Complementary notes on WNPSH dynamics

- Distinguish strong and weak ENSO impacts
- Beyond thinking of El Nino decaying phase

Variable and Robust East Asian precipitation response to El Nino

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Acknowledge co-authors: Dr. Juan Li and Qiong He

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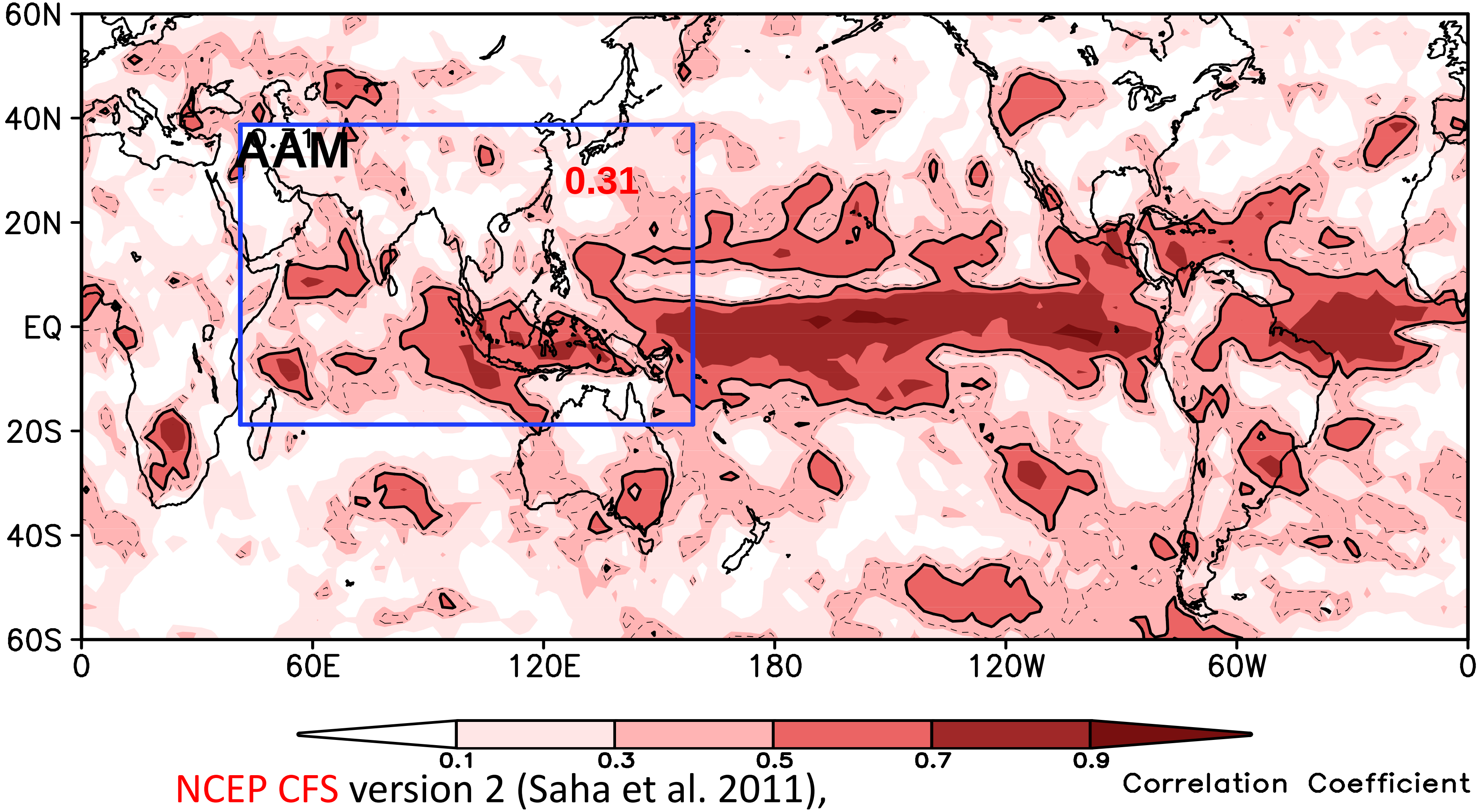
Rainfall Prediction is one of the foremost challenges in climate science



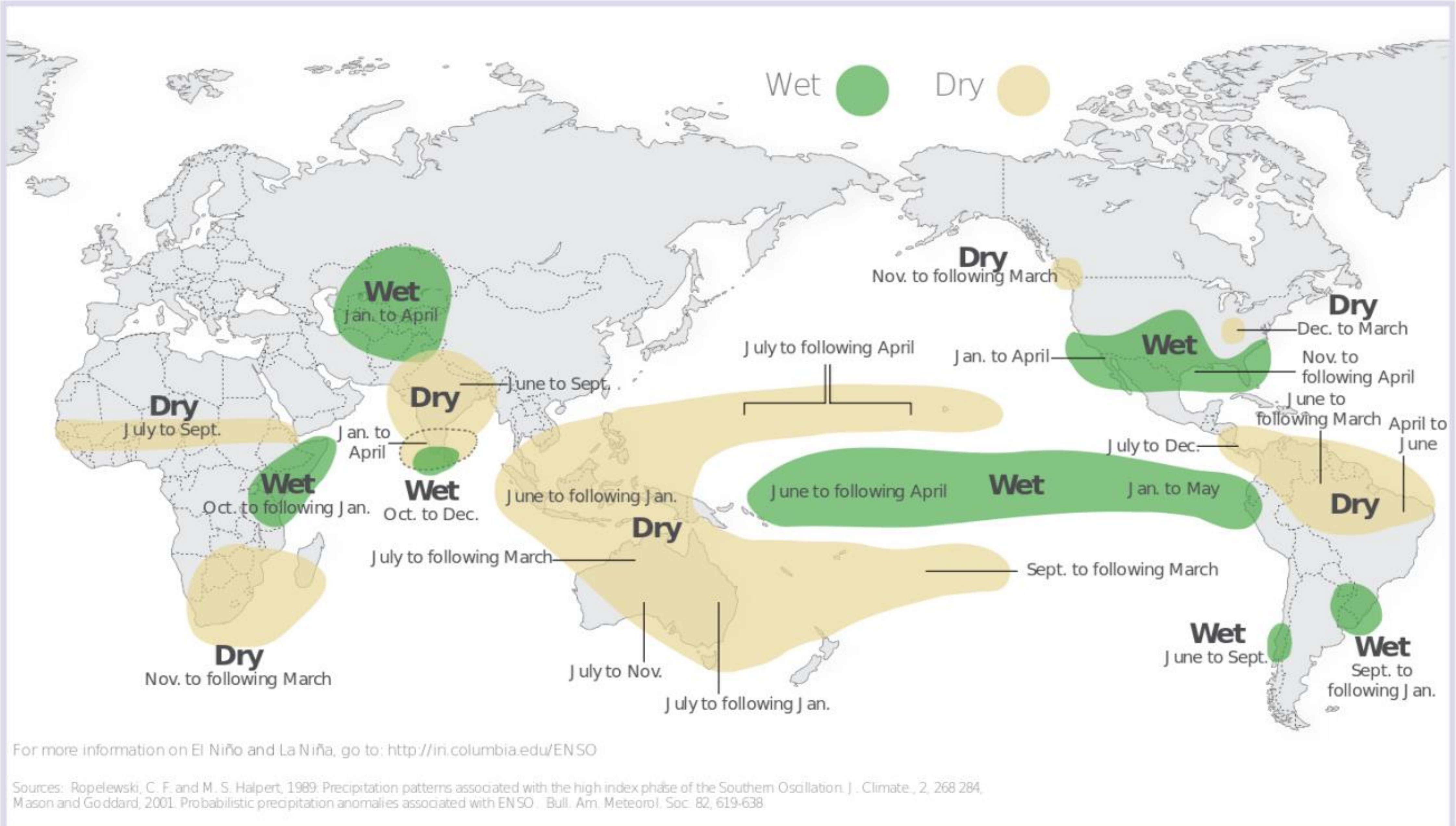
Four dynamical models' MME prediction **Temporal Correlation Skill for JJA rainfall (1979-2010)**

NCEP CFS version 2 (Saha et al. 2011),
ABOM POAMA version 2.4 (Hudson et al. 2011),
GFDL CM version 2.1 (Delworth et al. 2006), and
FRCGC SINTEX-F model (Luo et al. 2005).

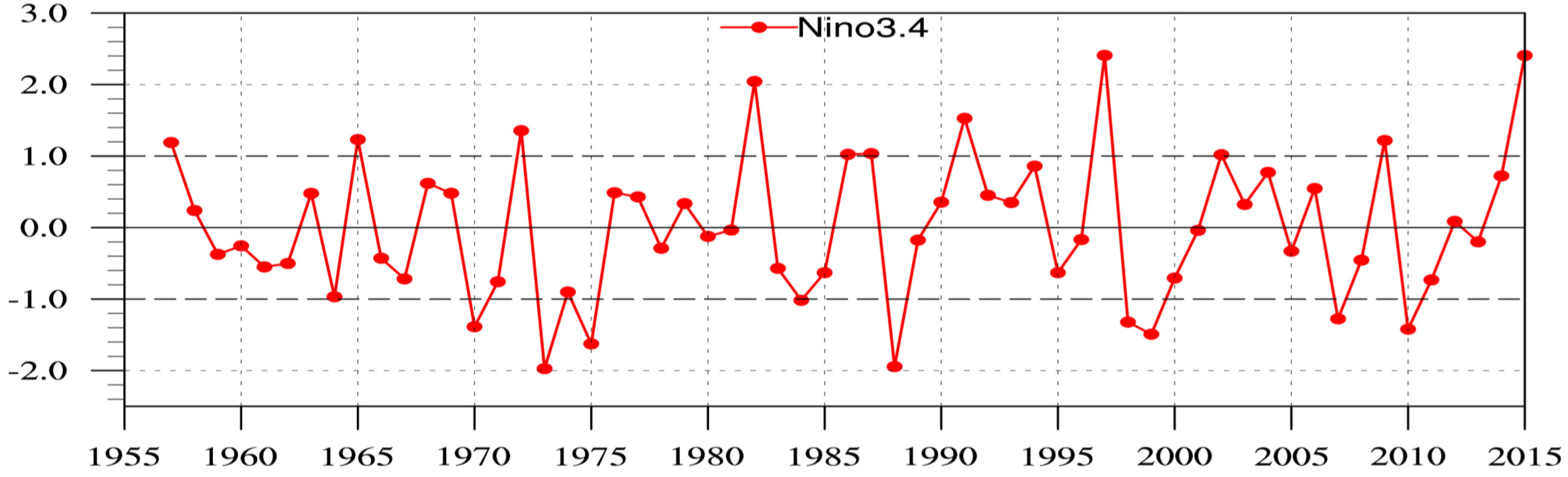
Dashed contour: 0.35

Wang et al. (2015)

El Nino impacts on global precipitation



ENSO anomalies seen from a Monsoon Year (June-May) perspective

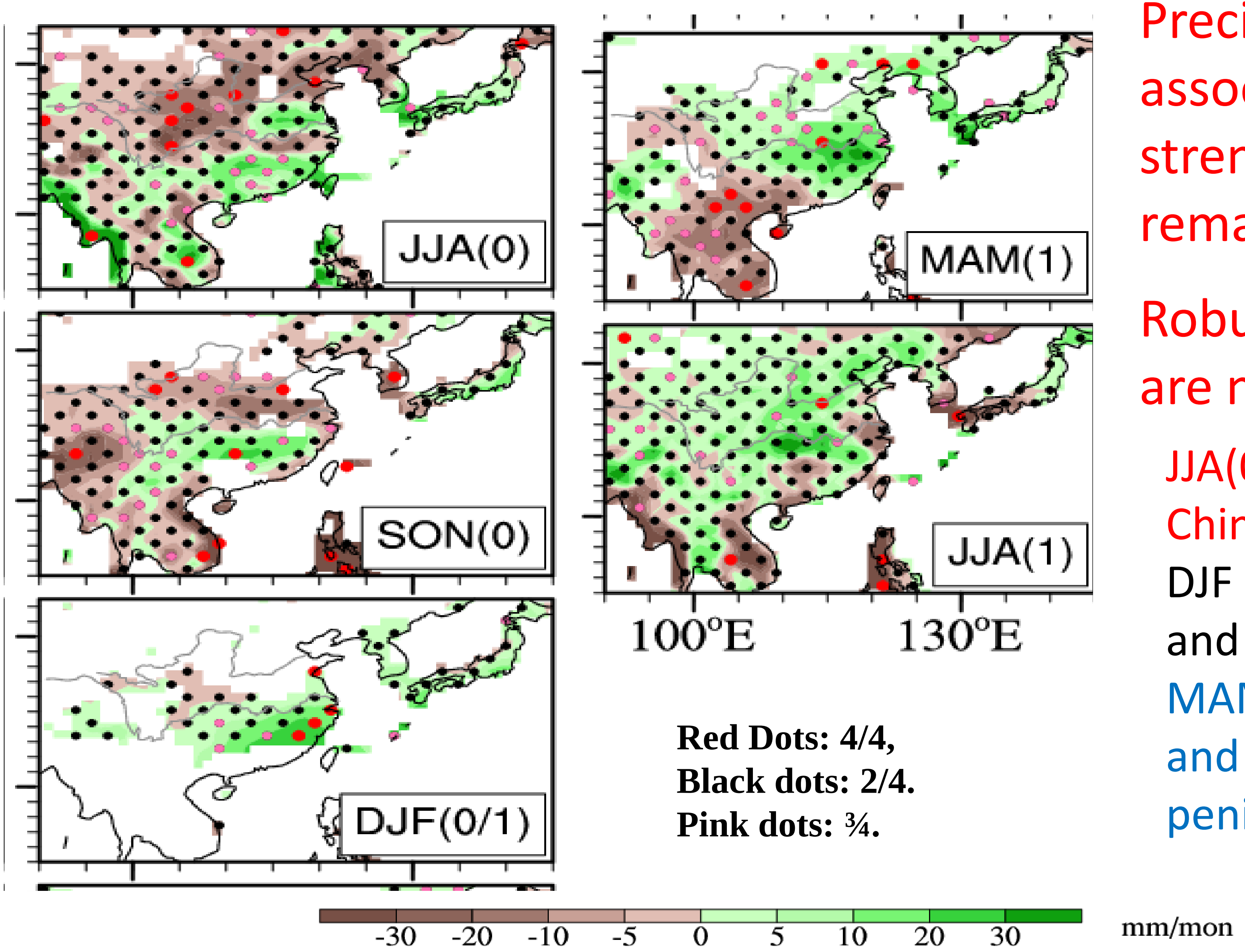


Normalized Nino3.4 index based on monsoon year (Meehl 1987, Yasunari 1991)

Categories of El Nino events	years
Super El Nino (>2SD)	1982, 1997, 2015
Major El Nino (1SD~2SD)	1957, 1965, 1972, 1991, 2009
Moderate El Nino(0.7SD~1SD)	1986, 1987, 1994, 2002, 2004
Minor El Nino(0.5SD~0.7SD)	1963, 1968, 1969, 1976, 2006

Monsoon-Year Nino 3.4 index measures the averaged El Nino intensity during the entire monsoon year.

All El Nino composites

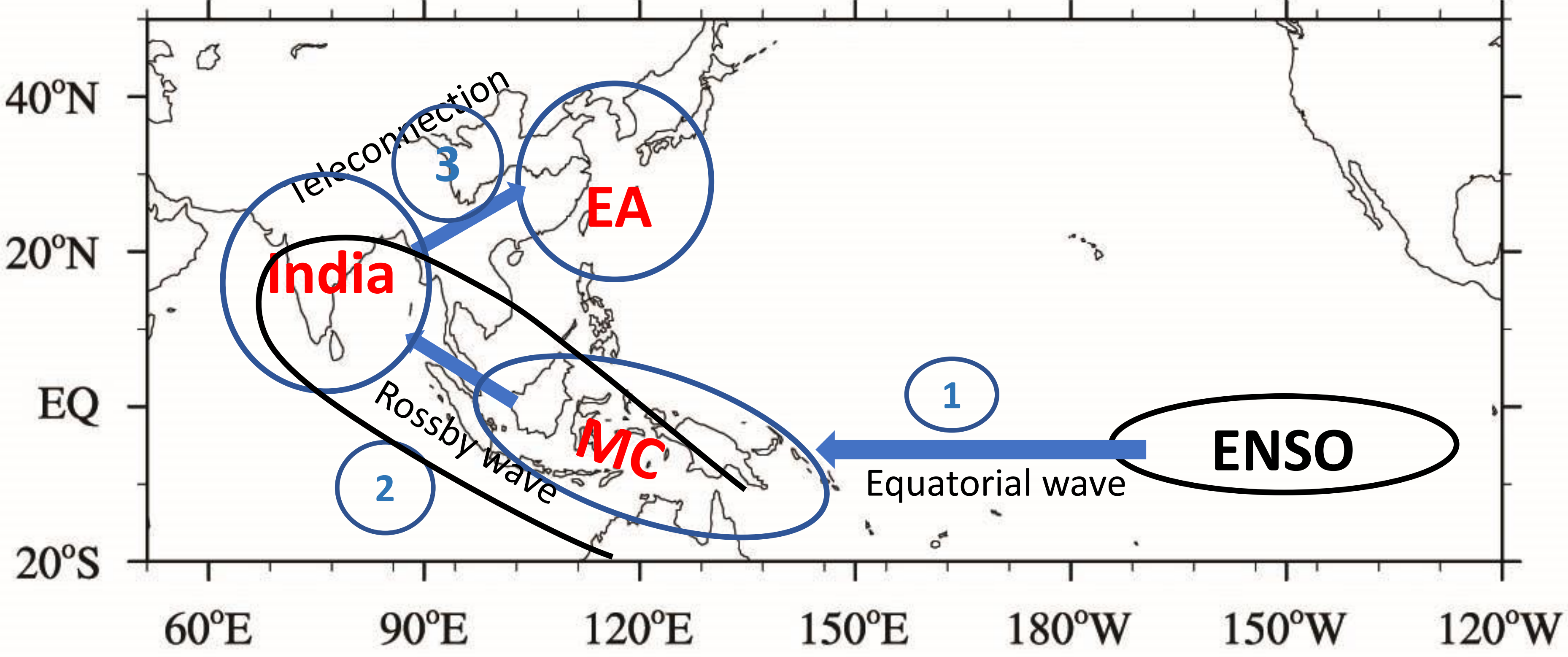


Precipitation anomalies associated with the different strengths of El Niño can be remarkably variable.

