Recent Climate Trends in the East Asia During the Baiu Season of 1979–2003

Nagio Hirota¹, Masaaki Takahashi¹, ², Naoki Sato¹, and Masahide Kimoto¹
¹Center for Climate System Research, The University of Tokyo, Kashiwa, Japan
²Frontier Research Center for Global Change, Yokohama, Japan
³Institute of Observational Research for Global Change, Yokohama, Japan

Abstract

Recent climate trends in the East Asia during the Baiu season (June) of 1979–2003 are investigated. The precipitation is significantly decreasing around Philippines and the northeastern part of China, while increasing along the Baiu frontal zone (the southwestern part of China and Japan) and the western part of Siberia. The pressure trend that corresponds to the precipitation has barotropic structure in the midlatitudes and baroclinic structure in the sub tropics. For the barotropic structure, the Rossby wave propagation from the western part of Siberia and Tibetan Plateau seems to play an important role. On the other hand, the trend of diabatic heating around Philippines and Japan is important for the baroclinic structure.

The pressure trend is investigated by a linearized primitive model. The results support the above idea that the effect of the Rossby wave propagation is important for the barotropic pressure trend in the midlatitudes and the trend of apparent diabatic heating is an important factor for the baroclinic pressure trend in the subtropics.

Interannual variability is also investigated. It is suggested that the trend of surface temperature around Mongolia and Philippines is related to the pressure trend.

1. Introduction

Understanding of the climate change in recent decades is important for the prediction of the future climate. There are much research concerning decadal change of the summer climate in the East Asia.

Nitta and Hu (1996) made EOF analysis of JJA (June, July, and August) precipitation using observational data. The first EOF mode of the precipitation has a maximum over Yangtze River basin and a large negative value over Yellow River basin. The time coefficient of this first mode is linearly increasing from 1958–1994. Moreover, they discuss correlation of the time coefficient with SST and geopotential height. The correlation pattern of 500 hPa geopotential height with the time coefficient looks like the Pacific-Japan (PJ) teleconnection pattern described by Nitta (1987). In the mid- and high-latitude region, the pattern also resembles the Eurasian (EU) teleconnection pattern which is positive in West Europe and central Asia, while negative in East Europe and West Asia (Wallace and Gutzler 1981).

Many other works such as Inoue (2003), Yasunari (2003), and Yatagai and Yasunari (1995) also show the similar precipitation change in the East Asia by analyzing observational data. Yatagai and Yasunari (2003) suggests that the change in land surface condition may be part of the cause for the expansion of dry climate over the Yellow River basin. Yasunari (2003) also points out that the westward displacement of the subtropical high in the western North Pacific causes more transportation of water vapor over the Yangtze River basin. Inoue (2003) explains that this dry and wet climate change corresponds to the seasonal delay of Baiu front northward movement in the recent years which is shown by Sato and Takahashi (2001). This delay is thought to be related with the strengthened Okhotsk high. All these data analyses agree about the decadal climate change, but what extent these mechanisms contribute to the change is still unclear.

This study discusses recent climate trend in the East Asia during the Baiu season (June) of 1979–2003. The relationship among precipitation, atmospheric field, and surface temperature is examined not only by analyzing data, but also by using a linearized primitive model.

2. Data

Data used in this study includes precipitation estimated by rain gauge data and satellite data (Xie and Arkin 1996) and reanalysis data made by the National Centers for Environmental Prediction/National Center for Atmospheric Research. Observation based data such as surface pressure and land surface temperature (sea surface temperature) created by the Climatic Research Unit of the University of East Anglia (Jones 1987) is also used to verify the consistency between the reanalysis data and observation.

3. The climate trend

The June precipitation trend from 1979–2003 is shown in Fig. 1. In this study, the trend is defined as a change for the 25 years on a best fit straight line of a precipitation time series (linear trend). This definition eliminates interannual variability. The thick black lines show the trend that is statistically significant at the level of 95%. The precipitation is significantly decreasing around the northeastern part of China including the Yellow River basin and increasing along the Baiu frontal zone (the southeastern part of China and Japan) including the Yangtze River basin. This trend is similar to the change described in Section 1. There is also the significant precipitation decrease around Philippines and the increase in the western part of Siberia.

The precipitation trend of JJA for the 25 years is similar to that of June (not shown). The JJA precipitation increases along the Baiu frontal zone and in the western part of Siberia, while decreases around the northeastern part of China and Philippines. Since the precipitation trend of July and August is relatively small compared to that of June, this study focuses on June.

The precipitation trend of June is closely related with the atmospheric pressure trend. Figure 2 shows the trend of geopotential height (shade) and wind velocity (arrow) at 850 hPa. The geostrophic southwesterly around the low pressure trend in China and the high pressure trend around Philippines carries water vapor...
to the Baiu frontal zone from its south. This results in the precipitation increase along the Baiu frontal zone and the decrease around Philippines. The precipitation decrease around the northeastern part of China and the increase around the western part of Siberia seem to be related to the high pressure trend around Mongolia and the low pressure trend around the western part of Siberia.

