The Influence of China's Climatic Changes on Water Resources during a nearly 50 Years Period

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ConTENTS

1. Introduction

Based on data gathered from 500 meteorological stations in China in 1957-2001 which have fairly complete temperature sequence record, this research analyzes temperature trends of 10 first class water resource divisions. Meanwhile, based on the result of investigation and assessment of China water resources situation, we analyze the volume of precipitation and surface runoff, and their relationships with temperature changes in 10 first class water resource divisions (hereinafter referred to water resource division).

This paper introduces the research results by 4 aspects:

(i) Methods & data;

(ii) Trend of temperature changes;

(iii) Trend of annual precipitation changes;

(iv) Trend of annual runoff Changes.

2.   Methods & Data

2.1 Research Methods

This paper employs Linear Regression Method to study the long term trends and regional characteristics of temperature, annual precipitation and annual runoff in China during the past nearly 50 years period. The model of long term change trend can be described as following:

$$y=a+bx$$

Where: y--Temperature, annual precipitation, annual runoff;

a--Regression constant;

b--Regression coefficient: represents annual increment (decrement);

x--Year

In the meanwhile, we use Relevant Coefficient r, t Inspection Methods to determine the significance level of the long term trend.

2.2 Temperature Data

Temperature data for 500 meteorological stations over China from 1956 to 2001

Original data is from the Weather Information Services of China Meteorological Administration.

Compile statistics of the average temperature series in each month and year of 10 water resource divisions by the number of stations, on this basis, the average monthly temperature of Southern China, Northern China and nation wide are calculated.

2.3 Hydrological Data

The 10 water resource division's annual precipitation and annual runoff data of 1956-2001 period are taken directly from the result of the investigation and assessment of China water resources of Institute of Hydropower Planning and Design of the Ministry of Water Resources of China, the distribution of the 10 first class water resource divisions is as Figure 2-1.

Figure 2-1 distribution of 10 water resource divisions of China (first class)

3. Trend of temperature changes

Based on the statistics of temperature data, the national average temperature is 11.5℃ (Table 1). Average annual temperature decreases from south to north gradually.

Table 1 average annual/seasonal temperature in different water resource divisions (1957-2001) unit：℃

Water Resources Division/Region	Year	Spring	Summer	Fall	Winter
China	11.50	12.19	22.57	12.22	−0.69
Northern China	7.39	8.69	21.38	7.99	−7.86
Songhuajiang River	2.27	4.00	19.82	3.22	−17.18
Liaohe River	7.34	4.00	22.12	3.22	−9.24
Haihe River	8.87	10.75	23.03	10.01	−5.09
the Yellow River	7.82	8.97	19.63	7.83	−5.1
Huaihe River	13.81	13.36	25.44	15.07	1.43
Rivers in Northwest	6.47	8.47	20.72	6.55	−9.34
Southern China	16.02	16.13	16.02	17.00	7.39
Yangtze River	14.07	14.07	22.96	14.80	6.02
Rivers in Southeast	17.88	16.67	26.5	19.73	10.8
Zhujiang River	21.08	21.29	27.26	22.25	15.08
Rivers in Southwest	13.67	14.58	19.2	14.02	7.59

We conduct a unary regression analysis towards the average annual/seasonal temperature sequence, the model parameter *a, b* in the analysis is listed in Table 2.

Table 2 regression constant *a* and regression coefficient *b* of annual/seasonal temperature linear change trends in different water resource divisions

Division/Region	Year		Spring		Summer		Fall		Winter	
	a(℃)	b(℃/a)	a(℃)	b(℃/a)	a(℃)	b(℃/a)	a(℃)	b(℃/a)	a(℃)	b(℃/a)
China	−24.050	0.018	21.486	0.017	−4.568	0.009	22.701	0.018	−61.442	0.031
Northern China	−43.518	0.026	47.279	0.028	−8.887	0.015	36.449	0.023	−70.637	0.033
Songhuajiang River	−68.758	0.036	92.502	0.049	39.964	0.030	45.133	0.024	108.807	0.046
Liaohe River	−46.594	0.027	92.502	0.049	11.812	0.017	45.133	0.244	−84.474	0.038
Haihe River	−30.512	0.020	53.246	0.032	14.081	0.019	36.050	0.233	−99.190	0.048
the Yellow River	−38.267	0.023	−3.077	0.006	−0.564	0.010	36.680	0.023	−86.308	0.041
Huaihe River	−21.384	0.018	33.937	0.024	33.444	−0.004	19.845	0.018	−58.847	0.031
Rivers in Northwest	−48.068	0.028	34.366	0.022	13.248	0.017	47.018	0.027	110.760	0.051
Southern China	−2.588	0.009	7.600	0.004	19.741	0.002	−7.199	0.012	−22.985	0.016
Yangtze River	0.971	0.007	6.800	0.004	32.859	−0.005	−6.335	0.011	−19.649	0.013
Rivers in Southeast	−3.757	0.011	2.211	0.007	19.742	0.003	3.322	0.008	−27.827	0.020
Zhujiang River	−1.660	0.012	20.143	0.001	4.027	0.012	−6.513	0.015	−21.625	0.019
Rivers in Southwest	−20.301	0.017	10.495	0.013	−9.278	0.014	37.547	0.023	−21.707	0.018

Table 2 shows that average annual temperature in all divisions of China is increasing.

Figure 3−1 shows the distribution of average annual temperature changes.
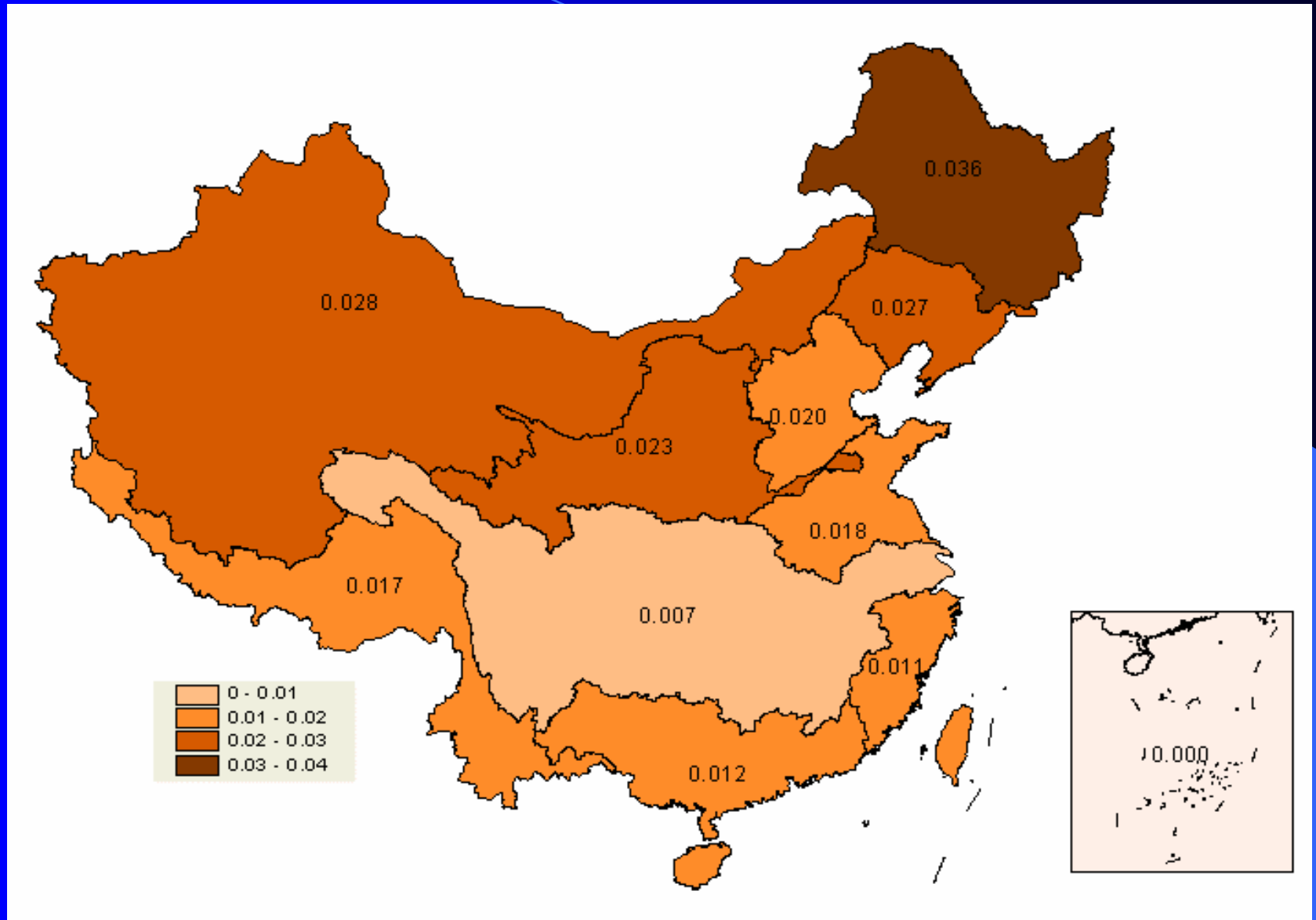

Figure 3−1 tempo of average annual temperature changes in different divisions

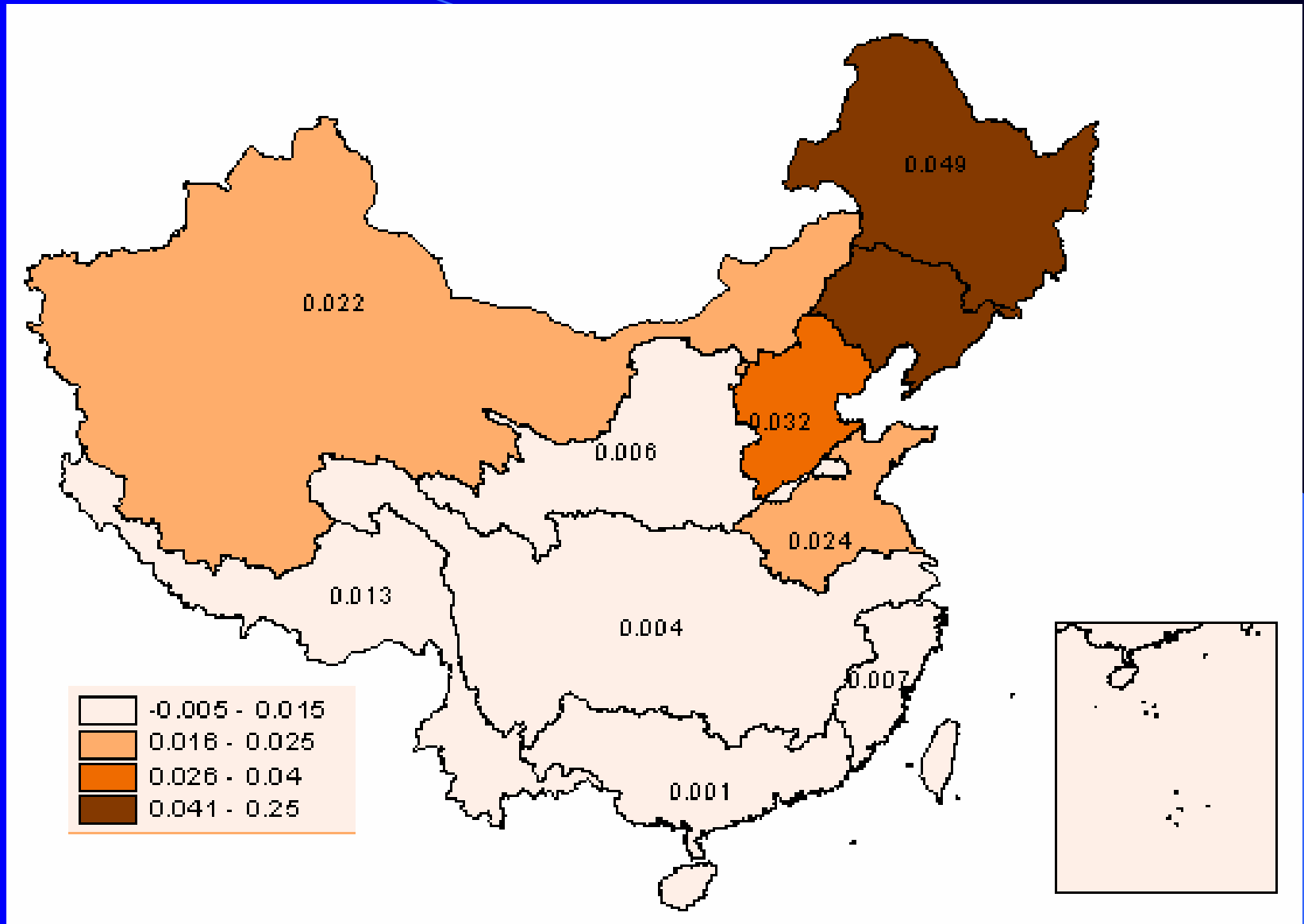Average spring temperature in all divisions has an increasing trend, see Figure 3−2.

