Interannual Variations of Seasonal Change of Precipitation and Moisture Transport over East Asia and the Western Pacific

*Miki Hattori and Kazuhisa Tsuboki
Hydrospheric Atmospheric Research Center, Nagoya University, Japan
Hydrospheric Atmospheric Research Center, Nagoya University, 464-8601,Japan
Tel: +81-52-789-3494, Fax: +81-52-789-3436, E-mail: hattori@ihas.nagoya-u.ac.jp

1. Introduction

The tropical western Pacific region is noted as for its strong convective activity and as the highest SST region which affects Asian monsoon and the global-scale atmosphere (e.g., Yasunari1979; Nitta and Yamada 1989; Yasunari and Seki 1992; Lau 1992; Huang and Sun 1992; Murakami and Matsumoto 1994). In order to clarify the variability of Asian summer monsoon, it is important to investigate the variability of the precipitation in the tropical western Pacific and the water circulation in East Asia and the western Pacific region. The seasonal changes of the convective activities in the tropics are associated with the northward shift of ITCZ (the Intertropical Convergence Zone) (e.g., Lau 1990, Lau 1992). However, the seasonal change of precipitation is complex and changes annually (e.g., Nitta 1986; Nitta 1987; Lau 1990; Lau 1992; Ueda et al. 1995; Ueda and Yasunari 1996). The purposes of this study are to clarify the interannual variations of seasonal change patterns of precipitation and associated moisture circulations and to investigate the water circulation over East Asia and the western Pacific region. Mainly, we focus on the distribution pattern of precipitation and its relationship with atmospheric conditions.

2. Data

The data utilized in this study were the global monthly precipitation data from CMAP (the Climate Prediction Center Merged Analysis of Precipitation) (Xie and Arkin 1996; Xie and Arkin 1997) and the monthly means of the NCEP-NCAR (the National Center for Environmental Prediction-National Center for Atmospheric Research) reanalysis for the 20 years from 1979 to 1998. The spatial resolution of these data is 2.5^{o} in latitude and longitude.

3. Seasonal change of precipitation pattern over East Asia and the western Pacific

In East Asia and the western Pacific, there are two major precipitation areas; one is located in the tropical western Pacific and the other in mid-latitude around Japan and China. We focus on the intense precipitation to the east of the Philippines to investigate water circulation in these regions.

In order to examine the seasonal change of its latitudinal distribution and intensity of precipitation, the time-latitude cross-section of monthly precipitation averaged between 125^{o}E and 150^{o}E including these large precipitation areas for 20 years is shown in Fig. 1.

From Fig. 1, it is clear that the averaged precipitation peak shows a significant northward shift from 5^{o}N to 15^{o}N during the period from June to August. The maximum reaches 12mm day^{-1} suddenly in June, is weakened in July and reaches 13mm day^{-1} in August. After August, the peak shifts southward until December.

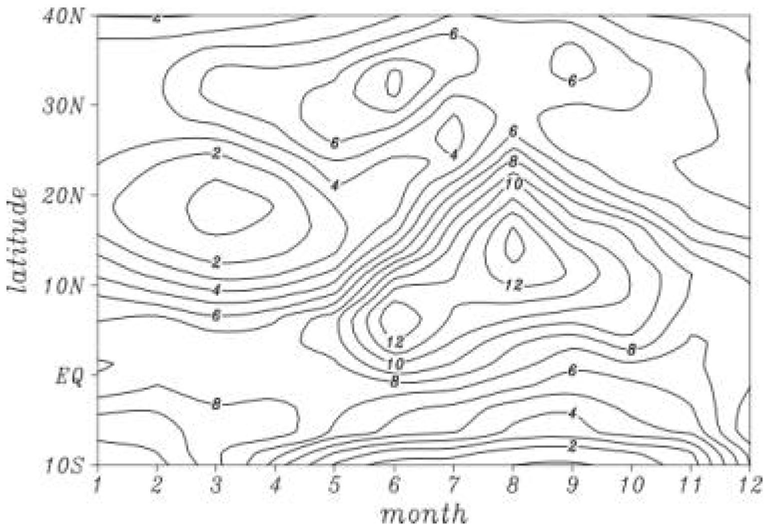

Fig. 1 Time-latitude cross section of monthly precipitation averaged between 125°E and 150°E for 20 years. The unit is mm day^{-1}.