In order to speculate how the change occurs, the three dimensional structure of the atmosphere is considered. Figure 3 shows the geopotential height trend (shade) and the wave activity flux (arrow) defined by Takaya and Nakamura (2001) at 300 hPa. The high pressure trend around Mongolia and the low pressure trend in China have barotropic structure. The wave activity flux implies the importance of the Rossby wave propagation from western part of Siberia and Tibetan Plateau to Mongolia and China. On the other hand, the pressure trend around Philippines has baroclinic structure. Therefore, the pressure trend is the combination of barotropic structure in the midlatitudes and the baroclinic structure in the subtropics.

The trend of land surface temperature and sea surface temperature is also examined (Fig. 4). There is a high temperature trend around Mongolia. This trend includes statistically important change, and may be related to the global warming. The temperature is also significantly increasing around Philippines. This is probably the result of the precipitation decrease followed by increase of sunshine. Although there are low temperature trends in the northeastern part of India and in the northeastern part of Siberia, these areas include discrepancy between the reanalysis data and the observational data (not shown). Therefore, the trend in these areas will not be discussed further.

4. A linear response problem

A linearized primitive model is used to investigate the pressure trend. The governing equations are:

\[
\begin{align*}
\frac{\partial \nabla'}{\partial t} + \overline{u} \cdot \nabla u' + u' \cdot \nabla \overline{u} - f \nabla' &= -\frac{\overline{w'} + u' \overline{v}}{R_e} \tan \phi + \frac{\partial z'}{\partial x}, \\
\frac{\partial \rho_c}{\partial x} + \frac{u'}{\tau} - \nu \frac{\partial u'}{\partial y} &= -\frac{\overline{w'}}{R_e} \tan \phi + \frac{\partial z'}{\partial y}, \\
\frac{\partial \overline{v'}}{\partial t} + \overline{u} \cdot \nabla v' + u' \cdot \nabla \overline{v} + f \overline{u'} + \frac{\overline{w'}}{R_e} \tan \phi + \frac{\partial z'}{\partial y} &= -\frac{\overline{w'}}{R_e} \tan \phi + \frac{\partial z'}{\partial y}, \\
\frac{\partial \nabla'}{\partial t} + \overline{u} \cdot \nabla \theta' + u' \cdot \nabla \overline{\theta} + \frac{\theta'}{\tau} &= -\frac{\overline{w'}}{R_e} \tan \phi + \frac{\partial z'}{\partial y}.
\end{align*}
\]
The low pressure anomaly in the Tibetan Plateau (area surrounded by a broken line) is a response to forcing over the western part of Siberia and of local forcing at various areas is investigated. The zonation of boundary layer processes.

The pressure anomaly pattern, which includes the characteristics mentioned in Section 3, is roughly reproduced. Figure 8 shows the response to the forcing around Philippines and Japan. The baroclinic pressure anomaly around Philippines and the south of Japan is represented. The relative importance of the forcing by the nonlinear term and the diabatic heating is investigated (not shown). The forcing by both the nonlinear terms and the diabatic heating have the impact over the western part of Siberia and Mongolia. On the other hand, the response around Philippines and Japan is mostly due to the diabatic heating.

These results support the idea that the forcing over the western part of Siberia and Tibetan Plateau plays an important role in producing the barotropic pressure trend around Mongolia and China, while the diabatic heating in Philippines and Japan is important for the baroclinic pressure trend in these areas.

5. The relationship between surface temperature and pressure pattern

In order to speculate the relationship between pressure trend and the surface temperature trend,
Recent climate trend in the East Asia during the Baiu season of 1979–2003 is studied by analyzing the data. It is found statistically significant that the precipitation is decreasing around Philippines and over the northeastern part of China, while it is increasing along the Baiu Frontal zone and in the eastern Siberia. The pressure trend, which corresponds to the precipitation trend, has the barotropic structure in the midlatitudes and the baroclinic structure in the subtropics. The wave activity flux implies that the Rossby wave propagations from the western part of Siberia and Tibetan Plateau are important for the barotropic structure. The baroclinic structure seems to be related with the diabatic heating.

The pressure trend is investigated by the linearized primitive model. The pressure anomaly pattern is reproduced as the linear response to the diabatic heating and the nonlinear terms for the 25 years. Using the linearity of the equations, the contribution of local forcing from various areas is examined. The results suggest that the forcing from the western part of Siberia and Tibetan Plateau is important for the barotropic pressure anomaly in the western part of Siberia, around Mongolia, and in China. On the other hand, the change in apparent diabatic heating around Philippines and the south of Japan seems to be responsible for the baroclinic pressure anomaly in these areas.

The interannual variability is also investigated to speculate the relationship between pressure and surface temperature. The result implies that the pressure trend is related with the surface temperature around Mongolia and Philippines.

In conclusion, it is found that the sea surface temperature around Philippines is closely related to the recent climate trend in the East Asia as Nitta and Hu (1996) suggested. In addition, the land surface temperature around Mongolia and the Rossby wave propagations from the western part of Siberia and Tibetan Plateau are also important for the climate trend.

6. Conclusion

Recent climate trend in the East Asia during the

References


Manuscript received 25 May 2005, accepted 15 July 2005
SOLA: http://www.jstage.jst.go.jp/browse/sola/