The Ordered Network Structure and its Prediction for the Big Floods of the Changjiang River Basins

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According to the latest statistical data of hydrology, a total of 21 floods took place over the Changjiang (Yangtze) River Basins from 1827 to 2012 and showed an obvious commensurable orderliness. In the guidance of the information forecasting theory of Wen-Bo Weng, based on previous research results, combining ordered analysis with complex network technology, we focus on the summary of the ordered network structure of the Changjiang floods, supplement new information, further optimize networks, construct the 2D- and 3D-ordered network structure and make prediction research. Predictions show that the future big deluges will probably occur over the Changjiang River Basin around 2013 – 2014, 2020 – 2021, 2030, 2036, 2051, and 2058.

Key words: The Changjiang River Basin; Informational Ordered Network Structure; Prediction of Big Flood.

1. Introduction

China is a vast country where natural disasters occur very frequently, especially big floods, droughts, strong earthquakes, and strong typhoon. Those disasters are widely distributed and bring great losses. According to the statistical data, affected population is over 200 million all the year round, and the middle value of all direct economic losses of natural disaster is about 4% gross domestic product of China in the same period [1]. This is China's basic national conditions. Thus, prediction of big floods, strong earthquakes, and other serious natural disasters is not only the essential content of disaster physics, but also the most urgent task we are facing in disaster prevention and mitigation.

Wen-Bo Weng's information forecasting theory combines the advantages of Chinese and Western sciences and cultures. It's a great creation in disaster prediction theory. Based on it, Weng has made successful prediction of earthquakes, floods, and droughts dozens of times [2 – 5]. As the development and supplement of disaster prediction theory, information orderliness and ordered network analysis method can be used in prediction of strong earthquakes [6 – 13] as well as floods and droughts [14 – 17].

On the basis of above research results, deeply exploring regularity of floods over the Changjiang (Yangtze) River Basins, this paper constructs the two-dimensional (2D) and three-dimensional (3D) ordered network structure to make predictions, which can provide basis for China to make decisions of disaster prevention and mitigation.

2. Constructing the Ordered Network of Changjiang River Flood

2.1. General Situation of the Changjiang River Basin

The Changjiang River is the largest river in China, which is 6397 km long. The Changjiang River Basin crosses three major economic zones of East, Central, and West China, involving 19 provinces (municipalities or autonomous region). The basin area is about 1.8085 million km^2, which means 18.8% of the whole country. The basin population is about $1/3$ of China's population, and the output is about 40% of the country. Most water of the Huaihe River goes into the Changjiang River through the Grand Canal. So we can also say that the Huaihe River is a tributary of the Changjiang River. Plus the Huaihe River Basin, the Changjiang River Basin area is about 2 million km^2.

Most area of the Changjiang River Basin belongs to the East Asian subtropical monsoon region. It is warm and humid and have four distinct seasons. With the most abundant water, the Changjiang's water resource is 9.616 billion m^3, about 36% of the whole country. It is 20 times of the Yellow River, and ranks the third in the world.

Precipitation in the Changjiang River Basin is very abundant, about 1067 mm one year in average. Due to the wide area and complex topography, the monsoon climate is very typical and the precipitation is very uneven in spatial distribution. In flood season, flooding is very easy to take place. When precipitation is not suitable for crop water requirement, it's very likely to result to droughts. The basin flood season moves from southeast to northwest with the rain band. Usually, the peak of middle and lower reaches of the south bank tributary is in May or June, and up of Yichang and Hanjiang is in July or August. Unusually, upstream, midstream, downstream, and tributaries floods meet together, which may result in big floods of the whole basin with high peak. The years 1931, 1954, and 1998 witnessed the three biggest floods over the whole Changjiang River Basins in the last century.

