

What does really matter to understand
the precipitation variability over East Asia?

Sang-Wook Yeh
Hanyang University

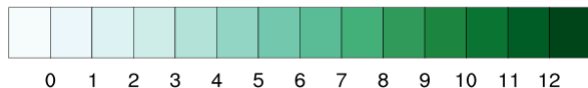
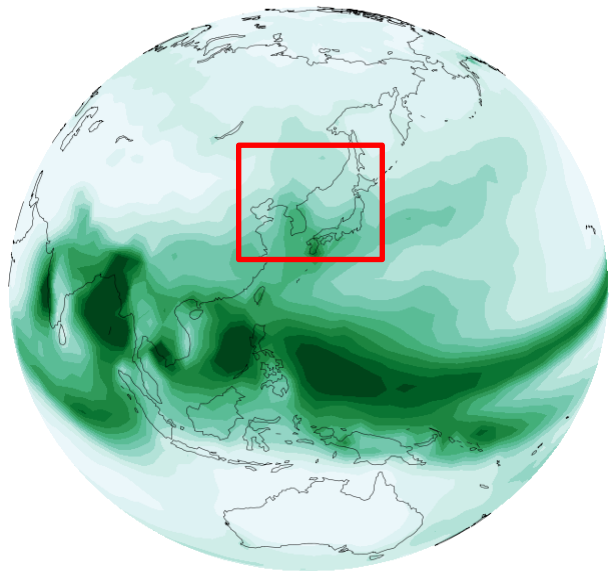
Tropical Convection: A product of Convergence



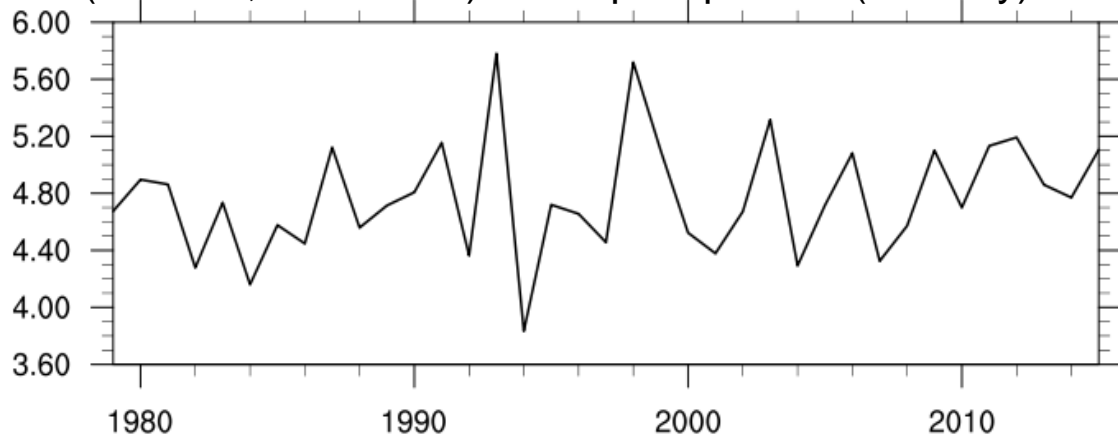
East Asian precipitation variability

• Precipitation: Observation

Climatological (1979-2015) precipitation (mm/day)
during summer [CMAP]

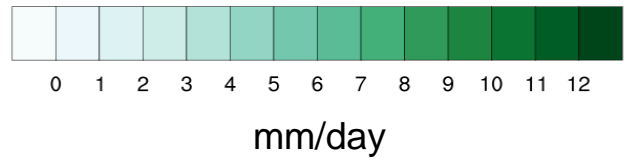
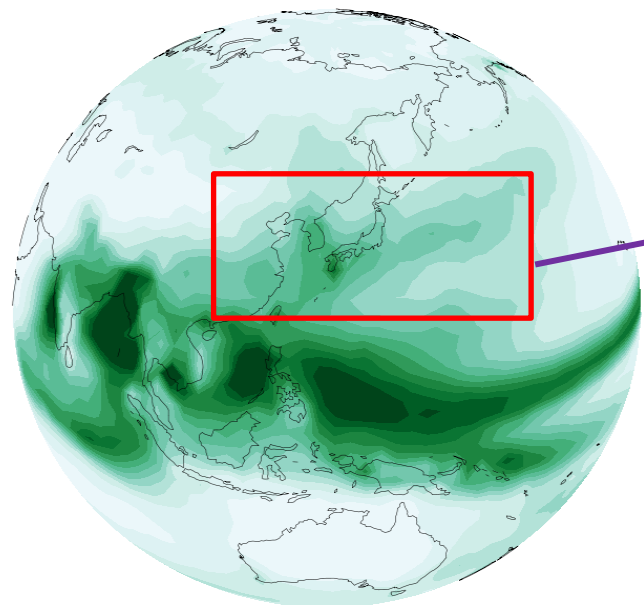


Northeast Asian Summer Rainfall Area (NEASRA)
(30~50N, 120~145E) mean precipitation (mm/day)

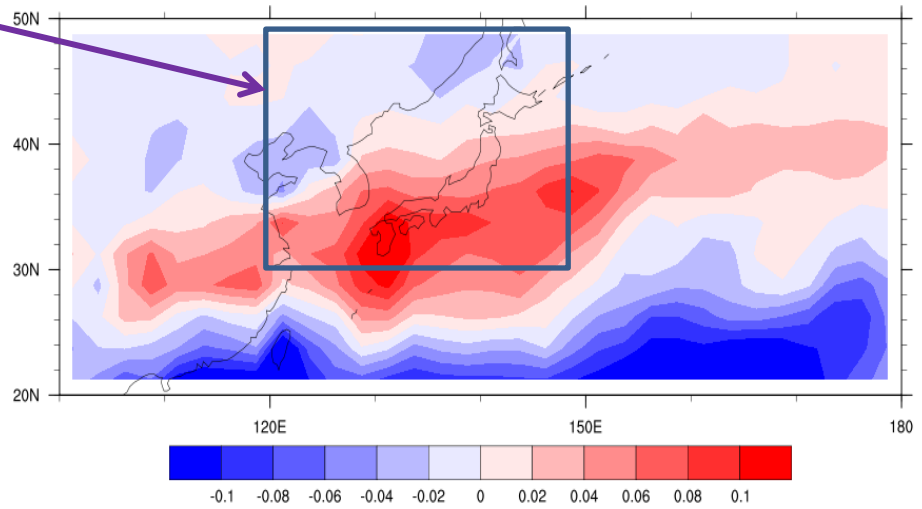


East Asian summer precipitation: Observation

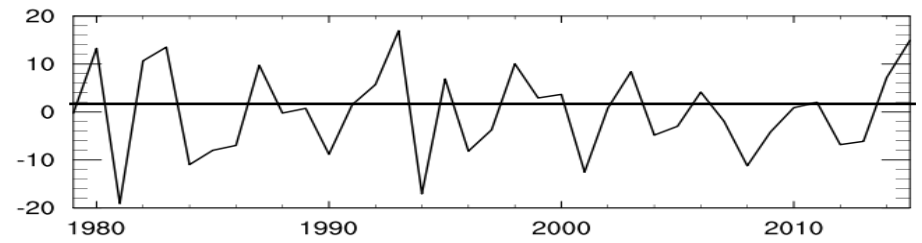
NEASRA



EOF1, 16.8%



EOF1 PC



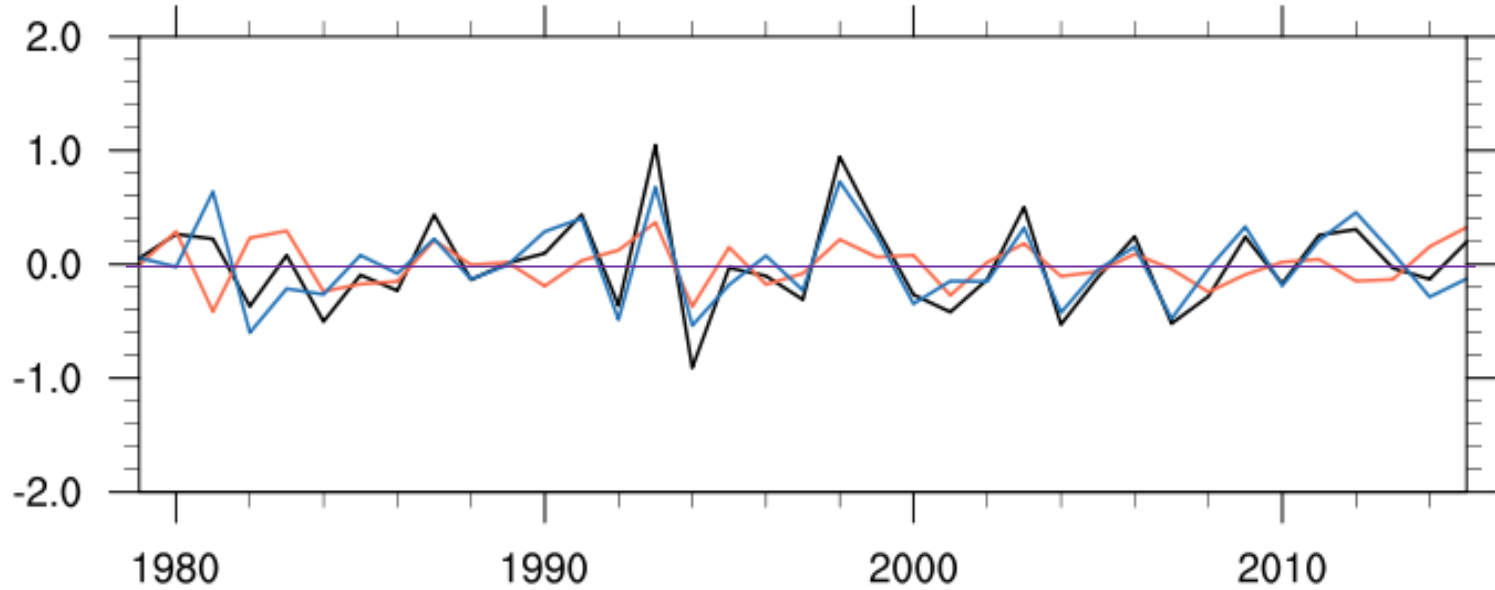
• Tropics-related & Extratropics-related rainfall variability: Observation

Lee et al. (2005)

Tropics-related precipitation: The EOF1 PC time series multiplied by the area-mean value of the first eigenvector over the same region as NEASRA[30-50N,120E-145E]

Extratropics-related precipitation: NEASRA minus Tropics-related precipitation

- Tropics-related & Extratropics-related rainfall variability: Observation



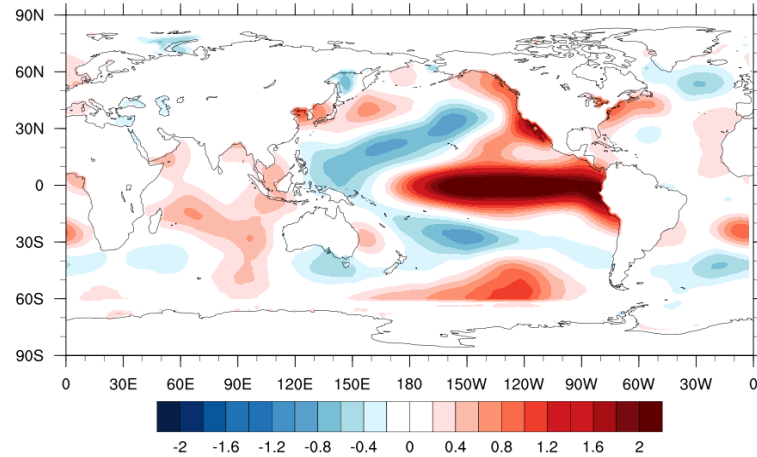
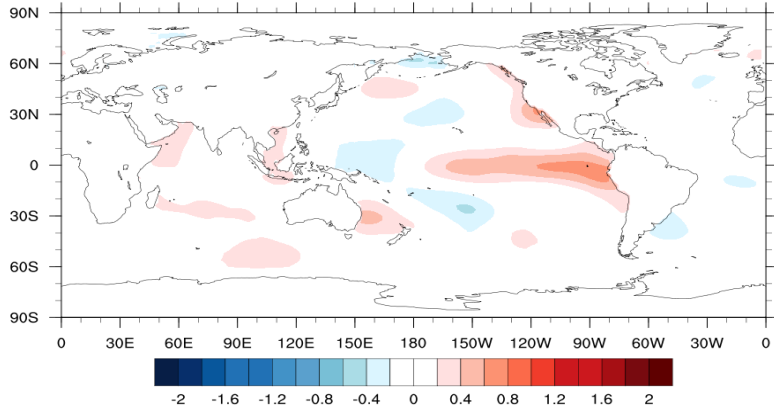
Black: NEASRA

Red : Tropics-related

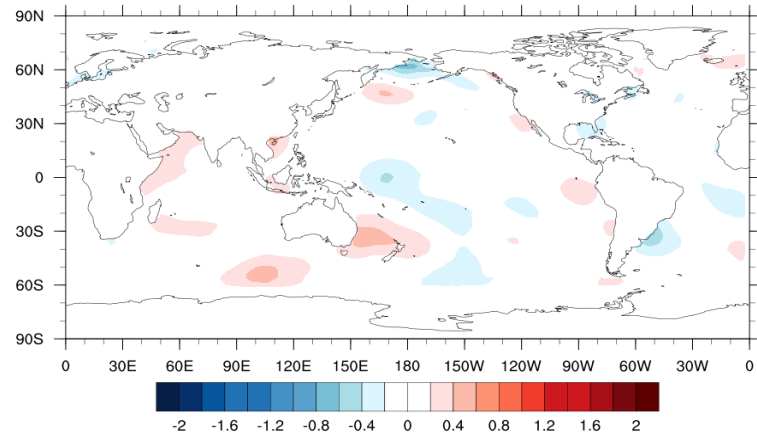
Residual: Extratropics-related

• Tropics-related & Extratropics-related rainfall variability: Observation

Regressed SSTA during D(-1)JF(0) against with NEASRA

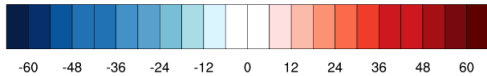
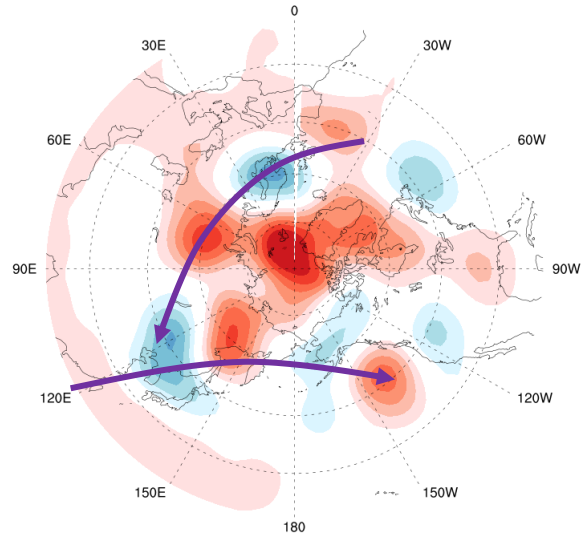


Against with Tropics-related precipitation

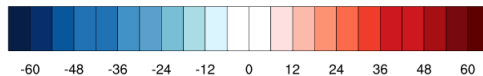
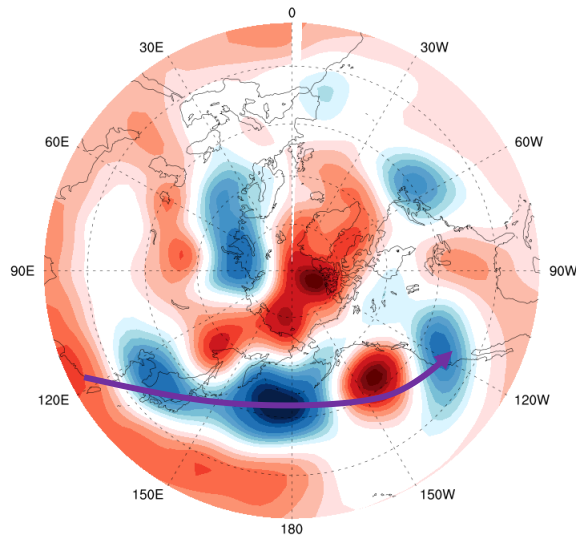


Against with Extratropics-related precipitation

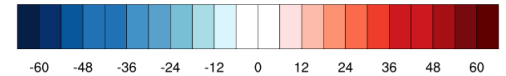
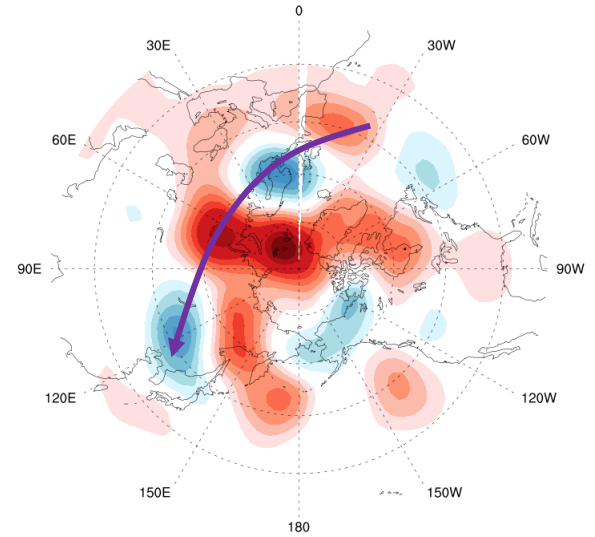
• Tropics-related & Extratropics-related rainfall variability: Observation



500 hPa GPH
& NEASRA



500 hPa GPH
& Tropics-related



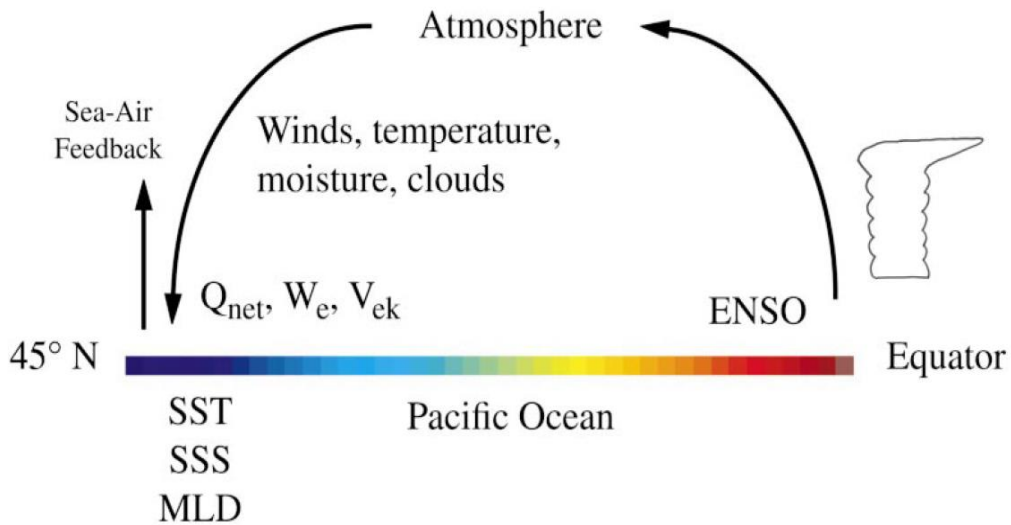
500 hPa GPH
& Extratropics-related

- Fundamental question

How the precipitation variability over East Asia can be affected by the tropical forcing ?

