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STUDY ON THE FREQUENCY AND PRINCIPLE OF FLOOD CATASTROPHE IN THE CHANGJIANG DELTA AND ITS NEIGHBORING REGIONS IN THE LAST 2000 YEARS

ZHANG Sheng, ZHU Cheng, ZHANG Qiang
(Department of Urban and Resources Sciences, Nanjing University, Nanjing 210093, P. R. China)

ABSTRACT: Documented materials, especially those about flooding catastrophe, are abundant comprehensive and well-preserved, which makes possible the systematical collection of materials about historical document about climate evolution in Changjiang (Yangtze) Delta region and its neighboring areas. We make good use of the exceptional information to discuss the genesis and principle of flooding in this region. Analysis shows that the main flooding periods in the studied region in the last 2000 years were the Western Jin Dynasty, Eastern Jin Dynasty, Northern and Southern Dynasties, Southern Song Dynasty, Yuan Dynasty, Ming Dynasty and Qing Dynasty. The periods with flooding peak values were the 4th century, 5th century, 7th century, 9th century, early 12th century, early 14th century, mid-15th century, and early 18th century A. D. Possibility of reappearance of flooding peak value in the early 21st century will be great, and the hazard prevention and the hazard reduction will be still hard.

KEY WORDS: Changjiang Delta; historical flood; frequently-occurred flood period; flooding peak period

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1 INTRODUCTION

The Changjiang (Yangtze) Delta and its neighboring regions mentioned in this article is located in the lower reaches of the Changjiang River, whose north, east, south and west adjacent places are Xingtongyang Canal, Huanghai Sea, East China Sea, Qiantang River, Hangzhou Bay and Nanjing, Zhenjiang respectively. These regions belong to Jiangsu Province, Zhejiang Province and Shanghai City in administrative division, being one of the economic developed regions. The studied region is characterized by typical subtropical monsoon climate, the annual mean precipitation is in the range of 1000 - 1400mm, the precipitation fluctuation is great and flooding reasons are concentrated. The terrain is dishing, making Taihu Lake as its center, the elevation of below 5m, dense water nets, low slope degree of riverbed and rivers, and lakes and sea exchanging with each other. The combination of climate and underlying surface, together with tide pushing and impact by human activities, make the studied region susceptible to natural calamity. According to historical records, frequent flooding occurred in the Changjiang Delta and its neighboring regions, for example, greatest flooding calamity occurred in 1931, 1954, 1991 and 1998 only during the 20th century. Since recorded

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Biography: ZHANG Sheng(1960 -), male, a native of Anhui, associate professor. His research interest includes physical geography.

history, increasing growth in population and stronger and stronger human activities combined to destroy the original features of the paleo-cultural site, making the flooding calamity events recorded in cultural layers hard to be distinguished. Therefore, discussion on the historical flooding hazards through sediment lithostratigraphics and archaeology lithostratigraphics becomes difficulty hard to tackle. As such, it's theoretically and practically significant to make full use of valuable climate material documented in history to study the principle of flooding scientifically, to analyze and forecast flooding evolution tendency on macro-standpoint and to serve local anti-hazard and hazard reduction.