Robust signals over EA are not prominent

- JJA(0): dry central North China.
- DJF (0/1): wet in Zhejiang and Fujian province.
- MAM(1): dry over Guangxi and western Indo-China peninsula.

EA response during an El Nino developing Summer

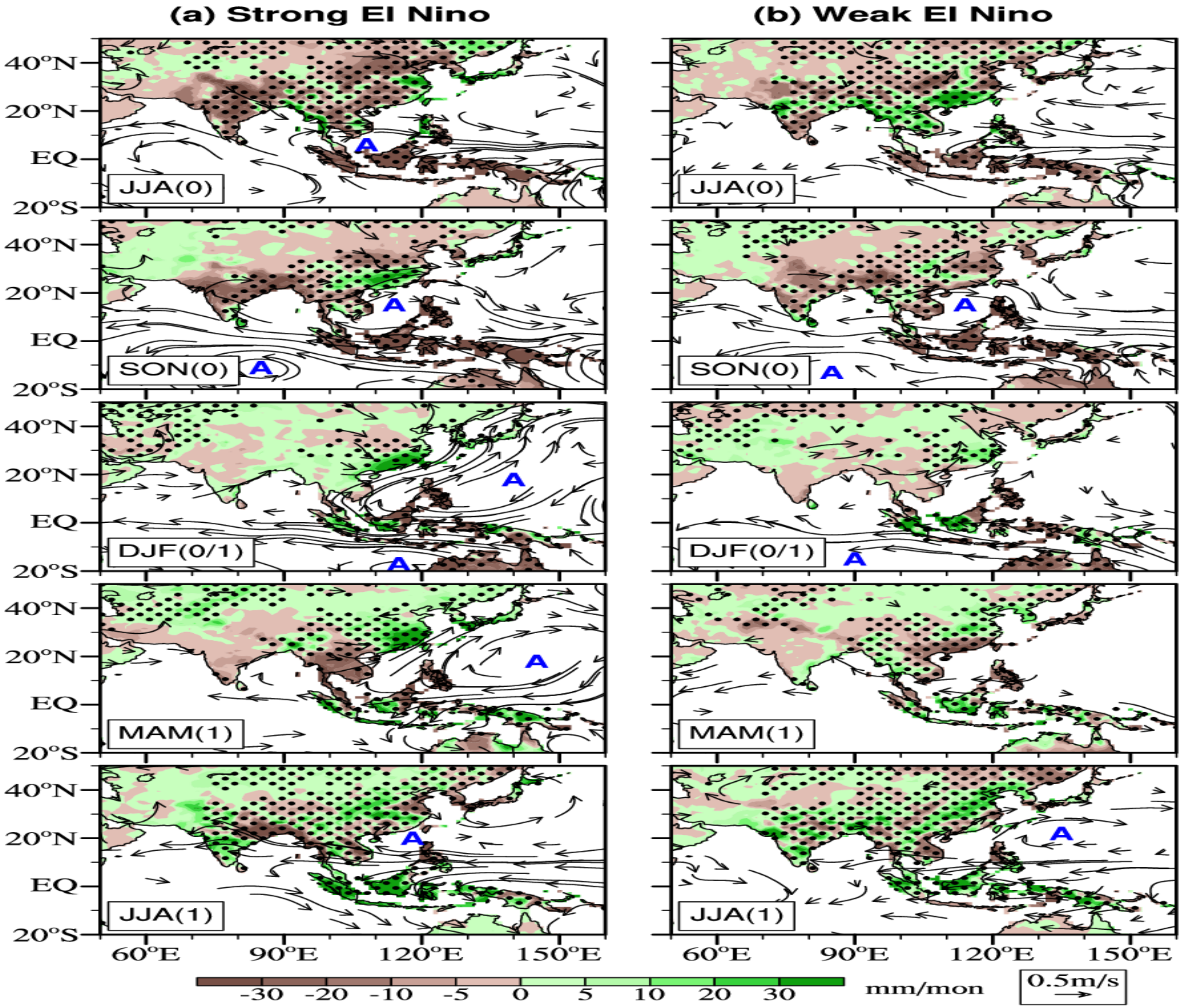


(1). Most robust impacts over MC and a less robust ion the Indian monsoon. Why?

- ❖ Efficient teleconnection along equatorial wave guide.
- ❖ Monsoon-ocean interaction offsets ISM response (Lau and Nath 2000; Saji et al. 1999; Webster et al. 1999; Wang et al. 2003)

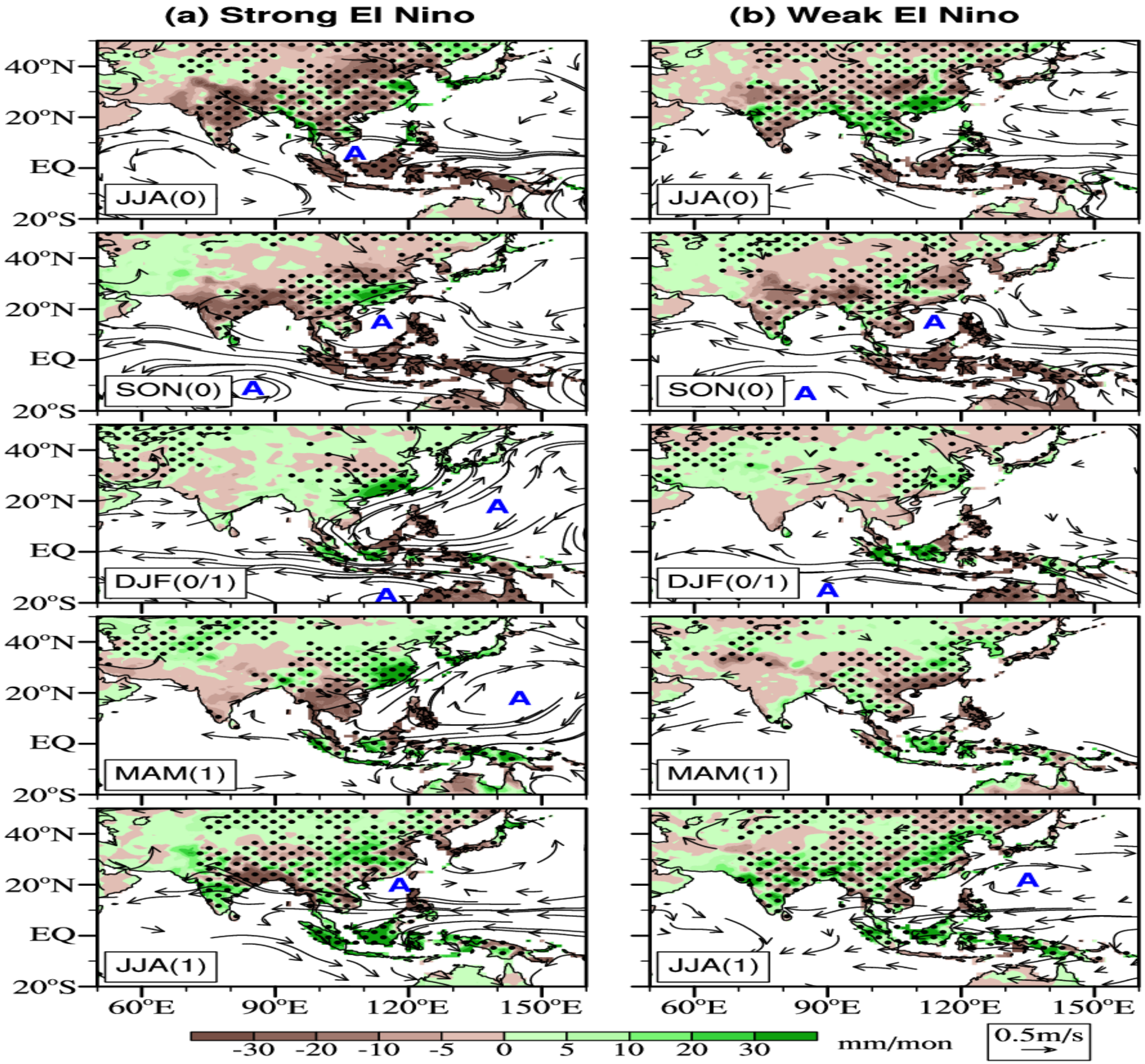
(2). The northern China response to the El Niño is more variable than the Indian summer monsoon response. Why?

- ❖ Teleconnection from ISM to EASM: Silk road (Enomoto et al. 2003); Circum-Global Teleconnection (CGT) (Ding and Wang 2005) depend on mean flows



Robust signals for Strong El Nino only

From SON(0) to MAM(1), the strong El Niño induces robust increasing precipitation along the EA subtropical frontal zone. But weak El Niño events do not.



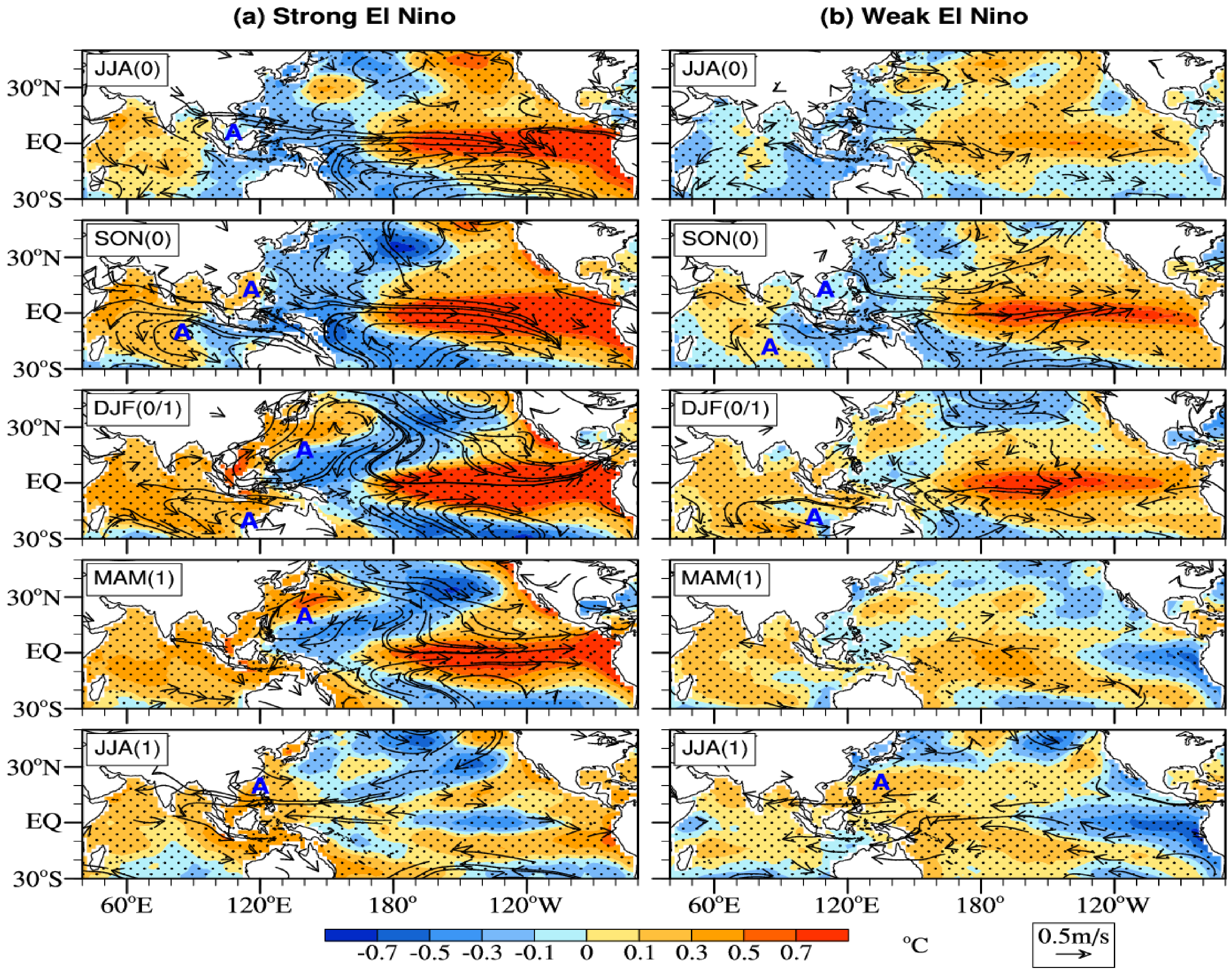
Different impacts between strong and weak El Ninos

Persistent WPAC anomaly is responsible for the wet southern China from SON(0) to MAM(1).

The WPAC anomaly occurs during the SON(0), further develops and expands eastward during DJF(0/1) and MAM(1), and weakens but maintains to JJA(1).

Only strong El Nino can excite persistent WPAC that persists into JJA (1).

Why?

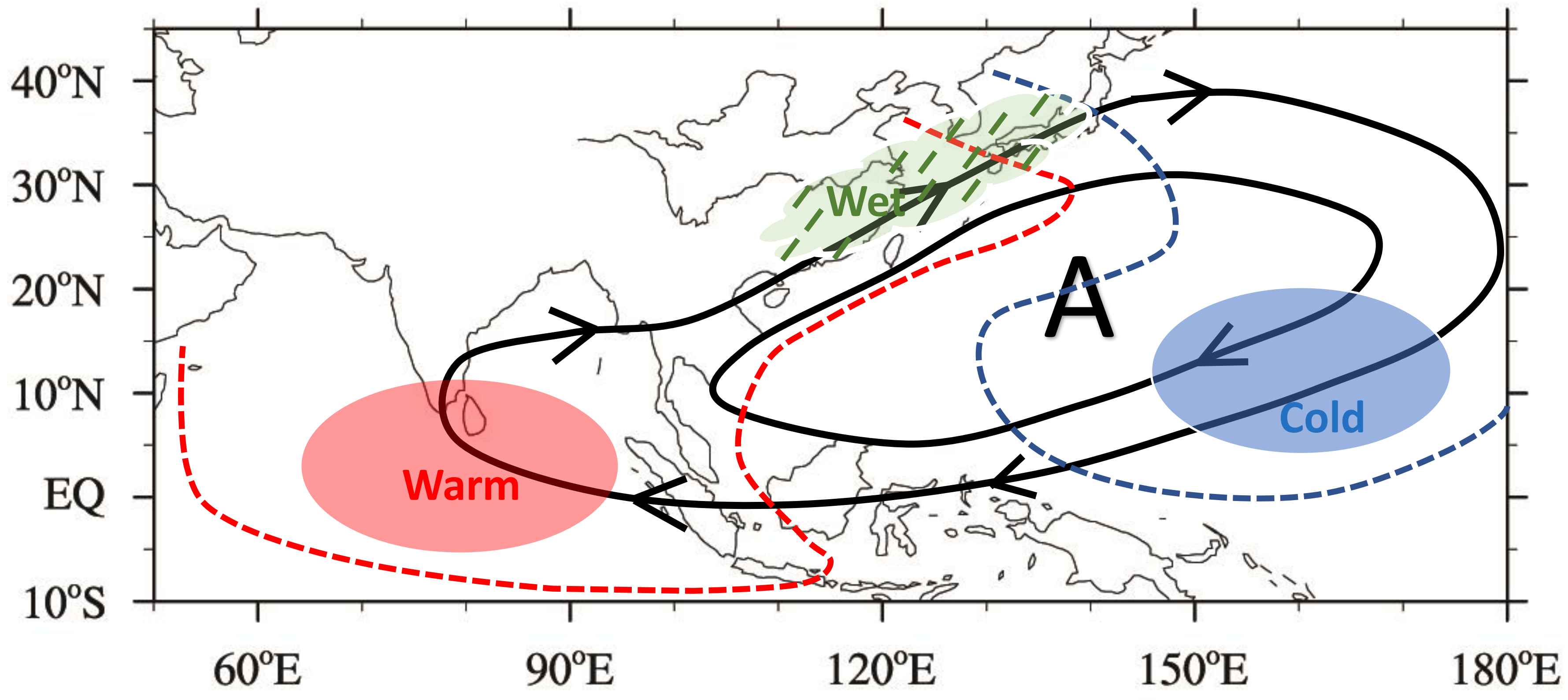


During strong El Nino, the WNP AC is coupled with a dipole SSTA in mature and decay phases, with cold SST to the E-SE and warm SST to the W-NW of the AC center.

During strong El Niño events, the coupled WPAC and SST dipole anomalies maintains the WPAC, providing a prolonged enhancement of EA subtropical frontal precipitation

(Wang et al. 2000; Lau and Nath 2003; Lau et al. 2004; Lau and Wang 2006; Chowdary et al. 2010, Xiang et al. 2013; Du et al. 2009, Xie et al. 2009, Wu et al. 2009, Xie et al. 2016)

Coupling mechanism between WPAC and Indo-Pacific SST dipole



Wang et al. (2013): WPSH - Indo-Pacific SST dipole coupled mode.
Xie et al. (2016): Indo-Pacific capacitor

Summary

(1) Over EA, the spatial patterns of the rainfall anomalies response to all El Nino are generally variable.