“Teleconnections”

“The Atmospheric Bridge”



Alexander et al., (2002)

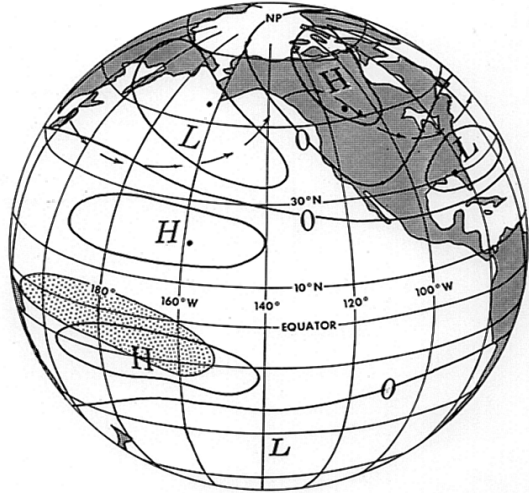
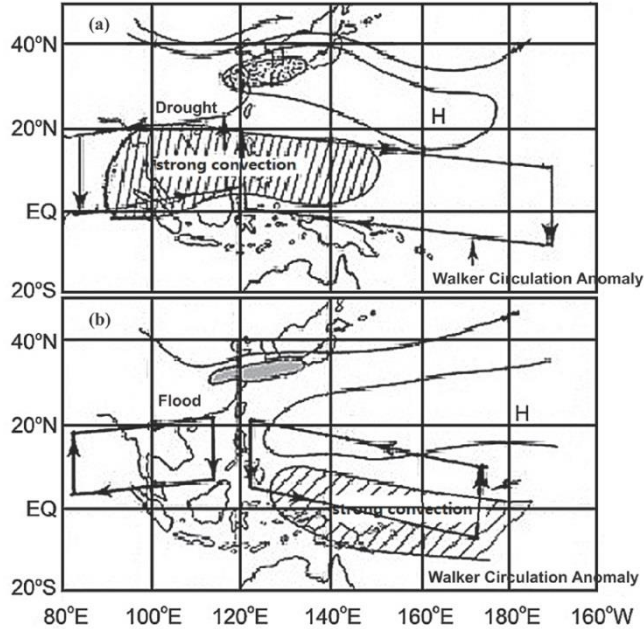
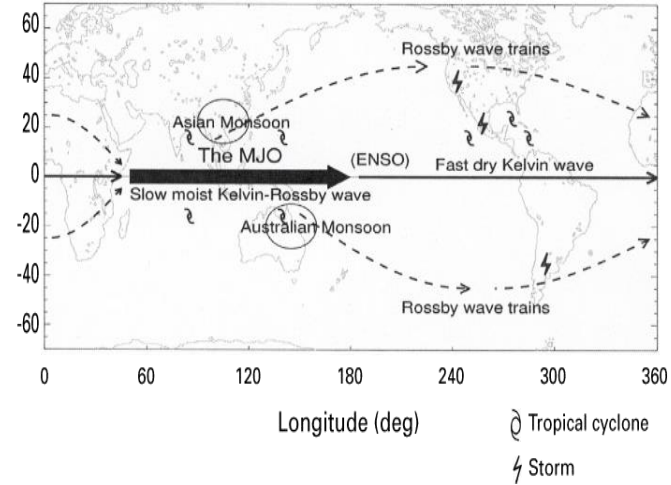


Figure 1.26. A schematic diagram of the Pacific North American (PNA) pattern of middle- and upper-tropospheric geopotential height anomalies during a Northern Hemisphere winter that coincides with El Niño conditions in the tropical Pacific. The arrows depict a mid-tropospheric streamline as distorted by the anomaly pattern, with pronounced "troughing" over the central Pacific and "ridging" over western Canada. Cloudiness and rainfall are enhanced over the shaded area. The dots indicate the stations used in the time series mentioned in Table 1.1. [From Horel and Wallace (1981).]

Horel and Wallace (1981)

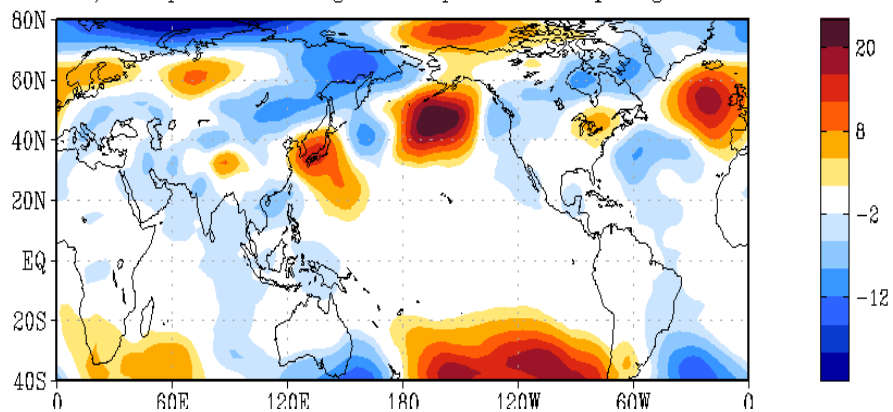


Huang et al. (2006)

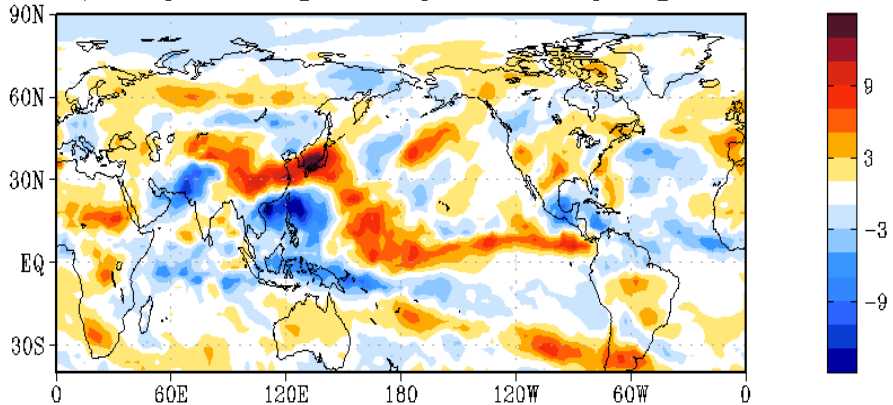


<https://public.wmo.int/en/bulletin/collaborative-research-intersection-weather-and-climate>

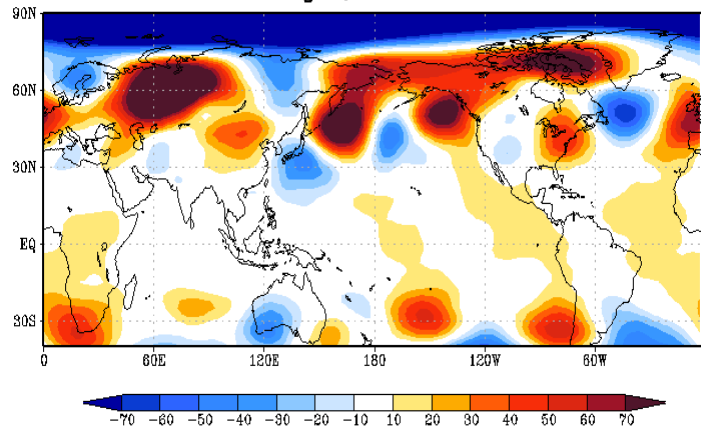
a) Comp. GPH850 August for positive Temp August



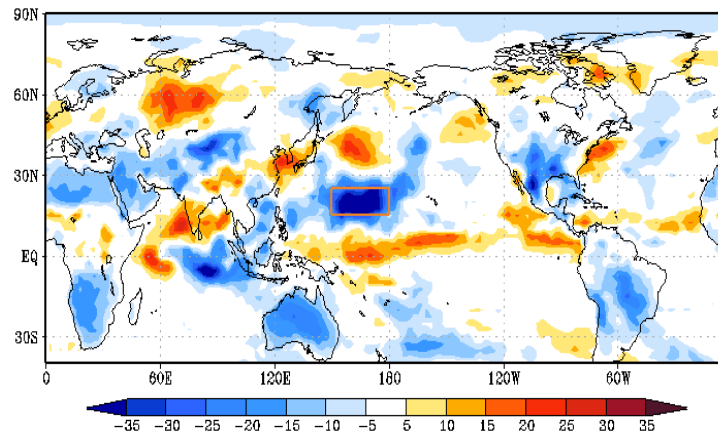
a) Comp. OLR August for positive Temp August



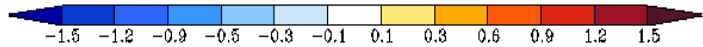
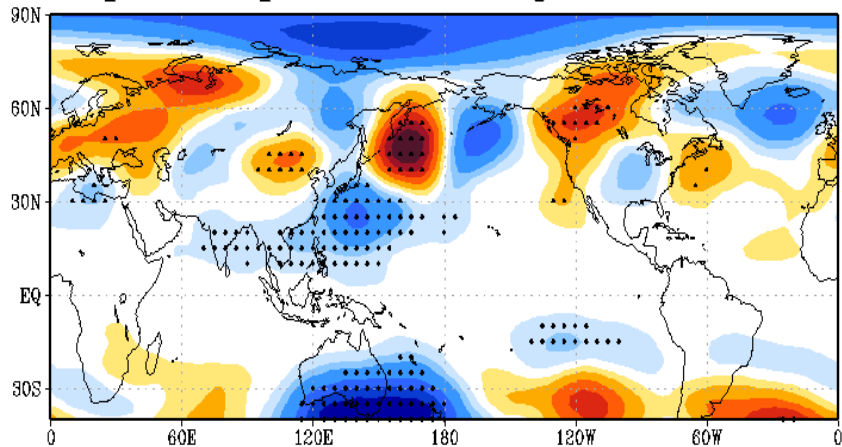
GPH500 anomalies in August, 2016



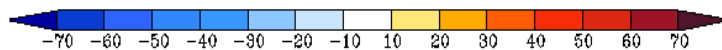
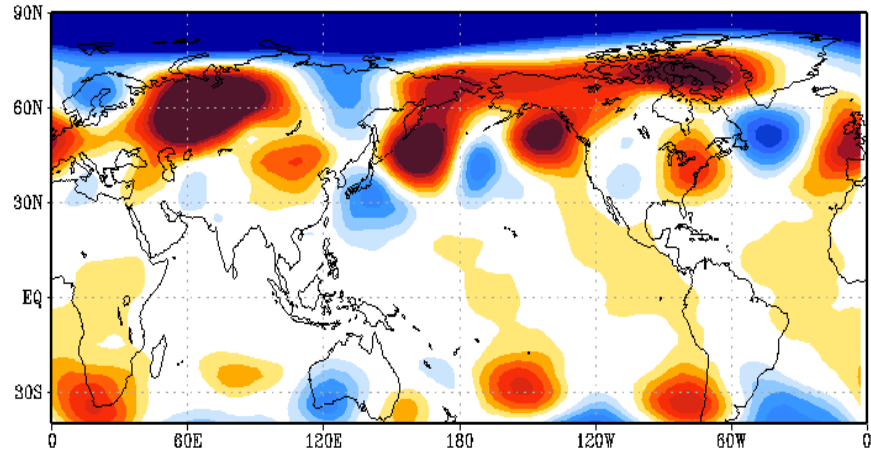
OLR anomalies in August, 2016



Reg. GPH500 August onto OLR Index August



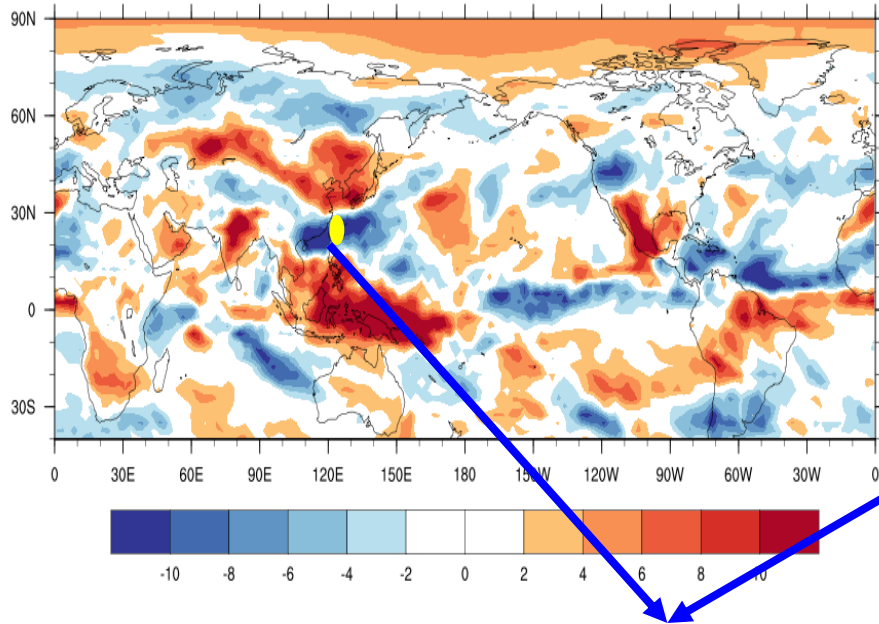
GPH500 anomalies in August, 2016



- 한반도 6월 T_{\max} , $T_{\min} > +1\text{S.D.}$ OLR 합성도

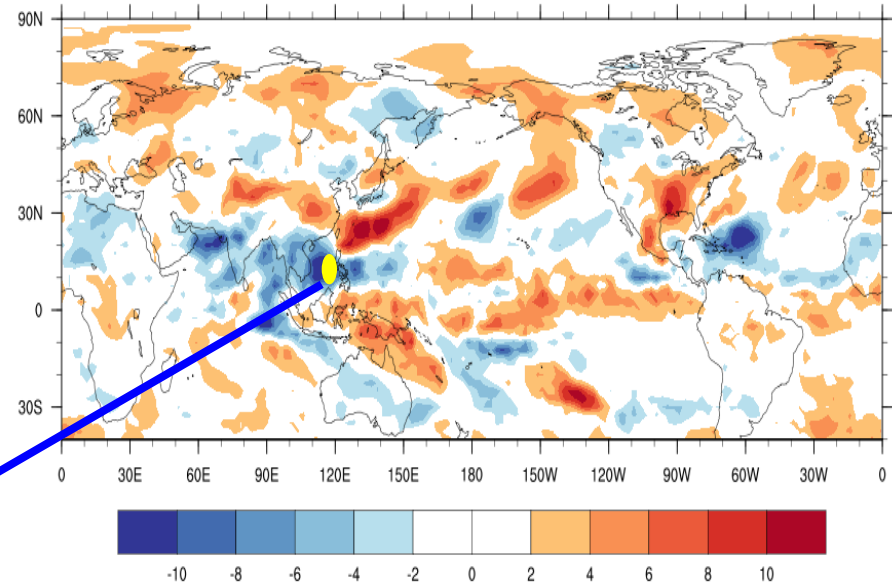
$T_{\max} > +1\text{S.D.}$

OLR Positive Composite(KOR_jun_Tmax)



$T_{\min} > +1\text{S.D.}$

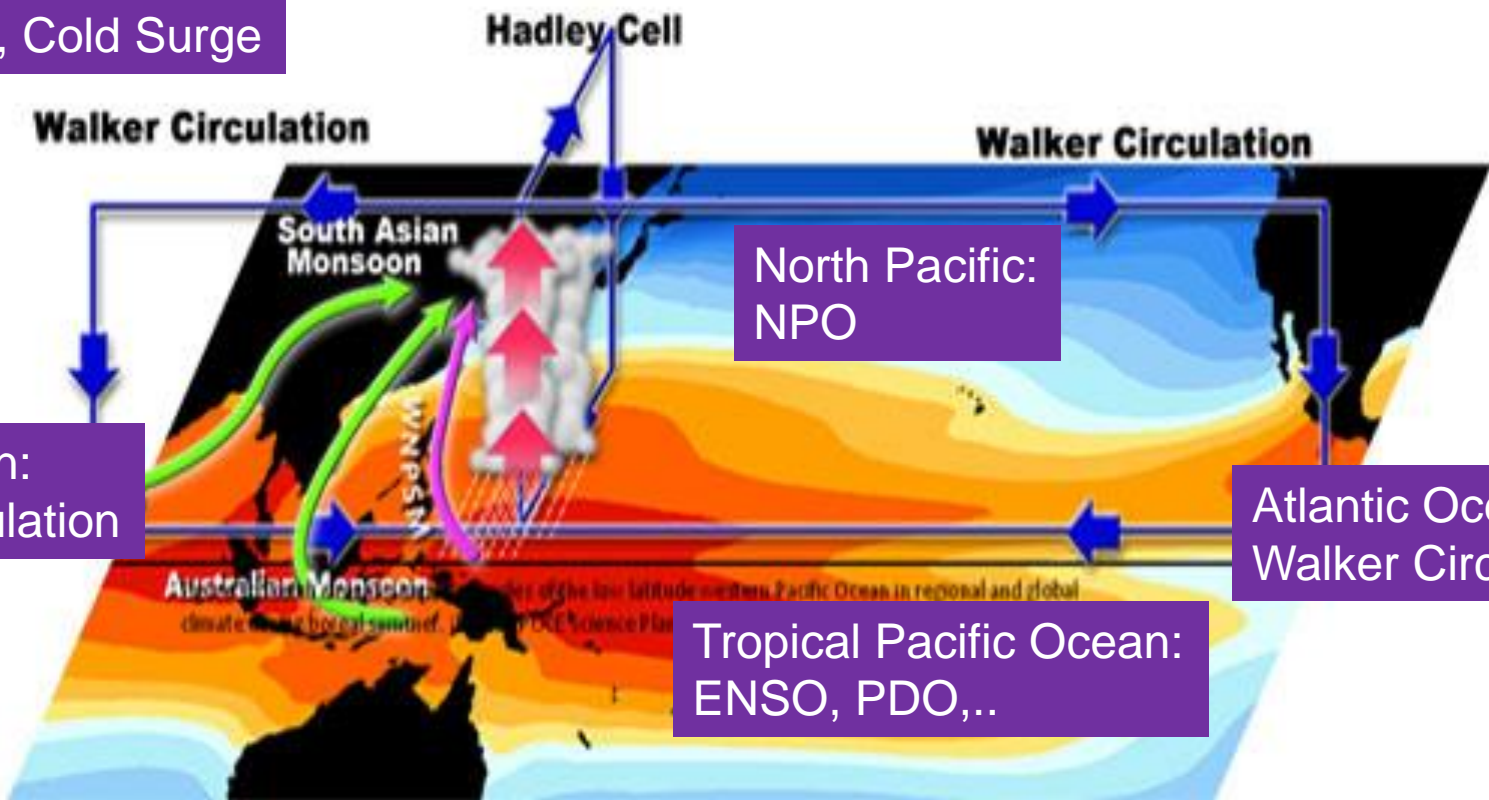
OLR positive Composite(KOR_jun_Tmin)



Convective forcing

Which factors influence the characteristics of convection in the tropical Pacific ?