2 MATERIAL

The historical document in China, beginning with Jiaguwen (inscriptions on bones or tortoise shells of the Shang Dynasty) since Yinshang during 13th century B. C. is rich in content and continuous in record, being the precious heritage in world historical record (CHENG *et al.*, 1984). The largest part of the abundant climate historical records is about flooding calamity, providing possibility for us to make further research on flooding calamity in historical period. It should be mentioned that flood events recorded in historical document isn't in agreement with amount, recording means and standard used in record, etc. As such, we made comprehensive and systematic collection, arrangement, choose and management on local historical document in climate evolution, by doing so, and as many as possible references to relevant evidence, the comparability of flooding events recovered in history on a larger spatial and temporal range should be greatly improved. The historical material about flooding calamity in the Changjiang Delta and its neighboring regions is mainly from "The Natural Disaster and Man-made Calamity in China since Recorded History" by CHEN Gao-yong *et al.* (1993). This is a masterpiece containing comprehensive and systematic record of natural disaster and man-made calamity in China for about 2000 years since the Qin Dynasty. Thereinto, some is about natural disaster mainly recording flood, drought, wind calamity, hail disaster, plague of locusts and epidemic situation etc., exerting significant influence on human living. The statistic results show that, only in the period from the Qin Dynasty to Mid-Tang Dynasty, the Changjiang Delta underwent 201 flooding calamities (ZHU *et al.*, 1996) for 1200 years in this period. Most of them occurred in the lower reaches of the Changjiang River, and the drought of the same period, however, was only 51 times according to record. These data indicate that more flooding than drought occurred to the Changjiang drainage basin, esp. the lower reaches of the Changjiang River, which provides ground and basic proof for the study confidence in local historical flooding calamity. These historical information are from "The Twenty-four Histories", "Chorography", "Books Arranged According to Subjects", "Taiping Imperial Encyclopaedia" and "Collection of Books". The data are listed chronologically as sequence tables, most of these records are descriptive but not quantitative, making direct quantitatively characteristic analyses difficult. These records are focused on the whole nation but not locality and the administrative range is different from dynasty to dynasty, making some administrative unite like eparchy, state, mansion and county not in good agreement with each other. The calamity situation reflected in the document is scattered, which makes arrangement, filter, compare and management necessary to perform study on the principle in flooding. To reveal objectively the basic principle of the flooding occurred in the studied area, frequency histogram of flood hazard in the Changing Delta and neighboring regions for last 2000 years are made based on the flooding data recorded in "The Natural Disaster and Man-made Calamity in China Since Recorded History". The flooding occurred in the studied region is classified into flooding calamity, great flooding calamity and greatest flooding calamity just because the degree and/or density is different, and simultaneously the according frequency histogram and density curves are made to show its changes (Fig. 1, Fig. 2). The criterion is that all the flooding events recorded is classified into flooding grade, those events marked large flood or that of equivalent degree is classified into large flooding grade and those containing description of heavy calamity. For example, abundant fields are destroyed, number of persons killed reach

above 10 000 or migrating population reaches 10 000, or events of equivalent degree, and at the same time with the range of many eparchy, many tastes, many mansions or many counties etc.

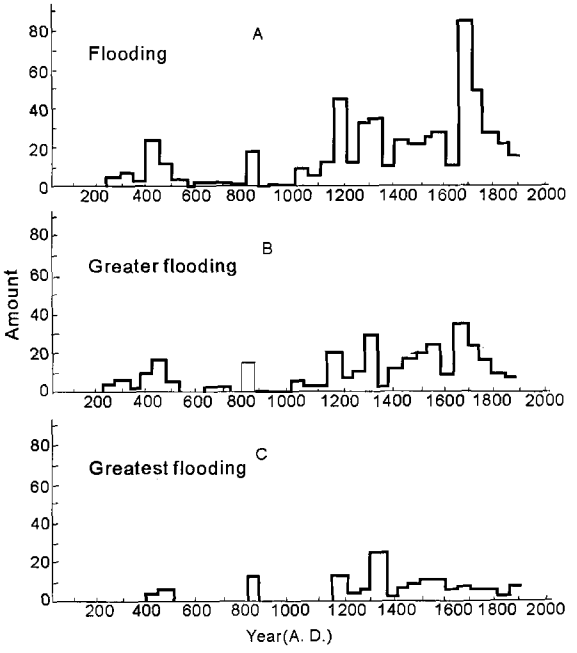

Fig. 1 Frequency histogram of flood hazard in the Changjiang Delta and its neighboring regions in the last 2000 years

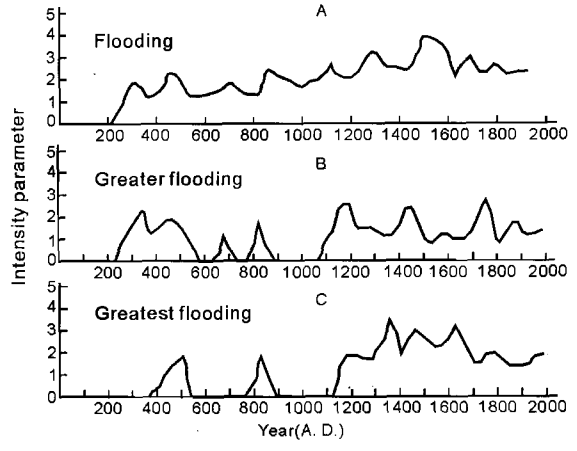

Fig. 2 Flood intensity curve in the Changjiang Delta and its neighboring regions in the last 2000 years

The number of the flooding calamity, great flooding calamity and greatest calamity are calculated according to time span of 50 years to made histogram. To avoid the influence on the statistic results exerted by the difference in degree of detail and brief of historical record during different historical periods and also to avoid the increasing tendency in flooding calamity frequency resulted from just the mentioned above and distortion in curve fluctuation, to reveal better the principle of the flooding calamity, definition of flooding intensity is introduced to reflect periodicity of the flooding (GUO, 1989).

