

# **SUBTROPICAL PREDICTABILITY**

## **Establishes a promising way for ASIAN MONSOON AND TROPICAL STORM PREDICTION**

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**Precipitation is the most relevant meteorological variable to food production and water resources**

**Seasonal prediction of precipitation is very **tough**– a long standing challenge.**

**Improving climate model prediction system**

**Multi-model ensemble prediction**

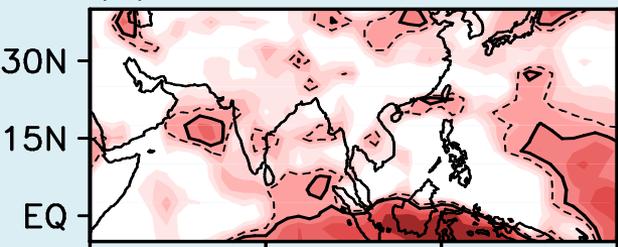
# The CLIPAS-ENSEMBLES MME System



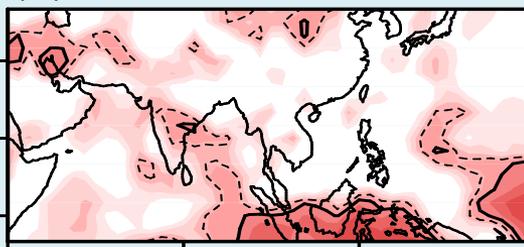
Institute	Model Name	AGCM	OGCM	Ensemble member	Reference
<b>ABOM</b>	POAMA1.5	BAM 3.0d T47 L17	ACOM3 0.5-1.5° lat x 2.0° lon L31	10	Zhong et al (2005)
<b>GFDL</b>	CM2.1	AM2.1 2°lat x 2.5°lon L24	MOM4 1/3°lat x 1°lon L50	10	Delworth et al (2006)
<b>NCEP</b>	CFS	GFS T62 L64	MOM3 1/3°lat x 5/8°lon L27	15	Saha et al (2006)
<b>SNU</b>	SNU	SNU T42L21	MOM2.2 1/3°lat x 1°lon L40	6	Kug et al (2008)
<b>CMCC-INGV</b>	CMCC	ECHAM5 T63 L19	OPA 8.2 2.0° x2.0° L31	9	Alessandri et al (2011) Pietro and Masina (2009)
<b>ECMWF</b>	ECMWF	IFS CY31R1 T159 L62	HOPE-E 1.4° x 0.3°-1.4° L29	9	Stockdale et al. (2011) Balmaseda et al. (2008)
<b>IFM-GEOMAR</b>	IFM	ECHAM4 T42 L19	OPA 8.2 2.0° lat x 2.0° lon L31	9	Keenlyside et al. (2005) Jungclaus et al. (2006)
<b>MF</b>	MF	IFS T95 L40	OPA 8.0 182GPx152GP L31	9	Daget et al. (2009) Salas Melia (2002)
<b>UKMO</b>	UKMO	ECHAM5 T42 L19	MPI-OM1 2.5° lat x 0.5°-2.5° lon L23	9	Collins et al. (2008)

# Temporal Correlation Coefficient (1981–2005)

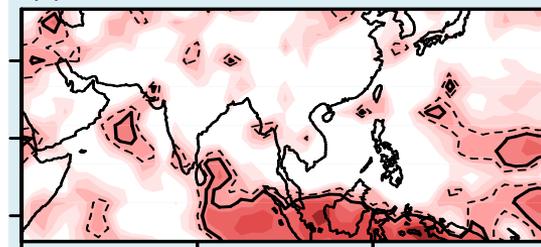
(a) One-Tier MME



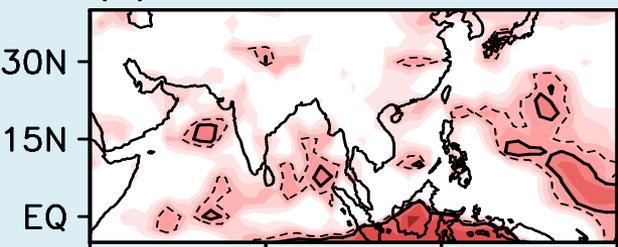
(e) SNU



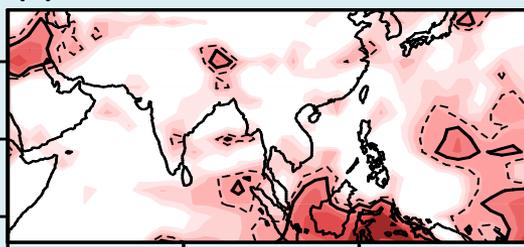
(i) MF



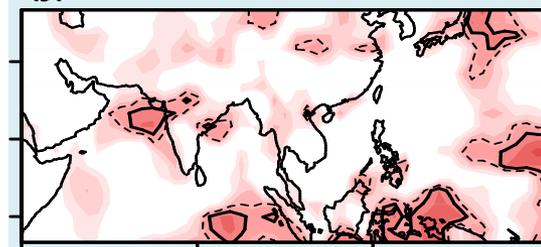
(b) ABOM



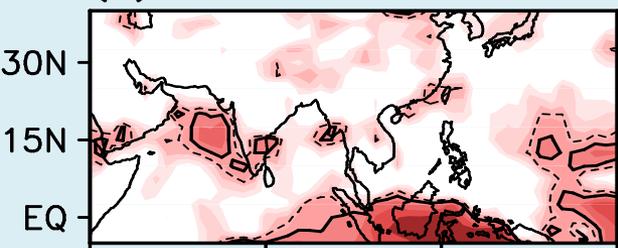
(f) CMCC-INGV



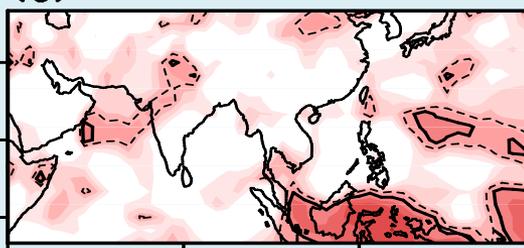
(j) UKMO



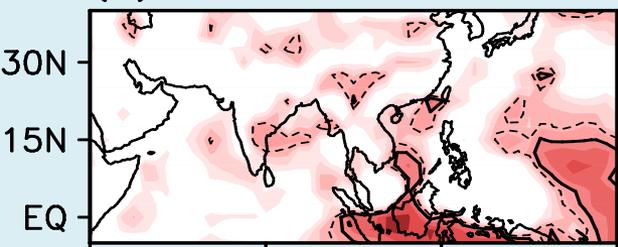
(c) GFDL



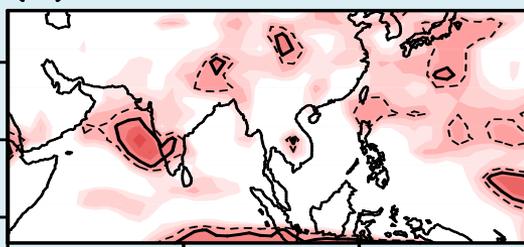
(g) ECMWF



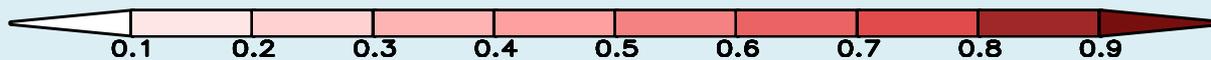
(d) NCEP



(h) IFM



**Current skills for Prediction of SM rainfall is far from satisfactory**

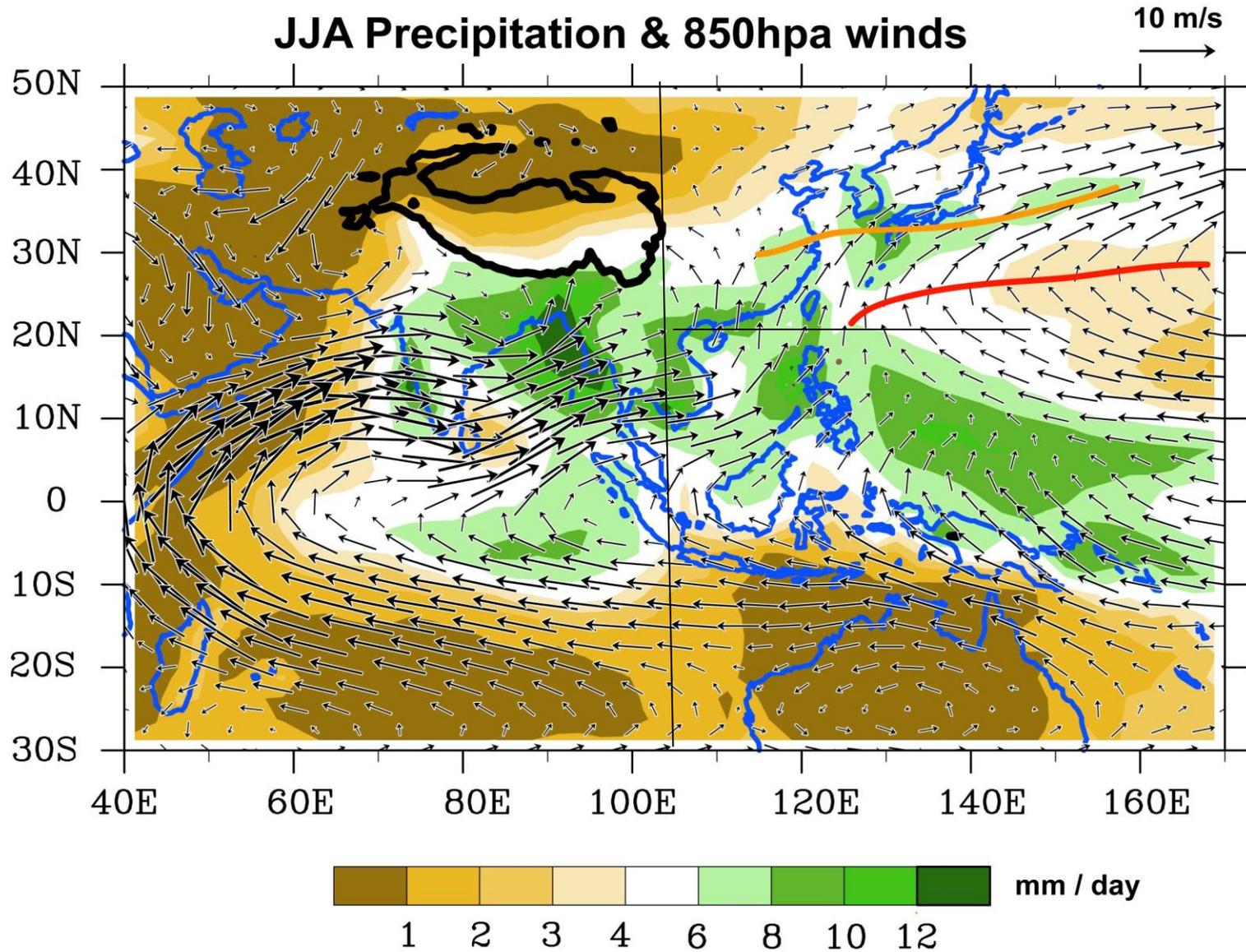


Given the limited skills of the current models, **Is there anything else we can do beside MME?**

**A new thrill:**

Use the high predictability of the **controlling circulation systems** to improve rainfall prediction and to do something the models cannot do

# Asian summer monsoon circulation system



Variations of WPSH is of utmost importance for seasonal forecast of EASM rainfall and WNP TS activity, (Tao and Chen 1987, Nita 1987, Wu et al. 2002, Wang et al. 2001, Lau and Weng 2002),

Yet the causes of the WPSH variability remains debated and the predictability of the WPSH has not been established.

**Strong WNPSH** often occurs during El Nino decaying year (e.g., Fu 1979)

**Two mechanisms:**

**1. WPSH-Ocean interaction**

(*Wang et al., 2000, Wang and Zhang 2002, Lau et al. 2005, Lau and Nath 2010*).

**2. Indian Ocean (IO) SST forcing**

(*Wu and Liu 1995; Yang et al., 2007; Wu et al., 2009; Kim et al., 2009; Li et al., 2008; Xie et al., 2009, 2010; Chowdary et al., 2010*).

However, only about half of the strong WPSH events are **related to IO warming or El Nino decay.**

It is necessary to reshape conventional thinking on the causes of the WPSH variation....

I. How to measure the year-to-year variation of the WPSH?

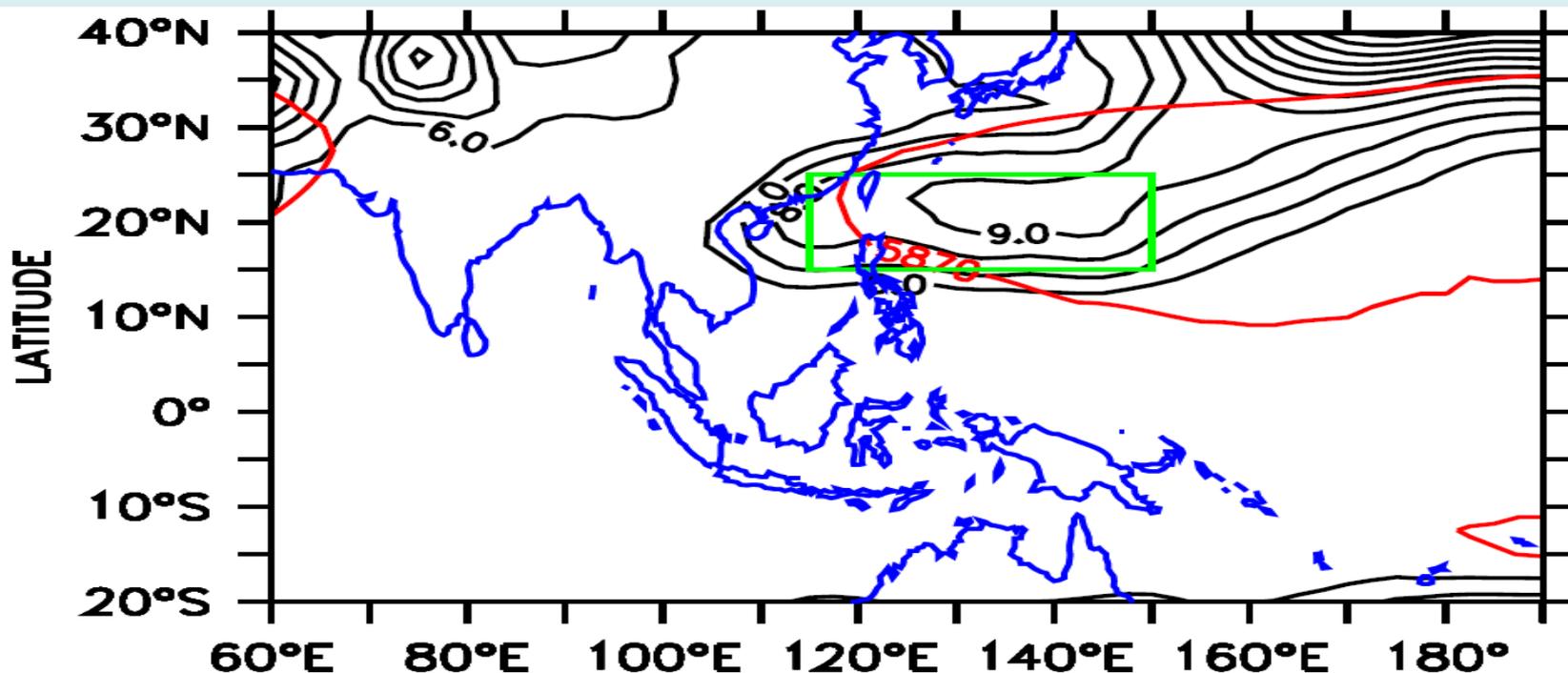
II. What determines WPSH interannual variability?

III. How predictable is the WPSH?

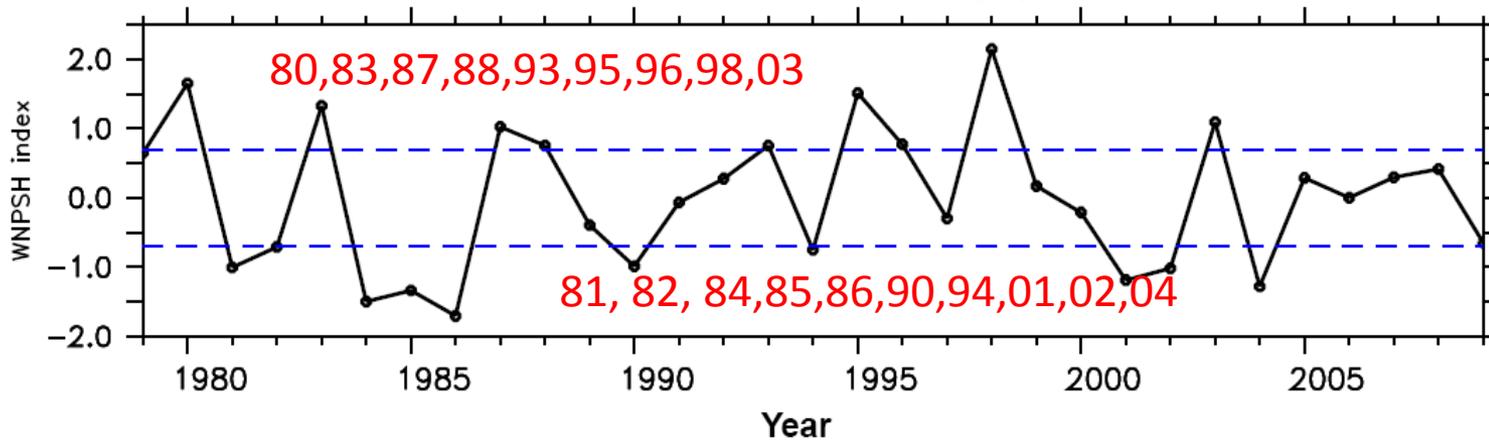
IV. Can WPSH predictability benefit EASM rainfall and WNP TS predictions?

