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ANALYSIS ON THE STATISTIC CHARACTERISTICS OF RUNOFF TIME SERIES IN THE YELLOW RIVER MOUTH AREA

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Abstract: Stochastic model of time series is used to study runoff at the Lijin Hydrological Station in the Yellow River estuary during 1950−2000. The results show that there exists a decreasing trend of the runoff series. The series may be divided into three phases with 1968 and 1985 as demarcation. The annual runoff decreased gradually and came to 14.38 billion m^3 during 1986−2000. The phenomenon is related to not only climate factor but also human activities. The excess water diversion in the lower reach is the main cause of zero flow in the mouth area and shore erosion. Therefore the lowest runoff for maintaining ecological environment guaranteed.

Key words: Yellow River, Mouth area, Runoff, Time series

1. INTRODUCTION

Yellow River is famous for its large amount of sediment. Since the 1990s, the frequent zero flow has badly affected the industry and agriculture in the river mouth, and it also endangers the ecological environment in the river mouth delta. The main cause is that the runoff has changed greatly during these years. Therefore the study of runoff is important to the evolution and ecological environment of Yellow River mouth area, and it can supply the evolution example for rivers with plentiful sediment. Many studies have been done about the runoff of the Yellow River, but there remain a lot of problems to be studied further with the broadening of human activities in recent years. This paper uses stochastic model of time series to analysis the measured runoff at the Lijin Hydrological Station during 1950−2000.

2. ANALYSIS OF TIME SERIES

The total amount of measured runoff of at Lijin Hydrological Station during 1950−2000 (totally 51years) is 1724.35 billion m^3. Cv=0.5659, Cs=0.6941=1.23Cv.

Linear decomposition model and multiplication model are usually used to describe time series, and linear decomposition model is often applied. This paper uses linear decomposition model to analysis the runoff time series at Lijin Hydrological Station:

$$Q_t = T_t + J_t + P_t + S_t \tag{1}$$

where Q_t is yearly runoff; T_t is trend component; J_t is jump component; P_t is period component; S_t is statistic component; t is the index, represents year t.

3. HYDROLOGICAL ANALYSIS

3.1 TREND ANALYSIS

Trend analysis mainly studies the increase or decrease of the time series, there are many methods such as Kendall correlation inspection, regression inspection of linear trend, slide average inspection ect. Kendall correlation inspection and linear trend regression inspection[1] are applied in this paper.

3.1.1 KENDALL CORRELATION INSPECTION OF RUNOFF

The basic points of Kendall correlation inspection is: about the runoff time series $Q_i,\ldots,Q_N$, first the numbers (P) of $Q_i<Q_j$ (Q_i, Q_j, $i<j$) must be specified. The subset (i, j) is (i=1, j=2,3,…,N), (i=2, j=3,4,…,N) ,…, (i=N−1, j=N). If the series has not a trend, P=N(N−1)/4. If P approach to $N(N-1)/2$, there is a increasing trend. If P approach to zero, there is a decreasing trend.

Kendall statistic:

$$\tau = \frac{4P}{N(N-1)} - 1 \tag{2}$$

standard variable:

$$M = \tau \cdot \sqrt{\frac{9N(N-1)}{2(2N+5)}} \tag{3}$$

If N increases, M quickly converges to standard normal distribution. If the original assumption is that the time series has not a trend, double inspection is applied. After the significant level α is given, if $|M| < |M|_{\alpha/2}$, original assumption is accepted, that is to say the trend is not significant; otherwise it is rejected.

The trend analysis results of yearly and monthly runoff of Yellow River are showed in Tab.1. The significant level is given as 0.05, checking the statistical table: $M_{0.05/2}$＝1.96. We can see that during 1950−2000 not only yearly average series but also monthly average series, the original assumptions are both rejected. Because P approach to zero, the series has a decreasing trend, that is, in the 1950−2000 measured series, runoff has a significant decreasing trend.

