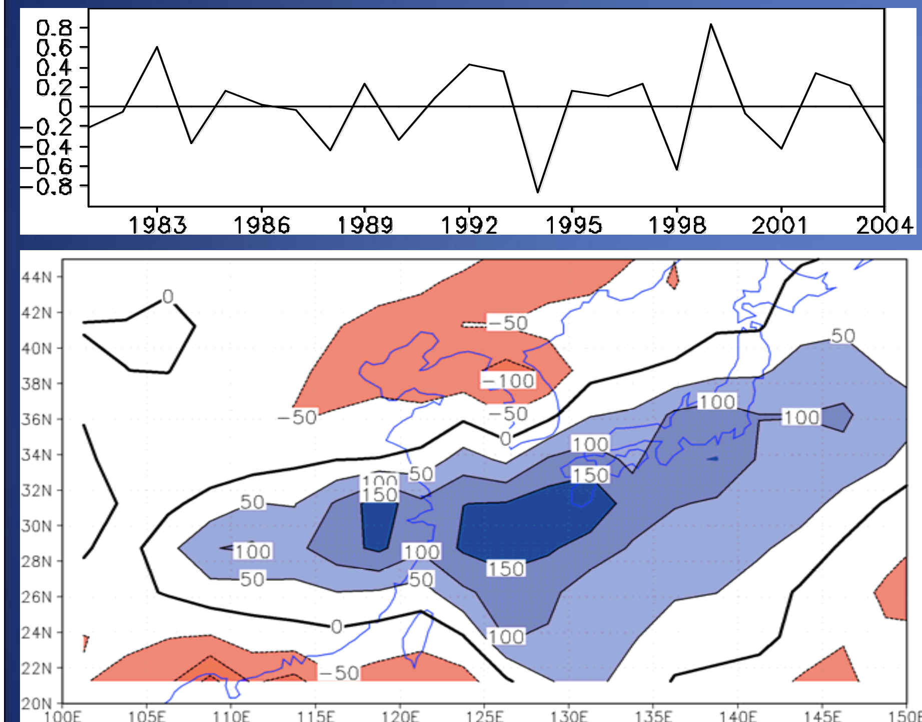


CFS

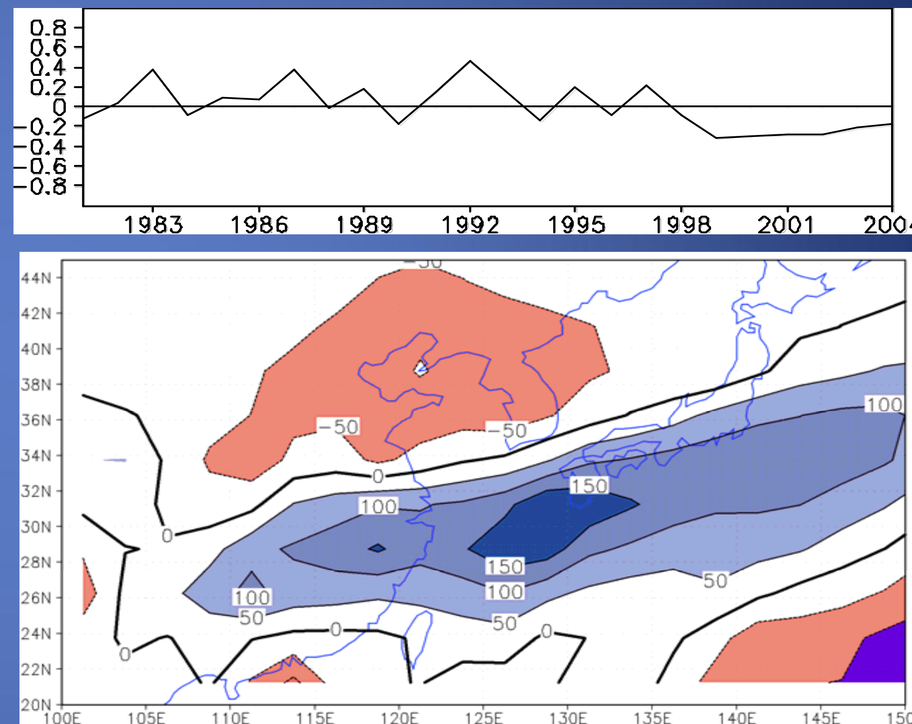


First EOF Modes of Jun-Jul