Figure 3−2 tempo of average spring temperature changes in different divisions (℃/a)

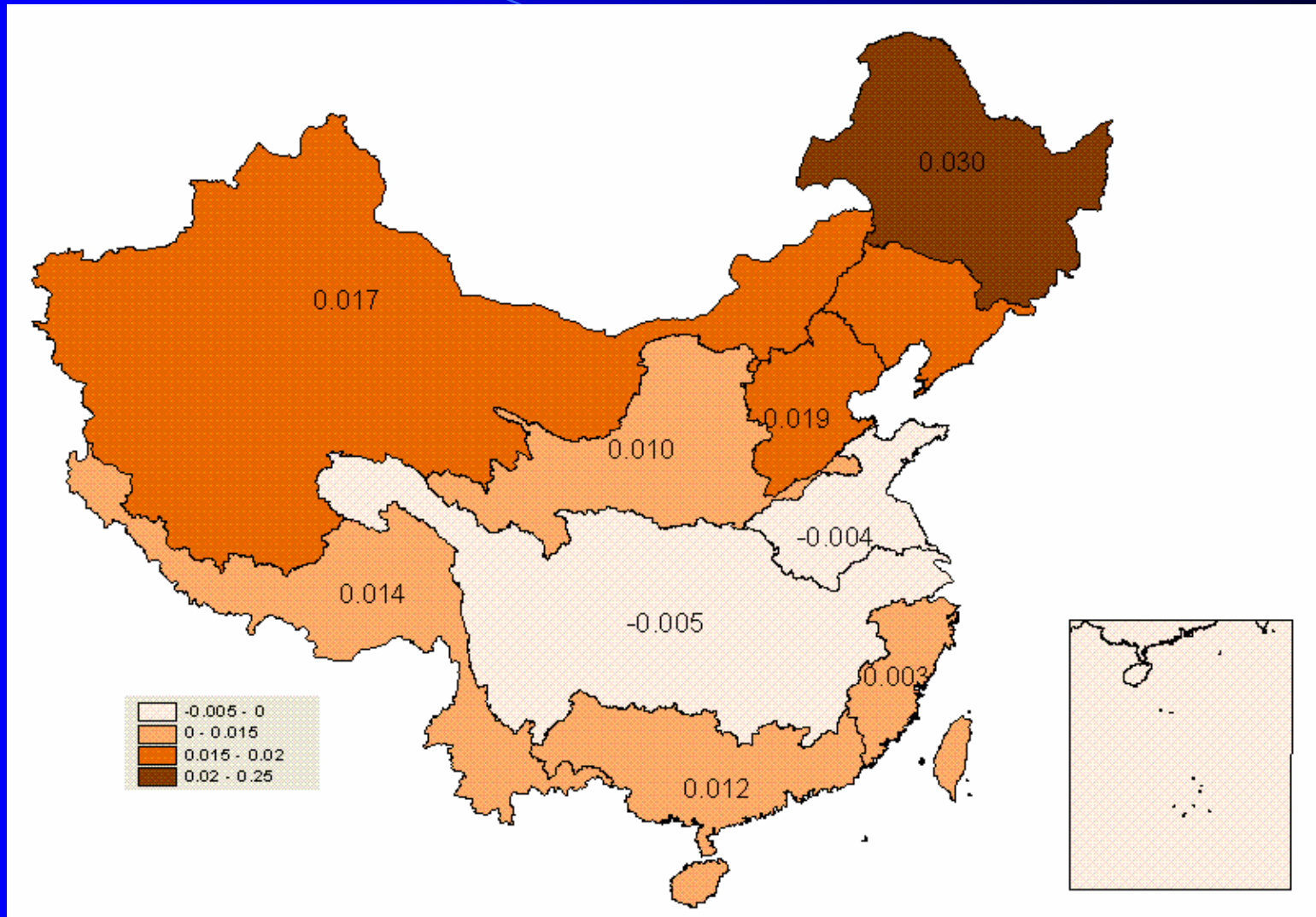# Summer temperature changes obviously as Figure 3−3.

Figure 3−3 tempo of average summer temperature changes in different divisions (℃/a)

Average temperature in fall in all divisions turns out to be warming trend, see Figure 3−4
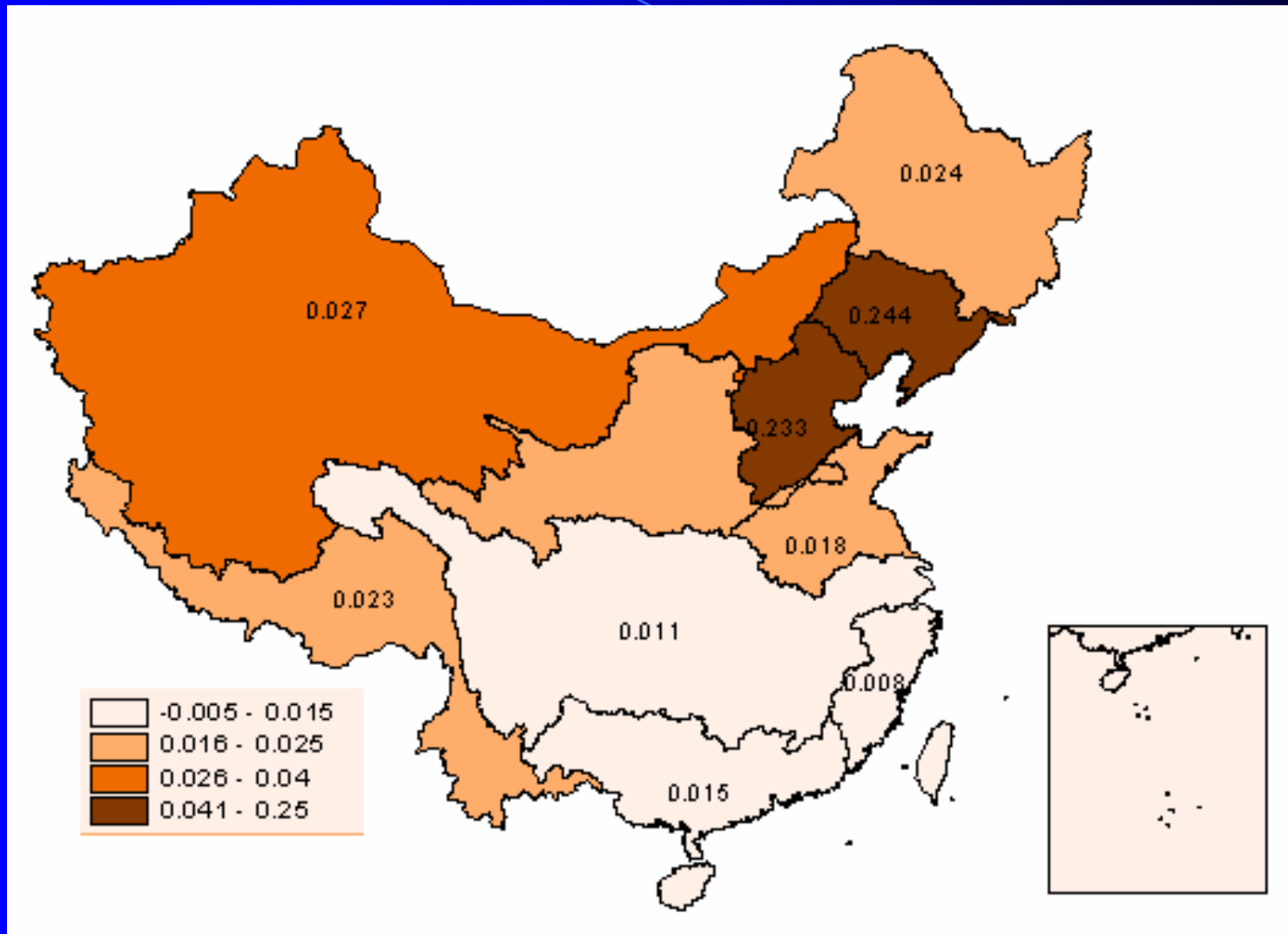
Figure 3−4 tempo of average autumn temperature changes in different divisions (℃/a)

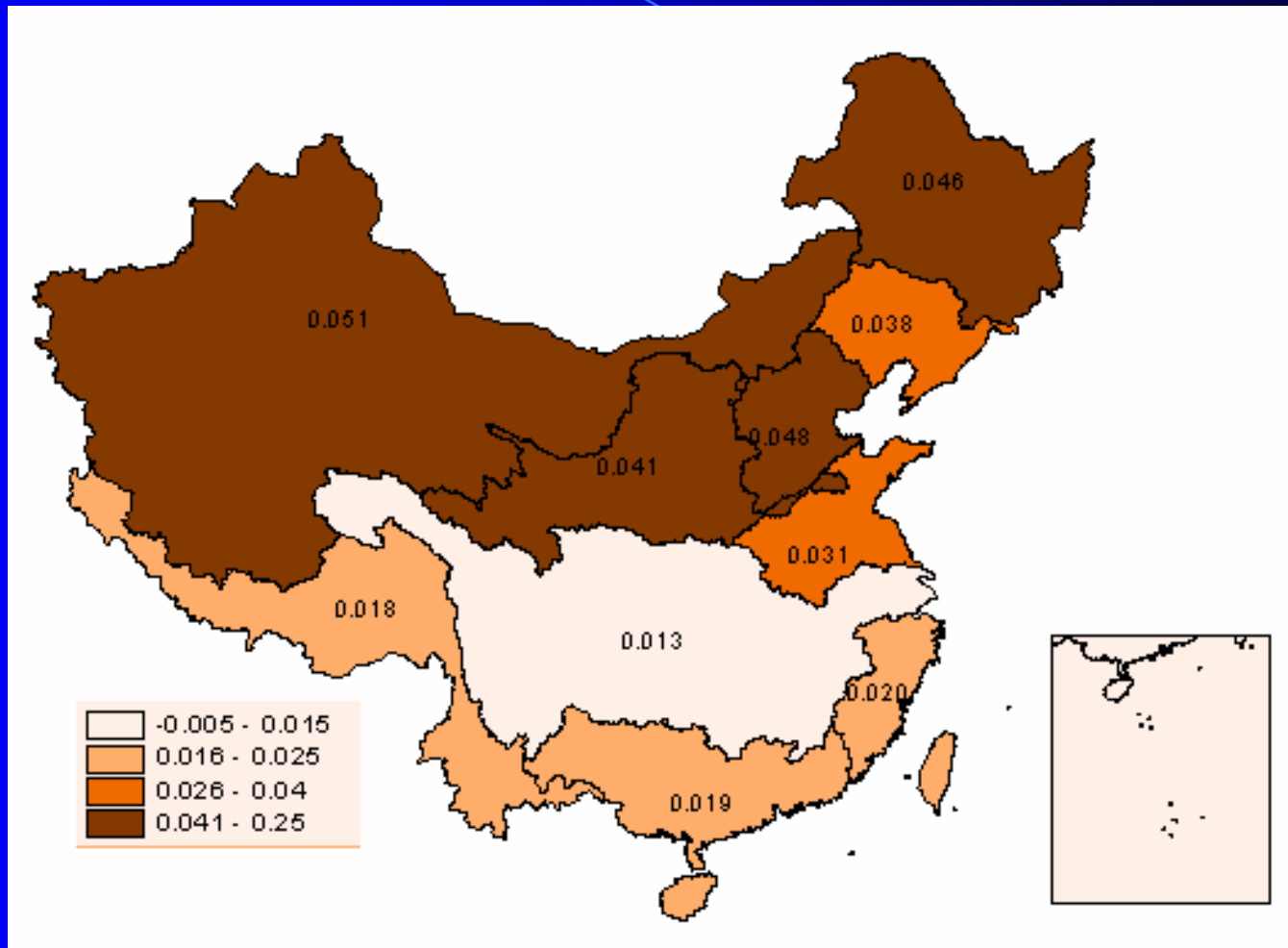# Figure 3−5 shows tempo of average spring temperature changes in different divisions

Figure 3−5 tempo of average spring temperature changes in different divisions (℃/a)

4. Trend of Annual Precipitation Change

4.1 Spatial Distribution of Average Annual Precipitation

According to the statistical analysis data of year 1956-2001, China's average annual precipitation in many years is 644.6mm, (Table 3). Precipitation in southern China is rich, annual volume accounts for 66% of the total of China while in northern China, only accounts for 34%.

