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The teleconnection between floods in the middle reaches of the Yangtze River and El Niño events

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Abstract The basins of the middle reaches of the Yangtze River are the worst flooded area of the whole basin. The objective was to study the variation of floods in this area with El Niño events over a long historical period, and to identify any teleconnection between them so as to improve flood predictions in the region. Using statistical analyses, both the time series of the floods and El Niño events since 1525 were studied. The results show that the main cycle of flood variation is longer than that of El Niño events. The latter shows obvious fluctuations of about 2-year and 3–4 year periods, while the former is not so significant; but the period of 2, 8 and 40 years can be identified (at least exceeding the level of confidence 0.03). By further analysis, the coupling fluctuation of the two time series, significant teleconnections between them at both high and moderate frequency sections are found. The result shows that the response of the floods along the middle reaches of the Yangtze River to the effects of El Nino events is not only an immediate delay (e.g. one year) as many Chinese scientists believe, but can also be somewhat long-lived (as long as about 8 years). The results also indicate that the shorter the interval of El Niño events, the sooner the following flood responds. However, flood could delay if the interval time of El Niño events is longer.

Key words EI Niño events; historical floods; middle reaches of the Yangtze River; teleconnection

INTRODUCTION

As the third largest river in the world and the largest river in China, the Yangtze River is so important to human society in China that it is a mirror of Chinese history. Since ancient times, people in its basins have been suffering from, and fighting against, flood disasters from generation to generation. It has long been known as “China’s sorrow” for the lives that have been lost and the damage done by its frequent and violent floods.

Originating in the Tibetan Plateau, the river flows eastwards through central China on its way to the Donghai (East China Sea) in Shanghai, on China’s east coast (Fig. 1). In its middle section, it passes through the immense Jianghan Plains from Yichang to Wuhan, named Jiangjiang. Because of the limited capacity for flood discharge, this region is the worst flooding area of the whole Yangtze basin. For instance, the capacity of flood discharge in Jing-Jiang is about 60 000 $m^3 s^{-1}$. However, there were an estimated 108 disastrous breaks in the river embankments across the Jingjiang reaches from 1525 to 1995 AD, and more than 24 years in which flood discharges have exceeded this capacity since 1892 (Table 1), in each case causing great damage.

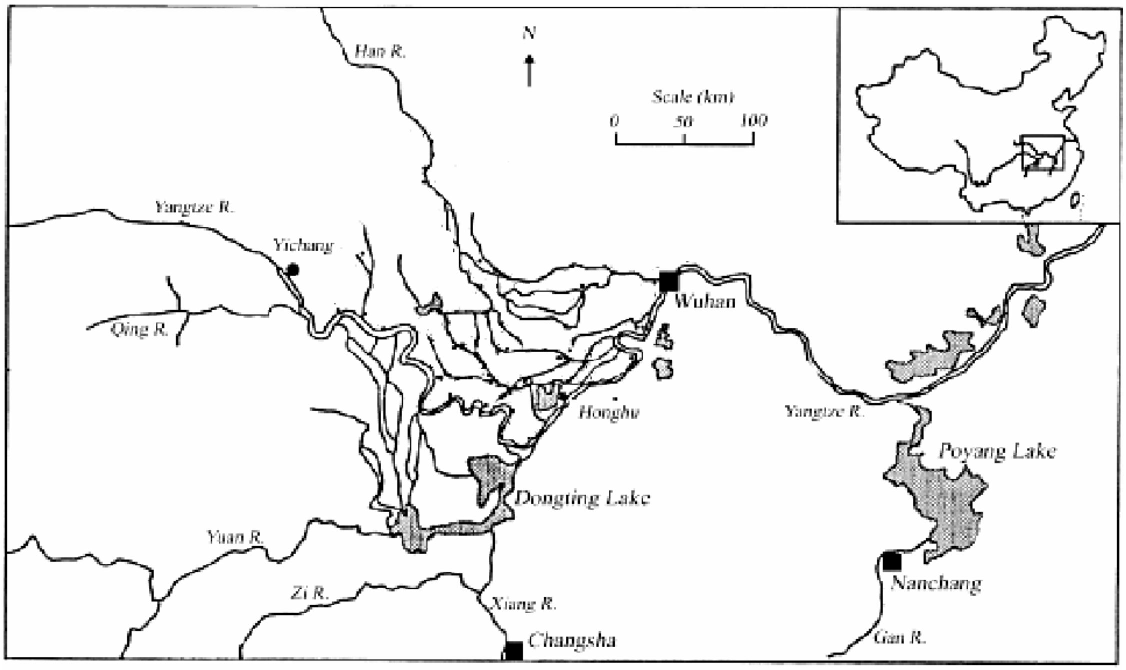

Fig. 1 The middle reaches of the Yangtze River basin.

