80a–Oscillation of Summer Rainfall over the East Part of China and East–Asian Summer Monsoon①②

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ABSTRACT

Relationship between summer rainfall over the east part of China and East–Asian Summer Monsoon (EASM) was studied based on the summer rainfall grade data set from 1470 to 1999 and the rain gauge data set from 1951 to 1999 over the east part of China, and sea level pressure (SLP) data for the period of 1871–2000. A distinct 80a–oscillation of summer rainfall was found over North China (NC), southern part of Northeast China, over the middle and lower reaches of the Yangtze River (YR) and South China (SC). The 80a oscillation of summer rainfall over NC was varied in phase with that over SC, and was out of phase to that along the middle and lower reaches of the Yangtze River. Summer rainfall over NC correlated negatively with the SLP averaged for the area from 105°E to 120°E, and from 30°N to 35°N, but positively to that for the area from 120°E to 130°E, and from 20°N to 25°N. Therefore, an index of EASM was defined by the difference of averaged SLP over the two regions. The summer rainfall over NC was greater than normal when the EASM was strong, and while drought occurred along the middle and lower reaches of the Yangtze River. The drought was found over NC, and flood along the middle and lower reaches of the Yangtze River when the EASM was close to normal. Finally, the interdecadal variability of EASM was studied by using of long term summer rainfall grade data set over NC for the past 530 years.

Key words: 80a–oscillation, Summer rainfall over the east part of China, Summer East–Asian monsoon

1. Introduction

The EASM is one of the important factors, which controls summer rainfall over the east part of China. Lots of studies have devoted to examine the relationships between the summer monsoon and flood / drought over the east part of China. Zhu (1934) firstly proposed that the floods or droughts over the east part of China could be attributed to the anomalous intensity of EASM. He has pointed out that there was a negative correlation coefficient (–0.674) between monthly mean July wind speed and precipitation in Shanghai. However, positive correlation occurred between July wind speed in Shanghai and contemporary summer precipitation in Beijing (0.583). So droughts occurred along the lower reaches of the Yangtze River, but floods in North China when the wind blew intensely from the southeast. Guo (1994) found that floods were dominated over the region of Yangtze River and the Huaihe River Valleys when the EASM was near normal, droughts would be found if EASM was too strong or too weak. Zhang (1998) studied on the variation of EASM, which affects the summer rainfall over the east part of China. It showed that the Meiyu front over subtropical East

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Asia was stronger than normal when the summer monsoon was weak, then precipitation was above the normal over the lower reaches of the Yangtze River. Studies revealed that the anomaly of summer rainfall of NC was usually reverse to that over the middle and lower reaches of the Yangtze River (Wang and Zhao, 1979).

The EASM has been studied systematically in 1950's (Gao et al., 1962). Gao et al. had related the monsoon to general circulation and the movement of center of action. It indicated that the migration of the rain belt in summer related closely to the intensity of summer monsoon. Shi et al. (1998) suggested that the rain belt would move northward much more when the summer monsoon was strong. The result from Xu (1979) showed that the wind from south was much strong during the summer months when droughts occurred over the region between the Yangtze River and Huaihe River before 1960, especially near the 30°N.

North China is a region sensitive to the intensity of EASM. From this point of view, EASM would have positive correlation with the summer rainfall over North China. The subtropical High and ITCZ move usually to the north if the summer monsoon is strong and active, then the precipitation will above normal over NC and SC. It belongs to the pattern 3, as defined by Wang et al. (1979). On the opposite, the subtropical High and ITCZ are located southerly when the summer monsoon is near normal, droughts will be found over NC and SC, and flood occurs along the middle and lower reaches of the Yangtze River. This belongs to pattern 1b of rainfall distribution according to Wang and Zhao (1979).