Table 1 Kendall Correlation of Runoff Series at Lijin Hydrological Station

Runoff Series	Month	Data（N）	P	N(N−1)/4	N(N−1)/2	M
1950~2000	1	51	514	637.5	1275	-2.006
	2	51	404	637.5	1275	-3.793
	3	51	345	637.5	1275	-4.752
	4	51	300	637.5	1275	-5.482
	5	51	336	637.5	1275	-4.900
	6	51	370	637.5	1275	-4.345
	7	51	353	637.5	1275	-4.622
	8	51	371	637.5	1275	-4.329
	9	51	400	637.5	1275	-3.858
	10	51	392	637.5	1275	-3.988
	11	51	312	637.5	1275	-5.288
	12	51	432	637.5	1275	-3.338
	Yearly	51	274	637.5	1275	-5.905

3.1.2 LINEAR TREND REGRESSION INSPECTION

If the runoff series at Lijin Hydrological Station has a linear trend, we can use the linear regression model to inspect. The model is:

$$Q(t) = a + bt + \varepsilon(t) \tag{4}$$

we can calculate the parameter a, b according to the method of regression analysis:

$$\hat{b} = \frac{\sum_{i=1}^{n}(t_i - \bar{t})(Q_i - \overline{Q})}{\sum_{i=1}^{n}(t_i - \bar{t})^2}$$

$$\hat{a} = \overline{Q} - \hat{b}\bar{t} \tag{5}$$

the estimated value of square deviation of $\hat{b}$ is:

$$S^2(\hat{b}) = S^2 / \sum_{i=1}^{n}(t_i - \bar{t})^2 \tag{6}$$

where:

$$S^2 = \frac{\sum_{i=1}^{n}(Q_i - \overline{Q})^2 - \sum_{i=1}^{n}(t_i - \overline{t})^2}{n-2}$$

$$\overline{Q} = \frac{1}{n}\sum_{i=1}^{n} Q_i, \tag{7}$$

$$\overline{t} = \sum_{i=1}^{n} t_i$$

under the assumption that there is not a linear trend, when $b = 0$, the statistic is: $T = \hat{b} / S(\hat{b})$ obey the t distribution with a free degree of $(n-2)$. The significant level α is given, if $|T| > T_{\alpha/2}$, the original assumption is rejected, that is the regression is significant; otherwise the original assumption is accepted, the linear trend is not significant.

The linear trend regression inspection results of runoff are showed in Tab.2. When N =51, $t_{0.05/2}$=2.012, $t_{0.01/2}$=2.684. As we can see, among the data during 1950−2000, every series can not pass the inspection of significant level 0.05 and 0.01 except January. So we can conclude that the majority of the monthly runoff series have a linear trend, as well as yearly runoff series. We can see this trend clearly in Fig.1.

Table 2 Linear Trend Regression Inspection of Runoff Series at Lijin Hydrological Station

1950−2000	Month	Constant a(billion m^3)	b	Statistic T
	1	1.5618	-0.129	-2.482
	2	1.5434	-0.205	-3.872
	3	2.8723	-0.485	-4.997
	4	3.2572	-0.638	-6.946
	5	3.1078	-0.603	-5.127
	6	2.7640	-0.523	-4.235
	7	6.7785	-1.122	-5.374
	8	10.1392	-1.529	-5.194
	9	8.9787	-1.278	-3.931
	10	8.4085	-1.308	-4.007
	11	5.2497	-0.854	-5.154
	12	2.5599	-0.330	-3.551
	Yearly	57.2211	-9.004	-6.852

