Physical Linkages between the East Asian Summer Monsoon and Sea Surface Temperature Anomalies in the Surrounding Oceans

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Introduction

The East Asian summer monsoon (EASM) is normally referred to as a subtropical monsoon covering eastern China, the Korean peninsula, Japan, and adjacent marginal seas. We divide the EASM into two regional systems, i.e., northern EASM (NEASM; 30°~50°N and 110°~145°E) and the southern EASM (SEASM; 20°~30°N and 110°~145°E), because the sub-EASM regions have different mean divergences at 150 hPa for June through August (Fig. 1). The sub-regions also have different correlations (Fig. 2) and physical mechanisms with the heat sources of the surrounding oceans (see Fig. 3).

The study of how the sub-EASMs are related to the changes of heat budgets in the surrounding oceans could help to determine the influence of a changing climate on the EASM and it may facilitate better forecasts.

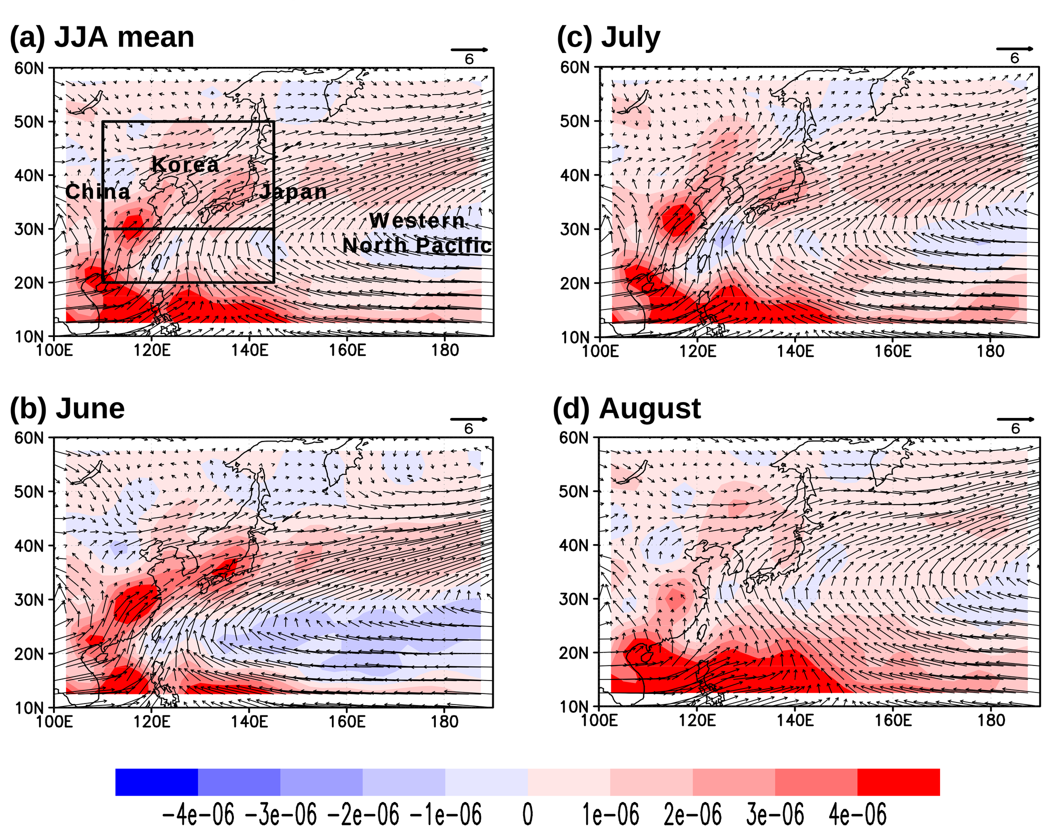

Fig. 1. 1979~2003 JJA and monthly mean 150 hPa divergences (s^{-1}; shaded) and 850 hPa wind vectors (m/s). The upper and lower boxes in (a) denote the NEASM and SEASM regions, respectively.