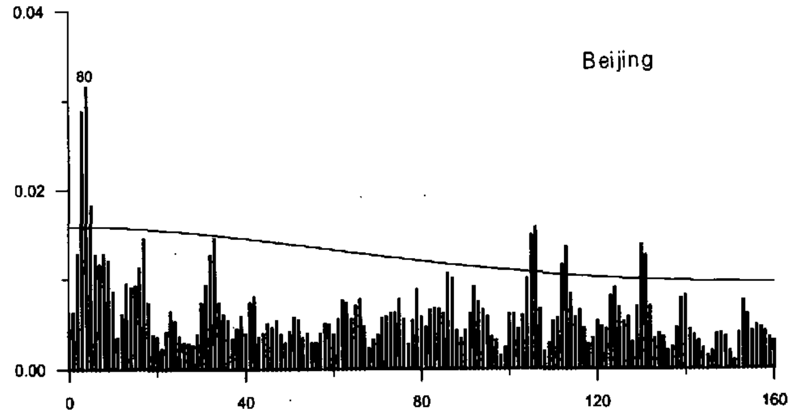
All the studies mentioned above were dealt with interannual variability, interdecadal variability was less examined. Wang and Zhao (1979) revealed that there was an 80a–oscillation of summer rainfall in Beijing and Nanjing by analyzing the 500a summer rainfall grade data set. It infers that there was also interdecadal variability in summer rainfall variations.

In this paper the long series of summer rainfall was analyzed to illustrate the 80a–oscillation over the east part of China, and the relationship between summer rainfall and the intensity of the EASM on interdecadal time scale. Finally, the variation of EASM was described according to the summer rainfall over NC from 1470.

2. 80a–oscillation of summer rainfall over the east part of China

Power spectrum analyses by use of 530 years of rainfall grade data set (1470–1999) showed a clear 80a oscillation in some stations, such as Beijing and Nanjing as, illustrated in Fig. 1. The 80a oscillation component of summer rainfall in Beijing explained about 30% variance in low frequency band. The correlation coefficients (CCs) were calculated between summer rainfall in Beijing and that over the east part of China by using of the instrumentally observed rainfall data set (Fig. 2) and the degrees of floods and droughts data set (Fig. 3). The region with positive CCs was crossed and that with negative CCs was shaded if they reached the significant level of 95%. Both of the two kind data showed the very high positive CCs in NC. It proved again that summer rainfall over NC usually correlated negatively with that along the Yangtze River, and the summer rainfall in Beijing characterized that over NC.

The 80a–oscillation components of summer rainfall of 25 stations were drawn from the wavelet transform. Fig. 4 showed the correlation coefficients of the 80a–oscillation components of summer rainfall between NC and the east part of China. It shows very clearly the positive correlation between NC and SC and negative correlation between NC and the middle and lower reaches of the Yangtze River. The time series of 80a–oscillation components of NC, YR and SC were given in Fig. 5. It illustrated finely the phase of 80a–oscillation components of summer rainfall over NC is in consistency with that over SC, and out of phase that along the Yangtze River.



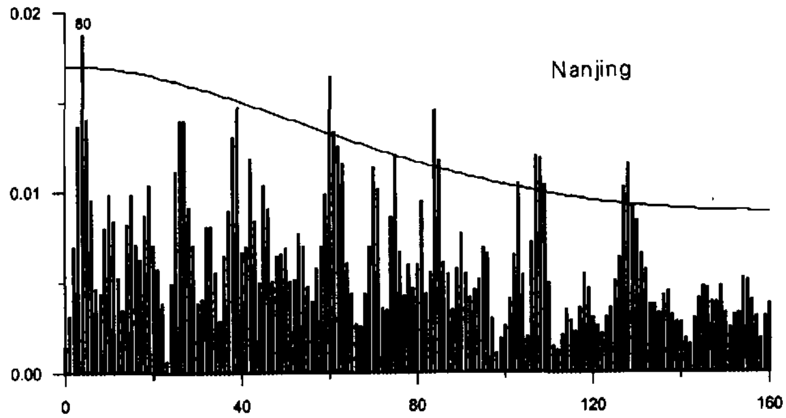


Fig. 1. Power spectra for Beijing (a) and Nanjing (b), by using historical data set from 1470 to 1999 (530a). Abscissa is frequency in cycles per 160 years. Ordinate is relative power. Figures above peaks give period in years. The solid line is the significant level of 95%.

