A Study of the Large Scale Flooding over Eastern China in 1755

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Abstract

Following disastrous flooding in several river valleys over eastern China in 1755, serious flooding occurred in the middle and lower reaches of the Yellow River in 1756 and 1757, a rarely seen precipitation pattern of north-flood and south-drought in China for two successive years. This is a serious meteorological disaster and extreme climatic event taking place under the climatic background of a warm phase of the Little Ice Age. In this paper, by means of historical literature records, the rainy and flooding situation and the weather characteristics of these years are reconstructed and the maps depicting areas of prolonged rain, flooding and concomitant famine, insect pest, and pestilence are made. The results show that, in 1755, the middle and lower reaches of the Yellow River and the Yangtze River, and the Huaihe River Basin experienced a prolonged rainy season with multiple torrential rain events. The continuous rainy period exceeded 40 days in the Huang-Huai Region. An early Meiyu occurred, and the duration of the Meiyu period in the lower Yangtze River Basin was 43 days, the longest in the 18th century. Particularly in Nanjing the annual rainfall of 1755 was 1,378 mm, the highest record of the 18th century. The year of 1755 is characterized by lower temperature in summer, early frost in autumn, and heavy snowfall and freezing rain in winter. These characteristics are extremely similar to those of 1823 and 1954, two typical years of extreme rainfall. And all these three years with extreme precipitation are corresponding to the minimum phase of the solar activity cycle.

Keywords: extreme climatic event; flood; meteorological disaster; 1755; historical climate


1 Introduction

Nowadays there have been frequent reports on extreme climate events in the press. Questions, such as whether these events are indeed unprecedented, or once in hundreds of years and under what conditions these events will occur in the future, have been raised. There have been hot debates about whether these events are the consequence of global warming. Naturally, the investigation has turned to inquiries in the historical climate studies. Studies in reconstruction of extreme climate events in history can produce cases that are comparable to contemporary events, thus provide aid in enhancing the understanding of these extreme climate events.

There are several quantitative methods and standards to define an extreme climate event. All of them call it “a very low probability event”. However, the determination of extreme precipitation event is more complicated, because it is not only determined by the annual precipitation amount but it also needs to take into account of the precipitation intensity, duration of the precipitation, and the season in which the precipitation occurs. Flood is typically localized; flooding
events over multiple regions and river basins are rare. Using historical records and the yearly dry/wet index series for 960–2000 over 6 regions in eastern China, the author identified 40 cases of multi-river-basin severe flooding events [Zhang et al., 1997]. Their frequency of occurrence is only 3.8%, meeting the “very low probability of occurrence” requirement; and in this sense they could be called extreme climate events. In the present paper, our discussion will be focused on the extensive and severe flooding event in 1755. We shall reconstruct its climatic process which will serve as a comparative case of contemporary extreme climate events. It is worth noting that again during 1756–1757 the Huang-Huai Region suffered continuous floods. This flood extreme event occurred under the background of relatively warm climate or the relatively warm period of the Little Ice Age. According to a study by the author, 1755–1757 was located within the warming period (1730–1810) of the Little Ice Age [Zhang and Zhu, 1983]; this was also true for the average temperature series of the Northern Hemisphere in the last one thousand years [IPCC, 2001]. The historical descriptions used in this paper were from A Compendium of Chinese Meteorological Records of the Last 3,000 Years [Zhang, 2004], which was comprehensively collected from 48 ancient Chinese literatures and was cross-validated where possible. The original names and versions of the literatures can be found in Zhang [2004] and they will not be noted individually in the present paper. In ancient literature, lunar calendar was used to denote dates. In this paper, dates in the quoted descriptions are the lunar dates; and other dates are based on western calendar.

2 Reconstruction of precipitation events

In 1755, in the middle and lower reaches of the Yellow River and the Yangtze River, and the Huaihe River Basin excessive rainfalls led to floods. Later in 1756 and 1757 the pluvial region moved to the north; for two consecutive years the pattern of flood in the north and drought in the south persisted, making a three-year-long flood in the Huang-Huai Region. To describe the situations after the 1755 flood event, the reconstruction of 1756 and 1757 weather patterns will also be made and discussed.