In 1954, a once-in-a-century flood in China took place over the Changjiang River. There are Hunan, Hubei, Jiangxi, Anhui, and Jiangsu five provinces in the middle-lower Changjiang River Basins. According to incomplete statistics, among them, 123 counties or cities suffered from the disaster, 3.17 million hm^2 farmland was flooded, 33 000 people died, and 4.276 million houses were damaged. The direct economic loss was as high as 10 billion Renminbi (RMB). Beijing-Guangzhou railway could not traffic normally a hundred days. Another big flood took place in 1998, only the Jiujiang dike was broken. It was blocked in a few days. Cities along the Changjiang River and the transportation routes were not flooded. The whole flooded area was 321 000 hm^2, among which the arable land was 197 000 hm^2. The suffered population was 2.316 million, among which 1562 people died. The loss was far less than that in year 1954.

2.2. Selecting the Data Samples

According to the historical data, since the Han dynasty, more than 200 big floods have taken place over the Changjiang River Basin. Research of Zhong-Shu

Table 1. Catalogue of hydrology of the Changjiang floods at three key stations from 1827 to 2012.

No.	Date Year	Time interval / (a)	Annual maximum peak flow / (m^3/s) Month-Day	Yichang Station	Month-Day	Hankou Station	Month-Day	Datong Station	Note
1	1827	/		/		/		/	$M-3$
2	1848	21		/		/		/	M
3	1870	22	07-20	105 000	08-05	65 200		/	M
4	1887	17	07-13	48 800	07-23	54 900		/	$m-2$
5	1892	5	07-15	64 600	07-25	46 100		/	$M-1$
6	1901	9	07-31	57 900	07-25	50 500		/	m
7	1909	8	07-13	61 100	07-16	50 300		/	$M+4$
8	1915	6	09-24	40 200	08-25	42 900		/	$M-2$
9	1931	16	08-10	64 600	08-19	59 900	06-20	52 300	$m-2$
10	1935	4	07-07	56 900	07-14	59 300	07-18	62 100	$m+2$
11	1937	2	07-21	61 900	08-23	56 200	08-25	61 400	M
12	1945	8	09-06	67 500		/		/	m+1
13	1948	3	07-21	57 600	07-26	56 000	07-23	63 200	$M+1$
14	1954	6	08-07	66 800	08-14	76 100	08-20	92 600	m
15	1962	8	07-11	56 200	07-13	58 600	07-11	68 300	$m-2$
16	1969	7	09-06	42 700	07-20	62 400	07-19	67 700	$M+1$
17	1975 (Aug. 5 – 8)	6	10-05	45 500	07-14	43 800	05-24	55 100	$m-1$
18	1983	8	08-04	52 600	07-19	65 000	07-19	72 600	$m-3$
19	1991	8	08-16	50 500	07-17	66 700	07-18	63 800	$M+2$
20	1998	7	08-16	63 300	08-19	71 100	08-21	82 300	$m+2$
21	2010	12	07-19	70 000		/		/	$m+2$

Note: In the Table 1, M and m denote the peak year and valley year of activities of sun's spots respectively, and $m-1$ denotes one year before the valley year of activities of sun's spots, $M+1$ denotes one year after the peak year of that. The rest of analogy and followings are the same.

Huang [18] shows that the average frequency of big flood (first class) in the Changjiang River Basin is 7.86%. The most frequent floods area locates near the middle-lower Changjiang River valleys. The central area includes Jingjiang in Hubei, middle-lower Sishui valley in Hunan, the Dongting Lake area, the Poyang Lake area, and downstream to the Changjiang River Delta. The frequency is above 10%. Average frequency of basin waterlogging (second class) is 23.48%, about three times of the first class flood. Total frequency of the two kinds of flood is as high as 31.34%, which means a first or second class disaster occurs in every three years. This paper is based on hydrological data [19 – 22] and peak flow data of Yichang, Hankou, and Datong hydrology station. For the sake of simplicity, we use the number of years to express the sample of big floods in this paper, showing as Table 1. The statistics shows that since 1827, a total of 21 big floods have occurred over the Changjiang River Basin, about once every seven years. In 1848 – 1849, 1869 – 1870, 1908 – 1909, 1948 – 1949, 1968 – 1969, and 1998 – 1999, floods occurred in two consecutive years, only the bigger flood was recorded.