3. Relationship between summer rainfall over NC and the EASM on interdecadal time scale

Studies revealed that summer rainfall related closely to EASM. However, interdecadal scale variability was less examined. In order to study the relationship between summer rainfall and EASM, the index of the EASM was defined. There have been a lot of indexes to describe the intensity of East–Asian monsoon (Huang, 1999). For example, the index from Webster and Yang (1992) was suitable to represent the intensity of large–scale tropical monsoon circulation in South Asia. Guo (1983) defined an index of EAM (East–Asian Monsoon) by using of SLP contrast over East Asia and western Pacific Ocean. A new index of EASM was defined here to describe the intensity of EASM related to summer rainfall over NC. This was

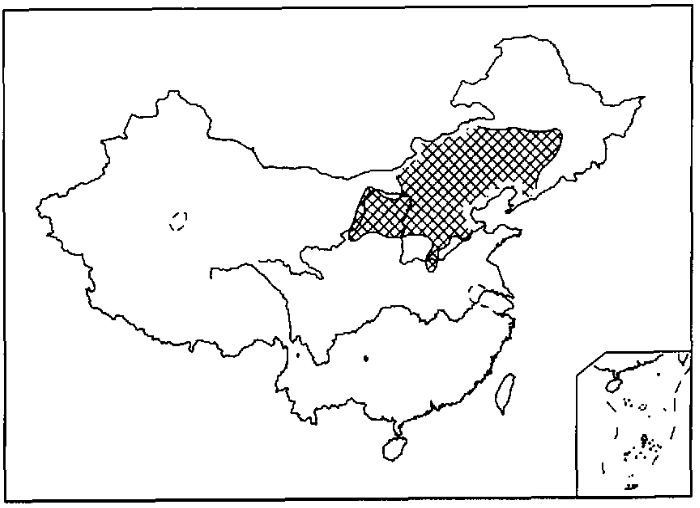


Fig. 2. Correlation coefficients between the summer rainfall in Beijing and that over the east part of China, from 1951 to 1999 of 160 stations.

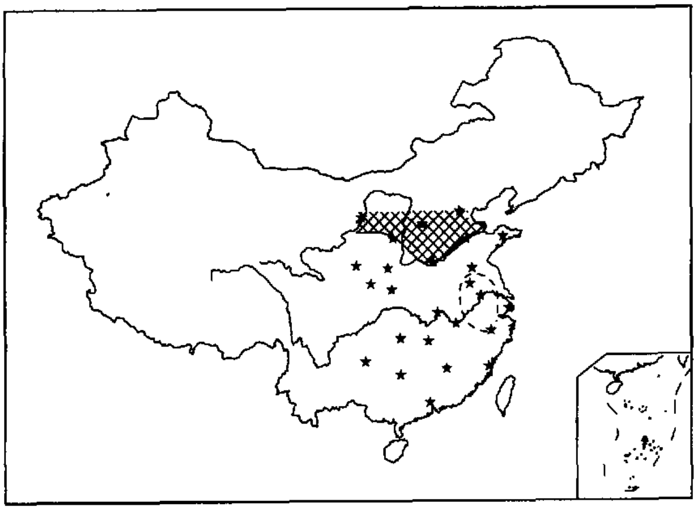


Fig. 3. Correlation coefficients between the summer rainfall grade in Beijing and that over the east part of China, from 1470 to 1999 of 25 stations, the position of 25 stations is showed by black stars.

constructed by the following procedure. Firstly, the correlation coefficients between summer rainfall over NC and SLP of NH from 1951 to 1999 were calculated (Fig. 6). The correlation