Monsoon:
Trough, Cold Surge



North Pacific:
NPO

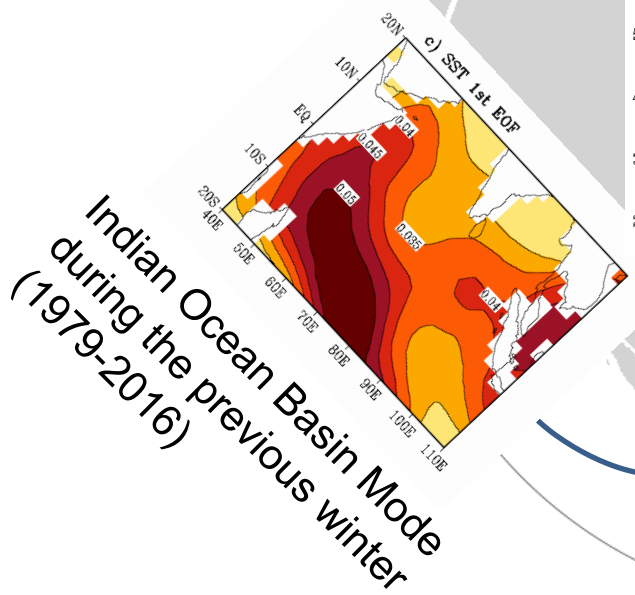
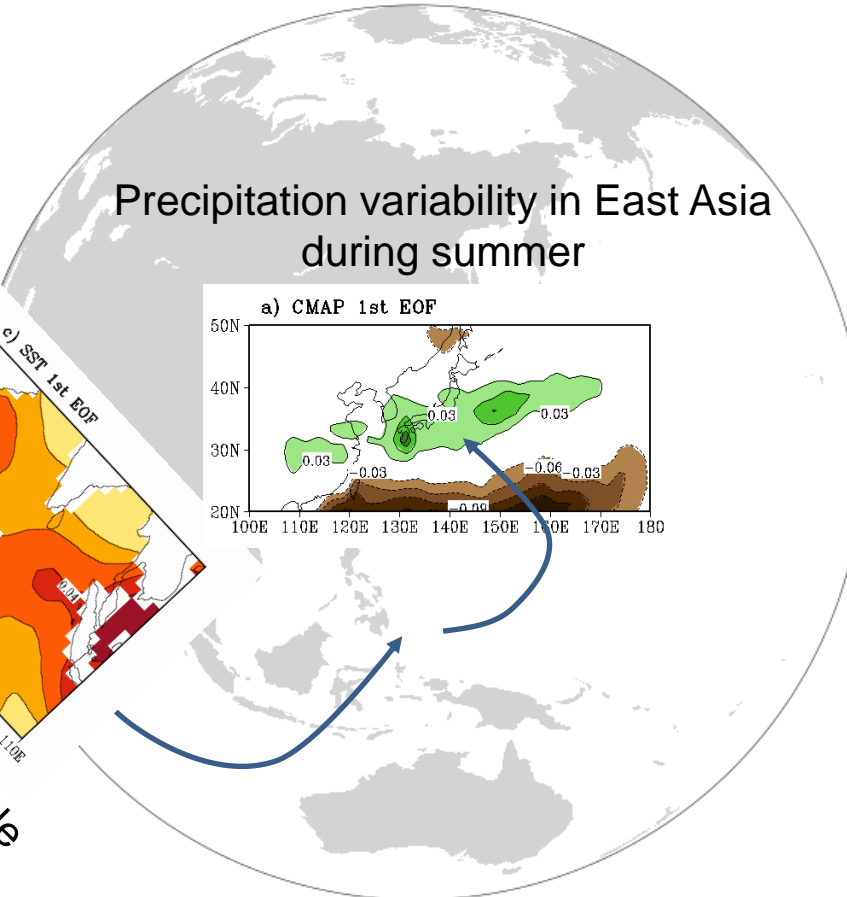
Indian Ocean:
Walker Circulation

Atlantic Ocean:
Walker Circulation

Tropical Pacific Ocean:
ENSO, PDO,..

