An aerial photograph of a tropical island with lush green vegetation and a clear turquoise lagoon. The sky is bright blue with scattered white clouds. The text is overlaid on the top half of the image.

**Changes in East Asian Winter
Monsoon**
due to the **Effect** of
the **ENSO** and **PDO** Interaction

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1. INTRODUCTION

The **East Asian Winter Monsoon (EAWM)**, accompanied by a strong Siberian high and active cold surges, is not only the great influencing factor on the local weather and climate in the East Asian region but also one of the most active components in the global climate system during boreal winter season. (*Chang et al. 1979*)

Basic features of **EAWM** are characterized by the **Strong Northwesterly Winds** and Cold temperatures over the northern China region induced by Siberian high, East Asian Jet, and East Asian Trough. (*Ding and Krishnamurti 1987*)

The Key driving force for **EAWM** is the available potential energy generated by the differential heating between land and ocean and the **Main Heating Source** exists near the equatorial western Pacific by using Southern Oscillation Index. (*Zhang et al. 1997*)

A **Dynamical link** between **EAWM** and **Variability in the Pacific Ocean** has been investigated *in many studies*.

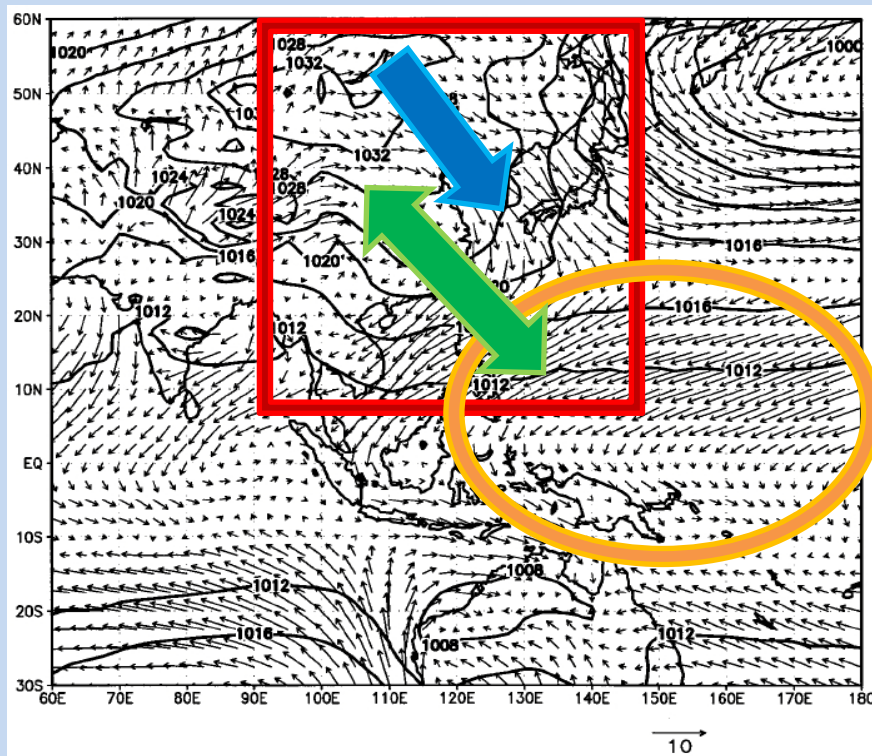


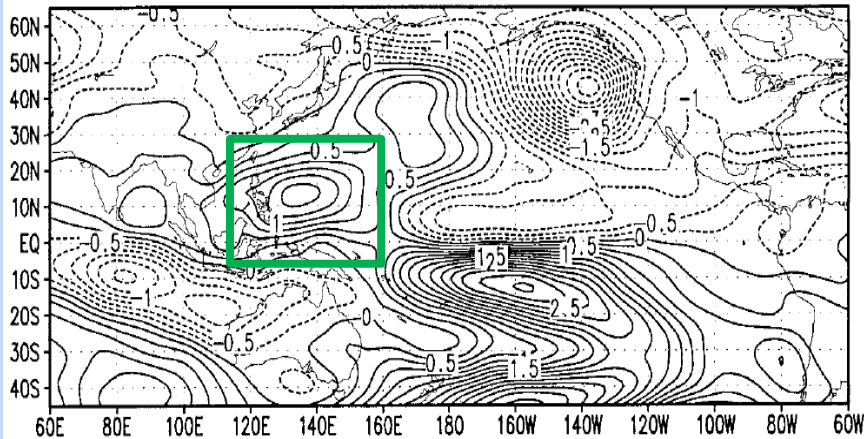
FIG. 2. The averaged East Asian mean sea level pressure (hPa) superimposed on the surface (10 m) wind (m s^{-1}) for winter (DJF) of 1979/80–1994/95.

From Zhang et al. (1997)

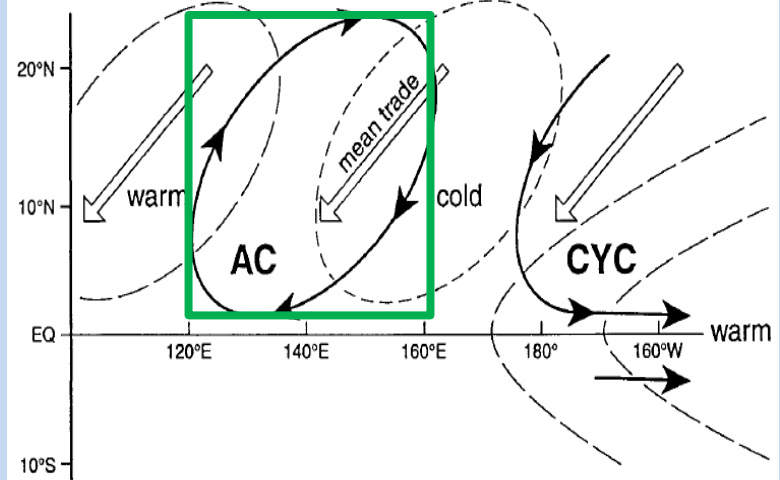
From Wang et al. (2000)

