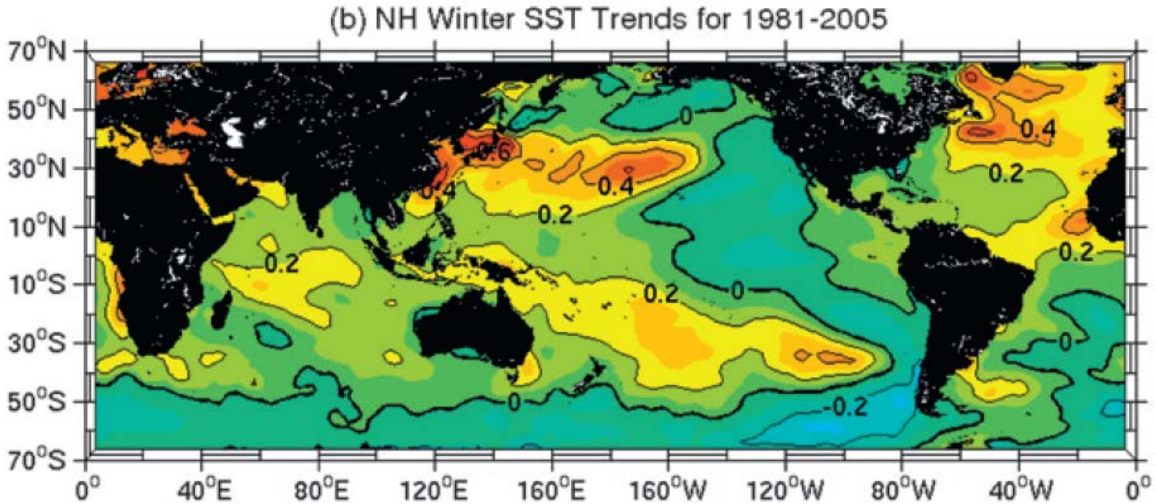
21. Oct. 2014

Regime-dependent nonstationary relationship between the East Asian winter monsoon and North Pacific Oscillation

Gyundo Pak, Young-Hyang Park, Frederic Vivier, Young-Oh Kwon, and Kyung-Il Chang

Climatic importance of the NW Pacific

- ▶ The western North Pacific shows the strongest warming in the world's oceans, and reveals a great sensitivity to the overlying atmospheric forcing, such as the East Asian winter monsoon (EAWM) and North Pacific Oscillation/west Pacific pattern (NPO/WP).



(Park et al. 2012)

Motivation

- ▶ The long-term winter SST variability in the Yellow/East China Sea is best attributable to the NPO (Yeh and Kim 2010).
- ▶ But, Park et al. (2012) showed that winter SST anomalies averaged over the East Asian marginal seas are much better correlated with the EAWM.
- ▶ A precise knowledge of interrelationship among EAWM, NPO, and SST is indispensable for better understand and predict the climate change over the western North Pacific.

Major results

- ▶ A new finding of nonstationary relationship between EAWM and NPO for two different winter monsoon regimes before and after 1988, as well as their impact on the SST.

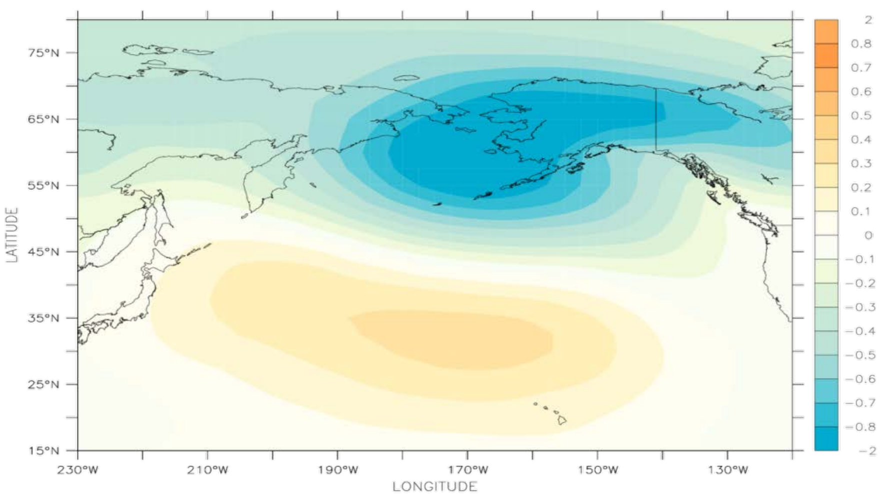
Background: EAWM and NPO/WP

http://blog.daum.net/ruihi2/28

East Asian winter monsoon

Change in atmospheric circulation (wind from land to sea in winter) associated with the asymmetric heating

Features
- Northerly or northwesterly wind
- Cold and dry



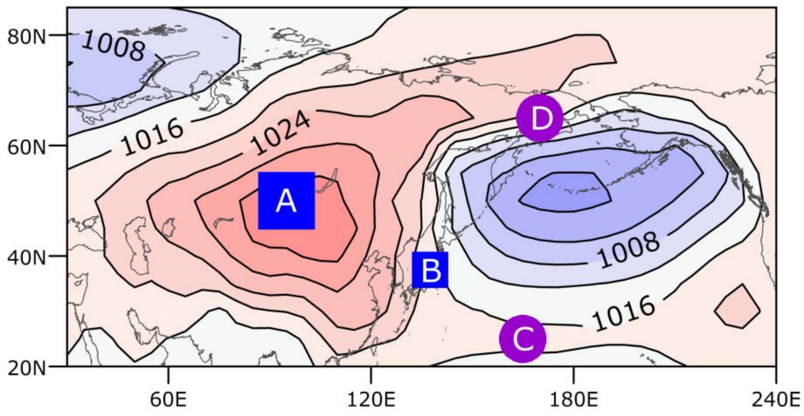
http://en.wikipedia.org/wiki/North_Pacific_Oscillation

North Pacific Oscillation

North-south seesaw in sea level pressure over the North Pacific

WP (West Pacific) pattern is upper-level expression of NPO

Data



Surface variables

HadISST (SST)

Trenberth SLP (SLP)

Climate Indices

Siberian high (SH): SLP_A

East Asian winter monsoon (EAWM): SLP_A – SLP_B (Park et al. 2012)

North Pacific Oscillation (NPO): SLP_C – SLP_D (Wallace and Gutzler 1981)