CMAP and CFS Rainfall

EOF-1 of CMAP: 21.3%

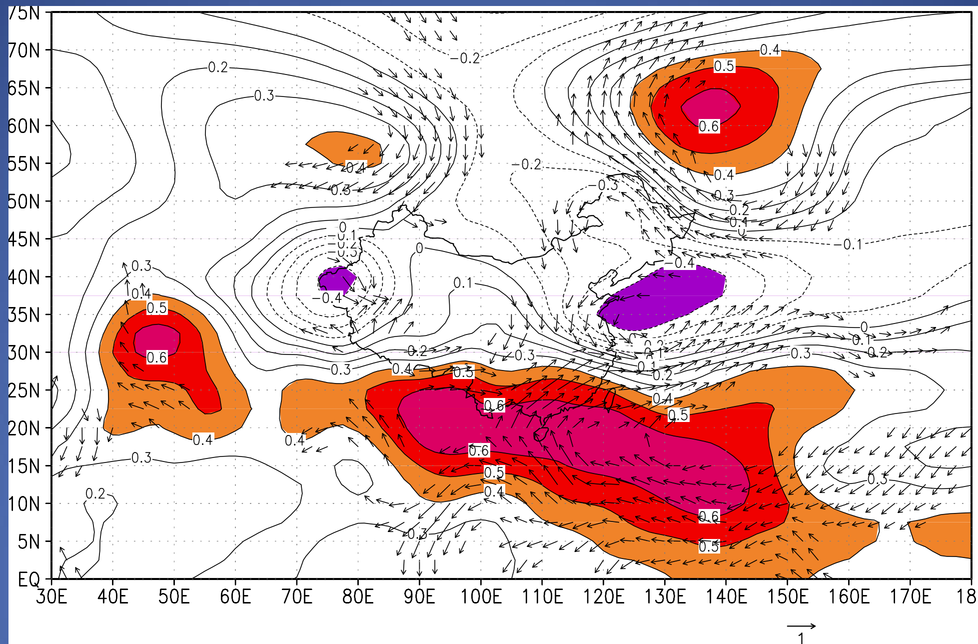


EOF-1 of CFS Ensemble: 28.0%