PEAT (Pacific-East Asian Teleconnection)

(a) 1000hPa streamfunction anomalies

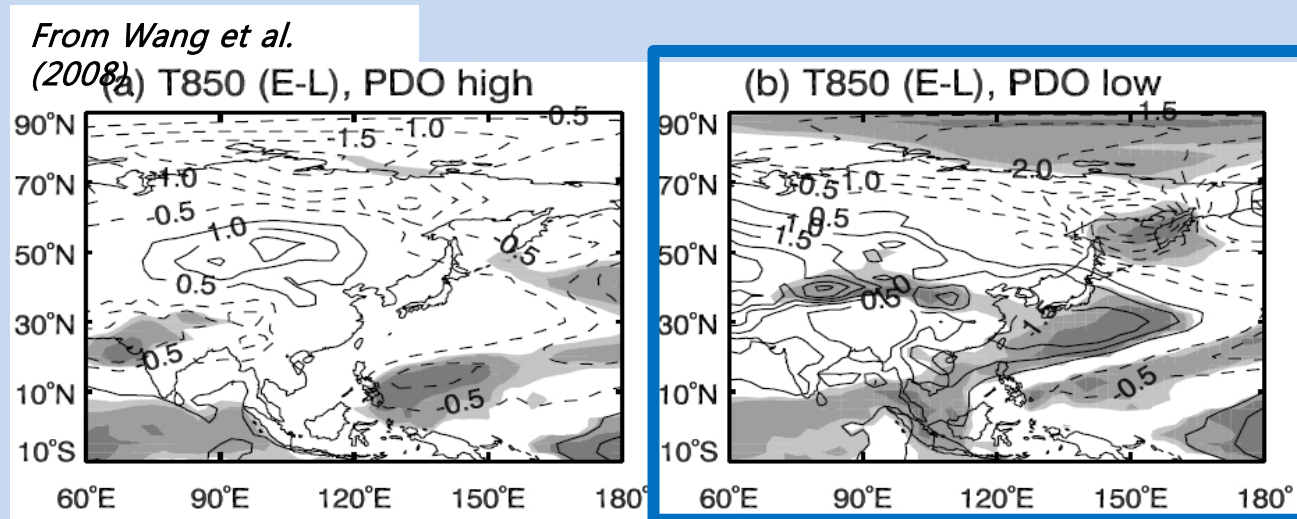


Air-Sea Interaction during El Niño periods



Wang et al. (2000) identified that the **Key system** which bridges the **El Niño** and **EAWM** is an **anomalous lower-tropospheric Anti-Cyclone** located in the **western North Pacific** (simply *WNPSH*), causing anomalously warm and wet conditions on the East Asian climate via *Pacific-East Asian Teleconnection pattern (PEAT)*.

Wang et al. (2008) investigated an interdecadal modulation impact of **PDO** on the **ENSO - EAWM relationship**. They argued that the **ENSO** exerts a strong impact on the **EAWM** only during the **Low phase of PDO** (*When High PDO phase, there is No Robust signal*).



The approach has a **Weak Point** because they **Focused on the Changes in PDO fixing ENSO variability** despite the existence of mutual dependence of **ENSO** and **PDO**. (Mantua et al. 1997)

The Aims of this study is to Reinvestigate the interdecadal modulation of PDO on the ENSO-EAWM Relationship and uncover their Interactive Dynamics using various observation data sets.

2. DATA & METHODOLOGY

Table 1. Datasets Used in This Study.

| | Resolution | Range of Years | Source |
|-------------------|-------------|----------------|---|
| Surface Air Temp. | 0.5° x 0.5° | 1900-2008 | http://jisao.washington.edu/data_sets/ud |
| ERA40 | 2.5° x 2.5° | 1957-2002 | Uppala et al. (2005) |
| ENSO index | | 1868-2010 | http://coaps.fsu.edu/jma.shtml |
| PDO index | | 1900-2010 | http://jisao.washington.edu/data_sets/pdo/ |

Table 2. Classification of years based on phases of ENSO and PDO for the period of 1900-2008.

| | High PDO (59) | Low PDO (50) |
|------------------------|---|--|
| El Nino (24) | 1902, 1904, 1905, 1925, 1929, 1930, 1940, 1982, 1986, 1987, 1991, 1997, 2002, 2006 | 1911, 1913, 1918, 1951, 1957, 1963, 1965, 1969, 1972, 1976 |
| Neutral (58) | 1900, 1901, 1907, 1921, 1923, 1926-1928, 1931-1937, 1939, 1941, 1943, 1978-1981, 1983, 1985, 1989, 1990, 1992, 1996, 2000, 2001, 2004, 2005 | 1912, 1914, 1915, 1917, 1919, 1920, 1945-1948, 1950, 1952, 1953, 1958-1962, 1966, 1968, 1977, 1993-1995, 2003, 2008 |
| La Nina (27) | 1903, 1906, 1908-1910, 1922, 1924, 1938, 1942, 1984, 1988, 1998, 1999 | 1916, 1944, 1949, 1954-1956, 1964, 1967, 1970, 1971, 1973-1975, 2007 |

