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PRECIPITATION PATTERNS IN FLOOD SEASON OVER CHINA ASSOCIATED WITH THE EL NIÑO/SOUTHERN OSCILIATION

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ABSTRACT: The precipitation patterns in flood season over China associated with the El Niño/Southern Oscillation (ENSO) are investigated, especially in the eastern China, using the rather long period rainfall data in this century. The results show that there were remarkable differences between the precipitation patterns in flood seasons of ENSO warm phase (El Niño year) and cold phase (La Niña year), as well as between the patterns in El Niño years and their following years. The most parts of China received below normal rainfall in flood season of the onset years of El Niño events, but the coastal area of Southeast China received above normal amounts. Comparatively, the most parts of China received above normal rainfall in flood season of the following years of El Niño events, but the eastern part of the reaches among the Huanghe (Yellow) River, the Huaihe River and the Haihe River, and the Northeast China received less. During ENSO cold phase, the reaches of the Changjiang (Yangtze) River and the North China received more amounts than normal rainfall in flood season of the onset years of La Niña events, and the other regions of China received less. In the following years of La Niña events, the coastal area of the Southeast China, the most part of the Northeast China and the regions between the Huanghe River and the Huaihe River received more precipitation during flood seasons, but the other parts received below normal precipitation.
KEY WORDS: ENSO, China, precipitation in flood season, teleconnection

I. INTRODUCTION

ENSO (El Niño/Southern Oscillation) events are the intensive signals of air-sea interaction in tropical area. Plenty of results from different researchers show that the ENSO signal can be detected on interannual variations of large scale atmospheric circulation and climate regimes over most parts of the world. Several kinds of relationship between ENSO and precipitation over China have been revealed by different researchers, but there are many differences among the published results. It maybe resulted from that different researchers used different indices of ENSO or precipitation data, even the methodology to process the original rainfall data. The

statistical results from Shi Jiu'en *et al*. (1983) show that the reaches of the Changjiang River received above normal precipitation during flood season in the onset years of ENSO events, but both the northern and the southern parts of the country received below normal amounts; opposite conditions occurred in the following years of El Niño events. Fu Congbin (1987) described a contrary result: the most parts of China, especially the reaches of the Changjiang River, received below normal rainfall in the onset years but above normal in the following years. Some of other researchers tried to classify different kinds of ENSO events and discussed their relations to precipitation over China. Zhao Hanguang *et al*. (1990) concluded their results as: the reaches of the Changjiang River got more than normal rainfall in both the onset years and the following years of El Niño events, if the remarkably warming processes of events occurred in autumn and winter, opposite conditions occurred in both the onset years and the following ones of the events, if the remarkably warming processes happened in spring and summer. Lin Xuechun *et al*. (1993) classified two kinds of El Niño patterns: eastern and central. They indicated: precipitation pattern in flood seasons over China, characterized by below normal in the reaches of the Changjiang River and above normal in regions south of the Changjiang River and North China, occurred after the warmest periods passed along with the eastern pattern; opposite precipitation pattern occurred after the warmest periods passed along with the central pattern of El Niño events. It is worthy to note that most results were based on the data since the 1950s and rarely dealt with the cold phases of ENSO, La Niña events.

On the basis of precipitation data as long periods as possible in this century, the precipitation patterns in flood season over China, especially in eastern part, associated with the different phases of ENSO are discussed hereafter. It is worthy to get more information about large scale characteristics of precipitation patterns during the different phases of ENSO for long-term forecast on precipitation in flood season. It would also be helpful to understand the effects of ENSO on weather and climate in China.

II. DATA AND METHODOLOGY

Flood seasons are different periods of a year over different parts of China, but they are the periods normally between March and September, June to September over most parts and May to August over some parts of southern China, except April to July or March to June over some other regions. The rainfall in flood seasons is considered here as the accumulated precipitation during the consecutive four months which are the months with maximum amounts in annual cycle.

The data are used for the period as long as possible, because the statistical results are usually influenced by the number of samples. Unfortunately, there are not many stations with long period rainfall records in China. Only 48 stations are selected mostly with rainfall records beginning before the 1930s, furthermore, there are some data missing cases at some stations. Considering data-missing cases, interpolation is not performed to keep the reliability of the da-

ta.