Table 3 average annual precipitation in different water resource divisions in China (1956-2001)

Division/Region	Average annual Precipitation		Maximum Annual Precipitation		Minimum Annual Precipitation	
	mm	100 Million m^3	mm	Year	mm	Year
China	644.6	61869.44	734.3	1998	577.7	1986
Northern China	338.1	20911.89	408.0	1964	275.3	2001
Songhuajiang River	497.9	4654.64	623.5	1998	389.7	2001
Liaohe River	542.5	1704.18	691.5	1986	408.1	2000
Haihe River	532.2	1703.33	800.0	1964	357.3	1965
the Yellow River	446.2	3547.50	622.6	1964	331.6	1965
Huaihe River	837.1	3840.74	1111.8	1964	457.9	2001
Rivers in Northwest	161.2	5420.79	198.7	1987	130.5	1965
Southern China	1200.4	40970.85	1341.7	1998	1078.7	1986
Yangtze River	1084.7	19337.87	1240.7	1998	921.1	1978
Rivers in Southeast	1663.0	3465.52	2091.8	1975	1243.6	1967
Zhujiang River	1553.6	8977.14	1872.1	1997	1216.5	1963
Rivers in Southwest	1088.8	9190.32	1347.0	2000	900.9	1992

Study by division, annual precipitation of 4 river divisions in south all exceed 1000 mm, while in divisions of northern China are all less than 1000 mm.

4.2 Trend of Annual Precipitation Changes

Based on regression analysis, the regression coefficient b and regression constant a of annual precipitation trend model ($y=bx+a$) of different water divisions in nearly 50 years is listed in Table 4.

Table 4 parameters of the annual precipitation linear change trend model (1956-2001)

Division/Region	Annual Precipitation Depth		Annual Precipitation Volume		Relative Change rate
	b(mm/a)	a(mm)	b(100 million m3/a)	a(100 million m3/a)	（%/10a）
China	-0.0161	676.52	-1.5418	64933	-0.02
Northern China	-0.3851	1100.1	-23.8195	68041	-1.14
Songhuajiang River	-0.3911	1276.1	-3.6563	11929	-0.79
Liaohe River	-1.0463	2612.7	-3.287	8207.6	-1.93
Haihe River	**-2.4161**	**5312.6**	**-7.7542**	**17045**	**-4.55**
the Yellow River	-1.3941	3204.4	-11.05	25461	-3.11
Huaihe River	-2.7865	6350.3	-12.784	29135	-3.3
YHHLS	**-1.365**	**3249.5**	**-38.5315**	**91727**	**-2.49**
Rivers in Northwest	0.4376	-704.48	14.712	-23686	2.71
Southern China	0.6528	91.052	22.2786	-3107.6	0.54
Yangtze River	0.4801	134.77	8.6914	2142	0.45
Rivers in Southeast	2.4621	-3208.2	5.0815	-6588.3	1.47
Zhujiang River	1.3381	-1093.9	7.732	-6320.6	0.78
Rivers in Southwest	0.0917	907.369	0.7737	7659.2	0.08
Zhujiang River, Southeast and Southwest	0.8334	-322	13.5872	-5249.7	0.63

From Table 4 we can see annual precipitation of 5 divisions (referred to **YHHLS**) have decreasing trend. Among them, Haihe River Division has the biggest decreasing rate of 4.552% in 10 years.

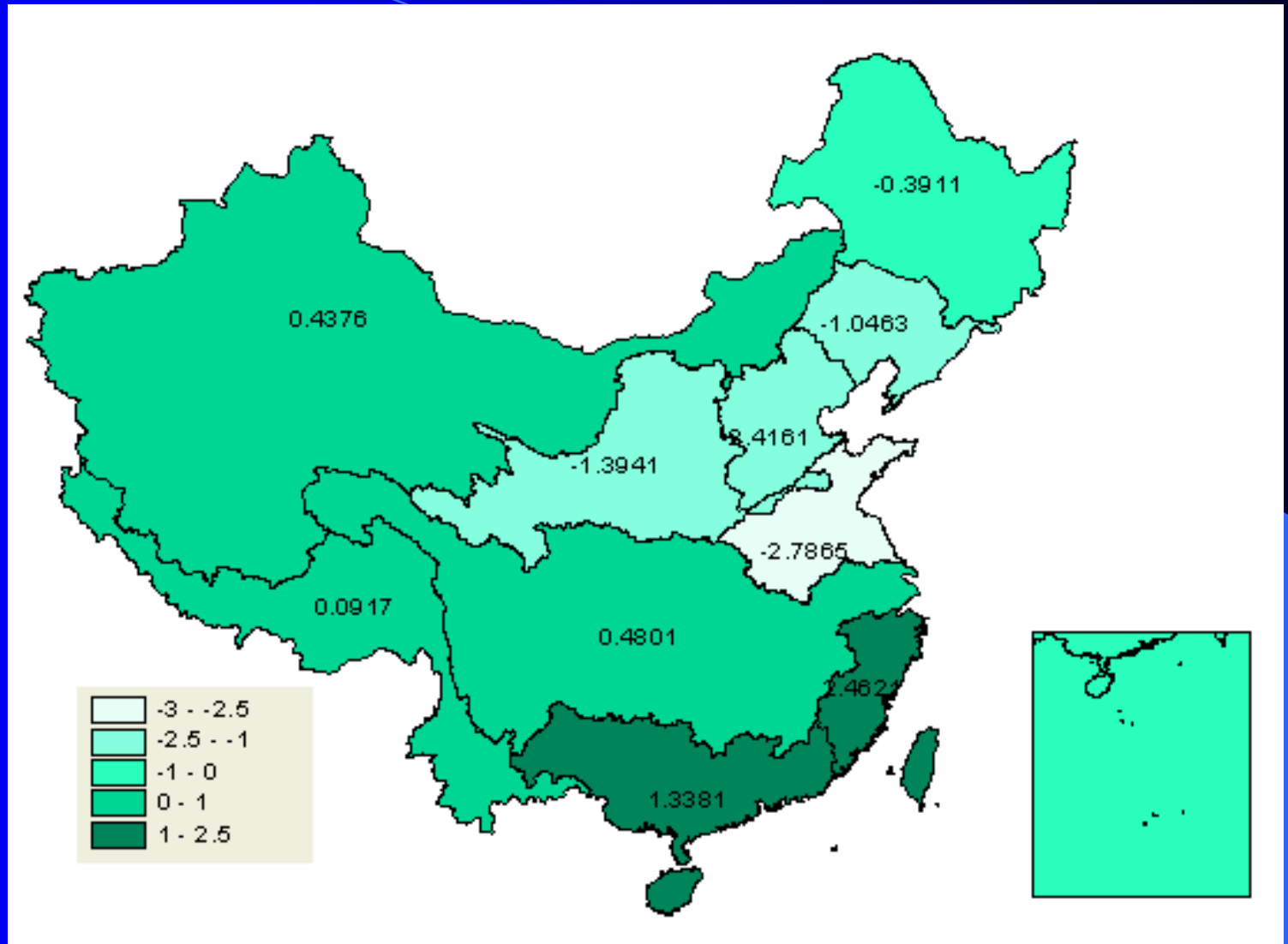Figure 4−1 shows the change of annual precipitation depth.

Figure 4−1 tempo of annual precipitation volume changes in different divisions (mm/a)

Figure 4-2 shows anomaly trend of China annual precipitation volume. According to analysis, average annual precipitation volume of China has a little decreasing trend.
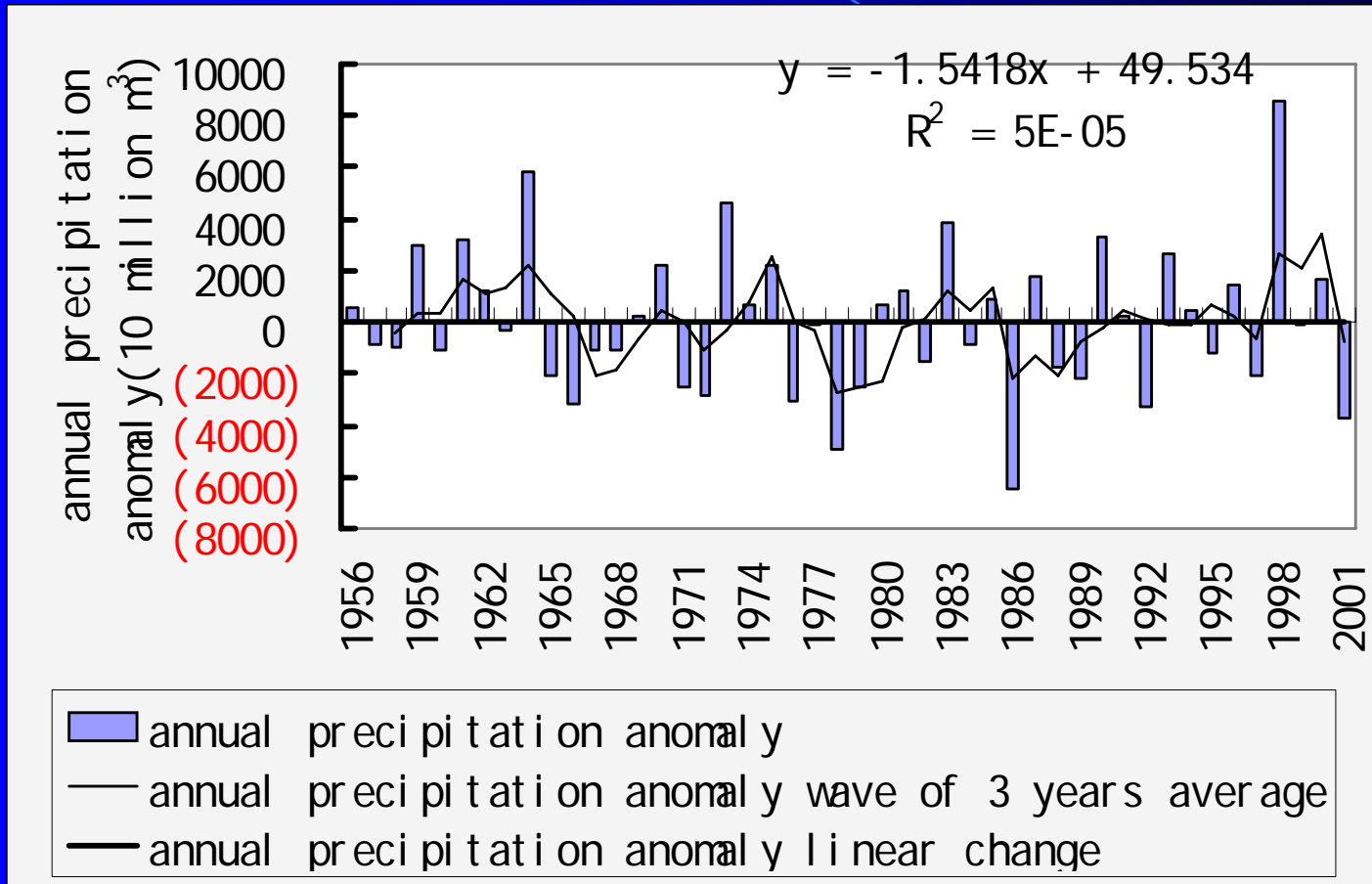