3. RESULTS

Regression Maps

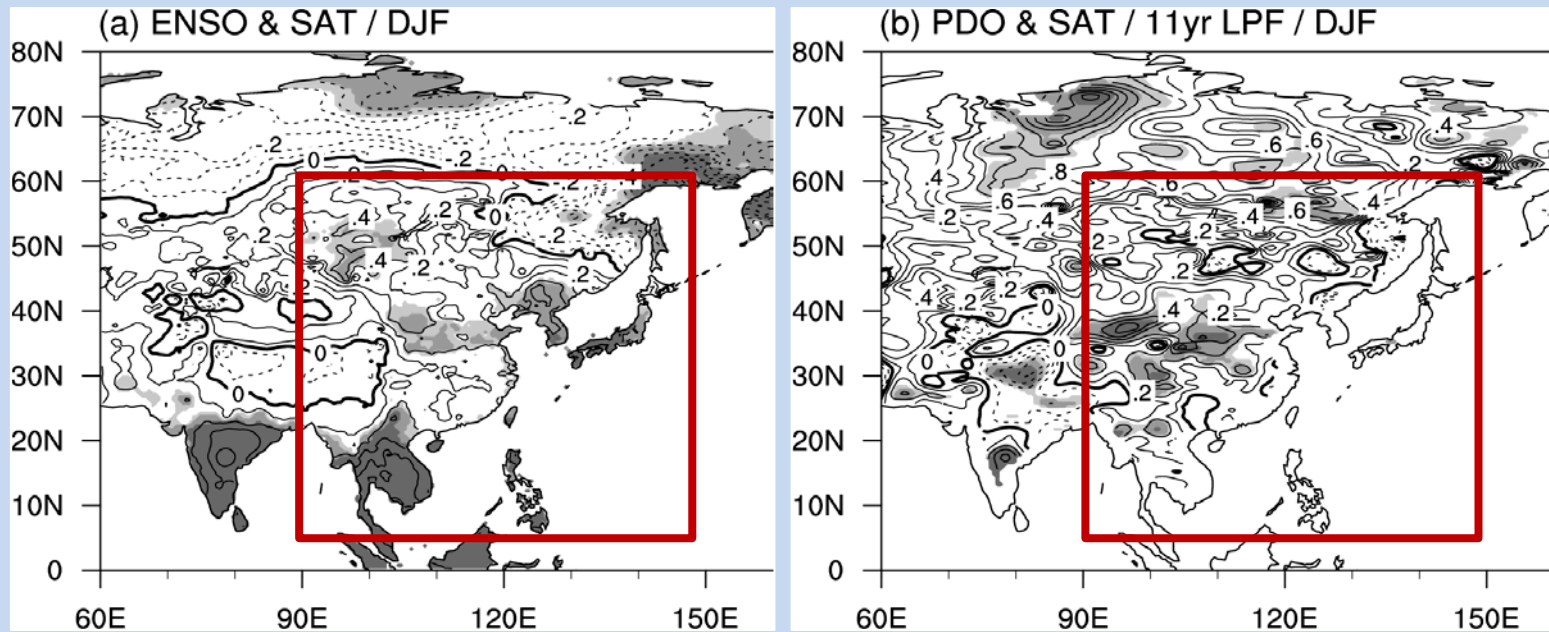


Fig1. Regression maps for the winter (DJF) SAT onto (a) ENSO and (b) 11-year low pass filtered PDO indices during the period of 1900-2008. Shadings are statistically significant values. Solid and dashed lines are positive and negative values.

Both spatial patterns are generally showing **positive Regression coefficients** over East Asian continent. It is implying that the **East Asian winter climate** will be **even Warmer** or **even Colder** if the **ENSO** and **PDO** have the **Same phases**.

Composite Maps

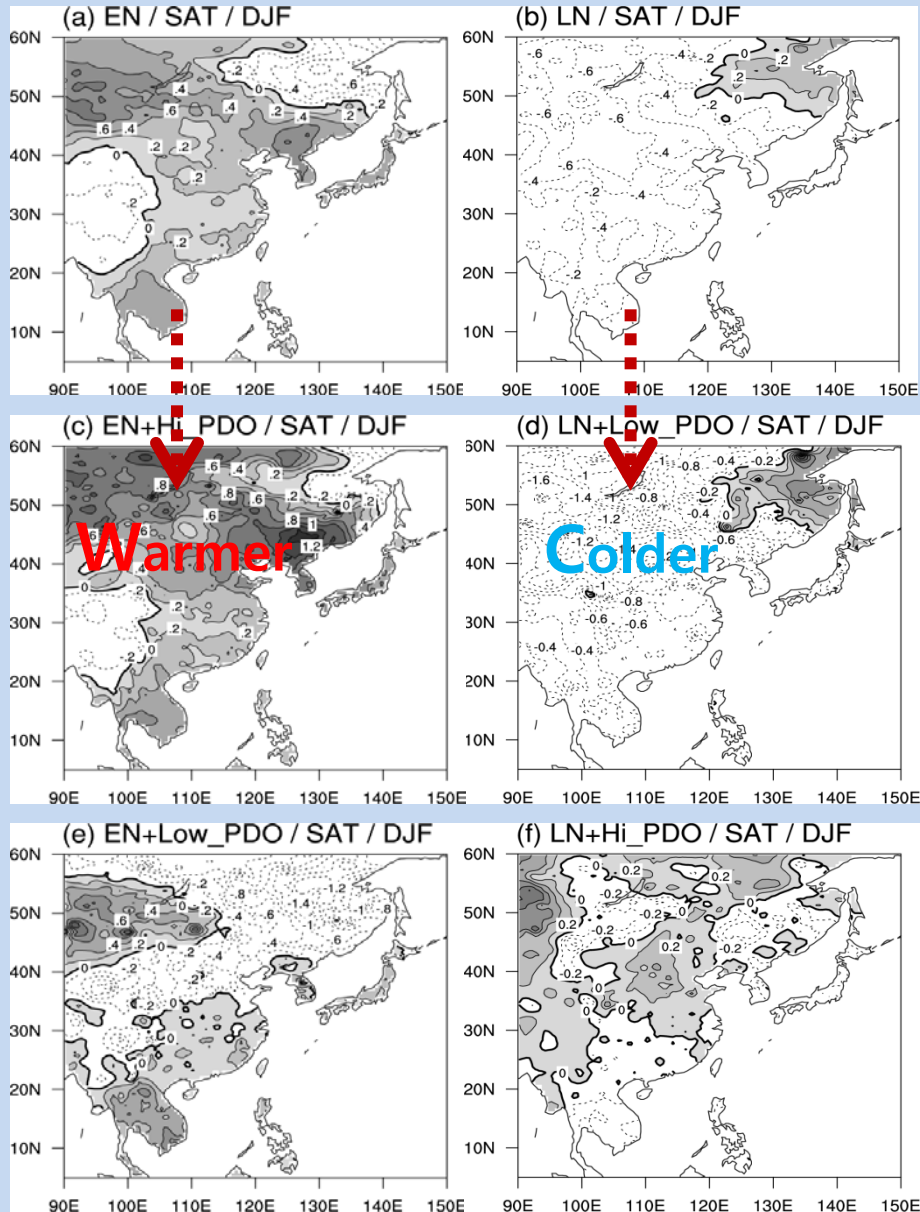


Fig2. SAT Anomaly Composites based on (a) EN and (b) LN; (c) EN+Hi_PDO and (d) LN+Low_PDO; (e) EN+Low_PDO and (f) LN+Hi_PDO. Shadings are positive values and dash lines are negative values.