# I. WPSH Index and its representation of the EASM and WNP tropical storms (TSs)

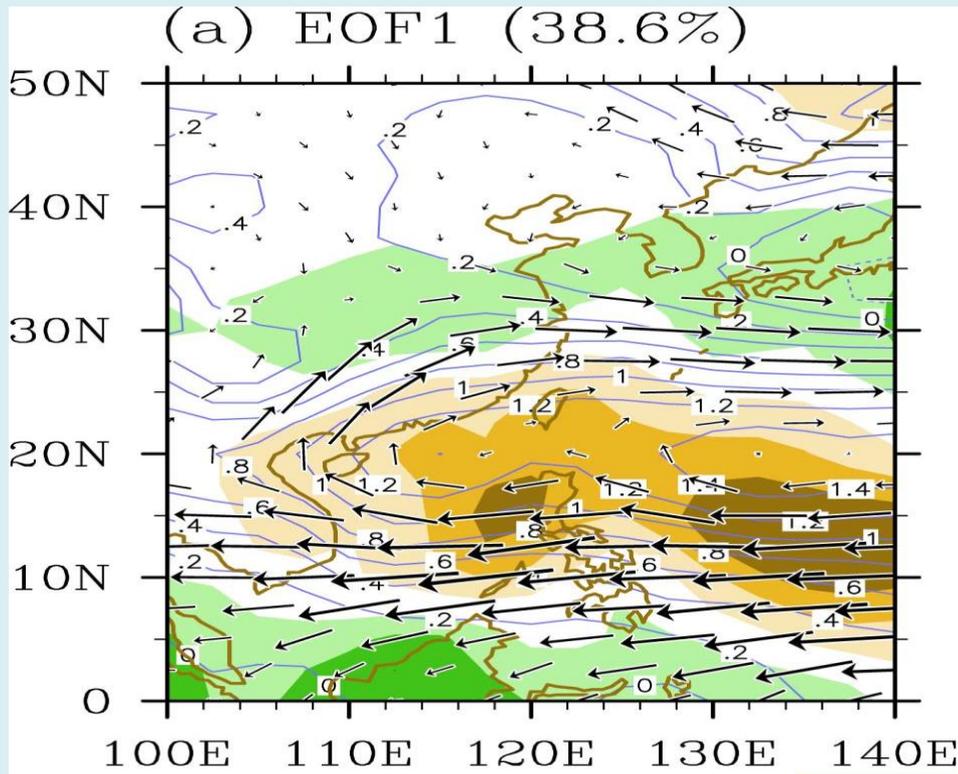
# WPSH Index: a measure at the Variability center of the H850 hPa



b **WNPSH index:** Normalized JJA H850 anomaly (15°N-25°N, 115°E-150°E)



# WPSH Index reflects the leading mode of EA-WPSM

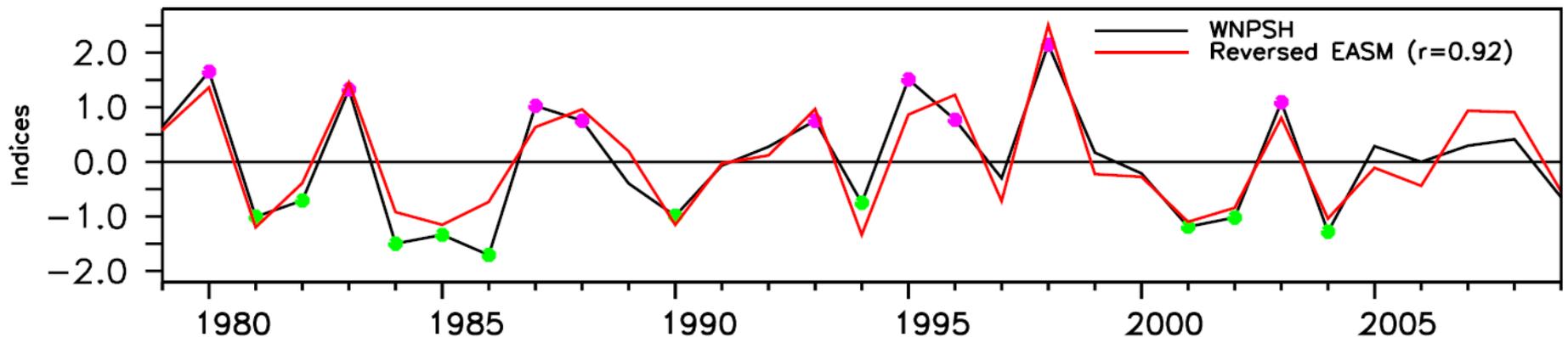


## The leading mode of EA-WPSM

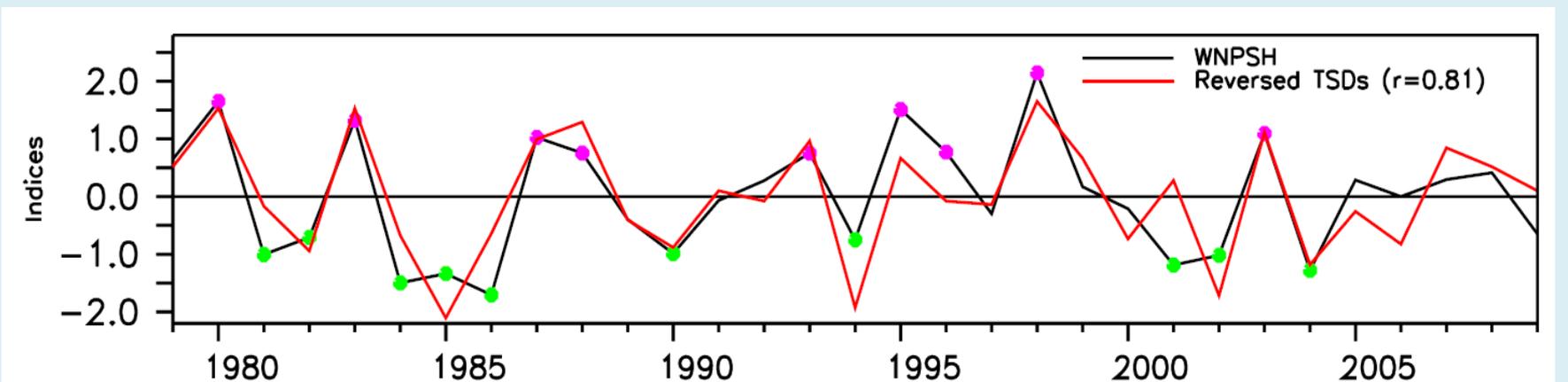
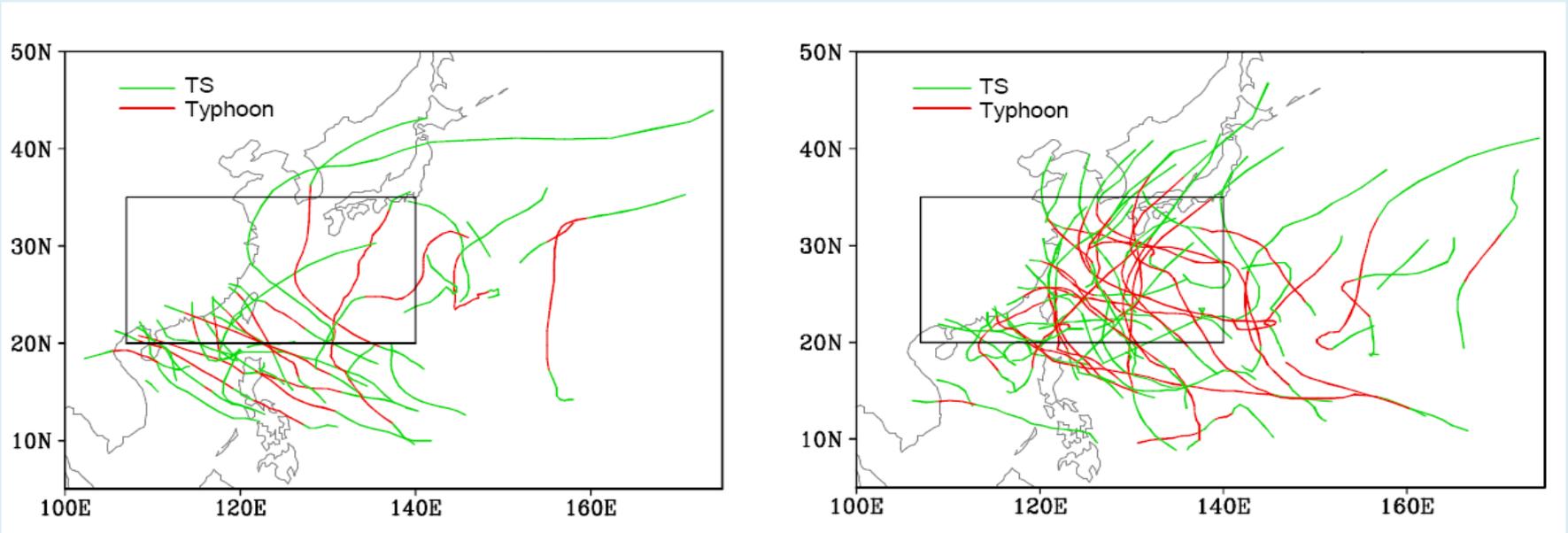
MV-EOF1: Precipitation, winds at 850 hPa and 200 hPa, and SLP.

Wang et al. 2009

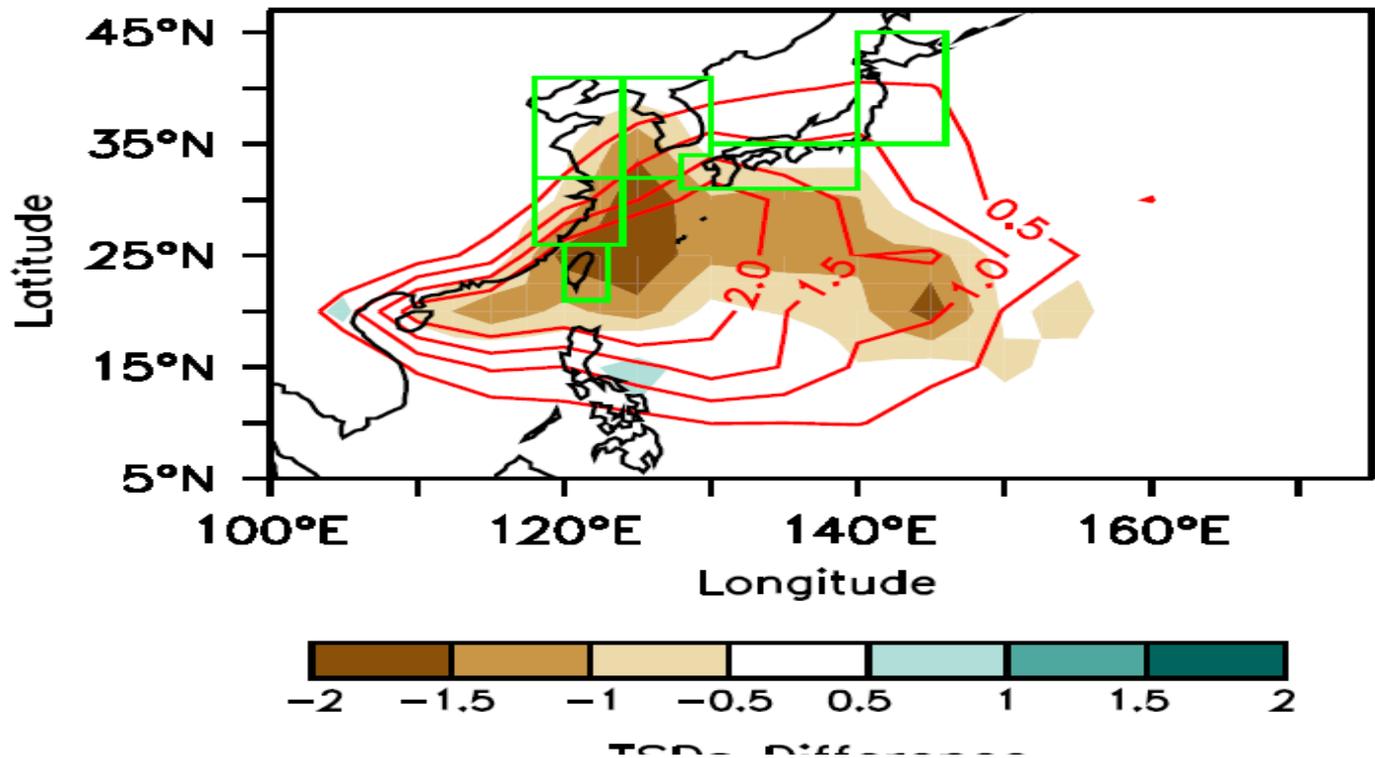
**WPSH Index and the EASM PC1:  $R=0.92$**



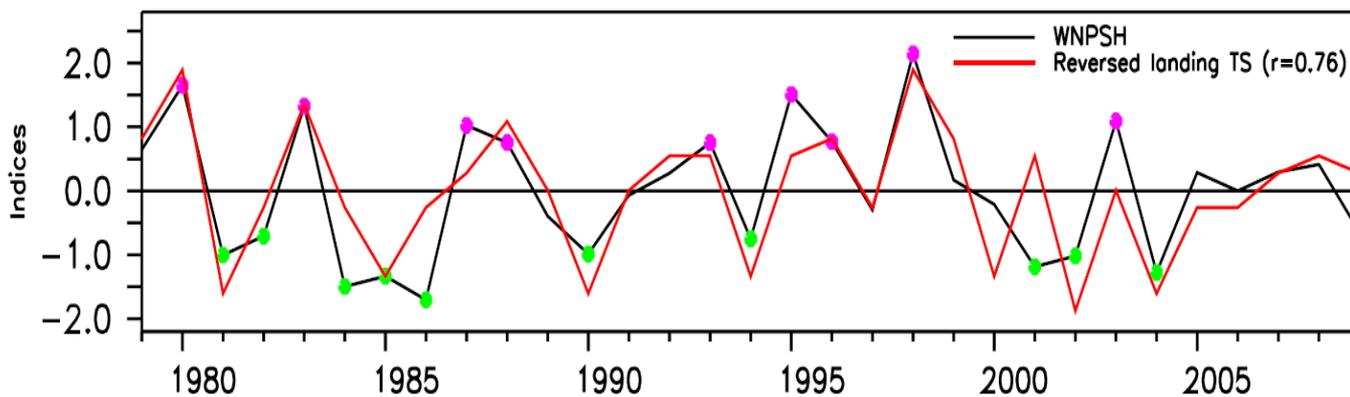
TS tracks for the 4 extremely strong WPSH years (left) and for the 4 extremely weak WPSH years (right).



# WPSH Index and the number of tropical storms affecting EA coastal areas



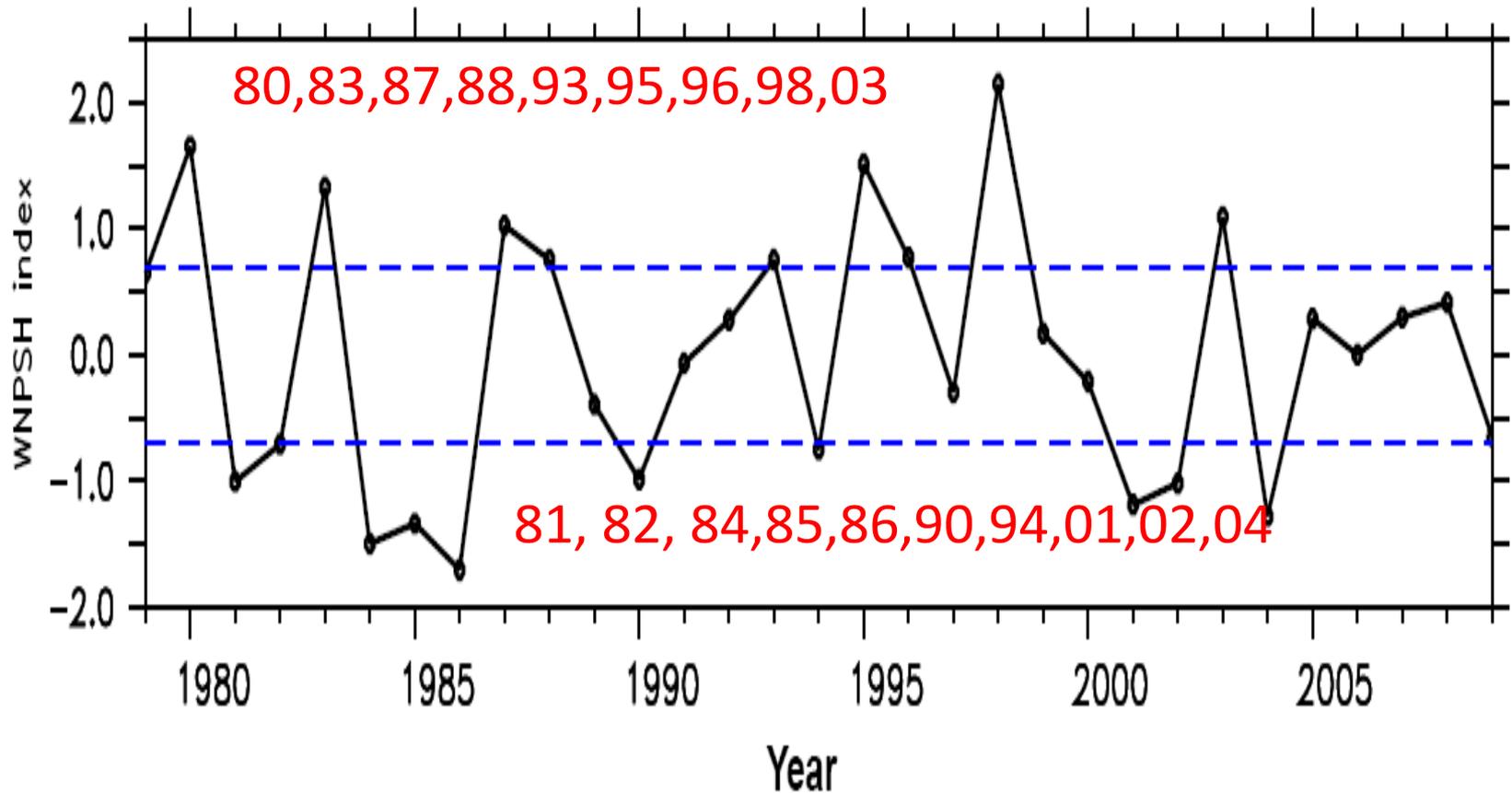
JJA TSDs:  
Climatology (contours) and the difference (shading) between 9 strong and 10 weak WPSH cases.



WPSHI and reversed TS numbers in six coastal regions ( $R=0.76$ ).

II. What control  
interannual variability of  
the WPSH?

# WPSH Index (1979-2009)



Simultaneous correlation coefficient with ENSO index: -0.12 (1979-2010)

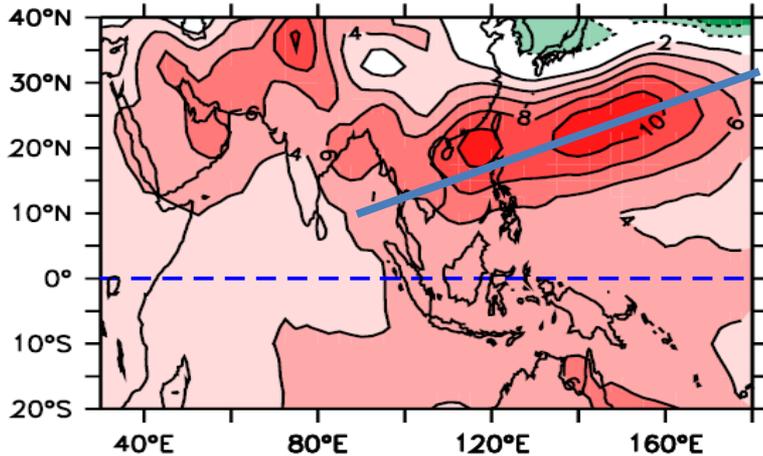
# Approach to answer this question

What are the major modes of the variability?