WP, AO, MEI (ENSO), PNA: NOAA

Other Atmospheric Variables

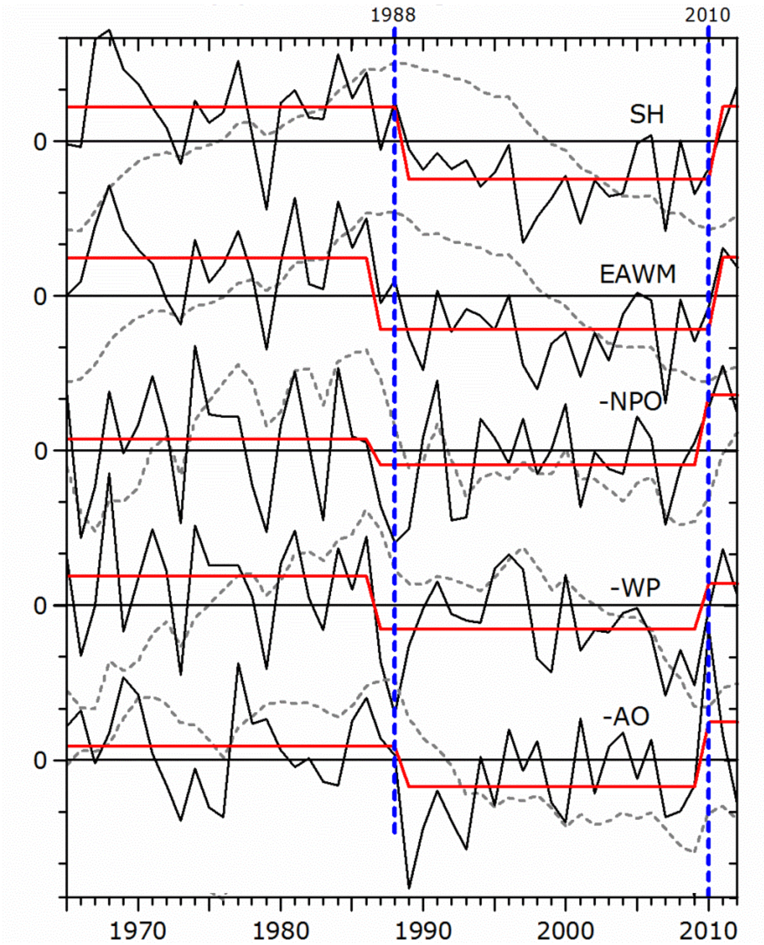
NCEP1: $Z_{300/500}$, SLP...

Analysis Period

48 winters (DJF or JFM) between 1965 and 2012

Regime shift detection

- **Strong** winter Monsoon Regime: Before 1988 (~1987)
- **Weak** winter Monsoon Regime: After 1988 (1988~)

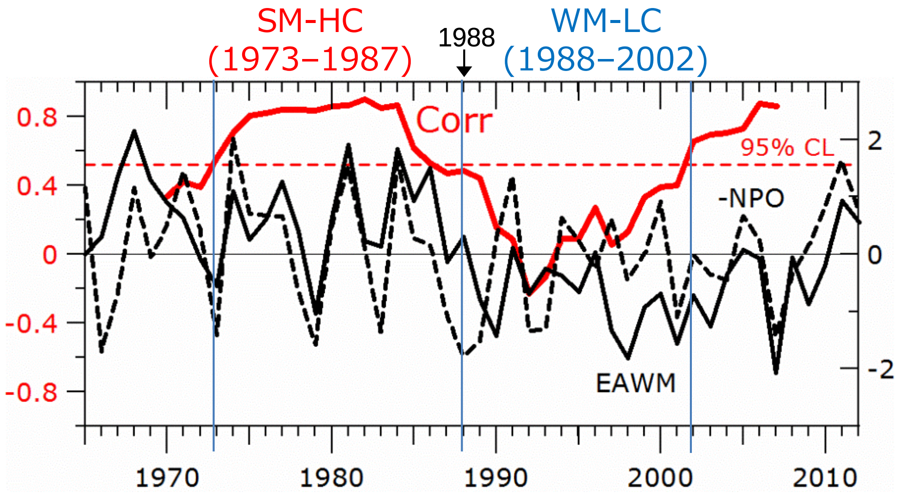


Regime shifts are defined as rapid changes of variables from one relatively stable state to another

The regime shift can be found by comparing two mean state using a sequential t-test with some given parameters (Rodionov 2004)

red: Climate Regime Shift determination
black: Normalized Climate Indices
gray: Normalized Cumulative Sums

Non-stationary relationships between the EAWM and NPO



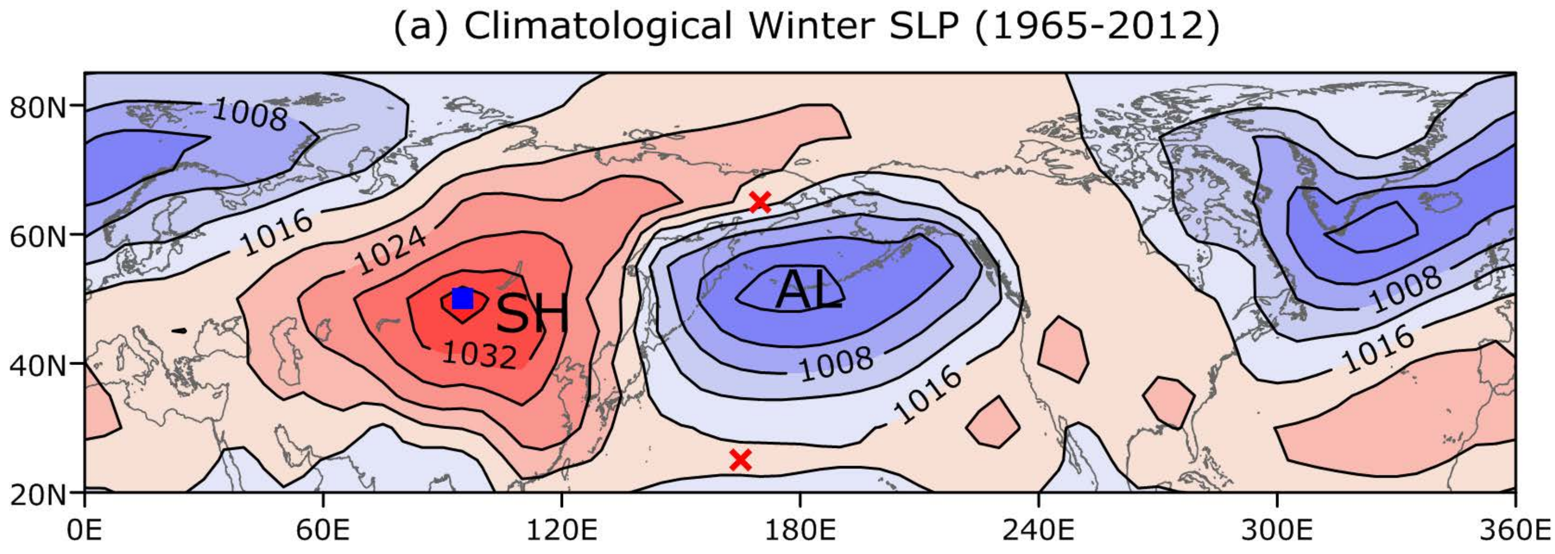
▲ 11-year moving correlation coefficient (red) between the EAWM and negative NPO indices (black).

- Moving correlation between EAWM and NPO shows pronounced low-frequency variation (insignificant correlation in the 1990s).
- Transition from significant to insignificant corr occurred very close to the 1988 regime shift.
- Two analysis periods
  - Strong Monsoon-High Correlation (SM-HC) 1973 ~ 1987
  - Weak Monsoon-Low Correlation (WM-LC) 1988 ~ 2002

▼ Correlation coefficients between pairs of climate indices with significant correlations at the 95% confidence level being marked in boldface.