When the ENSO and PDO are in **In-Phase** combinations (c. **EN+Hi_PDO** or d. **LN+Low_PDO**), they are clearly showing the **Intensified SAT Anomaly signals** over East Asian continent.

When the ENSO and PDO are in **Out-of-Phase** combinations (e. **EN+Low_PDO** or f. **LN+Hi_PDO**), the SAT anomaly signals show some incoherent patterns.

Difference Maps

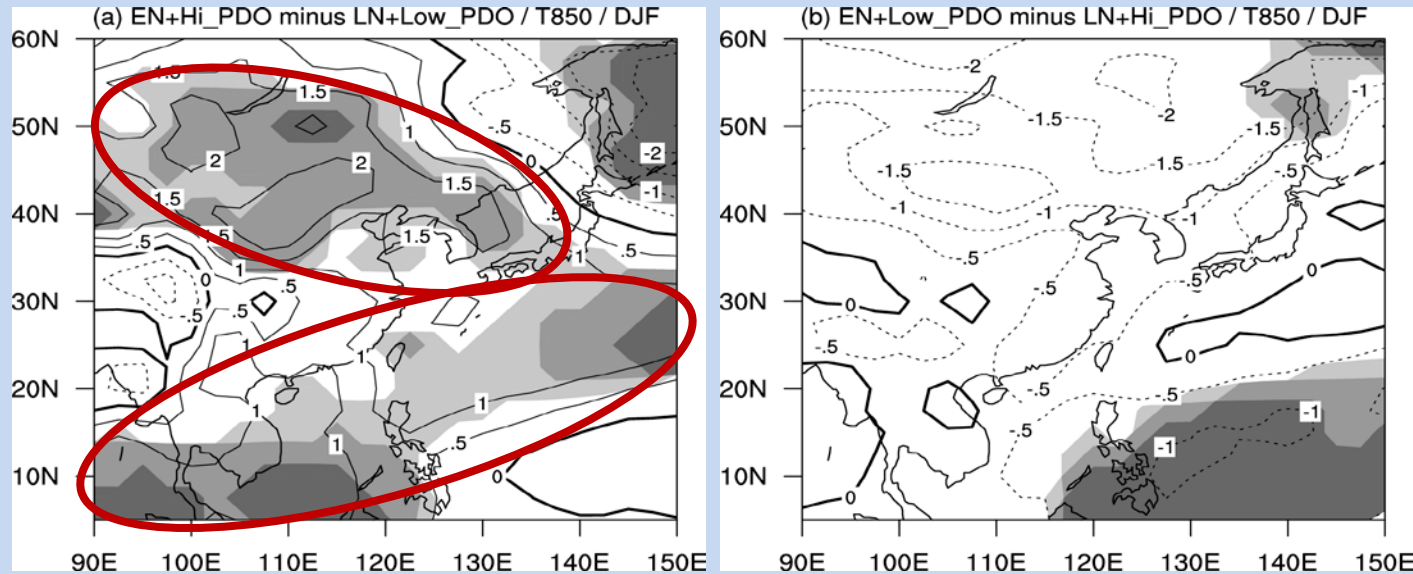


Fig3. 850-hPa Winter (DJF) Air temp. Composite Difference between (a) EN+Hi_PDO and LN+Low_PDO (In-Phase diff.); (b) EN+Low_PDO and LN+Hi_PDO (Out-of-Phase diff.) Shadings are significant values at the 90(light), 95(medium), 99(dark)% confidence levels.

In-Phase difference exhibits **Significant Positive anomalies** over the East Asia, but those of **Out-of-Phase difference** do not show any significances over East Asian continent.

When **ENSO** and **PDO** are in **In-Phase** combinations, the **EAWM** tends to be **Stronger or Weaker**, but the **EAWM** will be **Featureless** when they are in **Out-of-Phase** combinations.