2.1 Reality of the excessive precipitation in 1755

According to historical documents, from spring to summer or even to autumn of 1755, there were prolonged and excessive precipitations in all the following provinces along the Yangtze River: Hubei, Hunan, Jiangxi, Anhui, and Jiangsu. The spring and summer precipitation belt was persistently located along the Yangtze River. For instance, “excessive rains from March to May” were in Jiangling of Hubei province; “nonstop rains from January to May” were in Changsha of Hunan; “prolonged rain in spring and flood in summer” occurred in Pengze of Jiangxi; “continued heavy rain from February to June” was in Lingbi and “continuous rain from January to May” was in Wuwei of Anhui; “spring rain in February lasted through August in autumn” in Taixing of Jiangsu; and “starting in June prolonged heavy rain lasted for months” in Songjiang of Shanghai. In the Jiang-Huai Region continuous precipitations lasted more than 40 days, for example, Yangzhou and Gaoyou were documented to have “more than 40 days of continuous rain in May and June”. In the summer and autumn, the rain belt moved to the north, Henan and Shandong provinces had persistent heavy precipitations. For example, “summer heavy rains for 18 days and nights” occurred in Suiping, and “in August heavy rains for tens of days” in Wuzhi of Henan; “July heavy stormy rain” in Wendeng and Jimu, “stormy rain uprooted trees and flooded crop fields in August” in Huimin, and “constant raining” was in Rizhao of Shandong province. In that year, there were not many typhoon precipitation episodes. A few were recorded occurrences in Shanghai and the coastal areas in northern Jiangsu province. For instance, in Dongtai and Funing “stormy rains lasted in day and night of July 14–15 and the sea surged”; the storm region extended northward to Jimo of Shandong. This obviously was the result of a coastal typhoon together with an astronomical tidal effect. However, the excessive rainfall in eastern China in 1755 was a result of a
prolonged stay of the rain belt in the region; the map depicting areas of severe precipitations is shown in Figure 1.

2.2 North-flood and south-drought pattern in 1756 and 1757

In 1756, a precipitation belt was located mainly in the middle and lower reaches of the Yellow River and the Huang-Huai Region. By the mid to late June chunks of precipitation regions emerged and the centers were in the middle of Shanxi and Shandong, respectively. From late July, the rain region in Shanxi was sustained for about 30–40 days. This was described as, for example, “cloudy and rainy days lasted for 28 days” in Heshun; “it was raining from early July through the mid of September, fountains appeared on the ground” in Yuncheng of Shanxi; this rain regime persisted until early November, in particular, there were about 40 days of continuous heavy rains in Wanrong and Ruicheng located in the center of the rain regime. After late August, the main precipitation region was stabilized along Qingyang of Gansu province–Guanzhong–the southern parts of Shanxi province–Mengxian county of Henan province. In Mengxian “heavy rains persisted in August and the water level grew anomalously in the Yellow River,” and this was extended to Boxian and Sixian counties as well as Lingbi in northern Anhui (Fig. 1b). At the same time, both the Yangtze River Basin and South China had meteorological droughts; the so-called north-flood and south-drought pattern formed over eastern China.

In 1757 the rain belt was located to the north of the Huaihe River. In the spring to summer precipitations were abundant in the Huang-Huai Region; “there were heavy rains in April followed by lighter ones in May but plenty of rains in early June” in Henan, especially in Yanling “there were anomalously more rains in March” and “too much precipitation in June and continuous heavy rains lasted until July in autumn” in Yushi, Lankao and nearby counties. During this period, the intensity and duration of the stormy rains were really extraordinary, for example, in Huaiyang “heavy rain lasted for eight days and nights in June, water level went up to top of the city wall;” and “pouring rains destroyed the city wall” of Fengqiu. In the summer to autumn plentiful precipitations were in the
middle reach of the Yellow River. “Heavy autumn rain continued for more than 30 days” in Chengcheng of Shaanxi. “Continuous heavy rain in July led to the Fenhe River flood” in Jiexiu of Shanxi; and in Yuncheng “the whole August was raining” and “the Yaoxian canal was overwhelmed with rain water;” and in Zhangzi county “there were anomalous precipitations in summer to autumn with plain fields becoming fountains and roads becoming creeks and transportation becoming impossible.” In Zhecheng county of Henan, “cloudy and rainy days continued for months from summer to autumn.” See Figure 1c for details. The north-flood and south-drought pattern was still prevalent in 1757.