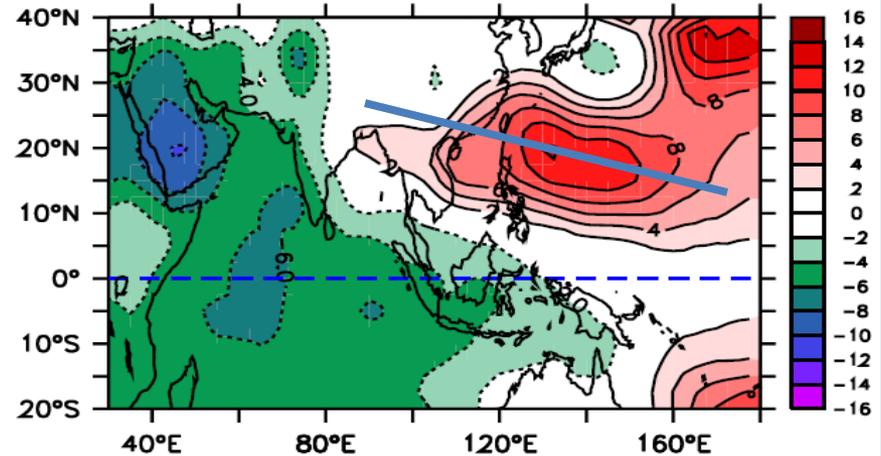
What controls the major modes of variability?

# Principal modes analysis

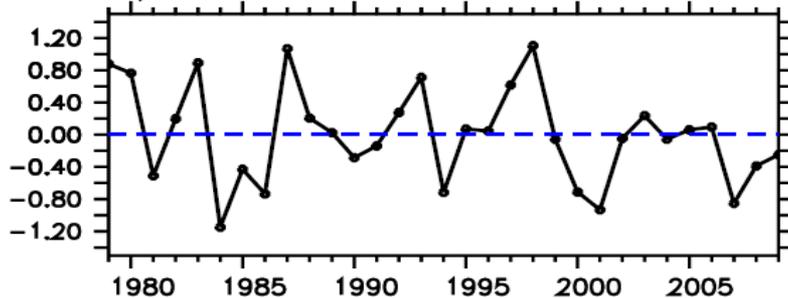
a) EOF-1 of H850 (31.2)



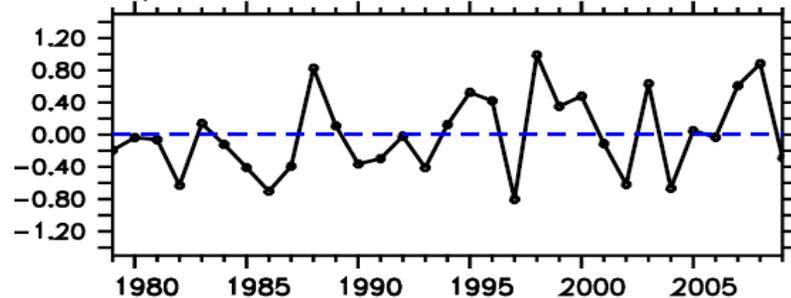
b) EOF-2 of H850 (20.9)



c) Time Series of EOF1



d) Time Series of EOF2



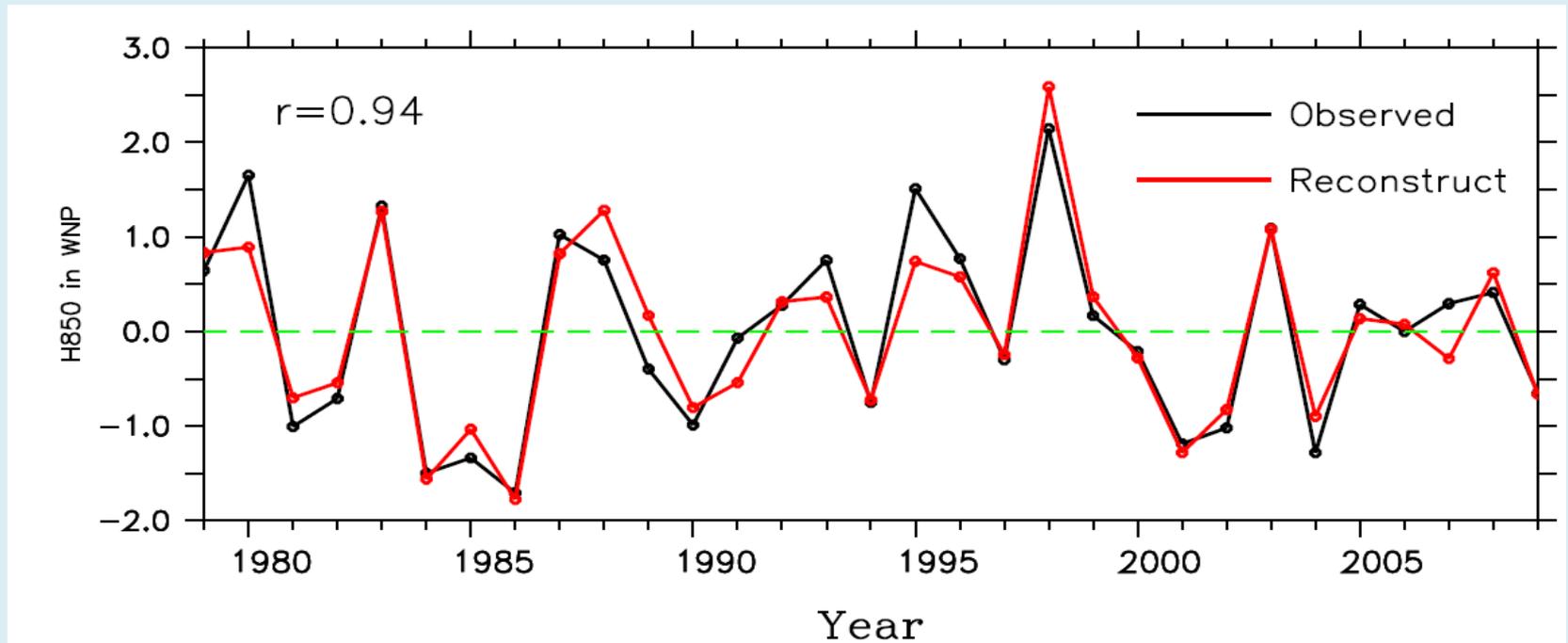
Cor with WPSHI

$r=0.60$

$r=0.73$

First two leading EOF modes of JJA 850 hPa GPH anomaly

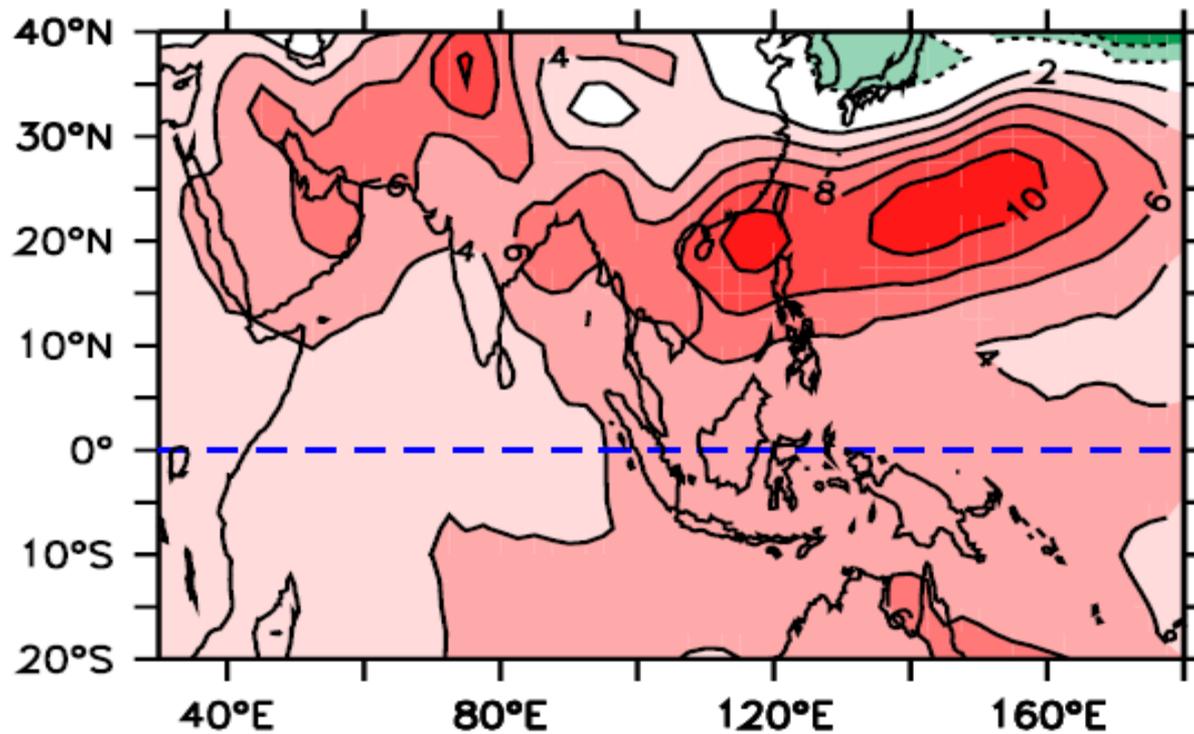
# WPSHI can be represented by PC1 and PC2



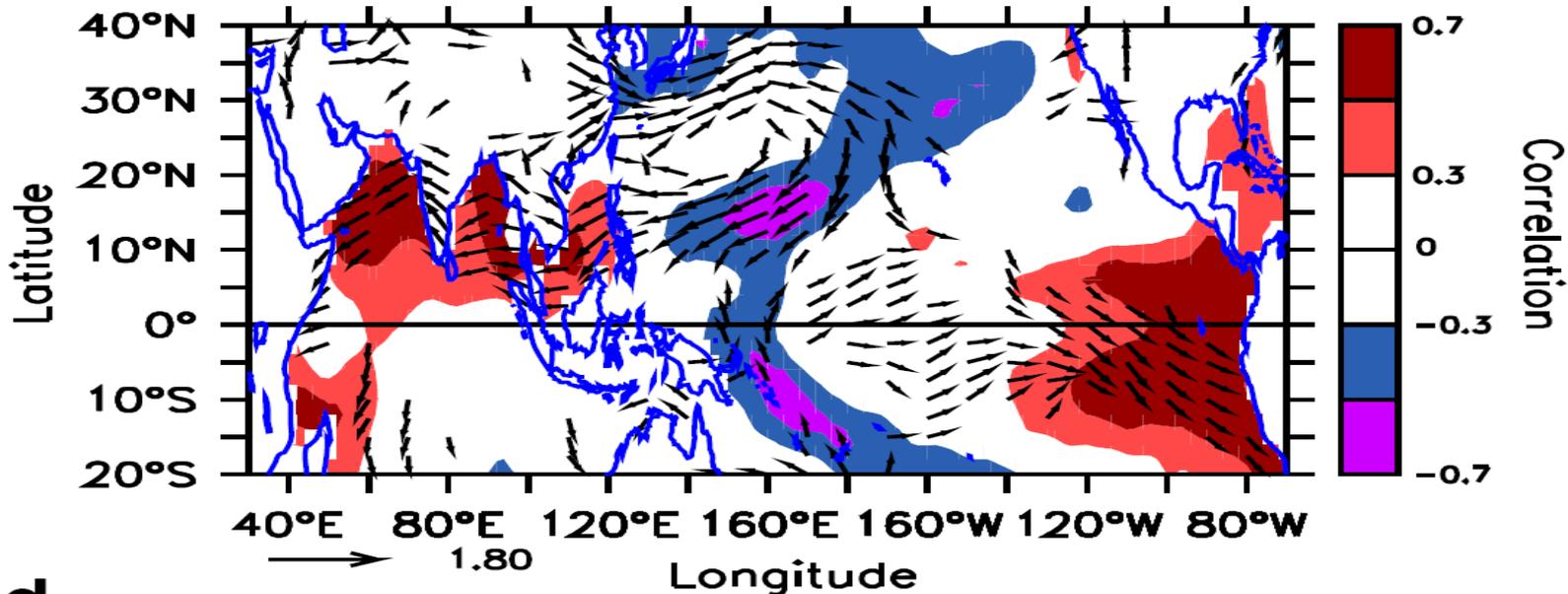
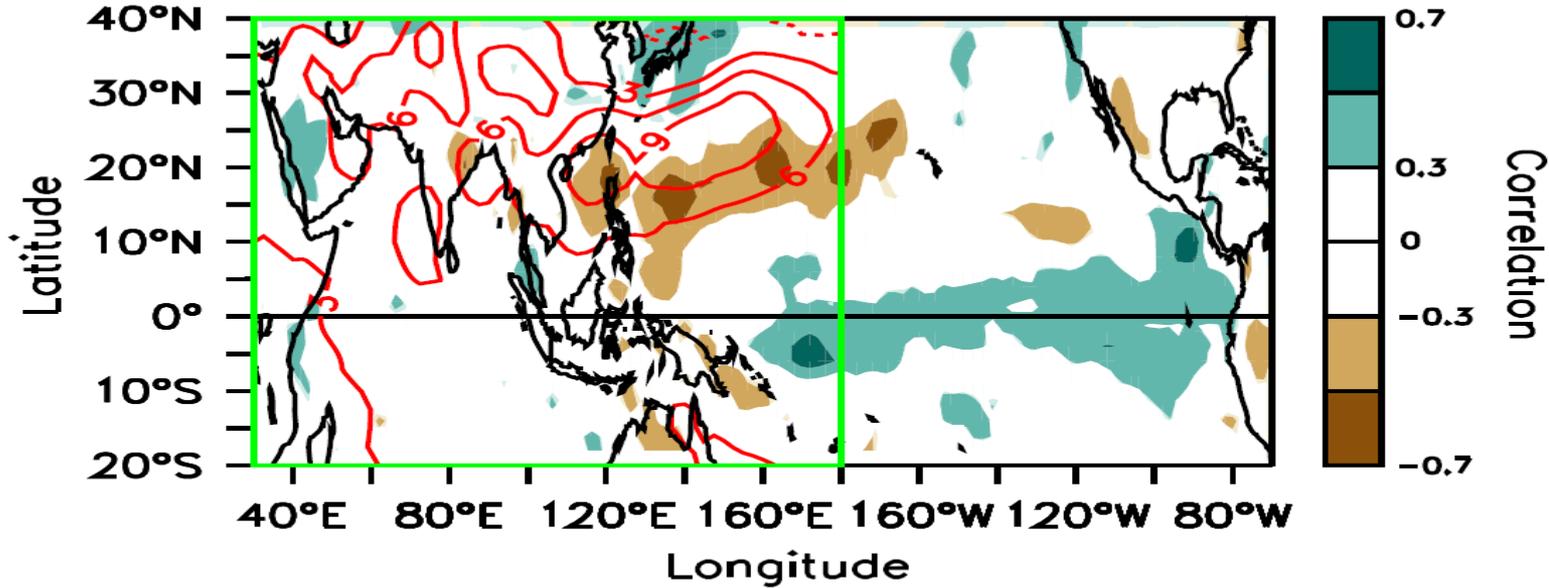
The normalized WNPSH index (black) and the reconstructed index based on PC1 and PC2 ( $1.226 \times \mathbf{EOF-1} + 1.245 \times \mathbf{EOF-2}$ ) from the EOF analysis of H850 anomaly (red). They have a correlation of about 0.94.

# Origin of EOF 1

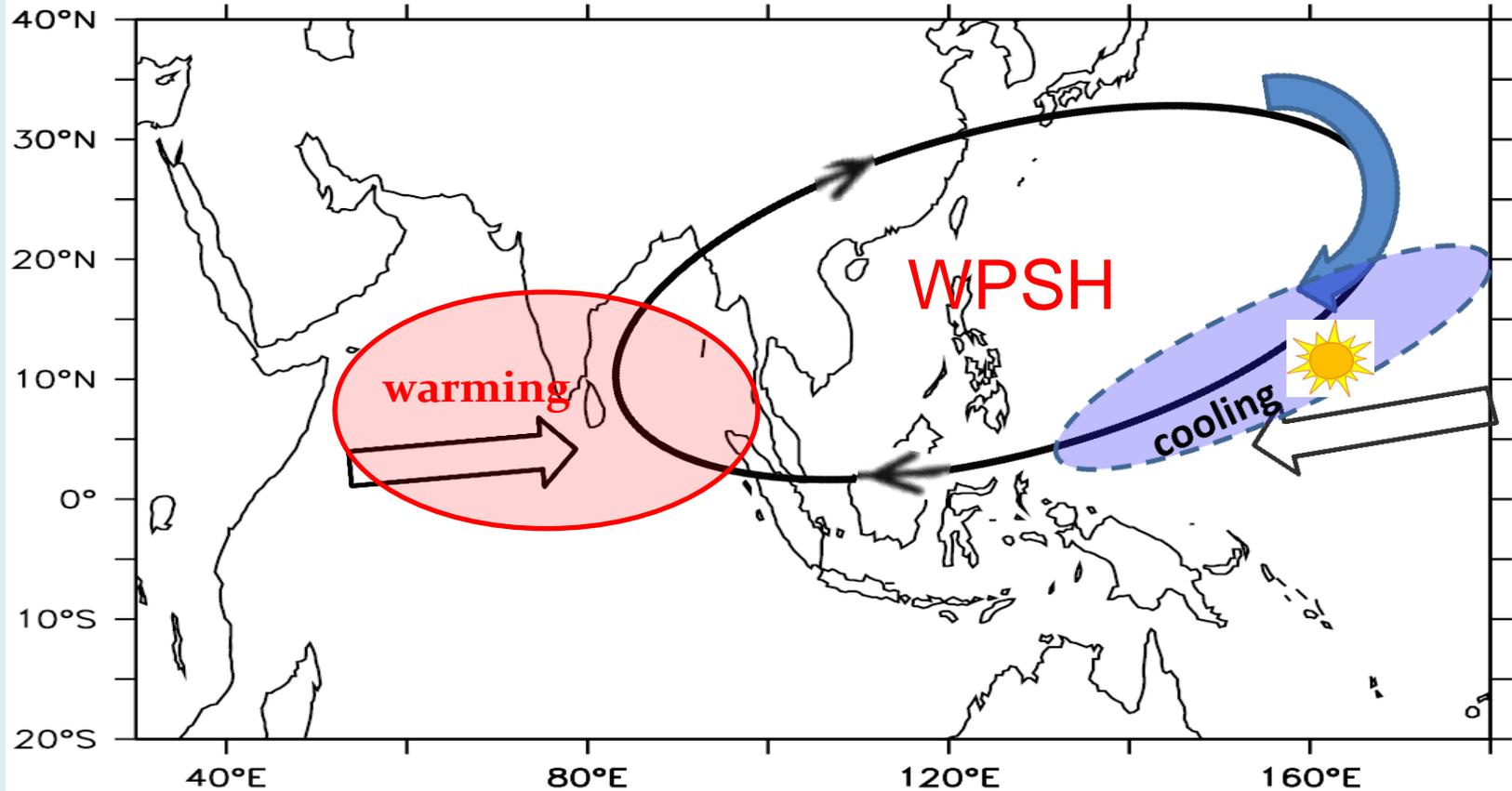
a) EOF-1 of H850 (31.2)



