Interannual and Seasonal Variation of Water Circulation over East Asia and the Western Pacific

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ABSTRACT

Interannual and seasonal variations of precipitation in East Asia and the western Pacific from June to August were investigated. According to latitudes of intense precipitation area to the east of the Philippines in June and August, three types of seasonal change of precipitation are classified into Groups A, B and C. Corresponding to this classification, seasonal change of moisture flux and surface pressure showed different characteristics respectively. Especially, it is found that these seasonal changes of precipitation to the east of the Philippines correspond to the amount of moisture flux from the west. The seasonal changes of the moisture fluxes from the west correspond to seasonal changes of surface pressure anomaly to the northeast of the Philippines. A negative surface pressure anomaly to the northeast of the Philippines strengthen anomaly of cyclonic circulation over there, which results in intensification of the westerly moisture flow to the Philippines. Moreover, the three types of seasonal change of precipitation correlate to seasonal changes of precipitation in China through the northward moisture flow from the area to the east of the Philippines toward China.

1. Introduction

The tropical western Pacific region is noted as the strong convective activity and the highest SST region which affects to the Asian monsoon and the global–scale meteorology (*e.g.,* Yasunari,1979; 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 variability of the convective activities in the tropical western Pacific and water circulation in East Asia and the western Pacific region. The seasonal change 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 the convective activities 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 the precipitation and associated moisture circulations and to investigate the water circulation over East Asia and western Pacific region. Mainly, we focus on the distribution pattern of the precipitation and its relationship with atmospheric conditions.

2. Data

The data utilized in this study were global monthly precipitation data of CMAP (the Climate Prediction Center Merged Analysis of Precipitation) (Xie and Arkin, 1996; Xie and Arkin, 1997) and monthly mean 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 is 2.5°in latitude and longitude. The analyzed area is East Asia and western Pacific region, and special attention was payed to the area to the east of the Philippines.

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 (Fig.1).

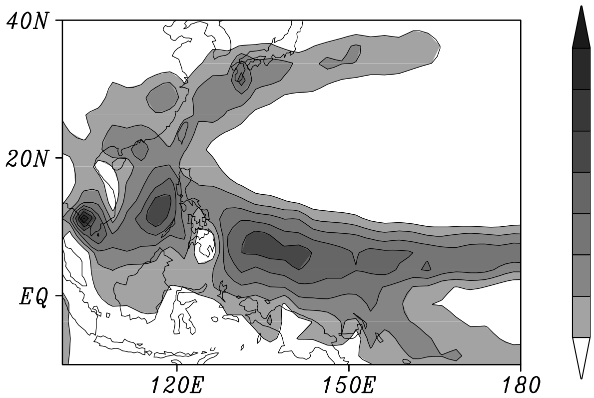

Fig. 1 Distributions of precipitation averaged from June to August in 20–year. The unit is mm day^{-1}.

We focus on intense precipitation to the east of the Philippines to investigate water circulation between these precipitation areas. 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°E and 150°E including these large precipitation area for 20 years is shown in Fig.2.

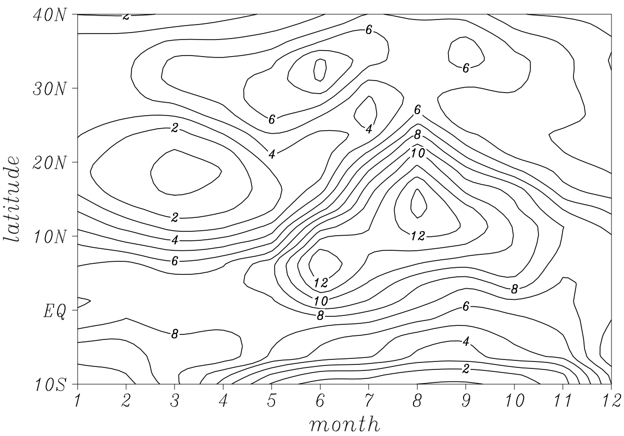

Fig. 2 Time–latitude cross section of monthly precipitation averaged between 125°E and 150°E for 20 years. The unit is mm day^{-1}.