Twenty-three cases of strong to moderate El Niño events and 17 cases of strong to moderate La Niña events in this century are dealt in this paper. They are determined by Shabbar (1993), based on the southern oscillation index, and listed in Table 1. Average flood-season precipitation anomalies expressed as percentage of normal precipitation is the mean flood-season rainfall during 1951 − 1980 at the same station. t-test is separately performed to test the statistical significance of the differences between above four groups and other years; statistics t is expressed as follows:

$$t = \frac{\bar{P}_t - \bar{P}_u}{S\sqrt{\frac{1}{n_t} + \frac{1}{n_u}}}$$

$$S^2 = \frac{\sum(P_t - \bar{P}_t)^2 + \sum(P_u - \bar{P}_u)^2}{n_t + n_u - 2}$$

$$\bar{P}_t = \frac{1}{n_t}\sum P_t \qquad \bar{P}_u = \frac{1}{n_u}\sum P_u$$

where P_t is the rainfall anomaly in flood season of one of the onset years of El Niño events at one station ($t = 1, 2, \ldots, n_t$); P_u is the anomaly in flood season of any other years except the onset years of El Niño events ($u = 1, 2, \ldots, n_u$); n_t is the number of samples relative to El Niño onset years, n_u is the number of samples of other years except El Niño onset years. The significant difference is true between the rainfall in El Niño onset years and all other years, when $|t| = t_{\alpha/2}(n_t + n_u - 2)$ is satisfied for a given significance level α. The similar tests are performed for the following years of El Niño events, the onset years and the following ones of La Niña events.

Table 1 Years of onset of strong to moderate El Niño and La Niña events from the turn of the century

El Niño	1902	1905	1911	1912	1914	1918	1919	1925	1926	1929	1930	1939
	1941	1951	1953	1957	1958	1965	1969	1972	1976	1982	1986	
La Niña	1904	1909	1910	1916	1917	1924	1928	1938	1950	1955	1956	1964
	1970	1971	1973	1975	1988							

III. PRECIPITATION PATTERNS ASSOCIATED WITH EL NIÑO

Fig. 1 shows the spatial distribution of average flood-season precipitation anomaly expressed as percentage of normal amounts for the onset years of El Niño events over China. In the onset years of El Niño, most parts of China, especially the regions respectively near to Beijing and Tianjin, the border between Sichuan and Shaanxi, northern part of Guangxi, received below normal rainfall in flood season, three regions mentioned above received only 80% − 90%

of normal amounts, and the differences between the onset years of El Niño and other ones are remarkable at significance level 95%; southeastern coastal areas and most part of Northeast China received a little more amounts than normal, but the differences are not significant significance level 95%.

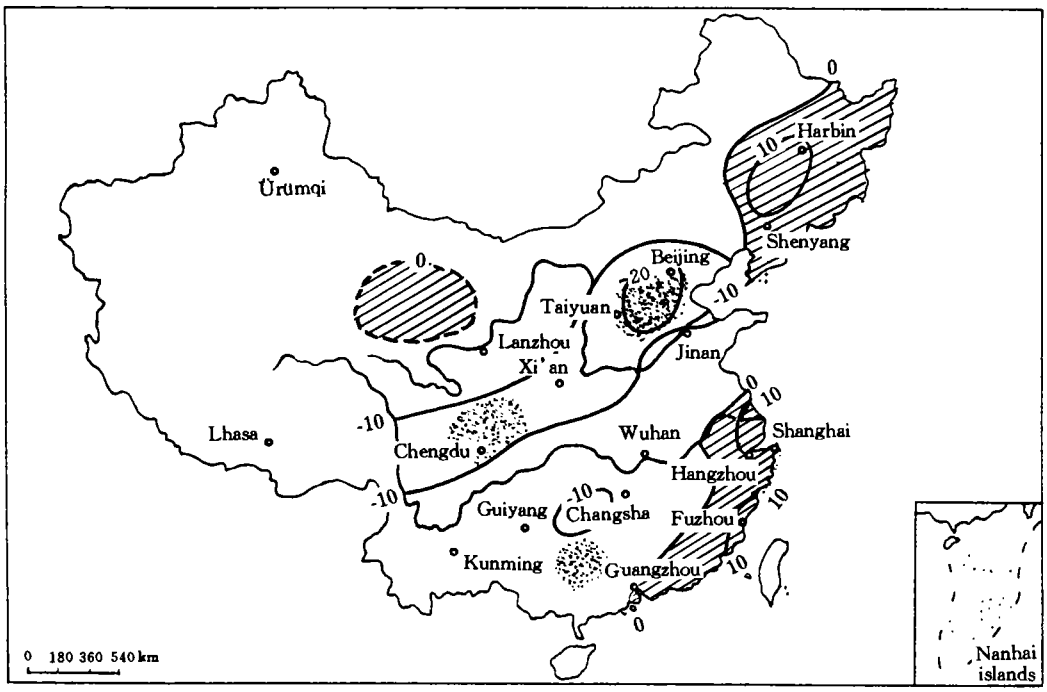

Fig. 1 Anomaly percentages of precipitation in flood season
for the onset years of El Niño events in China
(above normal in areas shaded with lines, statistical remarkable difference
at significance level 95% in areas shaded with dots)

