Interdecadal Change in the Relationship between ENSO and the Intraseasonal Oscillation in East Asia

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Introduction

- Importance of the ISO/ISV on the IAV

Total variance = Variances of annual mean + (Mean of annual standard deviations)$^2$ + Variances of annual standard deviations

\[
\frac{1}{IJ} \sum_i \sum_j (P_{ij} - \bar{P})^2 = \frac{1}{J} \sum_j (\hat{P}_j - \bar{P})^2 + S^2 + \frac{1}{J} \sum_j (S_j - S^2)
\]

- $P_{ij}$: monthly precipitation for the $i$th month of the $j$th year
- $\hat{P}_j$: annual mean of the monthly precipitation for the $j$th year
- $\bar{P}$: total mean
- $S_j$: standard deviation of monthly precipitation for the $j$th year
- $\overline{S}$: the mean of annual standard deviations

- The variances of annual standard deviations of monthly amounts of precipitation at Seoul

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<tbody>
<tr>
<td>Variance of annual means</td>
<td>3384.9</td>
<td>1528.8</td>
<td>1576.2</td>
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<tr>
<td>Variance of annual standard deviations</td>
<td>6516.2</td>
<td>4230.2</td>
<td>3328.3</td>
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Introduction

- Importance of the ISO/ISV in the EASM
  The boreal summer ISO is known to determine the timing of the active and break period of the East Asian Summer Monsoon (EASM) through the meridional movement of the monsoon trough (e.g., Chen and Chen, 1995).

- Interannual and interdecadal variability of the ISO/ISV

  1st and 2nd EOF mode of the summer ISV (MJJASO) and its associated PC timeseries.
Interannual and interdecadal (1979-2011) variability of the ISO/ISV

- 1st and 2nd EOF mode of the summer ISV (MJJASO) and its associated PC time series

- NOAA OLR (1979-2011)
- PC1: ISV has magnified over the south China Sea region after the late 1990s
- 1st EOF mode: decadal variation
Definition of Northward Propagating ISO

Northward Propagating ISO
- The leading two EOF patterns of the 30-60 day intraseasonally filtered OLR anomalies

Definition of NPISO activity
- The variance of the leading two (1st and 2nd) EOF time series
- The two PCs show significant correlations with a 10 day lag
- According to the rule of thumb of North et al. (1982), the first two modes are distinguished from the higher modes

**NPISO in time-space structure**

- **Principal structure of the NPISO**

1. **1st EOF mode**: Well-organized northward propagating structure with ~40 day period

What drives and steers the NPISO?
Possible mechanism: WNPSH

- Regression of JJA Z850hPa against JA NPISO
- Regression of JJA Z500hPa against JA NPISO

- low-level circulation regressed with NPISO index
- westward enhancement of high off the center
- surface divergence
- strong moisture-laden flow on the northern flank of the high

- shading: Significant value at the 95% confidence level
- contour: Z850 and Z500 regressed on NPISO activity
- thick blue line: climatology
The suppressed convection over the Philippine Sea and enhanced convection to its north
The coupling in the convection and circulation, implying the Rossby wave response to the reduced heating
Regression of SST anomalies onto July/August NPISO activity

- During the preceding winter (DJF(-1)), the evident warm anomalies in the eastern Pacific.
- In the Indian Ocean, weak warm (cold) anomalies (western Pacific) appear.
- During the MAM, the warm anomalies appear over South China Sea and Indian Ocean, through a tropical atmospheric bridge process such as the Walker and Hadley circulations [Klein *et al.*, 1999]
- IO has lingering and capacitor effects of ENSO on east Asian monsoon climate.
How does the ENSO affect NPISO? Lagged
NPISO index: MAM SSTA → JJA OLRA → JJA Z850A

- JJA OLRA regressed with MAM SSTA
  - The preceding (-DJF) El Nino, the springtime Indian Ocean warming leads to the suppressed convection over the Philippine Sea, which is attributed to a weakened Walker circulation (Lee et al., 2006).

- Z850A regressed with JJA OLRA
  - The suppressed convection over the Philippine Sea induces a strong wave train extending northeastward in Asia (enhanced WNPSH and cyclonic anomalies), resembling the PJ pattern (Nitta, 1987).
Impact of IO and WP SST on the NPISO dynamics

- EXP minus CTL difference of the 850hPa geopotential height and OLR during strong NPISO days, using the POEM with EP warming

- The IO and WP SST significantly represent the suppressed convection over WNP and the enhanced WNPSH.

- In the EXP_noWP run, the anticyclone anomaly shifted southward, which may be due to an earlier decay of the local SST forcing (Wu et al., 2010).

- IO with WP has lingering and capacitor effects of ENSO on east Asian monsoon climate.
Since the late 1970s, the dynamical relationship between the NPISO and ENSO becomes later and stronger in comparison to that in before the late 1970s.

In the years 1958-1979, ENSO affect the early summer NPISO, while in the years 1980-2001, the boreal summer NPISO activity in July-August is affected by the preceding winter ENSO.