# Anomalies associated with EOF 1



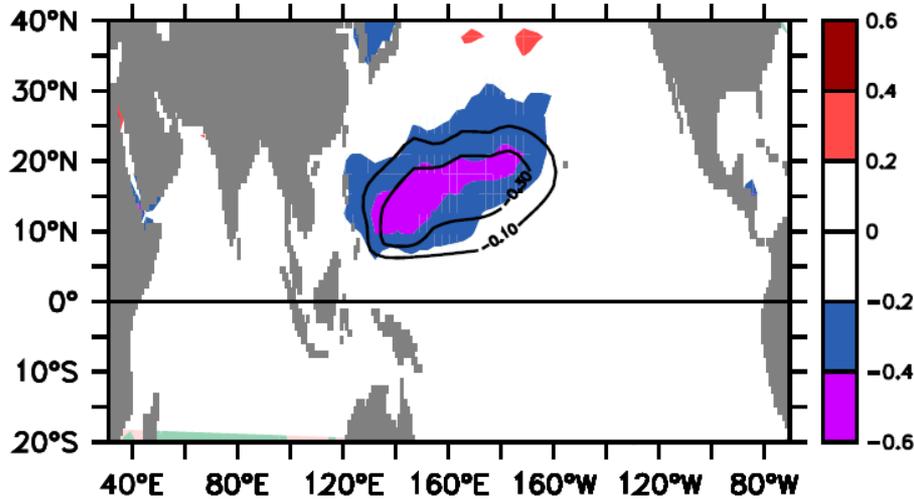
# EOF 1: WPSH and Indo-Pacific SST coupled Mode



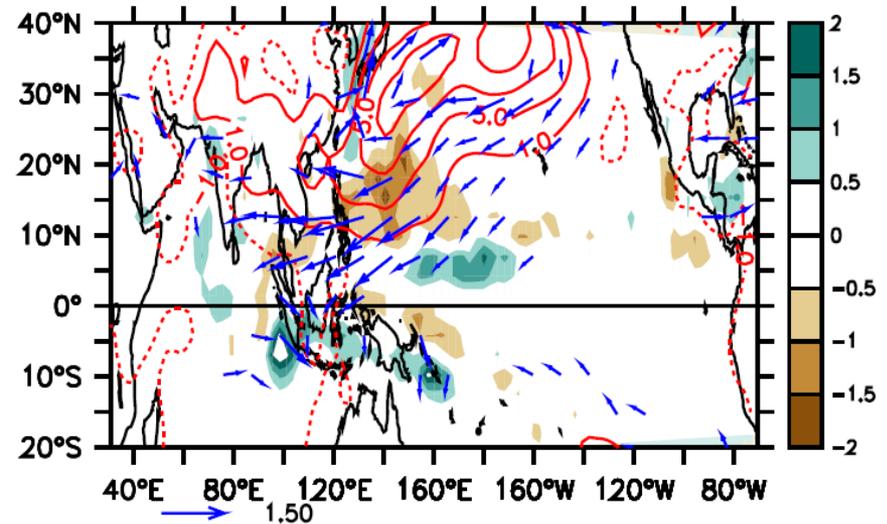
Positive A-O thermodynamic feedback between the WPSH and the Indo-Pacific warm pool ST dipole

# Coupled Model (POEM) Experiments

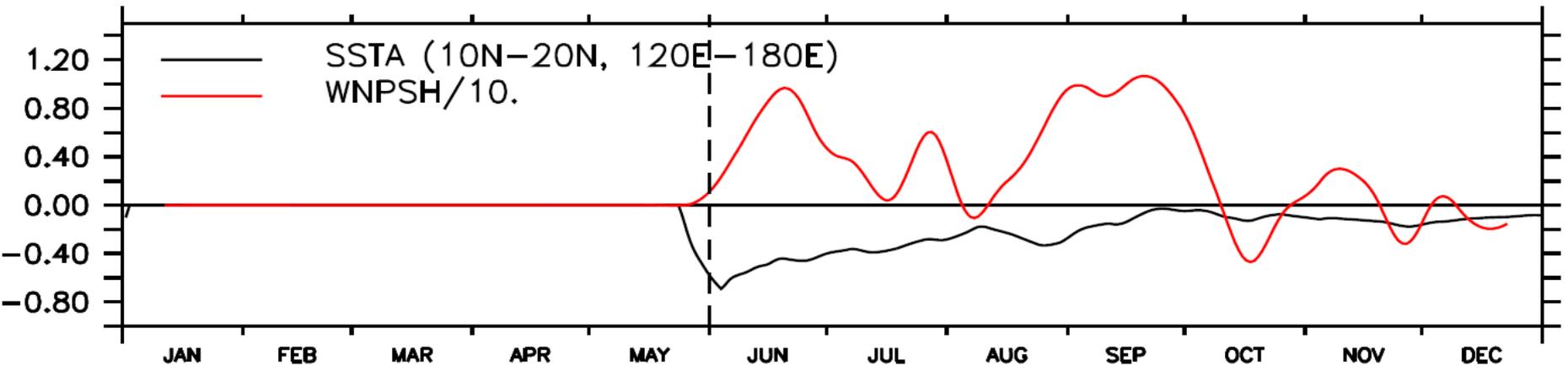
a) SSTA (JJA) & SST perturbation



b) Prep, H850 & surface wind (JJA)

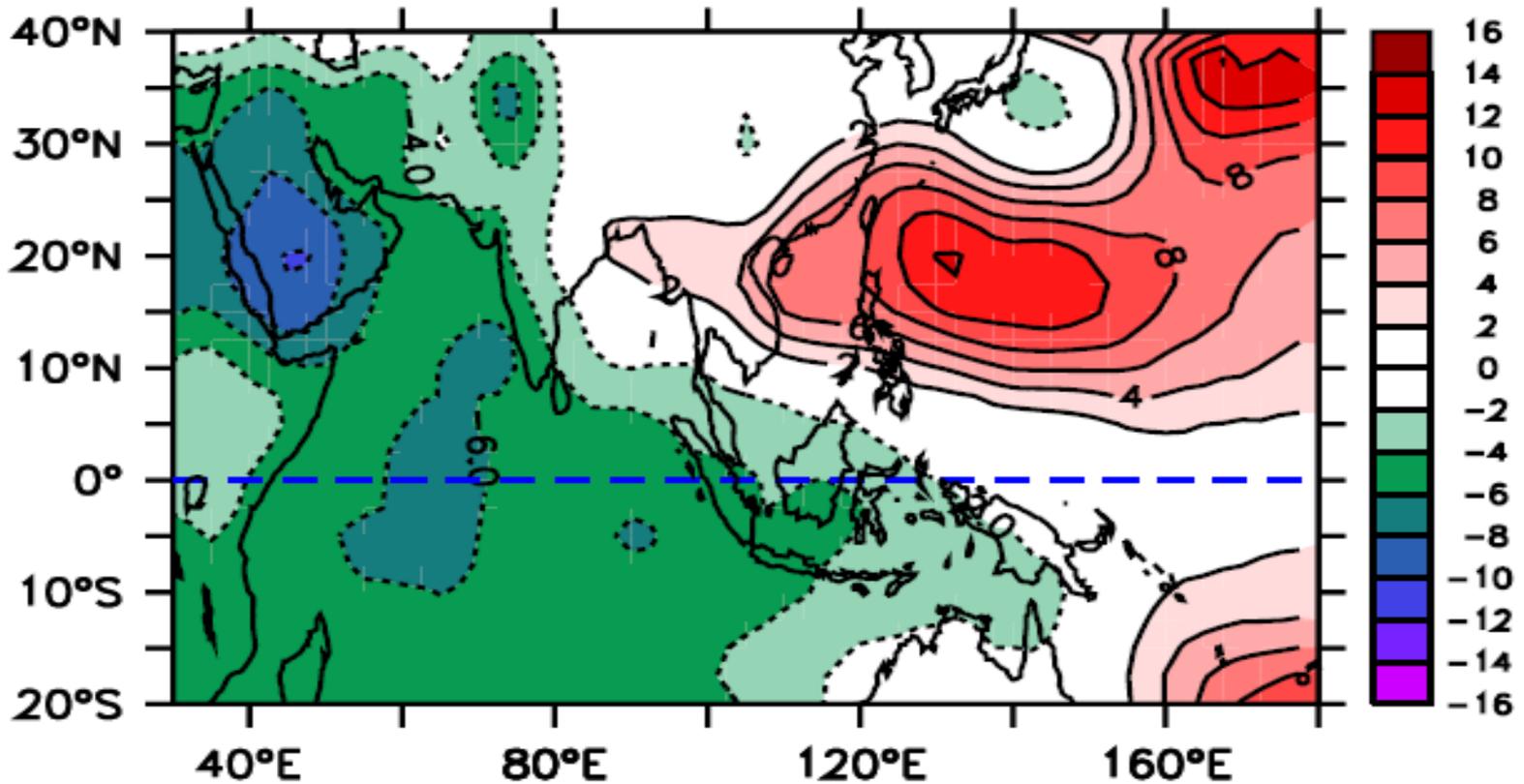


c) SSTA & WNPSH

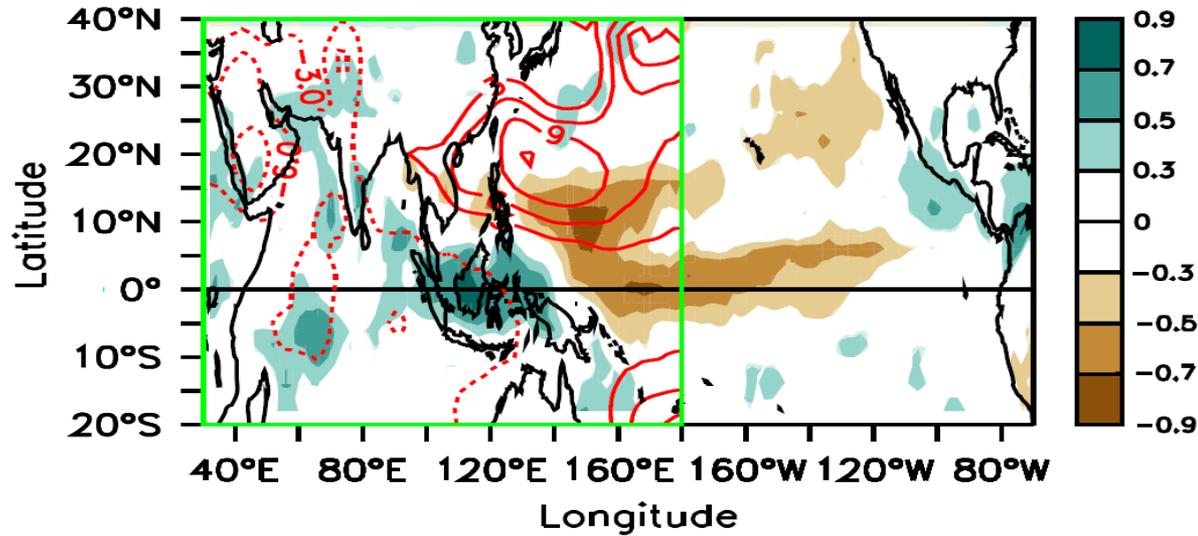


# Origin of EOF2

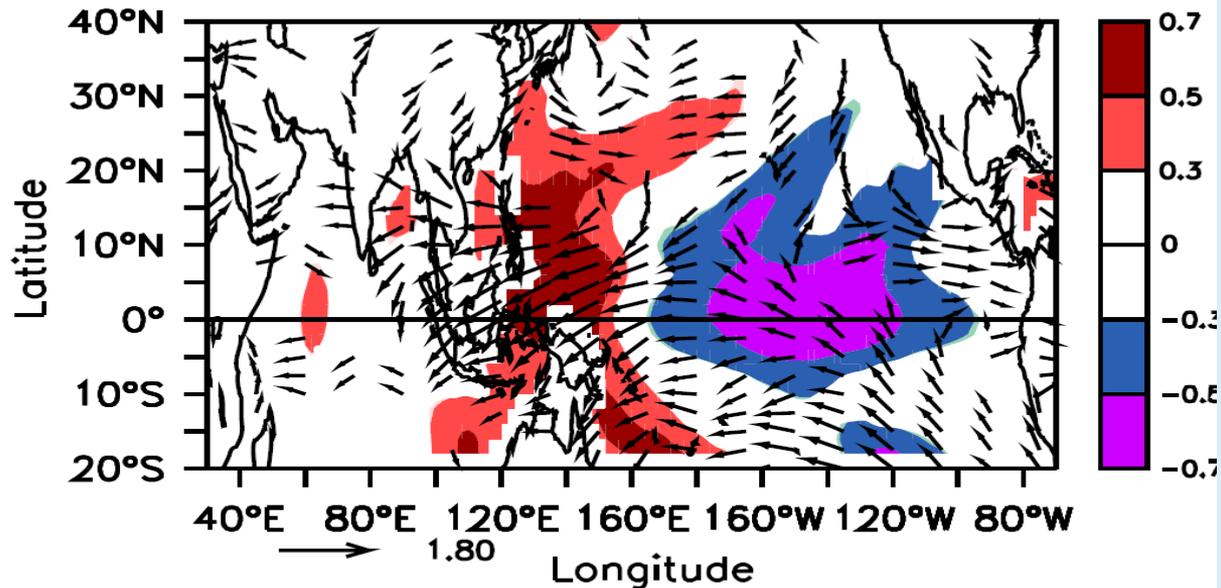
b) EOF-2 of H850 (20.9)



# Anomalies associated with EOF 2

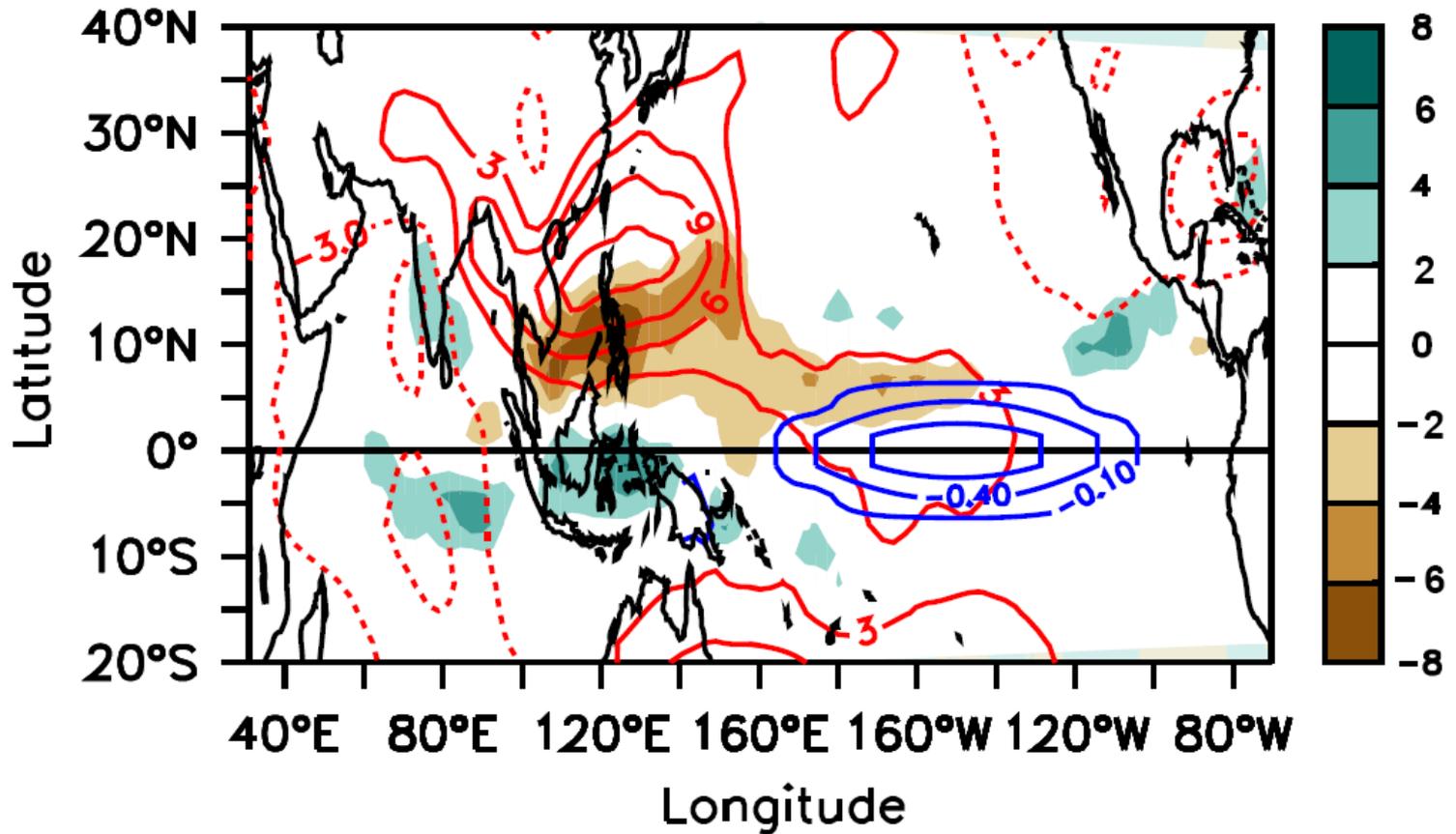


**H850 &  
precipitation**



**SST &  
850 winds**

## EOF2: Forced response to CP cooling



ECHAM ensemble experiments  
Anomalies forced by ECP SST cooling

# Causes of WPSH variation

- 1. remote cooling/warming in the equatorial central Pacific (EOF2)**
- 2. local positive thermodynamic feedback between the WNPSH and the Indo-Pacific warm pool SST dipole. (EOF1)**