From Fig.2, it is clear that the averaged precipitation peak shows a significant northward shift from 5°N to 15°N from June to August. The maximum reaches suddenly 12mm day^{-1} in June, once it is weakened in July and reaches 13mm day^{-1} in August. After August, the peak shifts southward until December.

4. Three types of the seasonal change

In order to examine the year to year variation of the northward shift of intense precipitation area, we used the latitude of northernmost edge of the precipitation area of 16$mm\ day^{-1}$ between 125°E and 140°E. The latitudes of the northern edge of the intense precipitation in June compared with those in August for the individual years in Fig.3. If a peak value is less than 16$mm\ day^{-1}$, the latitude of the maximum precipitation is used instead.

According to this diagram, we classified the pat-

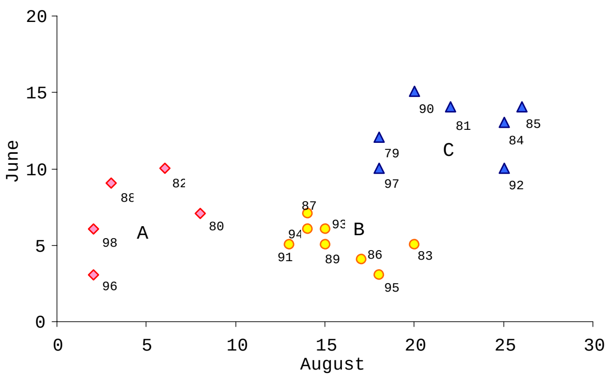

Fig. 3 Scatter diagram of northernmost latitude of the intense precipitation area (16mm day^{-1}) in June and August from 1979 to 1998. The squares, circles and rectangles indicate Groups A, B and C, respectively.

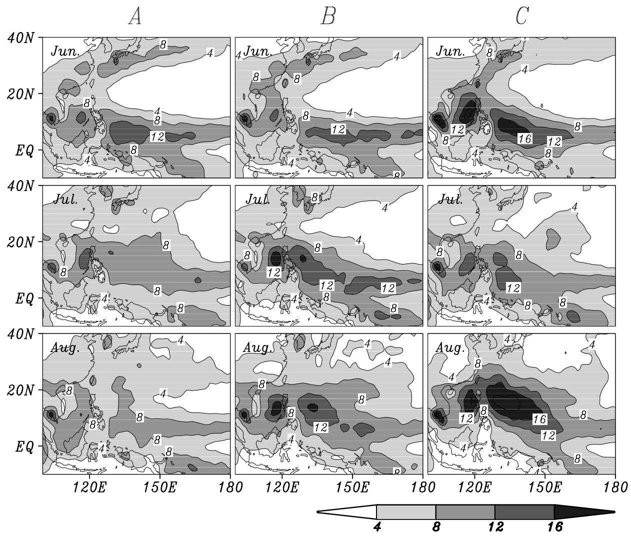

Fig. 4 Distributions of the monthly precipitation from June to August averaged with respect to A, B and C. The unit is mm day^{-1}.

tern of the northward shift of precipitation into the three groups; Group A shows no northward shift, or rather southward shift, Group B the northward shift from around 5°N to 15°N, and Group C the 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.4.

Characteristics of each group are summarized as follows;

Group A: there are neither precipitation increase nor northward shift from June to August. Intense precipitation area of June disappears in July. In August, precipitation to the east of the Philippines extremely weak compared 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 indicate most intense in three groups.

Group C: 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 to study a relationship between the precipitation and moisture field, moisture flux and moisture flux convergence at the lower level were averaged for Groups A, B and C from June to August are examined (Fig.5).

Distributions of the moisture flux convergence closely resemble to those of the precipitation. Paying attention to the moisture flux indicated by arrows, there are three major moisture flows; the westerly moisture flow which comes from the Indian monsoon westerly, the southwesterly moisture flow from the southeasterly to the north of Australia and the easterly moisture flow which is dominant widely in the tropical western Pacific. These moisture flows make convergence or confluent and results in northward moisture flow toward China and Japan.