(2) The robust signal to all El Nino events is the deficient rainfall in northern China during the El Niño developing summer. In addition, strong El Niño persuasively enhances rainfall along EA subtropical front zone from SON (0) to MAM(1), and in the Yangtze River Valley during JJA(1).

(3) The precipitation response strongly depends on the integrated intensity of the El Nino. Strong and weak El Nino affect post-El Nino summer rainfall through different physical processes.

(4) Only strong El Nino can excite monsoon-ocean interaction and prolong El Nino impact on EASM in JJA(1). During a weak El Niño the WPAC is a forced response to the eastern Pacific rapid cooling.

SUBTROPICAL PREDICTABILITY Establishes a promising way for ASIAN MONSOON and TROPICAL STORM PREDICTION

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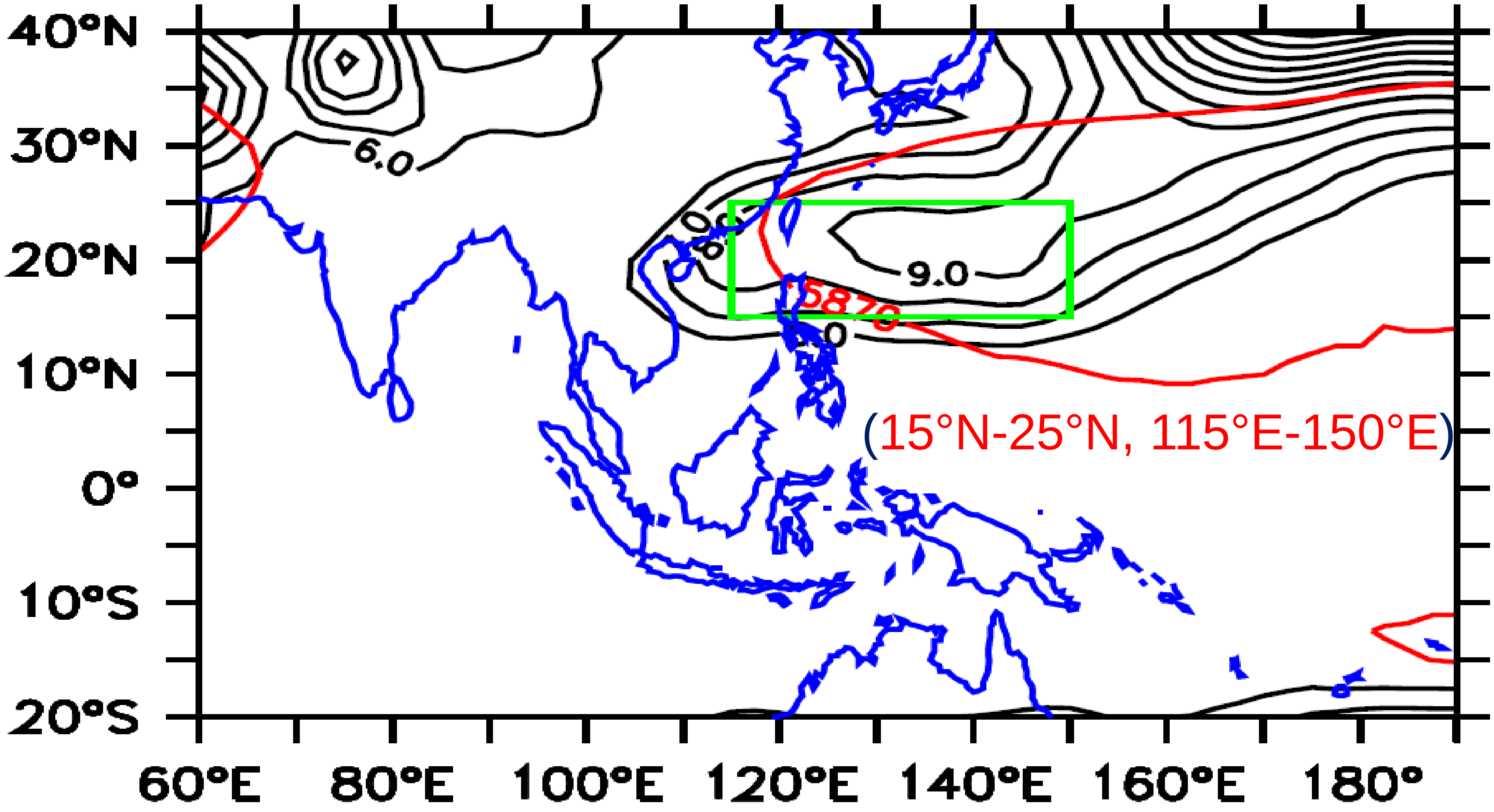
PNAS 2013

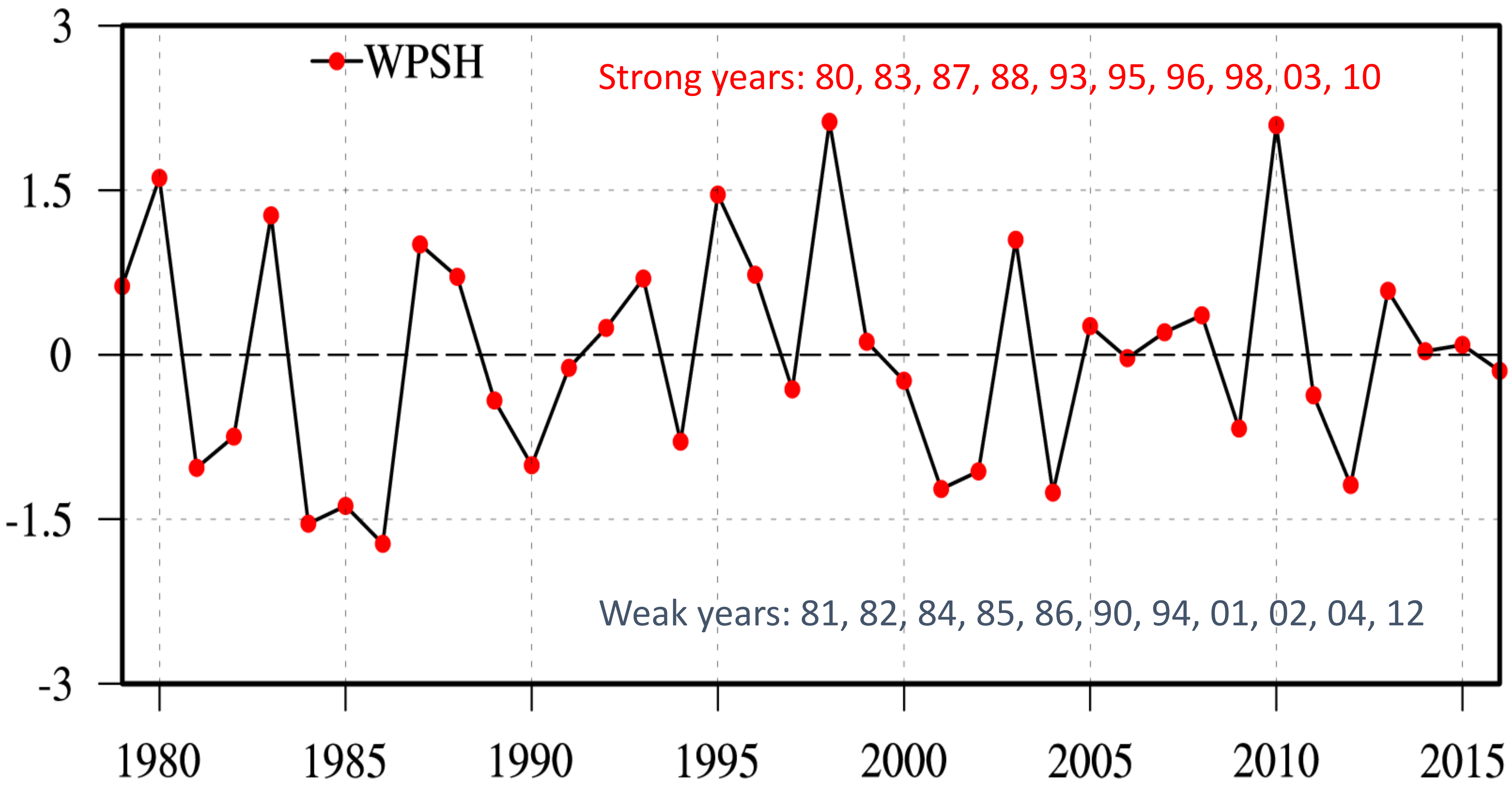
I. How important is the year-to-year variation of the WPSH?

Impacts and scientific issues

WPSH Index: measure of its intensity at the **Variability Center of H850**



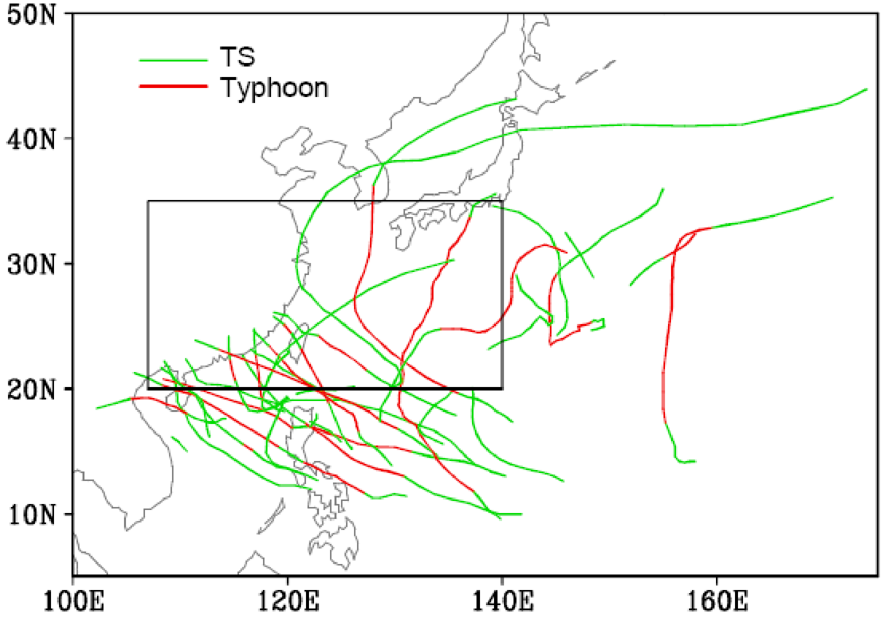
JJA mean WPSH intensity index (1979-2016)



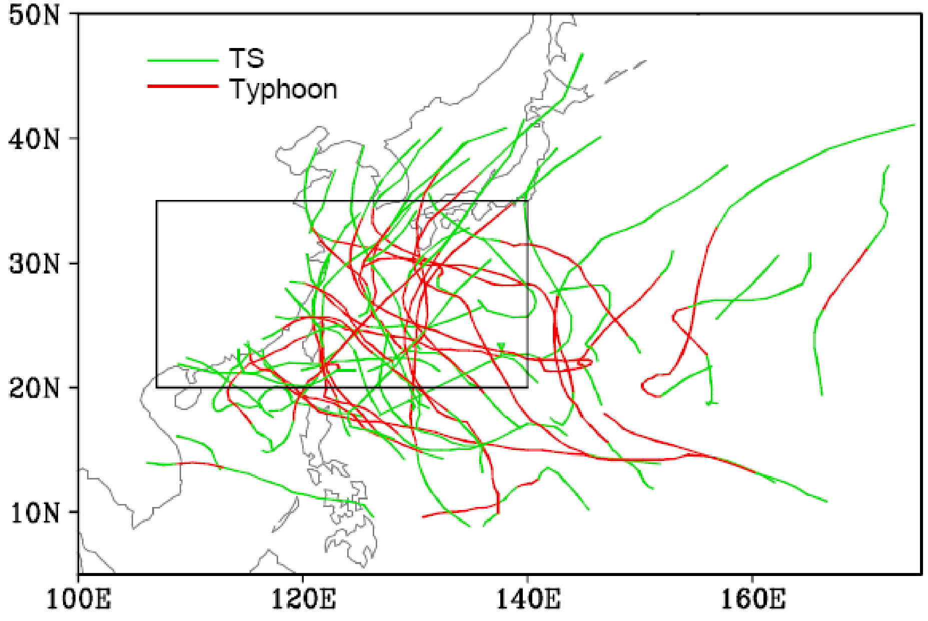
WPSH index: Normalized JJA H850 anomaly (15°N-25°N, 115°E-150°E)

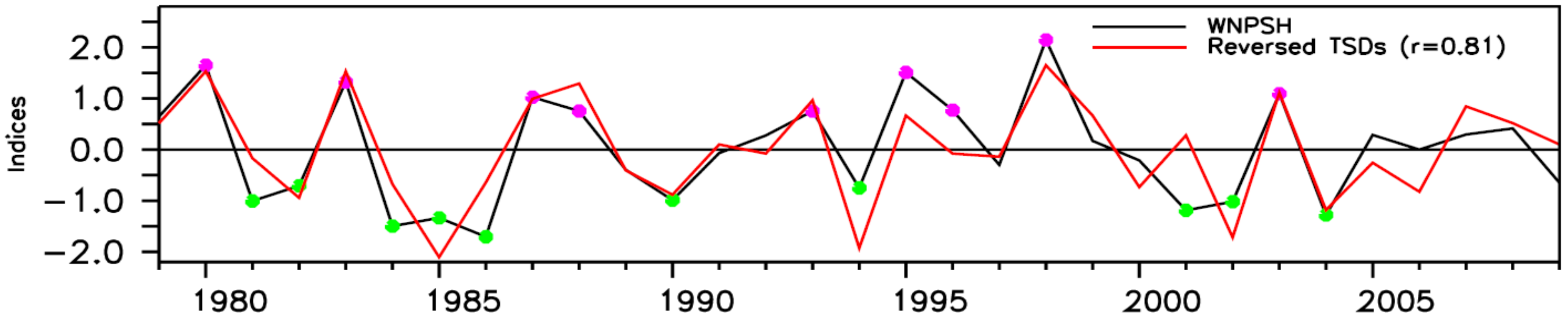
Weak WPSH increases the total number of tropical storm days in the Subtropical WNP: R=-0.81

4 Strongest WPSH years

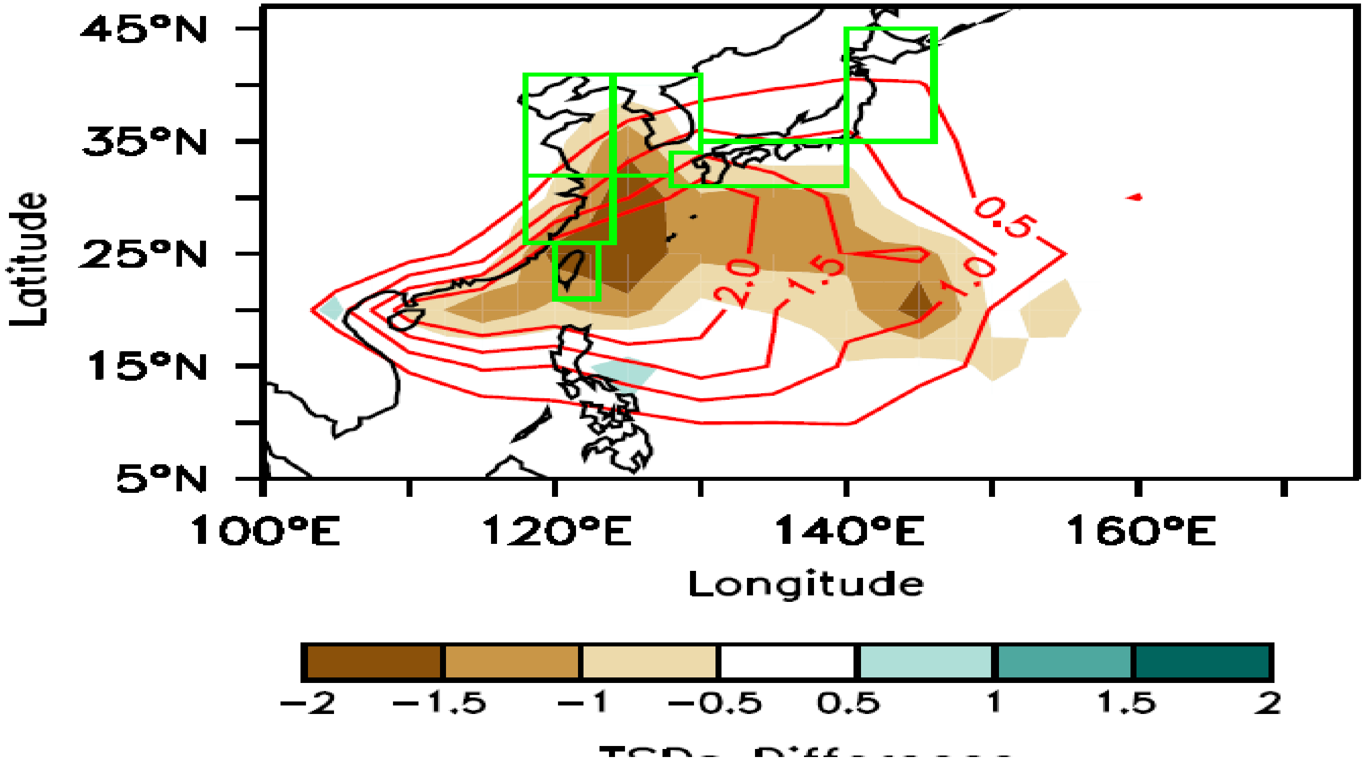


4 Weakest WPSH years

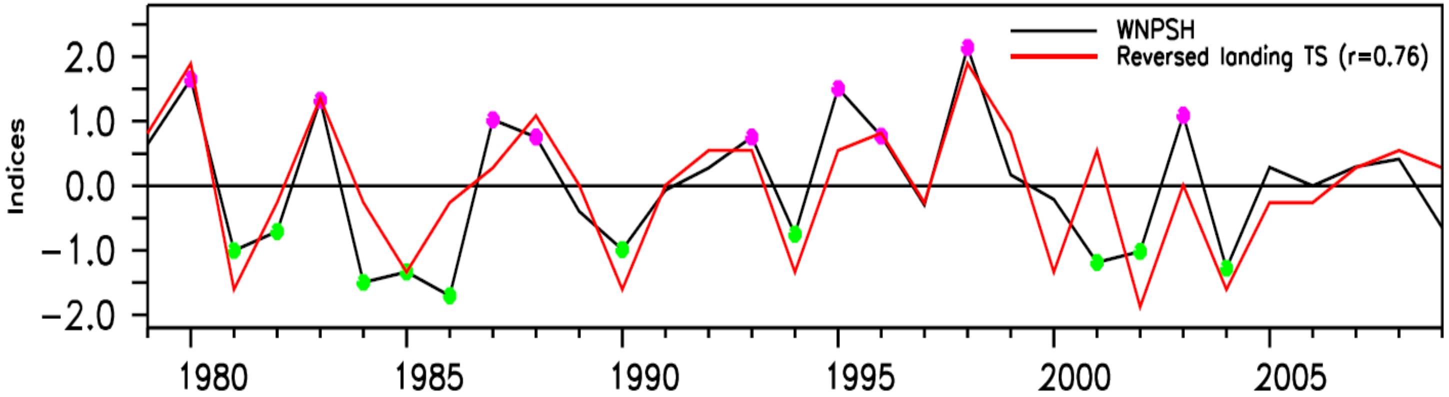




Weak WPSH increases the number of tropical storms affecting EA coastal areas: R=-0.76

