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RESEARCH ON DROUGHT / FLOOD INFLUENCE FACTORS IN CHINA

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ABSTRACT: In the fifth paper listed in the references, East China was divided into eight drought / flood regions. But we, taking earth rotation velocity, sunspots, southern oscillation, etc. as the influence factors, through step–wise regression analysis and typical analysis, discussed drought / flood influence factors of the eight regions. On the basis of them, applying spectrum analysis, we calculated the cycles of every influence factor variation and cycles of drought / flood variations of every region as well as cycles of vibration between them. The results indicate that the drought / flood influence factors of East China are southern oscillation, earth rotation velocity, etc. Specially, the influence of EL–Nino is more evident to drought / flood in most regions than that of others. Generally, there are good correlations between the year of EL–Nino and the year of drought / flood in most regions. The ways of these factors influencing drought / flood are shown in lag correlation, by 2–5–year high–frequency vibration cycle.

KEY WORDS: drought / flood, influence factors

I. INTRODUCTION

Many researches about drought / flood influence factors in China have been accomplished[1–3]. But these studies mainly focused on the areas that were divided according to administrative or geographic distribution. In this paper we will discuss drought / flood influence factors in the eight regions (Fig.1), which were classified[5] by using China's drought / flood grade atlas for past 500 years[4].

Taking earth rotation velocity, sunspots, Southern Oscillation (SO) and the Northern / Southern winter temperature with a boundary at the Huaihe River as the selecting factors, using log correlation coefficient test (fiducial level $\alpha = 0.05$), we get the factor field studied in this paper (shown in Table1).