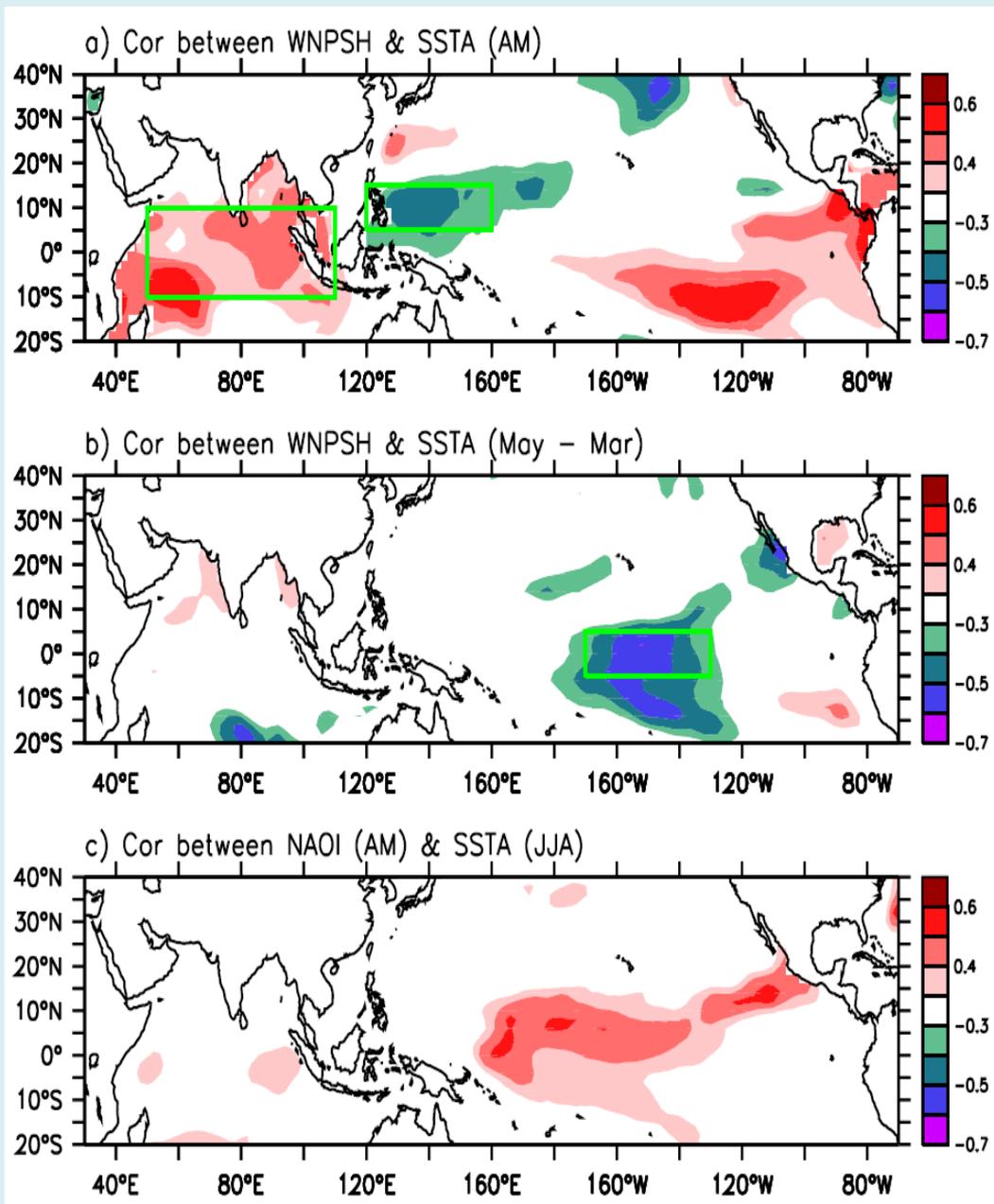
# III. How predictable is the interannual variation of the WPSH ?

Estimate the lower bound of the predictability

by

Physically based Empirical model  
Multi-dynamical models ensemble

# Predictors selected based on the EOF modes dynamics

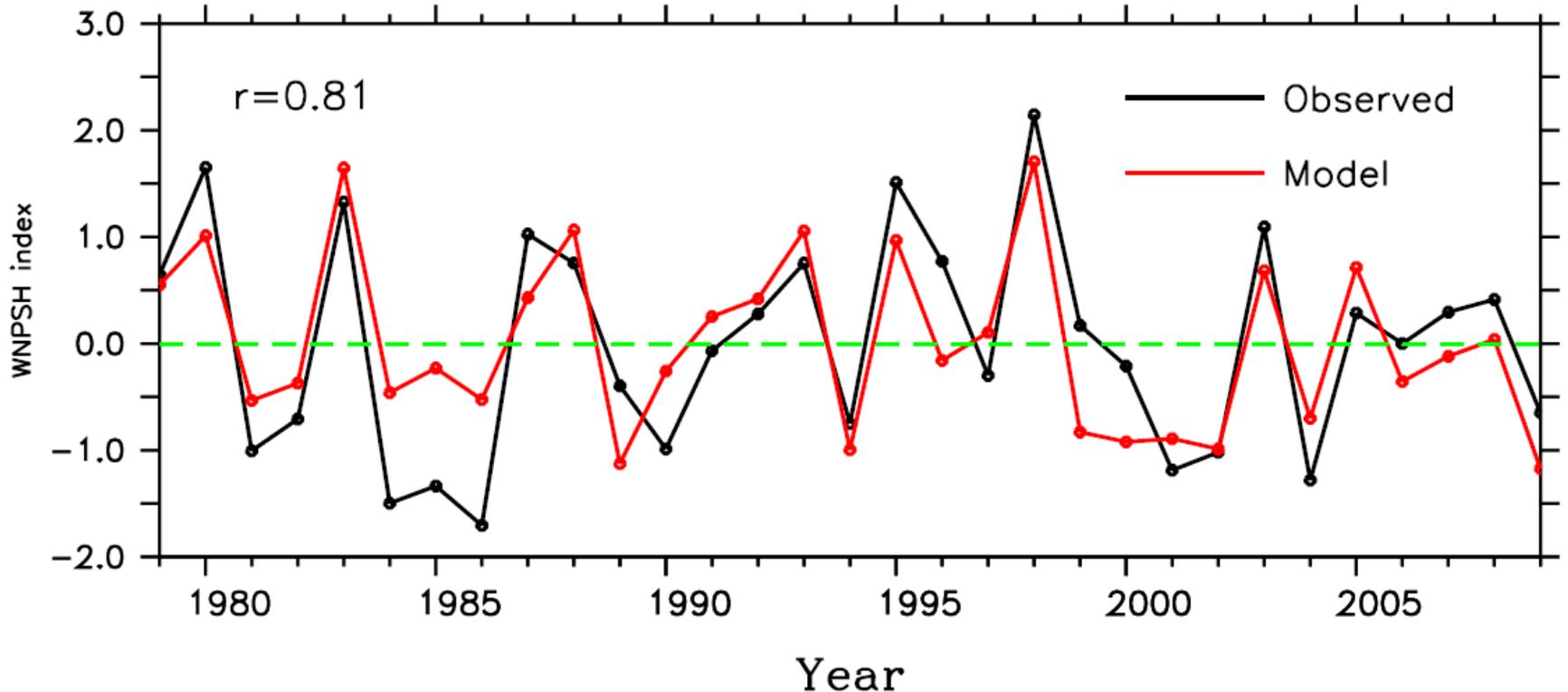


**IO-WNP** = SSTA in IO ( $10^{\circ}\text{S}$ - $10^{\circ}\text{N}$ ,  $50^{\circ}\text{E}$ - $110^{\circ}\text{E}$ ) minus SSTA in WNP ( $0^{\circ}$ - $15^{\circ}\text{N}$ ,  $120^{\circ}\text{E}$ - $160^{\circ}\text{E}$ ) during April-May.  $r = 0.76$

**CPSST** = May minus March (SSTA ( $5^{\circ}\text{S}$ - $5^{\circ}\text{N}$ ,  $170^{\circ}\text{W}$ - $130^{\circ}\text{W}$ ))  
 $r = -0.50$

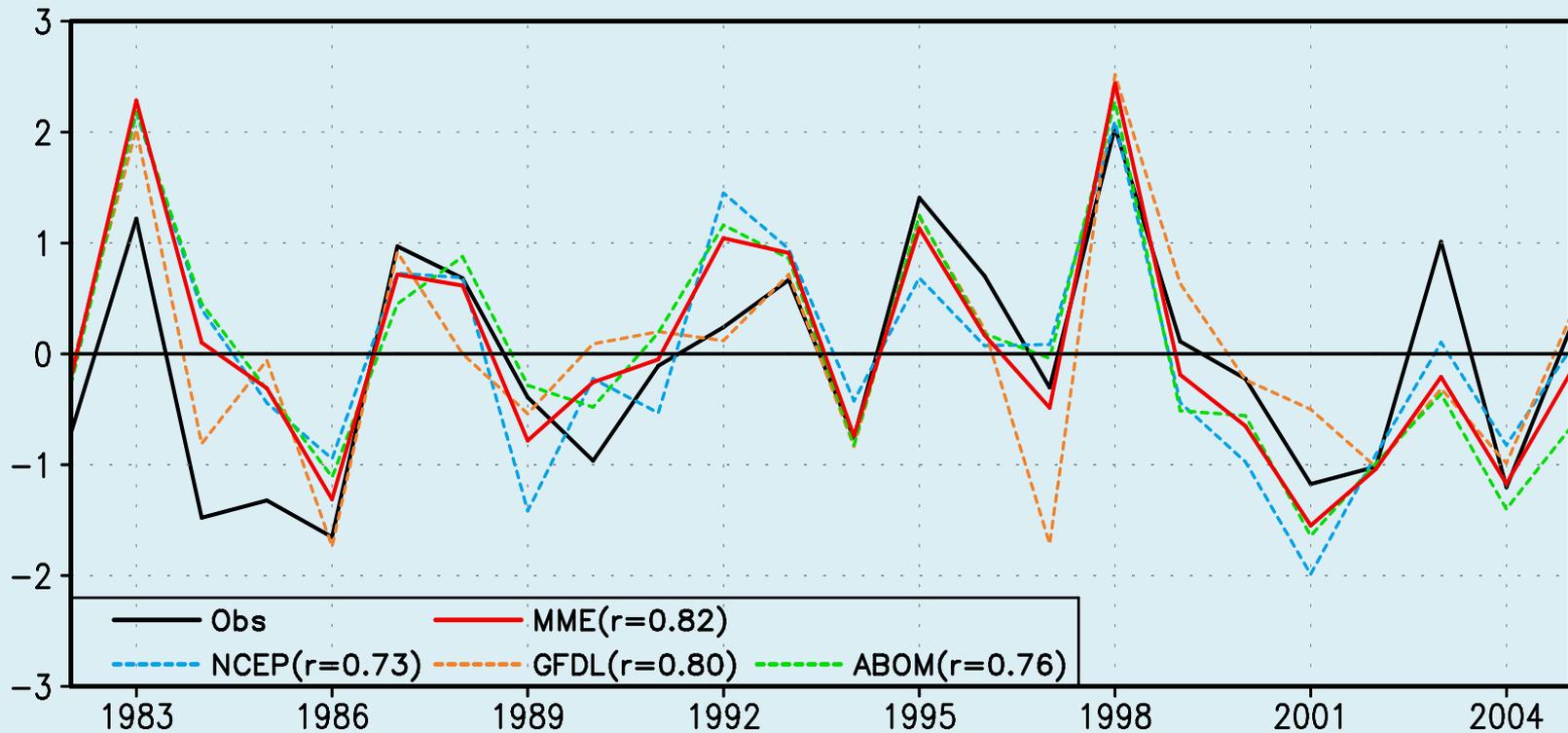
**NAOI** during April-May is a precursor for EOF2  
 $r = -0.41$

# WPSH intensity reproduced by a Physically based empirical model



$$\text{WPSH index} = 1.756 \times (\text{IO} - \text{WNP}) - 0.435 \times \text{CPSST} - 0.282 \times \text{NAOI}$$

# Re-forecast the WPSH intensity by coupled climate models (1982-2005)

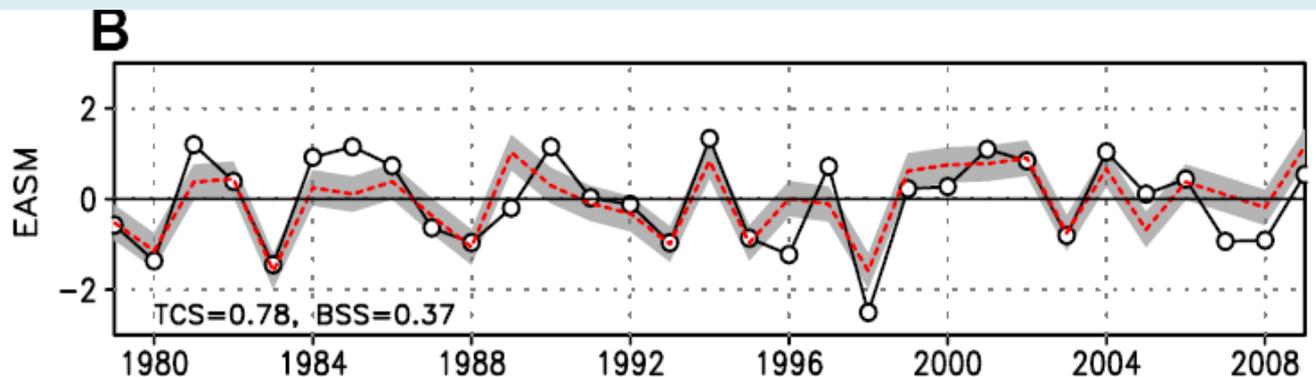


The WPSH is highly predictable!

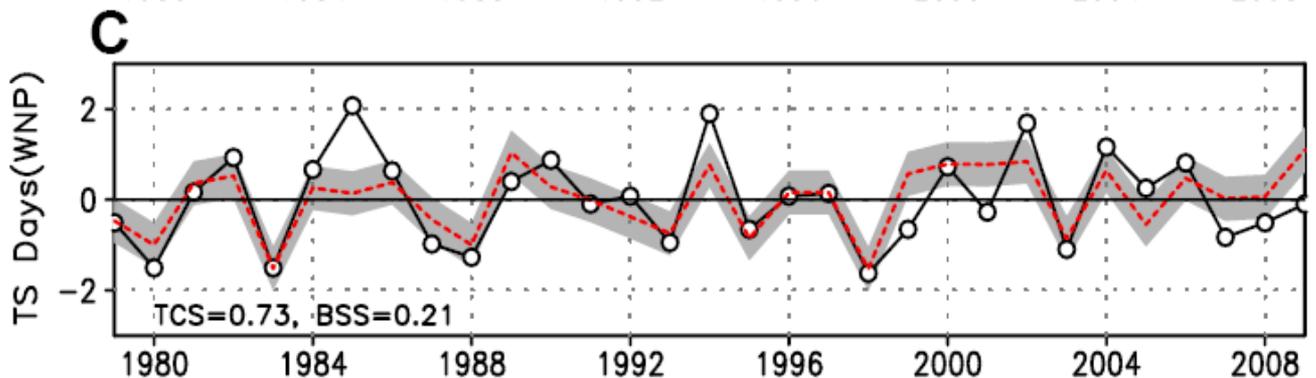
# IV. Using Subtropical Predictability to forecast EASM rainfall and WNP TS prediction

# Prediction of EASM strength, Tropical storm days (TSDs) and the TS numbers influencing EA

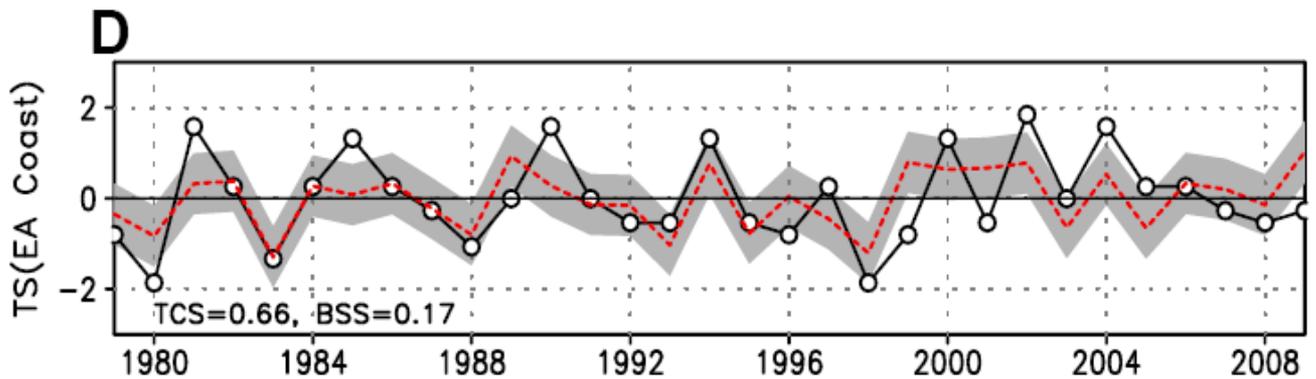
EASM  
Intensity  
index



Tropical  
storm days  
(WNP)



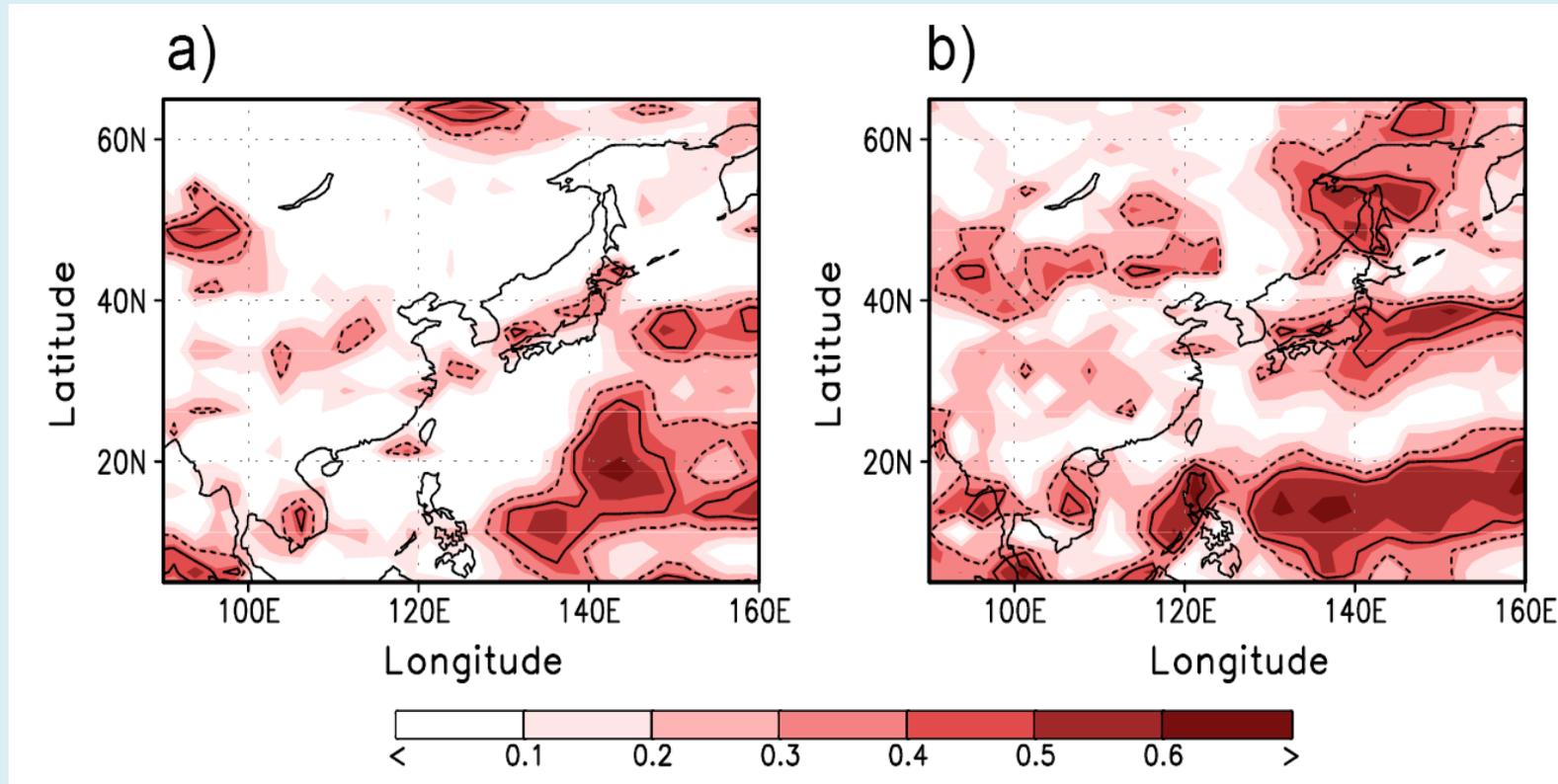
Number of  
TS impacting  
EA coasts



# TCS of JJA rainfall

3 coupled models' MME

Empirical model Prediction



The **empirical model prediction** is constructed by the product of the predicted WPSH index and the regressed precipitation onto the observed WPSH index.