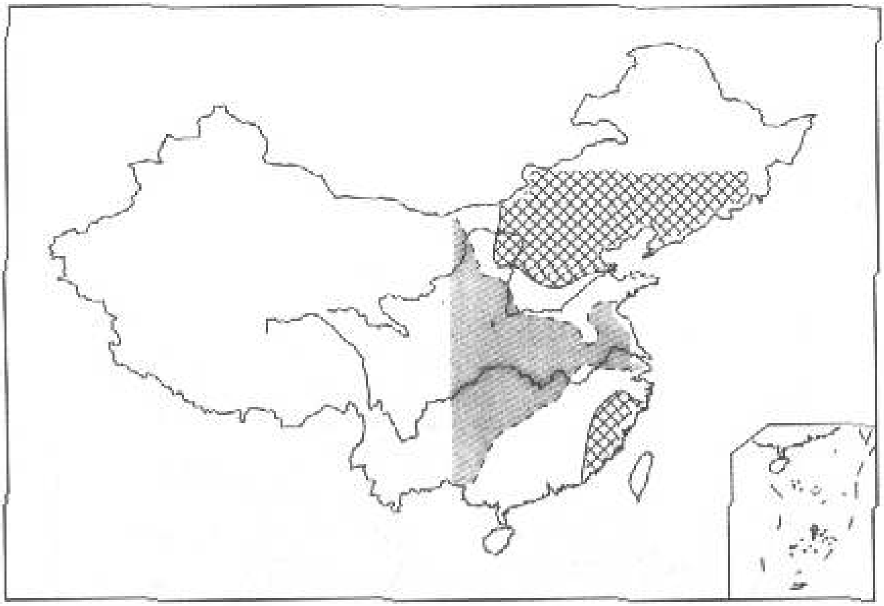


Fig. 4. Correlation coefficients of 80a–oscillation component between summer rainfall in Beijing and that over the east part of China, from 1470 to 1999 of 25 stations.

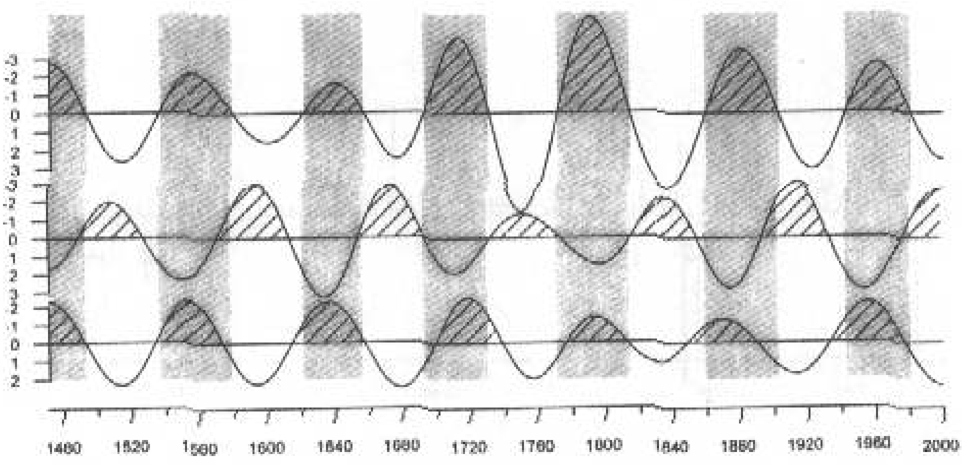


Fig. 5. The 80a–oscillation components of Beijing (a), Nanjing (b) and Fuzhou (c).

coefficients were negative in the region A from 105°N to 115°N and from 30°N to 35°N, but positive in region B (from 120°N to 130°N and 20°N to 25°N). Then, the SLP time series averaged for the region A was subtracted from the SLP time series averaged for the region *B* to form the index of EASM. The index from 1873 to 1979 calculated by using of Hulme's data set and since 1980 it was calculated based on NCEP reanalysis data set. So the index that represented the intensity of EASM was given in Fig. 7. Although the index series was of only 125a, power spectrum analyses for the index showed a significant 80a–oscillation (Fig. 8). The 80a–oscillation component of the index drawn according to wavelet transform analyses was compared *to the 80a component of the summer rainfall over NC (Fig. 9). It revealed that*