So-called flooding intensity is that, during a time period, the amount of the flood occurred to every flooding year generally. This is a ratio and it basically can reflect the fluctuation principle of flooding. Here the flooding intensity parameter I is defined as the ratio of A to B, A means the number of places where flooding calamity occurred and B means the times of flooding:

$$I = A / B$$

The intensity curve is made according to the value of I. The parameter reflects the number of eparchy, state, mansion and county, is a kind of relative intensity of flooding.

3 BASIC FLOODING PRINCIPLE REVEALED BY MATERIAL

3.1 Evolution principle of the Historical Flooding Obtained from the Frequency Periodicity of Flooding Calamity

According to the historical material, the flooding calamity, great calamity and greatest calamity occurred in the Changjiang Delta and its neighboring regions are 543, 306 and 116 times respectively (Fig. 1). Frequency histogram of flood hazard suggests two obvious peak flooding-occurrence periods during the last 2000 years. They are the Western Jin Dynasty and Eastern Jin Dynasty and the Northern and Southern Dynasties (3rd - 6th century A. D.) and the Southern Song Dynasty, the Yuan Dynasty, the Ming Dynasty and the Qing Dynasty (12th - 19th century A. D.) respectively. 7th - 11th century, however, is the low flooding-occurrence period (except weak flooding in earlier 9th century). Obvious fluctuation exists in these two frequently-occurred flooding periods, and the period

becomes shorter when time draws closer to now, which manifests itself well in periods of Southern Song Dynasty, the Yuan Dynasty, the Ming Dynasty and the Qing Dynasty. Fluctuation in periods of frequently-occurred large flooding calamity and that of largest one suggests that they are in considerable agreement with the changes of frequently-occurred flooding calamity period, indicating that largest flooding calamity recorded in history occurred usually in frequently-occurred flooding periods. This fact shows that the synchronism and correlation between largest flooding calamity and frequently-occurred flooding calamity period provides valuable evidence for forecasting largest flooding calamity (a time in 100 years or 1000 years). The following several peak periods can be obtained through analyses of frequency histogram of large flooding calamity and largest flooding calamity, they are: the 5th century A. D., earlier 9th century A. D., earlier 14th century A. D., 16th century A. D., later 17th century and till 18th century. The periods becomes shorter from 400 – 500 years to about 200 years.

It should be pointed out that, as to historical flooding-occurrence principle reflected by Fig. 1, we don't know the true situation of the flooding occurred in the studied region during the last 2000 years in relative sense. This is because there are many factors affecting the truth of the flooding historical record. For example, the political center of the Eastern Jin Dynasty and Southern Dynasty is in Nanjing, large immigration into the Changjiang Delta and its neighboring regions, development in economy and human civilization made the gerentocratic works have to care natural calamity in study region. In addition, Nanjng is the economic or political center or both, the appearance of choreography (after about the 14th century A. D.) made record detailed in flooding and drought calamity well kept, and simultaneously the historical document itself of every dynasty is unavoidably imperfect. All these are the reasons that the increasing tendency of flooding calamity reflected by histogram should not be in excellent agreement with the true reality of that time. The change tendency of the flooding calamity, however, is well revealed, we can make it certain that the existence of two long-term, large-scale frequently-occurred flooding periods and shorter and shorter of several peak flooding.

