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An analysis of the variation of maximum flood stage of Lower Yangtze River

Une analyse de la variation du niveau maximum de crue du Yang Tsé inférieur

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ABSTRACT

The study analyses the annual maximum flood stage of the Lower Yangtze River at Nanjing and the volume of runoff at Datong hydrologic station. It shows that during the most recent twenty years the higher maximum flood stages occur more frequently and the mean annual maximum flood stage has increased. The peak and the short period volume of runoff at Datong station have become larger while the average volume of runoff of longer period has been almost constant. These phenomena are explained by the change of characteristics within the catchment of Lower and Middle Yangtze River due to human activity.

RÉSUMÉ

L'étude analyse le niveau maximum annuel de crue du Yang Tsé à Nanjing et le débit à la station hydrologique de Datong. Elle montre que pendant les vingt dernières années les niveaux maximum les plus élevés de crue se produisent plus fréquemment et que le niveau maximum annuel moyen de crue a augmenté. La crête et le volume de courte période de l'écoulement à la station de Datong sont devenus plus grands tandis que le volume moyen de l'écoulement sur une période plus longue a été presque constant. Ces phénomènes s'expliquent par le changement des caractéristiques dans le bassin inférieur et moyen du Yang Tsé dû à l'activité humaine.

Keywords: Lower Yangtze River; maximum flood stage; variation; human activity.

1 Introduction

Yangtze River is the largest river in China, and also one of the largest river in the world. It has a drainage area of 1,800,000 km^2, and a length of 6,300 km. The part situated upstream of Yichang, with a drainage area of 1,005,500 km^2, is usually called the Upper Yangtze. The part situated between Yichang and Hukou, with a length of 1076 km and a drainage area of 680,800 km^2, is called the Middle Yangtze, while the part situated downstream of Hukou is called the Lower Yangtze. The Lower Yangtze is 761 km in length and has a drainage area of 116,000 km^2 (see Figure 1). Nanjing is the largest city on the Lower Yangtze and there are stage records available here from 1912 except for a period during the Second World War. The two stations Wuhu and Zhengjiang situated at the upstream and downstream of Nanjing have stage records since the beginning of this century. The drainage area above Nanjing is 1,750,000 km^2, about 97% of the whole river. Due to tidal influence, the nearest hydrology station Datong is 226 km upstream of Nanjing, and has a discharge record dated back to 1948. Datong hydrology station controls 1,705,000 km^2 with an average annual discharge of 29,000 m^3/s. Corresponding to the monsoon climate, the flood season of Lower Yangtze is usually from May to September and the annual maximum flood stage usually occurs during this period. Nanjing's average annual maximum flood stage is 8.37 m above mean sea level. In 1954, the largest flood ever recorded occurred and had a maximum flood stage of 10.22 m. The coefficient of variance of the annual maximum flood stage is 0.10.

2 The comparison study of the annual maximum flood stage of Nanjing

A comparison study of the annual maximum flood stages shows that there has been some variation during the last twenty years.

Firstly, the maximum flood stage has been greater in the recent period than in the past. In the first fifty years of this century there were three years when the maximum flood stage was higher than 9.00 m (the one before 1912 is derived by correlation analysis with a neighboring station). Till 1975, about 3/4 of this century, there were six years whose maximum flood stage was above 9.00 m, but in the period from 1976 to 1998 there were ten years whose maximum flood stage was above 9.00 m. In the first half of this century there were no record of annual maximum stages above 9.50 m, but from 1951 to 1998 there were six years whose annual maximum stage was above 9.50 m. Among these six years,

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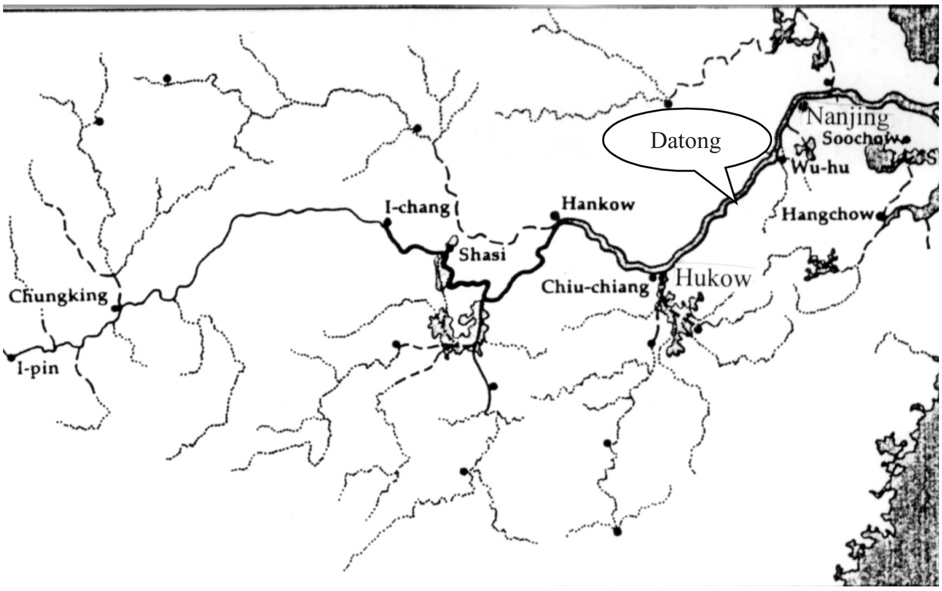