Figure 4-2 anomaly of China annual precipitation volume and its trend

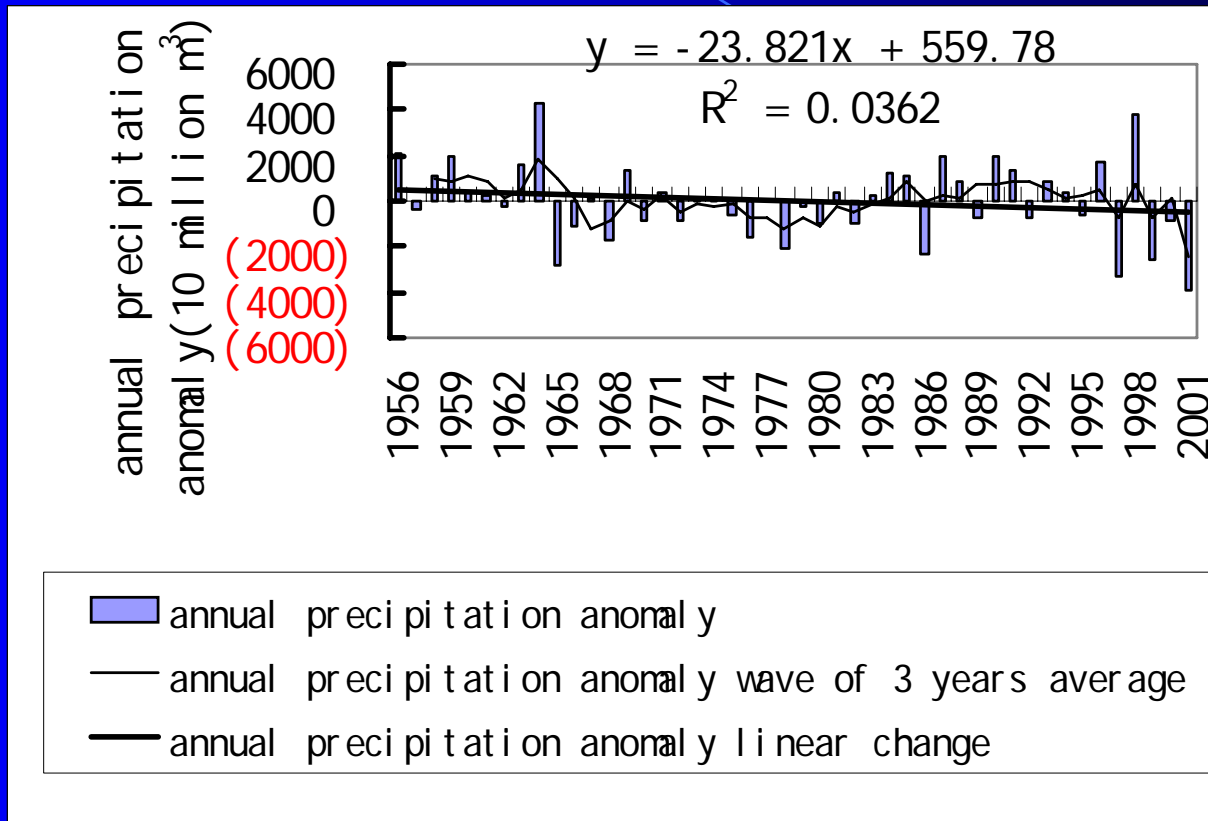**Annual precipitation changes has decreasing trend in north** (Figure 4−3).

Figure 4−3 anomaly of annual precipitation volume and its trend in north

Increasing trend can be found in southern China (Figure 4-4).
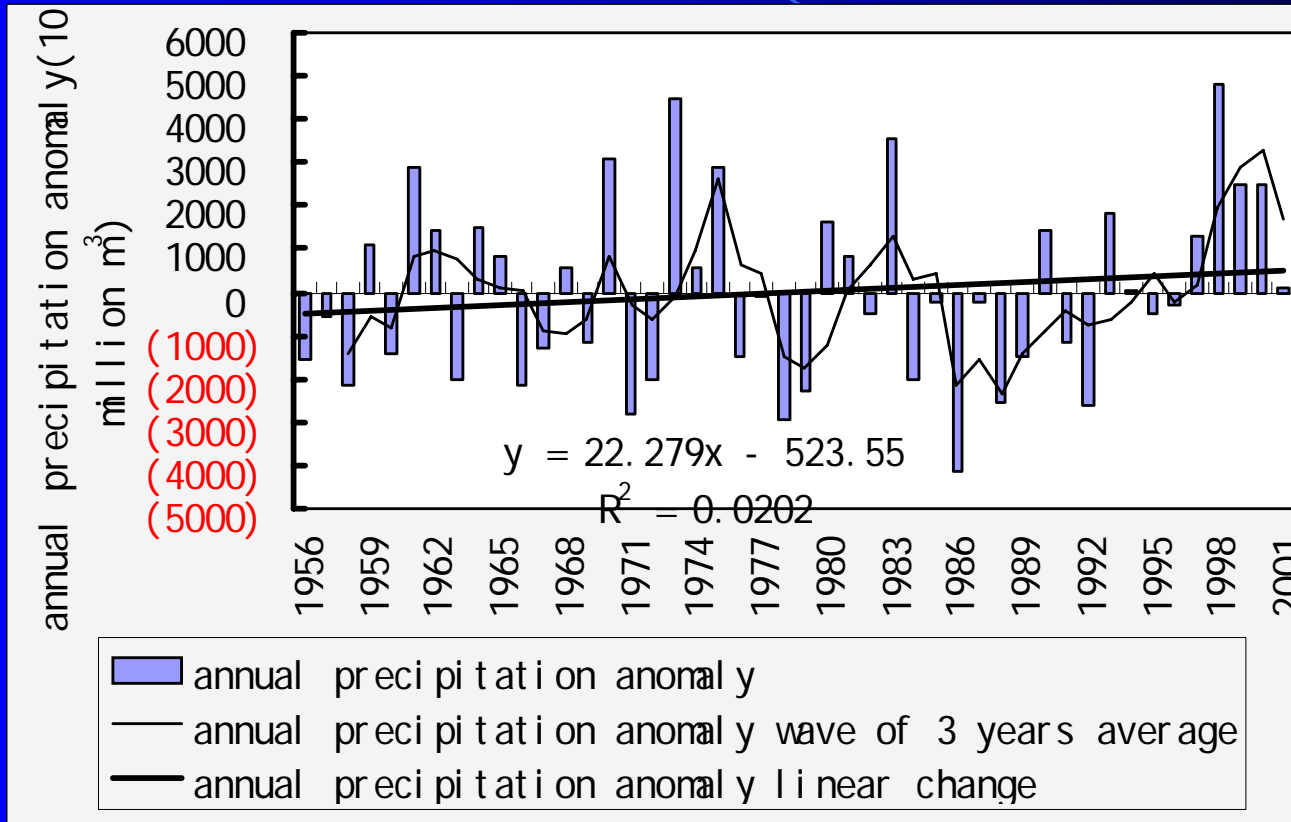
Figure 4-4 anomaly of annual precipitation volume and its trend in south

From the comparison between Table 4 and Table 2, we can see that 10 water resource divisions in China can be divided into 4 types due to annual precipitation and temperature changes:

(1) The Yangtze River Division: summer temperature decreases and precipitation increase region
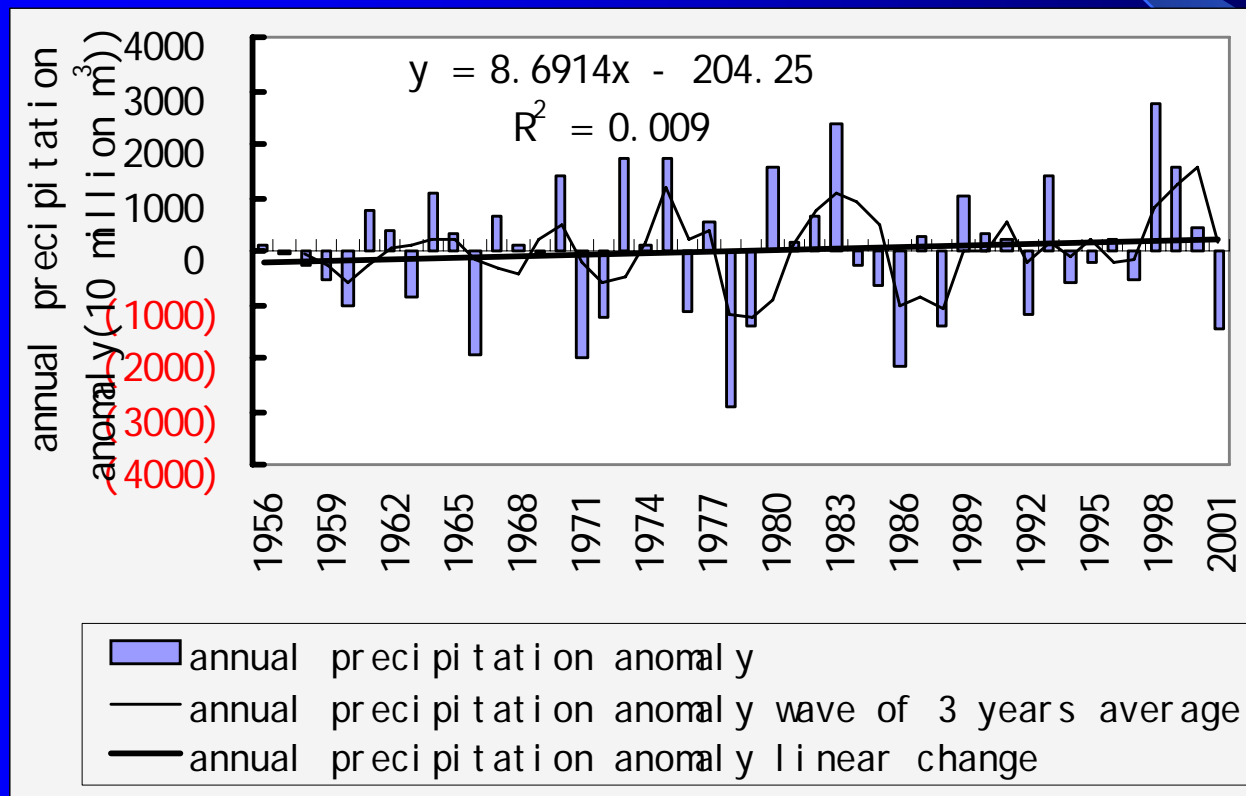
Figure 4-5 shows its precipitation increase.