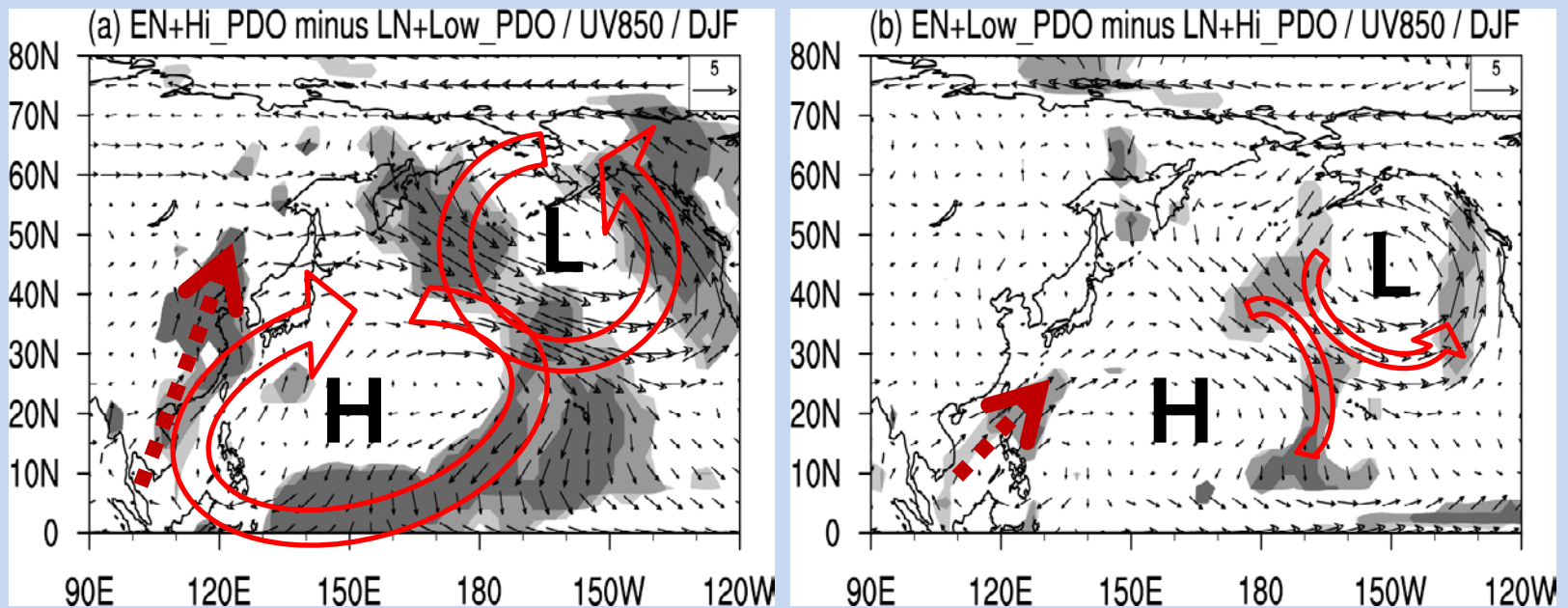


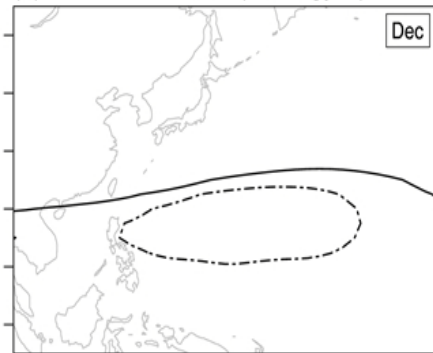
Fig4. 850-hPa U and V Wind fields DJF Composite Differences between (a) EN+Hi_PDO and LN+Low_PDO; (b) EN+Low_PDO and LN+Hi_PDO.

In-Phase difference shows **Well-established Southerly Wind anomalies** located in the western flank of the **Strong Anti-Cyclonic flow (WNPSH)**. In addition, there is a **Strong Cyclonic flow (Aleutian Low)**.

Out-of-Phase difference generally shows the **Weakened signals** compared to the previous pattern.

Winter Time Evolution of WNPSH

(a) In-Phase / Z500 (5860 gpm)



(b) Out-of-Phase / Z500 (5860 gpm)

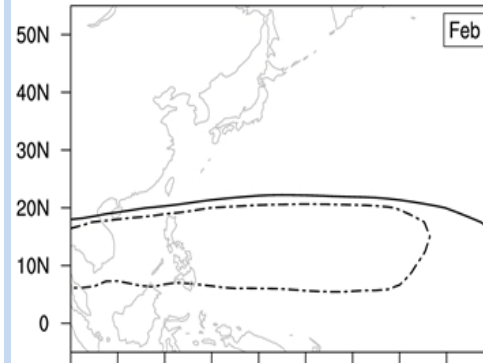
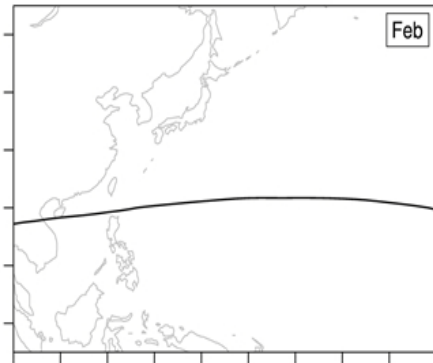
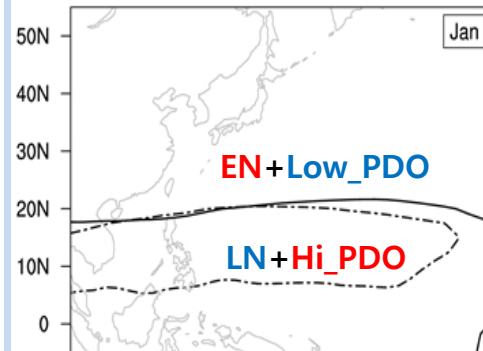
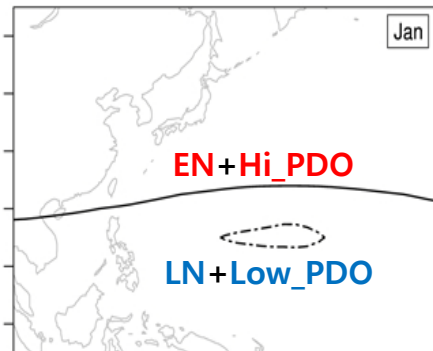
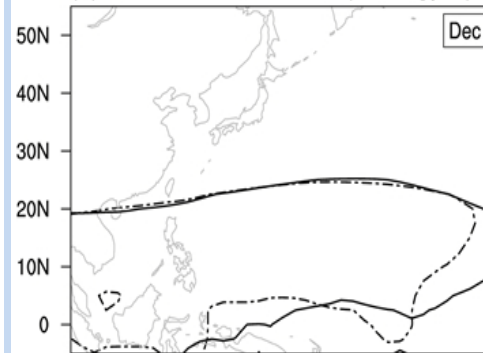


Fig5. 500-hPa GPH composites for the monthly winter, designated by the 5860-gpm contour, (a) EN+Hi_PDO and LN+Low_PDO; (b) EN+Low_PDO and LN+Hi_PDO.

The **magnitude of WNPSH** can be depicted by designating **5860-gpm contour line** over the western Pacific. (*Chan and Zhou, 2005*)

In **In-Phase** composites, the magnitudes of **EN+Hi_PDO** are much larger than those of **LN+Low_PDO**, even disappeared in February.