Fig. 2 describes the spatial distribution of average flood-season precipitation anomaly expressed as percentage of normal amounts for the following years of El Niño events. In the following years of El Niño events, most part of the country received more rainfall than normal, but most part of Northeast China, Sichuan Basin and eastern part of the reaches among the Huanghe River, the Haihe River and the Huaihe River received less amounts than normal. Zhejiang Province and the region near to the border between Hunan and Guangxi, received 10% – 17% more amount than normal; the differences between the following years of El Niño and all other ones are significant at significance level 95%. An interesting fact is, Ürümqi located in northern part of Xinjiang, received more 17% rainfall in the following years of El Niño than normal flood-season (April to July) amount. Negative anomalies are a little more remarkable in eastern part of the reaches among the Huanghe River, the Haihe River and the Huaihe River, especially in Shandong Peninsula with the lowest value – 15% of normal amount.

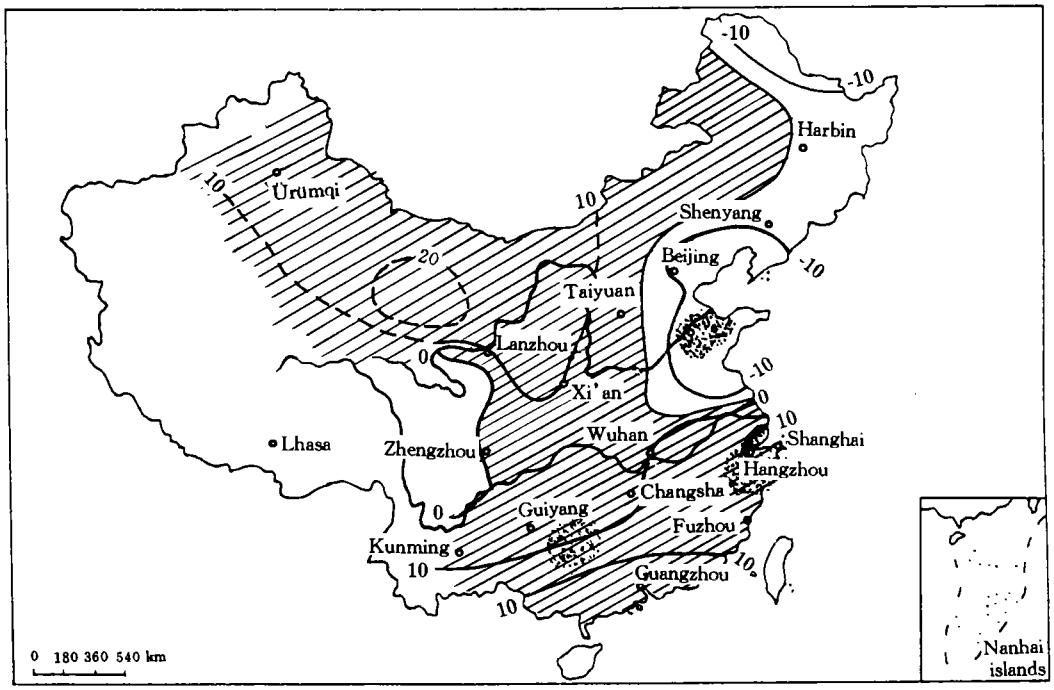

Fig. 2 Anomaly percentages of precipitation in flood season
for the following years of El Niño events
(the legends are the same as those in Fig. 1)

Comparing the characteristics shown in Fig. 1 and Fig. 2, the differences are remarkable. In the flood season of the onset years of El Niño events, most parts of China received below normal rainfall; only small parts, such as coastal area of southeastern part of the country and southern region of Northeast China, received more than normal. Otherwise, in the following years of El Niño events, most parts received more than normal flood-season rainfall; only small regions, eastern part of the reaches among the Huanghe River, the Haihe River and the Huaihe River, part of Northeast China, received less than normal. It has been well-known that there are close relationship between the flood-season rainfall over eastern China and the intensity and location of western Pacific subtropical high; furthermore, it has been confirmed that the subtropical high is influenced by the variation of sea surface temperature (SST) in the equatorial eastern Pacific Ocean (Ye *et al.*, 1991). The reaction of the subtropical high to the variation of SST usually happens with time lag; in other words, the influence of variation of SST in winter is normally reflected in behaviour of the subtropical high in following summer. Maybe it is the reason why there are obvious differences in flood-season precipitation patterns over China between the onset and the following years of El Niño events. In the onset years of El Niño, the western Pacific subtropical high was weak and located more southeastward than normal in spring and summer, the rain-belt in eastern part of China was also weak and located more

southeastward than normal in the same seasons, moreover, most parts of the country, especially the regions, respectively near to Beijing and Tianjin, the boundary between Sichuan and Shaanxi, received less amounts than normal in flood season. In contrast, most parts of China received more amounts of flood-season rainfall than normal in the following years of El Niño, because the effect of anomalously high SST in the equatorial eastern Pacific Ocean in previous winter was that the subtropical high became more intensive and northwestward.