4. Three types of the seasonal change

In order to examine the year-to-year variation of the northward shift of the intense precipitation area, we used the latitude of northernmost edge of the precipitation area of 16mm day^{-1} between 125°E and 140°E. The latitudes of the northern edge of the intense precipitation in June are compared with those in August for the individual years in Fig. 2. If a peak value is less than 16mm day^{-1}, the latitude of the maximum precipitation is used instead.

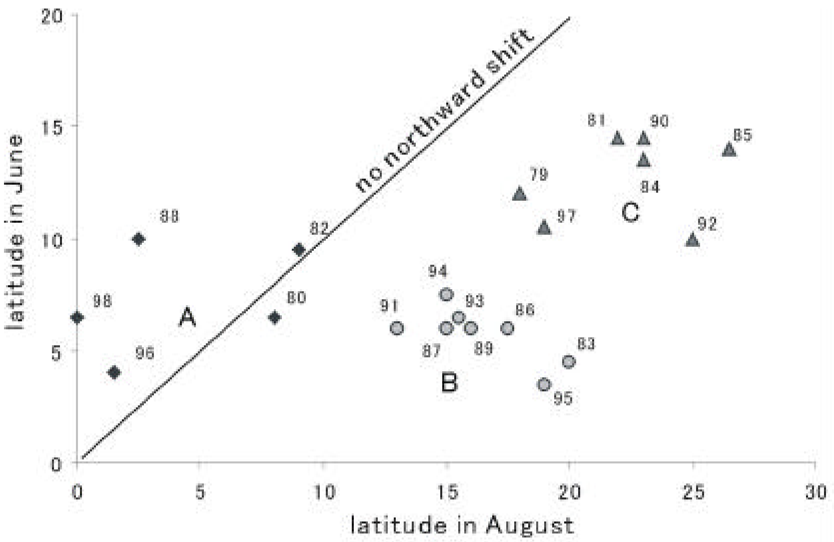

Fig. 2 Scatter diagram of northernmost latitude of the intense precipitation area (16mm day^{-1}) in June and August from 1979 to 1998. Squares, circles and rectangles indicate Groups A, B and C, respectively.

According to this diagram, we classified the pattern of the northward shift of precipitation into three groups; Group A shows no northward shift or rather a southward shift, Group B shows a northward shift from around 5°N to 15°N, and Group C shows a northward shift from around 15°N to 25°N.

Distributions of the precipitation from June to August, averaged with respect to Groups A, B and C, are shown in Fig. 3.