Spatial patterns of precipitations in rainy season in China can be divided into six categories [Wang et al., 1993; Yu and Lin, 1989]. The north-flood and south-drought pattern is the rarest of the 6 categories. In the past, the frequency of occurrence of this pattern was merely 11%; and that it occurred in two consecutive years was even harder to find. The interesting characteristic of the 1755 rain induced flood was that right after the extensive and long lasting flood over the east of China the area was controlled by the north-flood and south-drought pattern for two consecutive years. In another study [Zhang and Liang, 2009], it was found that the years of north-flood and south-drought were lined up with years of anomalous rains in eastern part of northern China. It was also found that in this area years with anomalous rains appeared in a concentrated episodic fashion. There were 6 such episodes of 20- to 40-year-long in the last 500 or so years, among which 1724–1761 was the third episode of frequent floods. Obviously, 1755–1757 fell in this episode. In other words, 1755–1757 lay in one of the periods of anomalous precipitations in northern China in the last 500 years.

3 Flood and accompanying hazards

The extensive torrential rains in 1755 led to severe flood and further to crop failure and famine; at the same time insect pest and pestilence occurred. The ensuing anomalous precipitations in the middle and lower reaches of the Yellow River caused flooding in the Huang-Huai Region and further worsened the famine. The disaster areas for respective years are depicted in Figure 2. Comparing Figure 2 with

![Figure 2 Distributions of famine (light purple), insect pest (dark green), and pestilence (red) areas in (a)1755, (b)1756, and (c)1757](image.png)
Figure 1, it can be found that areas with famine are usually corresponding to the flooding areas in previous year. For instance, the 1756 famine areas correspond well with areas of persistent precipitations in 1755. On the other hand, areas of insect pest correspond well with the areas of flooding for the same year.

3.1 Flood

The torrential and prolonged rains in 1755 led to eruptions of mountain torrents, rising water levels in rivers and lakes and broken dikes in various places, and eventually caused flood. “In South China, parts of place under the prefectures of Huaiyin, Xuzhou, and Yangzhou were flooded; to the south of the Yangtze River, Yanghu, Jiangyin, Jingjiang, Jinkui, and liyang counties, and to the north, Jiangpu and Luhe counties as well as parts of Huaiyin, Huiyin, and Hai’an prefectures were in one time or another under water.” In Gaoyou and Baoyin of Jiangsu, “river and lake water rose rapidly, water level was more than three feet above the ridges of dams at Nanguan and Chelu, around them farmlands and rivers were all under water.” At Nanjing the Yangtze River “water rose substantially and kept rising for more than 40 days.” “Dikes were overwhelmed and broken” in Shangyu and other counties of Zhejiang. In Wuwei of Anhui province, “dikes around farmlands were almost all under water.” In Henan, “the Qinhe River was overwhelmed;” “summer time, water in the Longshui River abruptly rose and caused a 20-meter-long opening in the dike, and the water went toward northeast all the way into the Jihe River; the two rivers merged at Jiuyan;” in Xin’an “the Shahe River was full and flooded the town of Cijian and drowned countless residents and merchants.” Some places were submerged for longer than six months, for example, Lingbi of Anhui “had torrential rains from February to June and after September land and houses were still under water” (Fig. 1a).

The northern heavy rains in 1756 also caused severe flood hazards. Later August and afterwards the heavy rains from Gansu to Henan led to abrupt rising and overflowing in the Yellow River, the Weihe River, the Luohe River, and the Jinghe River. For instance, “the overflowing water from the southern part of the Weihe River went eastward” and “submerged the autumn crops” in Huaxian and Huayin counties of Shaanxi; in Dali “land and crops were flooded due to the rising of the major rivers (the Yellow River, the Weihe River, the Luohe River, and the Jinhe River);” in Weinan county “on the southern side of the Weihe River, autumn crops were submerged and houses collapsed.” In Shaanxi “flooded water from the Yellow River reached south gate of the city of Yuanqu,” and at Yuxian county “the Yellow River expanded anomalously.” In Hebei, Guangping, Jixian, and Qingxian counties were all suffering floods from overflows and broken dikes over the Zhanghe and Hutuo Rivers. In the lower reaches of the Yellow River, “the river broke at Sunjiaji near Xuzhou and flooded dikes and dams and corroded the city wall, in the Weishan Lake water reached 23 feet deep and flooded six to seven counties;” “on September 13, flooding water broke into the city of Yutai in Shandong and caused the collapses of official and residential buildings;” in Sixian county of Anhui “both the Yellow River and the Huaihe River overflowed and the water in Sizhou city was more than 4 feet deep;” in northern Jiangsu a dike over the Grand Canal of China broke. The severest flooding occurred in the Huang-Huai Region (Fig. 1b).