To examine quantitatively the moisture flux around the Philippines in Groups A, B and C, we set two boxes on the east and west sides of the Philippines. We will refer to the west (east) box as Box

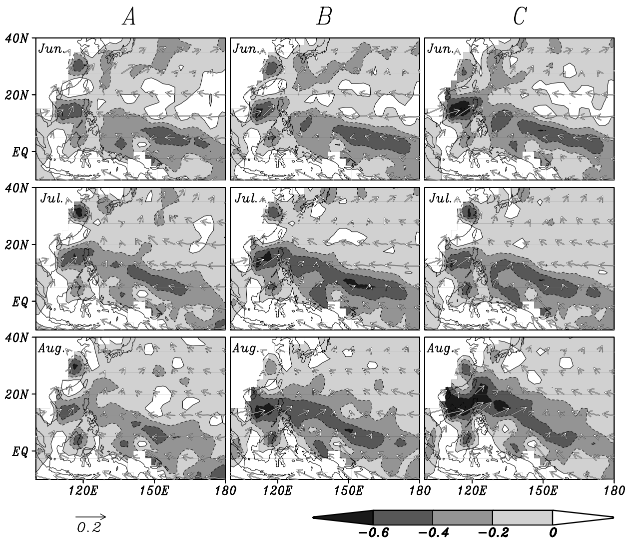

Fig. 5 As in Fig.4, but for moisture flux (kg m^{-2}s^{-1}) and moisture flux divergence (10^{-7}kg m^{-3}s^{-1}) at 925 hPa.

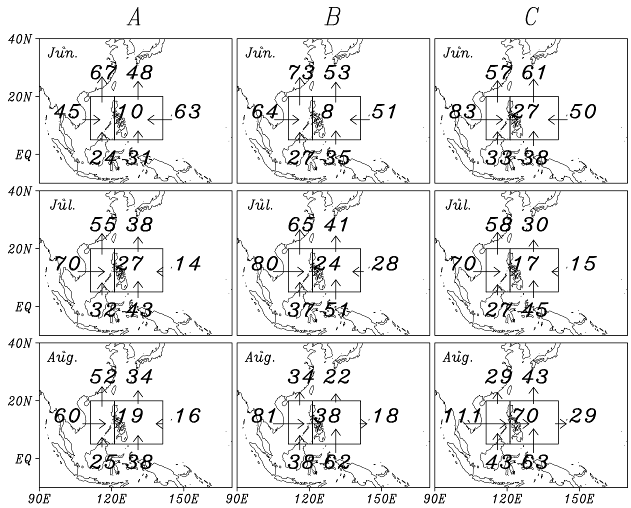

Fig. 6 Monthly mean zonal and meridional moisture fluxes at 925 hPa passing across boundaries of the two boxes from June to August averaged in Groups A, B and C, respectively. Arrows indicate the positive direction of flux. The unit is 10^{-3}kg m^{-2}s^{-1}.

W (Box E) and the moisture fluxes which through the north, south, east, and west sides as Flux N, S, E and Flux 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.6).

Flux W of both boxes and Flux S of Box W shows good agreement with precipitation except Group A in June in which these moisture fluxes are small but Flux E of Box E is significantly large. In the case of Group B, these moisture fluxes increase gradually from June to August. In Group C, these moisture fluxes are large in June, once decrease in July and increase significantly in August. These correspond to the precipitation. On the other hand, Flux S of Box E have no clear difference between Groups B and C. It is expected that the three types of the seasonal change of moisture flux convergence in Groups A, B and C shown in Fig.5 correspond mainly to the change of the westerly moisture fluxes than those of southerly or easterly moisture fluxes. Flux N of Box W toward China, also decreases gradually from June to August and is especially small in Group C. It correspond to precipitation in China. This result will be discussed later.