3. 2 Historical Flooding Evolution Principle Reflected by Periodical Fluctuation of Flooding Intensity

Fig. 2 is the intensity curves of flood occurred in the Changjiang Delta and its neighboring regions in the last 2000 years, and the number of flooding, large flooding and largest flooding is 277 178 and 64 respectively. The changes in curve fluctuation degree are smaller than those in Fig. 1. However, the main flooding periods are still in the Western Jin Dynasty, Eastern Jin Dynasty, Northern and Southern Dynasties, Southern Song Dynasty, Yuan Dynasty, Ming Dynasty and Qing Dynasty. It can't be said that intensity curves are actually the reflection of the truth, in fact, it's still a general tendency in relative sense. We just understand objectively, from another viewpoint, the basic state and changing tendency of the flooding occurred to the studied region in the last 2000 years. Several peak values of large flooding and largest flooding is still characterized by shorter and shorter period. The peak intensity in flooding lies in the 5th century A. D., early 9th century, 12th century, 14th century, 16th century and 18th century, with shorter and shorter periods from 400 years to 200 years.

Facts mentioned above are in great agreement with those reflected by histogram. Frequently-occurred periods of flood are also those of large flood and largest flood, with increasing intensity of flood, large flood and largest flood. We can conclude that the Western Jin Dynasty, Eastern Jin Dynasty, Northern and Southern Dynasties, Southern Song Dynasty, Yuan Dynasty, Ming Dynasty and Qing Dynasty are the main flooding periods and the flood occurred more frequently during latest 1000 years. The Southern Song Dynasty may act as the turning point. The interval may be about 100 years if calculated according to the historical periods in which these two peak values of the frequently-occurred flooding periods occurred. This result is equivalent to the span of time of the 7 flooding periods already confirmed by evidence from archaeo-lithostratigraphy (ZHU *et al.*, 1998). Analysis indicates that these two flooding periods are equivalent to the flooding origin-period in

grade, and other evidences can prove the viewpoint true. For example, the cultural interruption before the Tang and Song dynasties in Maqiao site, Shanghai, no relics before the Jin Dynasty in time can be discovered east to Gangshen (CHEN *et al.*, 1997). No relics of six-dynasty can be discovered in Taihu Lake region west to Gangshen (YI *et al.*, 1962), and also the cultural layer disappeared of the Jin Dynasty in Tangmiao village, Songjing, about 1500a B. P., in dating. All these facts suggest that this region as nation political and economic center, may be unsuitable for human settlement for frequent flooding and water expansion.

4 ANALYSES ON THE EVOLUTION TENDENCY OF THE FLOODING IN EARLIER 21ST CENTURY

The scale of thousand years is not enough in resolution for reflecting calamity changes, but it can serve as forecasting background. Study on changes in shorter periods should be carried out for further research on the evolution trend of the flooding during the early 21st century. It can be seen from Fig. 1 and Fig. 2 that fluctuation of peak value and lower value spanning about 200 years is obvious. Or rather, the peak value of flooding is in the early 4th century, later 5th century, later 7th century, early 9th century, 12th century, early 14th century, mid-15th century, mid-16th century and early 18th century, and the span of time is 150, 200, 150, 350, 150, 150, 100, 150 years. Extrapolation from mentioned above for the peak flooding period in the similar time-scale in the early 21st century is feasible (the span of time of the last peak flooding period is 3000 years) . As a kind of forecasting or estimation, and also making the possibility convinced, we arrange the most detailed 20 records of flooding calamity from details of largest flooding calamity. At the same time, according to the characteristics of the flooding calamities, the following points can be obtained: 1) large span of time can reach 300 or 350 years, e. g. 832 – 1170 A. D., 2) middle span of time can reach 150, 100, or 70, 60 and even 50 years, e. g. 1180 – 1286 A. D., 1330 – 1489 A. D., and 1591 – 1685 A. D. etc., 3) span of time of 30, 20, 10 years or shorter, e. g. 816 – 832 A. D., 1170 – 1181 A. D., 1589 – 1591 A. D., and 4) the largest flooding calamities in the 20th century occurred in 1931, 1954, 1991 and 1998 respectively. The interval is by and large in agreement with the mid-interval and short-interval in time. Although the randomicity of the reoccurrence of the historical flooding calamity of the same or similar grade is great (this is the true reason that why research and forecasting of the flooding calamity is a difficulty and it is impossible to discover and forecast accurately the flooding calamity), we use multi-method, multi-scale and multi-aspect on the finding of the possibility of the reoccurrence of the historical flooding calamity, which is reasonable. The possibility of reiteration of the flooding calamity of the different grades and different scales is much great, the evidence of the forecasting is more high.