The northern heavy rains in 1757 led to overflow of rivers in many places (Fig. 1c). In addition to “overflowing of the Fenhe River in July at Jiexiu” and losses of salt produces due to “water of the nitre ponds rush into salt fields by rains in August at Yuncheng,” the severest hazards were in Henan province. “There were 63 counties on both sides of the Yellow River flooded, among which Kaifeng, Shangqiu, and Huaibei were severer.” In Yanling “summer flood water was more than 10 feet deep over the plain and wheat crops were destroyed;” in Jixian county “the dike over the Qinhe River was broken in the summer and caused flood water of several feet deep in the city and both land and houses were submerged;” and in Zhecheng “nonstop heavy rain lasted from summer to autumn and led to overflows and flooding, and boats could float on water in the streets.” The summer and autumn heavy precipitations in Shanxi caused the rapid rising of water and overflow of the Zhanghe, Weihe, and Minghe Rivers.
and further led to flood hazards in Hebei, Shandong, and part of northern Jiangsu. “In May the Zhanghe River were overflowing; in June the overflowing Weihe River submerged farmland and houses;” in Daming city of Hebei “invading water from the Zhanghe and Weihe Rivers submerged the city 10 feet deep;” “on May 19, water from the Zhanghe River broke into the center of Weixian county causing collapse of houses and flooding the city;” in Yongnian “water breaking out of the Minghe River in the south of Xin township flew eastward into the Ox Tail River;” and in the Guanxian county “water from the broken Weihe River entered the county from the Xiaoatan town of Yuancheng, all four gates of the city were blocked and the surrounding crop fields were flooded.” At the same time, “because of the rapid rise of the Zhanghe River in July, water rushed into the Weihe River and both Guantao and Guanxian counties were suddenly flooded and the flooding water was trapped,” which led to “flooding of drought-stricken Jining and Jinxian of Shandong province,” and “flooding at the counties of Xuzhou prefecture,” and “the autumn flood damaged crops in Gaoyou” in northern Jiangsu.

### 3.2 Famine, insect pest and pestilence

The prolonged rains and flooding in 1755 caused “rotten wheat crops”, “submerged farmlands”. At the same time, insect pest led to widespread low crop yields; famine started to spread and epidemic emerged (Fig. 2a). There were records that described “non-harvest of various crops” in Anhui, Shandong, Jiangsu provinces. For example, in Fengyang of Anhui 80%-90% suffered from flood hazards; in Baoshan of Shanghai the yield of cotton and rice crops was only 1/10 of normal.” The summer and autumn season low temperature in the middle and lower reaches of the Yangtze River also resulted in losses in crops. For example, nearby Shanghai “the June weather was like in winter and various crops and cotton crop could not reach maturity;” and in Jiangyin of Jiangsu province “frost occurred early in August, crops and vegetables were injured.” Famine also followed. For example, in Jiangsu there was “no harvest in some 72 counties on both sides of the Yangtze River.” In Jingjiang county “wheat crops died and no crops and beans were harvested which led to high prices of rice, forced food substitution with wheat shells, grass roots, tree barks, and even a kind of white soil, and the spread of illness and epidemic.” In Fengxian of Shanghai “there were no crops and cottons and strewn with bodies of the starved along the roads.” In Kunshan of Jiangsu “the extraordinary disaster made many people starved to death.” And in Haiyan of Zhejiang “there was widespread famine; food and meat prices were sky high; and many starved deaths were reported.” The occurrence of insect pest might be related to bad and rainy weather. Most of Jiangsu, Zhejiang, and Anhui “were affected by insect pest, and crops were destroyed.” Southern counties in Jiangsu such as Lishui and Jiujiang “were under attack by caterpillars.” In Wuxi “crops were withered due to insect attack in August;” in Jiading of Shanghai “black insects were flying all over and crops were dead due to bitten stems;” and in Changshu “katydid attacked rice crops in August.” Food price hikes were the result of poor harvest. For example, in Lingbi of Anhui “entering the autumn prices for wheat and bean were extraordinarily high;” and in Changshui “cotton, rape, and beans were all affected, rice prices were extremely high, and deaths from starvation were everywhere.” Aid and relief measures were taken by the government to alleviate the starvation. For example, in the Shanghai area “August insect pest damaged crops and caused extreme price hike for rice, the government gave relief to households and let people live by the tough time;” in Hangzhou “crops were damaged by insects and prices for rice were very high, the government opened the reserve to sale rice at affordable prices.”