Data and Methodology

The mean precipitation (mm/day) is derived from the Global Precipitation Climatology Project version 2. Wind vector (m/s) and vorticity (s^{-1}) at 850 hPa are calculated with *u*- and *v*-winds from the National Centers for Environmental Prediction-National Center for Atmospheric Research (NCEP-NCAR) reanalysis. Sea surface temperature (SST; °C) is obtained from Hadley centre. We examine 25 years from 1979 to 2003, which is a period of increasing temperature and more accurate datasets.

We examine the relationships between EASM precipitation and the oceanic heat sources by means of spatial correlation analysis. A physical mechanism is then proposed to understand the relationships between the sub-EASMs and SST anomalies in the surrounding oceans using the composite analysis of low-level flow.

Results

Relationship between EASM precipitation and ocean heat sources

NEASM precipitation

SSTs over the large area of tropical Pacific and Indian Oceans are significantly correlated with NEASM precipitation from December through May at α=0.05 (Fig. 2a and b). NEASM precipitation is positively correlated with SSTs in the tropical eastern Pacific (TEP) and the tropical Indian Ocean, and negatively correlated with SSTs in the tropical western Pacific (TWP) and the subtropical South Pacific. A significant positive correlation (r=0.49) at α=0.05 between NEASM precipitation and SST in the TEP for December~May supports the strong relationship between the intensity of NEASM precipitation and El Niño events.

SEASM precipitation

SEASM precipitation is significantly correlated with SSTs in the subtropical Pacific during the pre-monsoon season at α=0.05 (Fig. 2d and e), but there is little correlation between SEASM precipitation and SST in Indian Ocean. SEASM precipitation has a negative correlation with SST in the eastern North Pacific (ENP), and it has positive correlations with SSTs in the western North Pacific (WNP), East and South China and Philippine Seas, and the subtropical South Pacific.