# Conclusions

1. **Importance:** The IAV of the WNPSH faithfully represents the strength of EASM ( $r=-0.92$ ), the TS days over the subtropical WNP ( $r=-0.81$ ), and the total number of TSs impacting East Asian coasts ( $r=-0.76$ ).
2. **Dynamics of WPSH:** The IAV of WNPSH is primarily controlled by **equatorial central Pacific warming/cooling** and a **positive atmosphere-ocean feedback** between the WNPSH and Indo-Pacific warm pool ocean (SST dipole).
3. **Predictability:** The **WNPSH is highly predictable**.
4. **Prediction of precipitation and TS:** Predictability of the WNPSH **opens a promising pathway for prediction of EASM, ASM and WNP tropical storm activity**.

# Implications

Positive monsoon-ocean interaction can provide a new source of climate predictability.

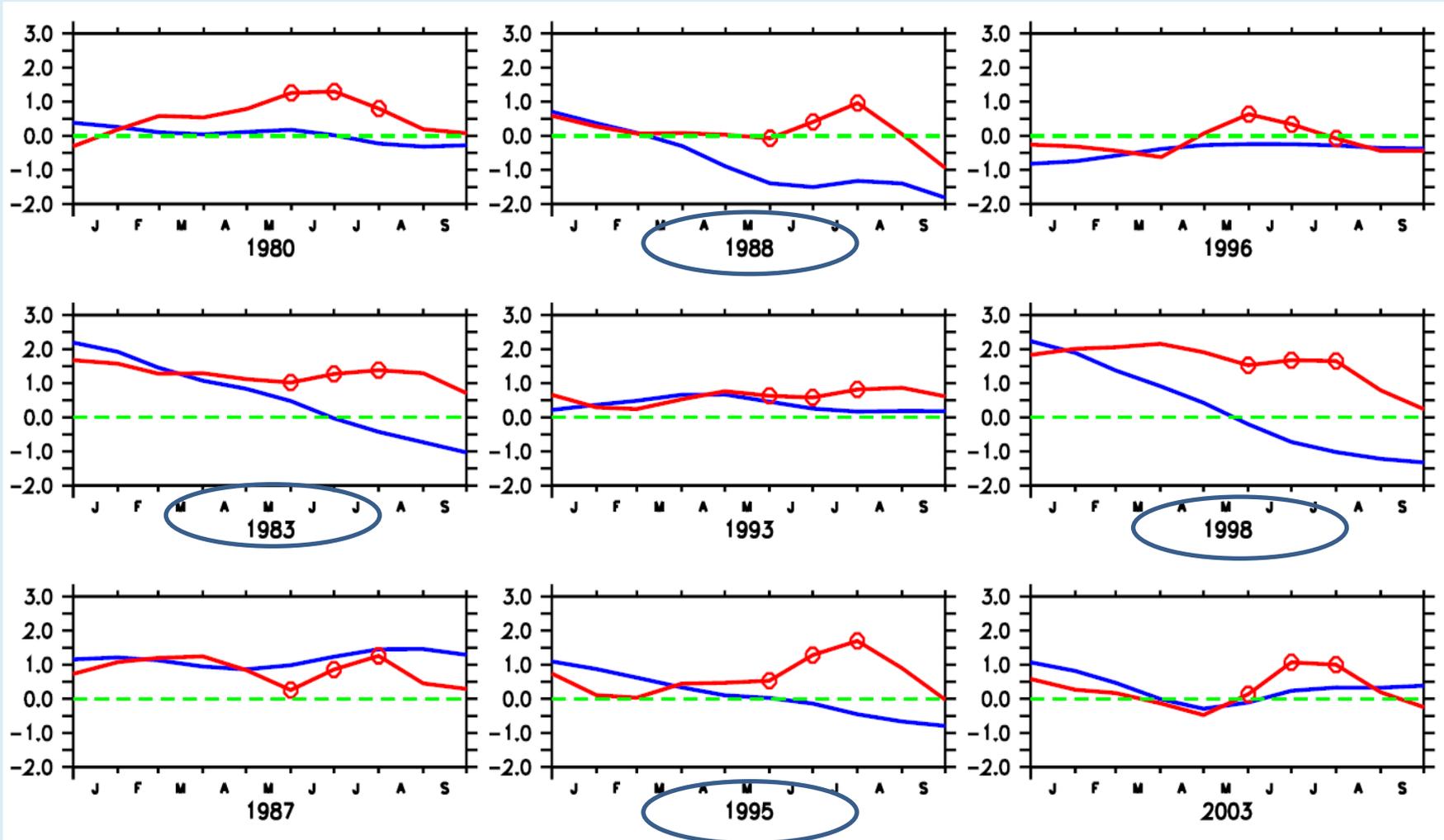
Subtropical dynamics is important for understanding monsoon/TS predictability.

Making use of the global models' strength in prediction of large scale circulation may substantially improve rainfall and TC prediction

Thank You

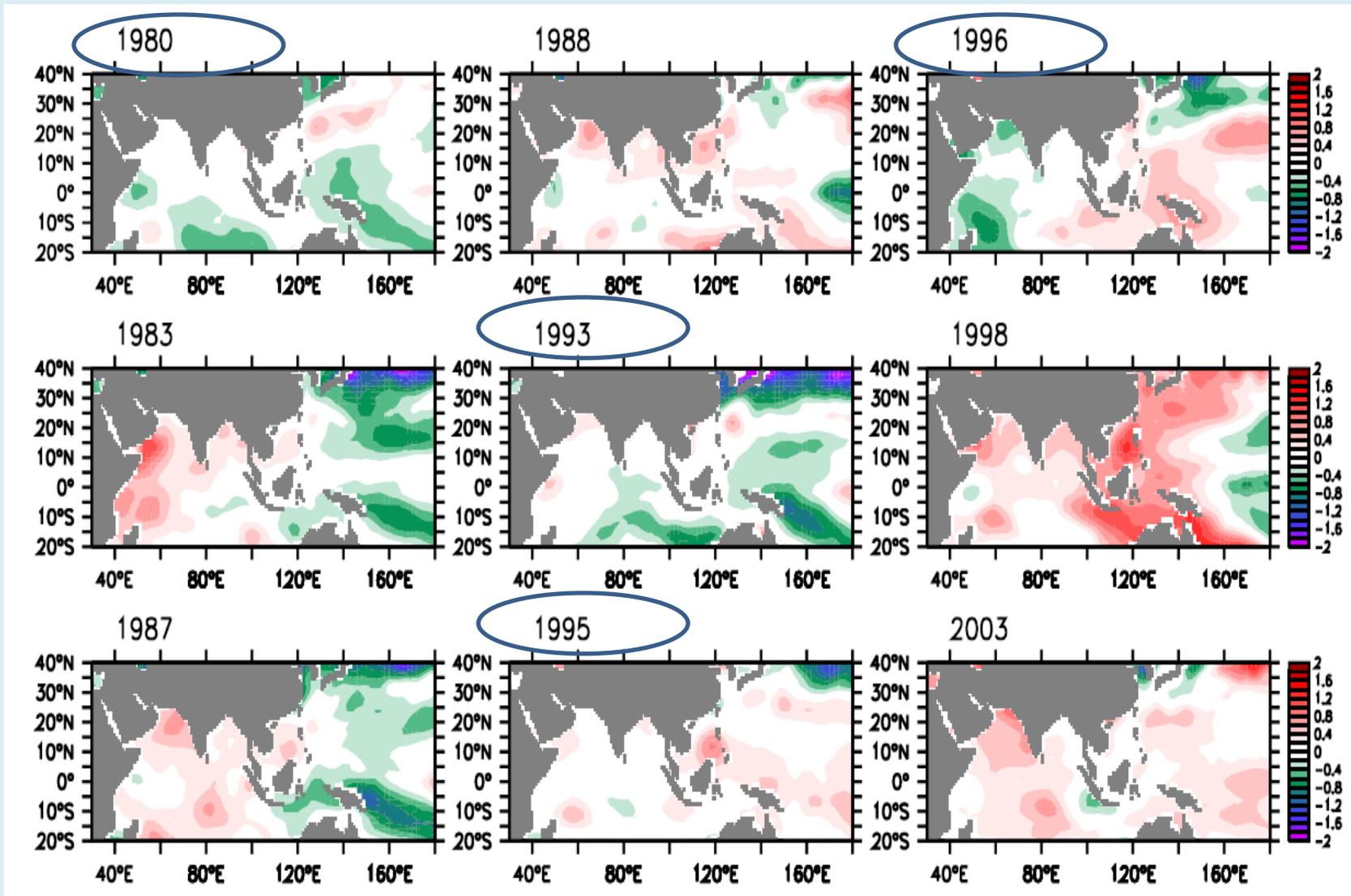
Comments?

# WPSH (red) and Nino3.4 SSTA (blue) for 9 strong WPSH



**Only 4 cases** (1983, 1988, 1995, and 1998) occurred during El Niño decay summers.

# SSTA for 9 strong WNPSH cases



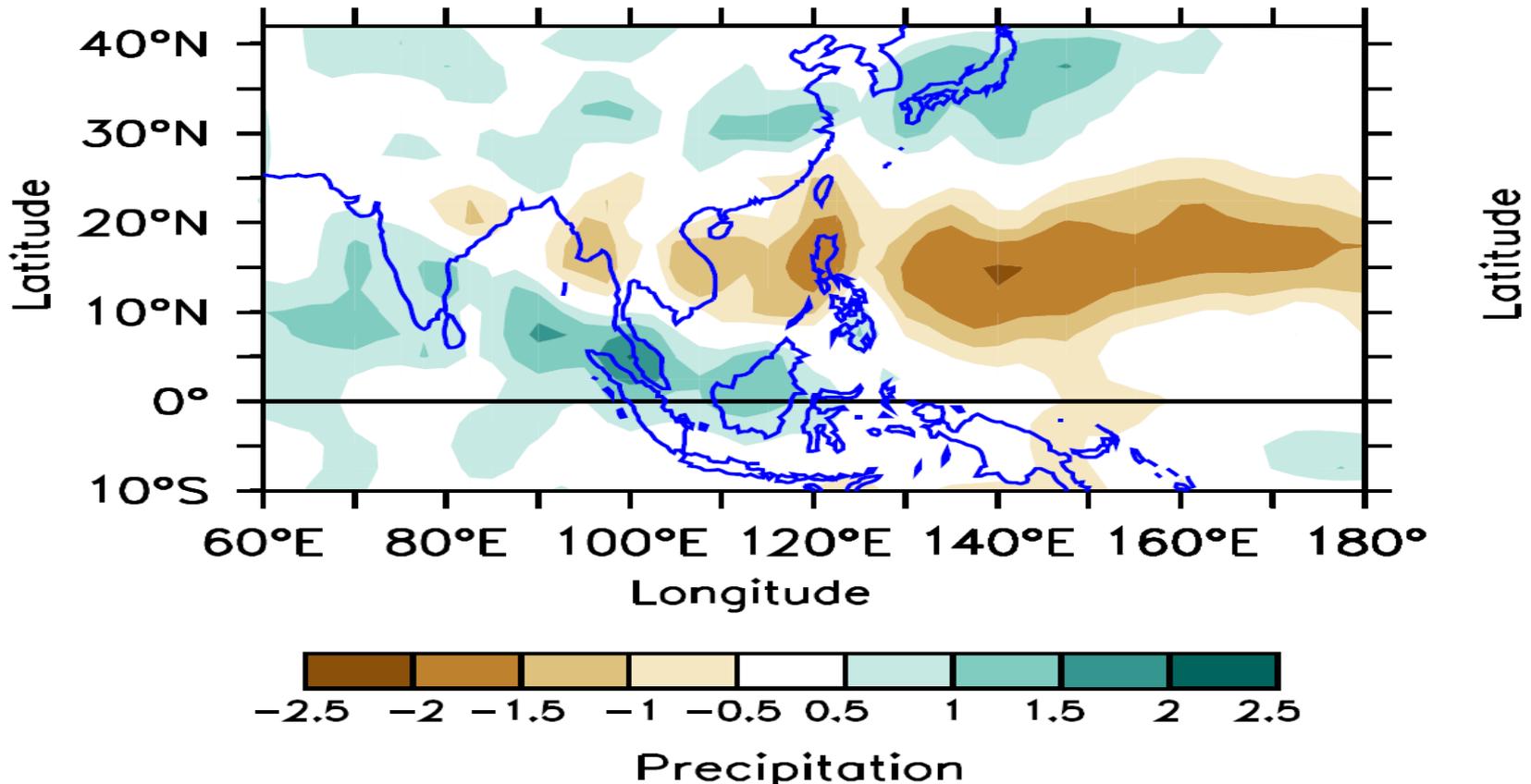
**4 cases** are not accompanied by Indian Ocean warming (1980, 1993, 1995, and 1996)

# WPSH Index and five indices used by NCC

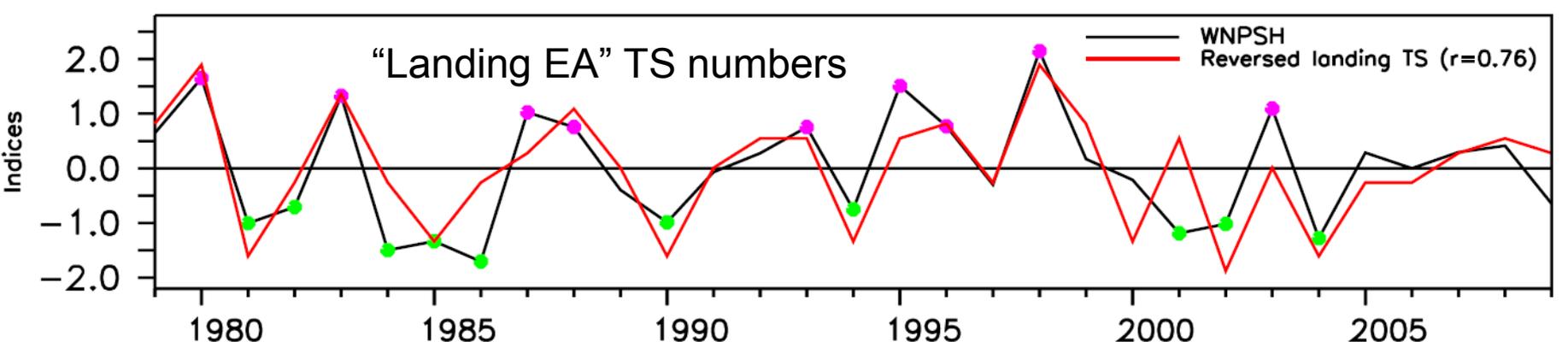
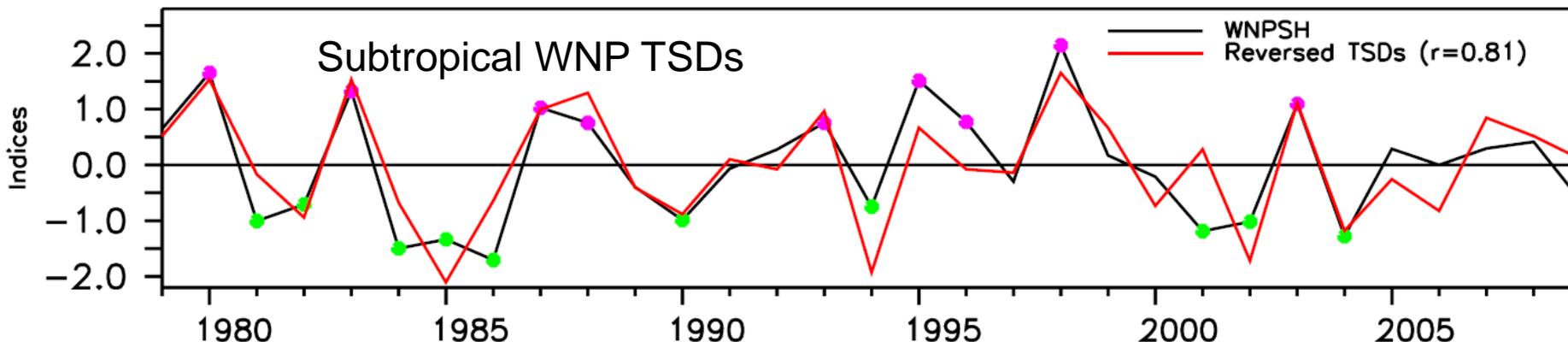
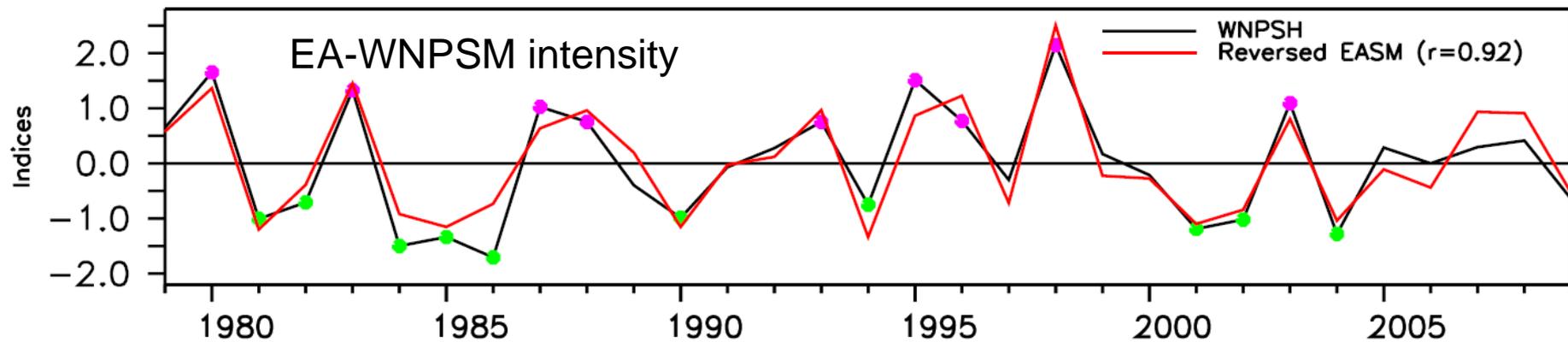
	<b>WPSH index</b>	<b>EASM strength</b>	<b>WNP TS days</b>	<b>TS affecting EA coast</b>
<b>WPSH index</b>	<b>1</b>	<b>-0.92</b>	<b>-0.81</b>	<b>-0.76</b>
Area index	<b>0.67</b>	<b>-0.55</b>	<b>-0.40</b>	<b>-0.36</b>
Intensity index	<b>0.69</b>	<b>-0.56</b>	<b>-0.46</b>	<b>-0.39</b>
North Edge index	<b>-0.08</b>	<b>0.27</b>	<b>0.20</b>	<b>0.20</b>
Mean Ridge index	<b>-0.38</b>	<b>0.55</b>	<b>0.47</b>	<b>0.47</b>
Westward Extension I	<b>-0.76</b>	<b>0.64</b>	<b>0.56</b>	<b>0.48</b>

Comparison of the WNPSH index we defined and other five indices that are used by NCC (<http://ncc.cma.gov.cn/cn/>) in representing the EASM, TS days in the WNP, and the total TS number of TS affecting EA coast.

