Winter Asia Jetstream and Seasonal Precipitation in East China

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ABSTRACT

The monthly mean geostrophic wind fields for January during 1951–1990 period are calculated by using data of 500 hPa monthly mean height. The relation between Asia jetstream in winter and the important seasonal precipitation in East China is analysed. The analysis shows that the south branch of jetstream is stronger (weaker) in winter, the rainfall will be more (less) than normal in the subsequent spring in South China, and summer rainfall in North China will be more (less), too; these important rainy seasons are related to each other; the Indian summer monsoon is not only related to the summer rainfall in North China, but also related to the spring rainfall in South China and the south branch of jetstream in winter.

Key words: Jetstream; Summer rainfall in North China; Spring rainfall in South China; Indian summer monsoon

I. INTRODUCTION

In the Northern Hemisphere, jetstream over East Asia is the strongest, and the jetstream has much influence on the weather and climate here. The jetstream characteristics and phenomenon of branching had been researched by Chinese meteorologists during 1950's. It was suggested that the south branch of jetstream moving forward to south or back to north marked the change of season (Wu and Chen, 1956; Ye and Xie, 1959; Zhang and Ge, 1983). Jetstream over East Asia is connected with extra–long wave systems, such as western Pacific subtropical high, East Asian trough and the high over Asia continent. The situation of jetstream also in some degree reflects the thermal regime for Asia continent, the Pacific Ocean and Indian Ocean. Therefore, it is necessary to concern the jetstream when we discuss the long–range process of seasonal precipitation.

In this paper, the analyses have been made of major rainy seasons in East China and the south branch of jetstream in Asia by using data of monthly precipitation for 160 stations in the whole country and data of 500 hPa monthly mean height during 1951–1990 period. These data are provided by National Meteorological Center, State Meteorological Administration. The statistical results show that the major rainy season occurred in July and August in North China. More than 40% of annual precipitation occurs over the north of the Huaihe River and more than 60% of annual precipitation occurs over the Beijing–Tianjin area during these two months. So the summer rainy season is the most important precipitation time. In the vast area south of the Changjiang River the most precipitation is in May or June, as shown by Zhang and Lin (1985) that spring rainfall is more than mei–yu rainfall in that area. The precipitation where during April to June is more than 40% of the annual; and in Nanchang and Pucheng the precipitation is more than 50% of the annual. So the spring rainy season is the important season. Therefore, in this paper our discussion focuses on the relationship between the north summer rainy season, the south spring rainy season and the south branch of jetstream in Asia.

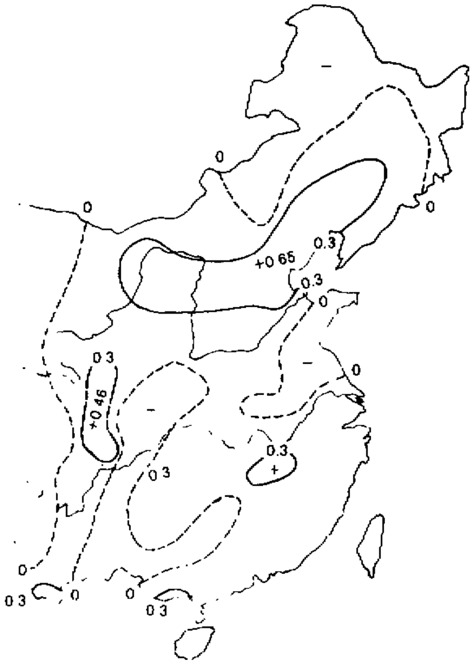

Fig. 1. The correlogram of index 1 in January with the rainfall of the stations in East China from June to September during 1951–1990. The solid lines are the boundary of the area with significance at 0.05 level.