Table 1 The extreme flood discharges at Yichang Station since 1892 (discharge: $m^3 s^{-1}$).

Year	Discharge	Year	Discharge	Year	Discharge	Year	Discharge
1892	64 600	1917	61 000	1931	64 600	1954	66 800
1896	71 100	1919	61 700	1936	62 300	1958	60 200
1898	60 600	1920	61 500	1937	61 900	1974	61 600
1905	64 400	1921	64 800	1938	61 200	1981	70 800
1908	61 800	1922	63 000	1945	67 500	1989	61 800
1909	61 100	1926	60 800	1946	62 100	1998	63 600

The extreme flood discharges were caused by heavy rainfall over the upper reaches of the Yangtze River valley. It is commonly known that the climate of China is strongly influenced by the East Asian monsoon. The primary physical manifestation of the summer monsoon is persistent, heavy precipitation identified with a coherent, well-defined rainband. Because of the variations in monsoons, the rainband shows interannual variability over the Yangtze River valley that causes yearly rainfall totals to fluctuate greatly, especially rainfall during the flooding season.

El Niño is a recurring pattern of climate variability in the eastern equatorial Pacific that is characterized by anomalies in warming periods of sea-surface temperature. As the remarkable connective signal between the whole near-global-scale climatic change and sea-surface temperature, EI Niño events profoundly affect the regional climate. There have been many studies on EI Niño and its relation to global and regional climates through atmospheric circulation (Chang *et al.*, 2001). And also, recent research shows that EI Niño events have some effect on regional long-term precipitation in China.

In this paper, we attempt to find the fluctuate regulation of both floods in the middle reaches of the Yangtze River and EI Niño events, and the teleconnection between them, based on historical data by using statistic methods.

DATA RESOURCES AND PROCESSING

Quinn & Neal (1992) have nicely presented the useful data about the strength of El Niño events which they identified, evaluated, and determined from many detailed reports from sailing vessel logs, diaries of the conquistadors and their entourages, missionaries, pirates, privateers, historians, geographers, engineers, geologists, hydrologists, newspapers, and scientists from various other disciplines, which provide a fairly continuous source of information over both those areas directly affected by El Niño and those areas affected by other unusual conditions related to the El Niño (e.g. the droughts that often affect southeastern Peru and adjacent parts of Bolivia during an El Niño), covering the period 1525–1987. In the Historical El Niño Events Data (Quinn & Neal, 1992), the strength of EI Niño events are classified into several categories, that is: very strong (VS), strong (S), and moderate (M). Among them, the S+, M+ and M– are added to fit those EI Niño events whose intensities are around standard categories. For the compound type of activity over the distant past, the signals of M/S or M–/M+ are used to cover two events of different intensities because of the lack of the detailed information to further refine them.

For quantitative purposes, those categories are digitized in this paper as shown in Table 2.

Table 2 Intensity categories of Historical EI Niño Events, and corresponding digitized numerical value.

Categories	very strong(VS)	S+	strong (S)	M+	moderate (M)	M–	M/S	M–/M+
Digital	3	2.5	2	1.5	1	0.5	1/2	0.5/1.5

Trenberth (1997) defined EI Niño events as 5-month running means of sea surface temperature (SST) anomalies in the Niño 3.4 region (5°N–5°S, 120°–170°W) exceeding 0.4°C for six months or more. We find that this definition matches Quinn's well for their common years during modern time. Therefore, the EI Niño events time series defined by Quinn & Neal (1992) was extended to 1995 by adding the El Niño events 1991–1992, 1993 and 1994–1995 derived from Trenberth's results.

As is probably well known, the Chinese have the best and most complete phenological records that exist (Rosenberg, 1982). During the Ming and Ch'ing dynasties, from the 15th to the 18th centuries, Chinese regional geographical records were carefully made so that archives of data on floods, droughts, and many other climatic events are now available for study. In this paper, historical flood data are derived from the "*Flood and Drought Distribution Atlas of China in the Last 500 Years*" (China Central Meteorology Bureau, 1989) and a careful examination of the data have been made for the Jingzhou station, which has continuous records. The data are extended to modern time by the methods used in the above atlas and converted into rainfall by the method proposed by Xiong Anyuan & Wu Yijin *et al*. (1999). Therefore, both the extent of floods and rainfall are calculated simultaneously to check if they are coincident.

All data used in this paper is from 1525 to 1995.

CALCULATION AND ANALYSIS

Cycles in El Niño events/floods

Power spectrum analysis was applied to each of the members of the El Niño events and floods series. The maximum lag in the analysis was set at 80 years. The computational procedure is the same as outlined in the WMO Technical Note: *Climate Change* (1966). The power spectra for El Niño events are shown in Fig. 2, which reveals that the highest peaks of the power spectrum occur at k = 78, 48 and 41, all of which exceed 0.01 degrees of confidence. It turns out that the time series of El Niño events have periods of about 2 years, and 3–4 years. This result is a little more convergent than that of Clement *et al*. (2001), who stated that ENSO occurs roughly every two to seven years as a result of heat and energy moving between the atmosphere and the oceans.