Indian Ocean-Tropical Pacific

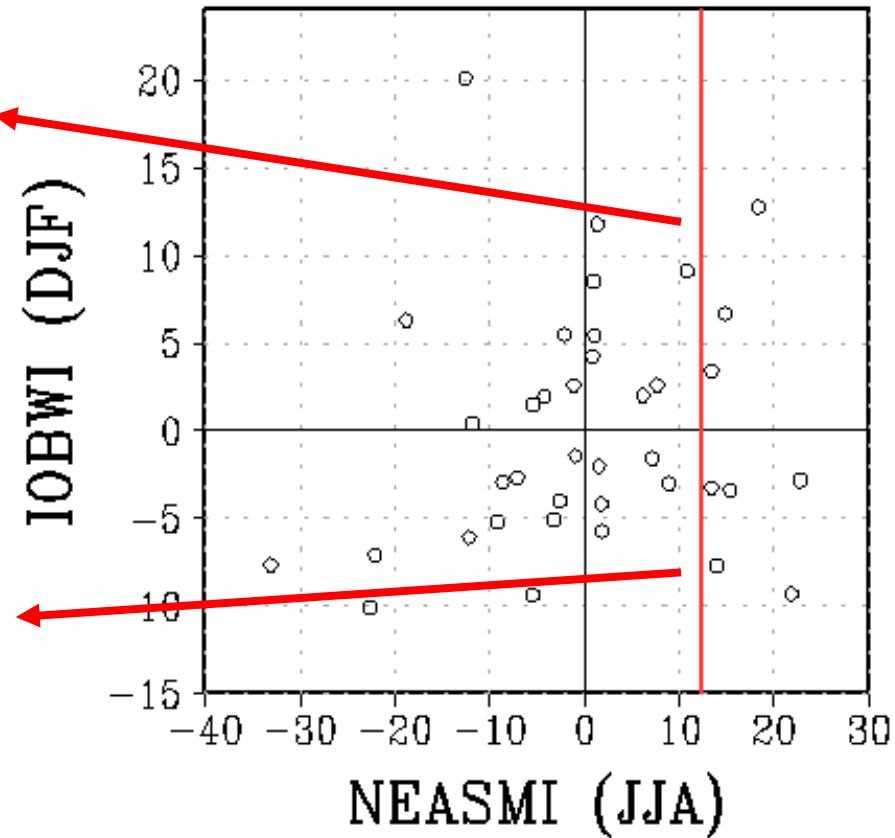
Indian Ocean-East Asian Summer Monsoon



Indian Ocean-East Asian Summer Monsoon

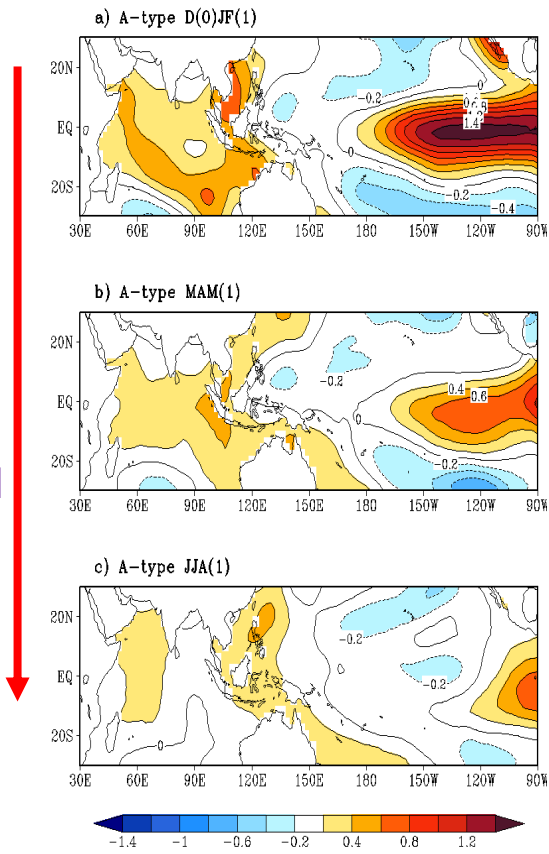
Strong EASM
With a warm IOBM

Strong EASM
with a cold IOBM

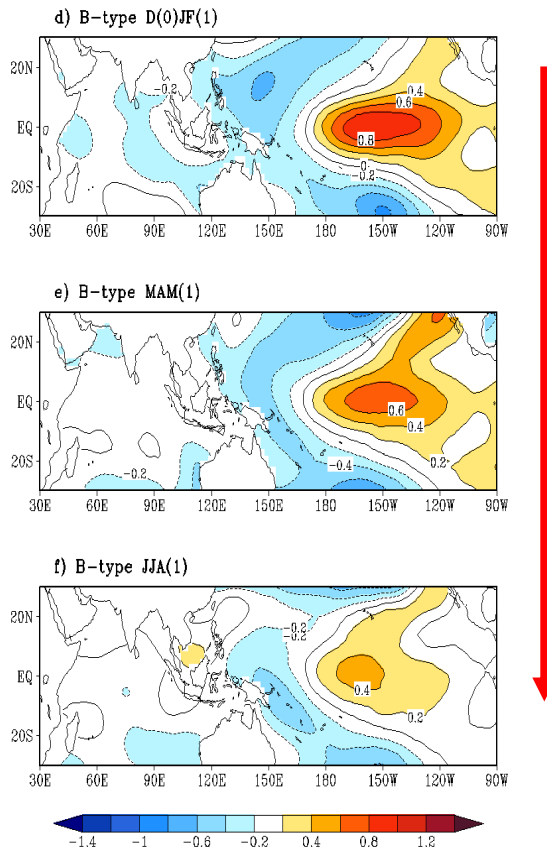


Indian Ocean-East Asian Summer Monsoon

Strong EASM
With a warm IOBM

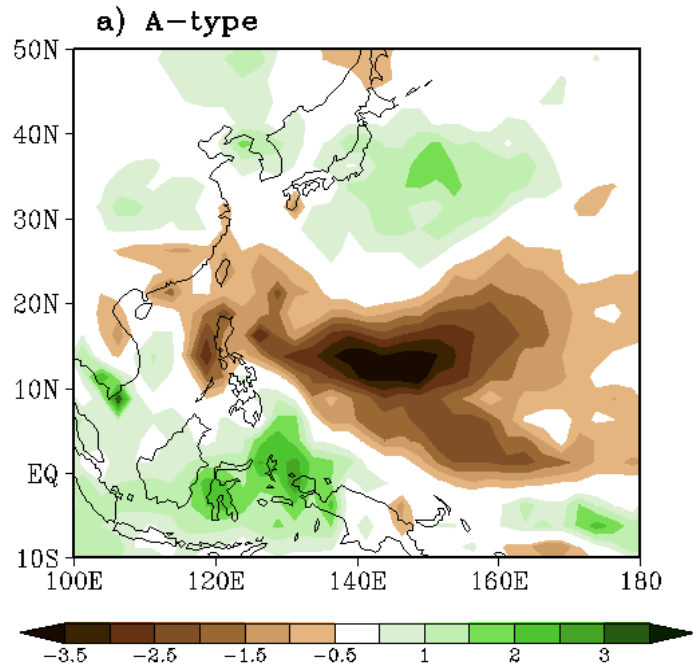


Strong EASM
with a cold IOBM

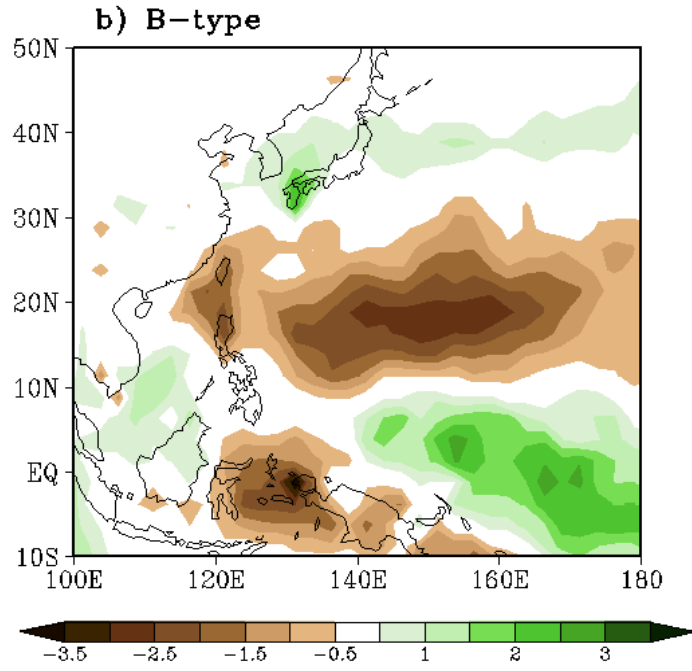


Indian Ocean-East Asian Summer Monsoon

Strong EASM
With a warm IOBM



Strong EASM
with a cold IOBM



Strong EASM with a warm IOBM minus Strong EASM with a cold IOBM

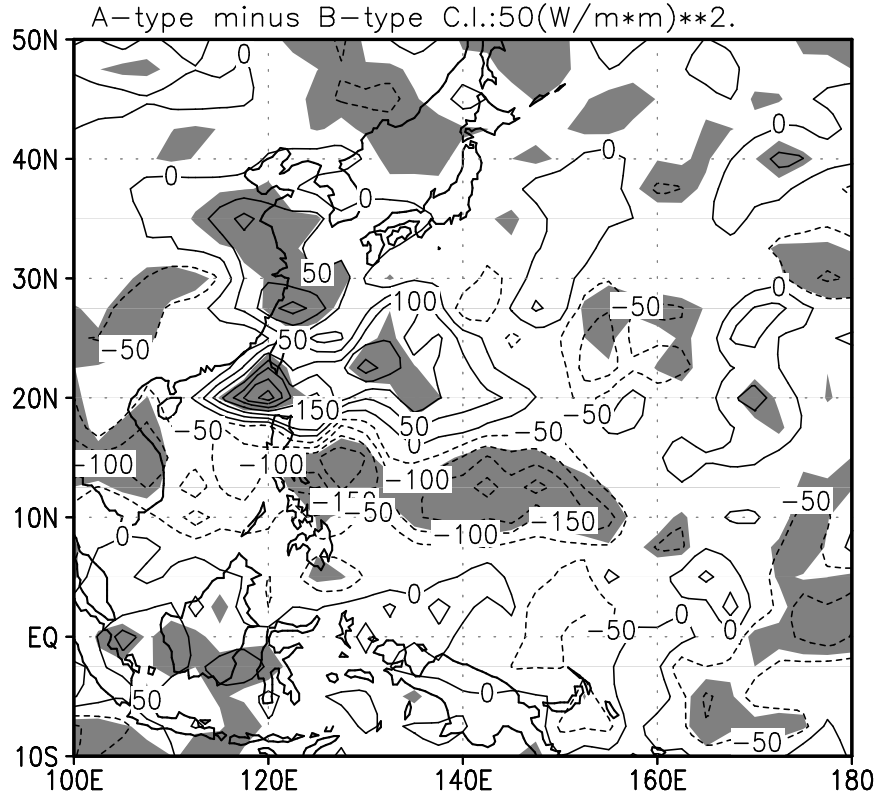
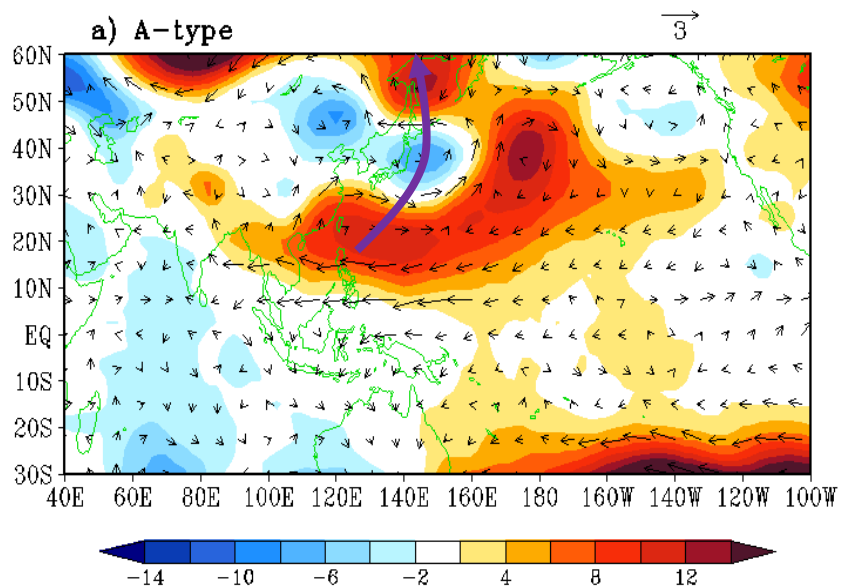
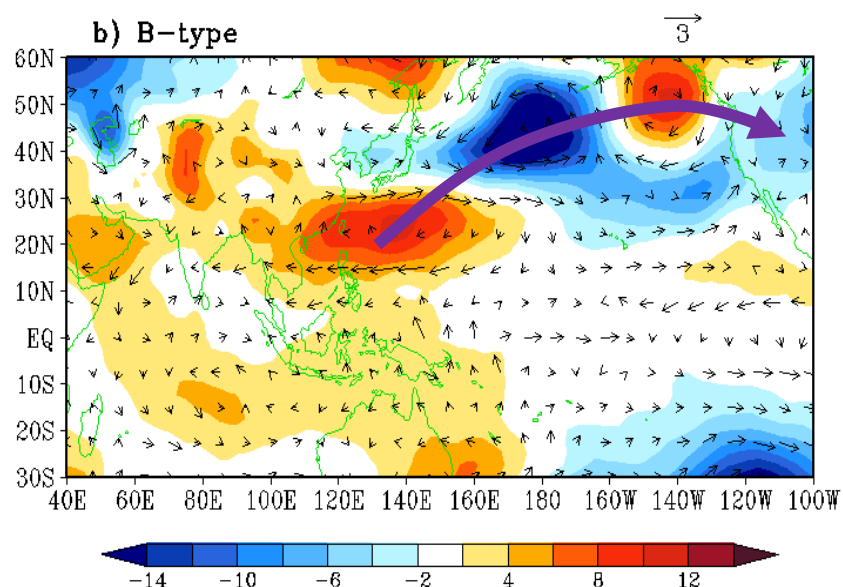


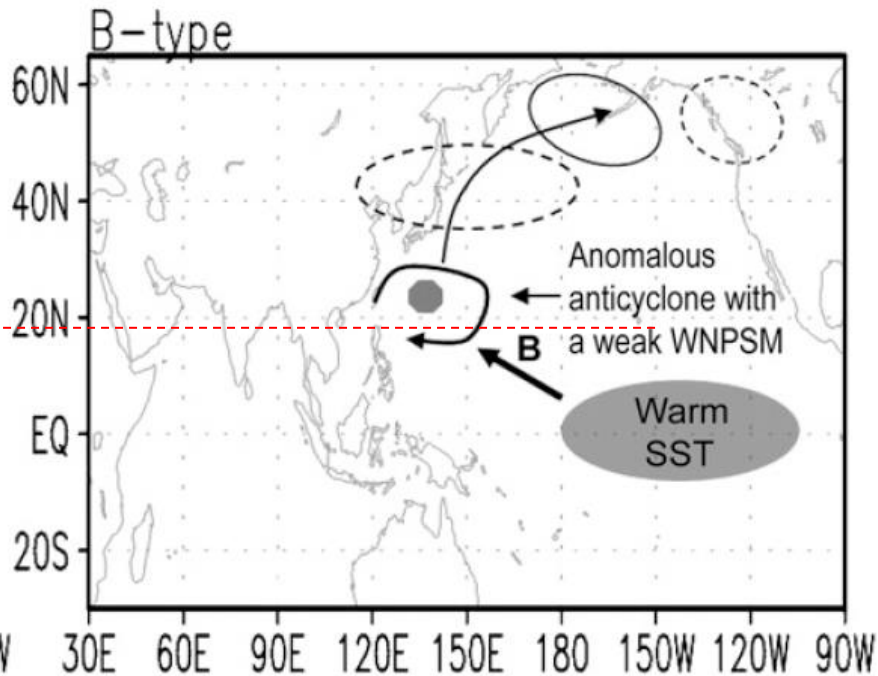
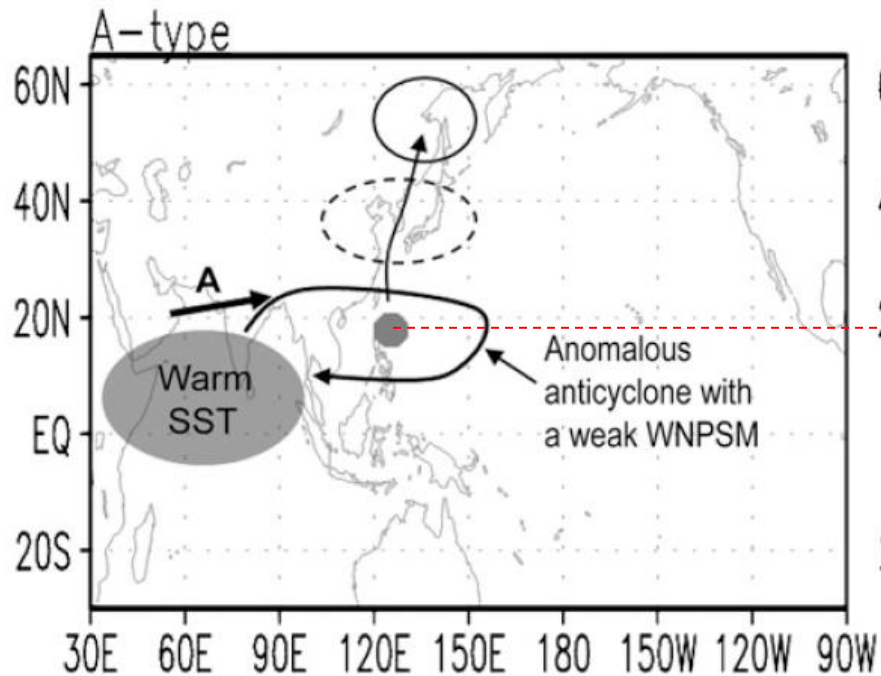
Figure 6. The difference of bandpass filtered (30-60 days) OLR variance between the A-type and the B-type strong NEASM. Contour interval is $50(\text{w/m}^2)^2$ and shading denotes statistical significance at 90% level using a t-test.

Strong EASM With a warm IOBM



Strong EASM with a cold IOBM





● center of suppressed convective forcing

A : Anomalous tropospheric heating by warm Indian Ocean SST, emanating a baroclinic Kelvin wave into the Pacific or inducing a Gill-type response (Xie et al. 2008, Li et al. 2008)

B : Remote forcing through a modulation of Walker circulation (Wang et al. 2000, Slingo and Annamalai 2000)

Why Has the Relationship between Indian and Pacific Ocean Decadal Variability Changed in Recent Decades?

LU DONG AND MICHAEL J. MCPHADEN

NOAA/Pacific Marine Environmental Laboratory, Seattle, Washington

(Manuscript received 14 April 2016, in final form 1 December 2016)

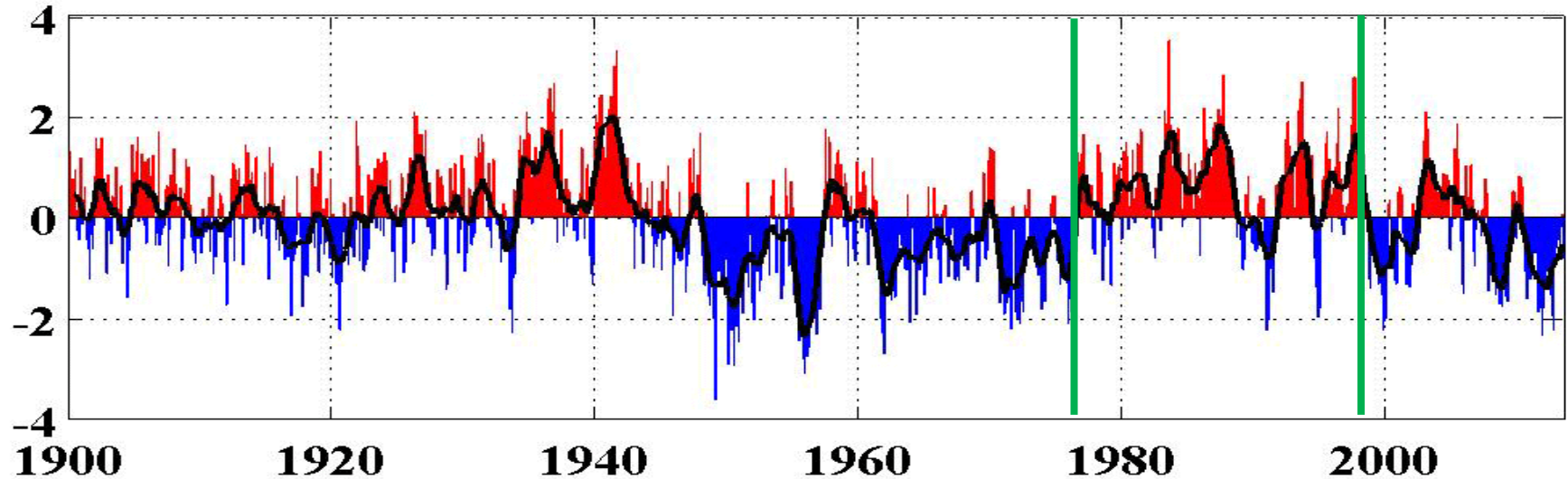
ABSTRACT

Both the Indian and Pacific Oceans exhibit prominent decadal time scale variations in sea surface temperature (SST), linked dynamically via atmospheric and oceanic processes. **However, the relationship between SST in these two basins underwent a dramatic transformation beginning around 1985.** Prior to that, SST variations associated with the Indian Ocean basin mode (IOB) and the interdecadal Pacific oscillation (IPO) were positively correlated, whereas afterward they were much less clearly synchronized. Evidence is presented from both observations and coupled state-of-the-art climate models that enhanced external forcing, particularly from increased anthropogenic greenhouse gases, was the principal cause of this changed relationship. Using coupled climate model experiments, it is shown that without external forcing, the evolution of the IOB would be strongly forced by variations in the IPO. **However, with strong external forcing, the dynamical linkage between the IOB and the IPO weakens so that the negative phase IPO after 2000 is unable to force a negative phase IOB-induced cooling of the Indian Ocean. This changed relationship in the IOB and IPO led to unique SST patterns in the Indo-Pacific region after 2000, which favored exceptionally strong easterly trade winds over the tropical Pacific Ocean and a pronounced global warming hiatus in the first decade of the twenty-first century.**

Tropical Pacific Basin

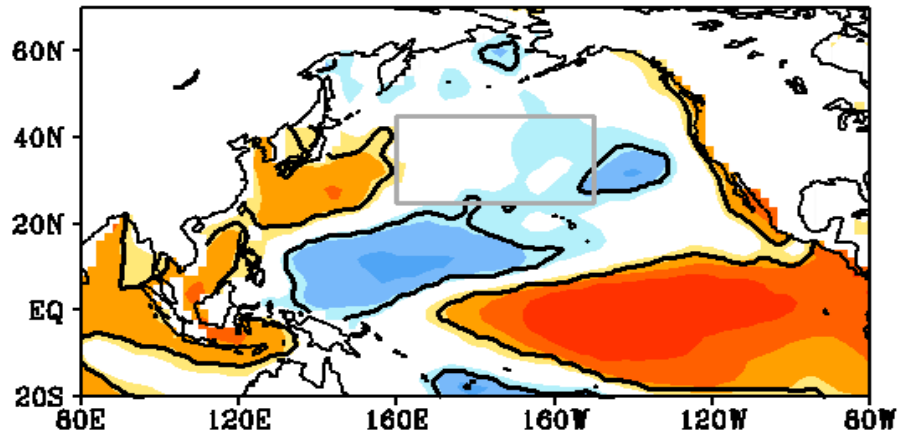
- Pacific Decadal Oscillation

monthly values for the PDO index: 1900-2013

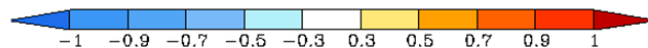
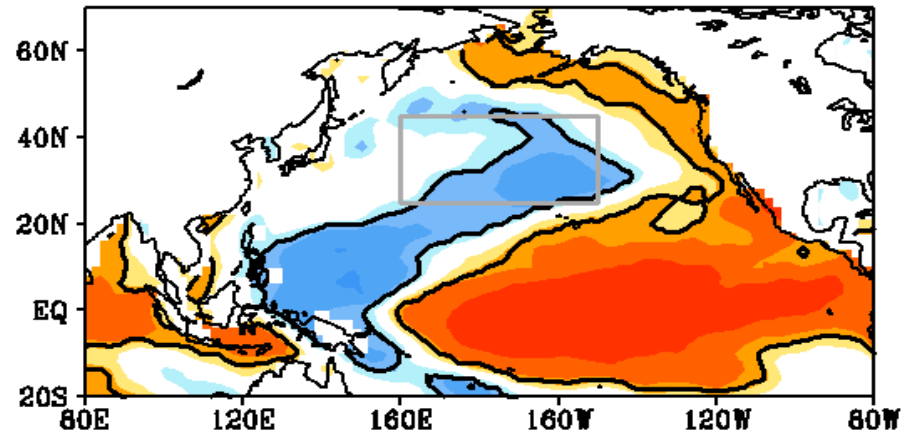


• Tropical Pacific-North Pacific interactions

(a) Corr. SST on Nino3.4 (1976–1997, DJF)



(e) Corr. SST on Nino3.4 (1998–2012, DJF)

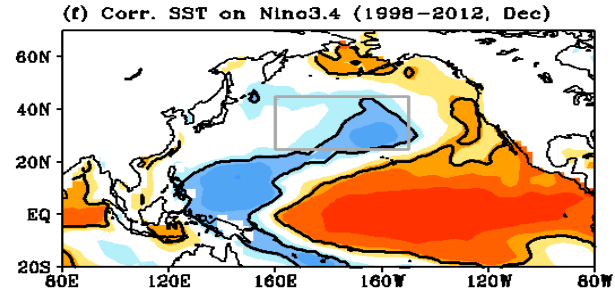
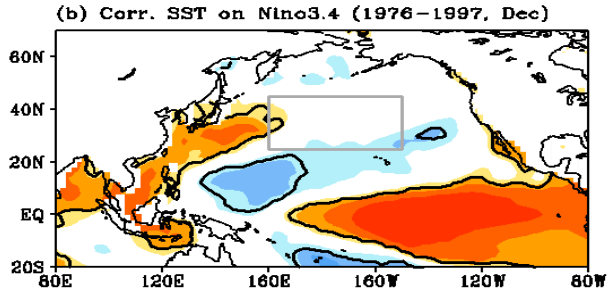


: ERSST v3. (1976/77-2012/13, Trend is removed)

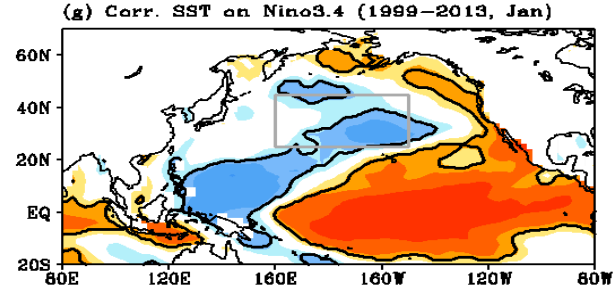
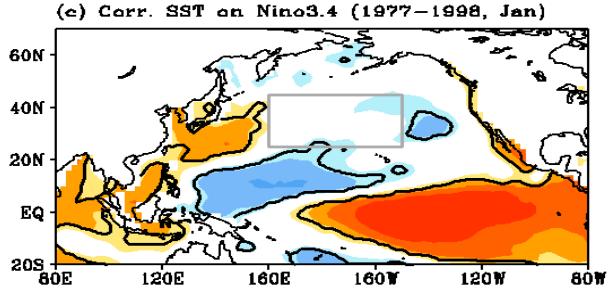
Jo et al. (2013)

• North Pacific SST in response to ENSO

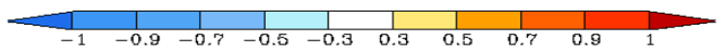
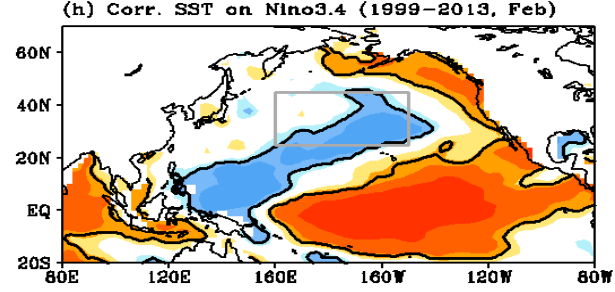
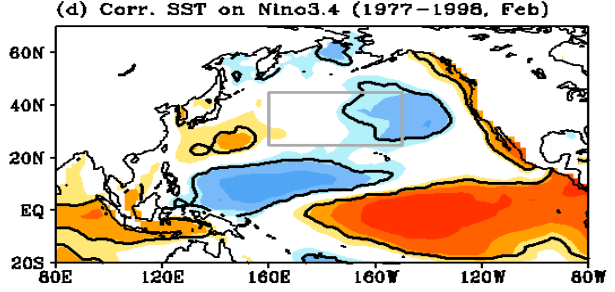
Dec.