IV. PRECIPITATION PATTERNS ASSOCIATED WITH LA NIÑA

Fig. 3 shows the spatial distribution of average flood - season precipitation anomaly ex

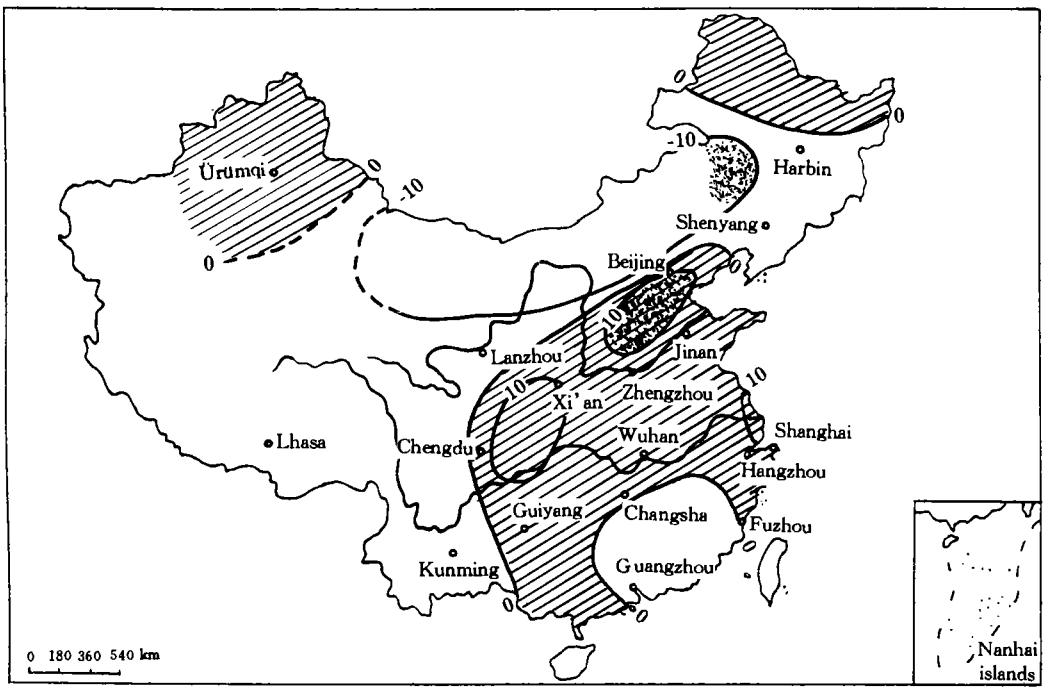

Fig. 3 Anomaly percentages of precipitation in flood season
for the onset years of La Niña events
(the legends are the same as those in Fig. 1)

pressed as percentage of normal amounts over China in the onset years of La Niña events, which is remarkably different from the pattern in the onset years of El Niño events. In flood season of the onset years of La Niña, the regions, including most part of Northeast China, South China, Hunan and Jiangxi provinces and western part of the country, received below normal precipitation; especially central area in Northeast China received only 87% of normal amount, the difference there is remarkable between the onset years of La Niña and all other ones at significance level 95%. Moreover, eastern part of the country, from the reaches of the

Yangtze River to the Great Plain of North China, received more than normal rainfall, the regions near to Beijing and Tianjin received over 10% more amount than normal at significance level 95%.

The spatial distribution of average flood-season precipitation anomaly as percentage of normal amounts over China is shown in Fig. 4 for the following years of La Niña events. In the following years of La Niña, most parts of China received below normal rainfall in flood season, especially the western part of the country where less than 90% of normal amounts was observed; Northeast China, coastal area of southeastern part and the region between the Huanghe River and the Huaihe River, received more than normal precipitation; for example, Fuzhou, the capital of Fujian Province, received over 16% more than normal. Compared Fig. 4 with Fig. 1, similarity can be confirmed between the patterns in the onset years of El Niño and the following years of La Niña, it is possibly caused by that several El Niño events occurred in the following years of La Niña. It implies that there are some regimes in transforming process between cold and warm phases of ENSO.