In 1975, the Changjiang flood was not so big, but Typhoon No. 7503 (August 5 – 8) brought surprisingly abundant rainfall to strike the south area (Zhumadian, Xuchang, Nanyang) of Henan Province, 56 reservoirs collapsed almost at the same time, about 6 billion m^3 of flood surged down and thousands of miles plain was flooded, which brought great losses to people's life and property. More than 10 million people suffered, among which about 100 000 people died. It was the largest flood with the largest suffered area and most dead people since the funding of new China. Thus, we record the flood as a flood sample.

It should be added that on July 19, 2010, the peak flow of the Changjiang flood is the largest since the Three Gorges was built, as high as 70 000 m^3/s. After storage control by the Three Gorges, the peak flow is 41 400 m^3/s. The efficiency is 40%, blocking and storing flood 7 billion m^3. Without the Three Gorges, reaches below Yichang would all pass the warning level.

2.3. Constructing the Ordered Network and Prediction

The so-called ordered network is a collection of the nodes and their connections. It's the extension of the concept of system. A network has no boundary, or boundary is fuzzy, and it can be extended without restriction. Its open degree is often greater than the closure, so it is more suitable to describe multi-contact complex things which are not included in the system. Here, the nodes are represented by the year of the big flood event occurrence, with the number in the line representing the time interval (or order parameter τ value) between the two floods in two nodes. In Table 1, there are 21 flood events. We can get $C_{21}^2 = 210\tau$ values of time interval by pairwise subtraction. As statistical analysis shows, floods over the Changjiang River Basin have obvious orderliness.

The main intervals are 82 ∼ 83a, 60 ∼ 61a, 53 ∼ 54a, 37 ∼ 38a, 21 ∼ 22a, 15 ∼ 16a, and 10 ∼ 11a, among which 60 ∼ 61a and 21 ∼ 22a are the most frequent and important order parameters. Connecting and expanding these values according to the time sequence from left to right, from up to down at the same time, we can construct the 2D- or 3D-network. Sometimes it is difficult for a network diagram to give a comprehensive summary, therefore we can divide a network structure into several parts to describe in detail from various angles.

In Figure 1, the 21 big floods are divided into four series. We define the first year number as the index of each flood series. They are 1827, 1887, 1948, and 2010 big flood order series (BFOS). To be simple, set 1935 and 1937 as one node, recorded as 1937. In Figure 1, the horizontal interval is 21 ∼ 22a, the vertical interval is 60 ∼ 61a, and the slash one is the sum of the two intervals. Seven real line rectangles are composed of four flood events by one-to-one correspondence between the 1827 BFOS and the 1887 BFOS, or between the 1887 BFOS and the 1948 BFOS. The opposite sides in each rectangle are equal or almost equal (the errors in a narrow range of 0 ∼ 2a). Figure 1 shows excellent symmetry and orderliness. Obviously, it is not accidental. It indicates the great regular pattern of big floods over the Changjiang River Basin. Figure 2 is the ordered network structure of big floods over the Changjiang River Basin since the 20th century, which shows the coupling relation of the order parameters 53 ∼ 54a, 37 ∼ 38a, and 15 ∼ 16a.

The 21 big floods in Table 1 seem to be disorganized. But after rearranging in Figures 1 and 2, they show obvious orderliness. According to the ordered analysis in Figures 1 and 2, the order parameters 60a, 22a, and 38a are the basis of big floods over the Changjiang River Basin. It's well-known that the 60a