Jan.

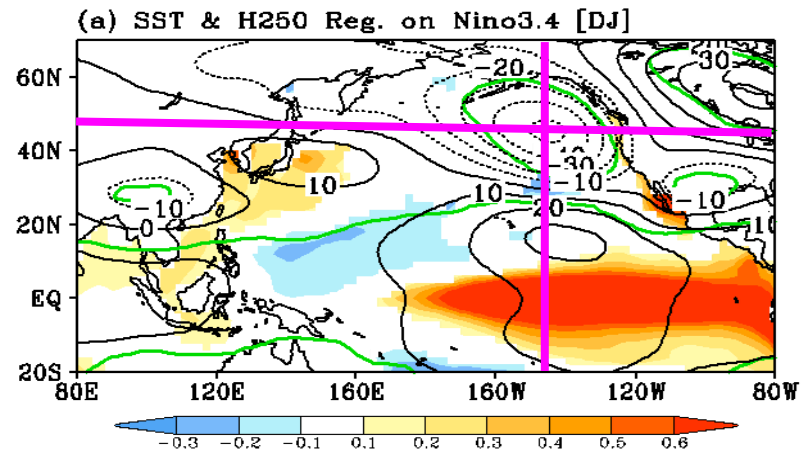


Feb.

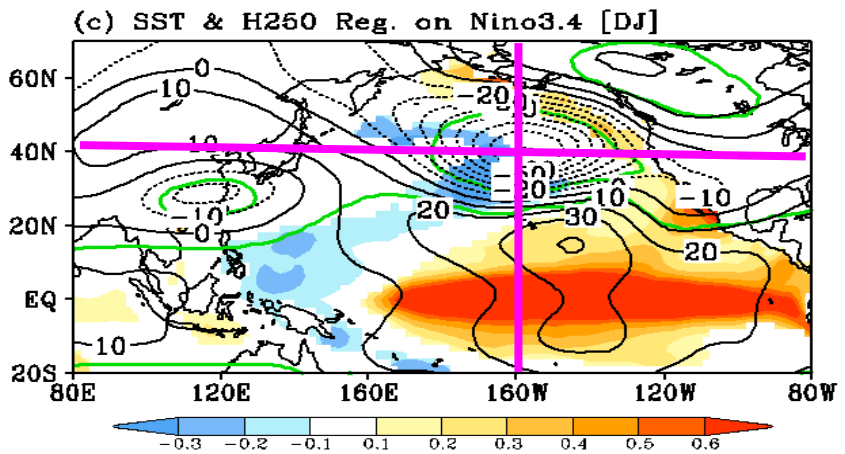


- Atmospheric anomalies in response to ENSO

Before the late-1990s

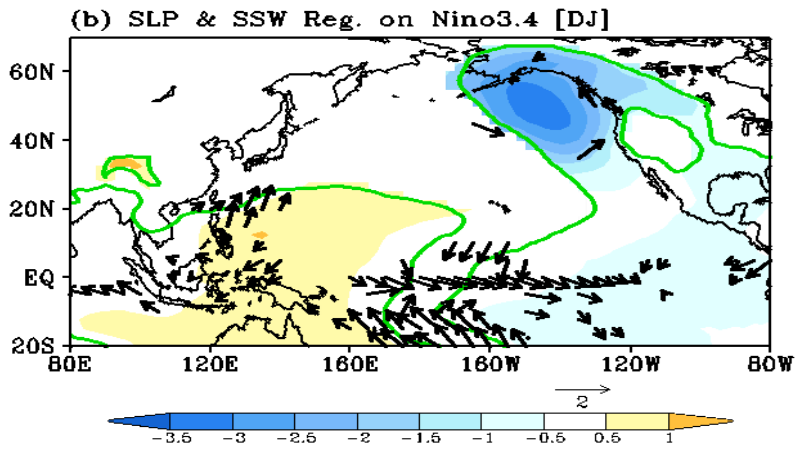


After the late-1990s

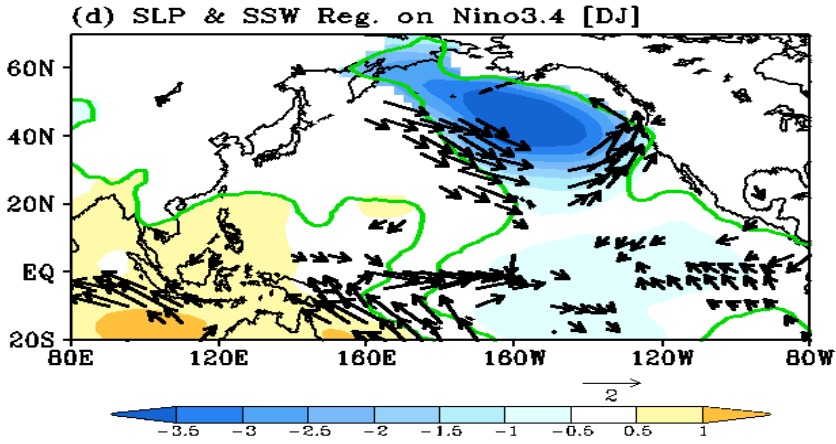


- Atmospheric anomalies in response to ENSO

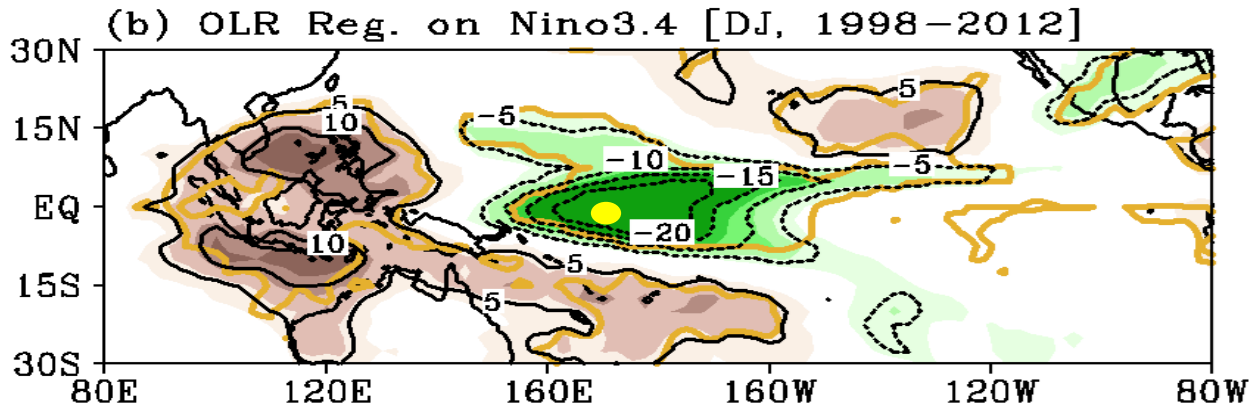
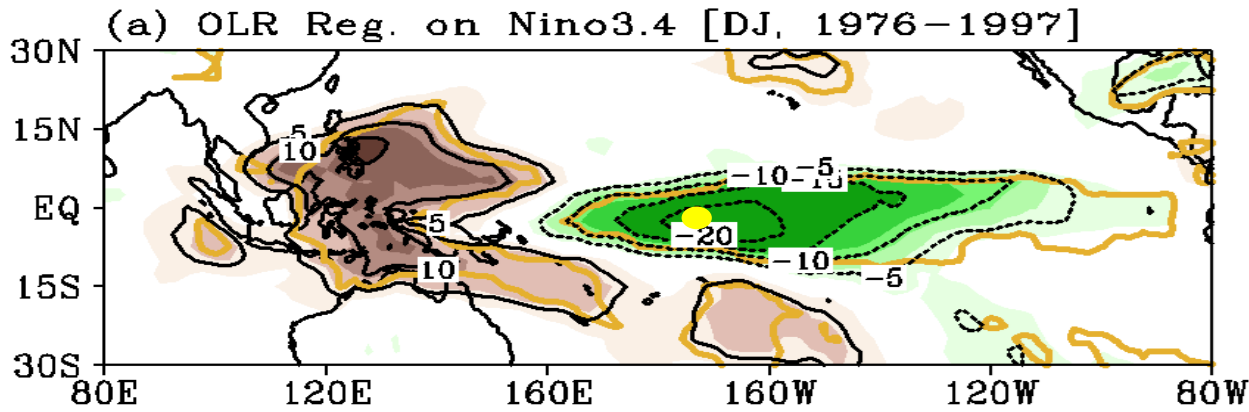
Before the late-1990s



After the late-1990s



• Outgoing longwave Radiation



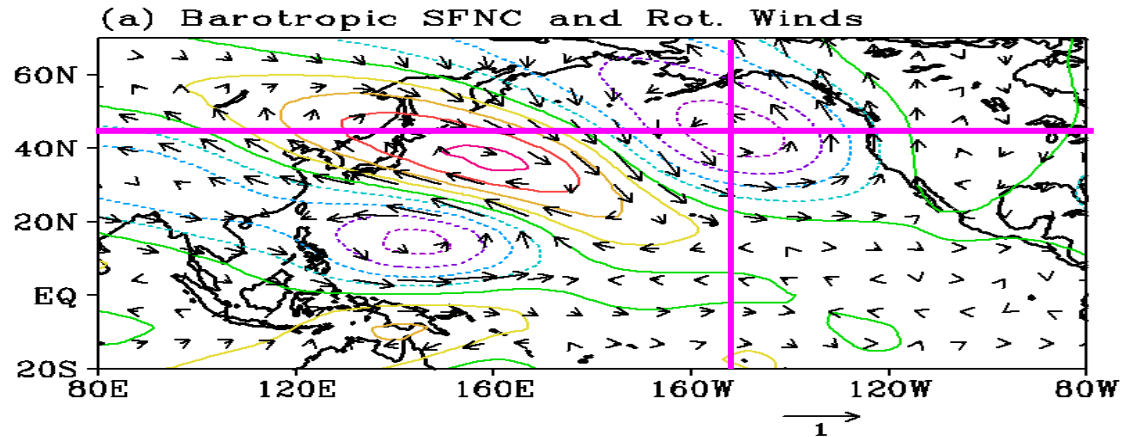
: OLR: NOAA

• Simple model experiment

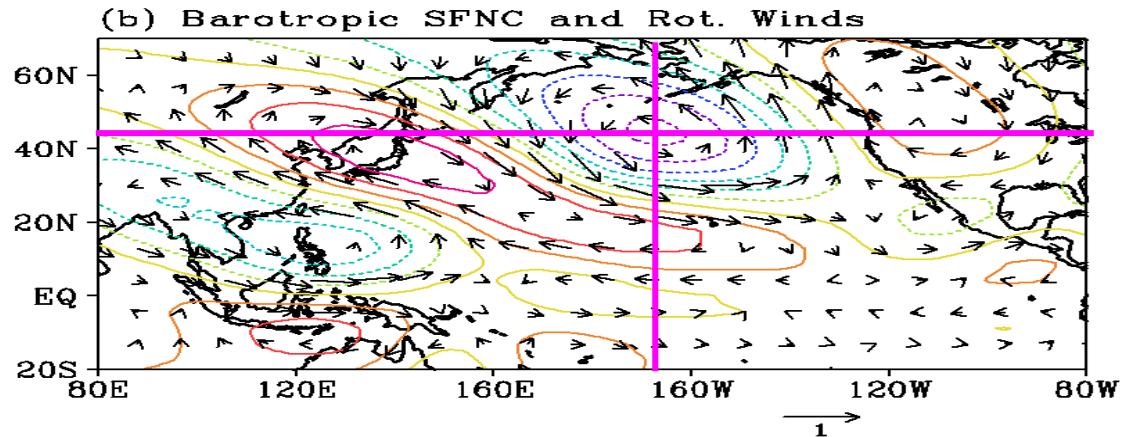
- A simple atmospheric model recently developed by *Lee et al.* (2009).
- A steady-state two-level model at 250hPa and 750hPa, and spherical-coordinate primitive equation model, linearized around a specified background flow.
- The model uses 18 triangular truncations for the horizontal grid.

- Simple model experiment

Before the late-1990s

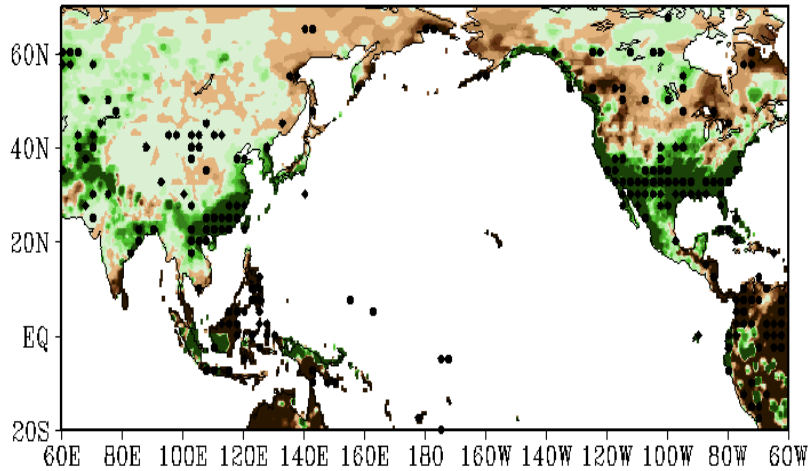


After the late-1990s



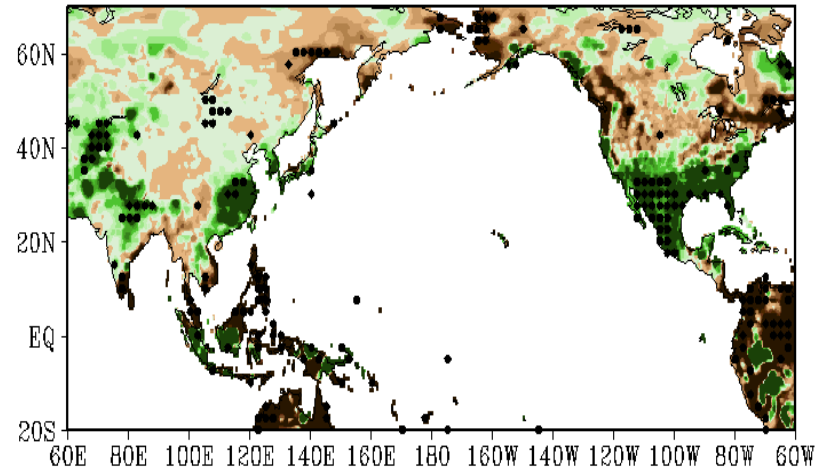
Before the late-1990s

a) Reg. Precip. onto PC1 [1976–1997]



After the late-1990s

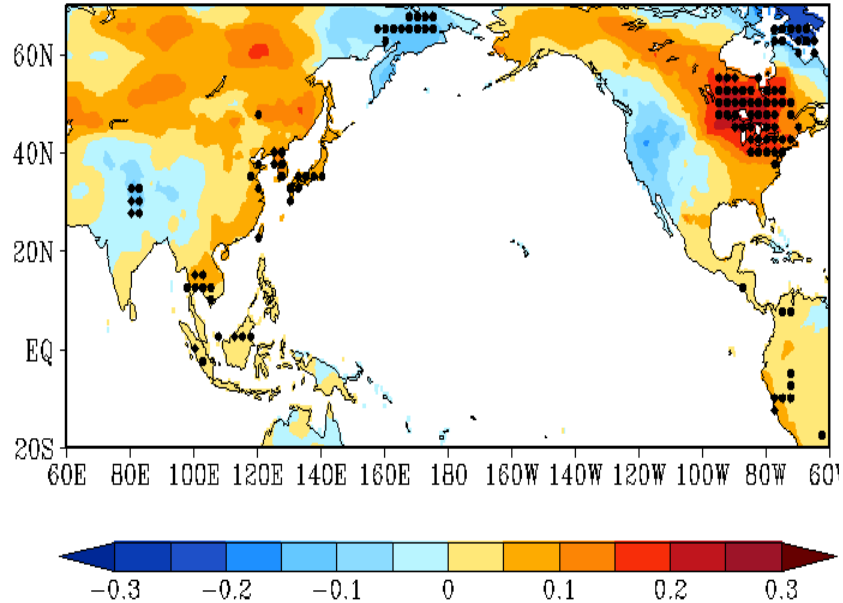
b) Reg. Precip. onto PC1 [1998–2012]



Precip. : GPCP (total precip. mm)

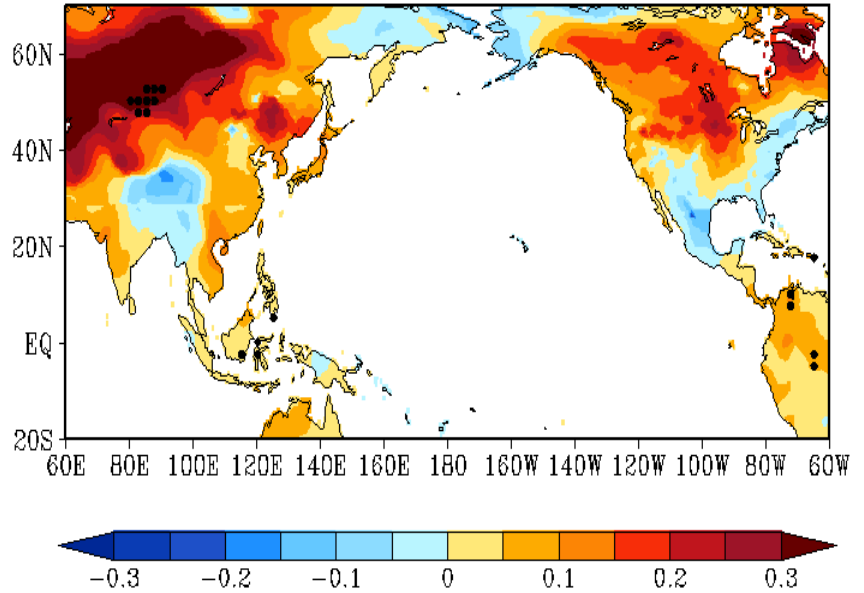
Before the late-1990s

c) Reg. SAT. onto PC1 [1976–1997]