Figure 4-5 anomaly of the Yangtze River Region's annual precipitation and its trend

(2) Zhujiang River Region, Region of Rivers in Southeast and Region of Rivers in Southwest: temperature increase slowly in spring and summer, precipitation increase regions

Figure 4−6 shows 3 divisions' annual precipitation anomaly trend. It belongs to non-significant increase region of annual precipitation.
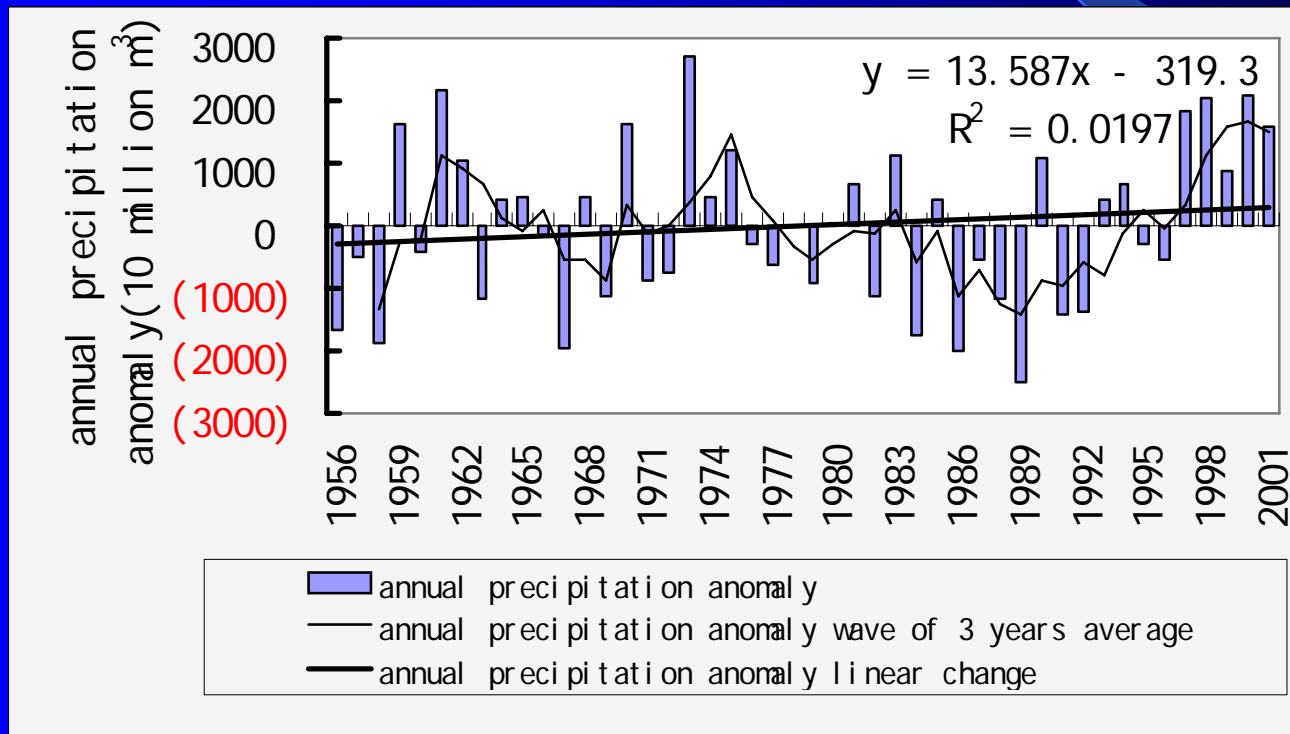

Figure 4−6 anomaly of annual precipitation in Zhujiang River Division, Division of Rivers in Southeast and Division of Rivers in Southwest

(3) The YHHLS are divisions with fast temperature increasing tempo and decreasing precipitation volume

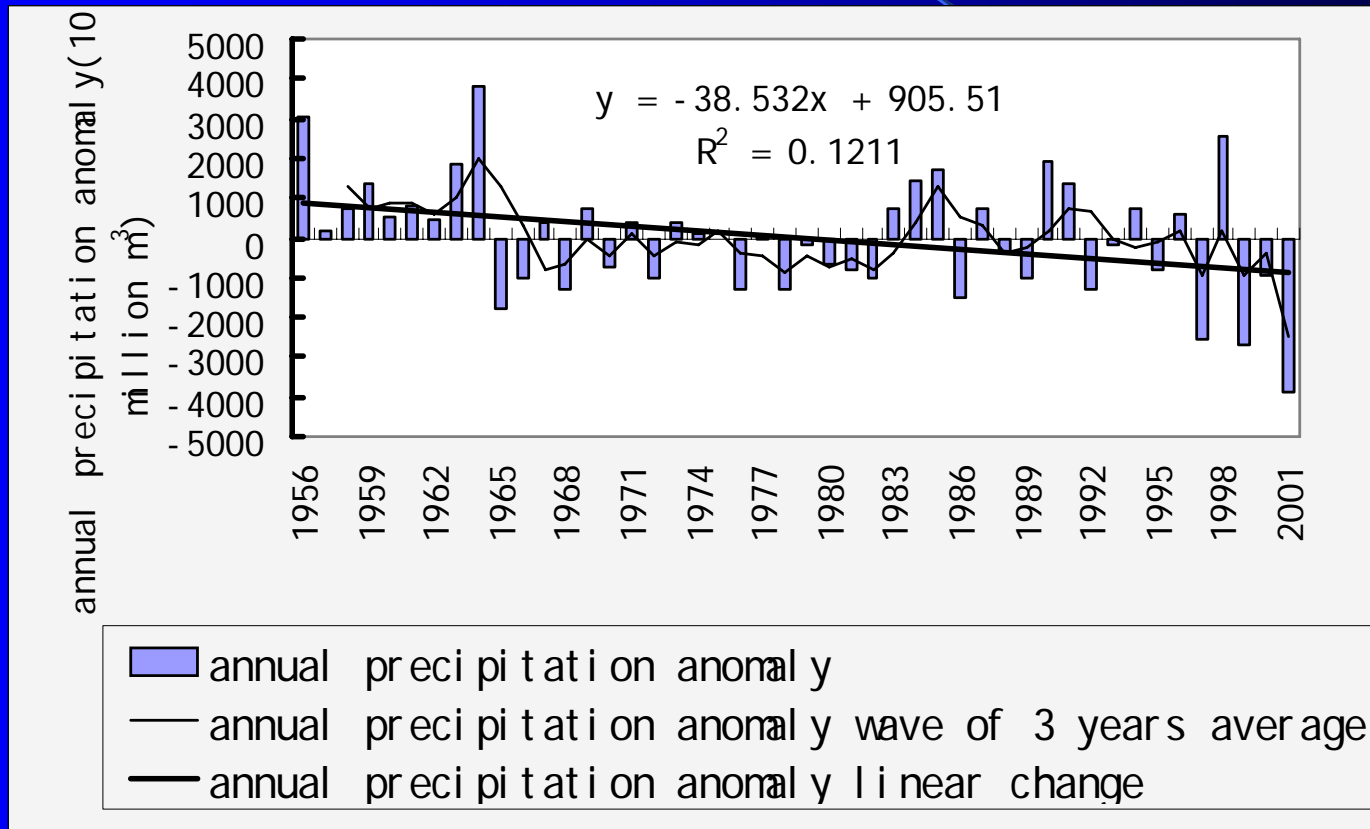Figure 4-7 shows its annual precipitation decrease rapidly.

Figure 4-7 annual precipitation anomaly of the YHHLS Division

（4) Northwest: fast temperature increase in summer and precipitation increase

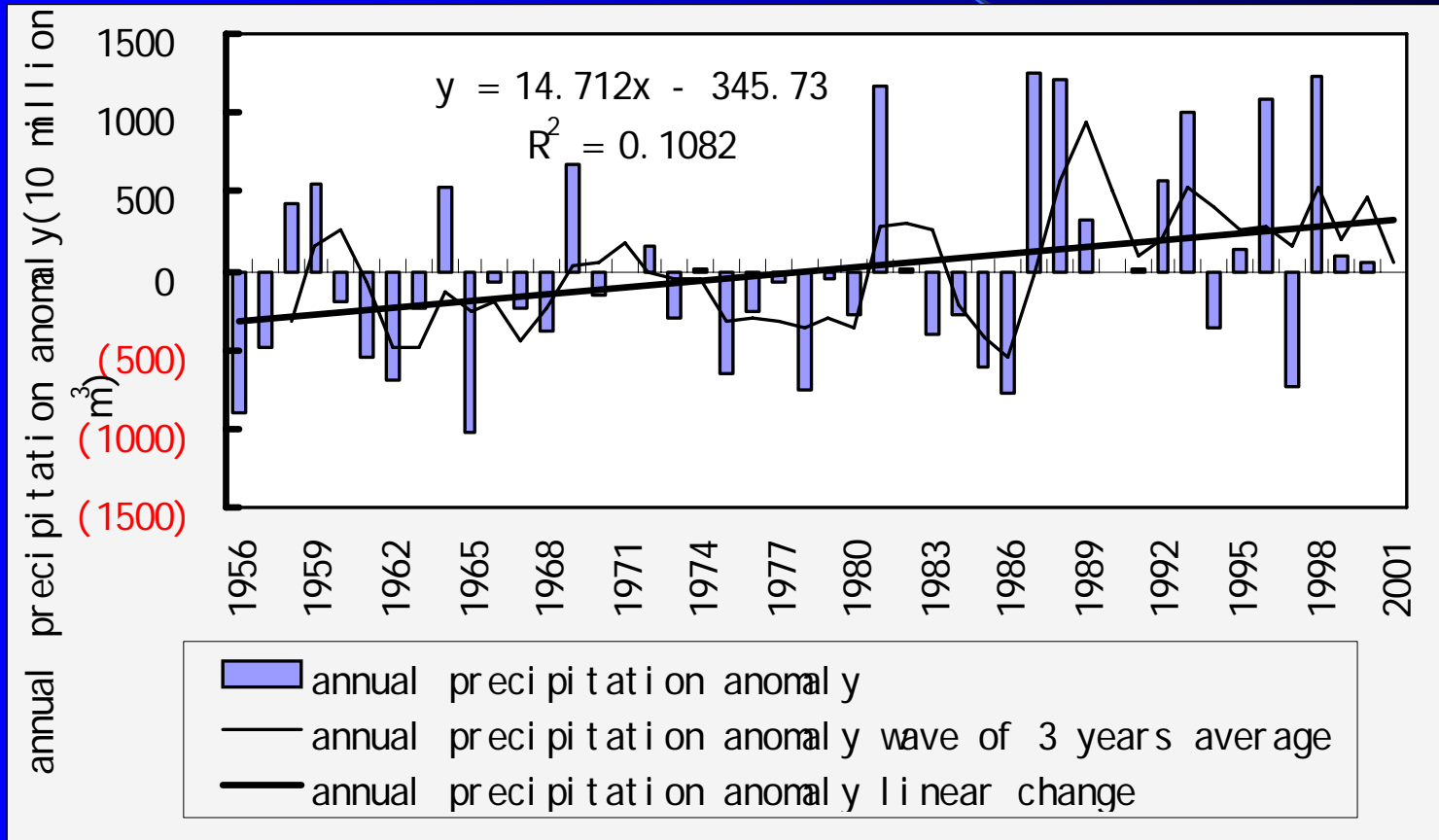Figure 4-8 shows its annual precipitation has a sharp increasing trend.

$$y = 14.712x - 345.73$$
$$R^2 = 0.1082$$

annual precipitation anomaly(10 million m^3)

annual precipitation anomaly
annual precipitation anomaly wave of 3 years average
annual precipitation anomaly linear change

Figure 4-8 annual precipitation anomaly of Division of Rivers in Northwest and its trend

5. Trend of Surface Water Resources Changes

The surface runoff in China is mainly precipitation supplied, therefore, the trend of surface water resources is in line with the trend of precipitation, but the change of surface water is dramatic than annual precipitation change.

5.1 Spatial Distribution of Average Annual Surface Water Resources

Surface water resources can be represented by average river runoff volume in many years. Annual runoffs in 10 river divisions are listed in Table 5

Table 5 average annual runoff volume in different river divisions (1956-2001)

Division/Region	Annual Runoff Depth (mm)	annual runoff(100 million m^3)	
		Annual Runoff(100 million m^3)	Percentage (%)
China	280.6	26934.74	100.00
Northern China	74.5	4608.74	17.11
Songhuajiang River	134.6	1286.8	4.78
Liaohe River	129.0	405.2	1.50
Haihe River	66.7	213.32	0.79
the Yellow River	74.3	590.3	2.19
Huaihe River	203.0	931.4	3.46
Rivers in Northwest	35.1	1181.68	4.39
Southern China	654.2	22327.27	82.89
Yangtze River	551.6	9834.08	36.51
Rivers in Southeast	954.0	1988.08	7.38
Zhujiang River	818.9	4731.7	17.57
Rivers in Southwest	684.0	5773.41	21.43

5.2 Trend of Annual Runoff Changes

Based on the statistics and analysis of the serial annual runoff volume data from 1956 to 2001, the annual runoff trend model's regression coefficient *b* and regression constant *a* in each division during the nearly 50 years are listed in Table 6.