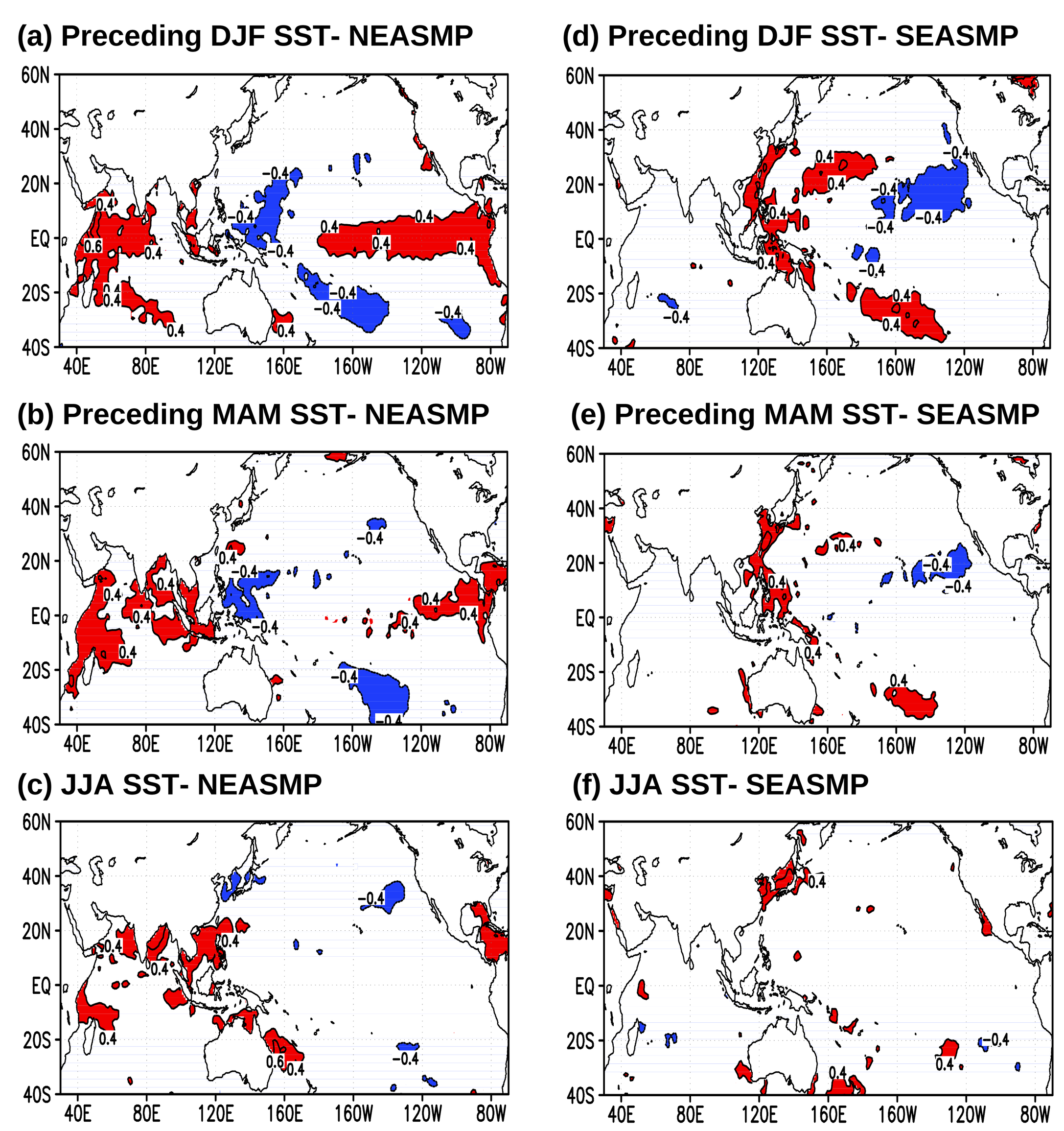

Fig. 2. Correlation coefficients of area-averaged JJA precipitation over the NEASM and SEASM regions (i.e., NEASMP and SEASMP) with the seasonal SSTs. Significant regions at the 95% level are shaded.

Physical mechanism

NEASM

For the years of highest SST anomalies in the TEP, the Pacific-East Asian (PEA) teleconnection pattern, which consists of a wave creating an anomalously strong WNP anticyclonic circulation and anomalously strong cyclonic circulation in the NEASM region, creates more monsoon rainfall (Fig. 3b). For the years of highest SST anomalies in the TWP, there are fewer WNP anticyclonic anomalies due to the PEA teleconnection and also fewer cyclonic anomalies in the NEASM region, which create a weaker NEASM (Fig. 3c).

SEASM

For the years of highest SST anomalies in the ENP, cold WNP SST anomalies create a stronger WNP anticyclone (Fig. 3e). The proximity of the SEASM to the WNP anticyclone causes diminished monsoon rainfall when the anticyclone is stronger or covers a larger area. For the years of highest SST anomalies in the WNP, there are fewer WNP anticyclonic anomalies and thus fewer anticyclonic anomalies in the SEASM region, creating a stronger monsoon (Fig. 3f).

Physical linkages proposed between SST anomalies and the sub-EASMs are shown in Fig. 4.