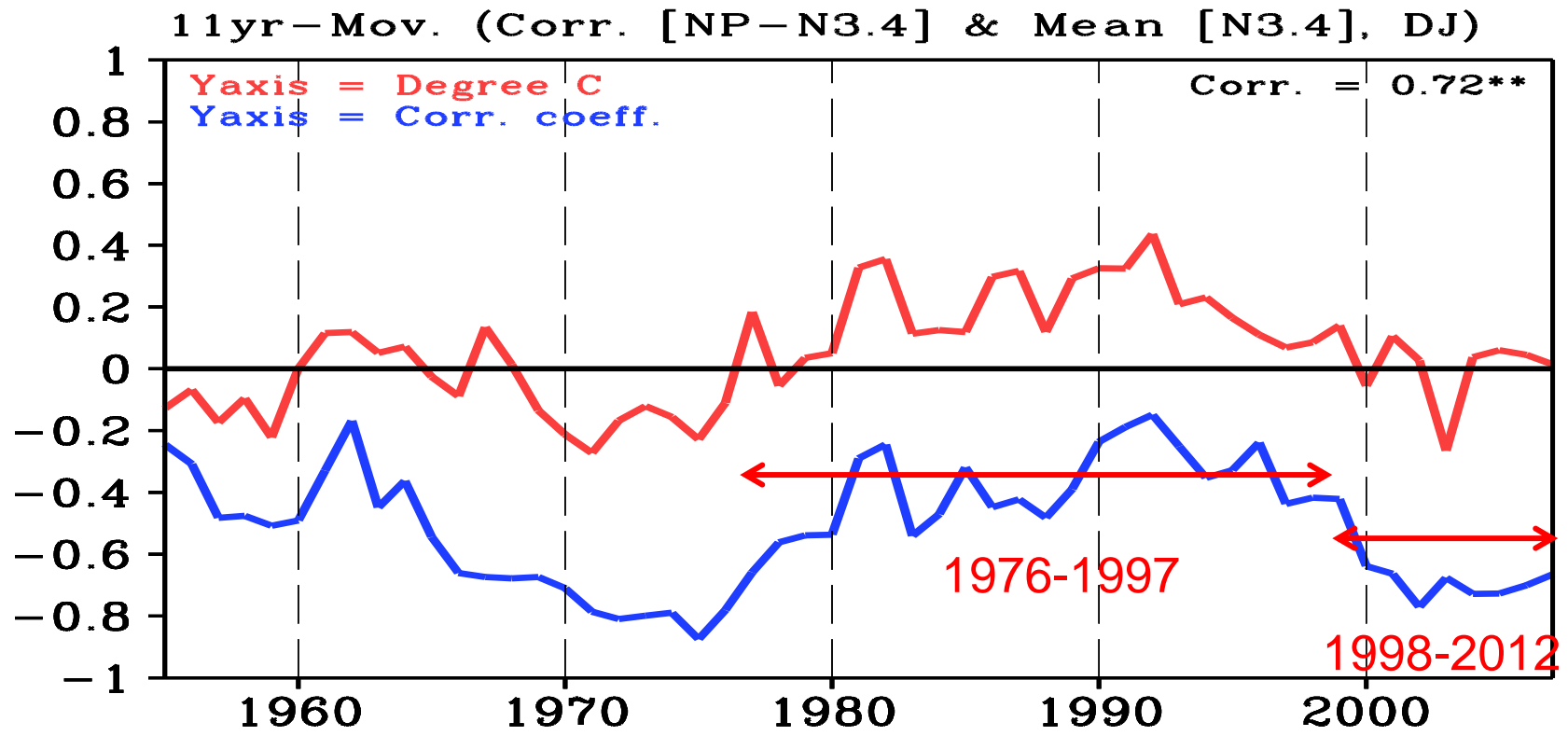
After the late-1990s

d) Reg. SAT. onto PC1 [1998–2012]

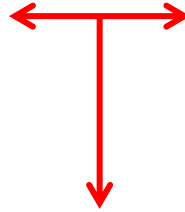


SAT. : GHCN CAMS surface temperature (Mean air degK)

- Low-frequency change in the tropical Pacific mean state



Changes in the tropical Pacific mean state on the low-frequency timescales



Changes in the convective forcing (OLR) in the equatorial Pacific

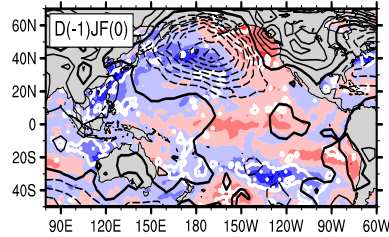
This can cause the changes in the atmospheric teleconnections from the tropics to the extratropics, leading to the different response of temperature and precipitation

North Pacific-Tropical Pacific

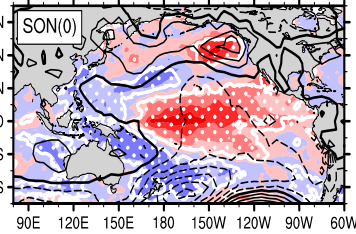
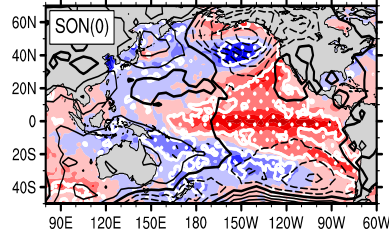
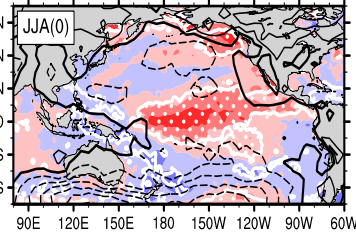
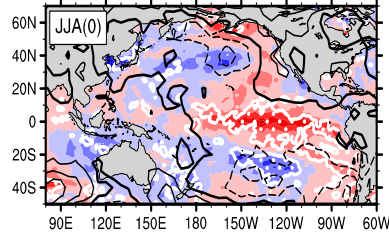
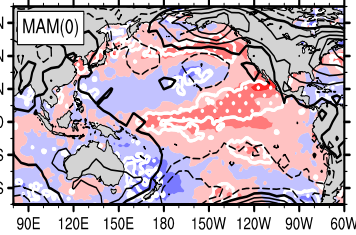
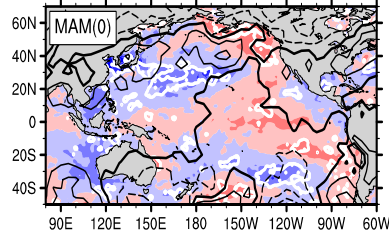
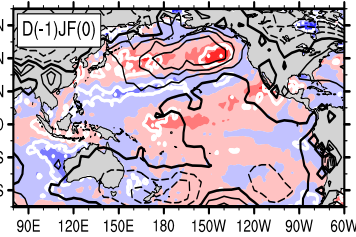
Table 1 The years for the CP El Niño-B90 and CP El Niño-A90, respectively, in the present study.

	CP El Niño years before 1990	CP El Niño after 1990
Year	1963/64, 1968/69, 1977/78, 1979/80, and 1987/88	1990/91, 1991/92, 1992/93, 1993/ 94, 1994/95, 2002/03, 2004/05, a nd 2009/10

CP El Nino-B90

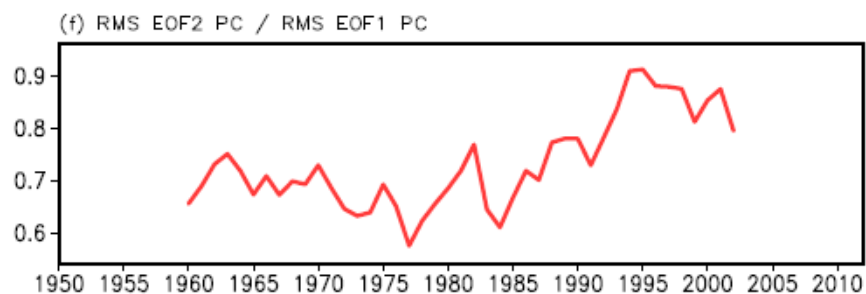
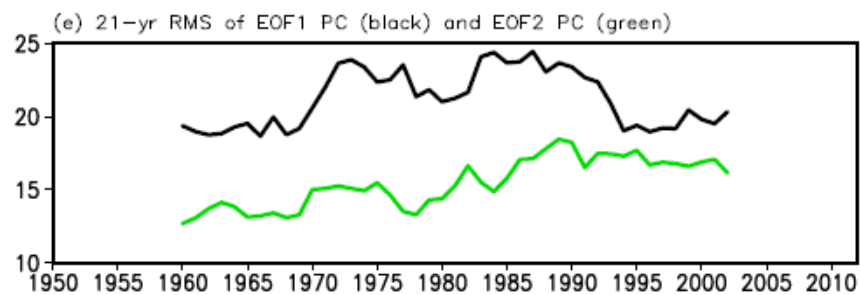
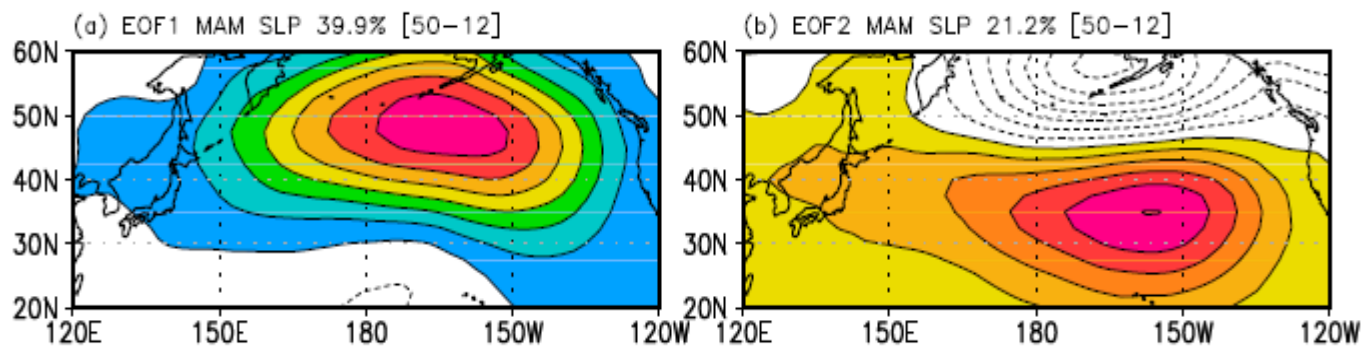


CP El Nino-A90



CP El Niño years
before 1990

CP El Niño years
after 1990



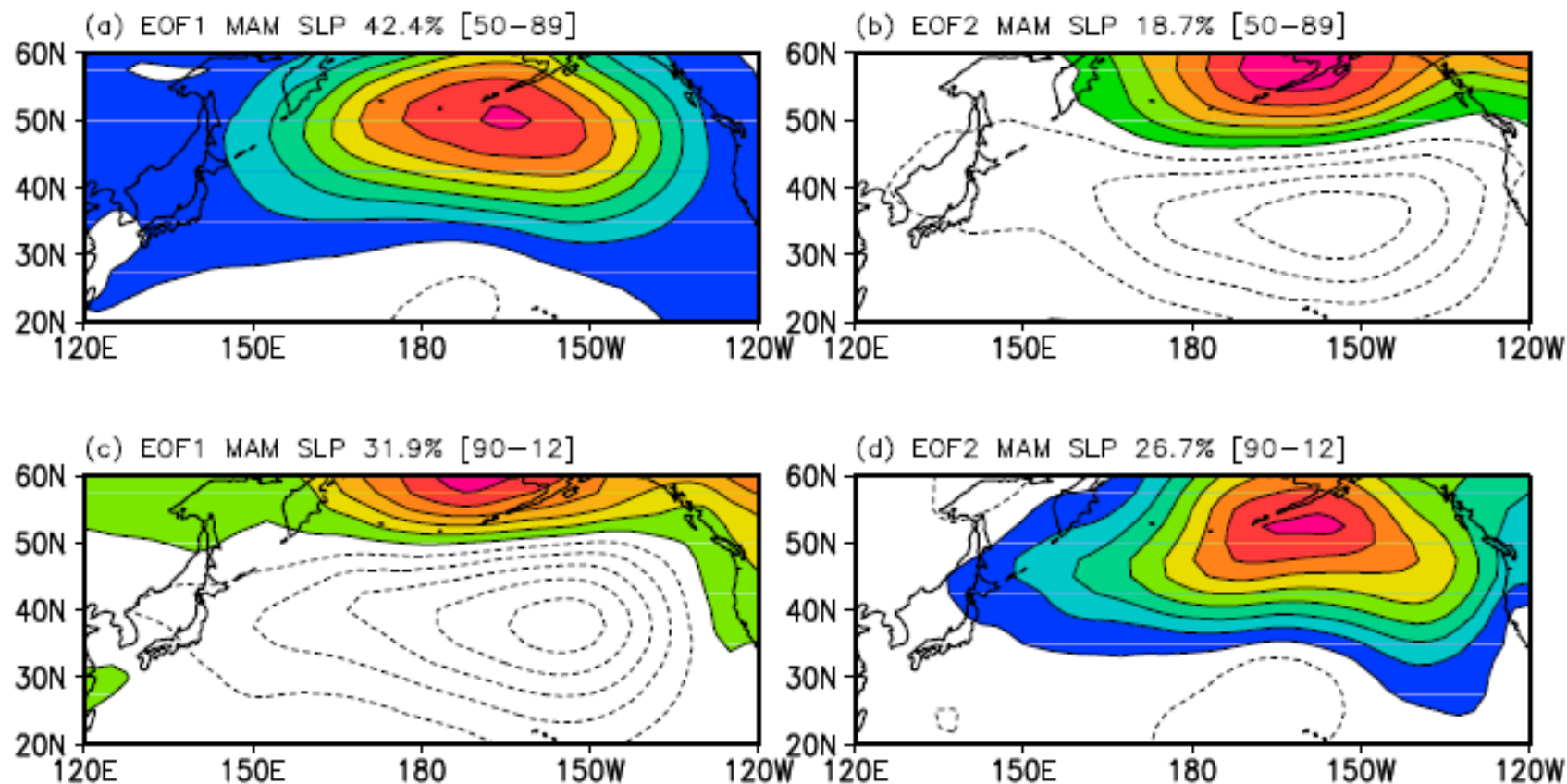
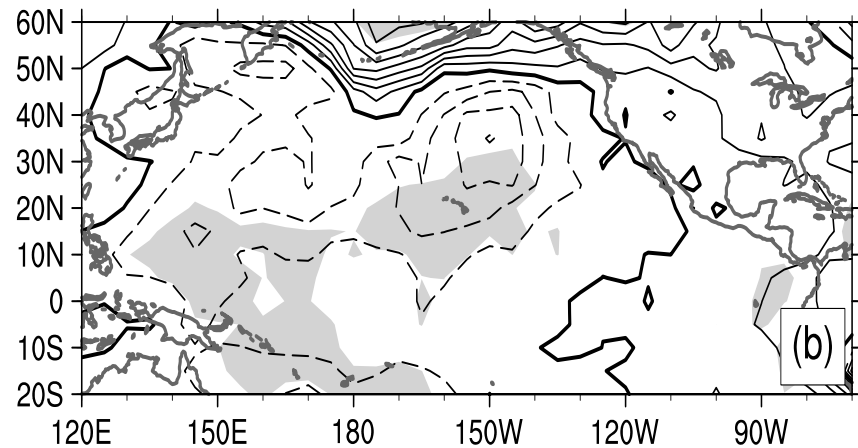
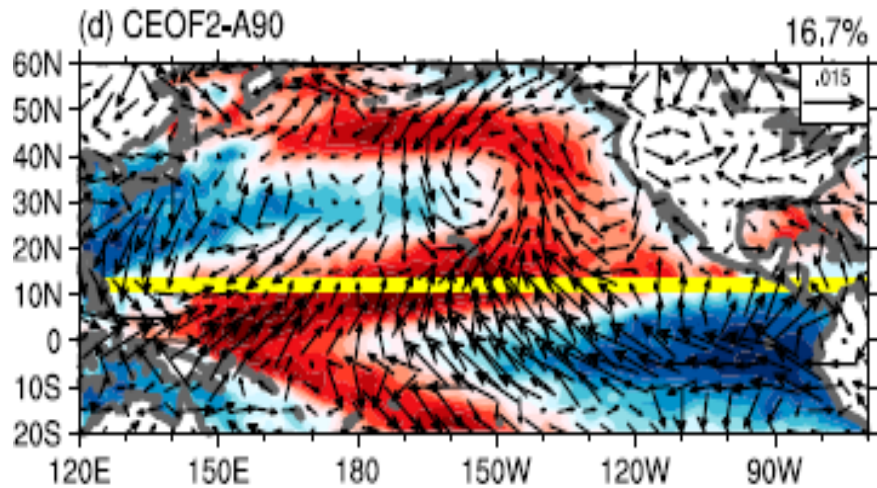
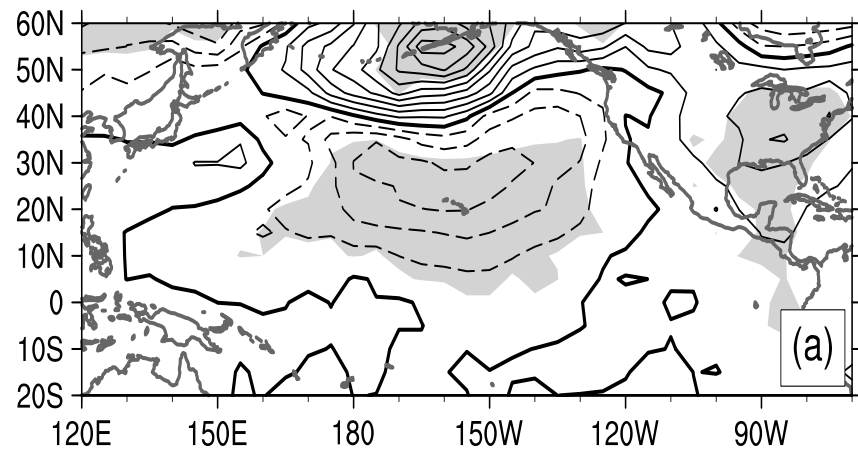
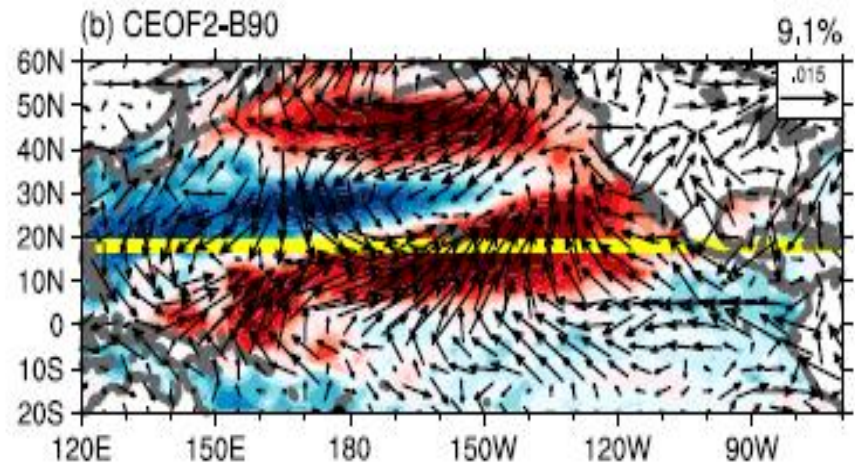
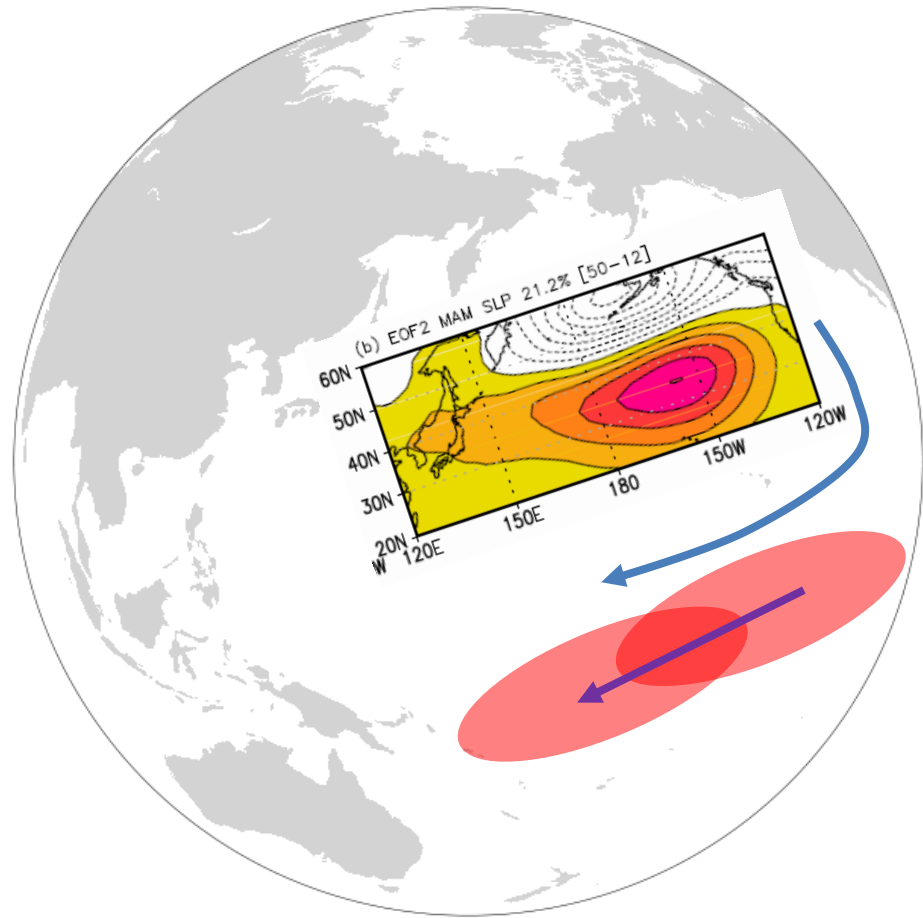
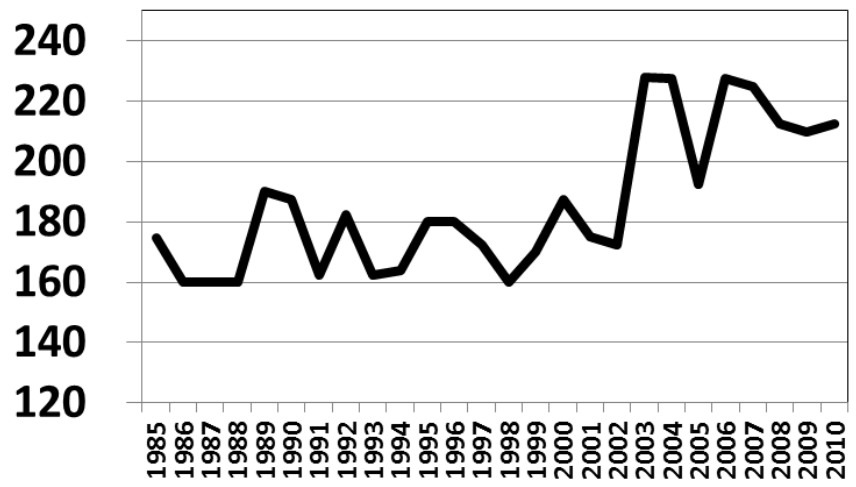
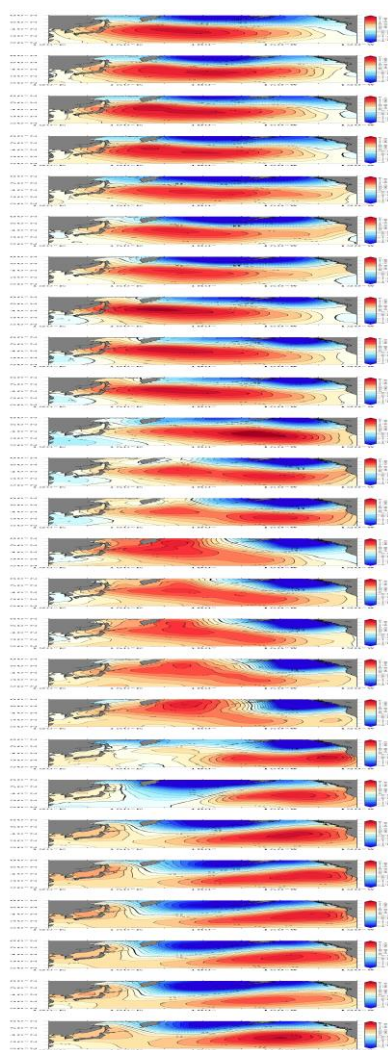