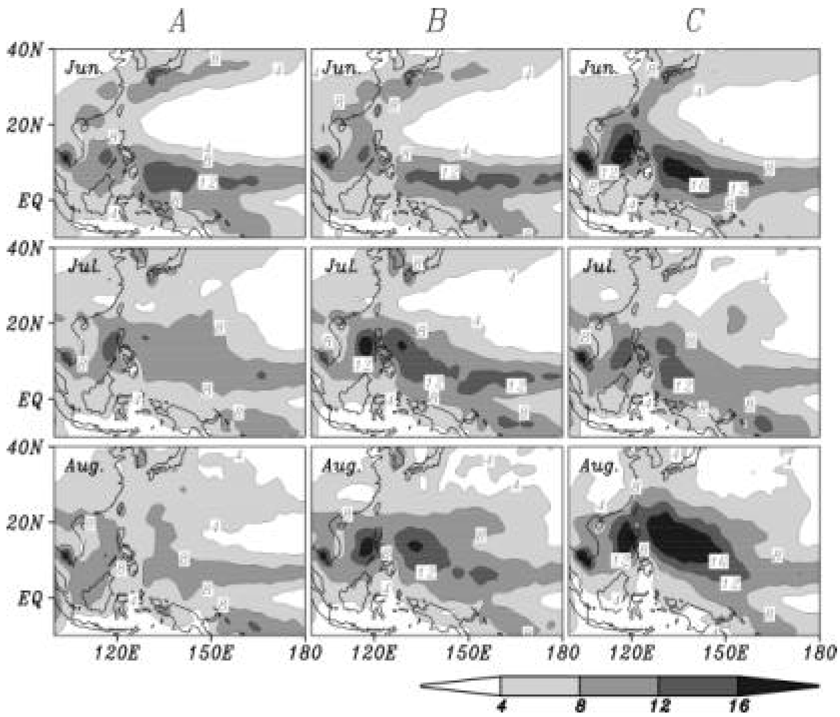

Fig. 3 Distributions of the monthly precipitation from June to August averaged with respect to A, B and C. The unit is mm day^{-1}.

Characteristics of each group are summarized as follows;

Group A: There is neither precipitation increase nor northward shift from June to August. The intense precipitation area of June disappears in July. In August, precipitation to the east of the Philippines is extremely weak comparing with other groups.

Group B: Precipitation increases gradually and the peak shifts northward from 5°N to 15°N. In July, the peak value of precipitation to the east of the Philippines shows most intense in three groups.

Group C: The precipitation amount is relatively large in June, decreases in July, and increases significantly to reach the maximum in August. The peak shifts northward from 15°N to 25°N.

5. Relation between the variation of the precipitation and moisture field

For the purpose of this study the relationship is examined between precipitation and the moisture field, moisture flux and moisture flux convergence at the lower level averaged for Groups A, B and C from June to August. To examine quantitatively the moisture flux around the Philippines in Groups A, B and C, two boxes were set on the east and west sides of the Philippines. We will refer to the west (east) box as Box W (Box E) and the boxes for moisture fluxes from the north, south, east, and west sides as Flux N, S, E and W, respectively. Box W is located from 110°E to 120°E and from 5°N to 20°N and Box E from 120°E to 140°E (Fig. 4).

Flux W of both boxes shows good agreement with precipitation to the east of the Philippines except for Group A in June in which the moisture fluxes are small but Flux E of Box E is significantly large. In the case of Group B, the moisture fluxes increase gradually from June to August. In Group C, the moisture fluxes are large in June, once decrease in July and increase significantly in August. All of which correspond to the precipitation. On the other hand, Flux S of Box E has no clear difference between Groups B and C. It is expected that the three types of seasonal change of precipitation in Groups A, B and C shown in Fig. 3 correspond more to the change of the westerly moisture fluxes than those of southerly or easterly moisture fluxes. Flux N of Box W, which is toward China, also decreases gradually from June to August and is significantly smaller in Group C. This corresponds to precipitation in China.

