Sub-Seasonal Variabilities and Their Interdecadal Change

Kyung-Ja Ha, and Kyung-Sook Yun
Division of Earth Environmental System, Pusan National University
* Corresponding author : Kyung-Ja Ha, E-mail: kjha@pusan.ac.kr

Introduction

- The East Asian summer monsoon (EASM), which is one of the extratropical monsoons, exhibits a substantially strong sub-seasonal (or intraseasonal) variabilities (e.g., Lau *et al.*, 1988; Wu and Wang, 2001).
- The different sub-seasonal variabilities for the interdecadal change in the EASM rainfall (e.g., Ha *et al.*, 2009; Lee *et al.*, 2010): insignificant change in July, but evident increase in August. The changes in the teleconnection pattern (e.g., PJ and EU) related to the upper tropospheric cooling over East Asia and ENSO impact were suggested as the possible causes.
- The distinct sub-seasonal variabilities for the interdecadal change in the monsoonal ISO -ENSO relationship (Yun *et al.*, 2010): before the late 1970s, the preceding winter ENSO influenced the early summer NPISO activity, whereas after the late 1970s a strong relationship appeared during the later summertime.

• Objective

- Why the interdecadal change is differently appeared in the sub-seasonal structure?
- The causes on the distinct sub-seasonal characteristics for the interdecadal change over the EASM region are investigated in terms of the tropical SST forcing, change in extratropical thermal state, and change in the sub-seasonal basic flow.

Impact of tropical SST warming

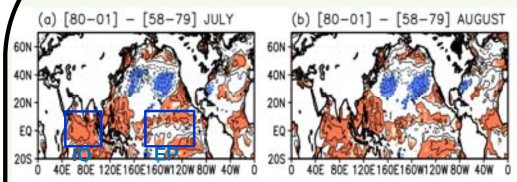


Fig. 1. Composite difference of SST anomaly between two periods 1980-2001 and 1958-1979 years during (a) July and (b) August. Shading indicates the anomaly significant at the 95% confidence level. The contour interval is 0.2K and the zero line is omitted.

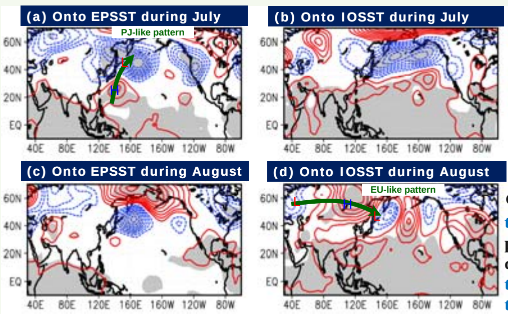
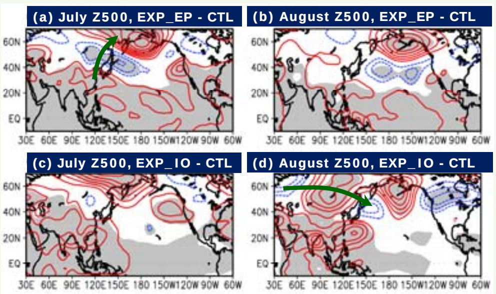


Fig. 2. Regression of the (a) July and (c) August 500hPa geopotential height anomaly against the (a) July and (c) August NINO3 index during 1980-2001. (b, d) Same as (a, c), but for the IOSST anomaly. Shading indicates the value significant at the 90 and 95% confidence level.

- **During July, the EP is related to PJ (Pacific-Japan) -like wave pattern along the East Asian coast, however, during August the IO warming is rather related to the EU (Eurasian)-like wave pattern**

Numerical experiment using ECHAM4.6 AGCM (Roeckner et al., 1996)



- **To show the impacts of the interdecadal EP and IO warming, the forcing is specified by the doubling the interdecadal change (1980-2001 minus 1958-1979) in the EP and IO SST, with perpetual experiments (i.e., July or August mean state is continued), respectively in July and August run.**

Fig. 3. The difference in 500hPa geopotential height of (a) EXP_EP_JUL - CTL_JUL, (b) EXP_EP_AUG - CTL_AUG, (c) EXP_IO_JUL - CTL_JUL, and (d) EXP_IO_AUG - CTL_AUG. The shading indicates the value significant at the 95% confidence level.