II. SOUTH BRANCH JETSTREAM AND SUMMER RAINFALL IN NORTH CHINA

Tianjin is located near the center of the north summer rainy area. As the representative the correlogram (figure not shown) is made by using Tianjin rainfall data in June–September and the u components of 500 hPa geostrophic wind fields in January during 1951–1990. It is seen from the omitted figure that January u components over the Changjiang River basin are significantly positively correlated to the Tianjin summer rainfall. And it is well known that the maximum wind speed of the south branch of jetstream is just over that area. The maximum correlation coefficient is 0.599. The relationship is significant at 0.001 level. The sum of u components for five points in the region (25–30°N, 95–115°E) is defined as the index 1 of south branch of jetstream, and this region is defined as the south jetstream region 1. The correlogram (Fig. 1) is made by using the data of index 1 and rainfall data of 160 stations from June to September. It is shown that the rainfall for these stations in the vast area from Yinchuan to Changchun is significantly positively correlated to index 1, the significance at 0.05 level, and half of these stations their significance at 0.01 level. The maximum correlation coefficient is 0.65. This area is just located at the middle part of the north summer rainy area. Another significant correlation area is located at Minxian, Chengdu to Yaan, and there is a summer rainy area too. The maximum correlation coefficient is 0.46. The curves of mean summer (June–September) rainfall for the north fourteen stations from Yinchuan to

Changchun and index 1 during 1951–1990 are shown in Fig. 2. The variations both in these two series are often in good agreement. The correlation coefficient between the two series is 0.666, and the significance is at 0.001 level. When the index $1>110$, it is defined as strong jetstream, and the index $1<100$, defind as weak jetstream. Among the forty years there are fifteen years with strong jetstream in January, the mean summer rainfall for the north fourteen stations in these years is 423 mm; and there are thirteen years with weak jetstream in January, the mean summer rainfall for the north fourteen stations in these years is 309 mm. The significance for the difference between the summer rainfall series in the years with strong jetstream and with weak jetstream is examined with t test (Huang, 1990). The value of t is computed by using:

$$t=\frac{\overline{AX}-\overline{BX}}{S(\frac{1}{n}+\frac{1}{m})^{1/2}}, \quad (1)$$

$$S^2=\frac{\sum_{i=1}^{n}(AX_i-\overline{AX})^2+\sum_{i=1}^{m}(BX_i-\overline{BX})^2}{n+m-2}, \quad (2)$$

where $n=15$, $m=13$. The calculated t value is 5.611, which is greater than 2.779, the critical significant value of t at 0.01 level for $n+m-2$ degrees of freedom. It is quite evident that the difference between the two series is significant.

Correlogram (Fig. 1), time series curves (Fig. 2) and the significant test for rainfall difference between the strong jetstream years and weak jetstream years suggest that there are more summer rainfall for North China when the year with strong jetstream in winter (January), and less summer rainfall for North China when the year with weak jetstream in winter. The well-known rainy years, such as 1954, 1956, 1959, 1964, 1969 and 1977 are all with strong jet

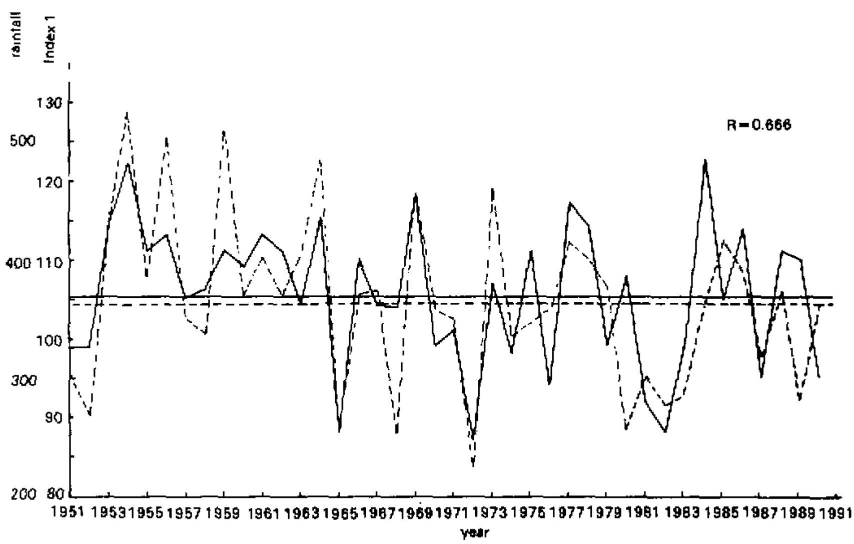

Fig. 2. The curves of mean summer (June–September) rainfall for the north fourteen stations from Yinchuan to Changchun (dashed line) and the index 1 (solid line).

stream in winter; and the well-known drought years, such as 1951, 1952, 1972, 1981 and 1982 are all with weak jetstream in winter.