Figure 1 The map of Yangtze River.

five of them were in the most recent twenty years (see Table 1).

Secondly, is that during the most recent twenty years the mean value of the annual maximum flood stage has tended to rise. The whole series of annual maximum flood stage is divided into two intervals, then the mean value of the later interval is larger than the former one. The whole series is divided to three intervals, then the average value of annual maximum flood stage of the most recent twenty years is larger than for earlier periods (See Table 2).

To investigate the long term trend in annual maximum flood stage the twenty years moving average method has been carried. The twenty-year moving average is the average value of the specific year and the nineteen years before it. The twenty years moving average value of the annual maximum flood stage is shown in Figure 2.

The increase in the annul maximum flood stage raises the question as to whether the samples of the maximum flood stage from the most recent twenty years and the samples before it belong to a unique sample. The following formula of "t" sample test method is used. The formula is

$$t = (Z_a - Z_b)/[n_a(Z_aC_{va})^2 + n_b(Z_bC_{vb})^2]^{1/2} \times [n_an_b(n_a + n_b - 2)/(n_a + n_b)]^{1/2}$$

The result is shown in Table 3.

Sure $t = 3.355$, this means that the two series do not belong to a unique sample.

No matter how the series is divided with different interval the coefficient of variance is rather small, which implies that the variance of the variables within each interval is quite uniform.

But different from the eminent rising tendency of annual maximum flood stage, the annual mean value of monthly flood stage of different intervals almost keeps constant. If we divides the whole series into three intervals as was done for the analysis in Table 2 the corresponding mean value of annual monthly flood stage of 1912–1937, 1948–1972 and 1973–1994 is 6.27, 6.22 and 6.35 m.

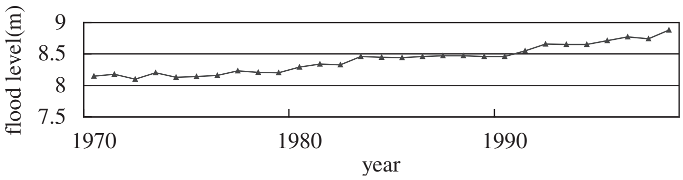


Figure 2 The twenty years moving average flood stage.

Table 3 Comparison of the two series of samples.

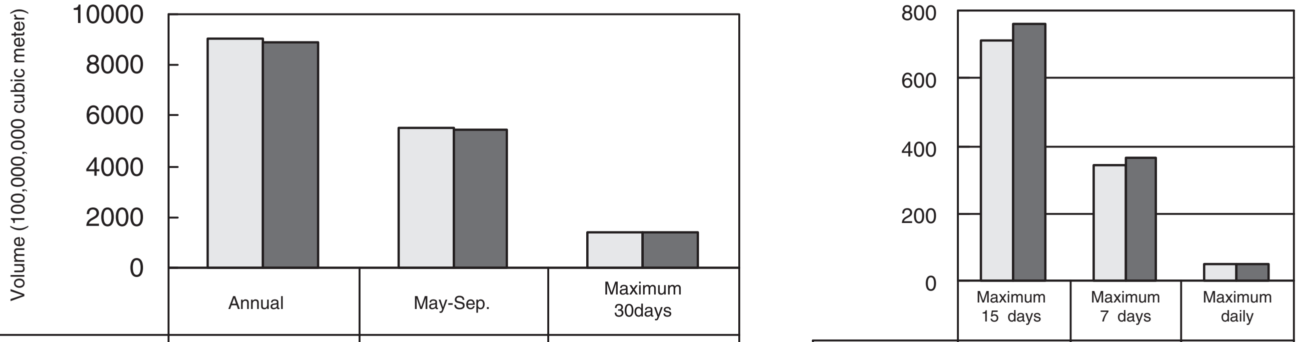
Interval	The number of samples	Mean value	Coefficient of variance
1947–1972	26	8.15	0.073
1973–1998	26	8.83	0.071

Table 1 The occurrence of high annual maximum flood stage of Nanjing.