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 7 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 and it 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 and it is significant in Group C and 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 north-

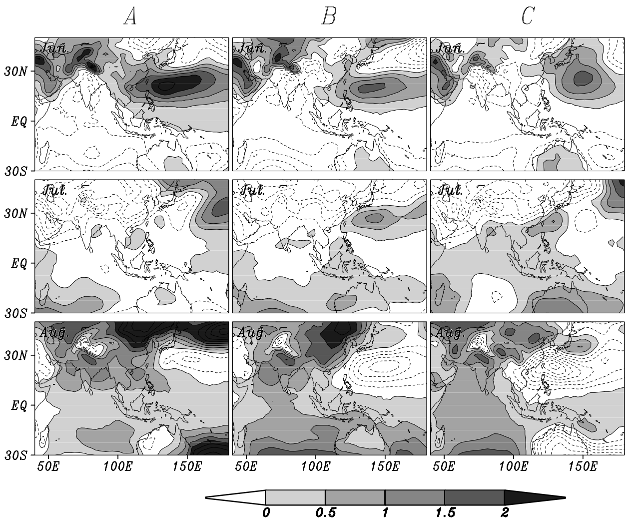

Fig. 7 Anomaly of monthly mean surface pressure from June to August with respect to Groups A, B and C. The anomaly is defined as a deviation from the averaged surface pressure of June, July and August during the period from 1979 to 1998.The unit is hPa.

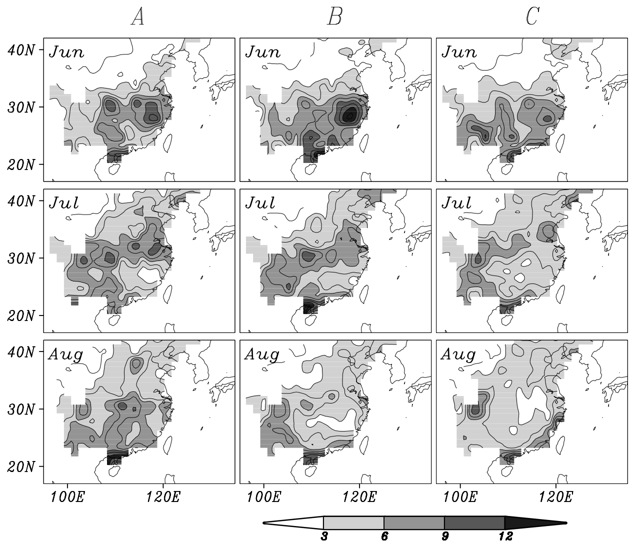

Fig. 8 Anomaly of monthly mean surface pressure from June to August with respect to Groups A, B and C. The anomaly is defined as a deviation from the averaged surface pressure of June, July and August during the period from 1979 to 1998.The unit is mm day^{-1}.

ward moisture flow to the west of the Philippines toward China at low level. These correspond to moisture fluxes in Fig.6. Flux W to Box W increases and Flux N from Box W decreases in order of Groups A, B and C from June to August.

7. Variation of the precipitation in China

In order to investigate a relationship between the seasonal changes of precipitation around the Philippines and a precipitation in China in Mei–Yu season, distributions of the monthly precipitation in China from June to August averaged with respect to A, B and C are shown in Fig.8.

In China, it is common to Groups A, B and C that a monthly precipitation decreases gradually from June to August. However, these Groups have different features each other. Group A has intense precipitation from June to August, Group B has it from June to July and Group C has weak precipitation instead. Especially in June and July, the precipitation is intense in Group B, and in August, it is intense in Group A and weak in Group C. These results correspond to that Flux N from Box W (Fig.6) is large in Group B in June and July, and large in Group A and small in Group C in August.

8. Summery

Three types of seasonal change of precipitation in the western Pacific from June to August were identified utilizing 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 change 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 the positive anomaly appears in the region to the northeast of the Philippines in June and that it weakens and is changed into the negative anomaly in August. The negative anomaly is intense in 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 cyclonic circulation anomaly to the northeast of the Philippines.

Further, precipitation in China correspond vary much to the northward moisture flux from the area to the west of the Philippines.

References

Huang, R. H. and F.–Y. Sun, 1992: Impact of the tropiacal 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 mnsoon. *East Asia and Western Pacific Meteorology and Climate, Eds. Sham and Cheng, World Scientific Press*, 94–104.

Lau, K.–M., 1992: East Asian summer monsoon rainfall variability and climate teleconection. *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.

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

Nitta, Ts. 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.

Ueda, H. and T. Yasunari, 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.

Xie, P. and P. A. Arkin, 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.

Yasunari, T. and Y. Seki, 1992: Lole of Asian monsoon on the interannual variability of the global climate system. *J. Meteor. Soc. Japan*, **70**, 177–189.