Followed the prior year flooding, the famine was very severe in the Jiang-Huai Region in 1756. In Henan, there was “severe famine” in Qixian, Xixian, and Zhengyang counties. In Huai’an of Jiangsu, “in spring the famine was extreme, price of rice was very high, and robberies were common among people.” Even in the usually rich Suzhou prefecture, “rice prices were extremely high, grass roots and tree barks were sought after foods, and many people were starved to death;” in Wujiang, “there were people seeking soft
stones in the mountains — the so-called Guanyin flour to make cakes for food;” and in Changshu, “the rice prices were so high that many were seeking tree barks for food.” In Jiashan of Zhejiang, “in March the rice price went through the roof, severe shortage of food was prevalent and tree barks and dirt in the mountains were used as substitutes for food.” Starting from June of 1756, an epidemic emerged, the affected area covered Jiangsu, Zhejiang, and Anhui provinces. For instance, in Peixian county of Jiangsu “there were flies all over, the plague followed and many townsmen died.” And, in Gaoyou “there were countless people dead from February to June.” “No households were untouched by the plague” in Taixing and Nantong which were in the center of the epidemic. In Wujiang of Jiangsu “from summer to autumn the epidemic swept all villages and the dead were left along the roads;” in Jiaxing of Zhejiang “plague broke in May;” and in Suxian, Lujiang, Fengyang, and Huaiyuan of Anhui province severe epidemic started in the spring (Fig. 2b). There has been no research on whether there was a relationship between the epidemic and the rainy climate conditions.

In 1757, in the flood-stricken area in the middle and lower reaches of the Yellow River the famine was worsening and “refugees were wandering” (Fig. 2c). The local governments took steps to aid those affected. For example, in Henan province, Lankao “followed the order to use crop reserve for relief efforts;” Qixian county “had widespread famine in the winter, many parents were selling their children; food relief was distributed;” in Changyuan “relief efforts were made on exempting people from their obligations on money or crop yields;” and Zhecheng “followed the emperor’s order to carry out widespread relief efforts by distributing 60,800 dan (1 dan≈70 kg) of crops and providing soup kitchens to serve the poor.” In Jiangsu province “on January 3 more relief were available for 19 flooded counties including Qinghe; on February 29 tax relief was provided to 12 flooded counties; on August 14 obligations of the flooded salt farmers in the Huaihe River Basin were exempted; on November 2 relief was provided to 21 affected counties by flood;” and “different ways of relief were used in Haizhou and Shuyang, including forgiveness of old debts and loan of crop seeds.”

4 Climate background and possible affecting factors

4.1 Climate background

In 1755 the middle and lower reaches of the Yellow River and the Yangtze River, and the Huaihe River Basin in eastern China had prolonged rainy season with mostly torrential rains and continuous heavy rains. The regular rainy season known as Meiyu in the Yangtze and Huaihe River Basins was anomalous, which was characterized by early start, extended period, and late ending. The characteristics of the anomalous precipitations recorded in the compendium [Zhang, 2004] could be verified by quantitative inferences from other ancient climate records. The reconstructed precipitation result based on a special kind of weather report of the Qing Dynasty palace, the clear and rain records, for Suzhou and Jiangning [Zhang and Wang, 1989] shows that the 1755 summer rainy season in the lower reaches of the Yangtze River could be divided into three time intervals: from May 1 through June 6, from June 22 through August 4, and from August 12 through August 31. According to a reconstruction study of the Meiyu in the 18th century [Zhang, 1991], in 1755 the early Meiyu in the lower reaches of the Yangtze River began on May 1, the regular Meiyu began on June 22 and ended on August 4–30 days later than the average ending date. The duration of this regular Meiyu was 43 days which was 23 days longer than the average and was among the longest of the 18th century. Based on the clear and rain records, the derived 1755 annual rainfall in Nanjing was 1,378 mm which was the highest of the 18th century. Furthermore, both the rainy season (May through September) rainfall of 990 mm and the summer season (June through August) rainfall of 728 mm were the second highest of the 18th century [Zhang et al., 2005].