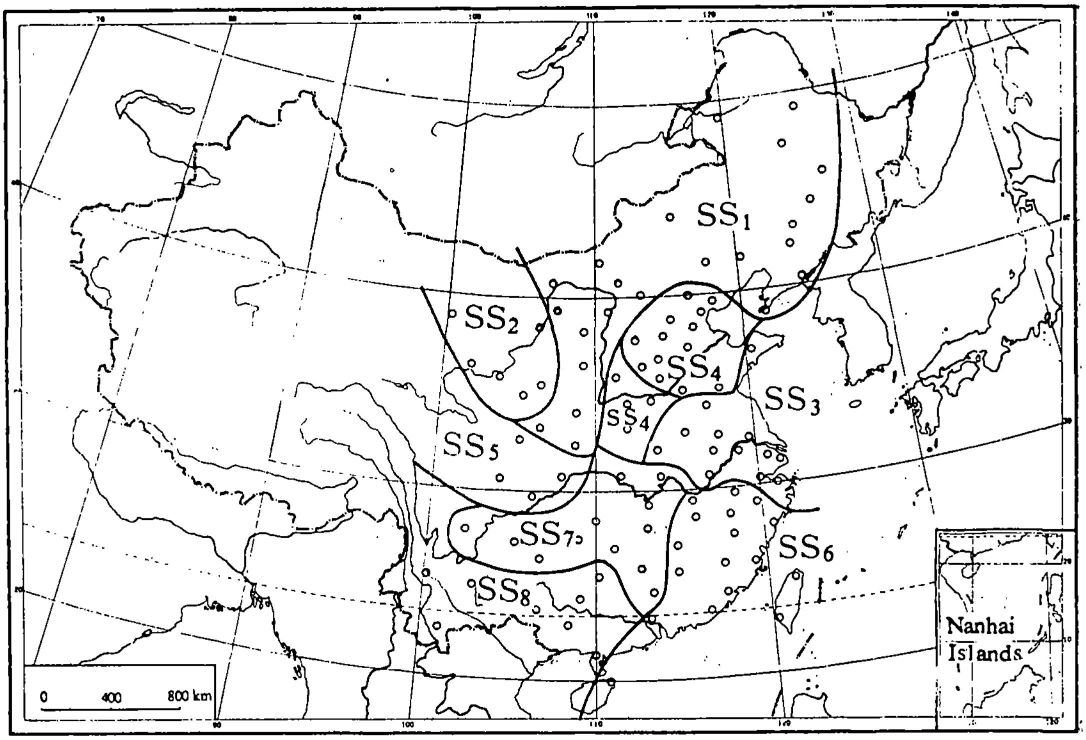

Fig.1 Division of regions of drought and flood in China

Table 1 Forecasting factors

X_1 SO Index (lag:−1)	X_{10} Drought / flood order of itself (lag:−1)
X_{21} Annual average sunspots (lag: −7) X_{22} Annual average sunspots (lag: −6) X_{23} Annual average sunspots (lag: −8)	X_{61} The earth rotation velocity (lag: −19) X_{62} The earth rotation velocity (lag: −18) X_{63} The earth rotation velocity (lag: −17)
X_{31} Sunspots in Mar. (lag: −7) X_{32} Sunspots in Mar. (lag: −6) X_{33} Sunspots in Mar. (lag: −8)	X_{81} Southern temperature in winter (lag: −2) X_{82} Southern temperature in winter (lag: −3) X_{83} Southern temperature in winter (lag: −1)
X_{41} Sunspots in July (lag: −7) X_{42} Sunspots in July (lag: −6) X_{43} Sunspots in July (lag: −8)	X_{91} Northern temperature in winter (lag: −2) X_{92} Northern temperature in winter (lag: −3) X_{93} Northern temperature in winter (lag: −1)
X_{51} Sunspots in Dec. (lag: −7) X_{52} Sunspots in Dec. (lag: −6) X_{53} Sunspots in Dec. (lag: −8)	

II. INFLUENCE FACTORS OF DROUGHT / FLOOD

1. Analysis of the Relation between Influence Factor Field and Drought / Flood Field

For discussing the relationship between factor field (in Table 1) and drought/ flood field (grade order of the eight regions), typical analysis is used. Noting the factor field as X_{nxp_2} and drought/ flood field as Y_{nxp_1}, we get:

$$X_{nxp_2} = \begin{bmatrix} X_{1,1} & X_{1,2} & \cdots & X_{1,22} \\ X_{2,1} & X_{2,2} & \cdots & X_{2,22} \\ \cdots & \cdots & \cdots & \cdots \\ X_{n,1} & X_{n,2} & \cdots & X_{n,22} \end{bmatrix}$$

$$Y_{nxp_2} = \begin{bmatrix} Y_{1,1} & Y_{1,2} & \cdots & Y_{1,8} \\ Y_{2,1} & Y_{2,2} & \cdots & Y_{2,8} \\ \cdots & \cdots & \cdots & \cdots \\ Y_{n,1} & Y_{n,2} & \cdots & Y_{n,8} \end{bmatrix}$$

Here n is the data length (drought/ flood order was from 1876 to 1980 and each factor was moved forwards according to its number of lag correlation, $n=105$); P_1 is the number of drought/ flood regions ($P_1=8$); P_2 is the number of factor except X_{10}($P_2=22$).

The calculating results are shown in Table 2. The statistical test is obviously passed from λ_1 to λ_5 taking fiducial level 0.05 according to below formula:

$$\Lambda k = \prod_{i=k}^{P_1}(1-\lambda_i)^2 = (1-\lambda_k^2)(1-\lambda_{k+1})^2\cdots(1-\lambda_{P_1})^2$$

$$Qk = -[N-k-\frac{1}{2}(P_1+P_2+1)]ln\Lambda k \sim X_a^2[(P_1-k)(P_2-k)]$$

Table 2 Typical correlation coefficients of drought / flood and factors

λ_1	λ_2	λ_3	λ_4	λ_5	λ_6	λ_7	λ_8	λ_9
0.9811	0.607	0.582	0.541	0.449	0.419	0.347	0.281	0.264

So, it is obvious that the factors in Table 1 are reasonable and they have a close relationship with drought/ flood in China.

2. Influence Factors of Each Region

Typical analysis is a whole relation analysis between the two fields. In order to discuss the influence factors of each region, step—wise regression is taken below.

Taken $F_2 = 1.5$, Table 3 is gotten. Every equation in Table 3 passes statistical test at the fiducial level of 0.05 except the SS_7, which passes the test at the fiducial level of 0.1. So it is reasonable to take statistical analysis using these equations.