Interval	1901–1998	1901–1950	1951–1975	1976–1998
$H > 9.00$ m	16	3	3	10
$H > 9.50$ m	6	0	1	5

Table 2 The average value of annual maximum flood stage of different interval of Nanjing.

Interval	1912–1998	1912–1937	1947–1972	1972–1998
Mean value	8.37	8.11	8.15	8.86
Samples	78	26	26	26



	Annual	May-Sep.	Maximum 30days
1948-1972	9031	5525	1369
1973-1996	8870	5439	1421

	Maximum 15 days	Maximum 7 days	Maximum daily
1948-1972	713	340	49.1
1973-1996	760	364	52.4

Figure 3 Mean value of volume of runoff of several interval of different period.

3 The comparison study of the volume of runoff of different intervals of Datong hydrologic station

The flood stage is closely related with the discharge or the volume of the runoff of the river. Therefore a comparison study of the volume of runoff for the different time interval was carried out. Neither the volume of annual runoff nor the volume of runoff of the annual flood season (May–Sep.) shows an increasing tendency during the most recent twenty years. But the volume of shorter periods shows difference. The results are shown in Figure 3.

The volume of annual runoff as well as the volume of May–Sep. runoff of the two intervals is almost the same. While the volume of runoff of maximum 30 days and 15 days of later interval gradually increase. The volume of maximum 15 days and 7 days runoff of later period is 106.6% and 106.9% of the former one. This means during recent twenty odd years, the average volume of peak value of runoff and the short period value of runoff become larger while the average volume of longer period keep almost constant.

4 The reason of the tendency of the rising of annual maximum flood stage of Nanjing

The reason for the increase in the annual maximum flood stage of Nanjing as well as the volume of runoff of short period of Datong station may be attributed to the change of characteristics within the catchments of Lower and Middle Yangtze River. They are as follows:

Firstly, there has been a decrease in the flooded area due to the great efforts which have been carried out to construct and enforce a levee along both sides of main stem of the river. The maximum flood stage of 1977 was 1 cm higher than that in 1931. But in 1931 all the flood plains along Lower Yangtze River were flooded while in 1977, none of these flood plains were inundated. The volume of the runoff during flood season of 1998 was 105% of the flood season of 1931, but the flooded area in 1998 was less than 10% of that in 1931. Similar effects are observed in the tributaries of the Yangtze River. Following the improvement of the flood control system of the tributaries, the peak flood discharge of the tributaries has increased. For instance, the Tsu River is a tributary of Lower Yangtze near Nanjing with a drainage area of 8,000 km^2. Its peak flood discharge has increased from 600 m^3/s in 1954 to 2,400 in 1991 with the similar precipitation.

Secondly, there has been a decrease in the area of lakes due to sediment deposit and reclamation. In 1949 the total area of the lakes of Middle Yangtze River was about 17,000 km^2, but by the 1990's the total area had been reduced to 6900 km^2. In 1949 the area of Dongting lake was 4,900 km^2, but at present the area of this lake is about 2,500 km^2.

Thirdly, the capacity of drainage pumping station along Middle and Lower Yangtze River has greatly increased. The total capacity of the drainage pumping stations is now at least 10,000 m^3/s more than that in the early fifty's.

There was a subsurface hydrographic survey every five years on Lower Yangtze River. The surveys show that there is no eminent variation either of river's bed altitude or of the area of gauging site. These effects may be neglected.

The decrease of flood plain area and the area of the lakes has increase the arable land that helps to yield more crops to a country with the largest population in the world. But on the other hand, this has been gained at the price of increased flood stages. This changes the character of flood and means that the people are at a great risk of being flooded. Consequently, people have to put more effort and investment into improving the flood control infrastructure. After the 1998 great flood of the Middle and Lower Yangtze River, the people and the government tried to find a reasonable balance between flooding and the ecological view, as well as to improve the infrastructure of flood control.

5 Conclusions

(a) During the most recent twenty years at the Lower Yangtze River higher annual maximum flood stage occurs more often and the mean value of annual maximum flood stage has increased.

(b) In recent years the peak value and the short period value of runoff of Datong hydrology station become larger while the average volume of longer period keeps almost constant.

(c) The reason for the variation in the high flood stage at Nanjing may be found by the change of characteristics within the catchment of Lower and Middle Yangtze River due to human activity.

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Notations

n_a = the number of samples of period A
n_b = the number of samples of period B
Z_a = the mean value of samples of period A
Z_b = the mean value of samples of period B
C_{va} = the coefficient of variance of samples of period A
C_{vb} = the coefficient of variance of samples of period B

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