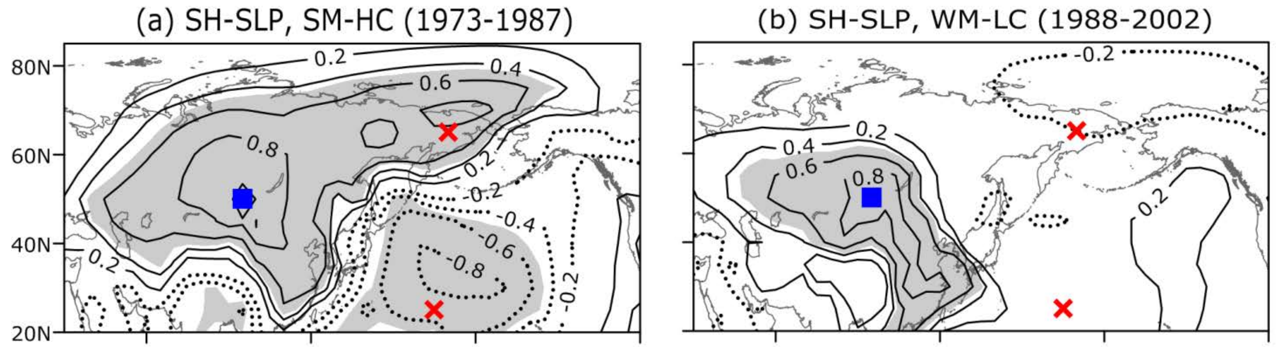
Indices	EAWM	NPO	WP
SH	**0.91** **0.93**, **0.77**	**-0.40** **-0.81**, 0.18	**-0.45** **-0.85**, 0.09
EAWM		**-0.53** **-0.89**, -0.11	**-0.57** **-0.92**, -0.15
NPO			**0.80** **0.92**, **0.61**

* All period (1965-2012); SM-HC (1973-1987); WM-LC (1988-2002)

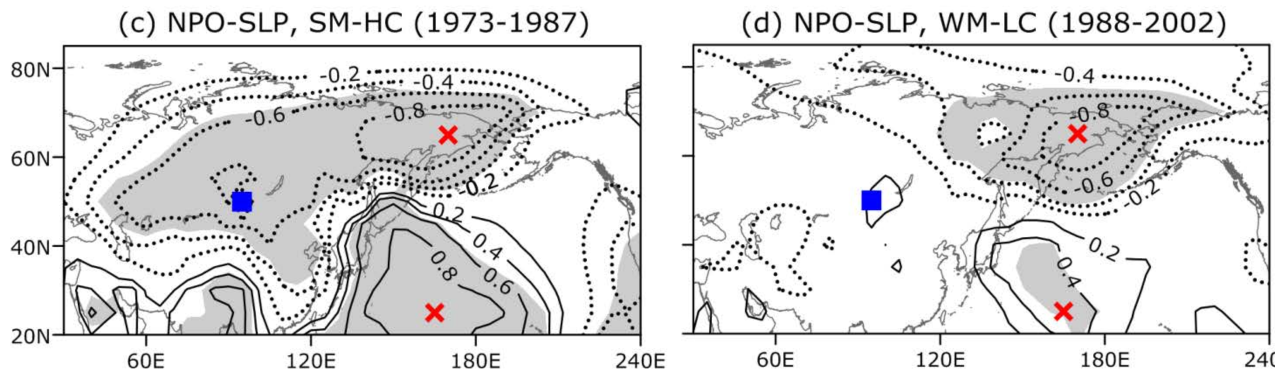

(a) Climatological Winter SLP (1965-2012)
80N
60N
40N
20N
0E
60E
120E
180E
240E
300E
360E
1008
1016
1024
1032
SH
AL
1008
1016
1008
1016

Spatial connection in SLP

- EAWM is replaced by SH (EAWM is mostly determined by the SH (r=0.91)) here.
- **SM-HC**: tight EAWM(SH)/NPO connection
- **WM-LC**: no significant EAWM(SH)/NPO connection

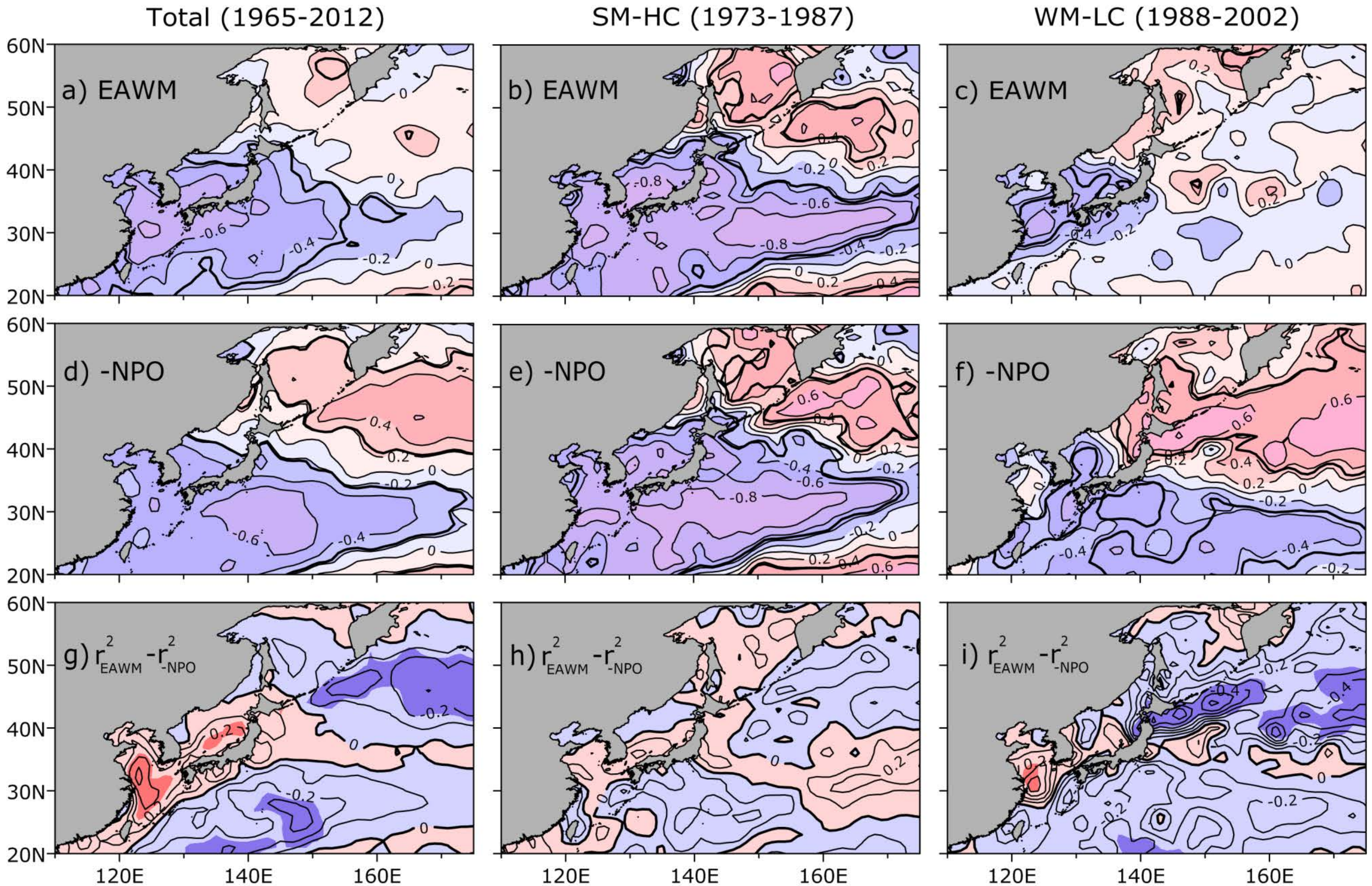


▲ Correlation of SLP anomalies with the SH index for SM-HC and WM-LC.