Table 6 parameters of linear change trend model of annual runoff in different divisions (1956-2001）

Region	Annual Runoff			Annual Runoff Depth	
	b(100 million m3/b)	a(100 million m3/a)	Relative Change rate （%/10a）	b(mm/a)	a(mm)
China	**24.961**	**-22449**	**0.9**	**0.2601**	**-233.88**
Northern China	**-18.1649**	**40548**	-3.9	**-0.2937**	**655.58**
Songhuajiang River	-3.8248	8854.2	-3	-0.4092	947.18
Liaohe River	-2.1963	4750.6	-5.4	-0.6991	1512.2
Haihe River	-3.2917	6725.9	-15.4	-1.028	2100.6
the Yellow River	-3.674	7859.3	-6.2	-0.4625	989.36
Huaihe River	-7.3233	15421	-7.9	-1.2636	3361.1
Rivers in Northwest	-20.3101	43611	-5.9	-0.7195	1544.9
Songhuajiang River	2.1452	3062.6	1.8	0.0638	-91.09
Southern China	**43.1257**	**-62997**	1.9	**1.2636**	**-1845.8**
Yangtze River	20.506	-30737	2.1	1.1465	-1716.8
Rivers in Southeast	6.1551	-10190	3.1	2.9676	-4917.4
Zhujiang River	13.979	-22926	3	2.4193	-3967.7
Rivers in Southwest	2.4856	855.7	0.4	0.2945	101.38
Zhujiang River, Southeast and Southwest	22.6197	-32260	1.8	1.3874	-1978.7

Figure 5-1 shows trend of China's annual runoff anomaly. From Figure 5-1we can see there is a slightly increasing trend in China's average annual runoff volume.
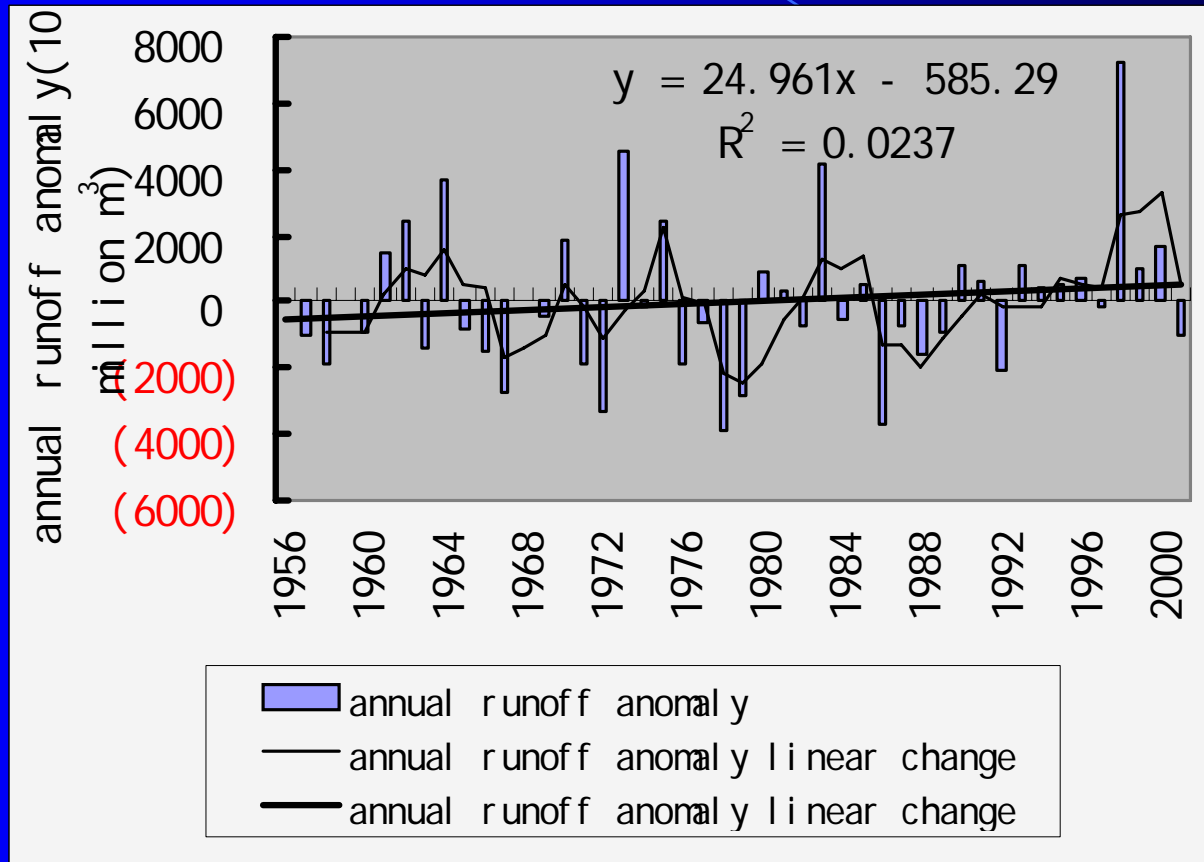

Figure 5-1 China's annual runoff anomaly and its trend

Figure 5−2 shows the tempo of annual runoff depth changes in different divisions
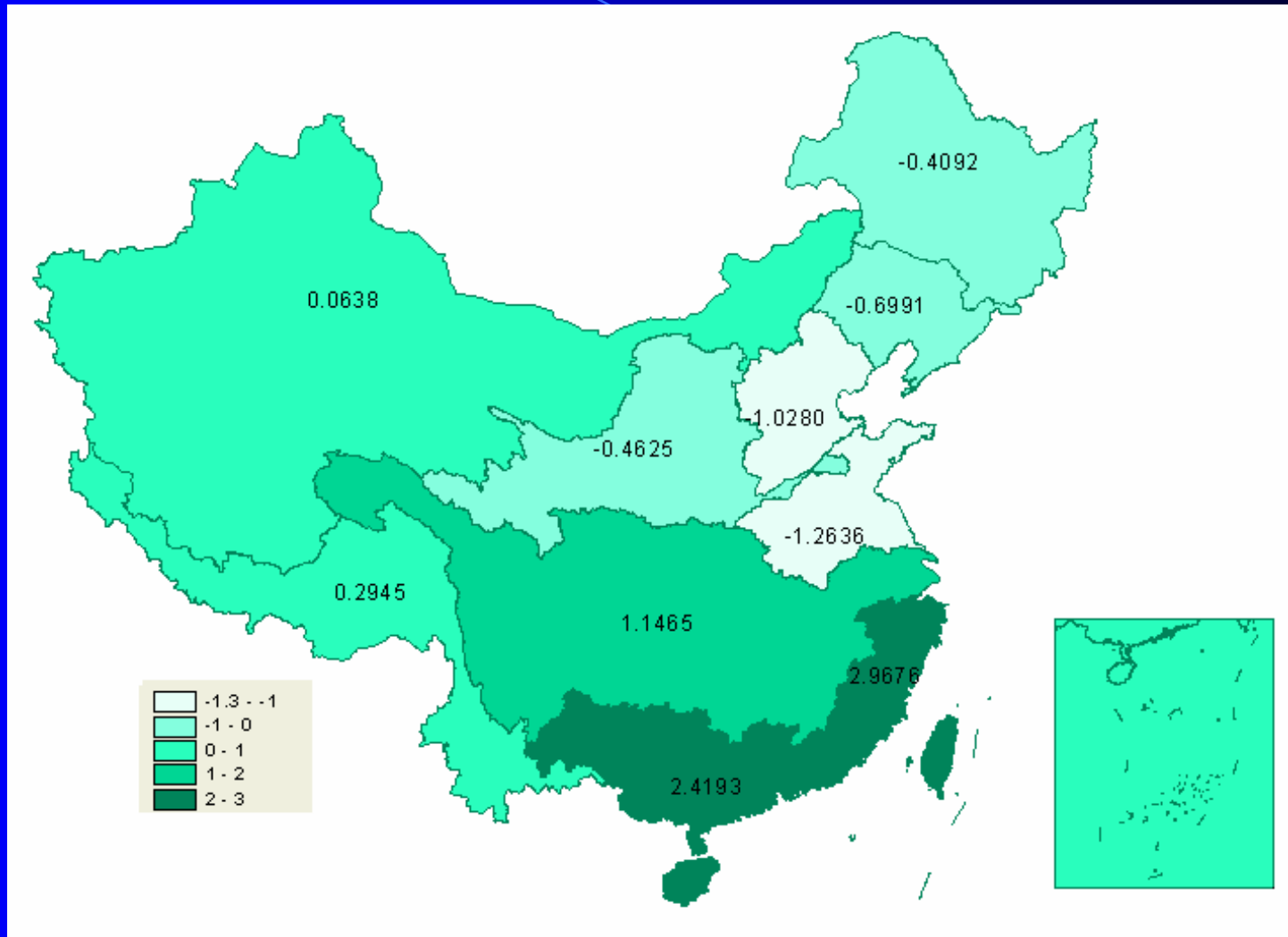

Figure 5−2 tempo of annual runoff depth changes in different divisions (mm/a)
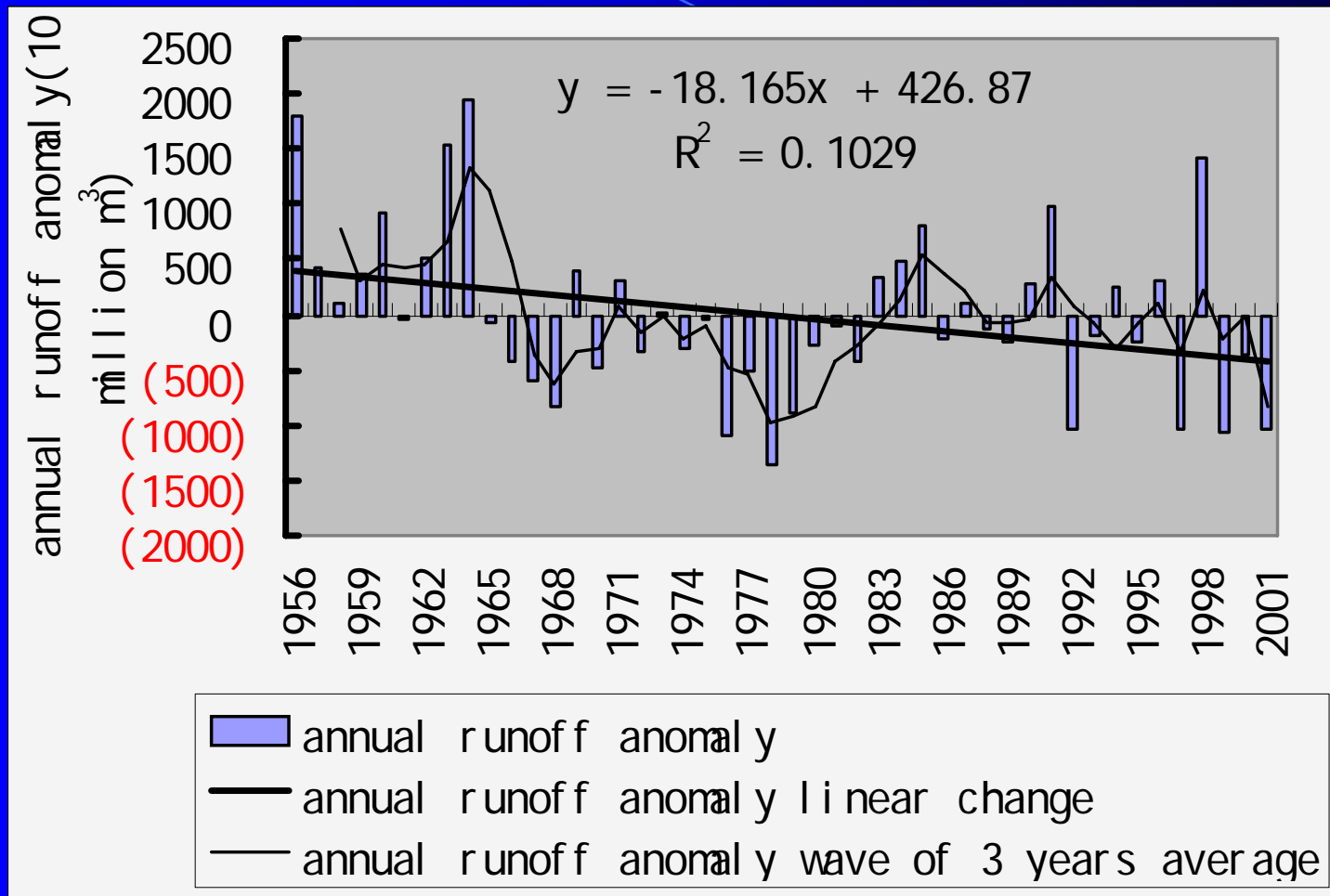
A decreasing trend in northern China (Figure 5-3)