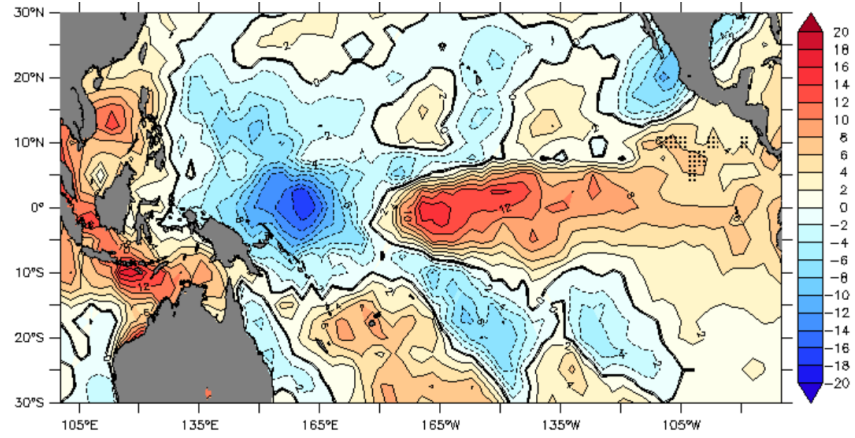
FIG. 5. The (a),(c) first and (b),(d) second EOFs of SLP during the spring (top) before 1990 and (bottom) after 1990. The contour interval is 0.02, and the unit is nondimensional.







Regressed OLR against with the longitude of NPO



Enhanced biennial variability in the Pacific due to Atlantic capacitor effect

Lei Wang^{1,2}, Jin-Yi Yu¹ & Houk Paek¹

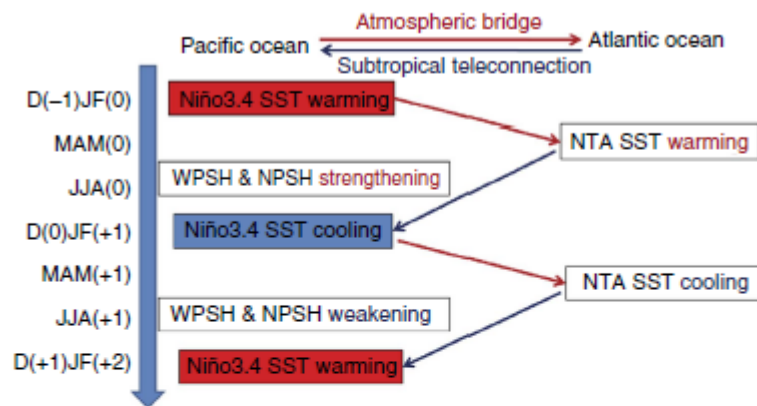


Figure 4 | A schematic diagram showing the biennial cycle of the ENSO induced by the Atlantic capacitor effect.

Prominent biennial variability in the boreal winter Niño3.4, spring NTA SST, summer WPSH and NPSH existed in this Atlantic-Pacific-coupled process. The red arrow represents the 'charging' process in which the preceding winter ENSO influences the spring NTA SST like a battery charges a capacitor via an atmospheric bridge mechanism, and the blue arrow is for the 'discharging' process in which the NTA SST exerts its climatic influences on the following ENSO like a discharging capacitor via a subtropical teleconnection mechanism.

감사합니다

미래 기후 변화

- CESM large ensemble (CESM-LE) experiment

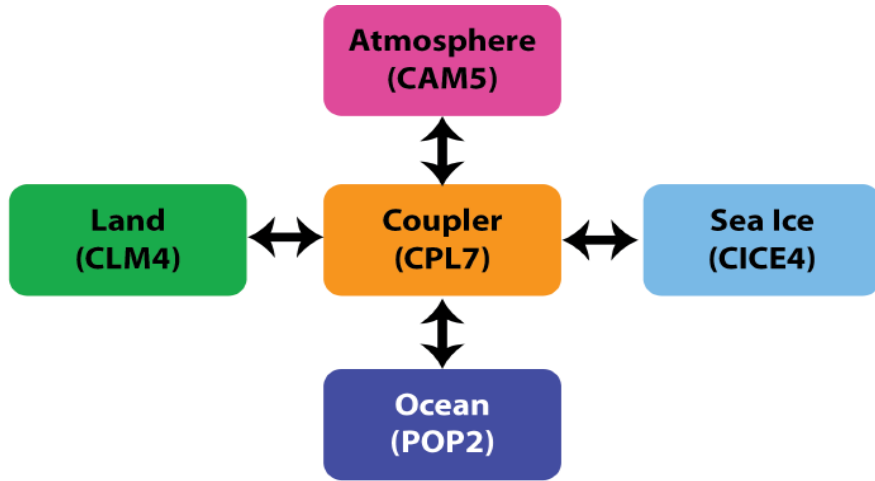


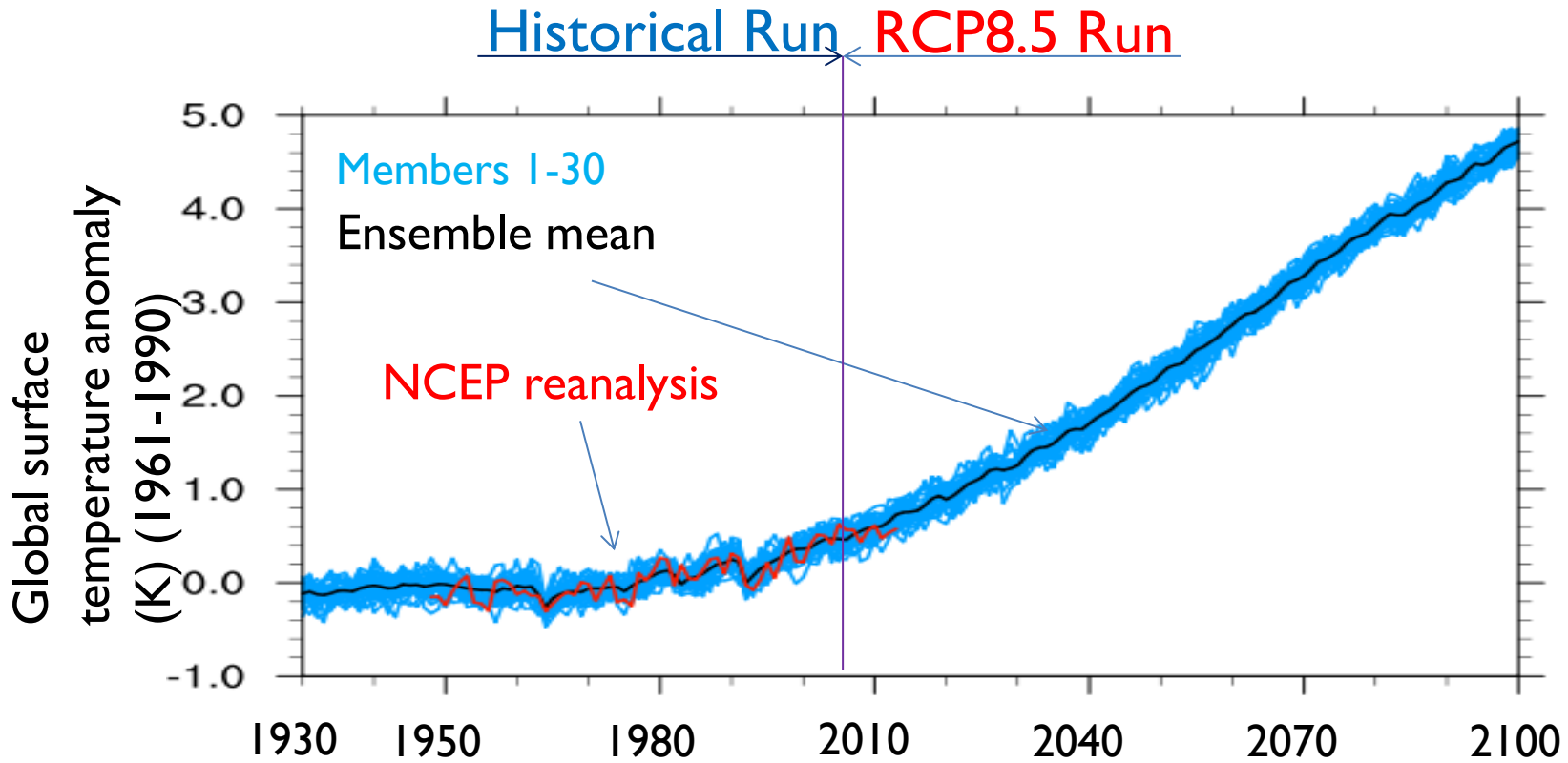
Figure 1 - CESM1(CAM5) component models and coupling (Hurrell et al. 2013). All components were run at ~ 1 degree horizontal resolution. CESM1(CAM5) consists of coupled atmosphere (Community Atmosphere Model version 5, CAM5, 30 vertical levels), ocean (Parallel Ocean Program version 2, POP, 60 vertical levels), land (Community Land Model version 4, CLM4), and sea ice (Los Alamos sea ice model version 4, CICE) component models.

All 30 CESM-LE members use the same model and the same external forcing.

Each CESM-LE ensemble member has a unique climate trajectory due to **small round-off level differences** in their atmospheric initial conditions. (Kay et al., 2015).