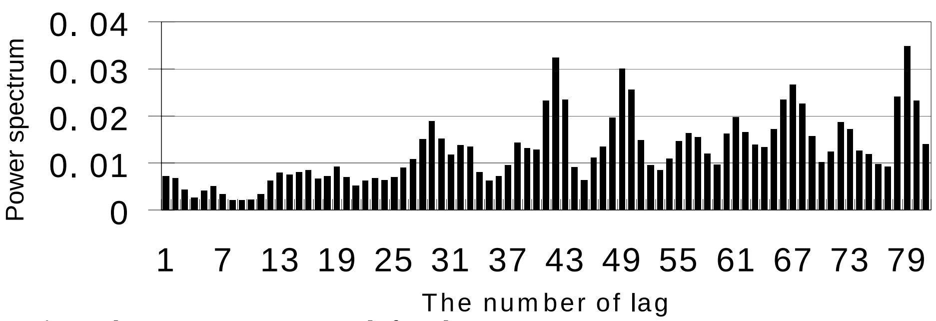

Fig. 2 The power spectrum result for El Niño events.

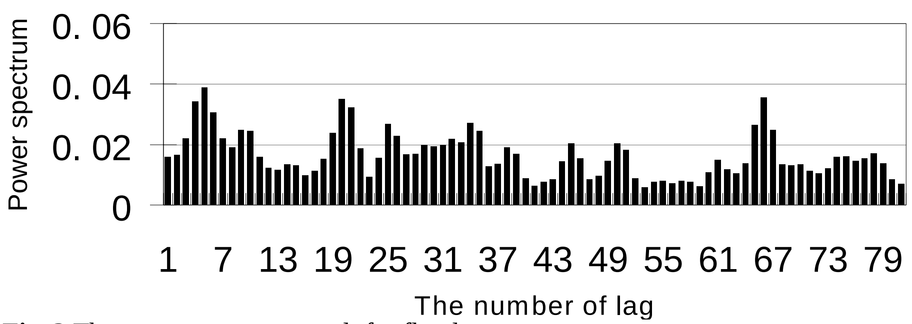

Fig. 3 The power spectrum result for floods.

Similar to the analysis of El Niño events, the resulting smoothed power spectrum for floods (Fig. 3) shows the highest peaks of power spectrum occurs at k = 65, 19 and 4, exceeding 0.02, 0.03 and 0.01 degrees of confidence, respectively. It turns out that the time series of flood events has periods of about 2, 8 and 40 years.

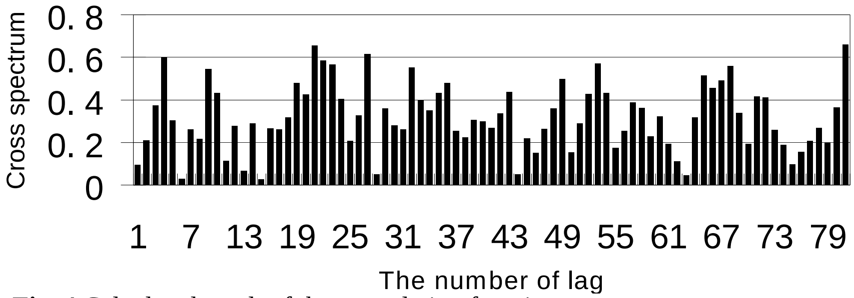

Fig. 4 Calculated result of the coagulation function.

The analysis of cross spectra

The result of the cross spectrum for El Niño events and floods (Fig. 4) shows that there are three frequencies at which the significant correlation of two time series exceeds the 0.01 level, i.e. at the peaks of k = 20, 26 and 80, respectively. From that, it can be concluded that the response of the floods in the middle reaches of the Yangtze River to El Niño events occurs, not only at high frequency, but also at moderate frequencies (see Table 3). The result also indicates that the shorter the interval between El Niño events, the sooner the following flood would respond, and *vice versa*, the delay time of flood will be longer when the interval of El Niño events is extended.

Table 3 Coincidence of coagulation function peaks with different periods.

Harmonic value (k)	20	26	80
Period (year)	8	6	2

Jacobs Ga *et al.* (1994) demonstrated that significant local effects of El Nino events in the Pacific Ocean can be extremely long-lived, not only lasting up to two years as other scientists thought. The above result demonstrates that the oceanic effects of El Nino events on the floods along the middle reaches of the Yangtze River is not only an immediately delay (say one year) as many Chinese scientists believe http://www.coi.gov.cn/hyzh/ernn/ernn10.htm, but can also be somewhat long-lived (e.g. 8 years).

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