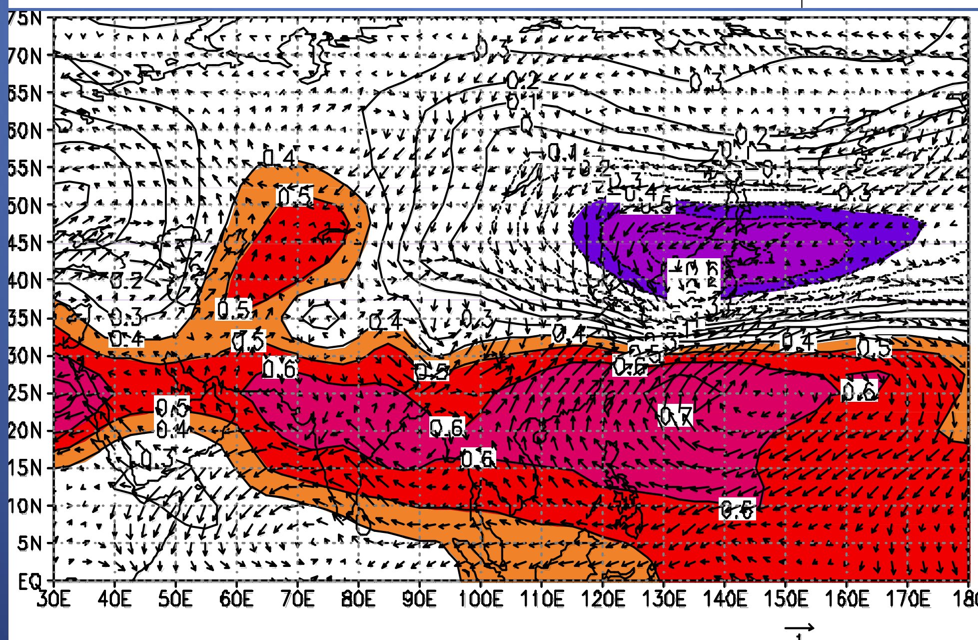


Jun-Jul Corr: EAMY with H500 & 850-mb Winds

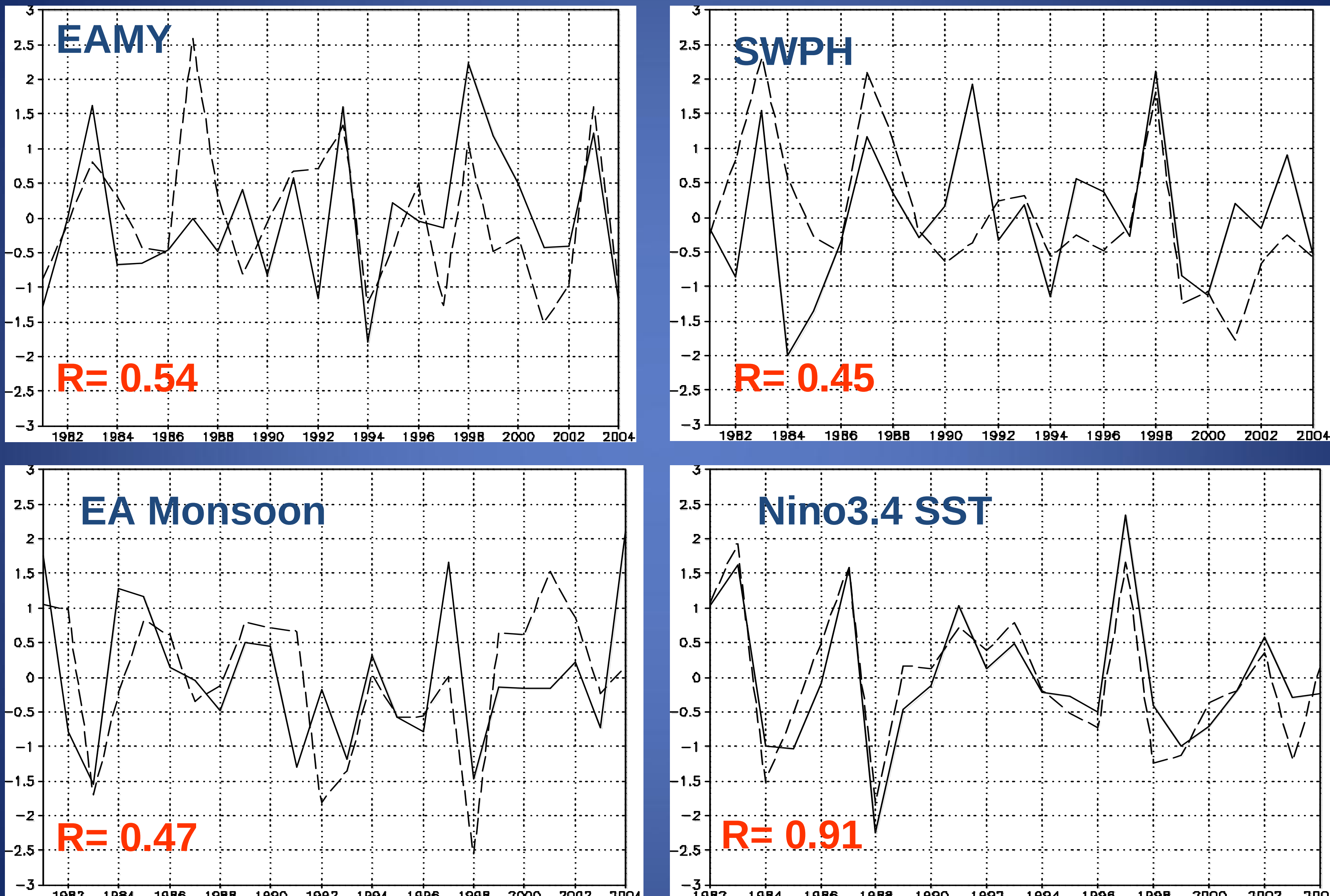