Table 3 Step—wise regression analysis of every drought / flood region

Analysis object	Regression equation
SS_1	$2.8611-0.839X_1+0.00387X_{42}-0.00591X_{51}+0.0088X_{81}$
SS_2	$2.509-0.0938X_1+0.0114X_{81}+0.00946X_{92}$
SS_3	$2.090-0.01743X_{91}+0.1268X_{10}$
SS_4	$2.45-0.148X_1-0.007X_{32}+0.0081X_{41}-0.0105X_{42}-0.0105X_{51}+0.0137X_{83}+0.022X_{92}$
SS_5	$2.45+0.009X_{41}-0.0113X_{51}-0.0614X_{61}-0.0088X_{81}+0.0099X_{93}+0.0117X_{83}$
SS_6	$3.047+0.1179X_1-0.0057X_{31}+0.061X_{51}-0.0083X_{92}$
SS_7	$2.777+0.08605X_1-0.00170X_{41}$
SS_8	$3.153+0.0141X_{22}-0.0047X_{52}-0.0058X_{53}-0.108X_{61}+0.0073X_{93}-0.230X_{10}$

Based on the factors entering each equation, we know that the influence factors of each region are different. In the northern region which includes SS_1, SS_2 and SS_4 (the rest being called the southern region), each equation has X_1(SO) and a higher negative value. This fact indicates that drought / flood is more obviously affected by SO than by other factors in the northern region. When SO index decreases, the possibility of drought in the northern region will increase. It is more obvious for SS_1 that possesses a variance contribution of 82%. Generally, the decrease in SO index means that walk—circulation is weak and El—Nino event may easily occur. We calculated the drought years in SS_1 from 1875 to 1980, and found that 80% of them happened in the El—Nino years or preceding one to two years (Table 4).

Table 4 Comparison of phases between El—Nino year and drought year in SS_1

Drought year	1876	1877	1878	1879	1891	1899	1900	1916	1919	1926
Phase Diff.	—	0	−1	−2	0	0	−1	−2	−1	−1
Drought year	1928	1929	1939	1941	1942	1957	1965	1968	1972	1980
Phase Diff.	—	—	0	0	−1	0	0	—	0	—

Note: 0 stands for no difference; — stands for no obvious relationship; −1, −2 stand for El—Nino year in one or two preceding years.

esides the influence of the SO, the southern and northern temperature variations within about two preceding years also have certain influence on the northern drought/ flood. The positive values of regression coefficients express the positive correlation between the temperature and drought/ flood. Droughts often appear under high temperature, and floods often appear under low temperature.

The influence of winter sunspots in about six preceding years and the northern temperature variation in about two preceding years are universal to each southern region. The only exception is SS_7, of which the equation does not consist of the winter sunspot number. The SO does not appear in the equation of SS_3, SS_5 and SS_8. This means that the influence of SO on the regions mentioned above is not obvious. On the contrary, the influence of SO in SS_6 and SS_7 is absolutely important, which can be observed from the coefficient values in the equations. Different from northern regions, their coefficient values are positive, meaning that the possibility of drought in the two regions mentioned above is high when the SO index is small. Tables 5 and 6 show the comparison of phases between El–Nino year and flood year in SS_6. We can see the excellent relativity from the tables.

Table 5 Comparison of phases between El–Nino year and flood year in SS_6

Flood year	1877	1878	1879	1880	1881	1882	1885	1886	1890
Phase diff.	0	−1	−2	0	−1	−2	−1	−2	—
Flood year	1905	1908	1910	1912	1914	1931	1925	1927	1929
Phase diff.	0	—	—	−1	0	—	0	−2	—
Flood year	1939	1942	1947	1948	1949	1952	1961	1962	1969
Phase diff.	0	−1	—	—	—	−1	—	—	0
Flood year	1901	1903	1904	1931	1935	1937	1973		
Phase diff.	−1	−1	−2	−1	—	—	−1		

Table 6 Comparison of phases between El–Nino year and flood year in SS_7

El–Nino year	1877	1884	1887	1891	1896	1899	1900	1902
Flood year	0	−1	−2	−3	0	—	−1	—
El–Nino year	1905	1911	1914	1918	1923	1925	1930	1932
Flood year	−1	0	−1	−1	−1	−1	−1	−1
El–Nino year	1939	1951	1953	1957	1965	1969	1972	1976
Flood year	—	−1	−1	—	—	−1	−1	—

It is necessary to mention that the influence of the earth rotation velocity (X_6) on drought/ flood in scme regions is somewhat obvious. Such as in SS_5 region, X_6 in the equation has contribution up to 54.3%. Similar conditions are in SS_2 and SS_8.