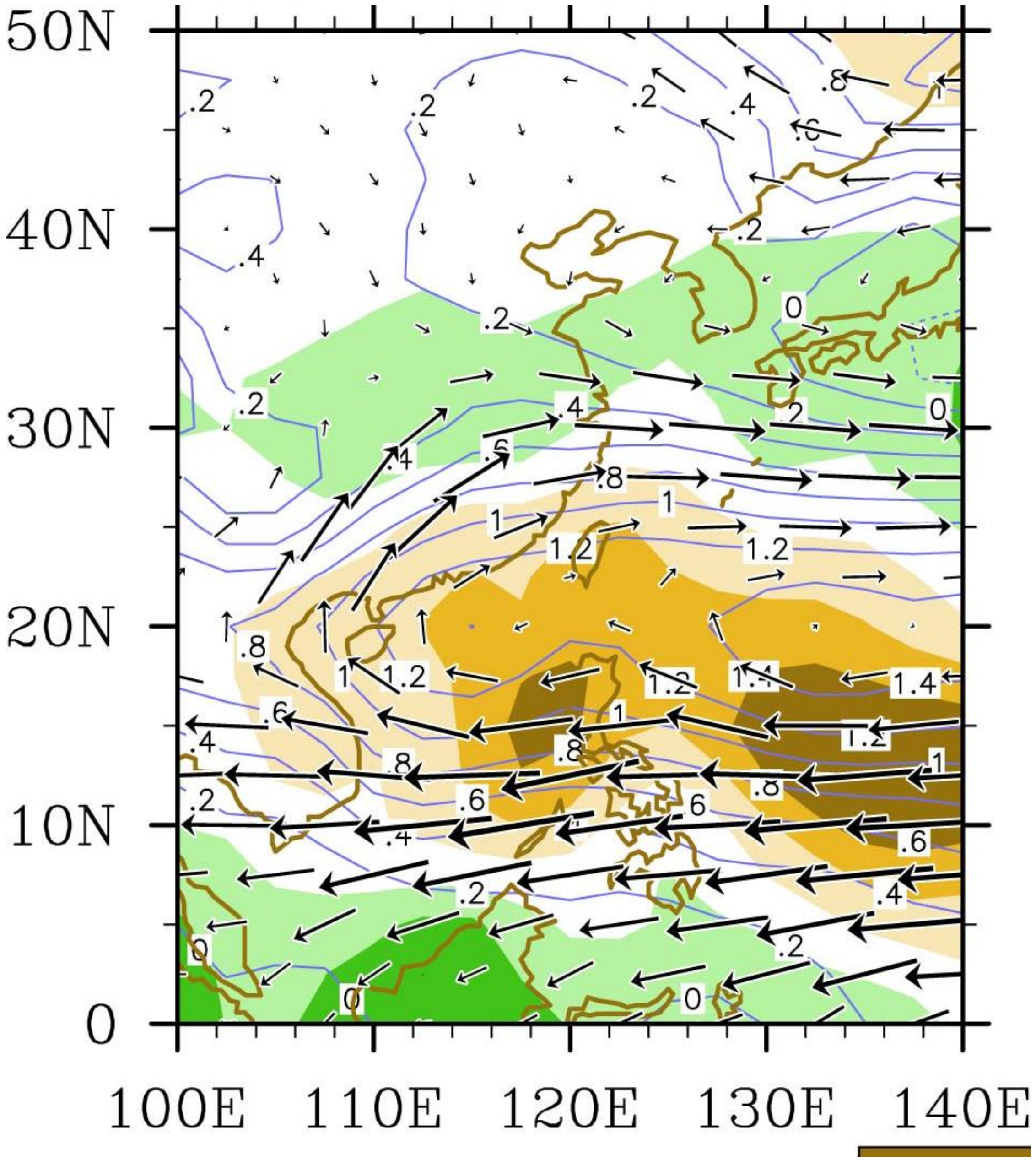


JJA TSDs: Climatology (contours) and the difference (shading) between 9 strong and 10 weak WPSH cases.



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

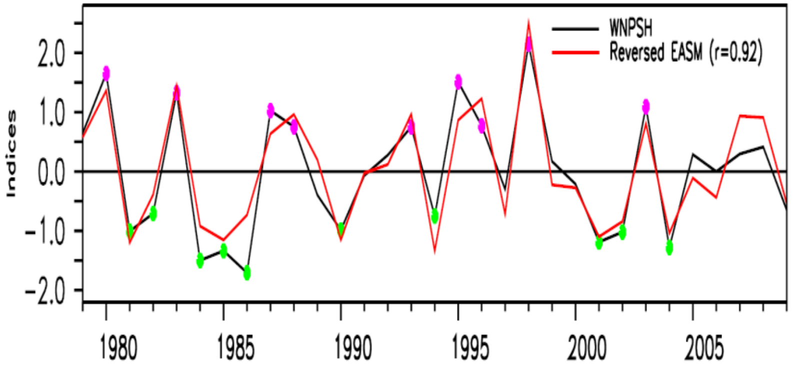
Leading mode of EA-WP summer monsoon



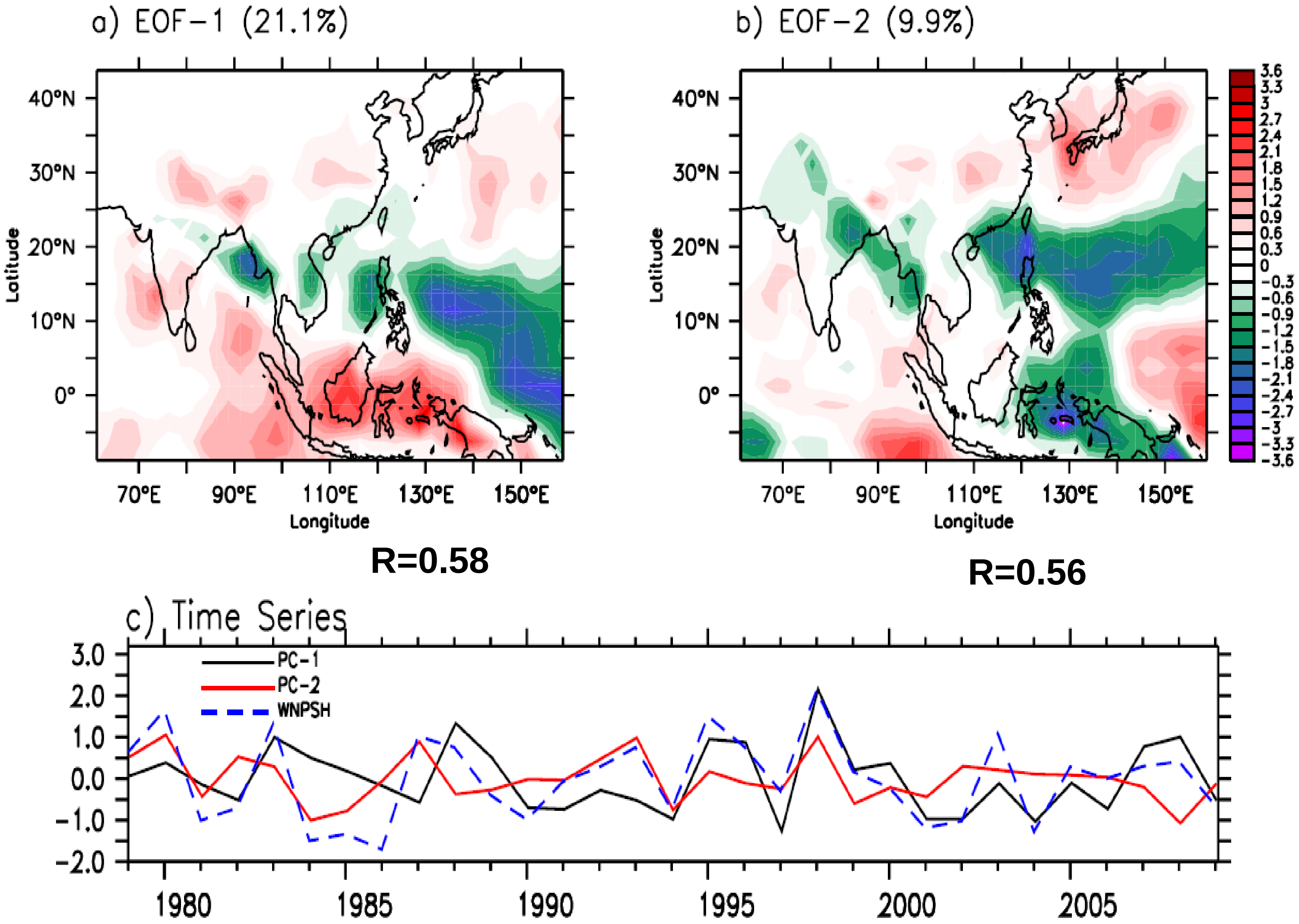
WPSH Index represents very well the leading mode of EA-WPSM

MV-EOF1 (39%): Precipitation, winds at 850 hPa and 200 hPa, and SLP.

WPSH Index and the EASM PC1: R=0.92



WPSH Index links to the Leading modes of Asian summer precipitation variation



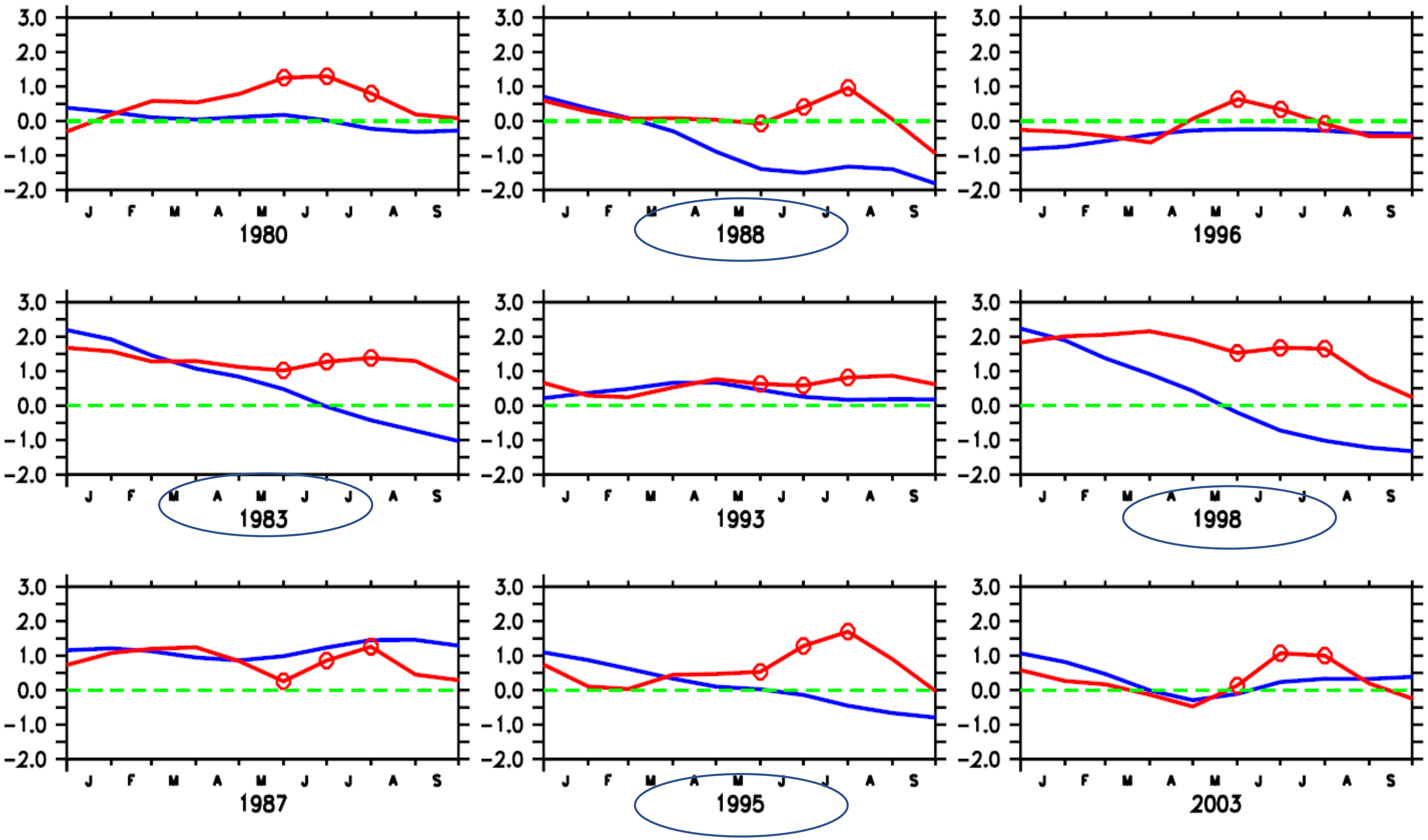
Interannual variations of WPSH intensity represents

1. Strength of EA-WNP summer monsoon (r=–0.92),
2. Total tropical storm days over the subtropical WNP (r=–0.81),
3. Total number of tropical storms affecting Japan, Korea, East China (r=–0.76), and
4. The first two leading modes of rainfall variability over the entire Asian summer monsoon in 40-180E, 20S-45N)(r=0.58 and 0.56, respectively).

Scientific issue

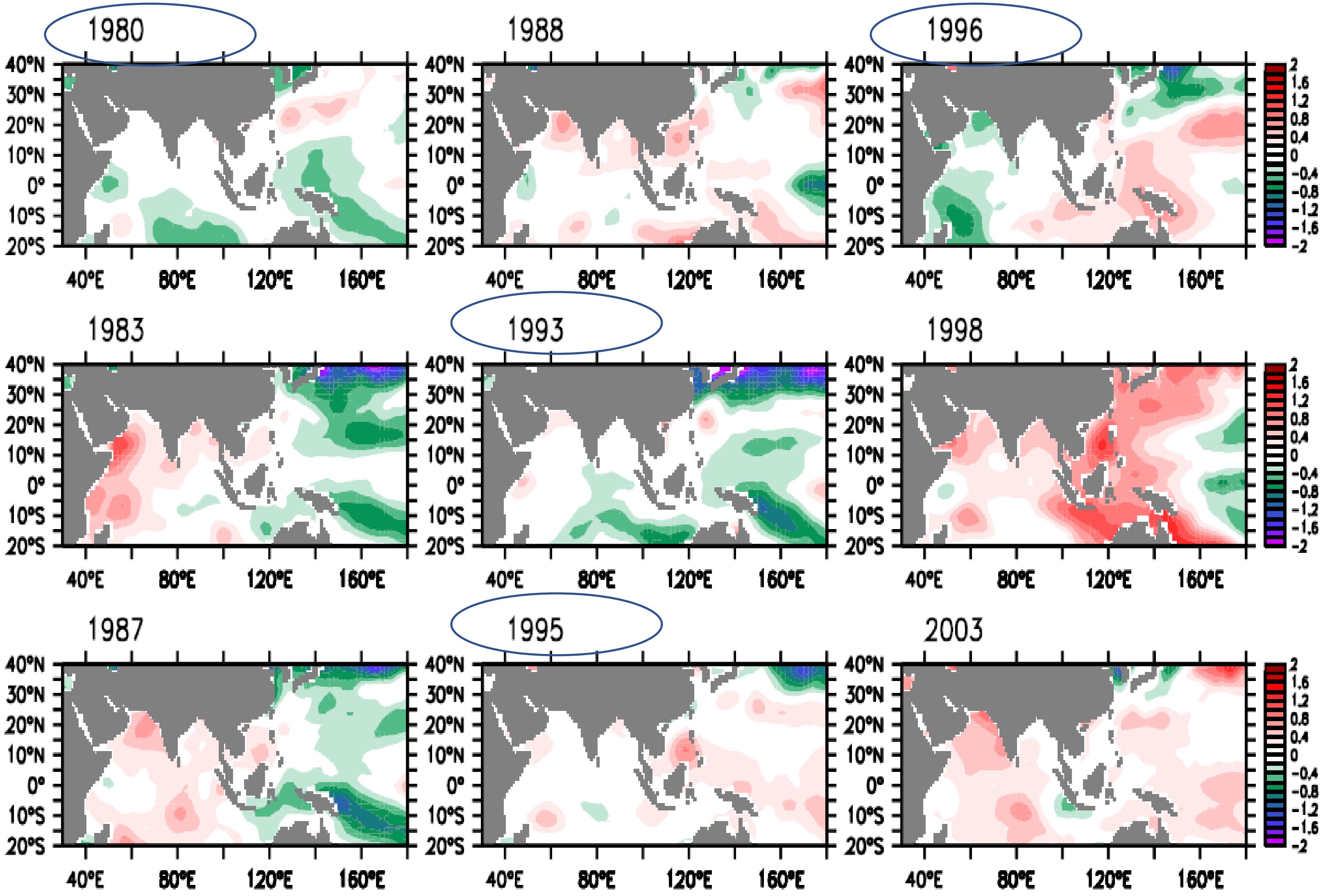
Does WPAC anomaly occur primarily on the decaying phase of El Nino?