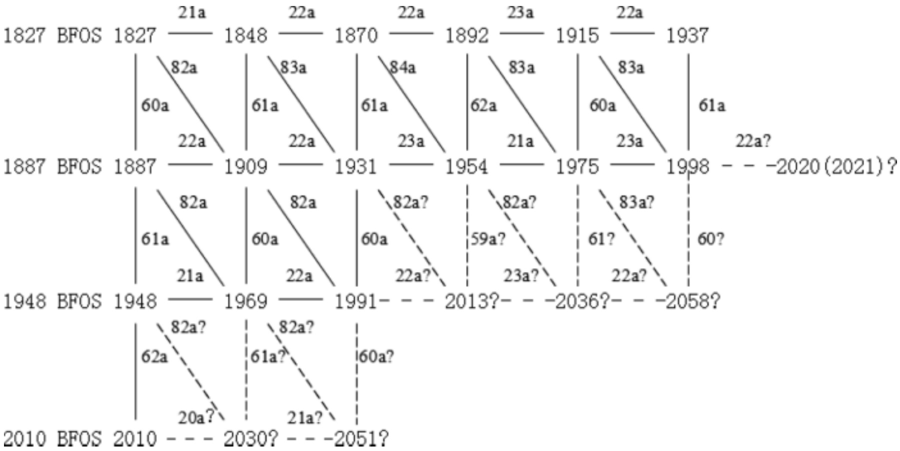

Fig. 1. Ordered network structure of big floods and its prediction over the Changjiang River Basin. (The dashed lines for prediction and the same below.)

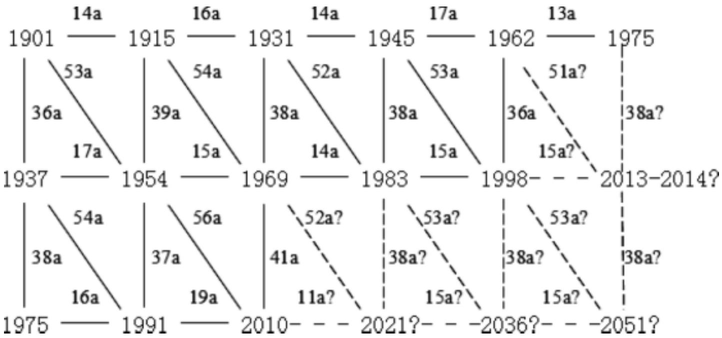

Fig. 2. Ordered network structure of big floods and its prediction over the Changjiang River Basin since the 20th century.

cycle is called the Stems-Branches (SB) period. Ancient Chinese recorded the year in terms of a unique system consisting of 10 Heaven Stems (10 Chinese characters) and 12 Earthly Branches (12 characters) to pair the names of years one by one, leading to 60 different year names. As an outstanding contribution to mankind, the SB cycle shows non-negligible ability in calamity prediction, revealing the motions of celestial bodies and thus their regularity [23]. The breeding and evolution of a disaster cannot occur without the effects of the periods of macroscopic motions in nature. The movements of celestial bodies like the solar system contain 60a, 12a, and 10a periods, which are the basis for the SB predictions.

The 22a period was proposed by Haire for the interval of activities of sun's spots. The 22a and 38a intervals make up 38.2% and 61.8% of a 60a interval, respectively, corresponding roughly to the two parts of the Golden Section. Similarly, the 82a interval consists of a 22a and a 60a interval. Activities of the sun's spots have not only 11a and 22a, but 60a and 80a intervals as well. For example, the big deluges in 1848, 1870, 1937, and 1991 (1954) took place at the peak (valley) year of the sun's activities pre and post. This means that the Changjiang floods take 60a, 22a, and 38a as the basic intervals, depending on the relative positions of the sun, earth, and moon, the SB interval and the intervals of sun's spot activities [24] (see Tab. 1).

According to the latest prediction of National Oceanic and Atmospheric Administration of United States (NOAA), the 24th peak of activities of sunspot will happen in 2013 pre and post, on which we must pay high attention. Figures 1 and 2 highly summarizes the active rule of big floods over the Changjiang River Basin during the recent 200 years. Thus, we can predict that the future flood will probably occur around 2013 – 2014, 2020 – 2021, 2030, 2036, 2051, and 2058 (since each big flood is named by its occurred year number, so the prediction error is ±1a.)

Changing Figure 1 to three-dimensional, a 3D-ordered network structure like a hexagonal prism can be constructed (see Fig. 3). Figure 3 can be divided into