Obs



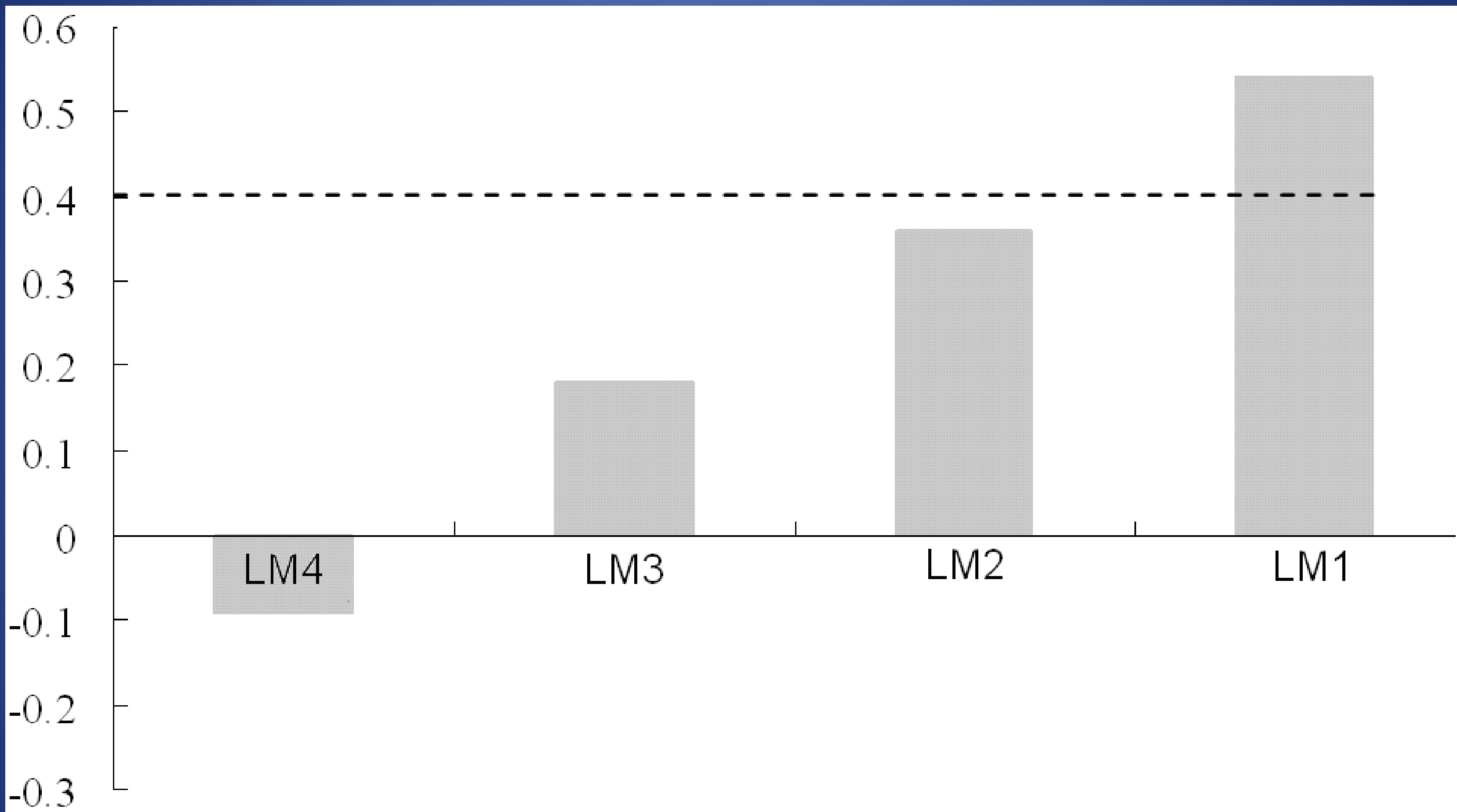
CFS



Observations (Solid) and CFS Simulations (Dash)