Figure 5-3 annual runoff anomaly and its trend in northern China

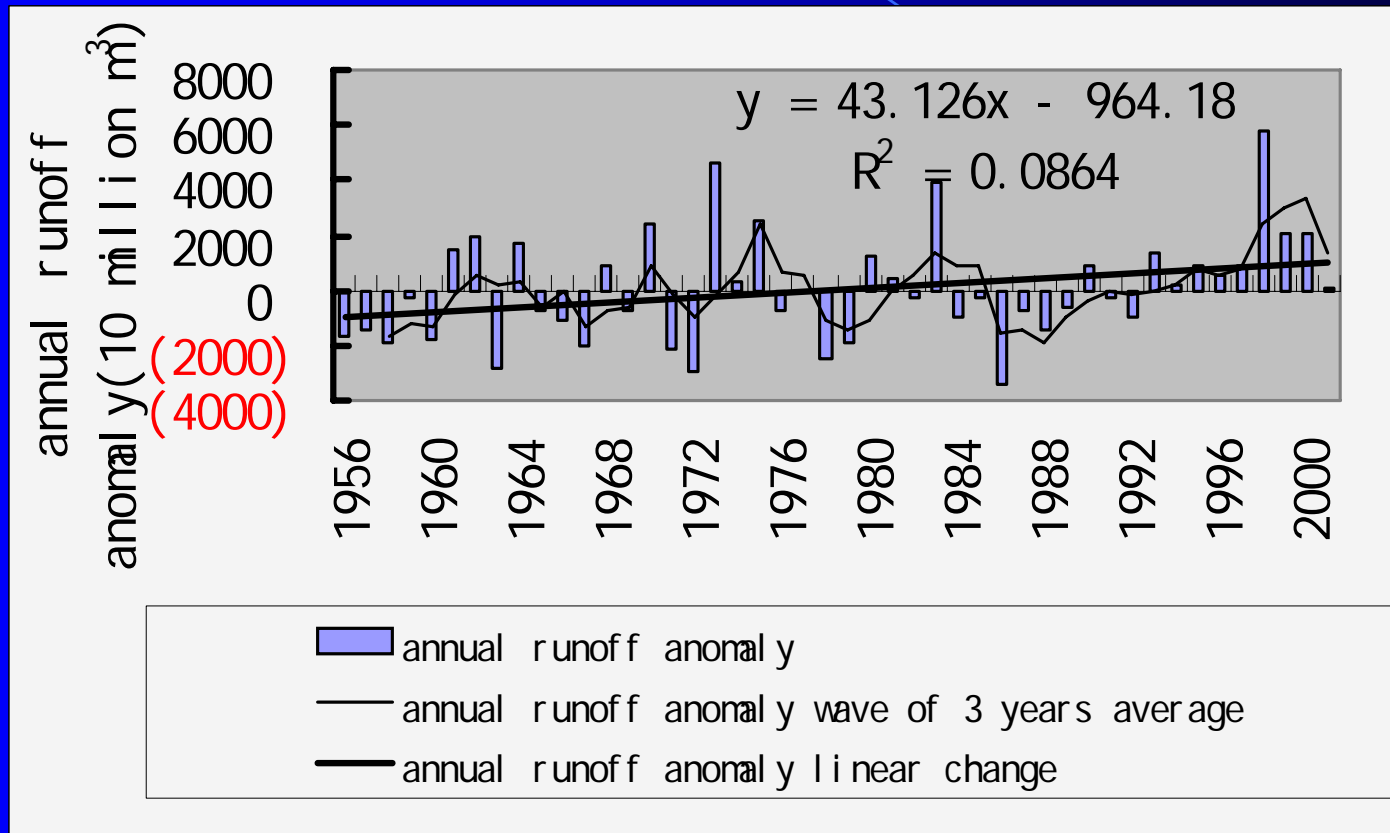# There is an increasing trend in southern China (Fig. 5-4).

Figure 5-4 annual runoff anomaly and its trend in southern China

From the comparison between Table 6 and Table 2, the 10 water resource divisions in China can be divided into 4 types due to annual precipitation and temperature changes.

(1) The Yangtze River Division: summer temperature decreases and annual runoff increase region

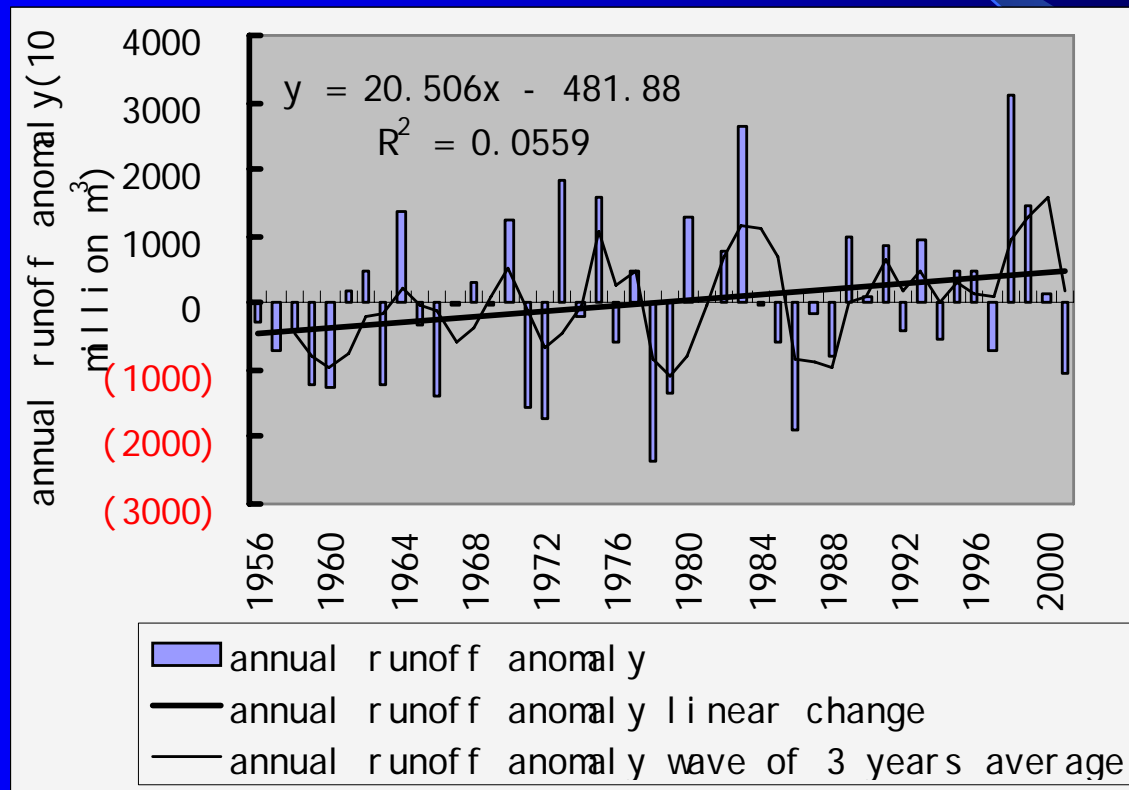Figure 5-5 shows annual runoff is increasing in this region.

Figure 5-5 annual runoff anomaly and trend in the Yangtze river Division

(2) Zhujiang River Division, Division of Rivers in Southeast and Division of Rivers in Southwest: temperature increase slowly in spring and summer, runoff increase regions

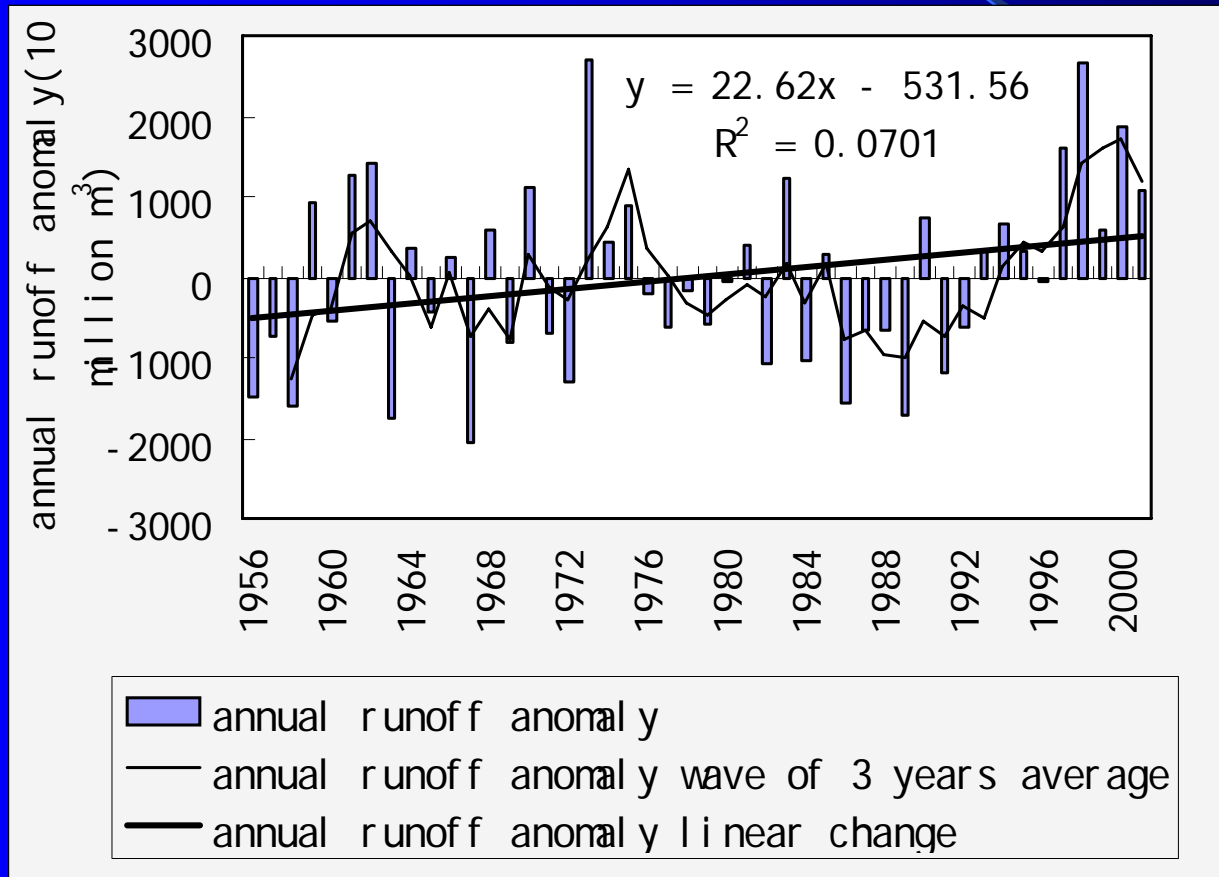Figure 5-6 shows annual runoff anomaly and its trend in this region.

Figure 5-6 annual runoff anomaly in the YHHLS Division

(3) The YHHLS Division is Regions with fast temperature increasing tempo and significant annual runoff decrease.