The temperatures were abnormally low in 1755. Chilly summer, in Shanghai “the June weather was like winter;” along the Yangtze River, in areas such as Wangjiang and Guichi of Anhui, “it was so cold in
July that people wore fur coats.” In autumn, cold air activities were strong. On August 21 (July 14–15 in lunar calendar), abrupt temperature drop due to the passage of a strong cold front led to the first frost of the year in Heshui of Gansu, Kelan of Shanxi, and Laiyuan of Hebei, which was almost one month earlier than the earliest first frost date of the present day record (September 15). In Jiangyin of Jiangsu province, “cold frost fell in August (lunar calendar),” which was also about one month earlier than the present day record (October 20). All these showed that temperatures were very low in the autumn. In the depth of the winter (December 10 of lunar calendar), jurisdictions of Jiangsu and Anhui provinces along the Yangtze River had heavy snowfalls, freezing, and frozen rains, indicating a rather cold winter in that year.

The prolonged rainy season and low temperatures that characterized 1755 were very similar to the climate background of two cases of extreme rainfalls in the 19th and 20th centuries (1823 and 1954). In 1823, the rainy season in northern China was long; there were anomalous precipitations and prolonged Meiuy in the middle and lower reaches of the Yangtze River which led to flooding of longer than four months in some area at low elevation; and the summer temperatures were low — in Shanghai “it was cold like winter in July” [Zhang, 2011]. In 1954, in the middle and lower reaches of the Yangtze River and the greater region to the south, the rainy season started early, the duration of the Meiuy was 50 days and the Meiuy rainfall was 3 times of the regular year; cold air activities were very active in the autumn in the middle and lower reaches of the Yangtze River and southern China, and in September and October there were episodes of “han-lu-feng” (low temperature damage in autumn) [Feng et al., 1985].

Temperatures in 1756 were not very unusual. Cold air activities started early in the autumn of 1757; early frost hazards were reported in various areas. In August (lunar calendar), severe frost occurred in Jiaxian county and Shengmu of northern Shaanxi; “early frost damaged crops and cotton plants were withered” in Shanghai; and even in Huiyang of Guangdong, where frost and freezing were rarely seen, “autumn frost killed crops.” One can imagine how low the temperature was in that autumn.

4.2 Possible external factors

The climate in 1755 was so abnormal that attentions have been drawn to the study of its cause. Unfortunately there were no observational data of atmospheric circulation and sea surface temperatures in the 18th century, it is impossible to have a discussion based on standard approaches that have been adopted to analyze contemporary climate anomalies. The following is an attempt to discuss possible external factors that might be responsible for this abnormal climate event. In the meantime, we will try to tie our discussion with the conclusions from previous studies on rain flood events [Zhang, 2011].

4.2.1 Solar activities

Based on records of solar activities [Waldmeier, 1961], 1755–1757 was in the first period of the solar activity period. 1755 was the minimal year of solar activity (m) and the relative numbers of the sunspots were only 9.6. The two years, 1756 and 1757, were respectively one and two years after the minimal year (denoted as m+1, m+2 respectively) and the relative numbers of the sunspots were 10.2 and 32.4, respectively. It is interesting to note that 1823 and 1954 were also the minimal years of the solar activity period (m), they respectively fell in the 7th and 19th period of solar activity. Their relative numbers of the sunspots were also very small. The annual mean relative numbers of the sunspots for 1823 and 1954 were 1.8 and 4.4, respectively.