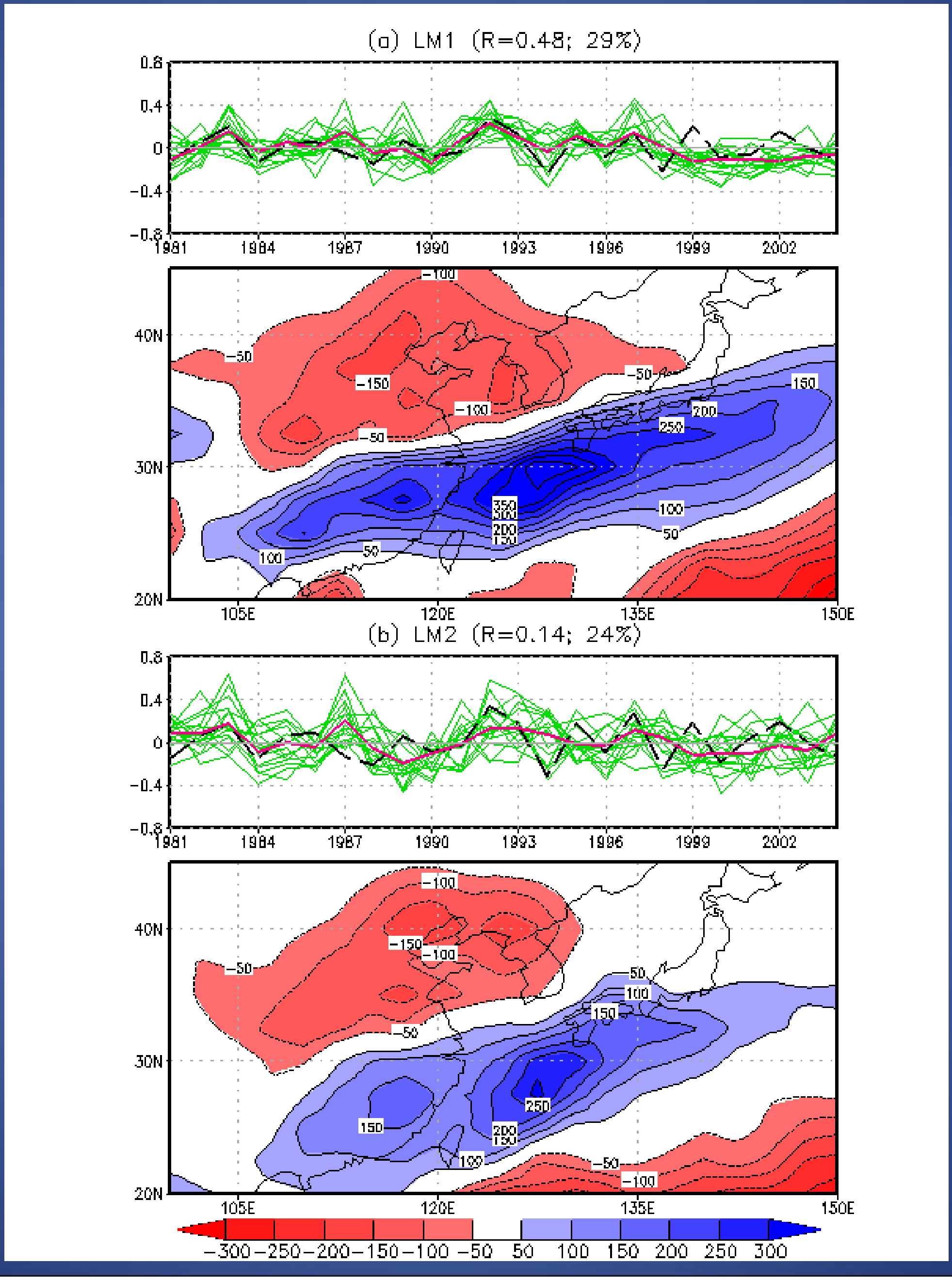
Corr of CMAP EAMY with CFS EAMY at Various Leads