- **In relation to the different thermal state between July and August (i.e., difference in land-sea contrast and solar insolation varying with latitude), the July EP forcing lead stronger suppressed convection and circulation over the WNP, resulting in the PJ-like pattern. However, the August IO forcing more strengthens (weakens) westerly mean flow south (north) of Asian jet, inducing the EU-like pattern.**

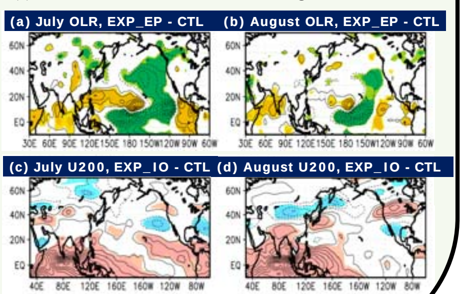
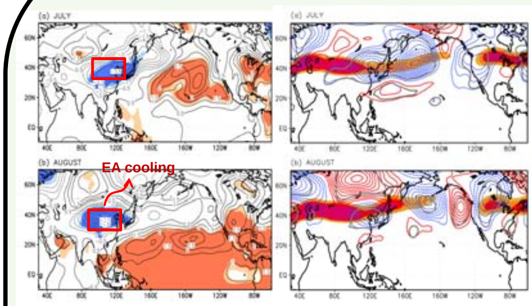


Fig. 4. Same as Fig. 3, except for (a)-(b) EXP_EP – CTL for the OLR anomaly, (c)-(d) EXP_IO – CTL for the U200 anomaly during (a, c)July and (b, d) August.

Change in extratropical thermal state



- **Upper tropospheric cooling over East Asia induce enhancement of the upper-level zonal wind in the exit of Jet stream, and in turn, the EU-like pattern during July and August.**

Fig. 5. Composite difference between 1958-1979 and 1980-2001 year of 850hPa-200hPa thickness. Shading indicates the value significant at the 90 and 95% confidence level.

Fig. 6. Regression of the (a) July and (b) August 500hPa geopotential height anomaly against the (a) July and (b) August T300 index during 1980-2001. Shading indicates the climatology of 200hPa u-wind. The thick solid line indicates the value significant at the 90% confidence level.

Change in the sub-seasonal basic flow

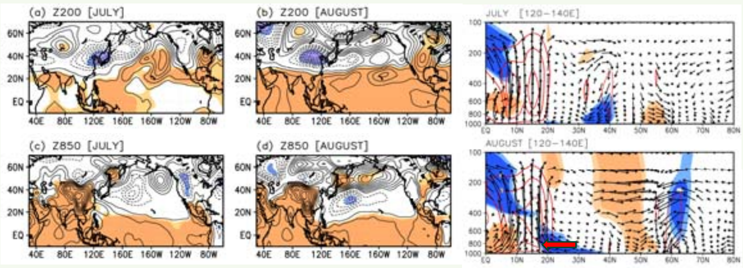


Fig. 7. 1980-2001 minus 1958-1979 of the Z200 and Z850 during July and August. The Shading indicates the value significant at the 90% confidence level.

Fig. 8. 1980-2001 minus 1958-1979 of the meridional velocity and vertical velocity, averaged over the WNP [120-140E] during July and August.

▪ Weakened PJ pattern during August

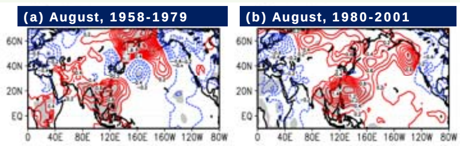


Fig. 9. Regression of the SLP anomaly against OLR over the WNP [120-160E, 10-20N] during (a) 1958-1979 and (b) 1980-2001. Shading indicates the value significant at the 95% confidence level.

Numerical experiment using LBM (Watanabe and Kimoto, 2000)

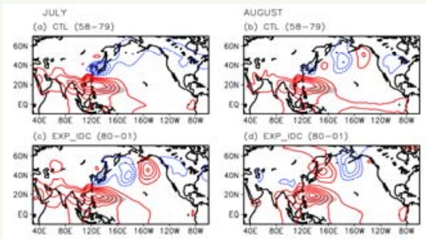
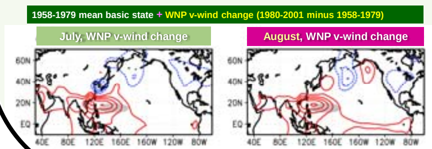


Fig. 10. The baroclinic responses of the SLP anomaly (hPa) on day 25 to the heat sink in the dark shaded region. (a)-(b) CTL and (c)-(d) EXP_IDC during (a), (c) July and (b), (d) August basic state. The contour interval is 0.2hPa. The shading indicates the forcing of diabatic sinking centered at (150°E, 15°N).



- **During August, the significant northerly anomaly (weakening of the south-westerlies flow) due to the low-level cyclone anomaly.**
- **Because the lower-level south-westerlies are primarily responsible for PJ teleconnection, the weakened the southerly flow provides the unfavorable condition for the PJ-like teleconnection into East Asia.**

Conclusion

	July	August	Cause
SST warming	EP-related PJ-like pattern	IO-related EU-like pattern	Differences in the basic states: A warmer tropics SST during July; Ocean warming and continent cooling during August
EA cooling	EU-like pattern	EU-like pattern	Change in upper-level zonal wind due to the thermal wind balance
WNP anomalous wind	Favorable PJ-like pattern	Unfavorable PJ-like pattern	Decreased south-westerly monsoon flow interrupts the PJ-like pattern into East Asia
	Combined effect of two wave patterns	Effect of strong EU-like pattern	

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