The East Asian summer monsoon circulation anomaly index and its interannual variations

HUANG Gang* and YAN Zhongwei

Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing 100029, *China*

* *Corresponding author. E-mail: hg@sgi50s.iap.ac.cn*

Abstract Based on the concept of East Asia-Pacific (EAP) teleconnection which influences East Asian summer monsoon, an index for East Asian summer monsoon circulation anomaly was defined and it was pointed out that this index can describle the interannual variation character of summer climate in East Asia, especially in the Yangtze River and Huaihe River Valley.

Keywords: East Asian monsoon, monsoon circulation anomaly index, East Asia-Pacific (EAP) teleconnection pattern, interannual variation.

MONSOON index is not only a criterion of measuring the strength of monsoon, but also a precondition for researching the interannual variations of monsoon. Because China is located in the East Asian monsoon region, much attention has long been paid to the definition of the East Asian summer monsoon. For a long time, many scholars have studied this problem[1—6] and put forward various definitions. However, since the focuses of these researchers are different, there are many differences among the indices of the East Asian summer monsoon. Due to the complexity of the East Asian monsoon system, each index cannot reflect all characteristics of the East Asian summer monsoon. In fact, the variations of East Asian summer

monsoon climate are closely related to some special large-scale circulation anomalies, therefore, concerning the large-scale circulation anomalies is important in the investigation of this problem.

Some previous studies[7,8] show that the East Asian summer monsoon has a close relationship with the East Asia-Pacific (EAP) teleconnection pattern. Therefore, in this note based on the concept of the EAP teleconnection pattern, we defind an index of the East Asian summer monsoon circulation anomalies, and investigated the relation between this circulation index and the interannual variations of the rainfall and other climatic elements related to the East Asian summer monsoon.

1 Data and method

Using NMC (NCEP) monthly data from 1946 to 1957, the monthly data from 1958 to 1996 reanalyzed by NCAR/NCEP, and the data of rainfall and temperature at 160 stations in China from 1951 to 1996, with the methods of statistical correlation and composite analysis, we examined the relationship between the 500 hPa geopotential height anomalies in East Asia and the resultant drought and flood in the eastern part of China in summer. Special attention was paid to the following two regions: the Yangtze River and the Huaihe River Valley (29°N—33°N, 114°E—125°E) and North China (34°N—40°N, 110°E—125°E).

2 Definition of East Asian summer monsoon circulation anomaly index and other indices

Because the EAP teleconnection pattern has a close relationship with the East Asian summer monsoon[7,8], we defined an East Asian summer monsoon circulation anomaly index (or EAP index in short, I_{EAP}), and studied the relationship between the interannual variations of the East Asian summer monsoon circulation anomaly and the interannual variations of some climatic elements in the East Asia summer monsoon region. The definition of I_{EAP} is

$$I_{EAP} = \mathrm{Nor}(-0.25Z_s'(20°\mathrm{N},125°\mathrm{E}) + 0.50Z_s'(40°\mathrm{N},125°\mathrm{E}) - 0.25Z_s'(60°\mathrm{N},125°\mathrm{E})), \quad (1)$$

where $Z' = Z - \bar{Z}$ (Z is the seasonal-mean 500 hPa geopotential height in a summer, $\bar{Z}$ is the climatological-mean geopotential height), $Z_s' = Z'\sin 45°/\sin\varphi$, φ is the latitude. $\mathrm{Nor}(X)$ means the normalization of X.