Most Predictable Modes Depicted by MSN EOF

LM1

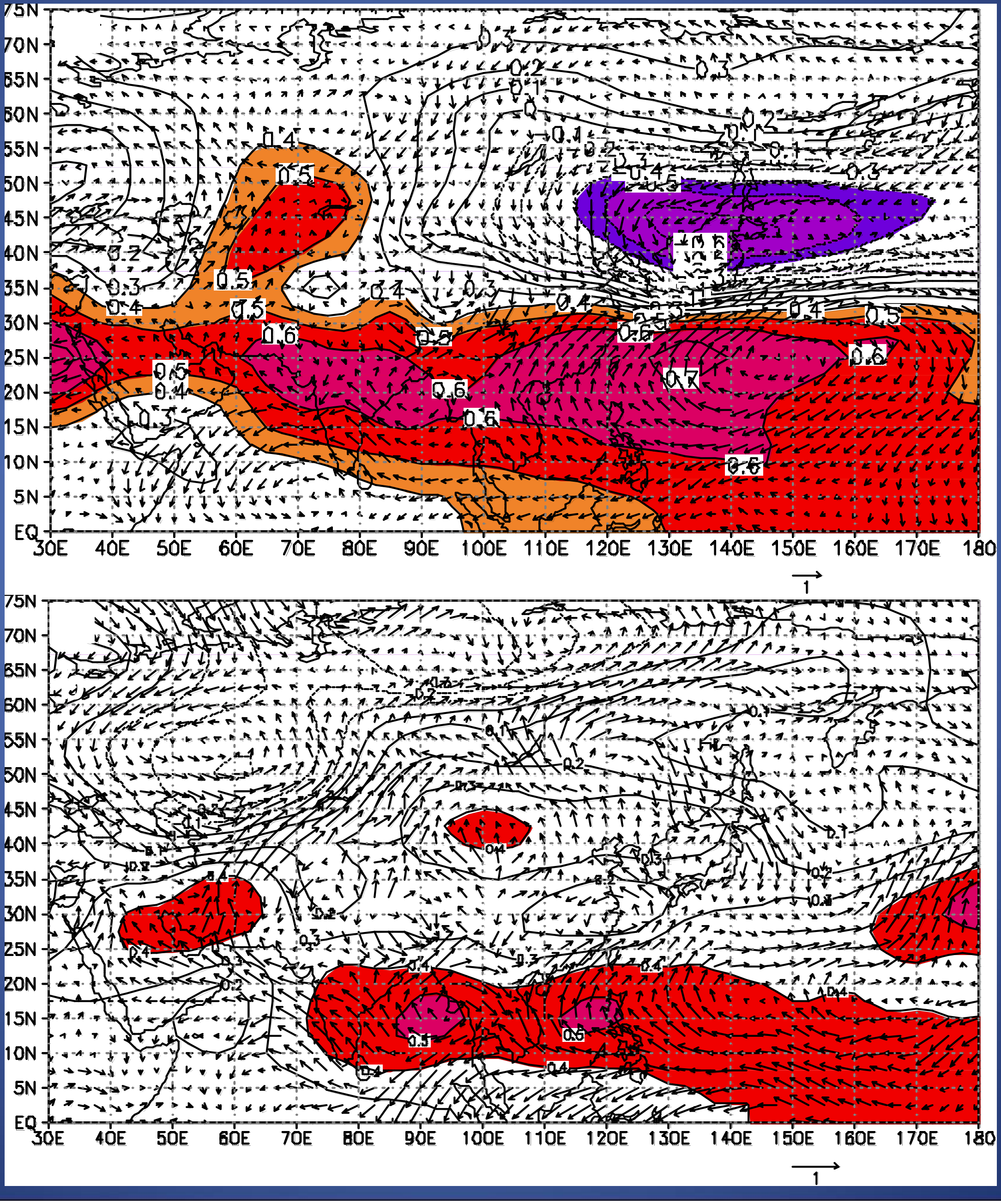
LM2



Jun-Jul Corr: EAMY with H500 & 850-mb Winds

CFS

AMIP



4. Summary

(a) Asian and Indo-Pacific Summer Monsoon

- The CFS is skillful in simulating the summer monsoon, which is the most predictable summer rainfall pattern in the model (skill from ENSO)
- Apparent improvement from T62 to T126, especially for the Tibetan plateau and the Indian Ocean
- Apparent improvement from the OSU land model to the Noah land model, especially for the cold bias over the Asian continent
- (Southern) Indian Ocean SST is important for the various monsoon components and the CFS is able to capture many features of the IO-monsoon relationships
- The CFS has a weak bias for the mean summer monsoon but overestimates the variability of monsoon on intraseasonal timescales
- The CFS is able to predict large-scale monsoon patterns in advance by several months with reasonable skills

Summary (cont.)

(b) East Asian Winter Monsoon

- Definition of a dynamical monsoon index
- As in observations, EAWM is prominent at both lower and upper troposphere and interactive with both high- and low-latitude systems in the CFS. It has strong relationships with ENSO, AO, Siberian high, East Asian trough, westerly jet stream, and cold surges).
- The CFS is able to predict EAWM in advance by 3 months with reasonable skills

(c) East Asian Mei-yu (Chinese Mei-yu, Japanese Baiu, and Korean Changma)

- EAMY is the most dominant mode and the most predictable pattern of mid-summer monsoon rainfall
- EAMY has strong relationships with ENSO, the subtropical northwestern Pacific high, and East Asian summer monsoon circulation
- As for the tropical monsoons, air-sea interaction is important for EAMY simulation & prediction
- The CFS is able to predict EAMY in advance by one month