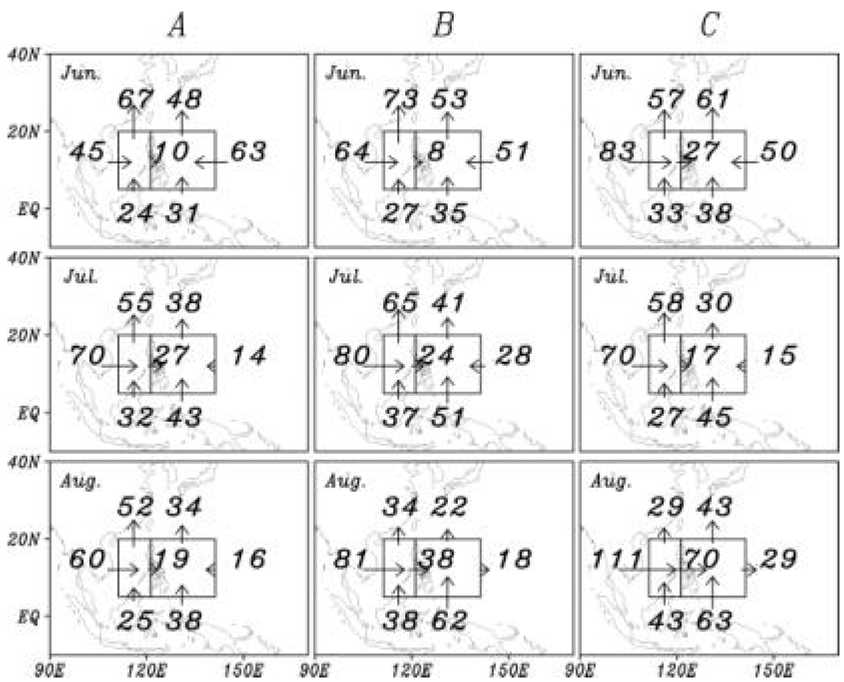

Fig. 4 Monthly mean zonal and meridional moisture fluxes at 925 hPa passing across boundaries of the two boxes from June to August averaged in Groups A, B and C, respectively. Arrows indicate the positive direction of flux. The unit is 10^{-3} kg m^{-2} s^{-1}.

6. Seasonal change of surface pressure

In order to find a relationship to the moisture flow at lower level around the Philippines, we examine surface pressure field. Figure 5 shows monthly anomaly of surface pressure averaged with respect to Groups A, B and C.

In June, a positive anomaly is present to the northeast of the Philippines, which is significantly large in Group A, while relatively small in Groups B and C. On the other hand, in August, a negative anomaly is present in the same region, which is significant in Group C, weaker in B and the weakest in A. This positive (negative) anomaly intensifies (weakens) the easterly moisture flow to the east of the Philippines and weakens (intensifies) the westerly moisture flow to the west of the Philippines. Moreover, this intensification of the cyclonic anomaly weakens the northward moisture flow to the west of the Philippines toward China at the low level. This corresponds to the moisture fluxes shown in Fig. 4. As the negative anomaly to the northeast of the Philippines increases from June to August and in order of Groups A, B and C, Flux N of Box W decreases while Flux W of Box W increases.

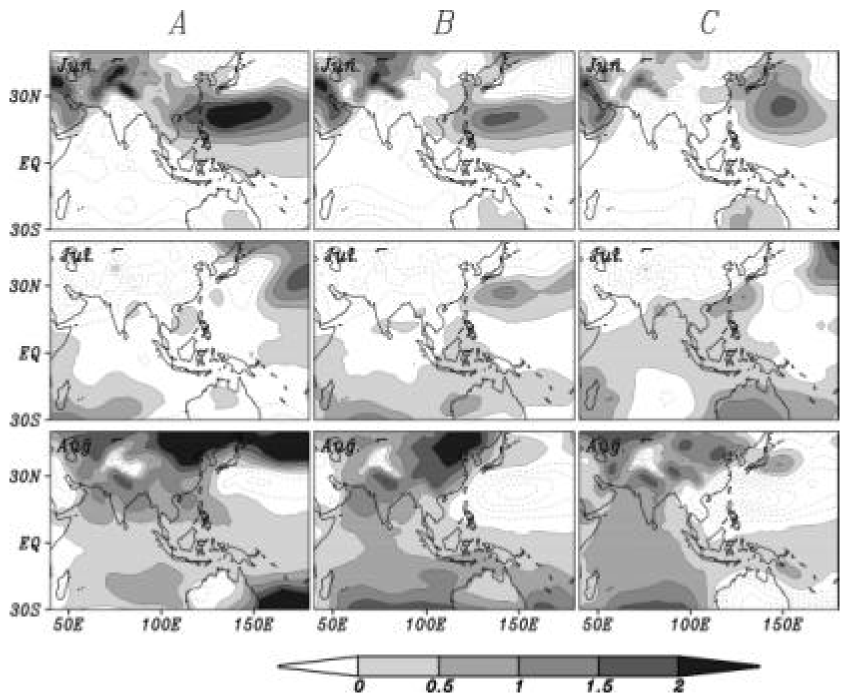

Fig. 5 Anomaly of monthly mean surface pressure from June to August with respect to Groups A, B and C. The anomaly is defined as a deviation from the averaged surface pressure of June, July and August during the period from 1979 to 1998.The unit is hPa.