The evolution principle of the flooding calamity in this region is under influence of sea-surface changes, lakes evolution, waters changes and population scale, hydro-engineering and the changes in land use, as well as climate changes (FANG *et al.*, 1995; WANG *et al.*, 1999; YANG *et al.*, 1995) Therefore, the estimate, based on the basic principle of the historical flooding calamity and the future trend of the flooding calamity is hard to tackle and the evidence is low. The influence of human activity on the local flooding calamity in the study region can't be overlooked. Study results show that the precipitation of 1991 is less than that of 1954 (CHEN, 1992), the water level however in 1991 is higher than that of 1954, and the same phenomenon also happened to 1998 (YAN, 2000), which makes risk prognostication and estimate more complex. As for the peak flooding to come, strengthening the observation in hydrology of the drainage basin and the statistic arrangement, based on the study result of the historical flooding calamity, may make anti-hazard and hazard reduction possible.

5 CONCLUSION

(1) The Western Jin Dynasty, Eastern Jin Dynasty, Northern and Southern Dynasties (3rd – 6th century A. D.) and the Southern Song Dynasty, Yuan Dynasty, Ming dynasty and Qing Dynasty (12th – 19th

Table 1 The age and status of the large flood hazards in the Changjiang Delta and its neighboring regions in the last 2000 years

Year(A. D.)	Range of calamity	Calamity situation
444	Jiankang	Inundation, hundreds of rain-days
499	Jiankang	Inundation, large population killed
816	Runzhou, Changzhou, Huzhou	Tens of thousand of hectares of fields destroyed
832	Huzhou and Suzhou	Inundation, relieve 2200L
1170	Pingjiang, Jiankang, Huzhou and Xiuzhou	Inundation, cities in Jiangdong were in water of 3.3 meters, houses were floating on the water and plants inundation, banks broken
1181	Shaoxing	More than 82 000 peoples killed, all plants in decomposition
1286	Hangzhou and Pingjiang	17 300 ha destroyed by flood
1290	Jiangyin	21 267ha was destroyed, more than 400 000 families killed
1302	Tong, Tai, Dingjiang, Zhenzhou	Rainstorm, river-water overflowed, 13 – 16 meters in water depth, houses were in inundation and 34 500 families became victim
1323	Pingjiang Road	Inundation, 49 300ha of fields were destroyed
1330	Pingjiang, Jiaxing, Suzhou and Songjiang	Inundation, 436 200ha were destroyed and 405 500 families became victim
1330	Hangzhou, Changzhou, Shaoxing, Zhenjiang, Xinghua	More than 13 500ha were in inundation
1439	Suzhou, Changzhou, Zhenjiang, Jiangning	Flood, numerous people were drawn
1454	Hangzhou, Jiaxing, Huzhou	Inundation, people eat each other
1518	Yingtian, Suzhou, Songjiang, Changzhou, Zhenjiang, Yangzhou	Months of rain-day, houses were on water, numerous people and animals died and drought came into being
1589	Hangzhou, Jiaxing, Huzhou, Yingtian	Rivers and lakes overflowed with more than several meters of water depth on the ground, windy.
1591	Suzhou, Songjiang	Inundation, tens of thousands of people drawn
1685	Gaoyou, Xinghua	Heavy waterlogging
1690	Shaoxing	Depth of water was several meters, houses were floated and uncountable people and animals killed
1865	Shaoxing, Xiaoshan	Weeks of rainy days, flood in Shaoxing, the water-level of Xiaoshan river wasthe level with the houses, tens of thousand s of people drawn

century A. D.) were the main flooding periods for the Changjiang Delta and its adjacent regions.

(2) The 4th century, later 5th century, later 7th century, early 9th century, 12th century, early 14th century, middle 15th century, middle 16th century and 18th century were the historical peaks of flooding, and the time span was 100 – 350 years, most fluctuate in the range of 150 – 200 years.

(3) Frequency and the fluctuating-period became shorter with the time draws closer to now. The frequency and the intensity of the flooding, great flooding and the largest flooding had the synchronization, that is, the frequently-occurred periods of the flood were the same with those of great flood and greatest flood. Simultaneously, the intensity of the flood, great flood and the greatest flood was increasing with the time draws to modern time.

(4) The possibility of the reoccurrences of the peak flooding in the early 21st century was great and the anti-flooding calamity was still hard.

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