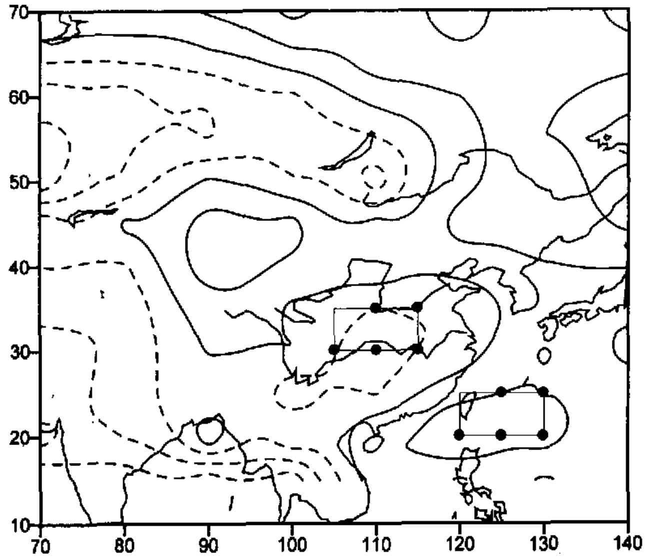


Fig. 6. Correlation coefficients between summer rainfall over NC and SLP from 1951 to 1999.

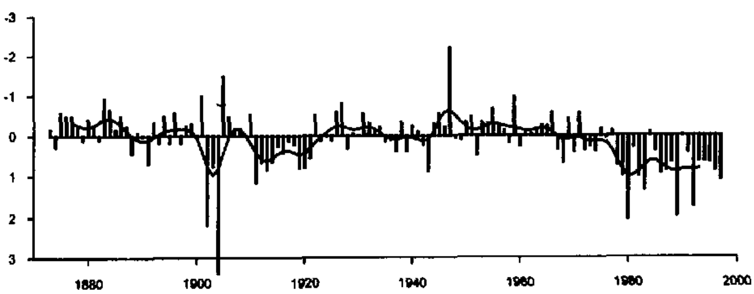


Fig. 7. The Index of the EASM from 1873 to 1997.

the summer rainfall was more than normal over NC when the index of EASM was higher. And it was drought over NC when the index was lower.

Figure 10 showed the summer rainfall over NC in the past 530a and the index of the EASM in the past 125a. From 1873 to 1890 and from 1950 to 1970, the index of the EASM was relatively high, and the summer rainfall was above normal over North China. From 1890 to 1950 and since 1970, the index of summer monsoon was below normal, the summer rainfall was less than normal. The correlation coefficient between summer rainfall and the index from 1873 to 1997 was 0.19, which reached the significant level of 95%. According to Fig. 10, it could be found that the summer rainfall was more than normal during 1530–1580, 1620–1660, 1690–1730, 1770–1810, 1860–1900, 1940–1980, and the summer monsoon might

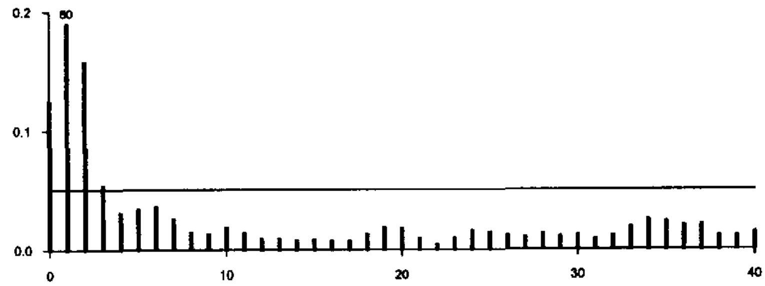


Fig. 8. Power spectra from the index of the EASM. Abscissa is frequency in cycles per 160 years. Ordinate is relative power. Figures above peaks give period in years. The solid line is the significant level of 95%.