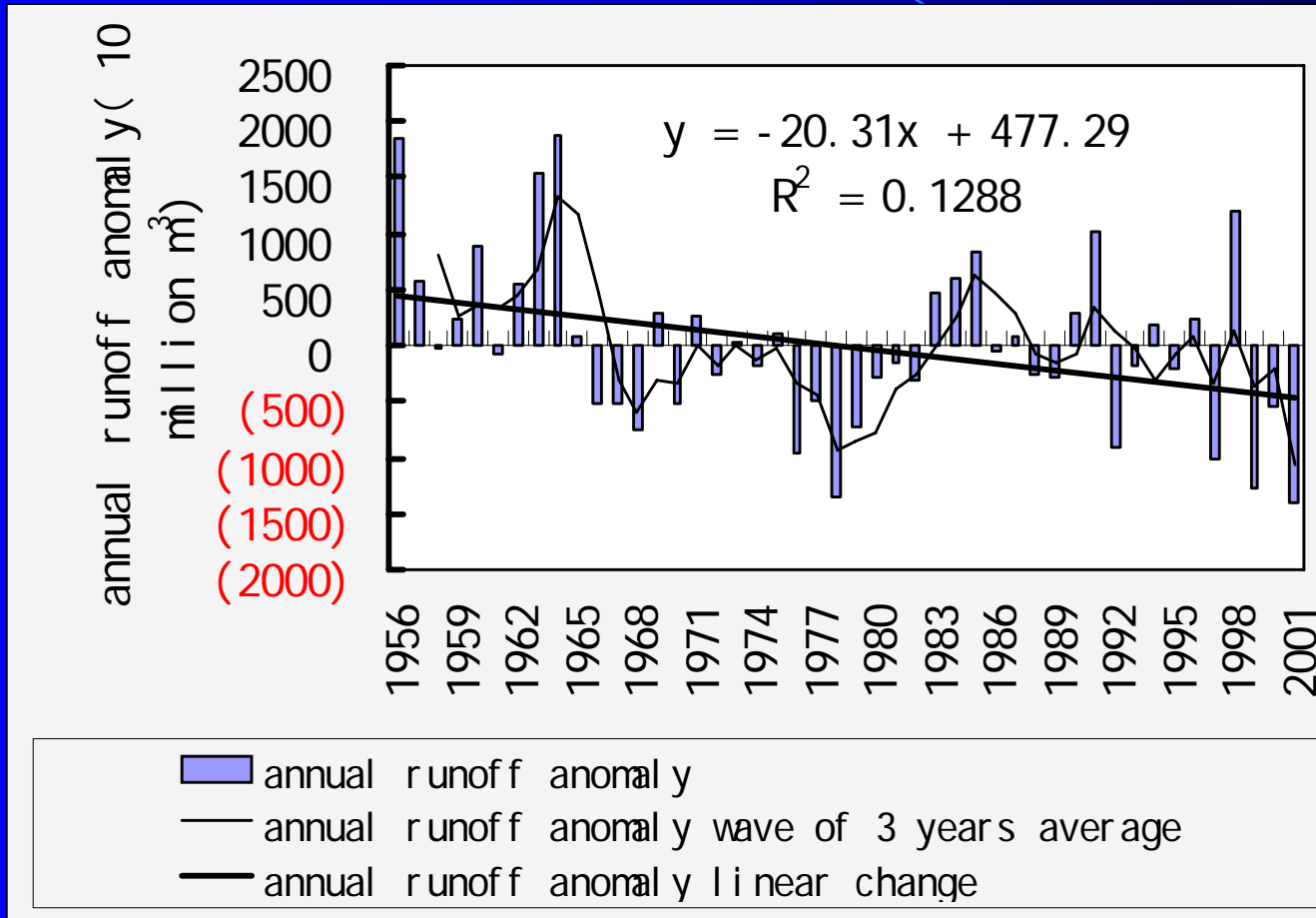Figure 5-7 shows the YHHLS Division's annual runoff decrease significantly.

Figure 5-7 annual runoff anomaly of the YHHLS Division

(4) Northwest: summer temperature increase quickly, annual runoff increase region

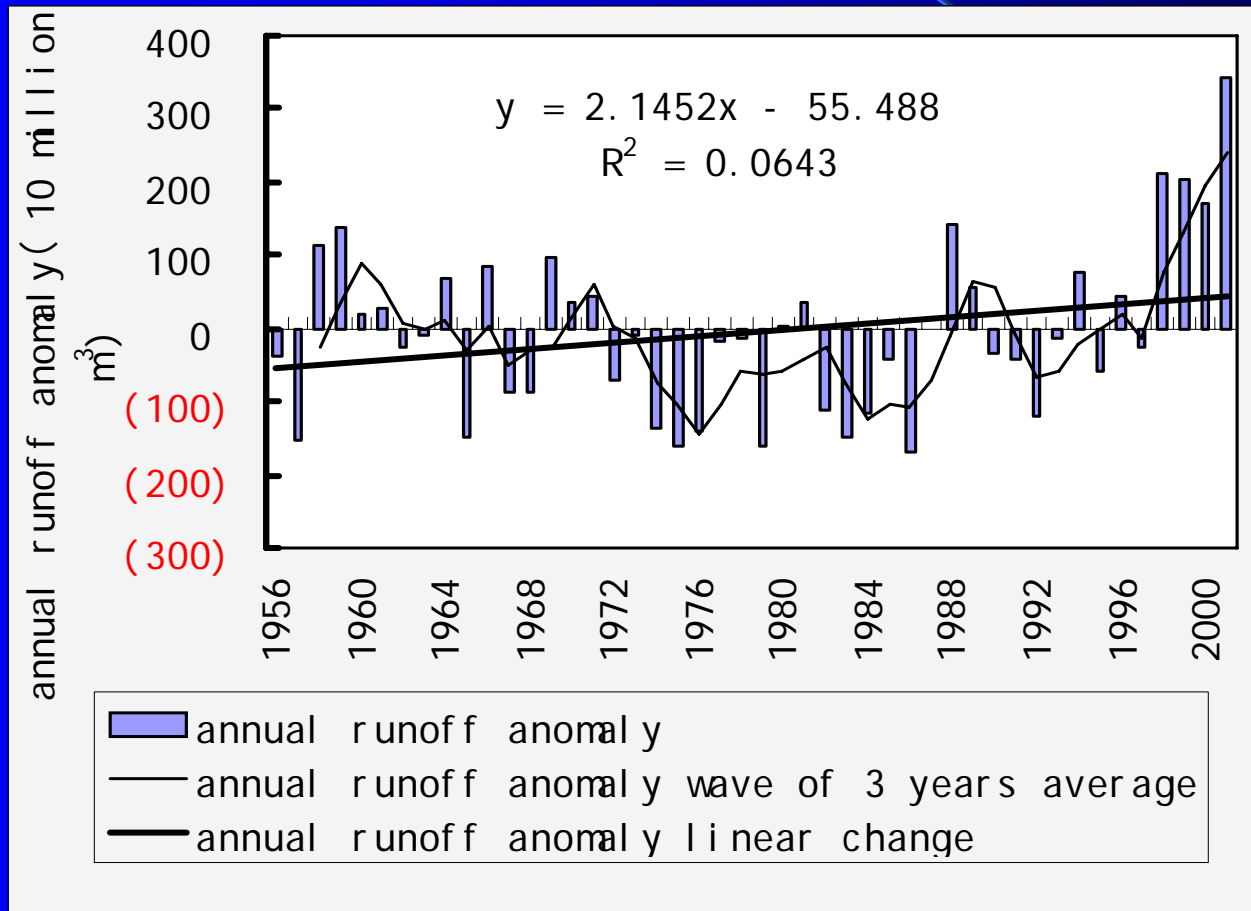Figure 5-8 shows annual runoff anomaly and trend in the region.

Figure 5-8 annual runoff anomaly and its trend in Division of Rivers in Northwest

6   Conclusion

1 Temperature in China has an increasing trend in about 50 year period; the increasing tempo varies in different divisions of different seasons. In the regional angle, temperature increase in north regions is greater than that of south regions; in the seasonal angle, temperature increase is fast in winter, while in summer it's not very distinct. In Yangtze River Division, temperature in summer has a decreasing trend.

2 Geographically, water volume of precipitation and surface water resources in China is abundant in southeastern China, scarce in northwest China, its overall distribution trend is decreasing from southeast to northwest.

3 The change of temperature, annual precipitation volume and annual runoff volume in China turn out opposite trend of increasing and decreasing, the 10 divisions can be divided into 4 types (fig 6)

Figure 6 types of annual prec., annual runoff depth and temperature changes
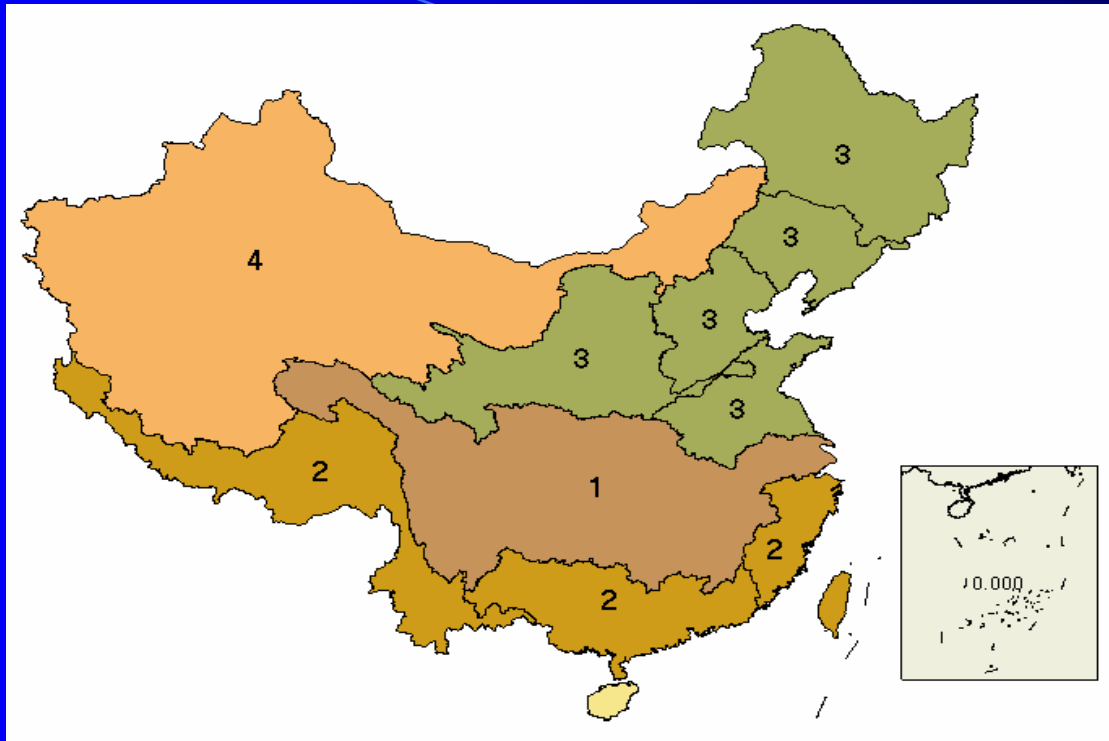
Region type		Relative change rate in 10 years			Effect
No	Name	**Temperature**	**Annual precipitation**	**Annual runoff depth**	
1	Yangtze River	**Summer ↓**	**↑ 0.45%**	**↑ 2.08%**	**flood ↑**
2	Zhujiang , Southeast & Southwest	**Spring & Summer ↑**	**↑ 0.63 %**	**↑ 1.81%**	**flood ↑**
3	YHHLS	**Summer ↑**	**↓ 2.49%**	**↓ 5.93%**	**dry ↑**
4	Northwest	**Summer ↑**	**↑ 1.47 %**	**↑ 1.82%**	**good**

4. Global warming drives annual Precipitation and annual runoff in China an increasing trend in south and a decreasing trend in north, this will bring more frequent floods to southern China and more dries to northern China, the situation of water resources shortage will become more fierce, which may probably influence China's economy construction, therefore, we should pay more attentions to it.