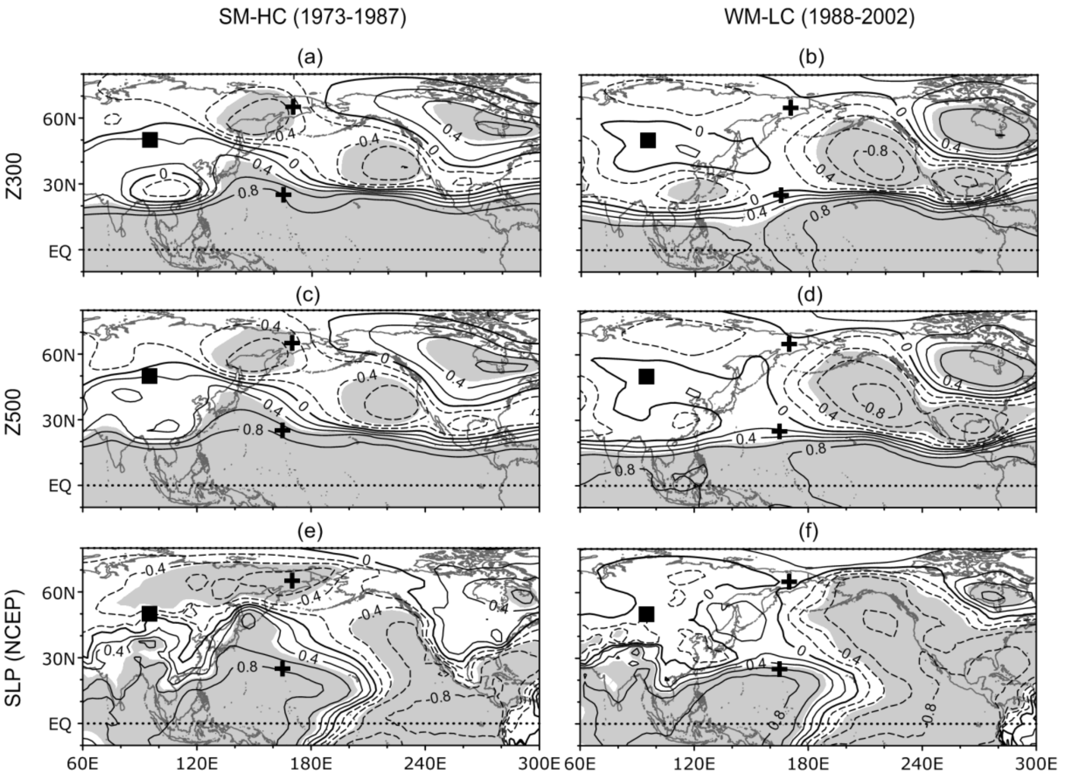
▲ Correlation of SLP anomalies with the NPO index for SM-HC and WM-LC.

Impact of DJF EAWM & NPO on the JFM SST

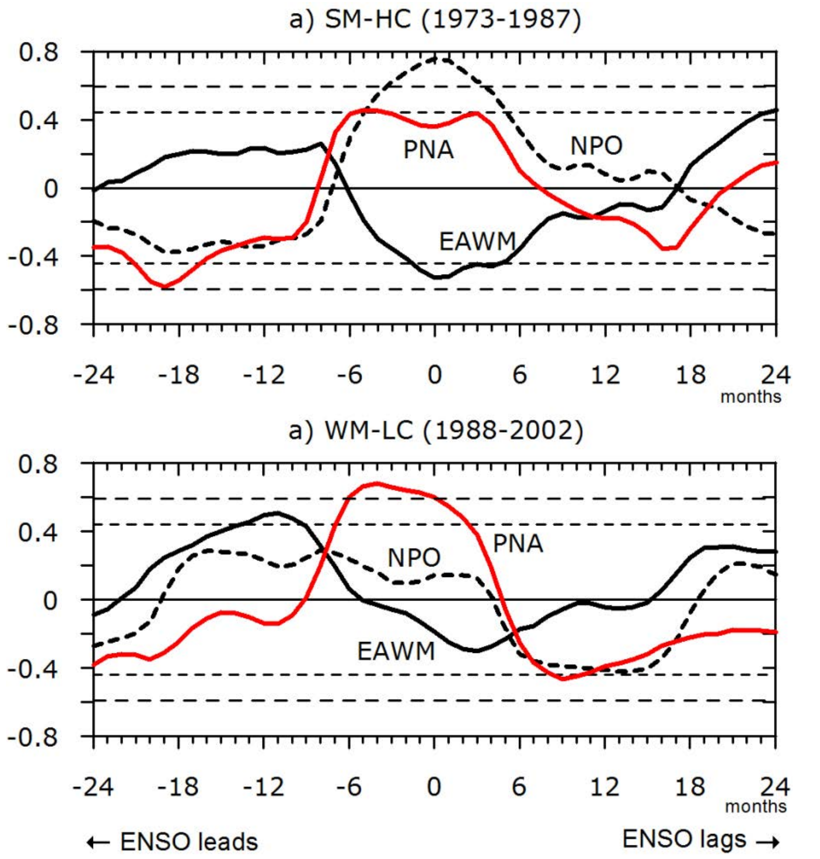


▲ Correlation coefficients of JFM SST anomalies with (a-c) the EAWM and (d-f) the negative NPO for three different periods, with significant correlations at the 95% confidence level being marked with the thicker curves. (g-i) Difference map of squared correlations (red color for the EAWM dominant regions), with a significant difference (at 90%) being shaded with a stronger tone.

Tropical influence



▲ Correlation of the ENSO index with DJF SLP and geopotential heights.



▲ Correlation of the EAWM, NPO, and PNA indices with lagged ENSO index (MEI).

The influence of the ENSO on midlatitude atmospheric circulation shifts eastward after late 80s.