In **Out-of-Phase** composites, **EN+Low_PDO** and **LN+Hi_PDO** are quite similar except for some differences over the equator.

4. CONCLUDING REMARKS

- ✓ By analyzing long-term SAT data and atmospheric re-analysis data sets, Changes in EAWM have been investigated using ENSO and PDO phase combinations.
- ✓ When ENSO and PDO are in In-Phase (i.e., EN+Hi_PDO / LN+Low_PDO), the EAWM tends to be stronger and weaker. However, when they are in Out-of-Phase (i.e., EN+Low_PDO / LN+Hi_PDO), the EAWM does not exhibit strong features. Additionally, it has been found that the magnitude of WNPSH is strongly affected by the changes in the ENSO and PDO interaction.
- ✓ Furthermore, an operational point of view, the ENSO-based long-range seasonal climate forecasts over the East Asian continent should be considered with the interdecadally-changing PDO variations to obtain more skillful prediction results.

THANK YOU

VERY MUCH

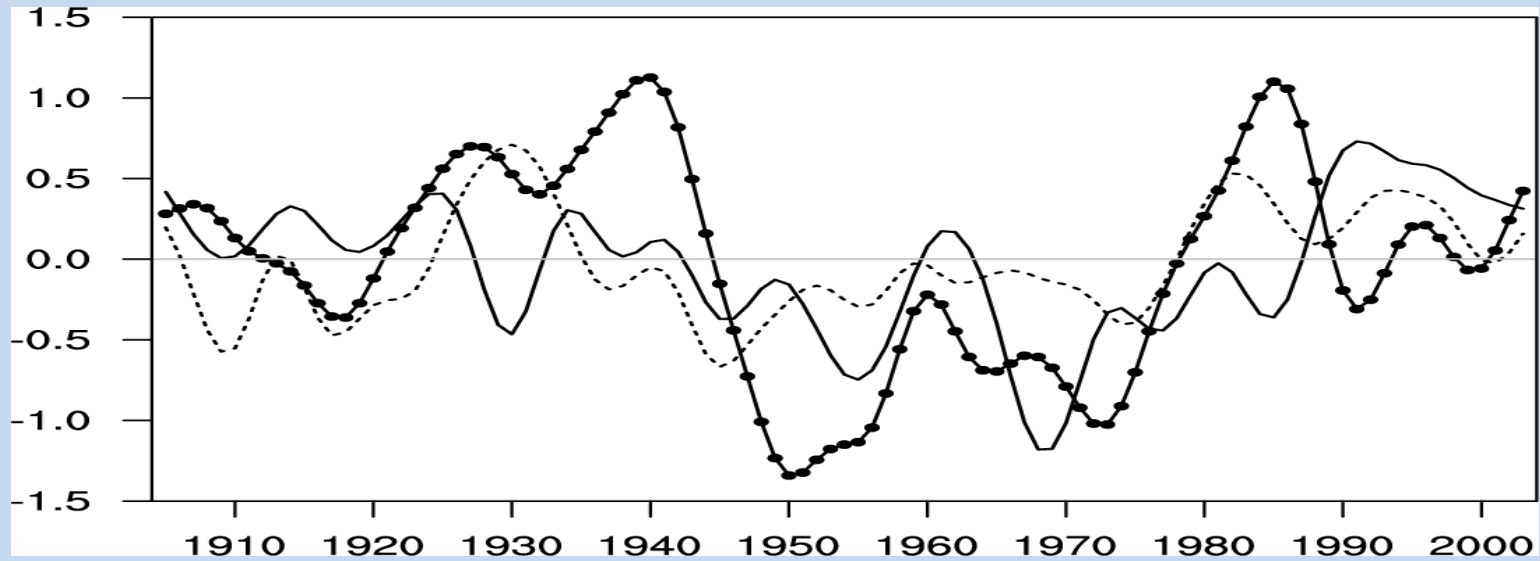
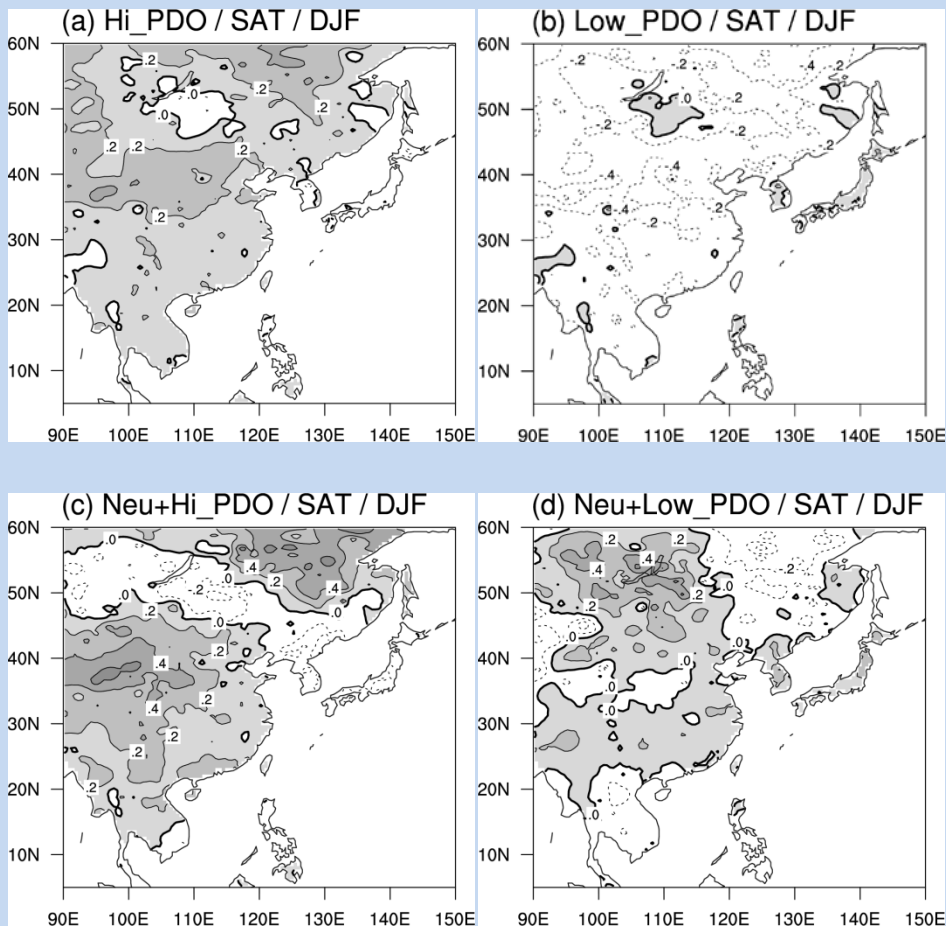


Fig2. 11yr Low-pass filtered normalized time series of East Asian winter-averaged SAT(solid), PDO (solid with circles) and ENSO (short dashed).