We also defined other indices in order to study the relationship between the north boundary of the East Asian summer monsoon and the transportation of the water vapor field. One is the regional south wind area index in North China in summer. In this region, we calculated the anomalous number of the grid points with south wind $v \geqslant 1$ m/s and performed the normalization. This index can describe the advance and retreat of south wind in summer. Although the region is fixed, it can reflect the northward advance of the East Asian summer monsoon, because the East Asian summer monsoon has an obvious northward or southward movement in together. In addition, according to the definition of pseudo-equivalent temperature by Tu and Huang[9] and the calculating method suggested by Ding[10], we calculated the variability of pseudo-equivalent temperature, and defined the region's pseudo-equivalent temperature strength index in North China. It is calculated over the whole region and is normalized. This strength index can show the strength of water vapor transportation in the East Asian summer monsoon region. Because the stream field and the water vapor field at 700 hPa have the most obvious character, we used the 700 hPa data reanalyzed by NCAR/NCEP to calculate the above-mentioned indices.

3 Result

Figure 1 shows the interannual variations of I_{EAP} calculated by using formula (1). It shows that in the summers of 1954, 1980, 1983 and 1991, when floods occurred in the Yangtze River and the Huaihe River Valley, the EAP index was smaller than or equal to -1. On the contrary, in the summers of 1994, 1961 and 1978, when droughts occurred in the Yangtze River and the Huaihe River Valley, the EAP index was larger than or equal to 1. The summer of 1991 was a serious flood season in the Yangtze River and the Huaihe River Valley, but the index was not so small as expected. This may be due to the fact that the EAP index was negative in June and July, but this index turned to stronger positive in August, 1991.

In order to investigate the difference between the circulation in the summers with high I_{EAP} and that in the summers with low I_{EAP}, a composite method was used to study the anomalies of 500 hPa geopotential height fields over East Asia in summer. When I_{EAP} is greater than or equals 1, the index is defined as a high index, on the contrary, when I_{EAP} is smaller or equals -1, the index is defined as a low index. Fig. 2(a), (b) shows the 500 hPa geopotential height anomaly patterns for the summer with high I_{EAP} and for the summer with low I_{EAP}, respectively. From fig. 2(a), (b) it may be seen that the 500 hPa geopotential height anomaly pattern for the summer high I_{EAP} is opposite to that for the summer with low I_{EAP}. When I_{EAP} is higher, the western Pacific subtropical high shifts northward, and drought in summer may occur in the Yangtze River and the Huaihe River Valley; on the contrary, when I_{EAP} is lower, the western Pacific subtropical high shifts southward, and flood may occur there in summer.

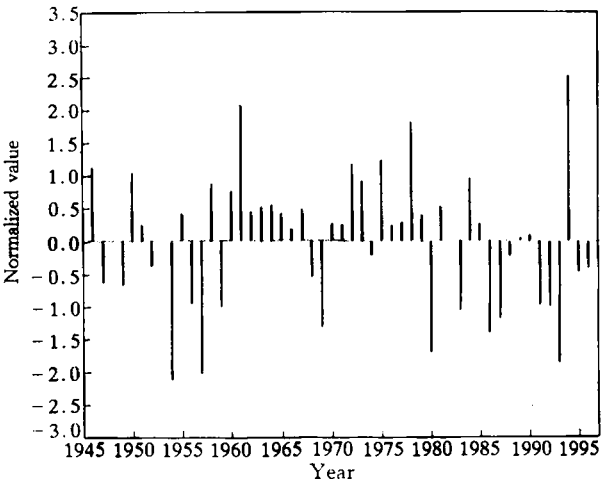

Fig. 1. Interannual variations of the East Asian summer monsoon circulation anomaly index from 1946 to 1996.