WPSH (red) and Nino3.4 SSTA (black) 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)

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

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

II. What control interannual variability of the WPSH ?

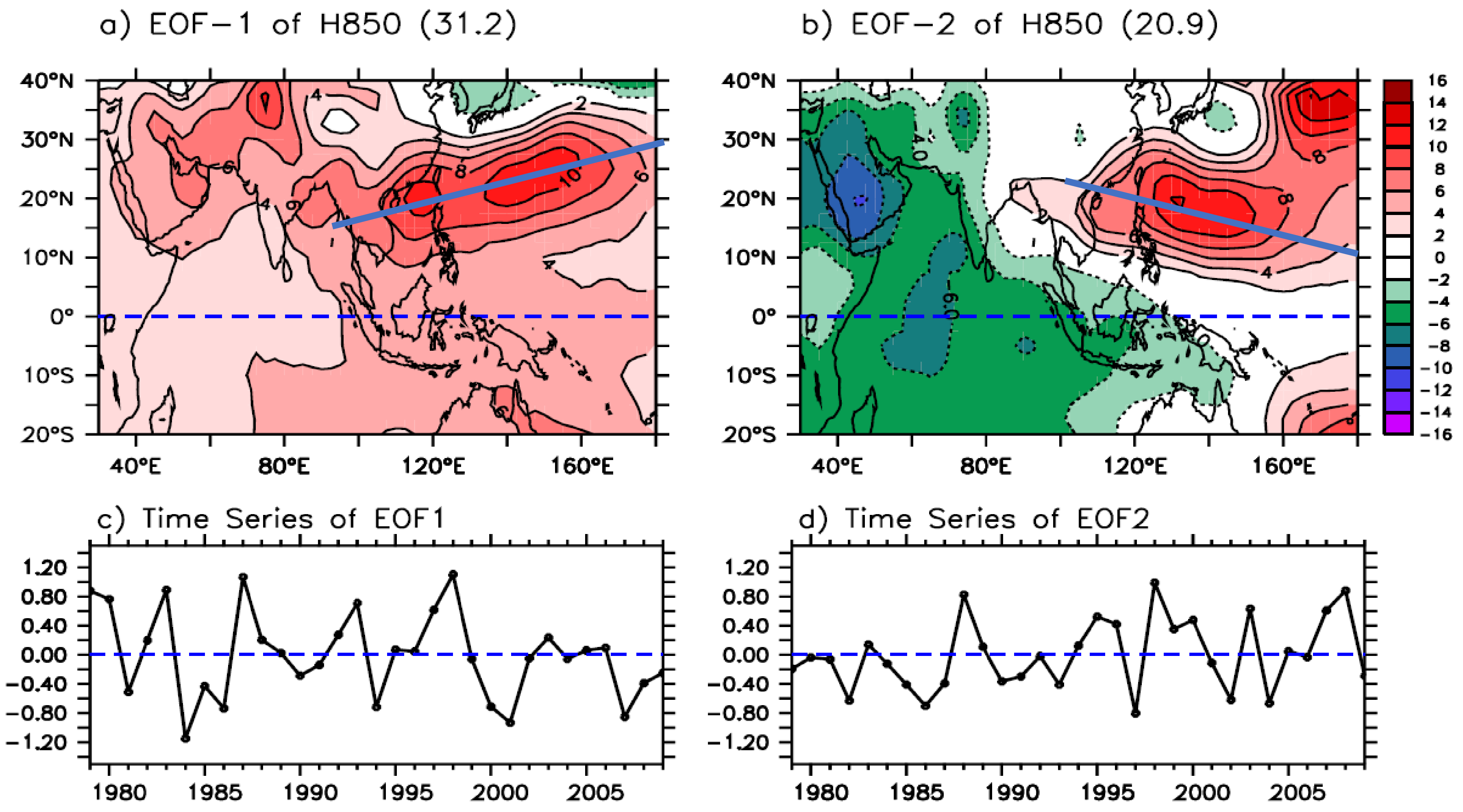
Method:

Principle modes analysis of the mechanisms of the WPSH variability

What are the major modes of the year-to-year variability?

What are the origins of these major modes of variability?

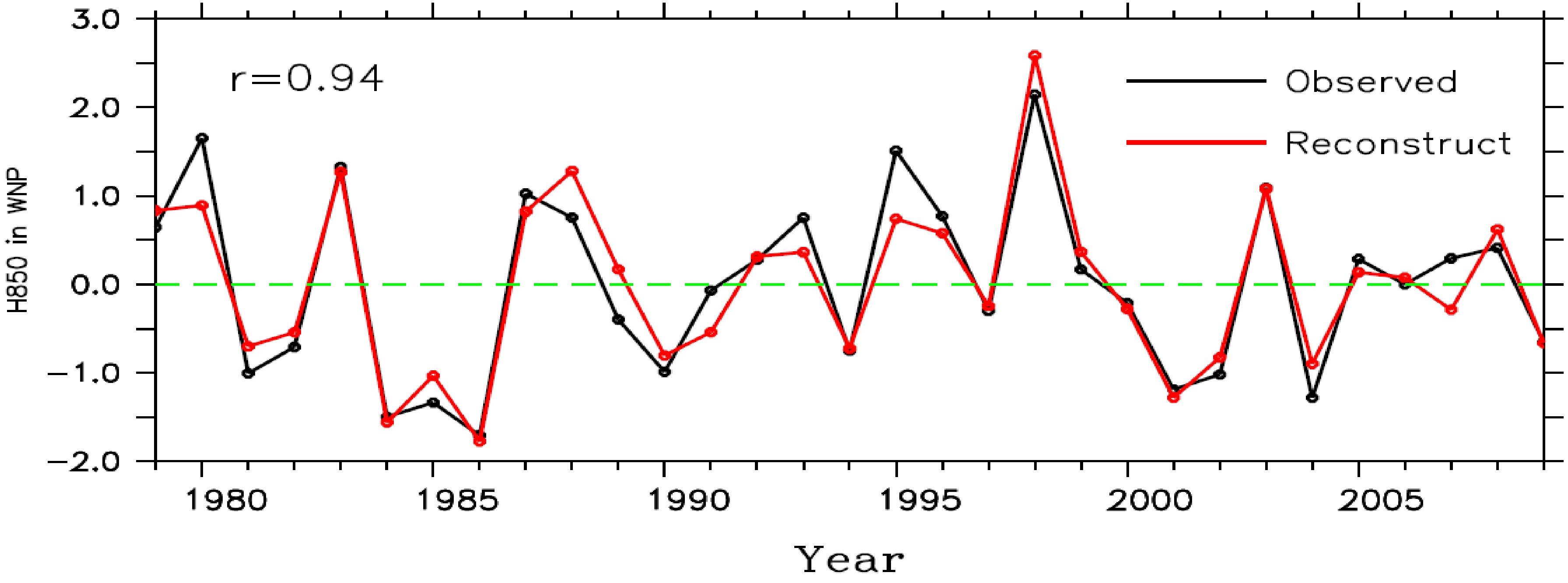
Principal modes of pressure field (JJA 1979-2009)



Cor with WPSHI r=0.60 r=0.73

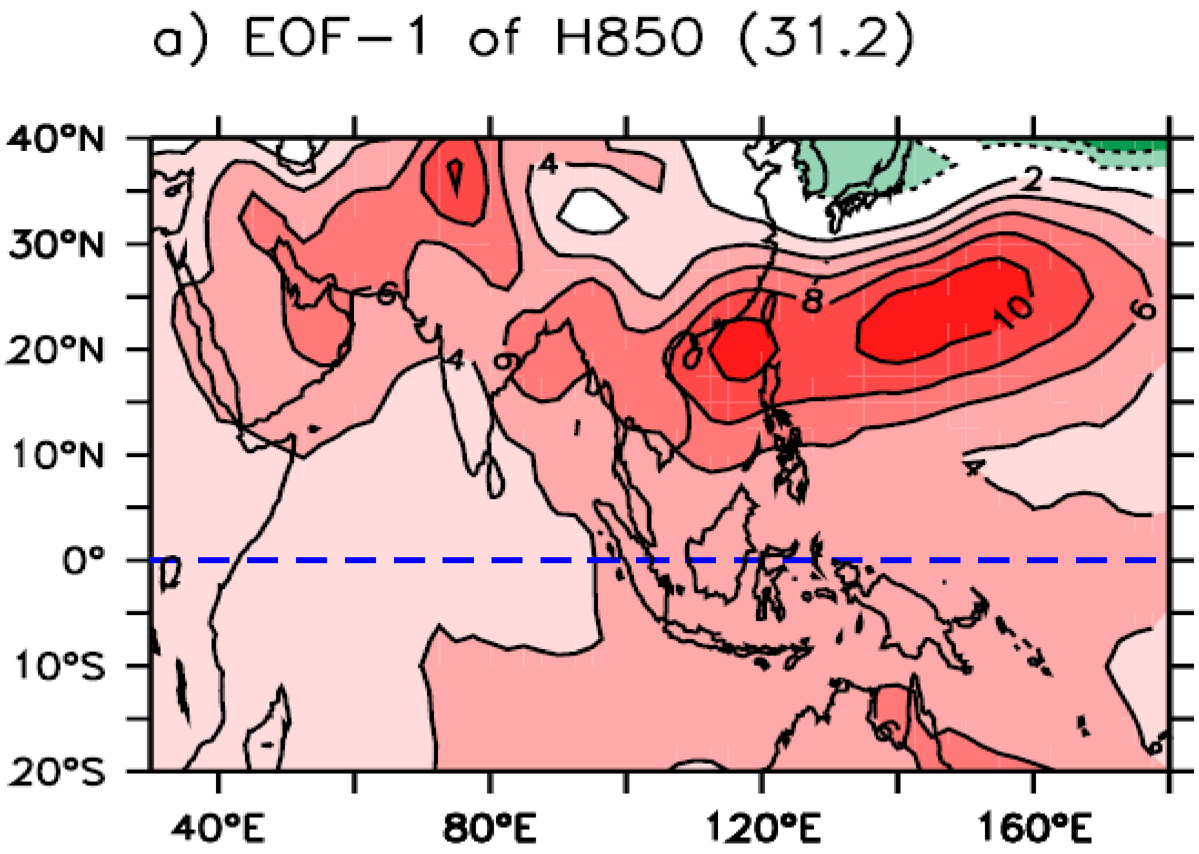
First two leading EOF modes of JJA 850 hPa GPH anomaly

WPSHI can be very well reconstructed by the two leading modes

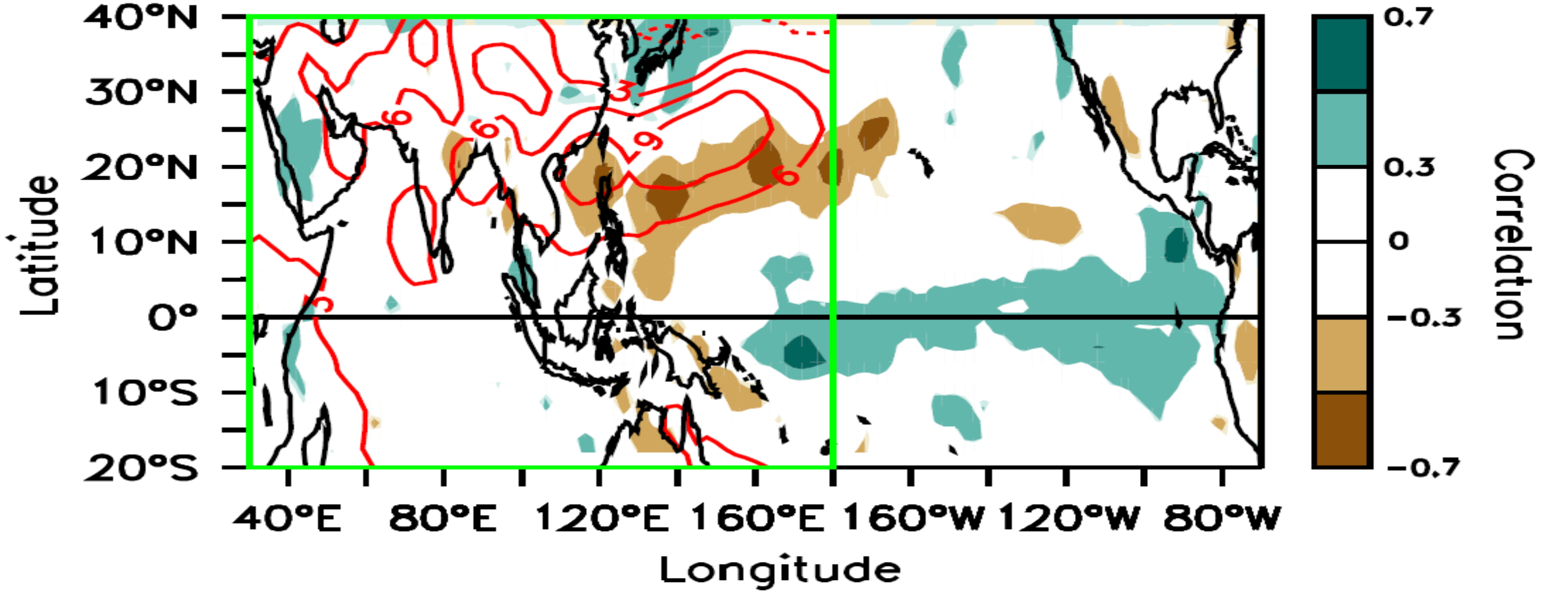


The normalized WNPSH index (black) and the reconstructed index based on PC1 and PC2 (**1.226×EOF-1+1.245×EOF-2**) from the EOF analysis of H850 anomaly (red). They have a correlation of about 0.94.

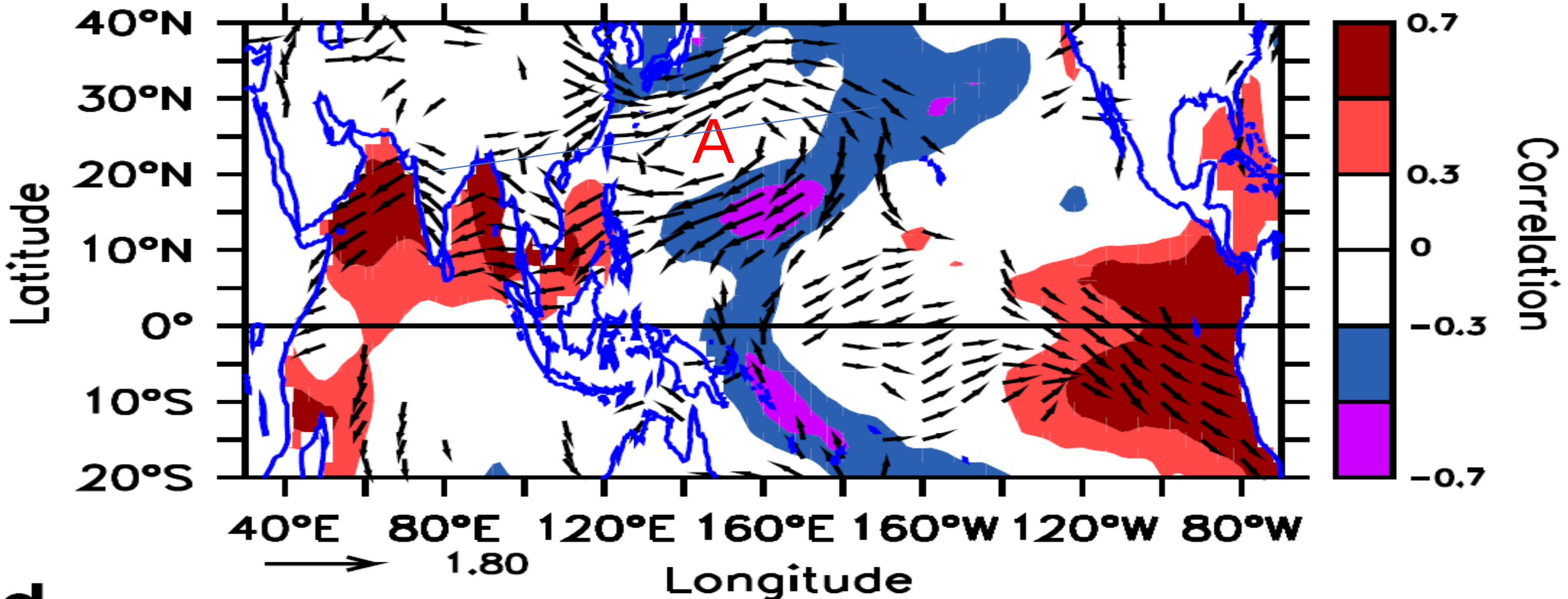
Origin of EOF 1?