Summary

- The EAWM and NPO are two outstanding surface atmospheric circulation patterns affecting winter SST variability in the NW Pacific

- A climate regime shift occured around 1988 in East Asia and the NW Pacific
  - strong monsoon regime (SMR) before 1988, SM-HC (1973-1987)
  - weak monsoon regime (WMR) after 1988, WM-LC (1988-2002)

- During SM-HC, the EAWM and NPO were highly correlated to each other (-0.89)

- During WM-LC, the correlation practically vanished (-0.11)

- The regime-dependent nonstationary relationship is related to a tight (insignificant) statistical connection in SLP variations between the SH and NPO centers of action during the SM-HC (WM-LC)

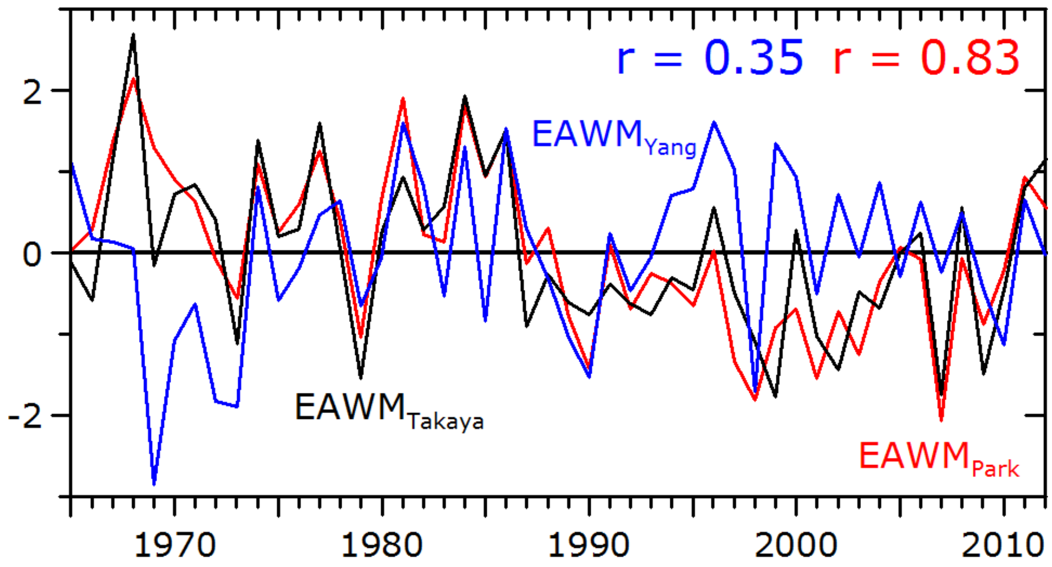
- The EAWM and NPO variability affect the western North Pacific SST differently in each regime:
  - similar and strong projection during the SM-HC
  - dissimilar and weakened pattern during WM-LC

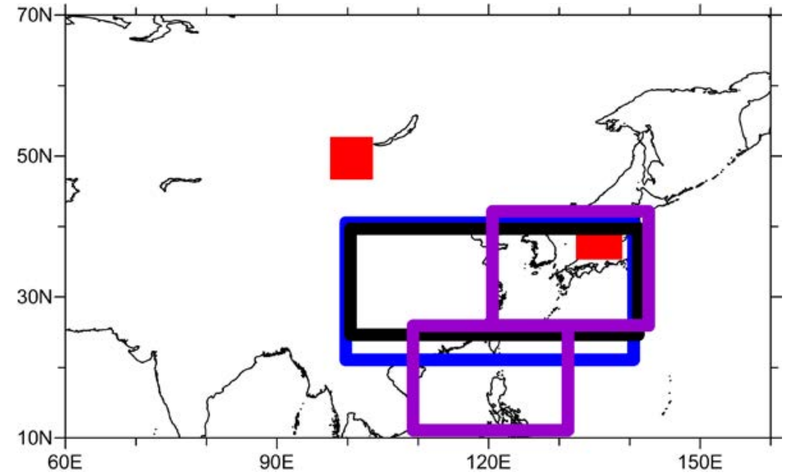
- Change of tropical influence may be related to this nonstationary relationship

- Coupled climate model study should be conducted to investigate underlying mechanisms of the nonstationary relationship in the next step

Thank you!!

EAWM index sensitivity (validation)





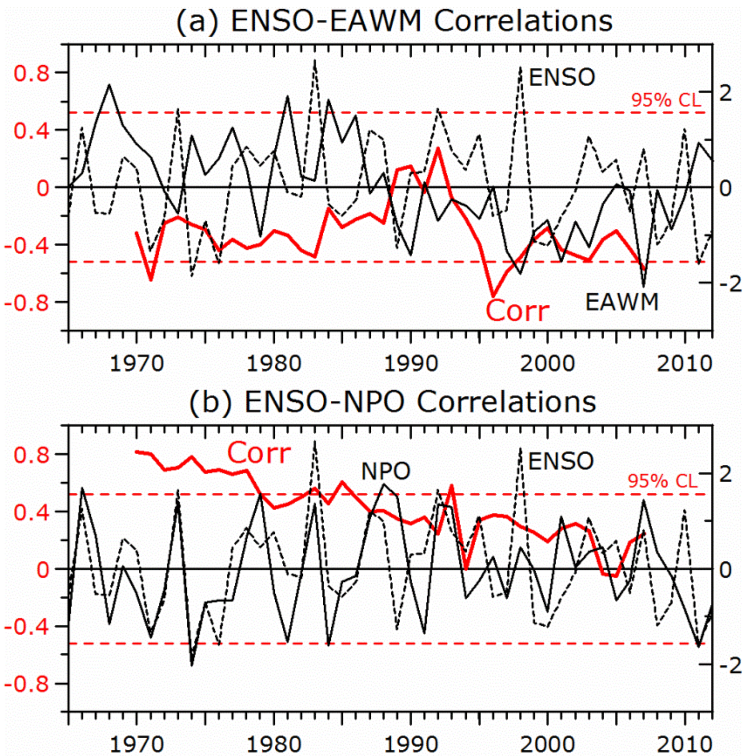
Diverse definition of EAWM index

- EAWM$_{Takaya}$: area-mean surface air temperature
- EAWM$_{Park}$: difference of area-mean SLP (r=0.83)
- EAWM$_{Yang}$: area-mean 850hPa meridional wind speed (r=0.35)
- EAWM$_{Chen}$: area-mean near-surface meridional wind speed (r=0.70)