4.2.2 Sea surface temperature

It can be seen from the chronological table of historical El Niño events [Quinn and Neal, 1992] that 1755 was an El Niño year coinciding with the El Niño event of moderate intensity (level M+) occurred in 1755–1756. Therefore, the characteristics of the sea surface temperature in 1755 were different from those in 1823 and 1954. These two years of anomalous precipitations were between two El Niño events. 1823 was a non-El Niño year in between two moderate El Niño events in 1821 and 1824; and 1954 was also a non-El Niño year which followed the moderate El Niño event
in 1953 (level M+) and preceded the strong El Niño event in 1957–1958 (level S) [Zhang, 2011].

4.2.3 Volcanic activities

If one uses volcanic eruption index (VEI) not less than 3 to define a major volcanic eruption, according to the records of past volcanic activities in the world [Simkin and Siebert, 1994], there were not many volcanic activities a year before the 1755 rain flood event. The eruption of Taal in the Philippines occurred on November 28, 1754 was the only major eruption (VEI=4). Other weak eruptions (VEI=2) included the Asama eruption in Japan on August 7, 1754, the Etna eruption in Italy and the Galeras eruption in Colombia; and their erupted materials could only reach the mid troposphere. There were strong volcanic activities in 1755. The eruption of the Etna in Italy on March 9, 1755 lasted for 6 days (VEI=3). The strong eruption of the Katla in Iceland (VEI=4) on October 17, 1755 lasted 119 days. It is not clear whether there was any relationship between the eruptions of these volcanoes and the occurrence of anomalous precipitations and summer and autumn low temperatures in large part of China in 1755. Nevertheless, volcanic activities are external affecting factors of worth noting. Even if it is impossible for now to further discuss the relationship between each volcanic activity and the anomalous precipitation, listing those volcanic activities will enrich our understanding of the historic climate events.

5 Conclusions

(1) In 1755, rain flooding occurred in multiply river basins in eastern China. The prolonged precipitations in the middle and lower reaches of the Yellow River in 1756 and 1757 led to a three-year-long rain flooding in the Huang-Huai Region. This was a major meteorological hazard and extreme climate event happened in the warming phase of the Little Ice Age.

(2) In 1755, continuous precipitations were in the middle and lower reaches of the Yellow River and the Yangtze River, and the Huaihe River Basin. There were more than 40 days of continuous raining in the Huang-Huai Region. The Meiyu season was also abnormal in the Jiang-Huai Region. There was early Meiyu in the lower reaches of the Yangtze River; and the duration of regular Meiyu period was 23 days longer than usual [Yu and Lin, 1989] which was among the longest of the 18th century. The estimated annual rainfall in Nanjing was the highest of the 18th century; the rainy season and summer season rainfall was the second highest of the 18th century [Zhang and Liang, 2009]. In 1756 and 1757, the rain belt moved northward. As a result, a rarely seen north-flood and south-drought pattern was over eastern China for two consecutive years. This rain flood event occurred in a pluvial stage of northern China.

(3) The torrential rain and continuous precipitations in 1755 caused eruption of mountain torrents and abrupt water level rising and broken dikes of rivers and lakes in various places. Anomalous precipitations in the north in 1756 and 1757 led to overflowing of the rivers in numerous places. The Huang-Huai Region was flooded for three consecutive years, the flooded water stayed for longer than half of a year in some places.

(4) Poor harvest in extensive area in 1755 led to famine accompanied by insect pest. Prices of crops began to rise through the roof. In the following two years the famine was worsening and the main affected areas included Henan, Shandong, Anhui, and Zhejiang provinces.

(5) After June 1756 an outbreak of pestilence occurred in large area which included Jiangsu, Zhejiang, and Anhui provinces. However, there have been no studies of whether spread of the pestilence and the flood were related.

(6) The characteristics of the climate in 1755 included longer duration of rainy season and low temperatures, early start, long last, and larger rainfall of the Meiyu, as well as cold summer, early frost in autumn, and bitter cold winter. All these were very similar to the two years (1823 and 1954) with extreme precipitations.

(7) As far as the external affecting factors are concerned, 1755 was the minimal year of solar activity period, which was the same case in 1823 and 1954. However, 1755 was an El Niño year, which was opposite to 1823 and 1954 — non-El Niño years. This indicated that the precipitation pattern in China did
not have a simple correlation with the El Niño phenomenon.

Acknowledgements

This work was supported in part by the China Global Change Research Program (No. 2010CB950103) and the National Science and Technology Support Program of China (No. 2007BAC29B01).

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