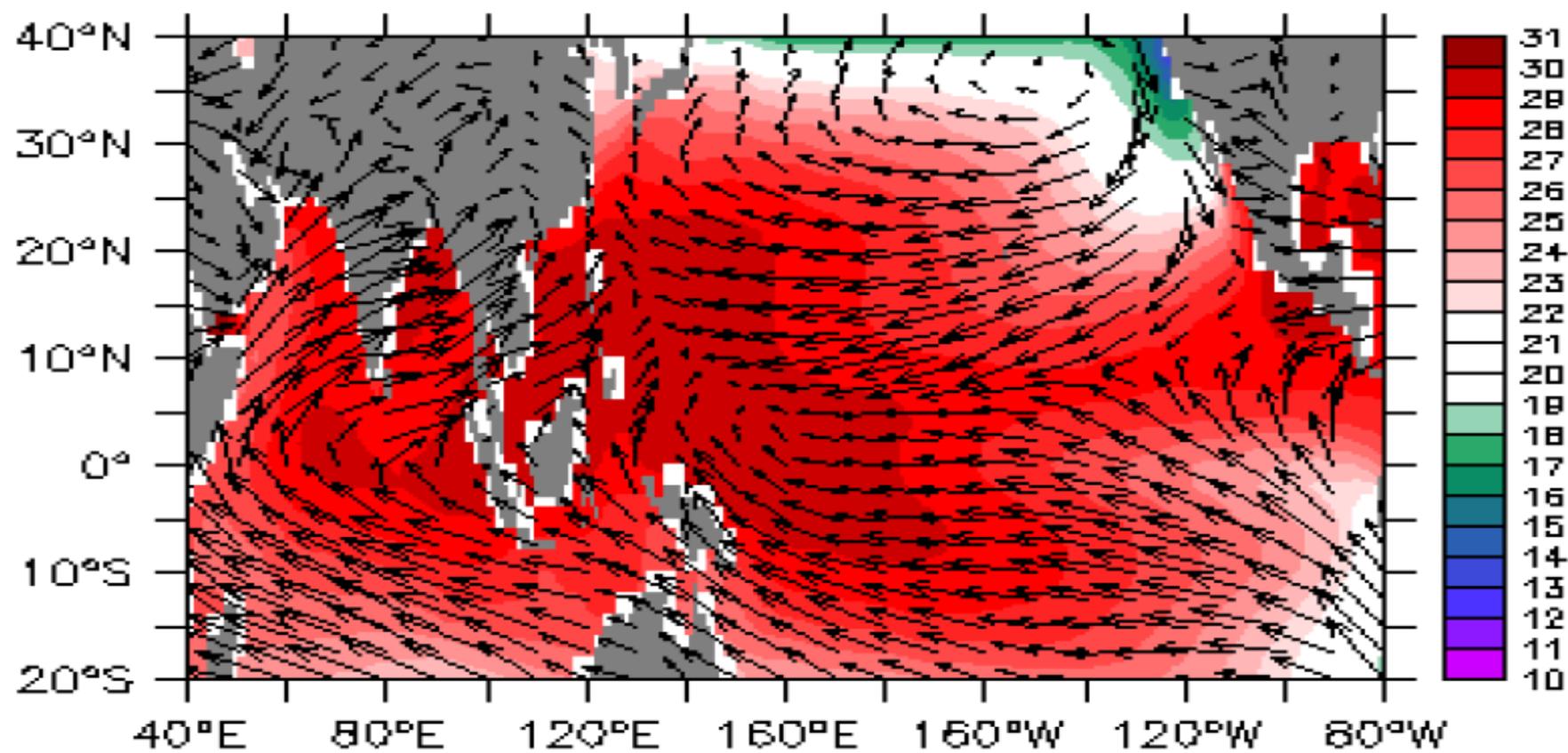
## Composite rainfall anomalies associated with a strong WPSH



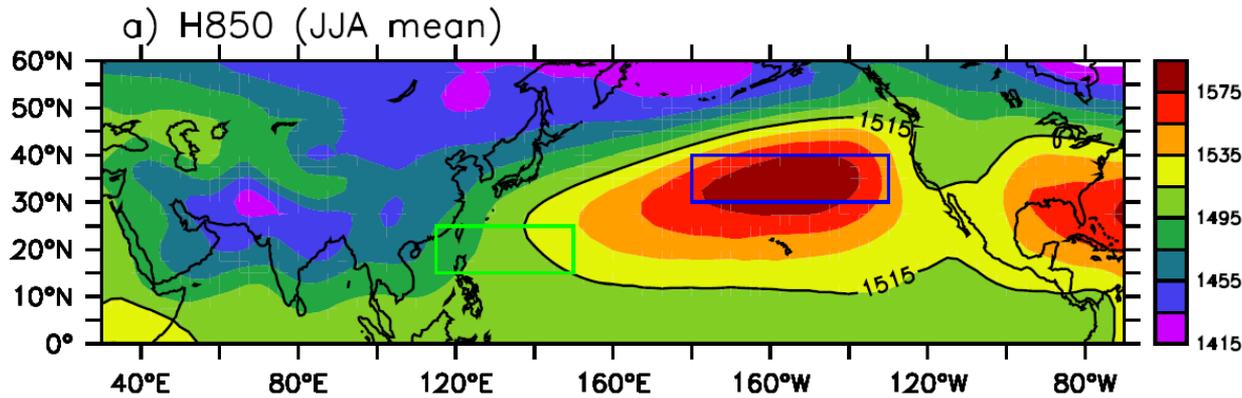
Correlation with the first two leading EOF modes of entire Asian summer monsoon rainfall; 0.58 and 0.56 (1979-2009)



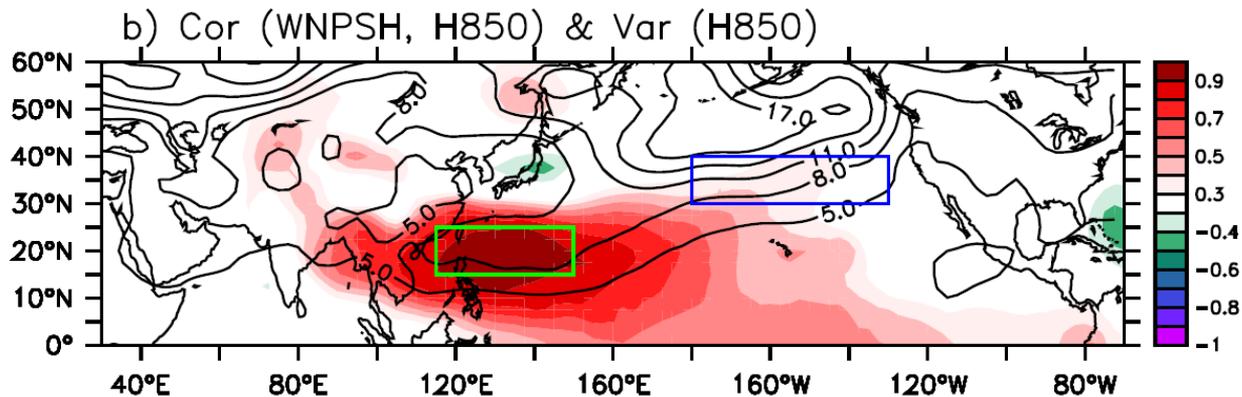
JJA



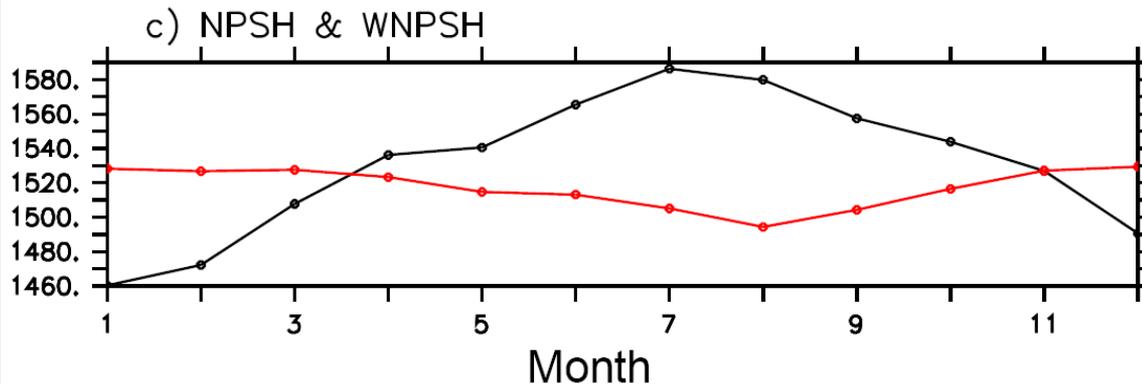
# WPSH: A monsoon system



JJA mean H850



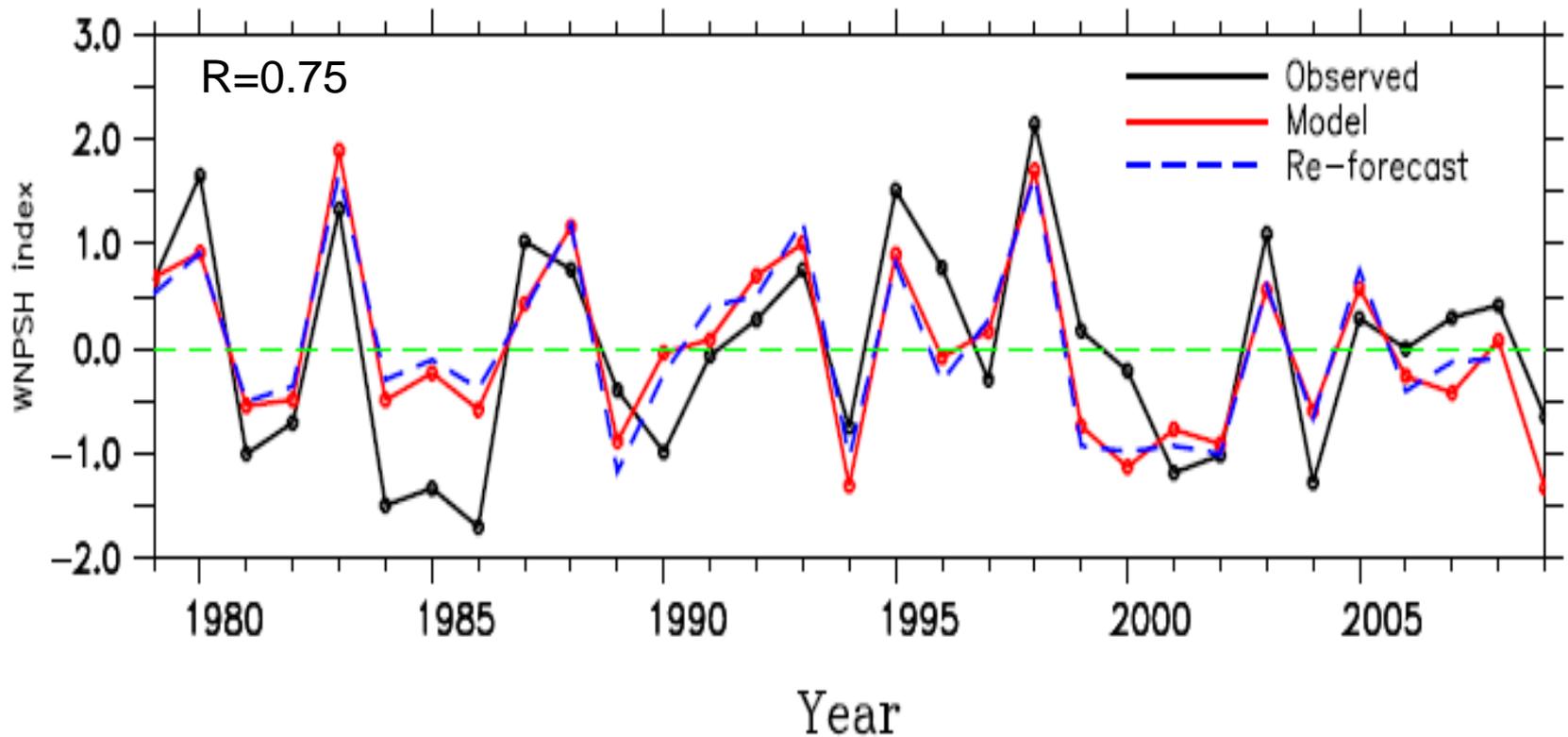
Interannual standard deviation of JJA H850



Seasonal march of the WNPSH (red) and NPSH intensity (black)

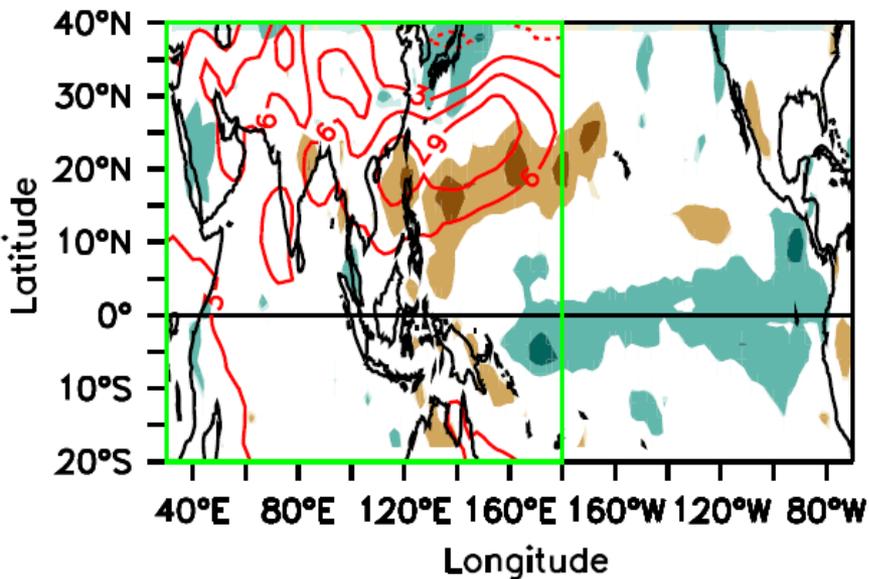
# Re-forecast WPSH intensity with the physical-empirical model

b

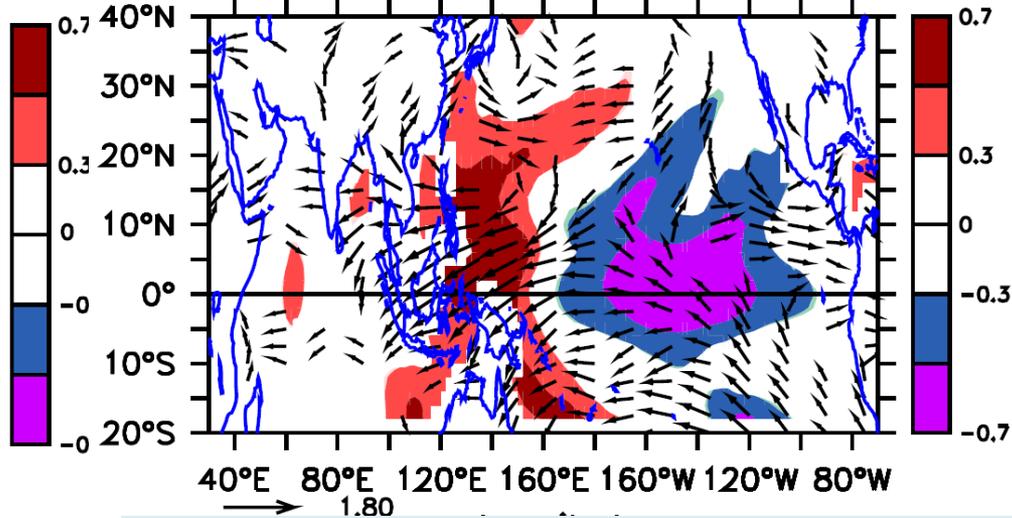
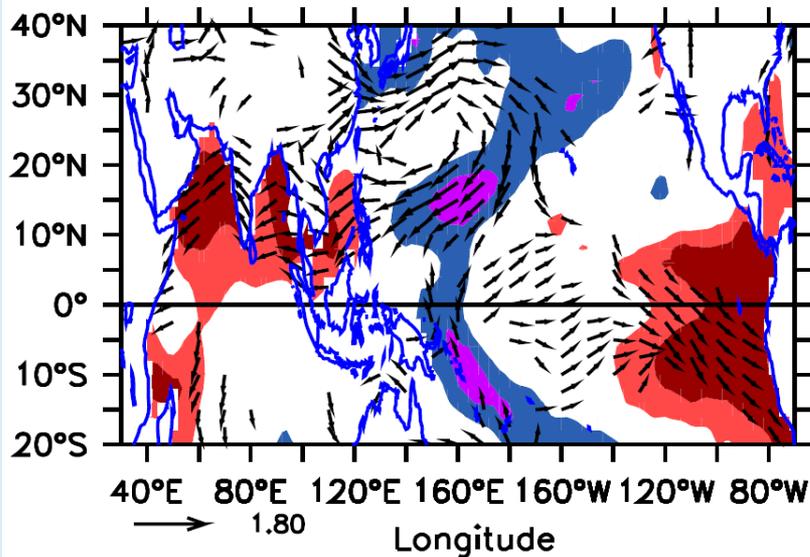
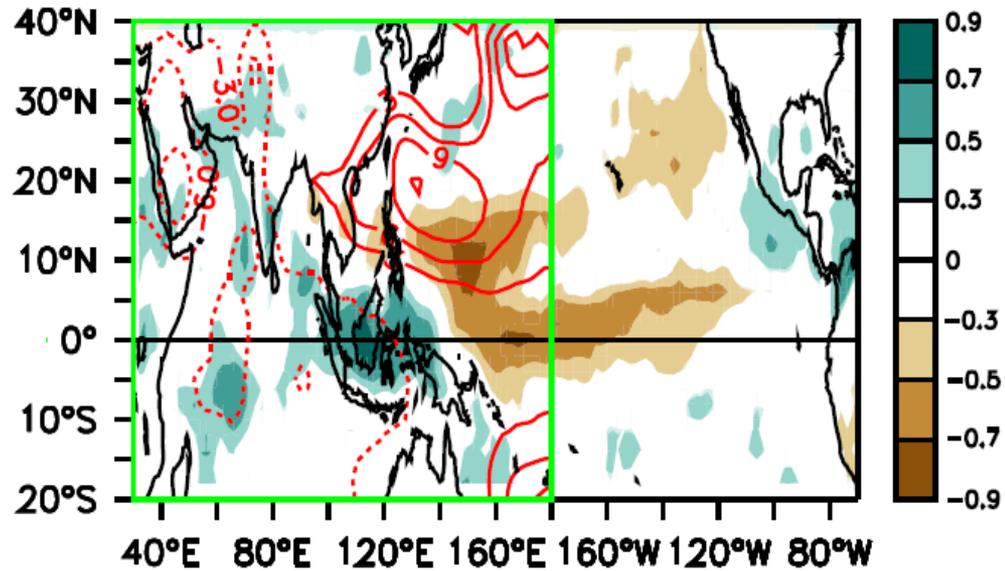