The correlation coefficient (r) of **EAWSAT** with **interdecadal-ENSO** is weak ($r = 0.27$) because the ENSO-related features are almost associated with the dominant year-to-year climate signals. (McPhaden et al. 2006)

r between **EAWSAT** and **interdecadal-PDO** variability is relatively strong ($r = 0.42$) positive correlation with statistical significance at 95% confidence level.

Figure 4. The surface air temperature (SAT) anomaly composites based on (a) **Hi_PDO** and (b) **Low_PDO**, (c) **Neu+Hi_PDO** and (d) **Neu+Hi_PDO**.



In order to elucidate the **specific influence of PDO** on the East Asian region, winter SAT anomaly composites for the different phases of PDO with **including or excluding ENSO years** have been examined during the period 1900-2008.

(a) Hi_PDO / (b) Low_PDO

Apparently, the composite map for the Hi PDO is essentially **out of phase** with that of the Low PDO and PDO has a **similar tendency** to be in the same phase for EN (LN) except relatively smaller magnitudes. It is likely that the PDO becomes a **supportive force** on the relationship between EAWM and ENSO on the interdecadal timescales.

(c) Neu+Hi_PDO / (d) Neu+Low_PDO

However, PDO phase during the ENSO-neutral periods, meaning that ENSO years are removed from the composites, the spatial structures are **no longer associated with** the coherent patterns. Surely, a rigorous analysis involving the PDO effect without ENSO variability will be required to a future study.