To sum up, the influences of the SO, temperature and earth rotation velocity on drought/ flood in China are obvious. Other factors have little influence.

3. Influence Mode of the Factors

It is important to know the influence modes of the main factors on relative regions. The power spectrum of drought/ flood and main factors in each region as well as their cross–spectrum are calculated here.

Because of drought/ flood grade data being from rectangular wave, we choice the Walsh function spectrum which is suitable to the rectangular wave instead of the Fourier spectrum.

For discrete function of X_l with N equidistance points ($N=2* P$, $n = 0, 1, 2, ..., N-1$). There is Walsh variation similar to Fourier variation.

$$An = \frac{1}{N}\sum_{i=0}^{N-1} X_i Wal(n,i)$$

Wal (n,i) is Walsh orthogonal polynomial. Its Wal power spectrum (also called order spectrum) can be calculated by the formula below[6–7]:

$$\begin{cases} P_0 = A_0^2 \\ P_i = A_{(2i-1)}^2 + A_{2i}^2 \\ P_{\frac{N}{2}} = A_{(N-1)}^2 \end{cases}$$

Order waving cycles = N / i

Variance test method is used to distinguish the cycles, their statistical quantity $F_i$is subordinated to the distribution of $F_{(2, N-2-l)}$. With the fiducial level of 0.05, the cycles of drought flood variations of each region are obtained (Table 7). The Fourier spectrum analysis is used to get the results of the power spectrum of the main factors as well as their cross–spectrum with every region's drought/ flood. With fiducial level of 0.05, Table 8 and Table 9 are obtained.

It is necessary to point out that the factor period selected to do the spectrum analysis are the same as drought/ flood period.

Comparing Table 7 with Table 8, we can see that there are some same cycles between the variations of main factors and variations of drought / flood of each region. These cycles prove the correspondence between the two variations.

Table 7 Cycles of drought / flood variations of every region

Regions	SS_1	SS_2	SS_3	SS_4	SS_5	SS_6	SS_7	SS_8
Cycles (year)	23.3	32	128	32	56.8	46.5	46.5	51.2
	19	11.4	14.2	24.3	13.1	7.6	7.3	12.2
	6.6	6.5	5.1	5.1	9.8	4.2	3.5	6.2
	2.7	3.1	3.2	2.6	2.2	2.7	2.3	2.5

Table 8 Cycles of main influence factors

Name of factors	SO	Earth rotation velocity	Southern Tem.	Northern Tem.
Cycles (year)	3.75*	2.3*	2.2	2.0
	2.1*	9.1	4.6*	5.3
	6.0**	12.5	7.0	12**
		6.2**	12.6**	83.3
			31.3**	
			250.0	

* Stands for high–frequent filter; ** Stands for low–frequent filter

Table 9 spectrum analysis between influence factors and every drought / flood region

Regions	Factors			
	SO	Earth rotation velocity	Southern Tem.	Northern Tem.
SS_1	15(0.709) 5.4(−1.25) 2.6(0.011)			
SS_2	30(1.7) 2.7(0.22) 6.6(0.45)			
SS_3				
SS_4	30(4.2) 2.06(0.32)			
SS_5		6.6(−0.42) 2.8(−0.09)		3.9(0.348) 2.0(−0.217)
SS_6	60(−12.5) 8.5(1.23) 3.75(0.59)			
SS_7	15(2.25) 5.4(0.44) 3.75(−0.84)			
SS_8		2.6(0.47) 4.34(−0.313)		

Note: The main factor is one possessing the biggest coefficient in equation

In Table 9, the interrelation of drought / flood of each region with its main factors generally has a cycle of 2—5 years. Besides, in the interrelation with the SO, there are the cycles of up to 15 years and 30 years.