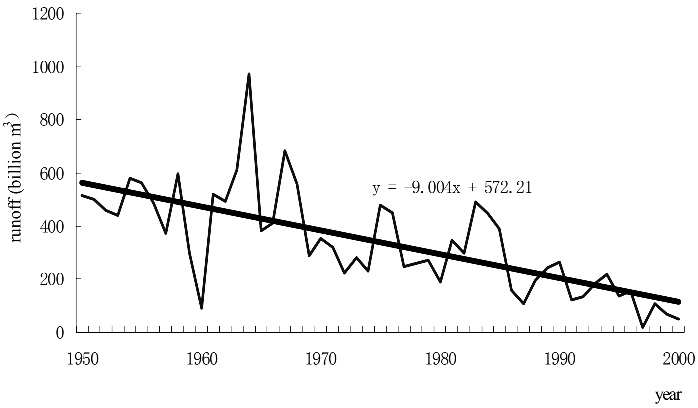

Fig. 1 Linear Fitting Curve of Runoff at Lijin Hydrological Station

Analysis method of A.F.S Lee , S.M.Heghinian: about the series $Q_t(t=1,2,...,n)$, its condition probability distribution function is $f(\tau/x_1,x_2,...,x_n)$, if it satisfies the demand:

$$f(\tau/x_1,x_2,...,x_n)=\max\{f(\tau/x_1,x_2,...,x_n)\} \tag{8}$$

τ_0 is the most possible jump point.

Analysis method of order classification: assume that the possible jump point is τ, if it satisfies the demand:

$$S_n(\tau)=\min\{S_n(\tau)\} \tag{9}$$

τ_0 is the most possible jump point.

In the first analysis, the maximum f is at 1968 and 1985, whereas in the second analysis, the minimum S is at 1968 and 1985, the same as the first method. So it is reasonable to take 1968 and 1985 as jump points. We can divide the runoff series to three phases(Fig.2): the average runoff of 1950−1968 is 50.15 billion m^3, the average runoff of 1969−1985 is 32.69 billion m^3, the average runoff of 1986−2000 is 14.38 billion m^3.

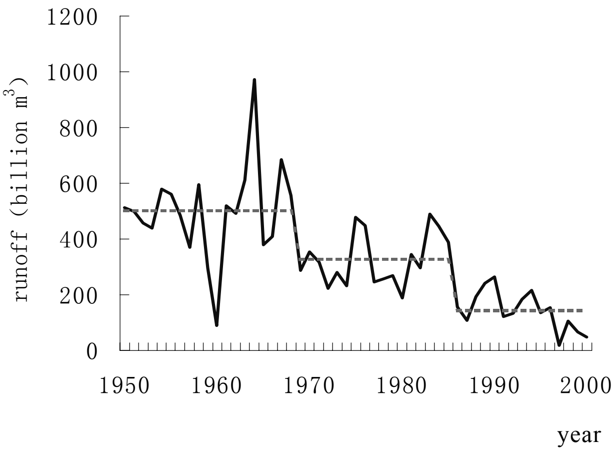

Fig. 2 Jump Analysis of Runoff at Lijin Hydrological Station

4. VARIATION OF RUNOFF WITHIN A YEAR

Table 3 shows the average monthly runoff at Lijin Hydrological Station:

Table 3 Average monthly runoff at Lijin Hydrological Station

Month	1	2	3	4	5	6	7	8	9	10	11	12
Runoff (billion m^3)	1.225	1.010	1.612	1.598	1.540	1.405	3.860	6.165	5.656	5.007	3.028	1.702
Percentage %	3.57	3.23	4.70	4.82	4.49	4.23	11.26	17.97	17.04	14.60	9.12	4.96

We can see from Table 3 that the distribution of runoff within a year is not equilibrium, and it has a seasonal variation. The maximum average runoff occurs in August, 1.797 billion m^3, and the minimum average runoff occurs in February, 0.323 billion m^3, and the ratio of the two is 5.56. The maximum of three months (August, September, October) accounts for 46.09% of the runoff of the whole year. The runoff of high water (July, August, September, October) accounts for 63.55%, while the runoff of low water accounts for 36.45%.

5. CONCLUSION

Many achievements about the runoff time series have been gained, but we lack some systemic cases, especially such rivers with plentiful sediment as the Yellow River. The Yellow River has been greatly affected by human activities, and the unusual variation of runoff and sediment brings great influence to the ecological environment. Using some effective method, this paper has a comprehensive analysis of the runoff time series at Lijin Hydrological Station. The results can offer references for river mouth regulation, preventing shore erosion and marine erosion.

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