Leave-three-out cross validation

EOF-1



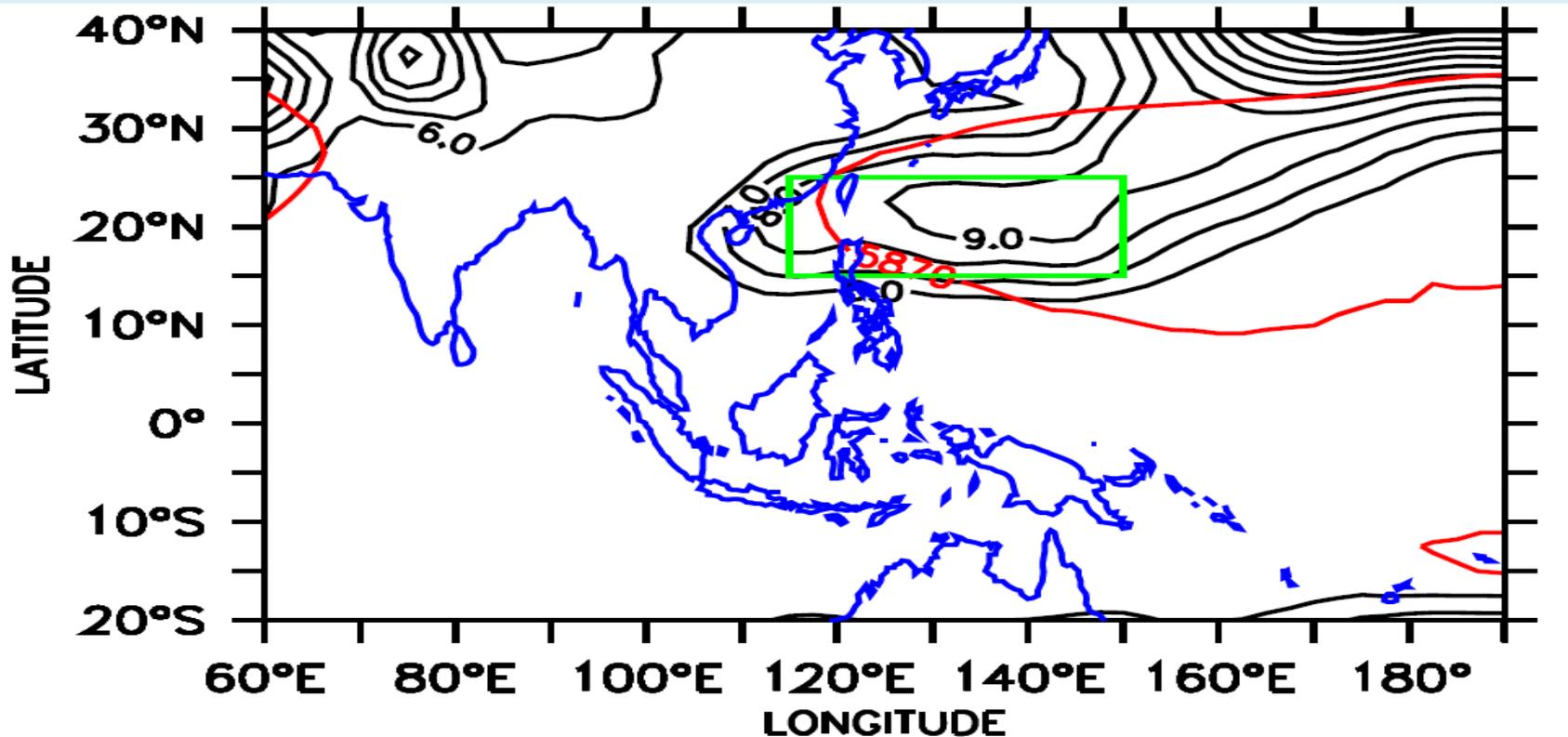
EOF-2



IO-WNP anticyclonic coupled mode

La Nina-forced mode

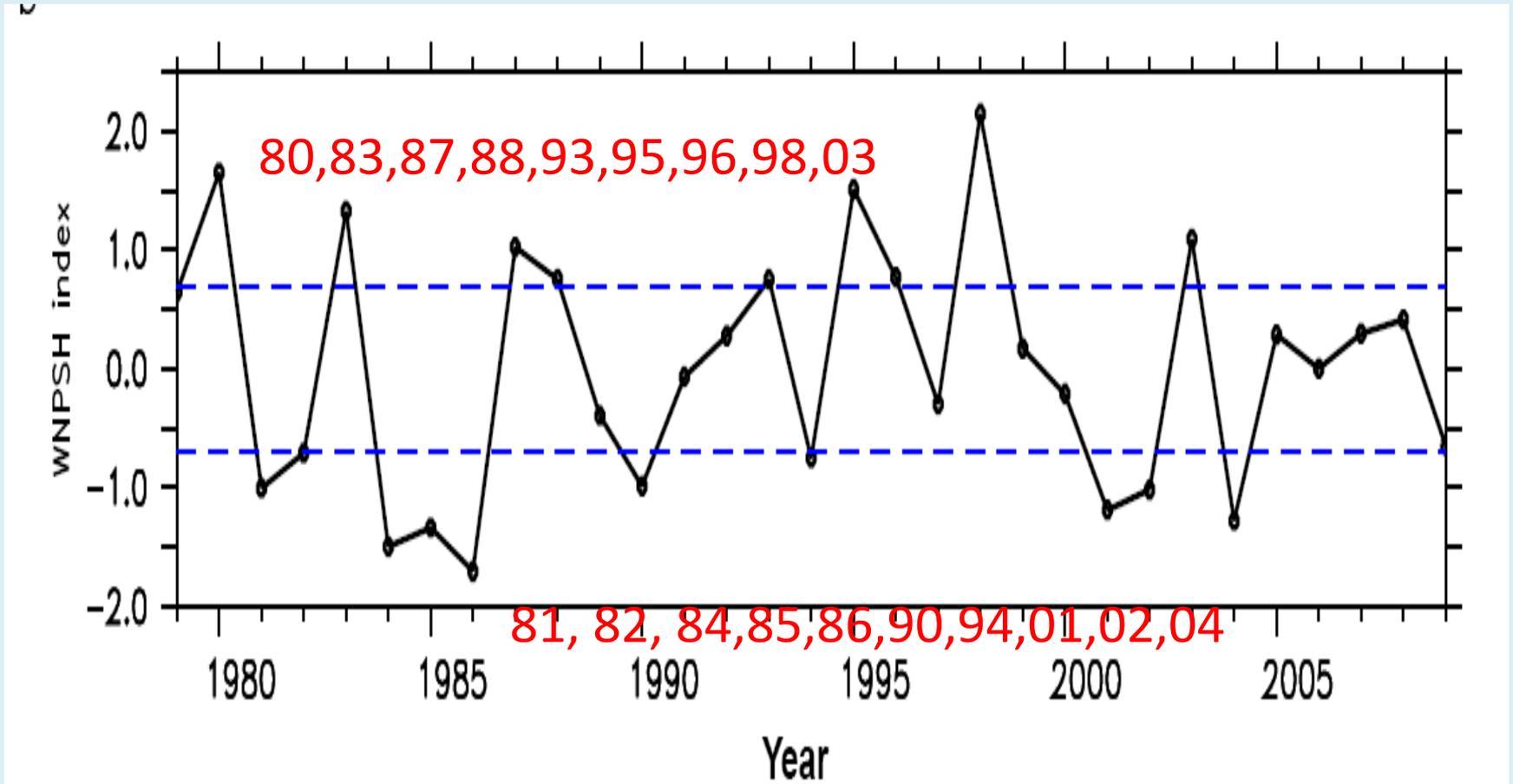
# Defining WPSH Index at the Variability center of the 850 hPa geopotential height



**WNPSH index:** The Normalized JJA H850 anomaly (15°N-25°N, 115°E-150°E)

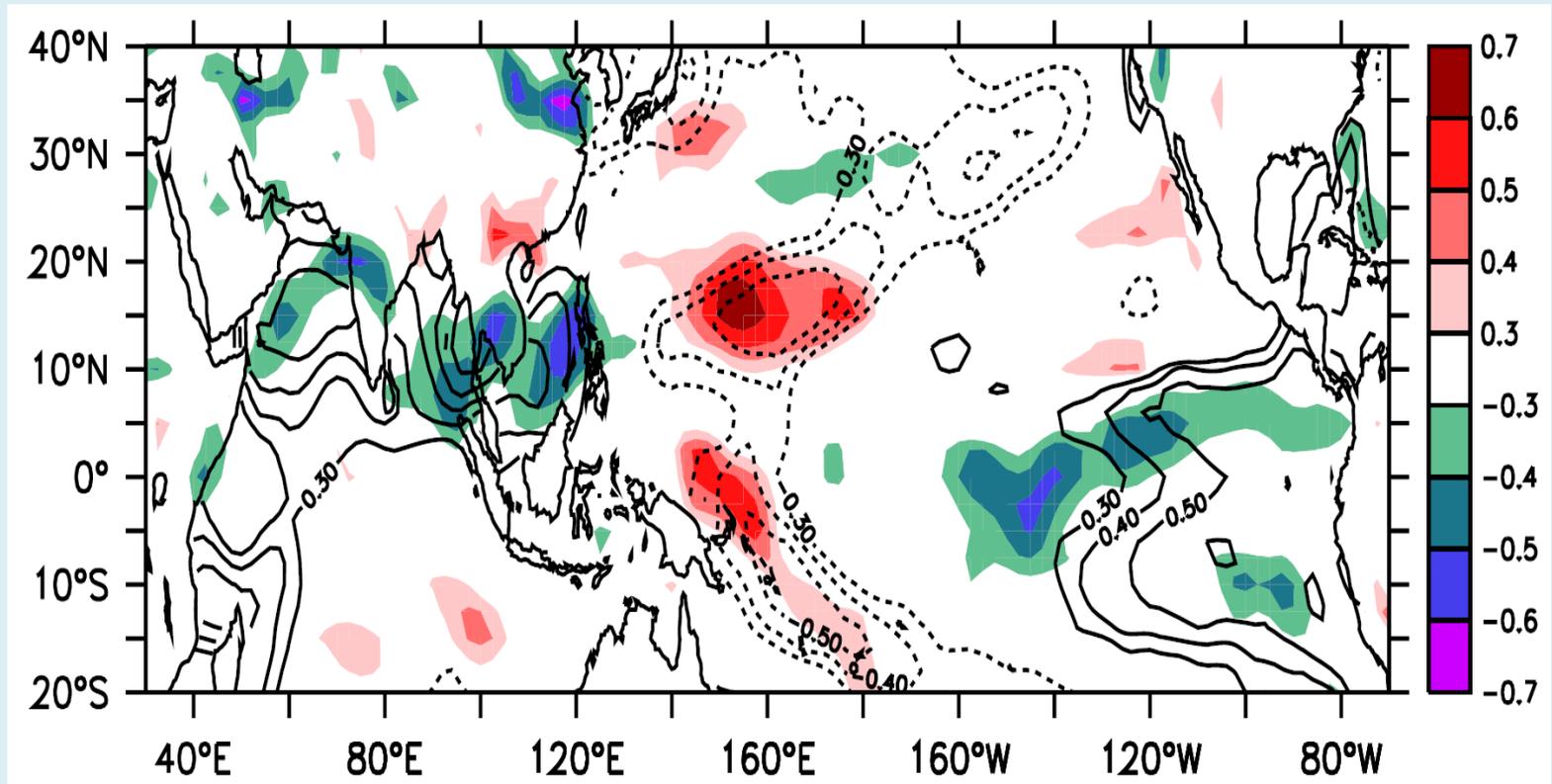
**Correlation with Wang-Fan index (1999): 0.94**

# WPSH Index (1979-2009)



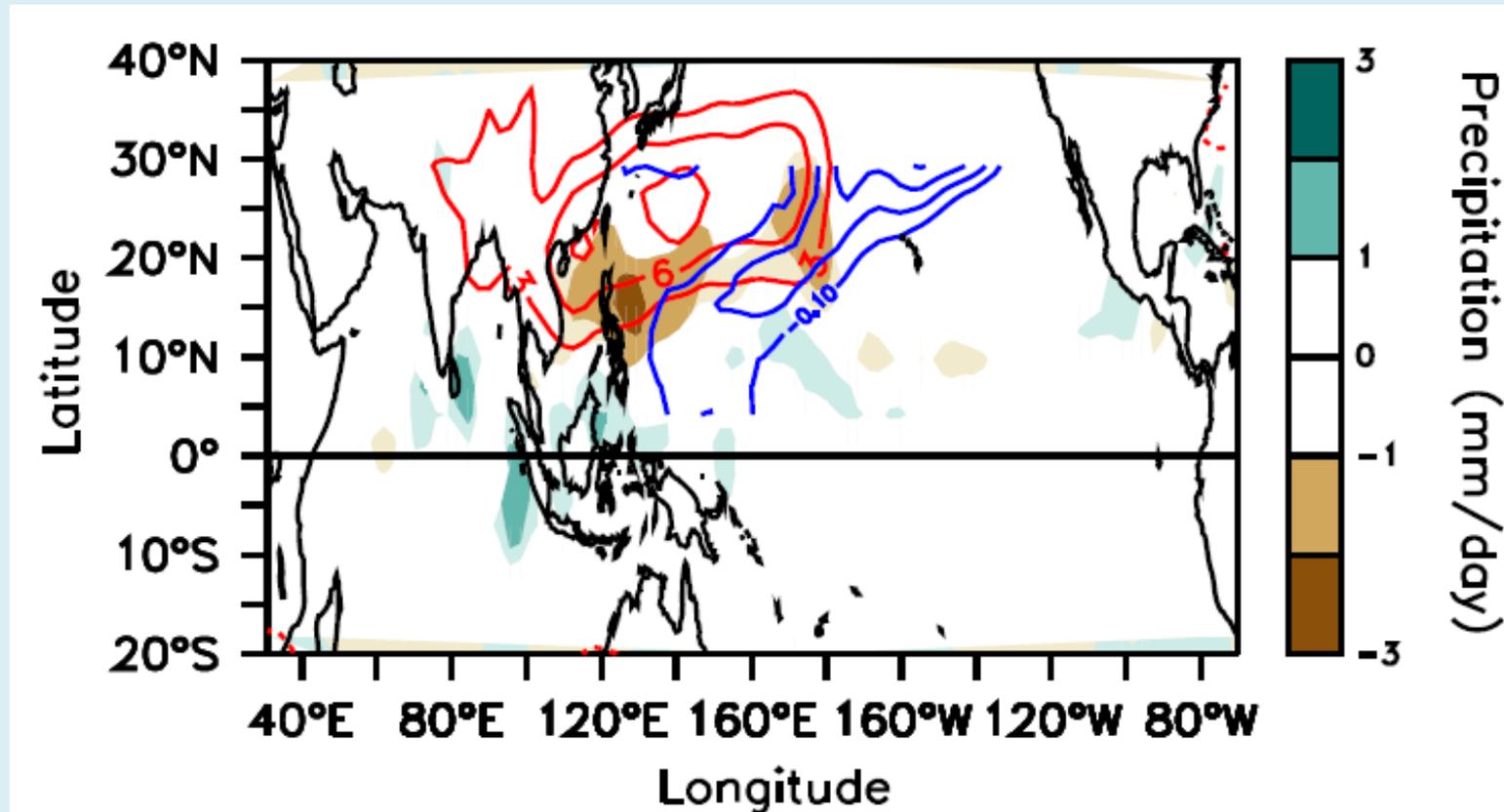
Simultaneous correlation coefficient with ENSO index: -0.12 (1979-2010)

# Observed evidence of Atmosphere-Ocean interaction



Correlation map of the simultaneous SSTA (contours) and 1000 hPa wind speed anomaly (shading) with reference to the PC1 of H850 anomaly

# AGCM (ECHAM) ensemble simulation



SST forcing (blue contours)

Precipitation (shading)

H850 (red contours)

**Moderate WNP cooling  
can force AC anomaly  
in WNP**

# Prediction skill of JJA precipitation (1981-2005)