Relationship between ENSO and EAWM/NPO

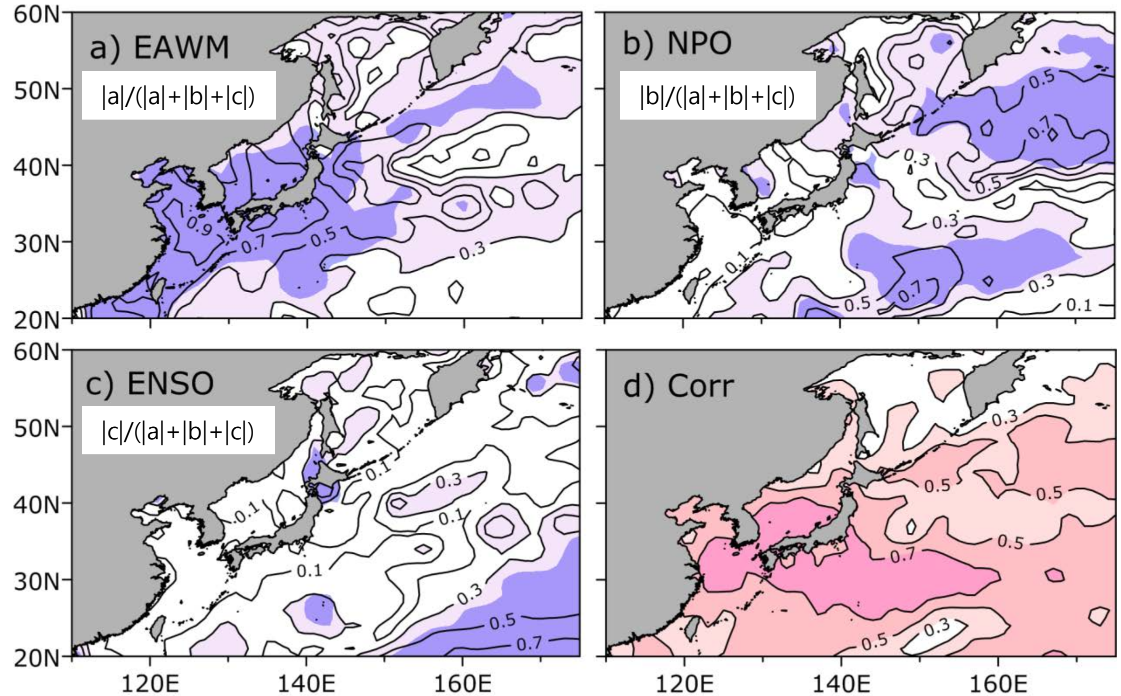
Total period (1965-2012) correlation

- EAWM-ENSO: -0.32
- NPO-ENSO: -0.54



▲ 11-year moving correlation coefficient (red)
(a) between the EAWM and ENSO indices, and
(b) between the NPO and ENSO indices

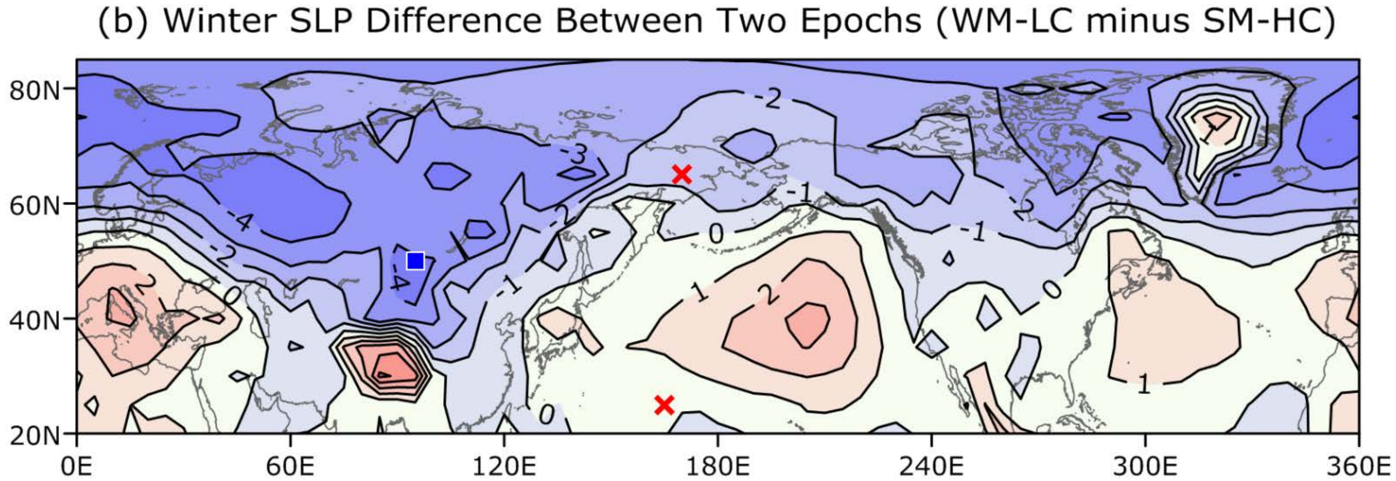
SST = aEAWM + bNPO + cENSO + residual

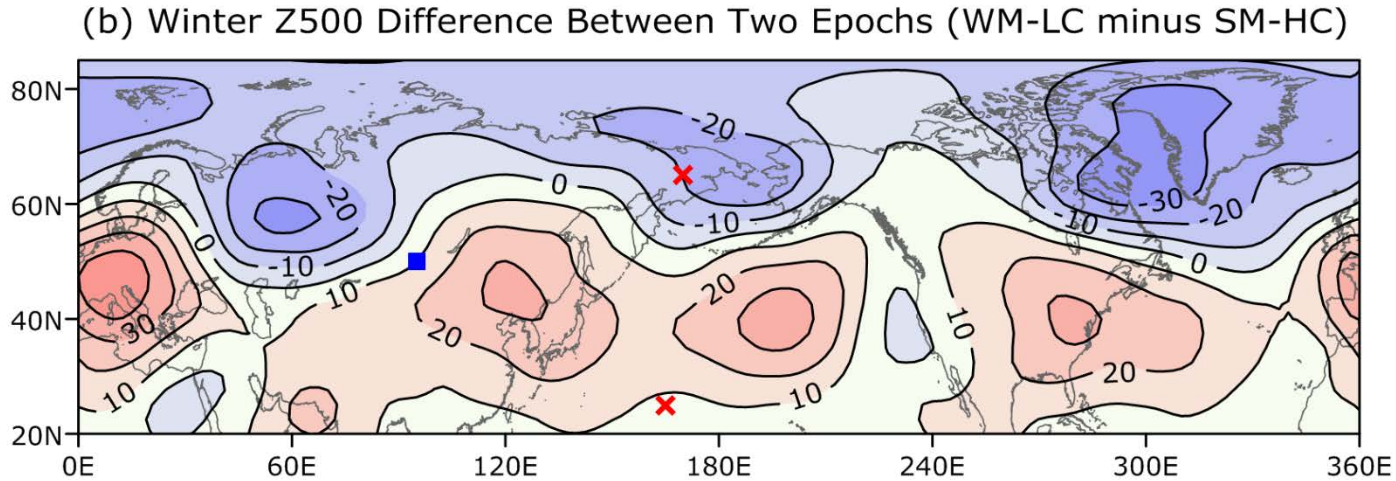


▲ Relative contribution of regression coefficients of (a) EAWM, (b) NPO, (c) ENSO, and correlation between SST and its regressed one

Change of Atmospheric Circulation

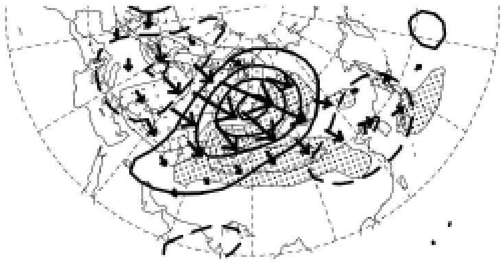
- Positive AO-like pattern
- Hemispheric planetary wave-like pattern (wave number 3~4)

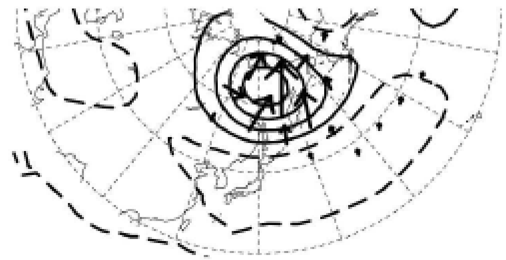




Connection between upper-level blockings and surface circulation modes

Ural blocking | Kamchatka blocking





(Takaya and Nakamura 2005)

▲ Composite Z250 anomaly and wave group velocity at blocking events near Ural mountains and Kamchatka region.