Anomalies associated with EOF 1

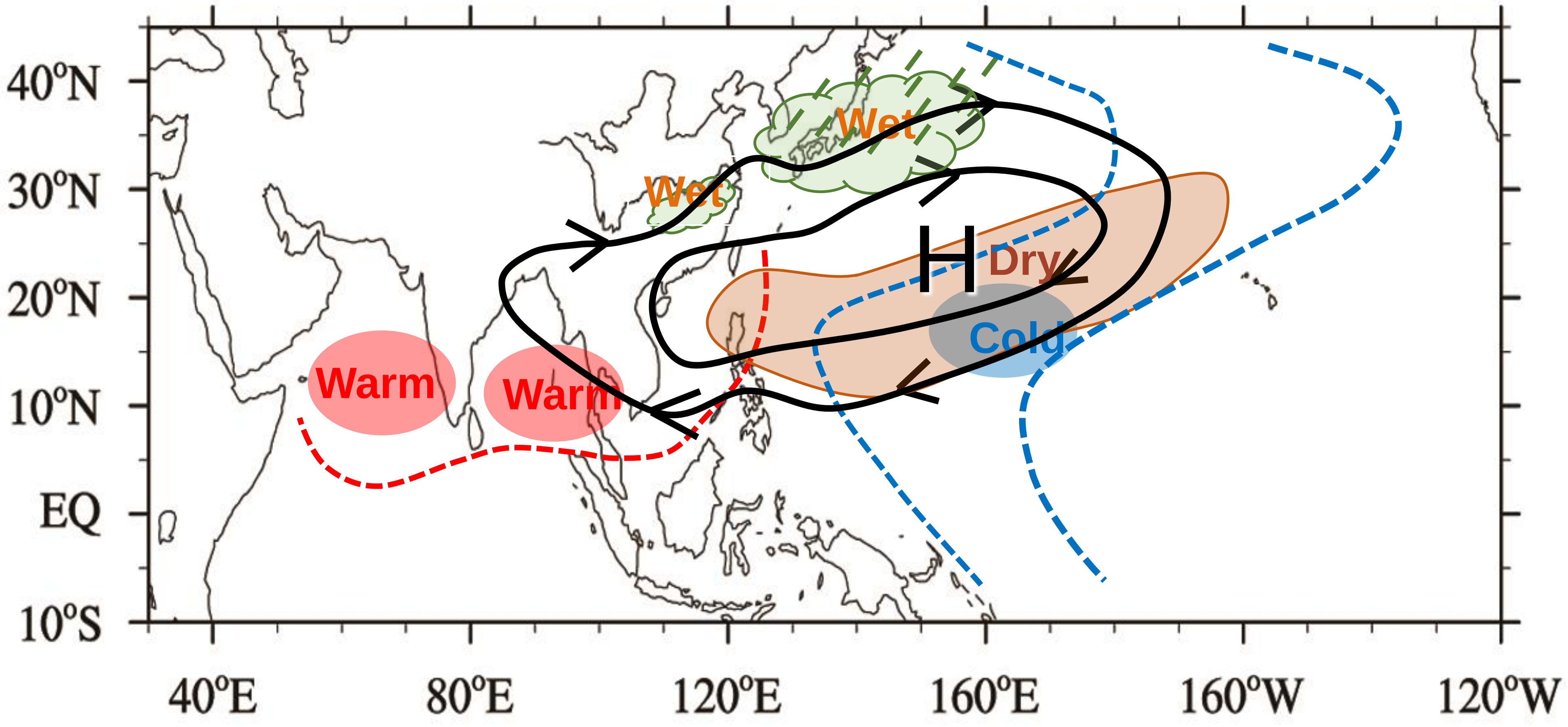


H 850 & rainfall

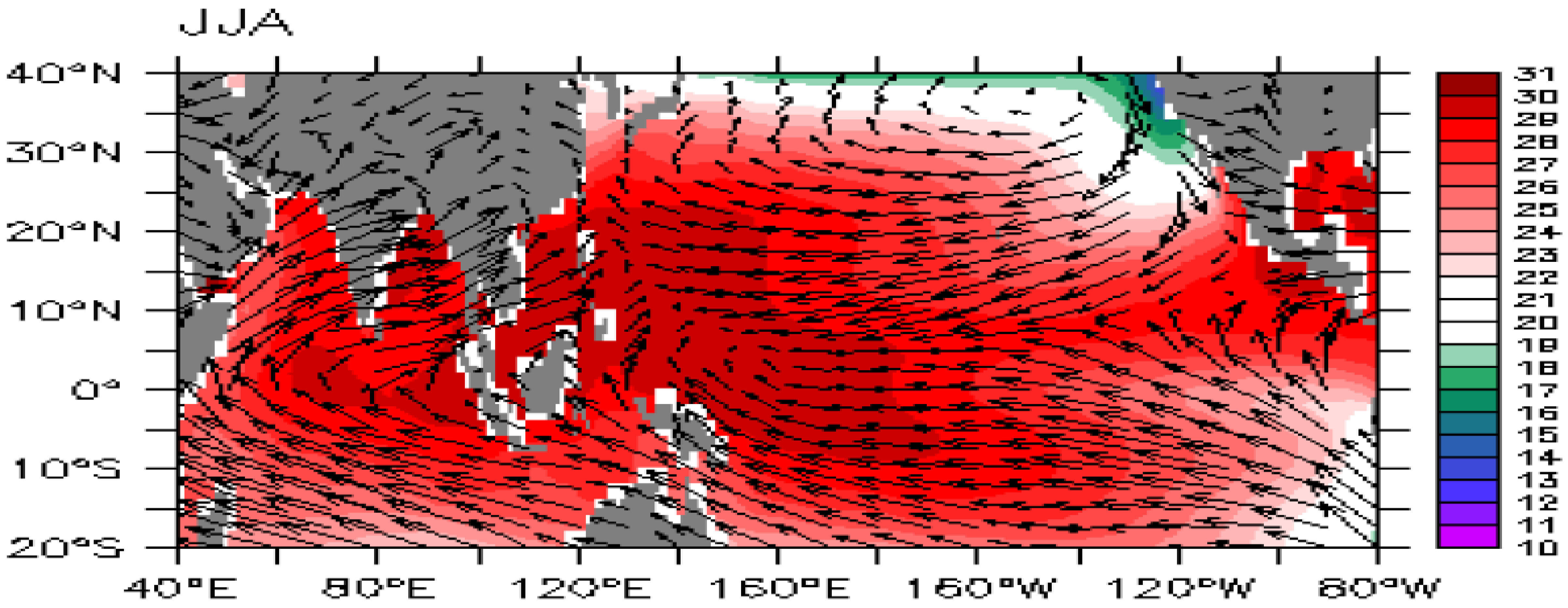


Winds 850 & SST

EOF 1: WPSH and Indo-Pacific SST coupled Mode



The positive thermodynamic feedback between anomalous WPSH and underlying Indo-Pacific SST dipole can sustain the anomalous WPSH.


JJA
40°N
30°N
20°N
10°N
0°
10°S
20°S
40°E
80°E
120°E
160°E
160°W
120°W
80°W
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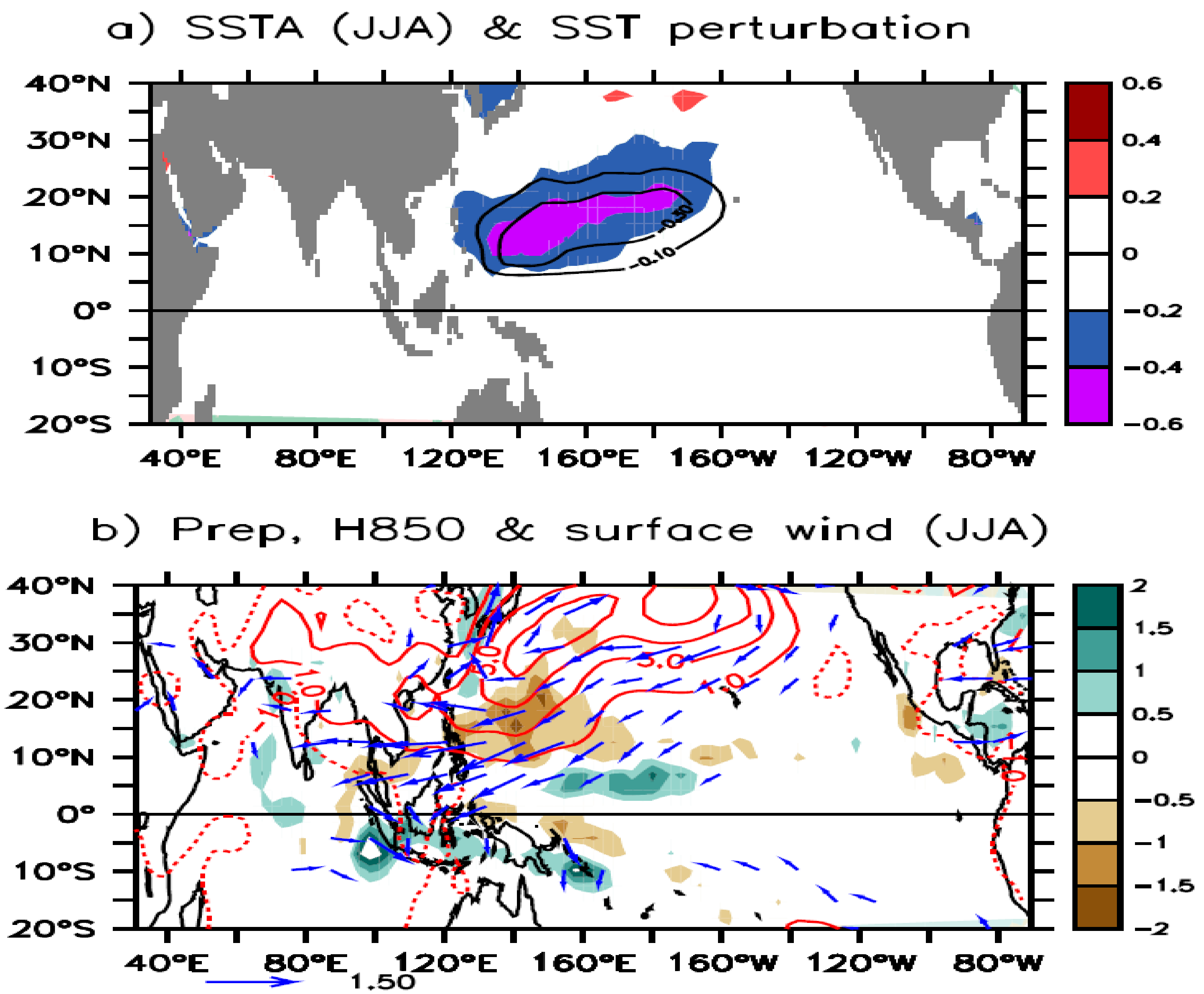
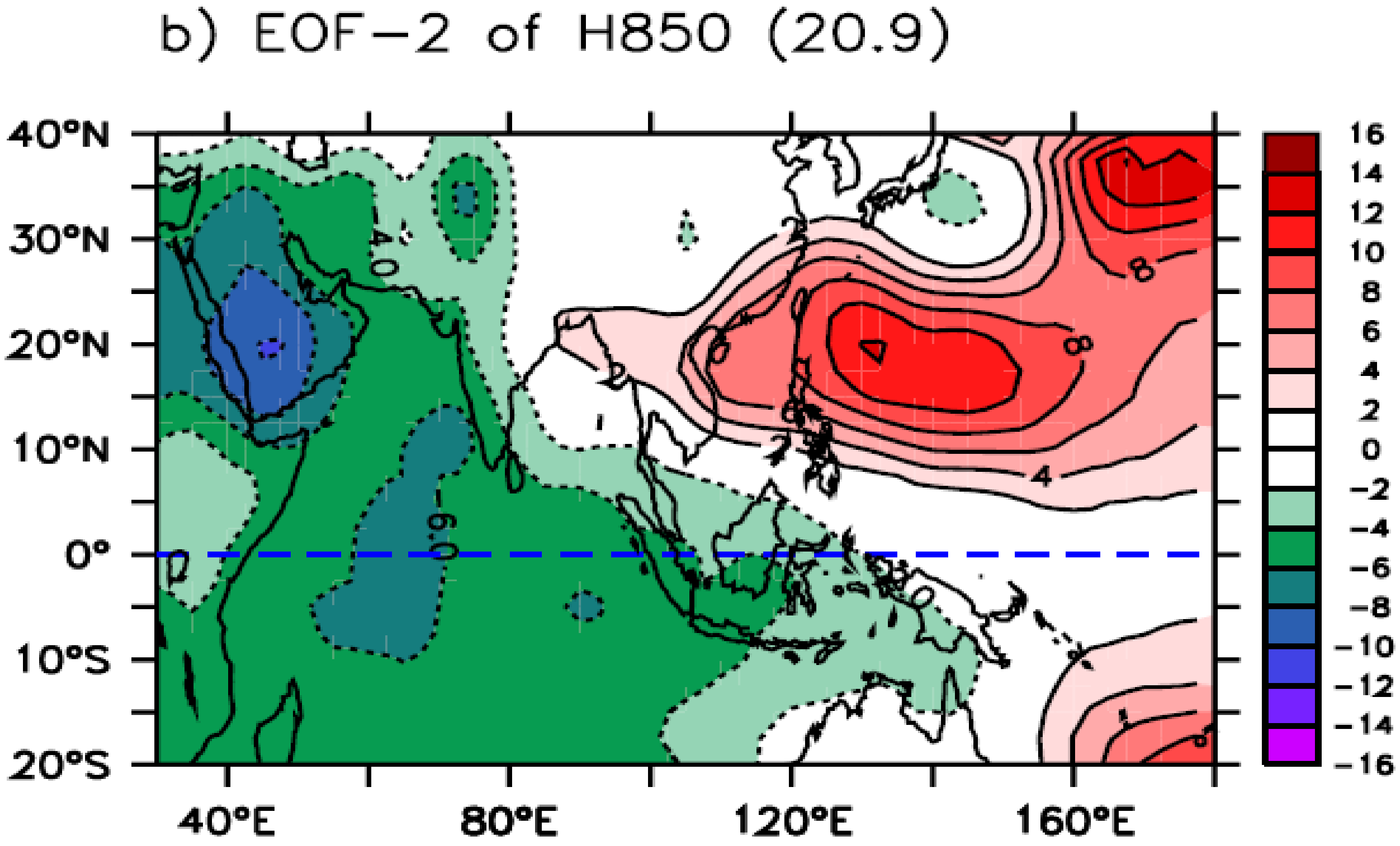
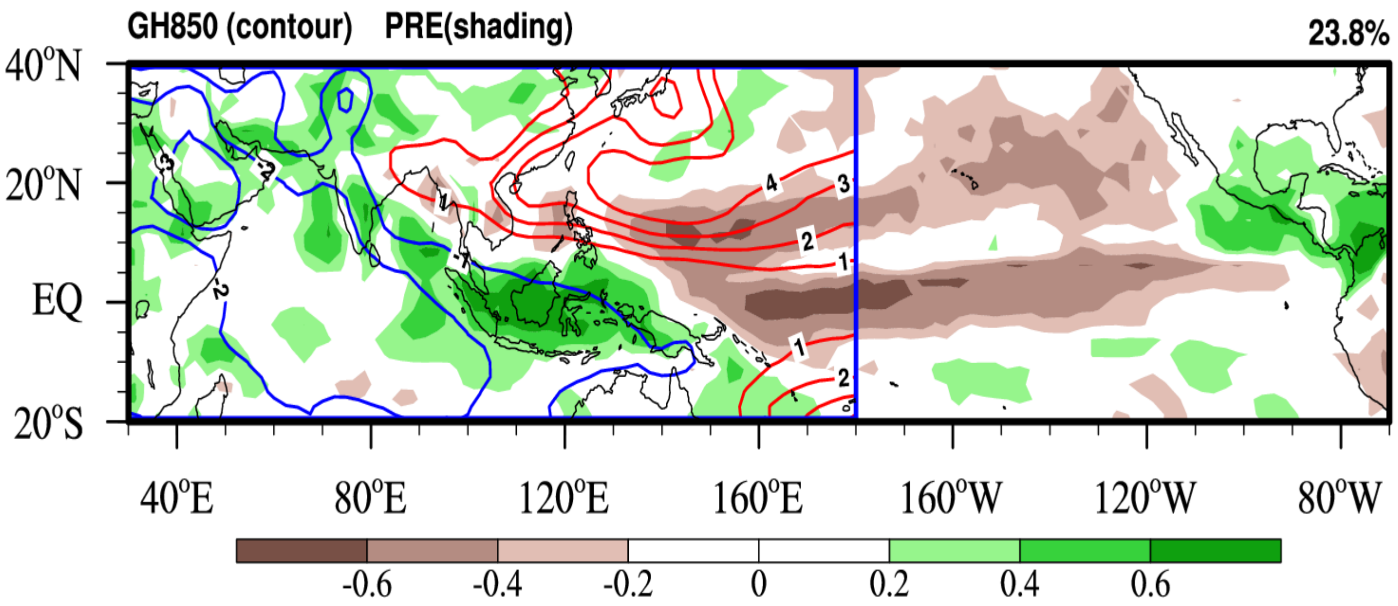
Coupled Model (POEM) Experiments