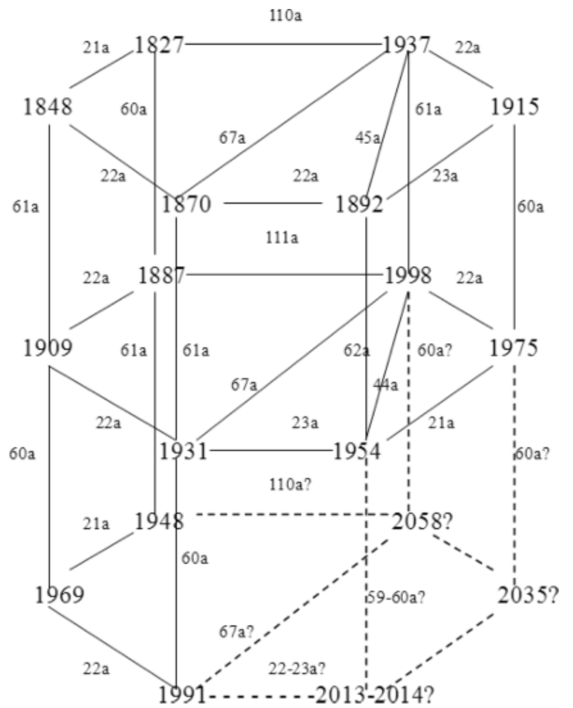

Fig. 3. 3D-ordered network structure of big floods and its prediction over the Changjiang River Basin.

2.4. *Prediction Examples of the Three Big Floods*

Since 1949, the founding of the People's Republic of China, three big floods have occurred over the Changjiang River Basin in 1954, 1991, and 1998. Not only 2D-ordered network structure (see Figs. 1 and 2) can make successful prediction of the three floods, but also 3D-ordered network structure can. Cutting the hexagonal prism in Figure 3 along the corresponding three layers with six nodes in each layer. Six nodes in the top layer are called 1827 BFOS in Figure 1, the middle layer is called 1887 BFOS, and the six nodes in bottom layer are 1948 BFOS. The corresponding four nodes in each layer and the side can form a symmetrical rectangle, which is well regular. Based on Figure 3, we can predict that the future big flood over the Changjiang River Basin will probably occur around 2013 – 2014, 2035, and 2058.

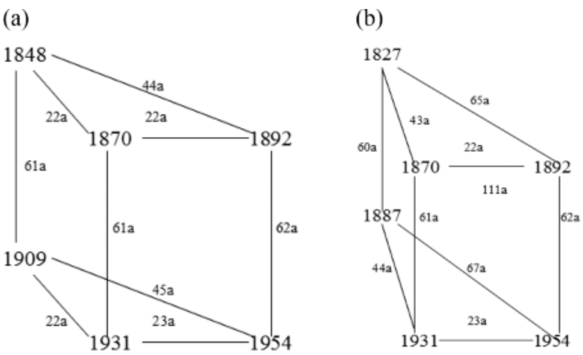

Fig. 4. Prediction for the 1954 big flood of the Changjiang Rive Basin.

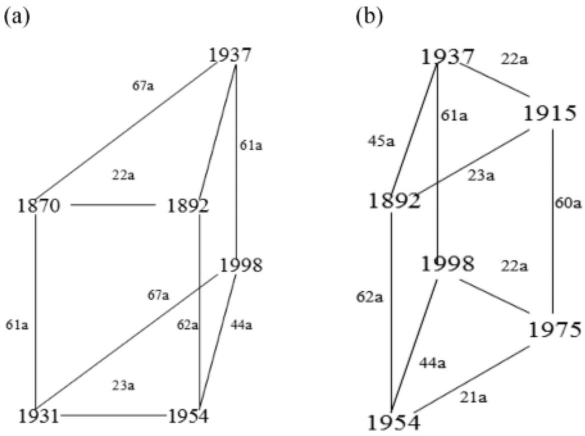

Fig. 5. Prediction for the 1998 big flood of the Changjiang River Basin.