Hurrell et al. (2013)

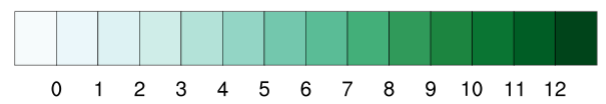
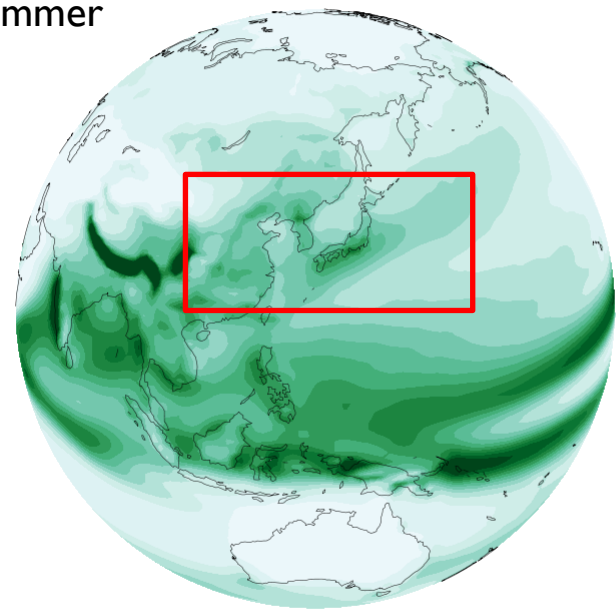
- Global mean surface temperature anomaly: CESM-LE



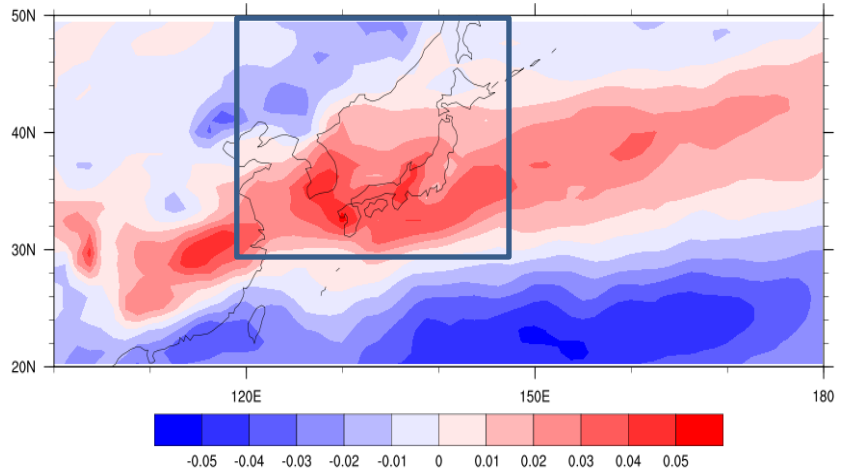
East Asian summer precipitation: CESM-LE

CESM-LE Mem. I historical (1930~2005)

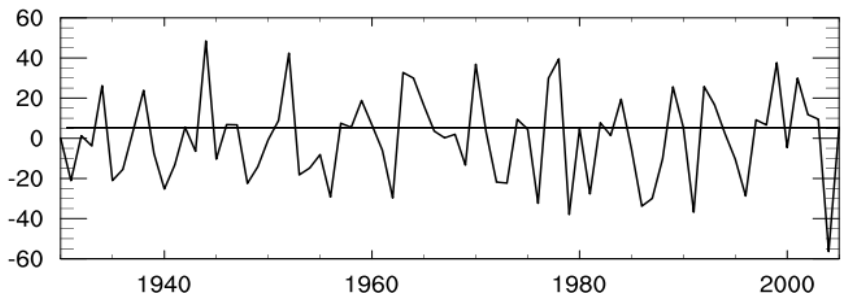
Mean precipitation during summer



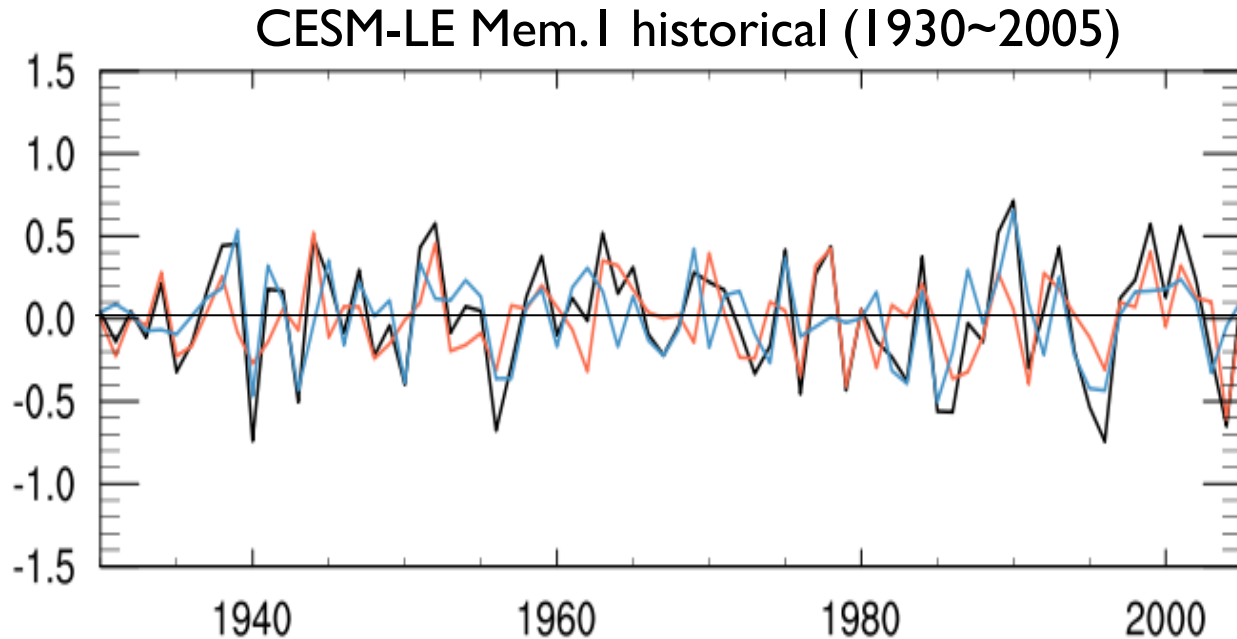
EOFI, 15.6%



EOFI PC



- East Asian summer precipitation: CESM-LE



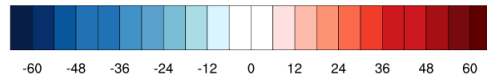
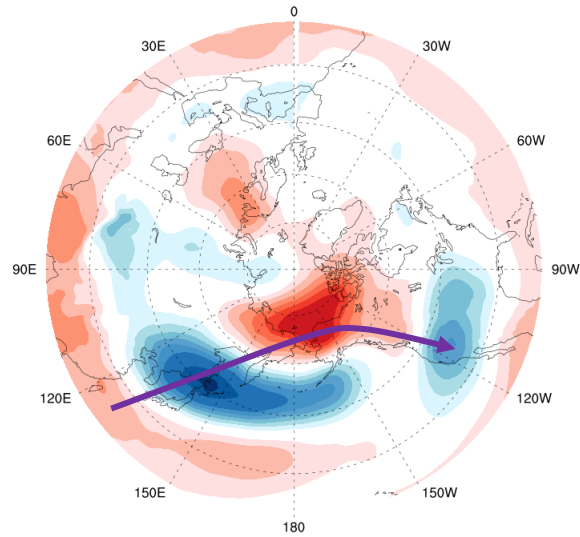
Black : EASRA

Red: Tropics-related

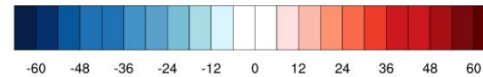
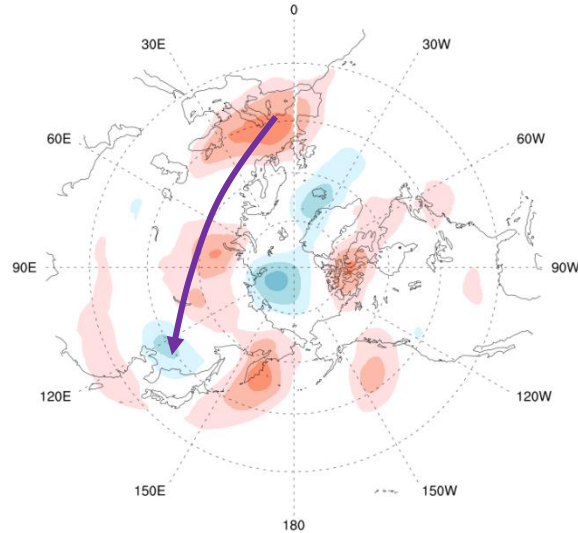
blue: Extratropics-related

• Tropics-related & Extratropics-related rainfall variability: CESM-LE

CESM-LE no.1 historical (1930~2005)



500 hPa GPH
& Tropics-related



500 hPa GPH
& Extratropics-related

- Spread

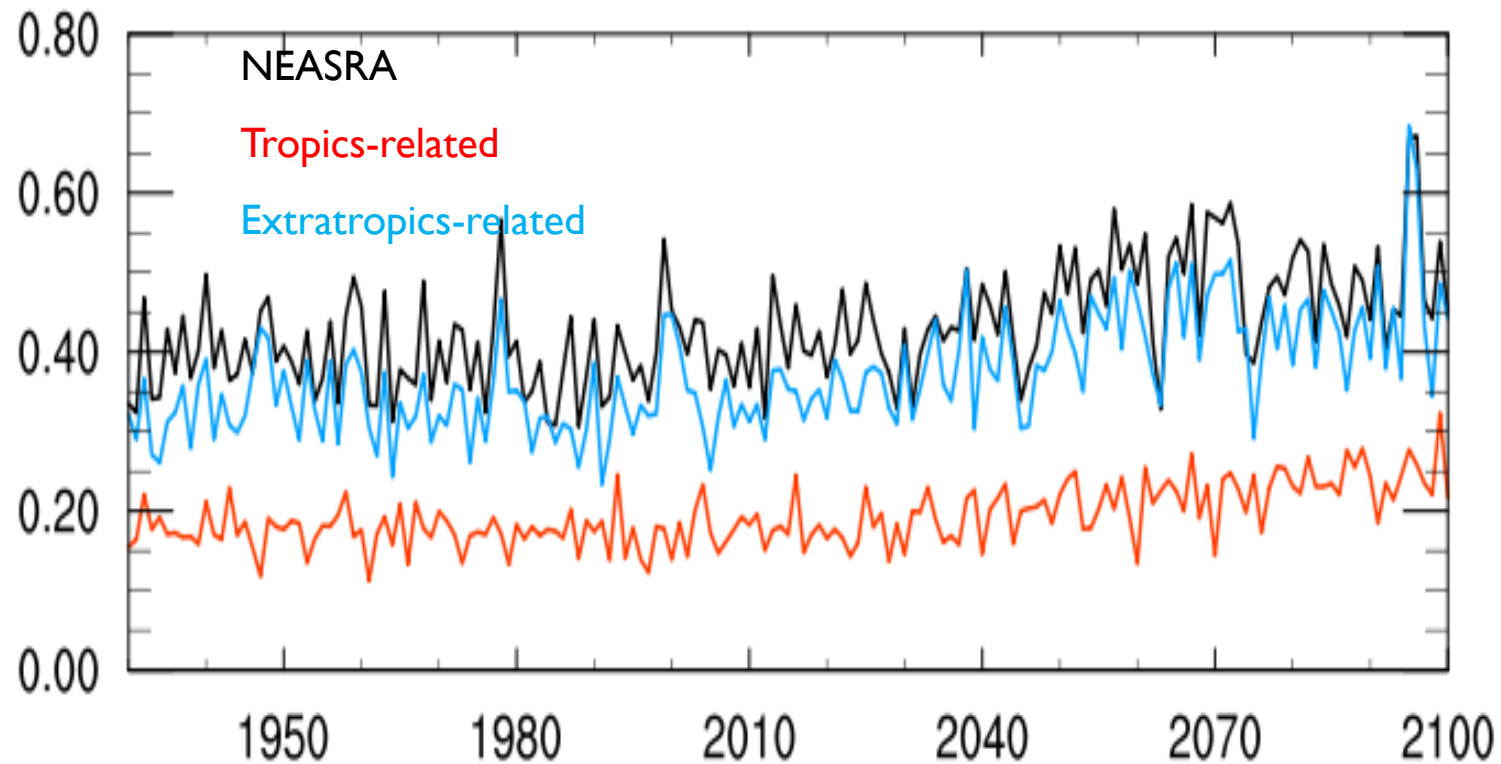
$$\sqrt{\left[\sum_{i=1}^{30} (x_i - \bar{x})^2 \right] / 30}$$

\bar{x} : Ensemble mean

x_i : Each member

- Spread means the standard deviation of the absolute values of differences between ensemble mean and 30 members.

• Spread of Tropics-related & Extratropics-related: CESM-LE



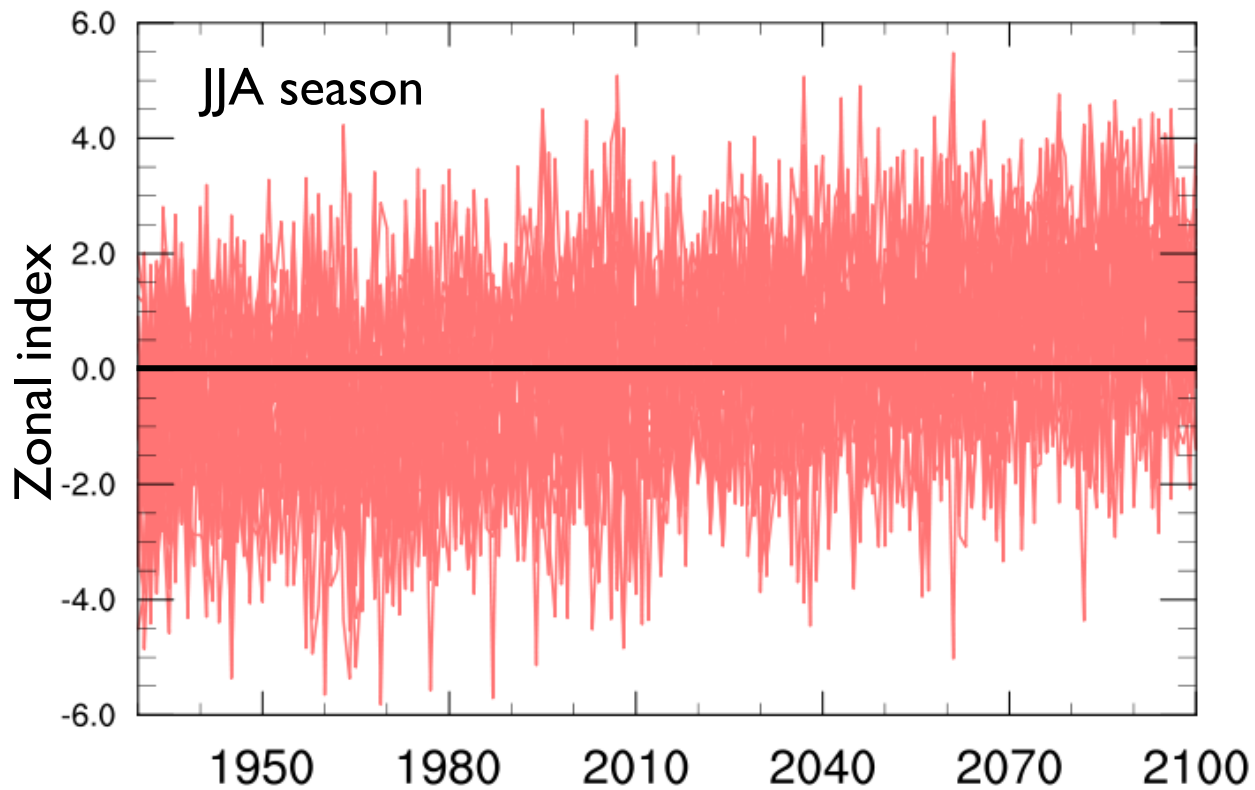
Why the spread of extratropics-related rainfall variability is increased under global warming ?

- Zonal index

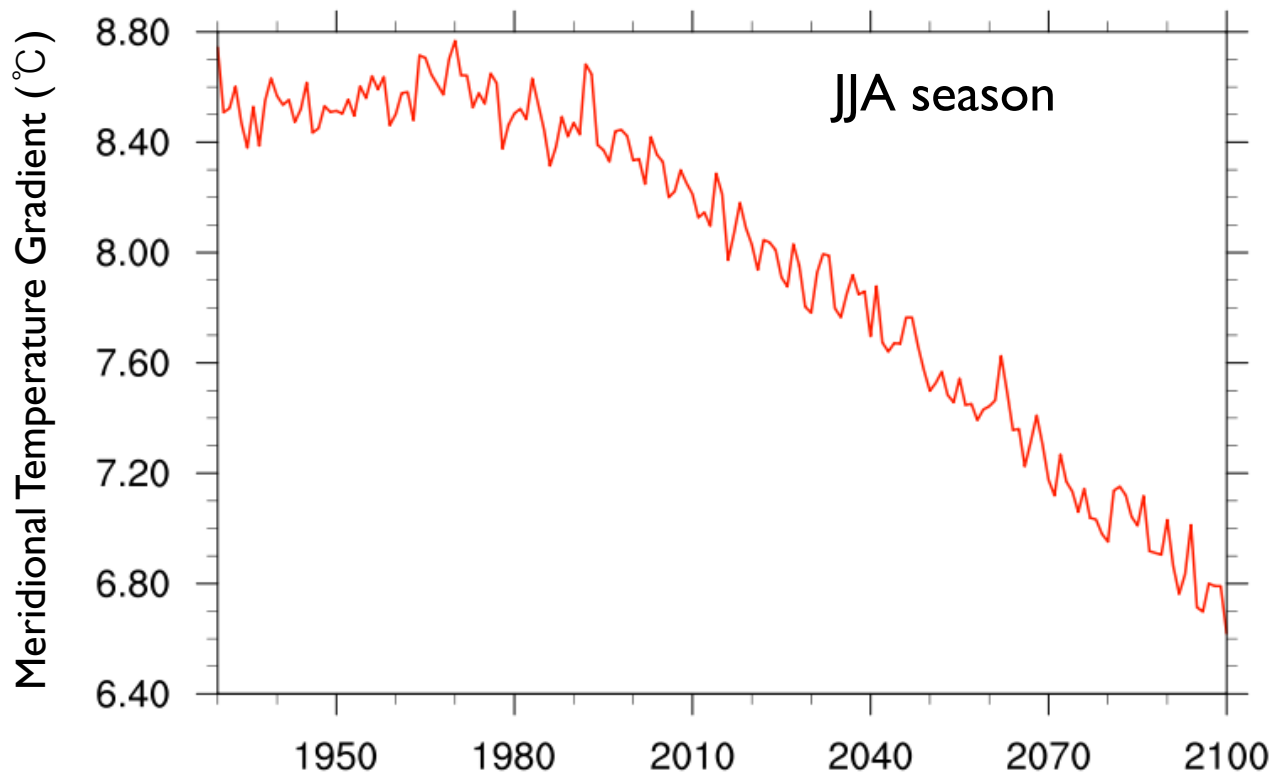
$$ZI = \hat{P}_{35^{\circ}\text{N}} - \hat{P}_{65^{\circ}\text{N}}$$

The ZI is a measure of the hemisphere-wide fluctuations in surface air mass between the two zones as the annular belts of action and ZI is defined as the normalized difference in zonal averaged SLP anomalies between 35N and 65N. (Li and Wang, 2003)

- Zonal index: CESM-LE



- Meridional Temperature Gradient : CESM-LE



Global mean surface temperature difference between
[20~30N] minus [40~50N]

● Conclusion