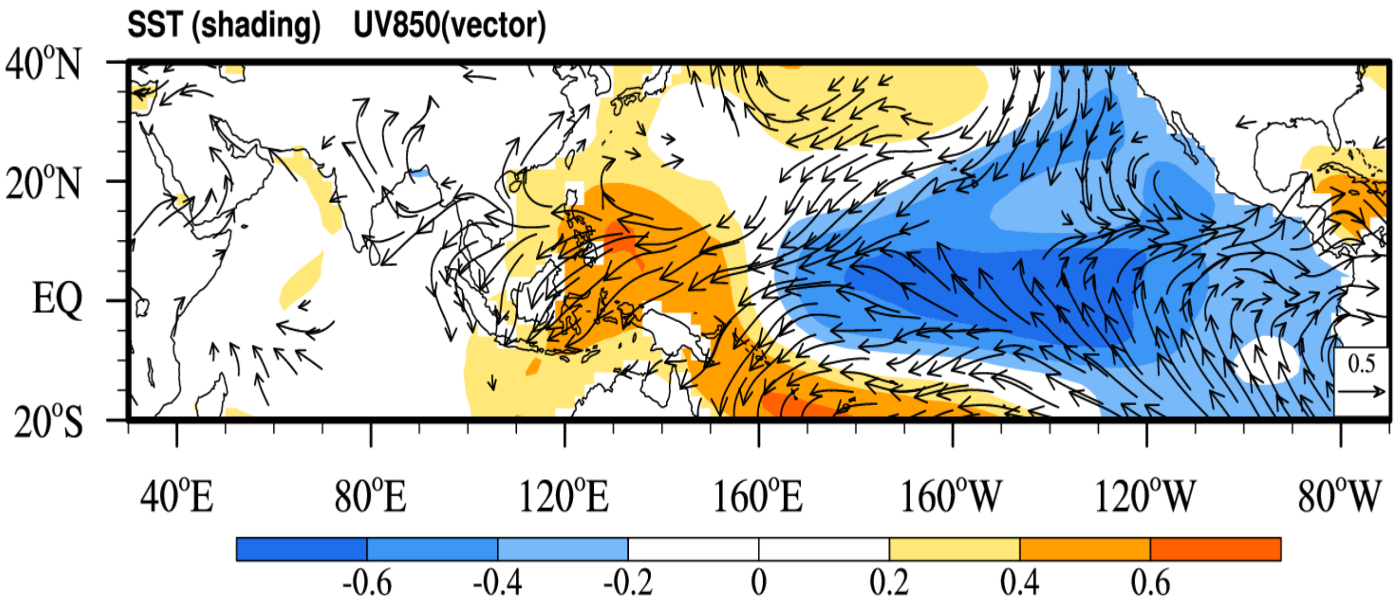
Origin of EOF2?



Anomalies associated with EOF 2



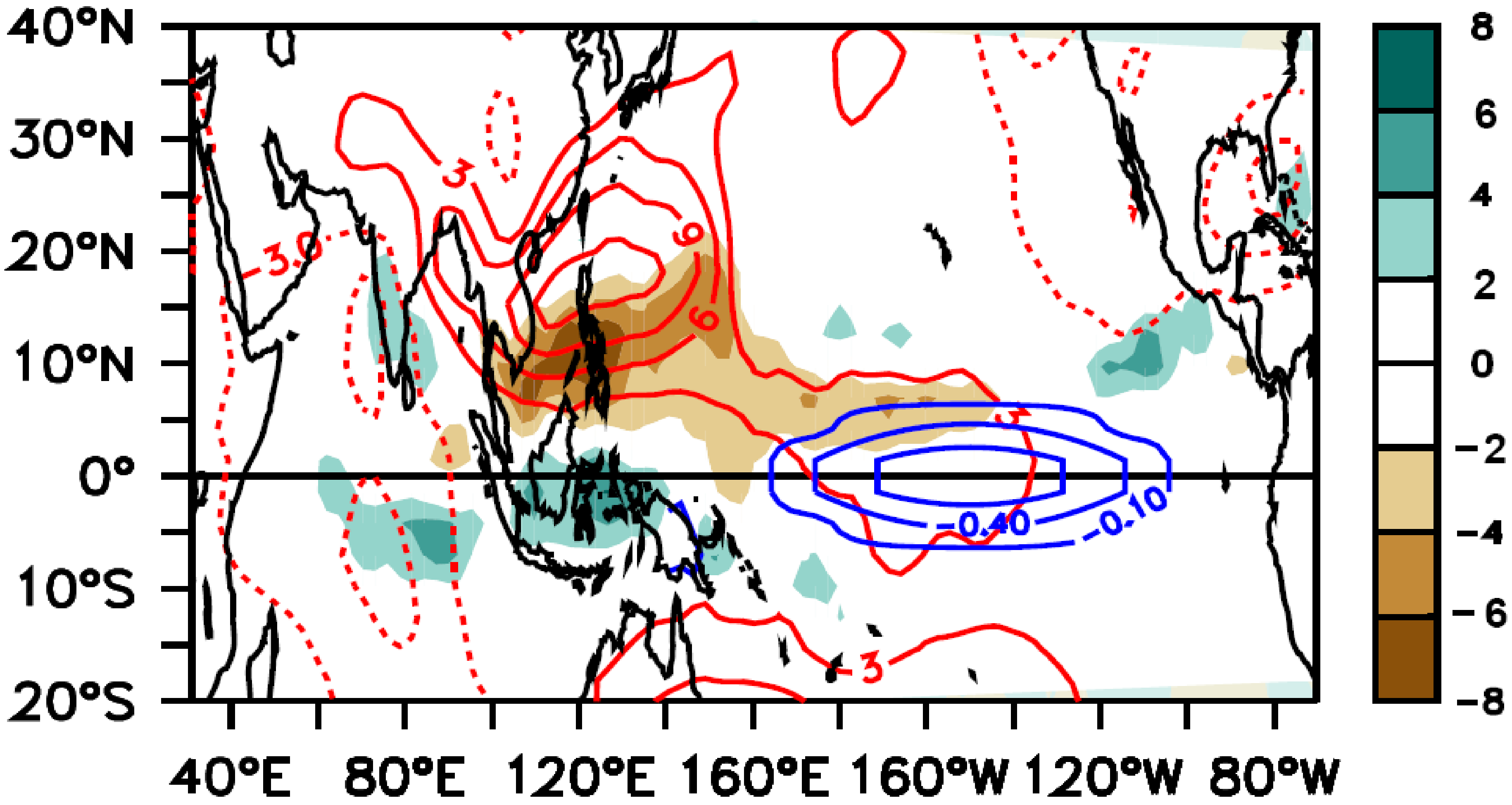
H850 & precipitation



SST & 850 winds

EOF2: Forced response to Central Pacific cooling

AGCM ensemble numberical experiments



Anomalies forced by ECP SST cooling

Origins of the dominant modes of WPSH

1. positive thermodynamic feedback between the WPSH and the Indo-Pacific SST dipole. (EOF1)

2. remote cooling/warming in the equatorial central-eastern Pacific (EOF2)

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

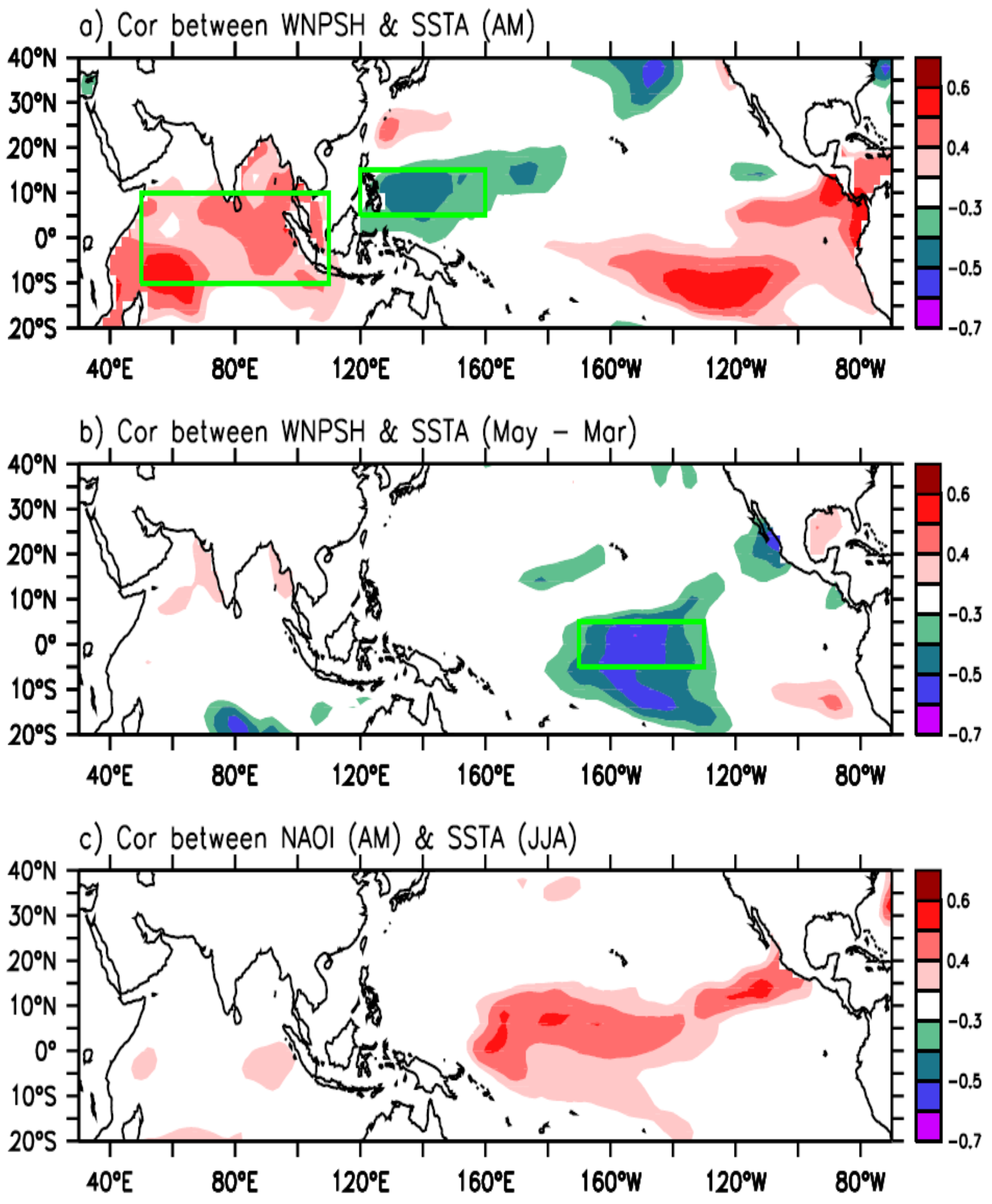
Estimate the practical predictability

by

Physically based Empirical (P-E) model

Multi-dynamical models ensemble prediction

WPSH Predictors selected based on EOF modes dynamics

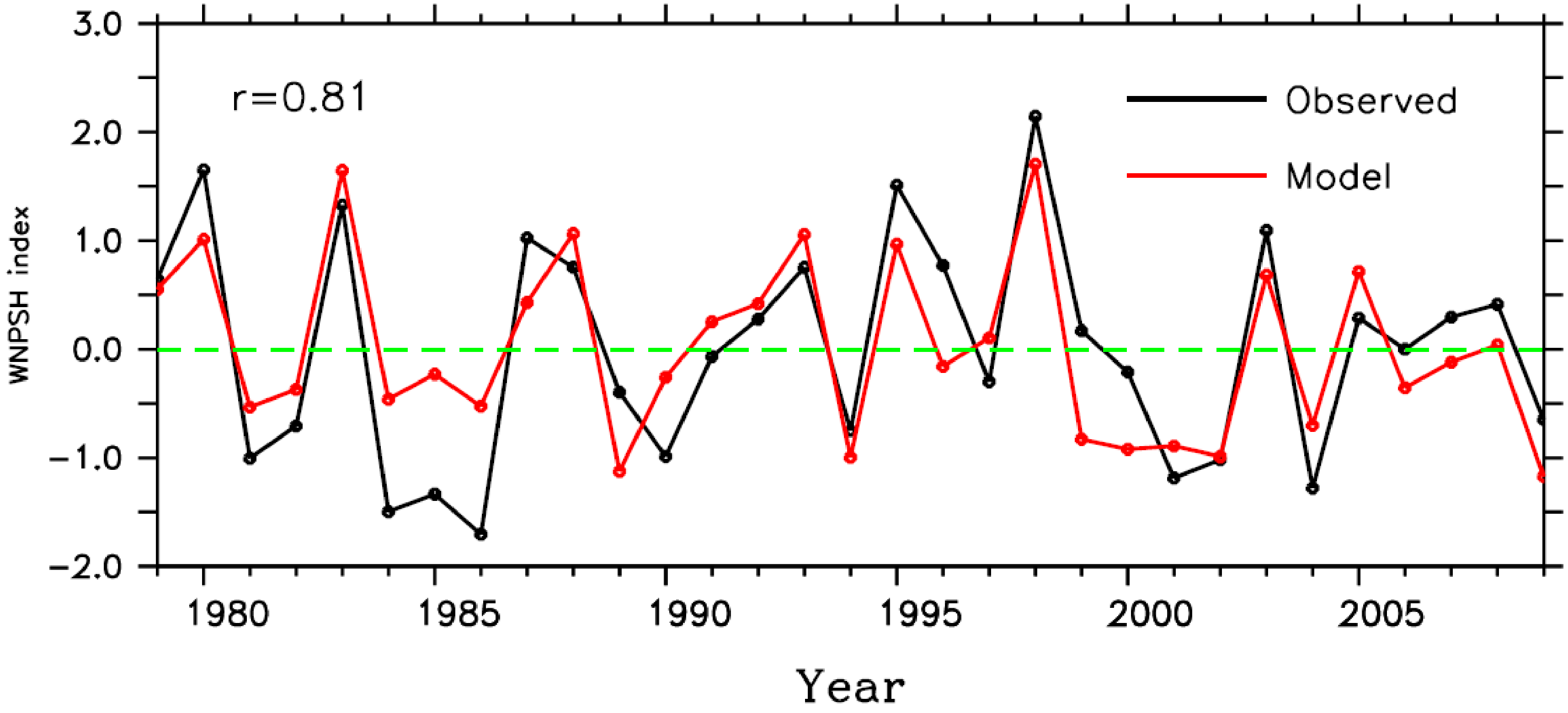


IO-WNP = SSTA in IO (10°S-10°N, 50°E-110°E) minus SSTA in WNP (0°-15°N, 120°E-160°E) during April-May. r= 0.76

$ENSO_{develop}$ = May minus March (SSTA (5°S-5°N, 170°W-130°W)
r = - 0.50

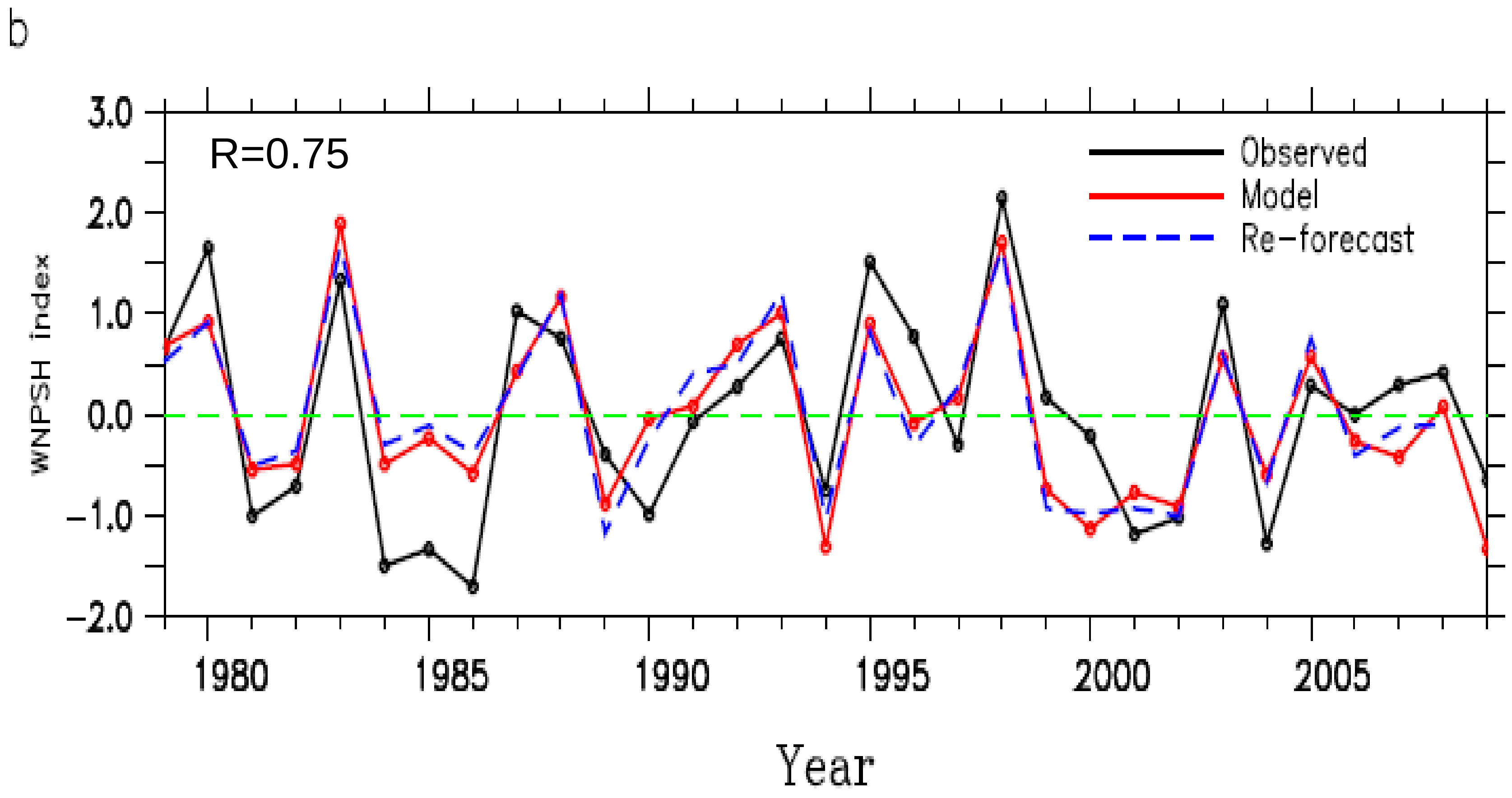
NAOI during April-May is a precursor for EOF2
r = - 0.41