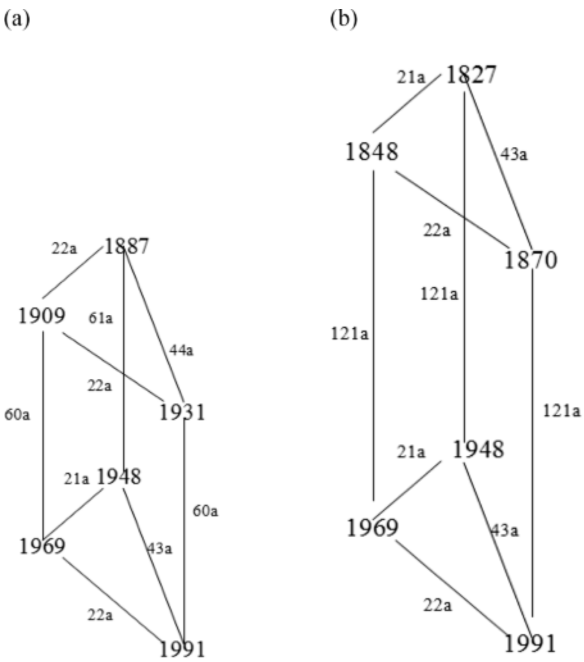

Fig. 6. Prediction for the 1991 Jiang-Huai big flood.

diagonal in top and bottom side, we can get several triangular prisms, quadrangular prisms, and pentagonal prism. Five triangular prisms are listed in Figures 4, 5, and 6. Triangular prism network structure is the substructure network of hexagonal prism. It's the foundation of spatial structure, but sometimes its prediction is excellent.

2.4.1. Prediction for the 1954 Changjiang Flood

In Figure 4a and b, there are three rectangles whose opposite side is almost equal, this is obviously regular. Thus, just with five big floods over the Changjiang River Basin before 1954, the 1954 Changjiang flood can be predicted.

2.4.2. Prediction for the 1998 Changjiang Flood

In a similar manner, by using five flood events over the Changjiang River Basin before 1998, according to Figure 5a and b, the 1998 Changjiang flood can be predicted based on the property that opposite sides are equal in a rectangle.

2.4.3. Prediction for the 1991 Jiang-Huai Flood

Similarly, with five flood events over the Changjiang River Basin before 1991, from Figure 6a and b, the 1991 Jiang-Huai flood can be predicted too.

3. Conclusion and Discussion

(i) Symmetry and non-symmetry, or symmetry breaking, are basic attributes of nature. They are the identity and variation during the natural changes. The mutual dependence and transformation make up the colorful, complex, and lively images [25]. Symmetry means orderliness, simplicity, and inevitability. To explore the symmetry is to find orderliness in arbitrariness, to find simplicity in complexity, to find inevitability in haphazard [26]. Oderliness always comes together with disorder and it runs through human, biology as well as nature. Symmetry, commensurability, fractal self-similarity, informational orderliness etc. all belong to the category of orderliness [27]. Exploring orderliness has a profound inspiration for us to explore the development of human science and nature [28]. The 2D- and 3D-ordered network structure of big floods over the Changjiang River Basin in this paper digs out symmetrical, simple and inevitable ordered information from disorderliness, complexity, and haphazard. It reveals the regularity of big floods during the last above 200 years.

(ii) The ordered network analysis is a visual image, a concise and easy method of moderate term and long term prediction for severe disasters. It avoids the complicated and non-identifiable analyzed by the traditional mathematical model. Although the prediction of severe disaster is a hard problem in the whole world, big floods can be predicted. According to the proposed ordered network structure in this paper, the future big floods over the Changjiang River Basin will probably occur in the flood season in 2013 – 2014, 2020 – 2021, 2030, 2036, 2051, and 2058 pre and post. The results show that the ordered network structure based on Wen-Bo Weng's information forecasting theory is effective to analyze and solve leaping (especially long time and long distance) prediction for moderate term and long term of big floods.

(iii) The universe is an integer. The motions of the sun, earth, and moon are interrelated with the emergence of natural calamities, and they mutually depend on and affect each other. The occurrences of floods and strong earthquakes can be viewed as the results from nonlinear interactions between internal (inside the earth's system) and external (astronomical) factors. No doubt, big floods and droughts result from intensified interactions between numerous factors. As a result, comprehensive study of natural disasters in a framework of the universe, earth, and living creatures is a feasible line along which multiple-discipline research should be conducted. China has frequent floods, droughts, and strong earthquakes as its basic situation, which has in recent years been frequented. Natural calamities and their combating and preventing are the unfailing subject of mankind survival and sustainable development. As a result, it is urgent to make every effort for intensive research and speed up the establishment of a modernized system against calamities in terms of high technology.

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