Since the late 1970s, the dynamical relationship between the NPISO and ENSO becomes later and stronger in comparison to that in before the late 1970s.

Yun, K.-S., K.-H. Seo, and K.-J. Ha, 2010: Interdecadal change in the relationship between ENSO and the intraseasonal oscillation in East Asia, *Journal of Climate*, 23(13), 3599-3612.
During 1958-1979 years, the early summer (i.e., May-June) NPISO is related to a north-south dipole of anomalies over the North Pacific, resembling the west Pacific (WP) pattern.

During 1980-2001 years, the July-August NPISO is related to the western North Pacific subtropical high (WNPSH), forming the Pacific-Japan (PJ) pattern.
Distinct mechanism in NPISO-ENSO relationship

- Regression of IOSST-related convection and geopotential height

**First period (1958-1979)**
- Regression of MAM OLR onto MAM IOSST

**Second period (1980-2001)**
- Regression of JJA OLR onto MAM IOSST

- 1980-2001: IOSST warming → WNP suppressed convection → Pacific-Japan (PJ) pattern
- 1958-1979: IOSST warming → central Pacific suppressed convection → west Pacific (WP) pattern
Before the late 1970s, ENSO is closely linked to the WP pattern in winter through spring, in turn, the WP pattern affects the early summer NPISO activity.

After the late 1970s, ENSO is well-linked to the PJ pattern in summer. In the increasing connection between ENSO and the PJ pattern, the summertime NPISO activity is significantly correlated to the PJ index.

- PJ index: the difference in the OLR anomaly between $[16^\circ -20^\circ N, 142^\circ -150^\circ E]$ and $[32^\circ -38^\circ N, 134^\circ -142^\circ E]$ [Nitta, 1987 (JMSJ)]
In the second period, the IOSST warming and suppressed convection pattern is quite similar to the springtime pattern in the first period.
Enhanced characteristics in Southern Oscillation


The strong SO characteristics may interrupt to generate an evident WP pattern, and consequently, the early NPISO activity is no longer related to ENSO via the WP pattern.

The increasing relationship between NPISO and PJ pattern is contributed by the persistent ENSO-induced convection and circulation anomalies over the WNP and Indian Ocean.

- The strong SO characteristics may interrupt to generate an evident WP pattern, and consequently, the early NPISO activity is no longer related to ENSO via the WP pattern.
- The increasing relationship between NPISO and PJ pattern is contributed by the persistent ENSO-induced convection and circulation anomalies over the WNP and Indian Ocean.
Change in the IO-EASM relationship (IOD vs IOBW)

- Relationship of SST (upper) and Z500 (lower) anomaly with EASMI

Interannual and interdecadal (1979-2011) variability of the ISO/ISV

- 1st and 2nd EOF mode of the summer ISV (MJJASO) and its associated PC time series

- NOAA OLR (1979-2011)
- PC1: ISV has magnified over the south China Sea region after the late 1990s
- 1st EOF mode: decadal variation
Interdecadal change (79-98/99-11) in NPISO-ENSO relationship

- Sliding correlation coefficient between the NPISO activity and monthly NINO3 index

**First period (79-98)**
- Negative lag indicates that ENSO precedes the NPISO activity.
- In the years 1979-1998, strong positive correlation appears during the months of June to September with the preceding winter Nino-3 index.
- In the years 1979-1998, the boreal summer NPISO activity in July-August is affected by the preceding winter ENSO.

**Second period (99-11)**
- In the years 1999-2011, the relationship between NPISO activity and ENSO is almost absent.
**Summary and Discussion**

- **The possible mechanism on the NPISO activity over East Asia**
  - Western North Pacific subtropical high (WNPSH)
  - Coupling process in the convection-circulation
  - IO warming, WP cooling, and EP warming

- **Interdecadal change in NPISO-ENSO relationship**
  - In the 1958-1979 years, a preceding winter ENSO influences the early summer NPISO activity. The May-June NPISO is modulated by the springtime IOSST warming and central North Pacific suppressed convection anomalies, and consequently, related to the ENSO-induced WP pattern in winter through spring.

  - Since the late 1970s, a stronger Walker-Hadley circulation is produced due to a warmer mean SST anomaly. It leads more persistent ENSO-induced IOSST warming and suppressed PSCA, WNPSH after El Nino itself has dissipated, which in turn enhances NPISO until mid-late summer.
Summary and Discussion

  - NPISO/ENSO relationship exhaustive
  - What controls the relationship between NPISO and ENSO
  - IO capacitor

The relationship between NPISO and ENSO (feedback NPISO → ENSO)
  - Can the NPISO over East Asia affect ENSO?

- This sub-seasonal distinction in the NPISO-ENSO relationship and its interdecadal change contribute to understanding the climate change in the EASM.
Change in low-level circulation

- Regression of the 850hPa wind and geopotential height onto the IAV of NPISO

Low-level circulation

- Easterly wind anomalies in central Pacific is deepen and propagated eastward after the concurrent summer
- Anticyclonic circulation in WNP region during JJA(0)
- The apparent east-west circulation pattern in DJF(0), as well matched large SO index

Shading : 95% significant level

Can the preceding NPISO affect ENSO?