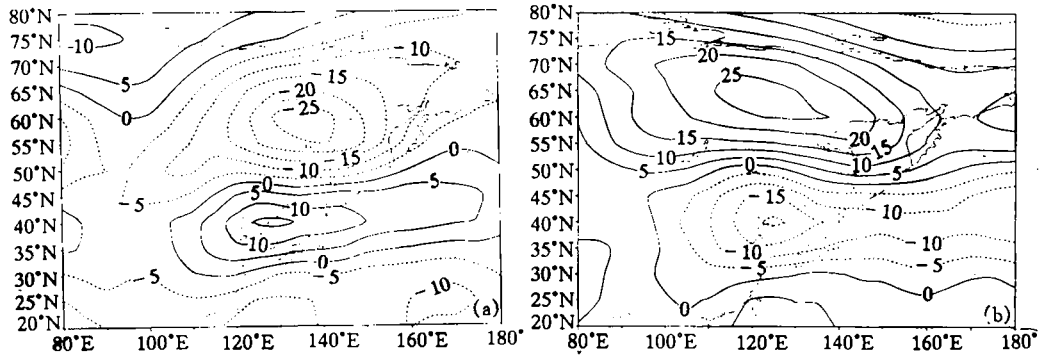

Fig. 2. The composite 500 hPa geopotential height anomalies in East Asia for the summers with high index ((a) $I_{EAP} \geq 1$) and with low index ((b) $I_{EAP} \leq -1$), respectively (unit: GPM).

In order to study the relationship between this index and other climatic elements in the eastern part of China, we calculated the variations of rainfall and temperature in the Yangtze River and the Huaihe River Valley, and the variations of south wind area index and pseudo-equivalent temperature strength index in North China. Fig. 3(a) shows the interannual variations of the East Asian summer monsoon circulation anomaly index and the seasonal mean rainfall and temperature in the Yangtze River and the Huaihe River Valley in summer, and fig. 3(b) indicates the interannual variations of I_{EAP}, the south wind area index and the pseudo-equivalent temperature strength index in North China in summer. It can be seen from fig. 3 that there is a negative correlation between I_{EAP} and the rainfall of the Yangtze River and the Huaihe River Valley, and a positive correlation between I_{EAP} and the temperature in the Yangtze River and the Huaihe Valley. Moreover, there is a positive correlation between I_{EAP} and the south wind area index and pseudo-equivalent temperature strength index in North China. All the correlation coefficients pass