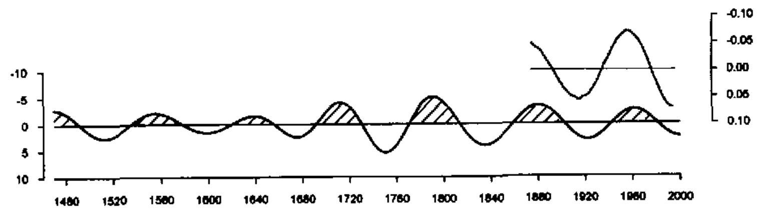


Fig. 9. The 80a–oscillation component of summer rainfall over NC and the index of the EASM.

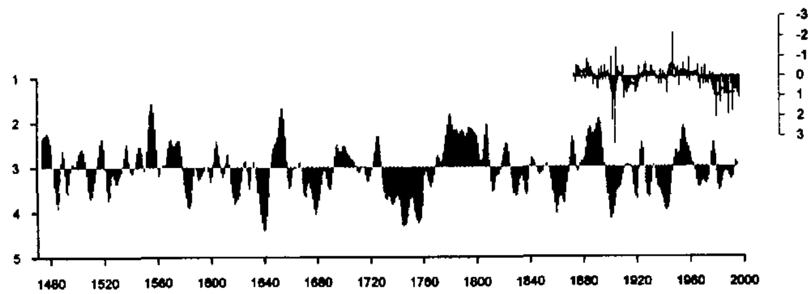


Fig. 10 The variation of the summer rainfall over NC from 1470.

be stronger during the same periods if the relationship kept unchanged. During the other periods, it had less summer rainfall than normal over NC, and the summer monsoon might be weaker.

4. Summary and Discussion

There is a clear 80a oscillation of summer rainfall over the east part of China. The 80a–oscillation component over NC was in phase with that over SC and out of phase to the middle and lower reaches of the Yangtze River. A new index of the EASM was defined; it showed a clear 80a–oscillation although the series was limited only for the last 125a. The summer rainfall over NC related closely to the intensity of the EASM on interdecadal time scale. The summer rainfall over NC and SC would be more than normal, and it would be drought along the middle and lower reaches of Yangtze River when the summer monsoon was strong. So the intensity of East–Asian Summer Monsoon could be inferred from 1470 according to the summer rainfall over NC.

It is very complex for the variation of summer rainfall over the east part of China. There are many factors, which influence the summer rainfall. And the relationship among them is very complex. Many studies showed that only one or several factors couldn't account for the summer rainfall over the east part of China. However, the summer monsoon was one of the most important factors controlled summer rainfall over the east part of China, its interannual variability was very clear and had a significant influence on distribution of summer rainfall over the east part of China.

The mechanism and cause of 80a oscillation of summer monsoon is not to be understood. Wang et al. (1981, 2000) suggested that the movement of the position of rain belt over the east part of China might be related closely to solar activity. It was possible that the variation of solar radiation affects distribution and balances of energy in climate system, the atmospheric circulation and the intensity of EASM, also the movement of rain belt. It needs to be proved both by diagnostics and GCM further.

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中国东部夏季降水80年振荡与东亚夏季风的关系

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摘 要

利用中国东部1470-1999年夏季降水级别资料和1951-1999年夏季降水观测资料，以及1871-2000年北半球海平面气压资料研究了中国东部夏季降水与东亚夏季风的关系。研究表明华北及东北南部、长江中下游地区和华南夏季降水存在明显的80年振荡，华北夏季降水的80年振荡与华南同位相，与长江中下游反位相。华北夏季降水与海平面气压在120°-130°E，20°-25°N区域内呈负相关，在120°-130°E，20°-25°N区域内呈正相关，并达到95%信度。因此，利用这两个区域平均海平面气压差定义了一个表征夏季西南风强度的东亚夏季风指数。当东亚夏季风强时，华北夏季降水偏多，同时长江中下游少雨；当东亚夏季风接近正常时，华北干旱，长江中下游多雨。最后，利用530年的华北夏季降水长序列资料研究了东亚夏季风的年代际变率。

关键词: 80年振荡，中国东部夏季降水，东亚夏季风