WNPSH intensity reproduced by a physical-empirical model



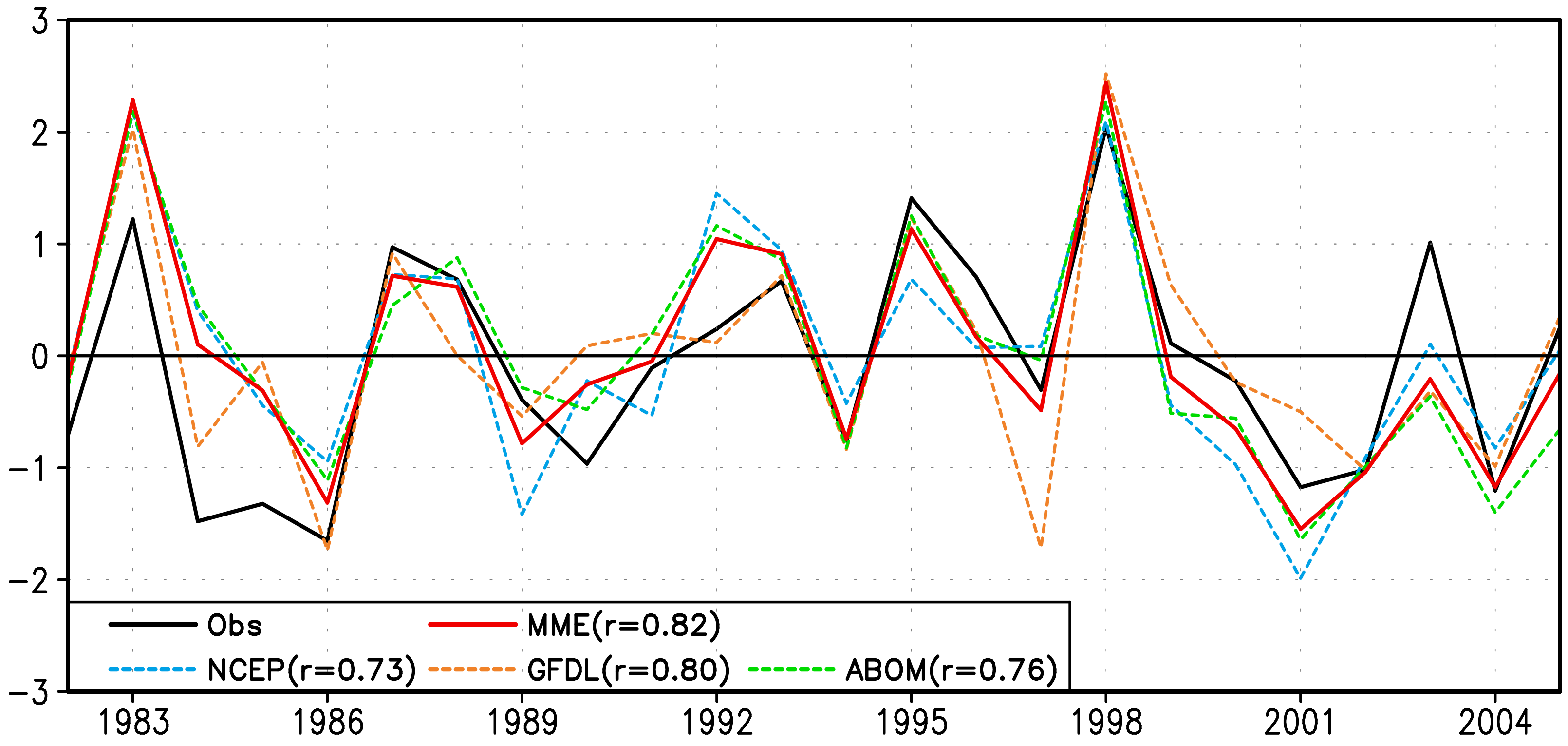
$$\text{WNPSH index} = 1.756\times(\text{IO-WNP}) - 0.435\times\text{ENSO}_{develop} - 0.282\times\text{NAOI}$$

Re-forecast WNPSH intensity with the physical-empirical model



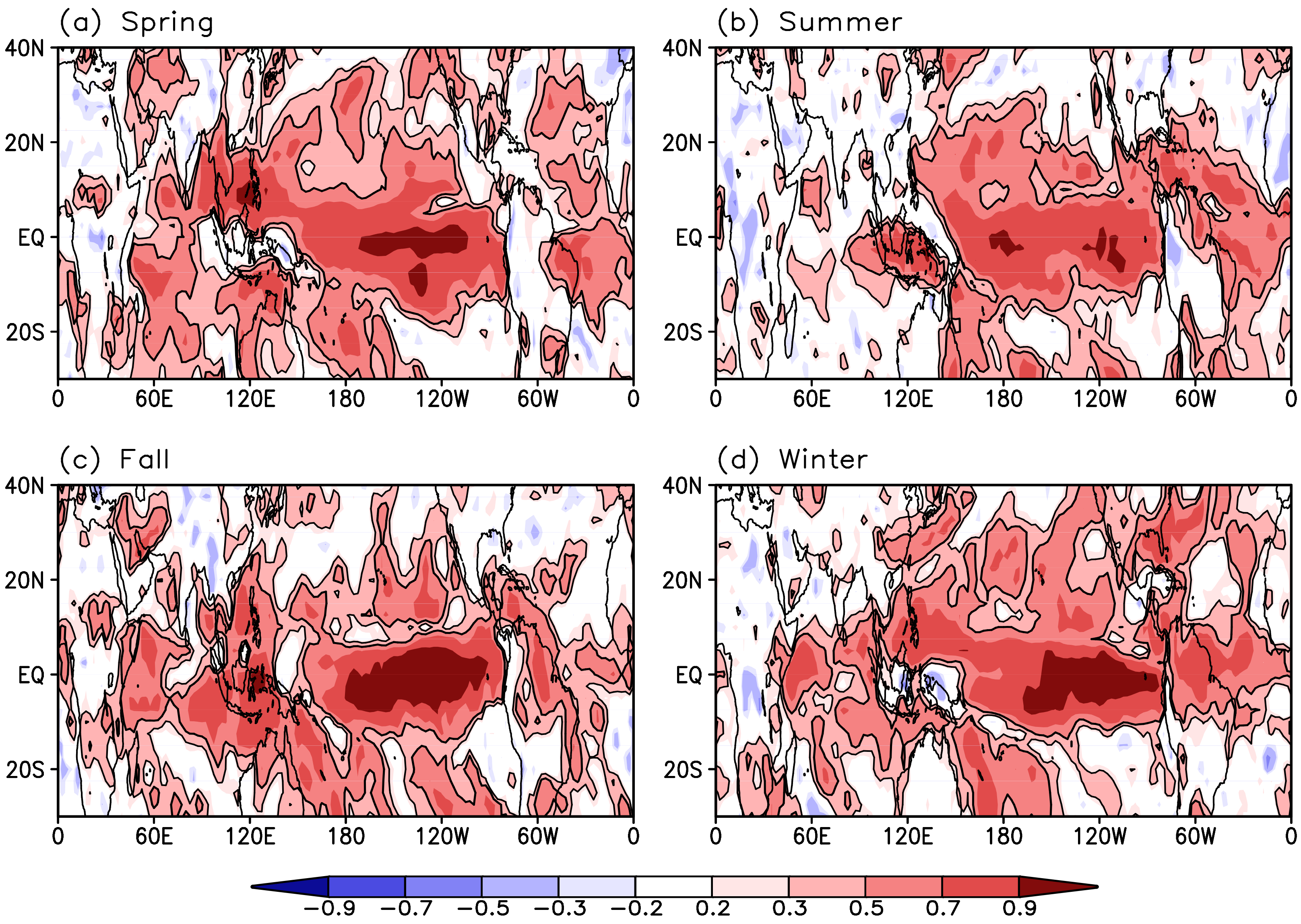
Leave-three year -out cross validation

Hindcast the WNPSH intensity by 3 coupled climate models (1982-2005)



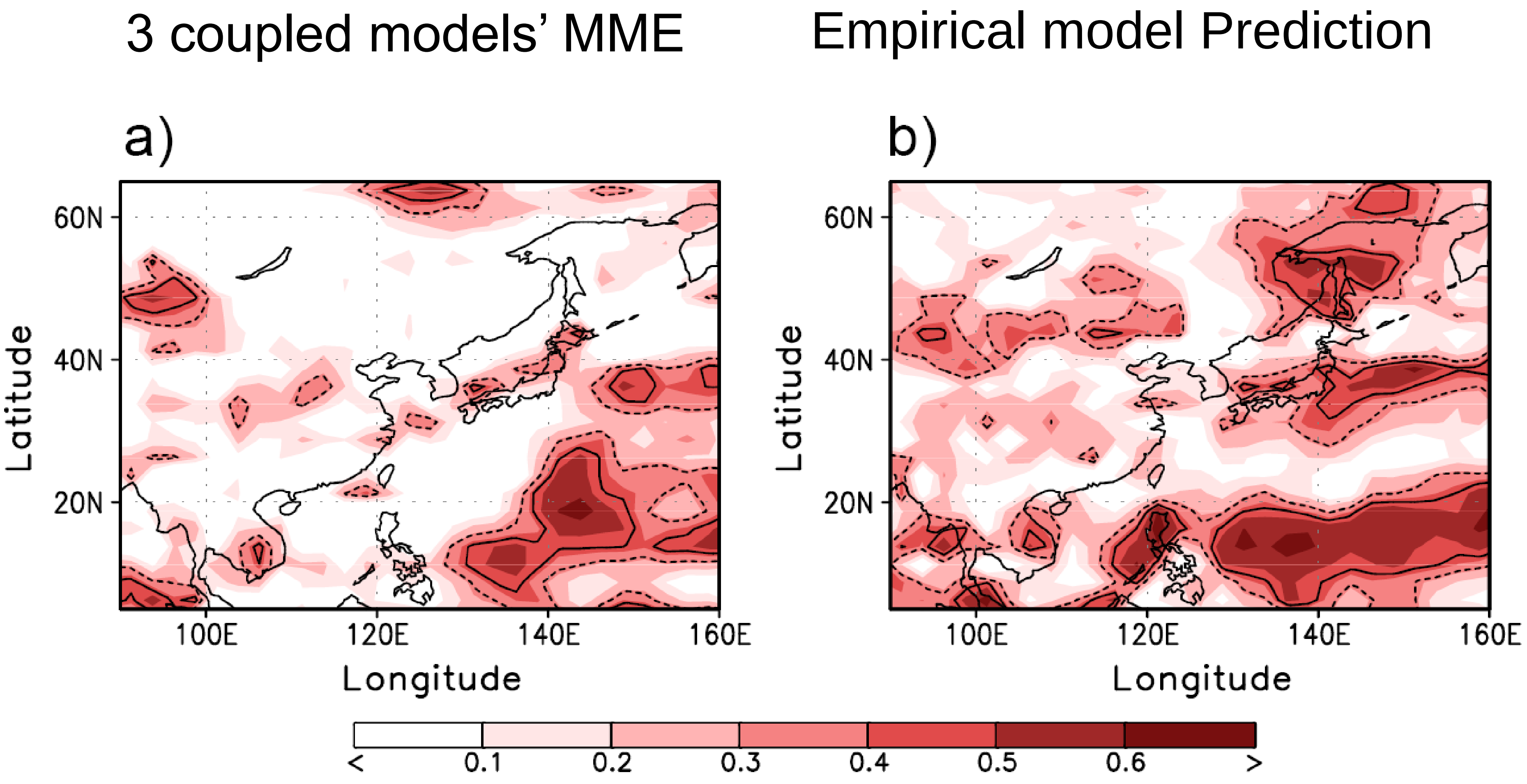
IV. Using WPSH Predictability to improve EASM rainfall and WNP TS prediction

Precipitation Prediction: TCC 13 Coupled Model MME



13 CGCM: DEMETER 6 plus CLIPAS 7 1980-2002, one-month lead. **Wang et al. 2009**

Temporal correlation skills of JJA rainfall



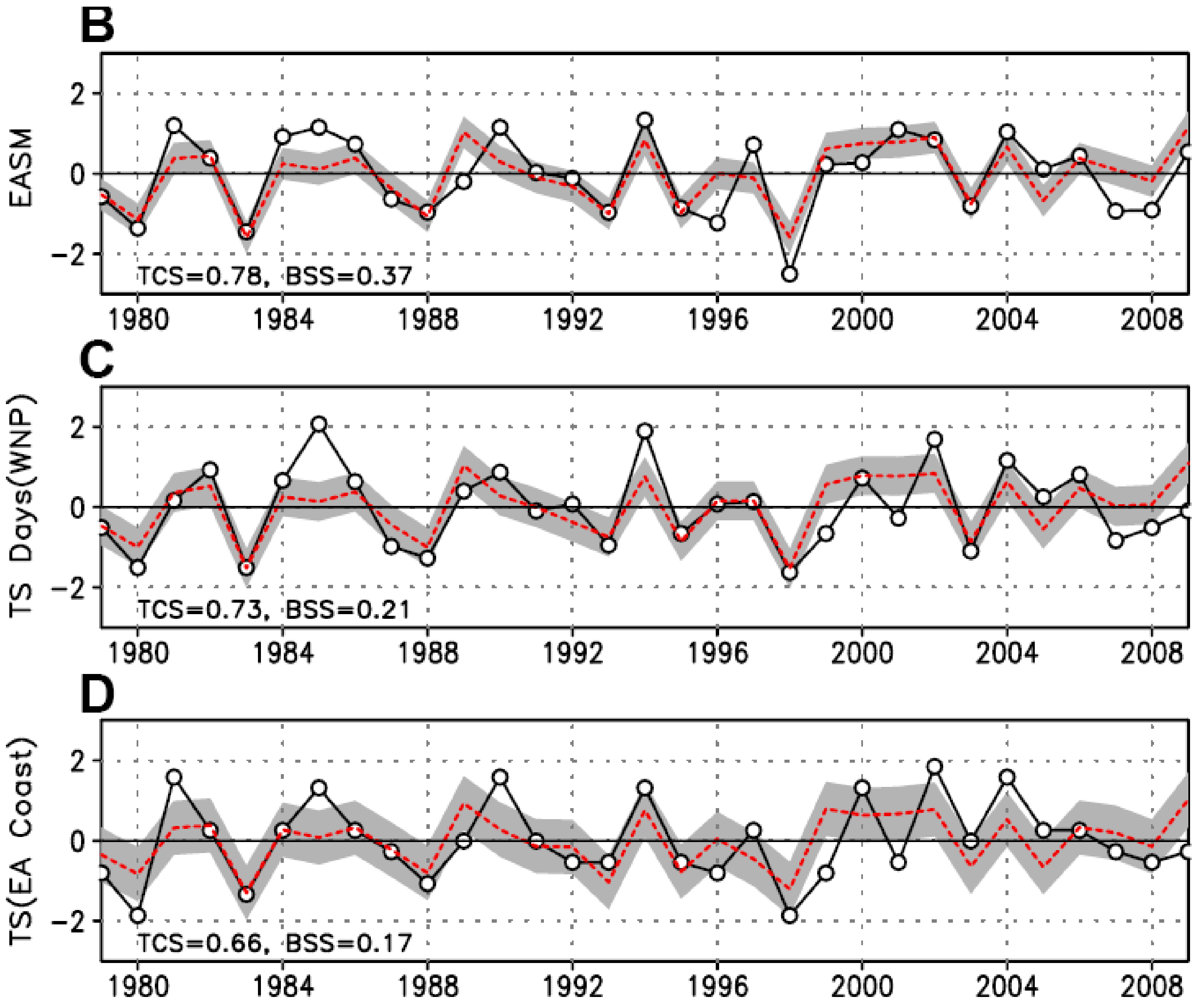
The empirical model prediction is constructed by the product of the predicted WPSH index and the regressed precipitation onto the observed WPSH index.

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



Conclusions

1. The IAV of WPSH is primarily controlled by a positive atmosphere-ocean feedback between the WPSH and Indo-Pacific SST dipole and the forcing from equatorial central Pacific warming/cooling.
2. The WPSH intensity has considerably higher predictability than Monsoon precipitation.
3. Predictability of the WPSH opens a promising pathway for predictions of EASM, ASM and WNP tropical storm activity.

Implications

Subtropical dynamics is important for understanding and predicting monsoon/TS variations.

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

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

Further studies

- Due to the strong seasonal march, does separate study of the WPSH predictability for early and late summer more fruitful?
- Is there interdecadal variation of WPSH? What forms does it take?
- How does CMIP models capture the dynamics of WPSH? Climatology and variability?
- How will WPSH change in future global warming scenario?

Thank You

Comments?