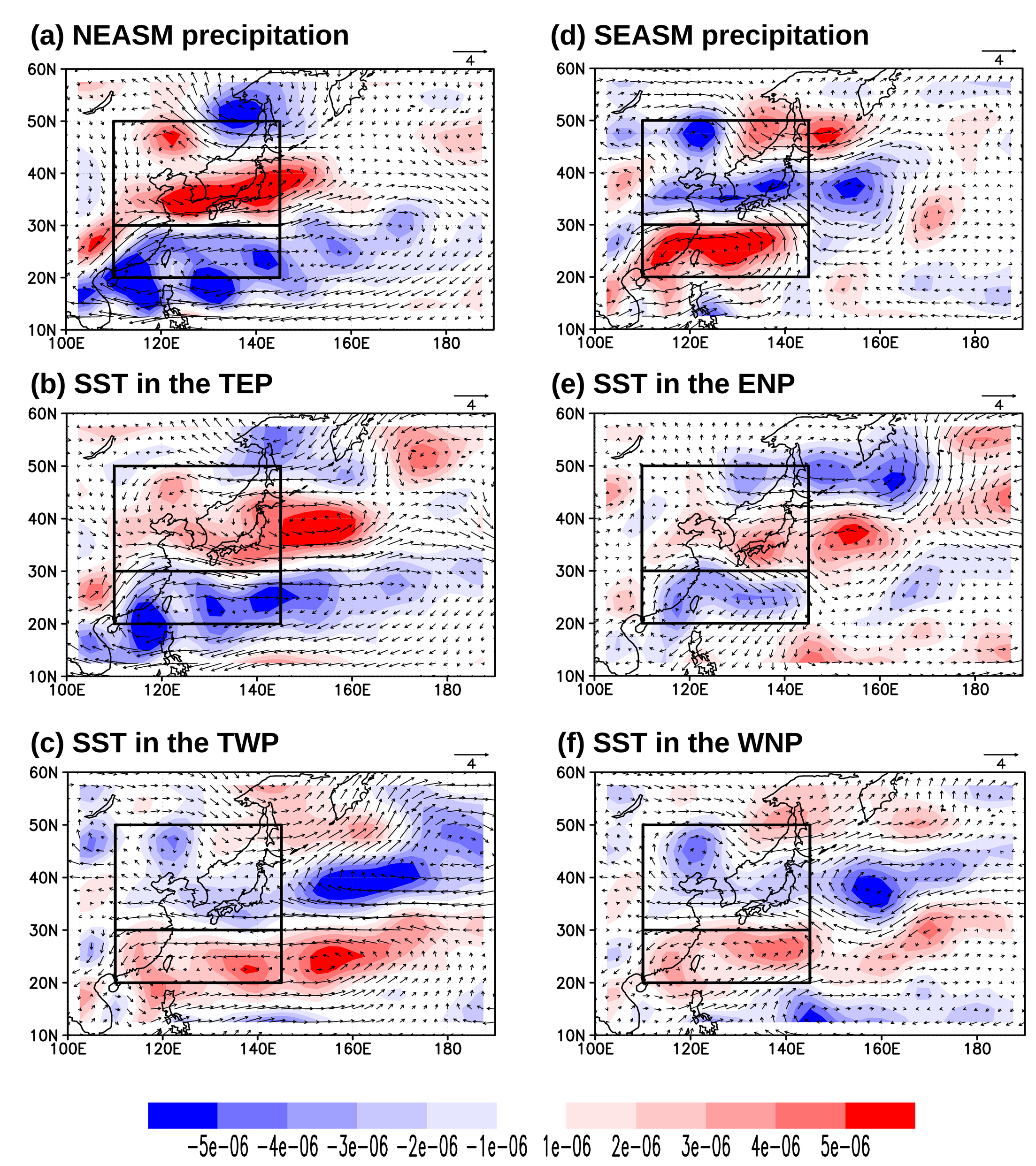

Fig. 3. Composite differences of mean JJA 850 hPa wind vectors (m/s) and vorticity (s^{-1}; shaded) for the five years of highest and of lowest of (a) NEASM precipitation, (b) SST in the TEP, (c) SST in the TWP, (d) SEASM precipitation, (e) SST in the ENP, and (f) SST in the WNP. The upper and lower boxes denote the NEASM and SEASM regions.

NEASM	SEASM
High SST anomalies in the TEP & Low SST anomalies in the TWP (i.e., El Niño events)	High SST anomalies in the WNP & Low SST anomalies in the ENP (i.e., SST dipole in the North Pacific)
↓	↓
PEA teleconnection	Local air-sea interaction
↓	↓
Enhanced WNP anticyclonic anomalies	Weakened WNP anticyclonic anomalies
↓	↓
More cyclonic anomalies in the NEASM region	More cyclonic anomalies in the SEASM region
↓	↓
A stronger NEASM	A stronger SEASM

Fig. 4. Physical linkages proposed between SST anomalies and the sub-EASMs.

Conclusions

We find that the EASM can be subdivided into a northern and southern component with distinctly different driving mechanisms. The NEASM is affected by heat sources in the tropical oceans related to El Niño events while the SEASM is affected by the subtropical oceans related to a North Pacific SST dipole mode. A stronger NEASM is related to the enhanced WNP anticyclonic anomalies and thus more cyclonic anomalies in the NEASM region due to the PEA teleconnection, which is connected to tropical SST anomalies. A stronger SEASM is related to the weakened WNP anticyclonic anomalies and also more cyclonic anomalies in the SEASM region due to the local air-sea interaction, which is also connected to subtropical SST anomalies.

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