7. Summary

Three types of seasonal change for precipitation in the western Pacific from June to August were identified with respect to the latitude of the intense precipitation area. Corresponding to these patterns, moisture flux and pressure fields also have characteristics features in individual Groups.

From moisture flux at 925 hPa, seasonal changes of precipitation, classified into A, B and C, have good agreement with the change of the westerly moisture flux from the Indian monsoon regions whereas the southerly and easterly moisture fluxes have no significant correspondence to the classification.

Seasonal changes of sea level pressure averaged in Groups A, B and C, individually, show that a positive anomaly appears in the region to the northeast of the Philippines in June and that it weakens and changes into a negative anomaly in August. The negative anomaly is intense in the order of C, B and A. This anomaly indicates the intensification of the cyclonic circulation anomaly to the northeast of the Philippines. It is found that the decrease of the sea level pressure is in good correlation with the increase of the westerly moisture fluxes through the strengthening of the cyclonic circulation anomaly to the northeast of the Philippines.

References

Huang, R. H. and F. -Y. Sun, 1992: Impact of the tropical western Pacific on the East Asian summer monsoon. *J. Meteor. Soc. Japan*, **70**, 243-256.

Lau, K. -M., 1990: Seasonal and intraseasonal variations of the East Asian summer monsoon. *East*

Asia and Western Pacific Meteorology and Climate, Eds. Sham and Cheng, World Scientific Press, 94-104.

______, 1992: East Asian summer monsoon rainfall variability and climate teleconnection. *J. Meteor. Soc. Japan*, **70**, 211-242.

Murakami, T. and J. Matsumoto, 1994: Summer monsoon over the Asian continent and western north Pacific. *J. Meteor. Soc. Japan*, **72**, 719-745.

Nitta, Ts., 1986: Long-term variation of cloud amount in the western Pacific region. *J. Meteor. Soc. Japan*, **64**, 373-390.

______, 1987: Convective activities in the tropical western Pacific and their impact on the Northern Hemisphere summer circulation. *J. Meteor. Soc. Japan*, **65**, 373-390.

______ and S. Yamada, 1989: Recent warming of tropical sea surface temperature and its relationship to the Northern Hemisphere circulation. *J. Meteor. Soc. Japan*, **67**, 375-383.

Ueda, H., T. Yasunari and R. Kawamura, 1995: Abrupt seasonal change of large-scale convective activity over the western Pacific in the northern summer. *J. Meteor. Soc. Japan*, **73**, 795-809.

______ and ______, 1996: Maturing process of the summer monsoon over the western north Pacific. -A coupled ocean / atmosphere system- *J. Meteor. Soc. Japan*, **74**, 493-508.

Xie, P. and P. A. Arkin, 1996: Analyses of global monthly precipitation using gauge observations, satellite estimate, and numerical model predictions. *J. Climate*, **9**, 840-858.

______ and ______, 1997: Global precipitation: a 17-year monthly analysis based on gauge observations, satellite estimates, and numerical model outputs. *Bull. Amer. Meteor. Soc.*, **78**, 2539-2558.

Yasunari, T., 1979: Cloudiness fluctuations associated with the Northern Hemisphere summer monsoon. *J. Meteor. Soc. Japan*, **57**, 227-242.

______ and Y. Seki, 1992: Role of Asian monsoon on the interannual variability of the global climate system. *J. Meteor. Soc. Japan*, **70**, 177-189.