Blocking index: normalized projection of monthly Z500 anomaly onto composite blocking pattern (Wang et al. 2010)

$$BI = \frac{<\Delta Z_b, \Delta Z_m>}{<\Delta Z_b, \Delta Z_b>}$$

ΔZ_b : winter composite of daily Z500 anomaly corresponding to the days of blocking events (Barriopedro et al. 2006) over a selected blocking sector. (fixed for all period)

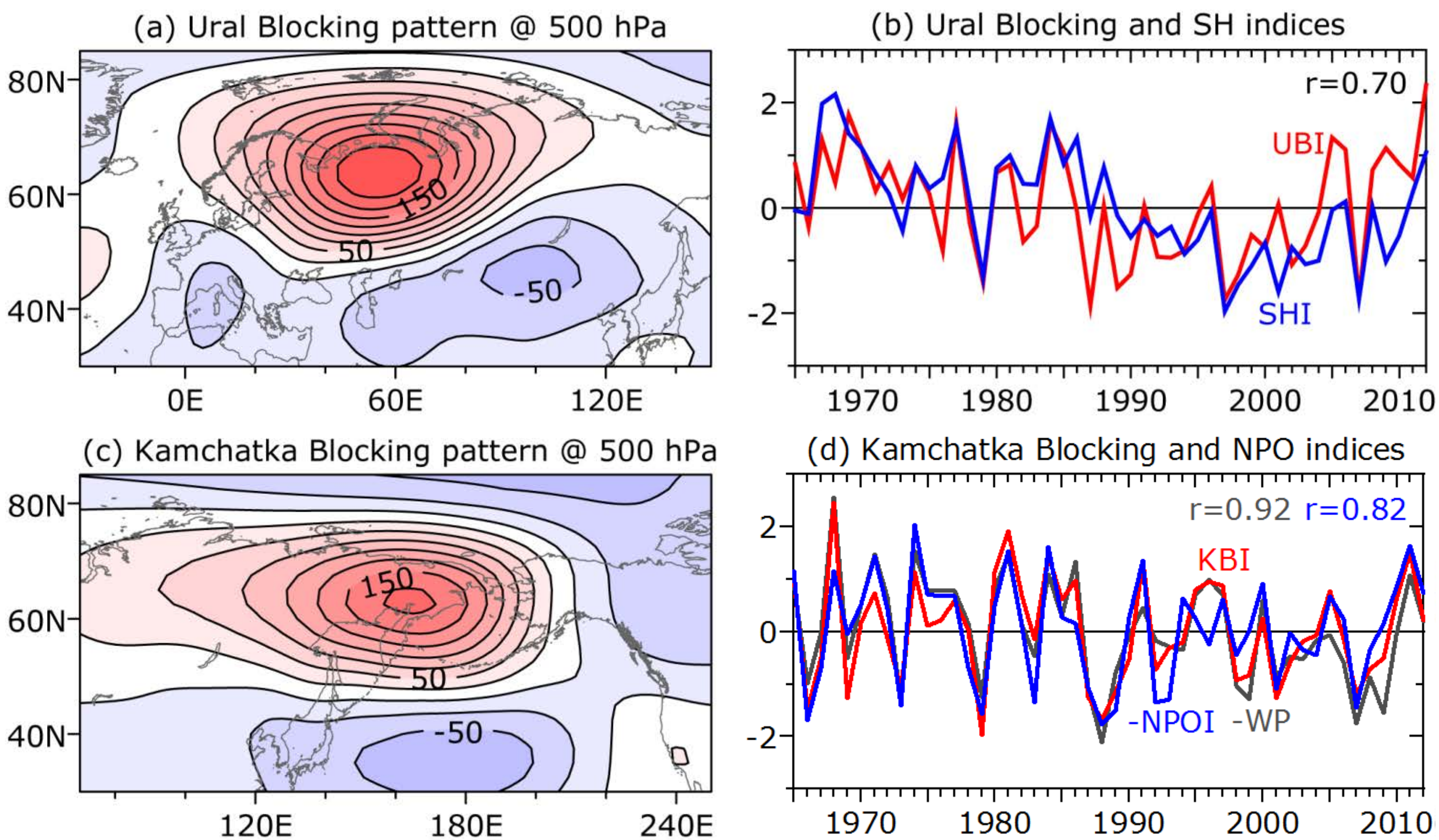
ΔZ_m : monthly Z500 anomaly.

$< , >$: inner product.

Climate indices and blocking indices

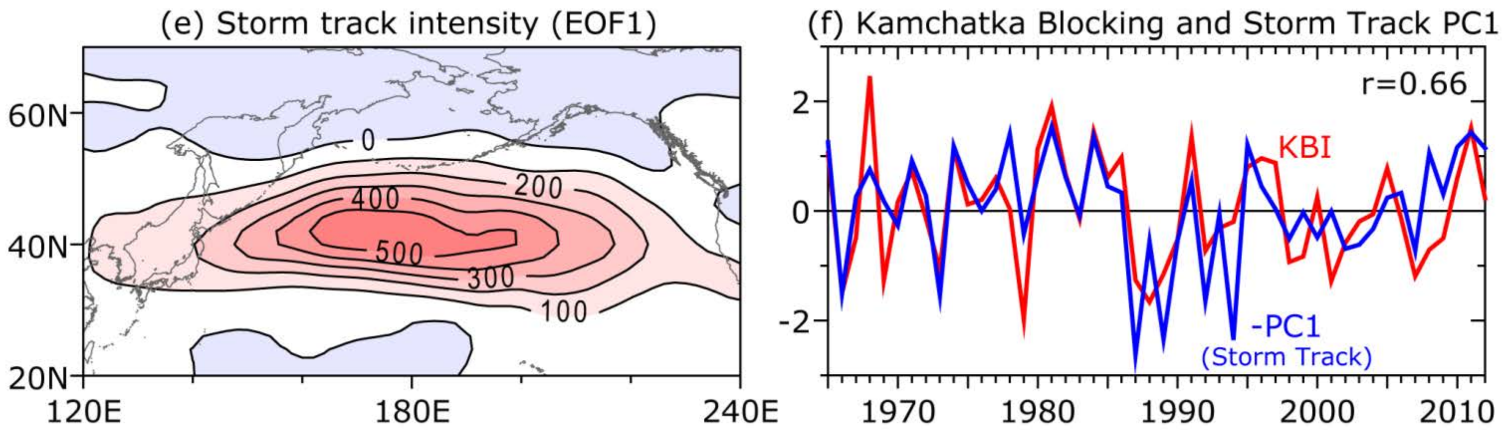
A close relationship

- between **Ural** blocking and **SH/EAWM**
- between **Kamchatka** blocking and **NPO/WP**