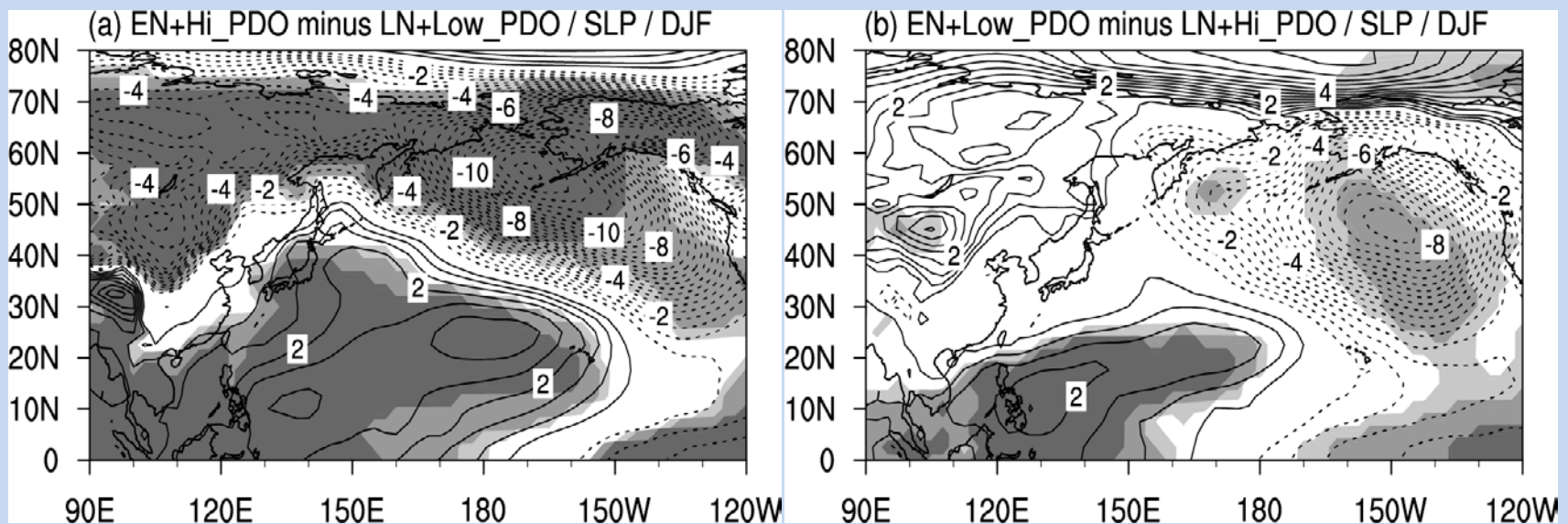


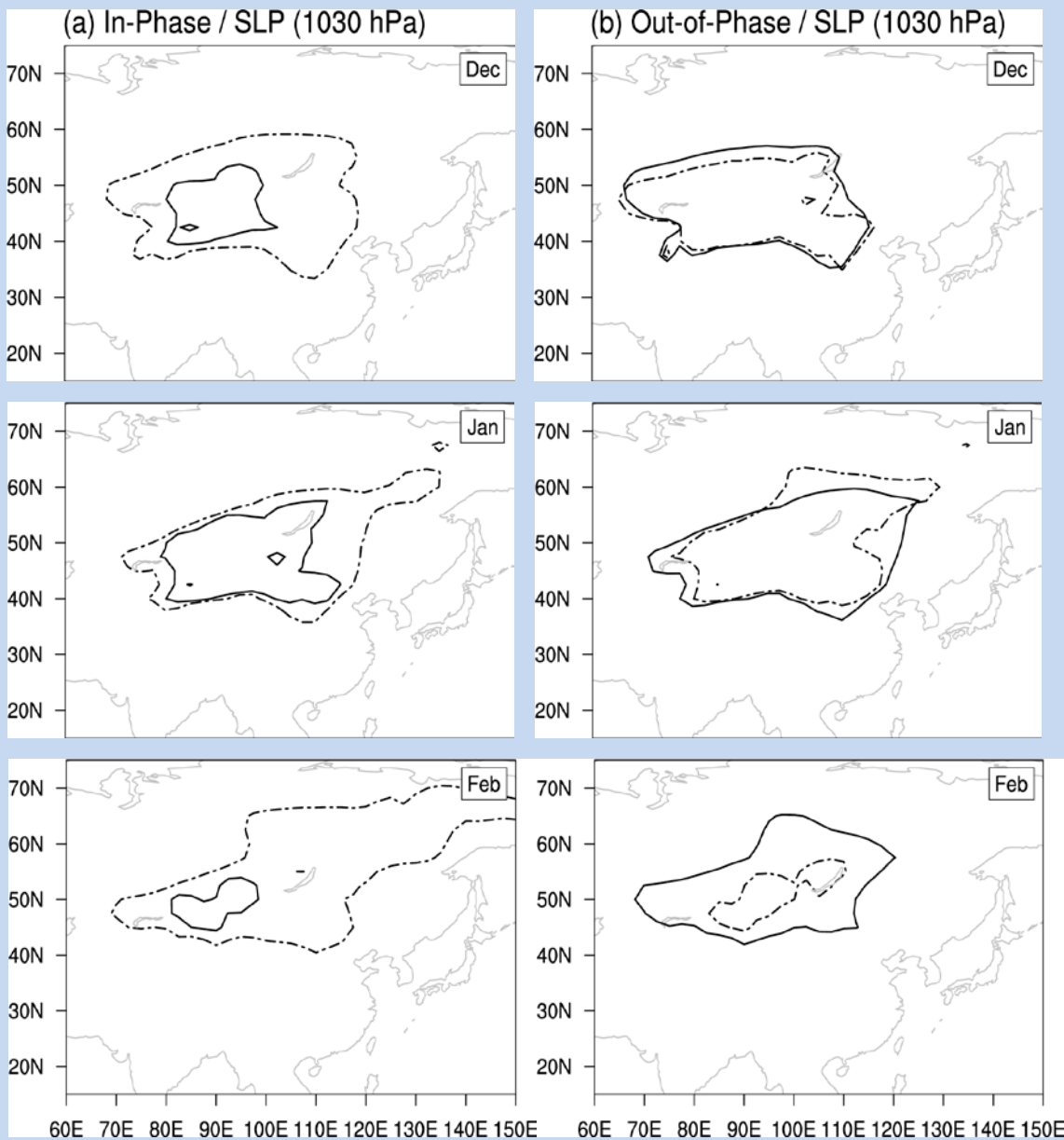
Figure 7. The same as in Figure 5 but for the **SLP** field. Contour intervals are 0.5 hPa and zero contour lines are suppressed.

(a) EN+Hi_PDO - LN+Low_PDO

In the in-phase difference, the **pressure gradient** over the East Asia is **decreased** due to the weakened Siberian high and strengthened SLP anomalies over the western North Pacific region. The **decreased pressure gradient** on the margin of the East Asian continent can **make a weakened monsoon circulation** over East Asia.

(b) EN+Low_PDO - LN+Hi_PDO

Meanwhile, the high pressure anomalies over the western Pacific are **strictly confined** to the tropical region and the low pressure anomalies over the eastern North Pacific is **largely shifted to the southeastward** in the out-of-phase difference. It is likely that the **Siberian high** is the **only one dominant force** over East Asia regardless of the ENSO and PDO interactive effect.



(a) **EN+Hi_PDO** (solid) / **LN+Low_PDO** (long dashed)

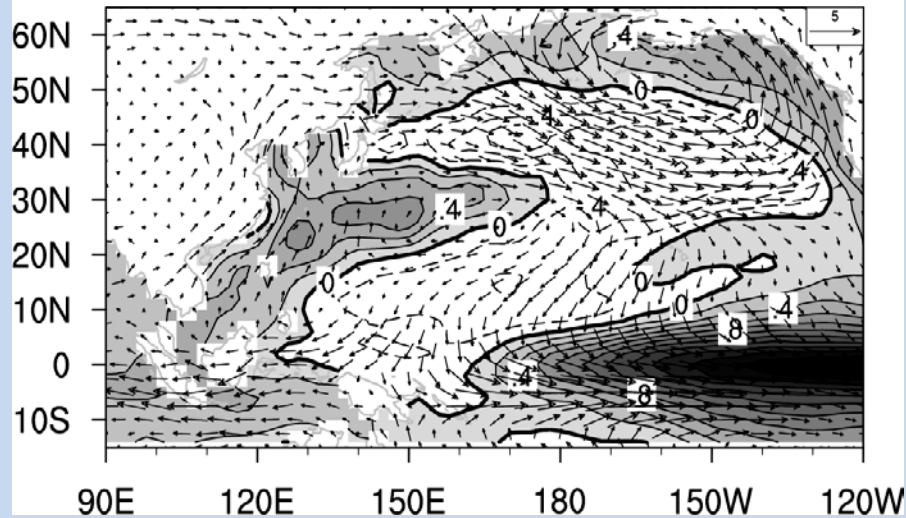
In the **EN+Hi_PDO** condition, the magnitude of Siberian High (1030 hPa) is clearly **smaller**, while the Siberian High widely **expands** in the **LN+Low_PDO** condition. It implies again the EAWM is very sensitive when ENSO and PDO are in-phase.

(b) **EN+Low_PDO** (solid) / **LN+Hi_PDO** (long dashed)

However, when the ENSO and PDO are out-of-phase, they are **somewhat similar** except for February.

Figure 9. The same as in Figure 8 but for the **SLP**, designated by the **1030 hPa** contour.

(a) EN+Hi_PDO / SST and UV850 / DJF



(b) EN+Low_PDO / SST and UV850 / DJF