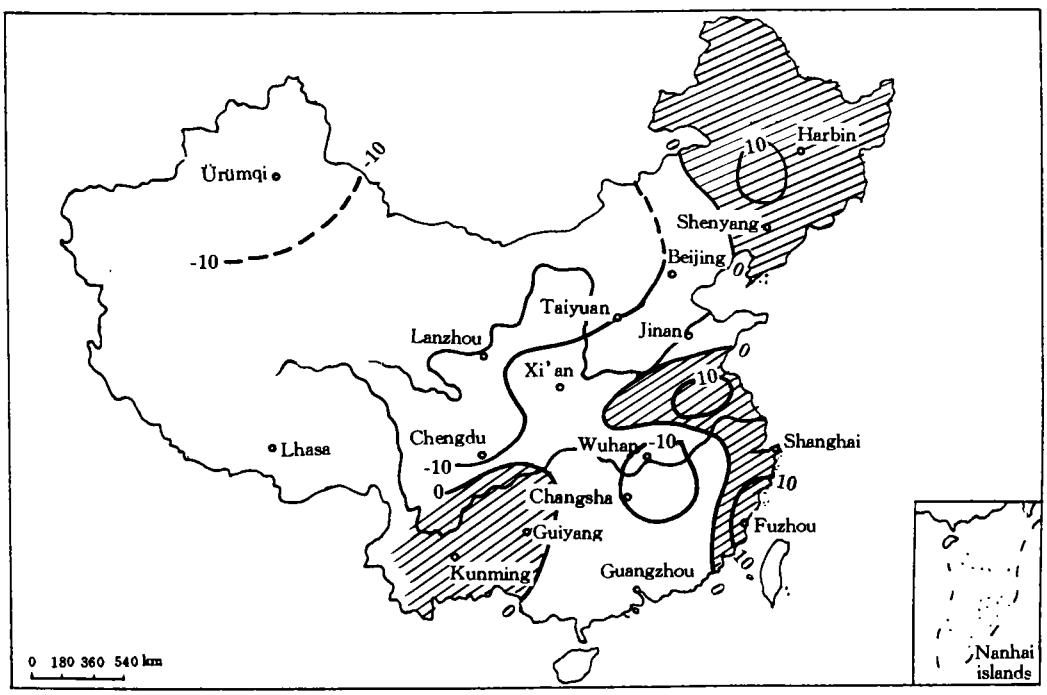

Fig. 4 Anomaly percentages of precipitation in flood season
for the following years of La Niña events
(the legends are the same as those in Fig. 1)

Comparing the large scale characteristics shown in Fig. 3 and Fig. 4, the effect of time-lagged response of the western Pacific subtropical high to SST in the equatorial eastern Pacific Ocean, can also be observed. In La Niña onset years, the subtropical high was in the trans-

forming process from intensive to weak one but more intensive and northward than normal situation in spring and summer, the reaches of the Changjiang River and North China, especially North China, could receive more than normal precipitation. Otherwise, in the following years of La Niña, the subtropical high was weaker and more eastward than normal in spring and summer because SST was anomalously low in previous winter; most parts of China then received below normal rainfall in flood season, although coastal parts of eastern China could receive a little more precipitation than normal.

V. SUMMARY

On the basis of statistical results performed to a set of precipitation data with rather long period, it can be confirmed that there were some relations between the flood-season precipitation over China and ENSO events, but there was no statistical significance in most parts of the country. It implies that there was not a simple linear correlation between ENSO and flood-season precipitation in China. It seems helpful to develop some kinds of methodology to filter ENSO signal from the noisy precipitation data.

On the other hand, the large scale characteristics of spatial distribution of average flood-season precipitation anomaly in different phases of ENSO indicated that there were some large scale precipitation patterns associated with ENSO in flood season over China, these patterns could reflect the effect of time-lagged response of the western Pacific subtropical high to the variation of SST in the equatorial eastern Pacific Ocean.

There were remarkable differences between precipitation patterns associated with different phases of ENSO. In the onset years of El Niño, most parts of China received below normal flood-season rainfall, only some regions, such as coastal area of southeastern part and southern part of Northeast China received above normal amounts. On contrast, a large part of the country from the reaches of the Yangtze River to North China received more precipitation in the onset years of La Niña. Two regions were sensitive to the influence of ENSO, one is Sichuan Basin, another is the region near to Beijing and Tianjin. It is also meaningful that there were considerable distinctions in precipitation patterns between the onset and the following years of El Niño. These results are helpful to long-term forecast of flood-season precipitation over China.

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