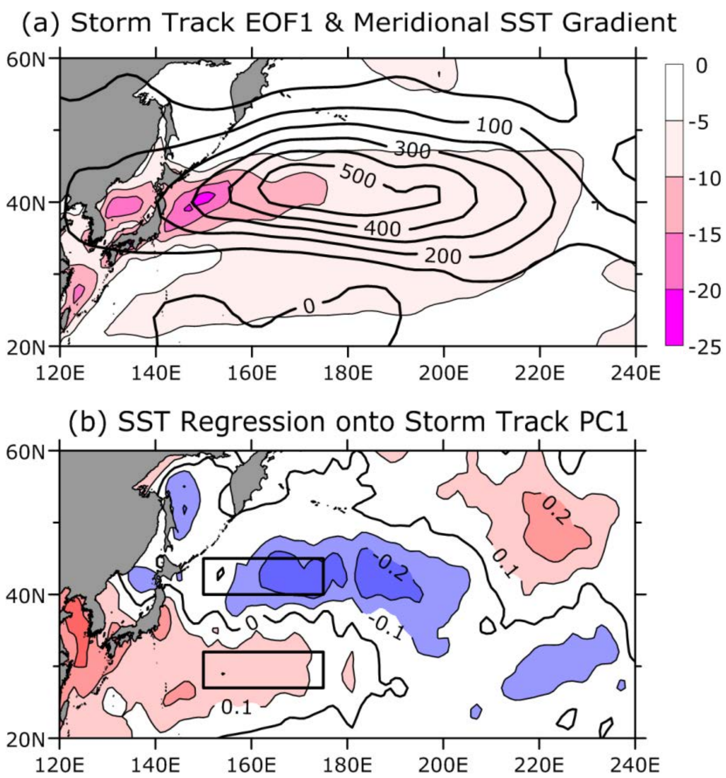


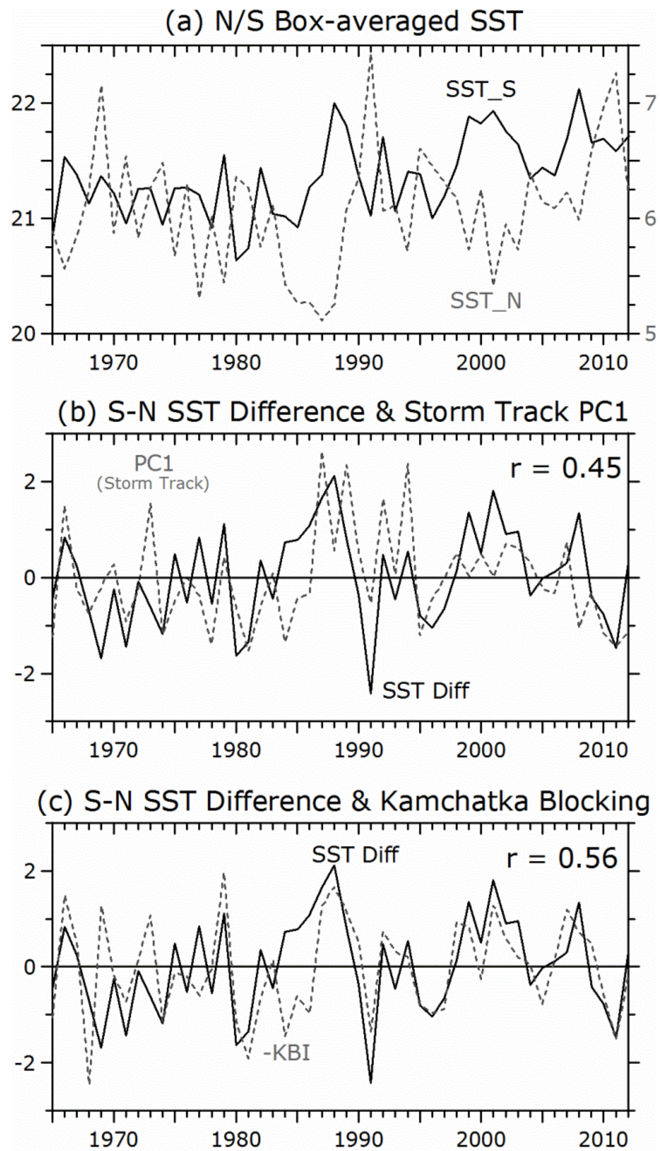
Storm track activity and Kamchatka blocking

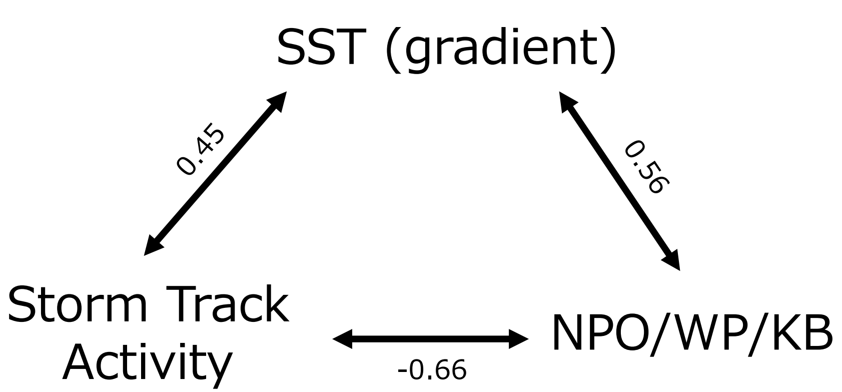
- Storm track: Synoptic (2-6 day) Z300 variance
- Strong relationship between Kamchatka blocking and storm track activity



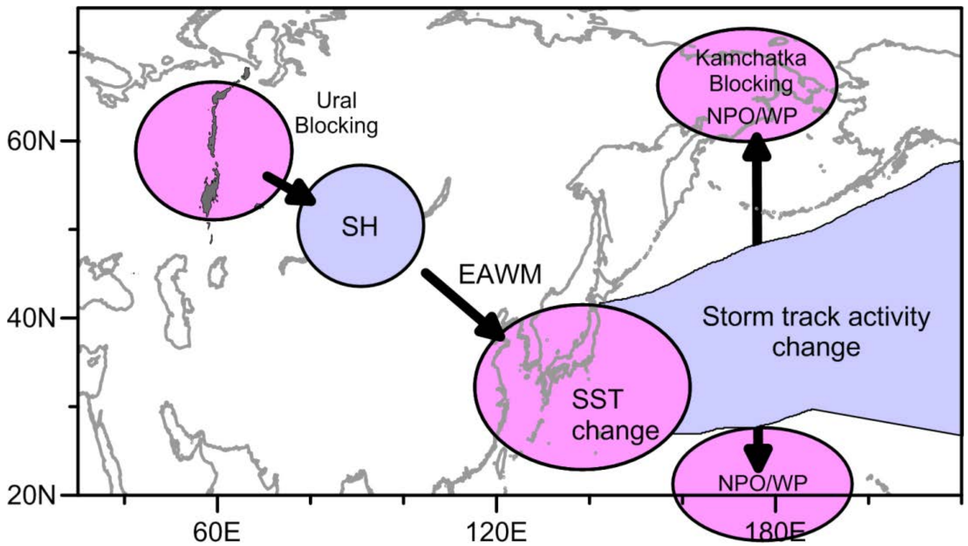
Storm Track, SST (gradient), and NPO/WP/KB







Chain of processes (Previous version)



- A chain of ocean-atmosphere interaction processes in long-term statistics

UB → SH/EAWM → SST ano → Storm track → KB/WP/NPO

- **worked well during SMR**
- **broke down during WMR**, because of no significant relationship in EAWM-SST and SST-storm track couplets