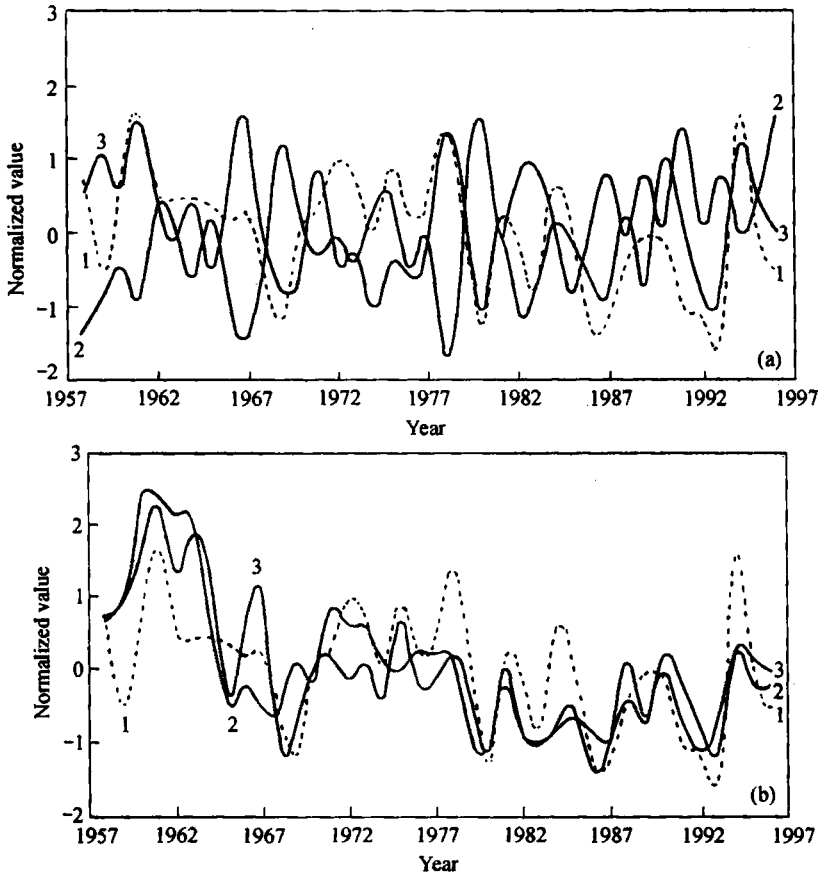

Fig. 3. (a) The interannual variations of the East Asian summer monsoon circulation anomaly index (curve 1) and the interannual variations of the normalized rainfall (curve 2) and temperature anomalies (curve 3) in the Yangtze River and Huaihe River Valley in summer. (b) The interannual variations of the East Asian summer monsoon circulation anomaly index (curve 1) and the interannual variations of the south wind area index (curve 2) and the pseudo-equivalent temperature strength index (curve 3) in North China.

99% statistical significance test. Thus, there are close relations between I_{EAP} and these elements, and it can be said that I_{EAP} has a close relationship with the climatic elements variations in East Asia. This index can show not only the variations of rainfall or temperature in the Yangtze River and the Huaihe River Valley, but also the northward shift of the East Asian summer monsoon system and the northward transportation of water vapor. In short, I_{EAP} can well describe the interannual variations of the East Asia summer monsoons.

4 Conclusions

There is a close relationship between the EAP pattern and the drought and flood patterns in East Asia, especially in the Yangtze River and the Huaihe River Valley in summer. When the East Asian summer monsoon circulation anomaly index I_{EAP} is above normal, droughts occur in the Yangtze River and Huaihe River Valley, on the contrary, when the I_{EAP} is below normal, floods happen there.

I_{EAP} defined in this note can describe the interannual climatic variability in East Asia. It can describe not only the variations of the rainfall and temperature in the Yangtze River and the Huaihe River Valley, but also the northward shift of the East Asian summer monsoon system and the northward transportation of water vapor.

Acknowledgement The authors are grateful to Prof. Yeh T.C. for supervision and to Dr. Lu R. Y. and Dr. Wu B.Y. for their

help. This work was supported by State Key Program "96-908" and the Major Project "Asian Monsoon Change and Global Change" of the Chinese Academy Sciences.

References

1 Chang, C.P., Krishnamnti, T.N., *Monsoon Meteorology*, New York: Oxford University Press, 1987, 60—93.
2 Chen, L.X., Zhu, Q.G., Luo, H.B. *et al.*, *East Asian Monsoon* (in Chinese), Beijing: China Meteorological Press, 1991, 192—244.
3 Guo, Q.Y., East Asian summer monsoon strength index and its variation, *Chinese J. Geography. Society* (in Chinese), 1983, 38(3): 207.
4 Webster. P.J., Yang, S., Monsoon and ENSO: Selectively interactive system, *Quart. J.R. Met. Soc.*, 1992, 118: 877.
5 Ye, D.Z., Huang, R.H., *The Study on Rules and Reason of Flood or Drought in Yangtze River and Yellow River Basins* (in Chinese), Jinan: Science and Technological Press of Shandong Province, 1996, 61—93.
6 Zeng, Q.C., Zhang, B.L., Liang, Y.L. *et al.*, East Asian Summer Monsoon——A case study, in *Proc. Indian, Nat. Sci. Acad.*, 1994, 60A(1): 81.
7 Huang, R.H., Sun, F.Y., Impacts of the tropical western Pacific on the East Asian summer monsoon, *J. Meteor. Soc. Japan*, 1992, 72(6): 937.
8 Huang, R.H., The East Asia/Pacific pattern teleconnection of summer Circulation and Climate Anomaly in East Asia, *Acta Meterologica Sinica*, 1992, 6(1): 25.
9 Tu, C.W., Huang, S.S., The advance or retreat of the summer monsoon in China, *Acta Meteorologica Sinica* (in Chinese), 1944, 18: 81.
10 Ding, Y.H., *The Diagnostic Methods in Meteorological Dynamics* (in Chinese), Beijing: Science Press, 1989, 46—47.

(*Received November* 2, 1998)