- Yun et al. 2009, Tellus A, The 30-60day oscillation in the EASM and its time-dependent association with the ENSO.

- eastward propagation with the upwelling of oceanic Kelvin wave
- NPISO in the EASM may be link to the evolution of the QBO-type ENSO.
Thank you
For your attention


Shift of the active period in the summer monsoon rainfall


**Difference in annual cycle**

• The response to the mid-latITUDE FORCING is stronger in August than in July.

• The response to the TROPICAL FORCING is stronger in July than in August.
Jet-triggered dynamical effect

- Difference of response between August and July basic state, using linear baroclinic model

A stronger response of Rossby wave propagation in August than in July, due to the Jet-triggered dynamical effect

※ Yun K-S, SY Kim, Ha, K.-J. and M. Watanabe, 2011 : JGR.
An possible cause on the shifting active period: Change in the northward propagating ISO/ISV

- Interdecadal change in the northward propagating ISV (Jiang et al., 2008; Kajiwara et al., 2009)

- Climatological 5-day running mean rainfall index (solid lines) averaged over 110–120 E. Heavy dashed line denotes 850hPa equivalent potential temperature =337.5K, and the heavy solid line denotes 500hPa U-wind = 0. (Jiang et al., 2008, Meteorol. Atmos. Phys.)
Relationship with Jet stream

Reg of Z500hPa JJA(0) onto Jul/Aug NPISO Activity

Shading: U200 anomalies regressed onto NPISO activity, contour: Z500 anomalies
The temporal evolution of the NPISO

- Using the first Extended EOF mode with a window of 50 days for MJJASO

- Northwestward propagating convection anomalies with a period of ~40 days.

- Basically consistent with the EOF analysis.
Importance on the WNP suppressed convection

- Numerical experiment using Linear baroclinic model (Watanabe and Kimoto, 2000)

The reduced heating induces a strong WNPSH and clear wave train structure along the East Asia coast.

Xie et al. (2009, J. Climate)
Lag correlation between NPISO, OLRA, and IOSST

- Lagged correlation coefficient between the NPISO, OLRA, and IOSST

- The association with the OLRA anomalies [120-150E, 5-20N]

- The association with the IOSST anomalies [50-100E, 20S-20N]

- Except for the effect of OLRA[120-150E, 5-20N]

- Except for the effect of Z850[120-180E, 15-25N]
Relationship between WP and WNPSH

- Association of Bonin high at retreat and Spring WP
- Sharp decrease of linkage of April WP-Bonin high at onset
- When El Niño years are excepted: Decrease of correlation between WP-Bonin high at retreat from late-1970s ⇐ ENSO effect

Regression of the August Z850 anomaly against the JA IOSST

- SST warming over the Indo-Pacific region in La Nina years during PII period is very well associated with the development of subtropical western Pacific high in August.

Definition of Northward Propagating ISO

Northward Propagating ISO (NPISO)

- The coherent northward propagating structure of EOF patterns of the 30-60 day intraseasonally filtered OLR anomalies
- A quadrature phase difference between the first two EOFs

NPISO activity index

$$NPISO = \sqrt{(PC1)^2 + (PC2)^2}$$

Effect of ENSO and IOSST warming

- Regression of the summer low-level height onto MAM IOSST[50-100E, 20S-20N]

(a) Reg of JJA Z850hPa onto MAM IOSST (reg NDJ(-1) NINO3)

(b) Reg of JJA Z850hPa onto MAM IOSST (excl NDJ(-1) NINO3)

How ENSO and the following WNPH are connected?

Linearly associated with DJF(-1) ENSO
- a clear wave train with a similar structure to that appeared in previous result

Not related with DJF(-1) ENSO
- insignificant anomaly pattern.
Interdecadal change (79-98/99-11) in NPISO-ENSO relationship

- **Regression of AMJ to ASO SST against MJ to SO NPISO**

**First period (79-98)**

1. Regression of AMJ to ASO SST against MJ to SO NPISO.

2. In the years 1979-1998, the May-June and July-August NPISO is related to the Indian Ocean warming anomalies.

**Second period (99-11)**

1. In the years 1999-2011, no significant SST anomalies exist.

Shading: Significant value at the 90% (light), 95% (heavy) confidence level of Z850hPa.
Interdecadal change (79-98/99-11) in NPISO-ENSO relationship

- Regression of AMJ to ASO Z850hPa and 850hPa wind against MJ to SO NPISO

**First period (79-98)**
- In the years 1979-1998, the WNPSH anomaly is formed over the WNP region in the boreal summer.

**Second period (99-11)**
- In the years 1999-2011, no significant anticyclonic anomalies exist WNP region.
- In the years 1999-2011, the relationship between September-October NPISO activity and ASO cyclonic anomalies over the north Pacific is strong.

shading: Significant value at the 90%(light), 95%(heavy) confidence level of Z850hPa
vector: 850hPa wind anomalies against significant at the 95% confidence level