The integration of tables 3, 7, 8 and 9 shows that the drought / flood of SS_1, SS_2, SS_4, $SS_7$and SS_6 are mainly influenced by SO, most relationships between them are vibration forms with low and high frequencies. Generally quasi—synchronous vibrations are in high frequency. In low frequency vibration, drought / flood variation of most regions (except for SS_6) is behind the variation of SO (the phase difference values in the brackets of Table 9 are negative). The main influence factors of drought / flood of SS_5 and SS_8 are two—cycle—behind earth rotation velocities. Their influences in quasi—synchronous frequency vibration forms are most obvious. SS_3 is mainly influenced by the southern / northern temperature variations in the two preceding years, and they also have a high frequency vibration with 2—5 years cycle.

Maybe there are other influence factors to the drought / flood of every region in China. But the factors in this paper, especially the main influence factors are certainly influential to the drought / flood of every region in China.

III. FORECAST ANALYSIS OF THE REGRESSION EQUATIONS

Whether the calculated values fit the observed values mostly reflect whether there are close relationships between the forecast objects and the independent variables.

The analysis of the regression equations of every region in China (Table 3) shows that the regression values perfectly fit the observed values. Fig.2 is a comparison between calculated values and observed values of drought / flood in SS_8. Similar situations appear in other regions. (All are not given in this paper because of the space limit). So it is proved that the factors selected by this paper are obviously influential to drought / flood in China.

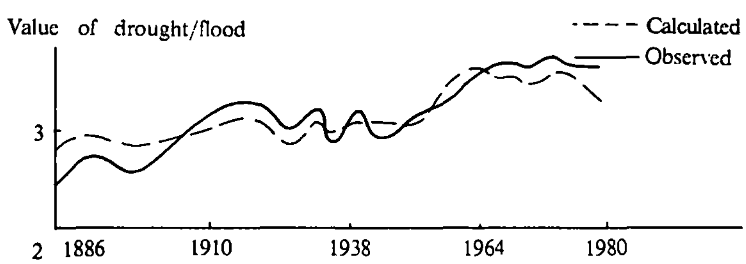

Fig.2 Comparison between calculated and observed values of drought / flood in SS_8

To test the forecastabity of the factors in this paper, the regression equations are calculated again by the method of step—wise regression with the sample length of 1876—1975 (n = 100). The results fit the equations in Table 3. These equations are used to forecast independently from 1976 to 1980. Table 10 shows the fitting relations between forecasted and observed values of every region. The fitting rates of most regions are over 60%. The fitting standard here is to compare the normal years or drought/ flood years by forecasting with that by observing. The drought/ flood standard is selected from the drought/ flood index of Zhang Jiacheng[8]:

Drought year: > 3.45;

Flood year: < 2.55;

Normal year: 2.55—3.45.

Table 10 Fitting relation between forecasted and observed values

Year	SS_1	SS_2	SS_3	SS_4	SS_5	SS_6	SS_7	SS_8
1976	+	−	−	+	+	+	+	+
1977	+	+	+	−	+	+	+	+
1978	+	+	−	+	−	−	+	+
1979	+	+	+	+	+	−	+	+
1980	−	−	+	−	+	+	+	+

+: No difference between forecasted and observed values

−: Difference between forecasted and observed values

IV. DISCUSSION

The analysis of influence factors of drought/ flood in China shows that the factors of drought/ flood in each region of China are very different. The SO has obvious influence on drought/ flood in most regions. The variations of factors including earth rotation, sunspots and winter temperatures also have certain influence in different degrees on drought/ flood of different regions. The influence of these factors on the drought/ flood of each region are shown in the form of lag correlation vibration.

The statistics of El—Nino years and drought/ flood years of each region show that within El—Nino years or preceding 1 year or 2 years, droughts are heavier in northern regions, and floods are heavier in some southern regions. This phenomenon is the most obvious in SS_1, SS_6 and SS_7.

According to some developed theories and some researches[9—10], the factors studied in this paper may have following relationships with drought/ flood:

The earth rotation influences the action of the sun on the one hand. On the other hand, together with the action of the sun, it influences the progresses of atmosphere and ocean. The variations of the atmosphere and ocean progresses influence the interaction between the atmospheric circulation and ocean, and they also influence each other, and finally the variations of atmospheric circulation influence the drought / flood.

The detail influence mechanism and physical progress still need further research.

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