The regression equation from index 1 is:

$$y = -201.93 + 5.364x \ , \qquad (3)$$

where y is the estimate value for mean rainfall of the north fourteen stations, x is the index 1 for south branch of jetstream. The root-mean-square error is 54.48 mm. The standard deviation of north fourteen stations mean summer rainfall is 73.01. So that the root-mean-square error is less than 75% of the error for climate forecast. Respectively classify the index 1 series and north summer rainfall series into three classes (i.e. more, normal and less), it is seen that there are 72.5%of the forty years summer rainfall and jet index in the same class.

The another interesting phenomenon is seen in Fig. 2, that index 1 and the north summer rainfall all are tending to decrease in the last forty years. For these two series every ten-year average values are shown in Table 1. We can see that the index 1 and the north summer rainfall both are decreased decade by decade. It is suggested that south branch of jetstream not only related to the north summer rainfall as a seasonal long range process, but they associated with same climate tendency.

Table 1. Decade Average Values for Index 1 of Winter Jetstream and Summer Rainfall of the Fourteen Stations in North China

decade	index 1 for jetstream in winter	summer rainfall in North China
1951-60	108.9	397.8 mm
1961-70	106.6	372.1 mm
1971-80	103.6	351.3 mm
1981-90	103.2	326.3 mm

It was pointed out that there exists a steady and significant positive correlation between the Indian summer monsoon rainfall and summer rainfall in North China (Liang, 1989, 1990). The correlogram (figure omitted) is made by using Indian summer monsoon rainfall (Mooley and Parthasarathy, 1984) and u components of 500 hPa geostropic wind fields in January during 1951-1983. In that figure, the most significant correlation area is located at the south branch of jetstream too. One center is over the Changjiang River basin, another over India. So it may be inferred that a strong or weak south branch of jetstream in winter is likely to induce the subsequent Indian summer monsoon rainfall excess or deficit. The correlation coefficient between index 1 and Indian summer monsoon rainfall is 0.60, with the significance at 0.001 level. So that the relationship between Indian summer monsoon rainfall and south branch of jetstream is the same to the relationship between summer rainfall in North China and the south branch of jetstream.

III. SOUTH BRANCH OF JETSTREAM AND SPRING RAINFALL IN SOUTH CHINA

Nanchang is located near the center of the south spring rainy area. As the representative the correlogram (figure not shown) is made by using Nanchang rainfall data in April-June and the u components of 500 hPa geostrophic wind fields in January during 1951-1990. It is seen that most significant correlation area is located at south branch of jetstream too, but the

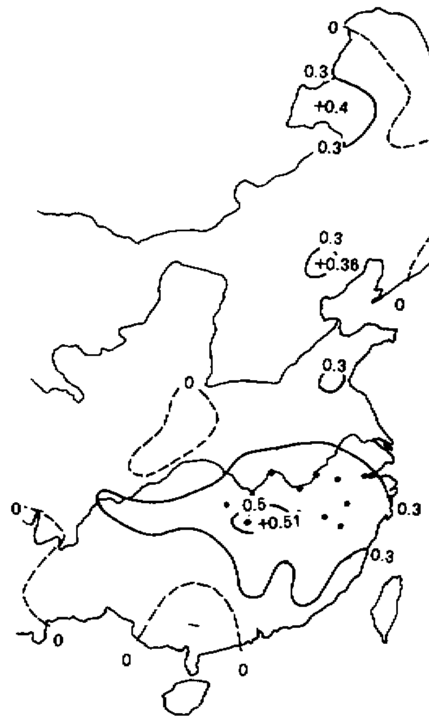

Fig. 3. The correlogram of the index 2 with the rainfall in April–June of the stations in East China during 1951–1990. The solid lines are the boundary of the area with the significance at 0.05 level.

center moved westwards to 70–100°E. The maximum correlation coefficient is 0.54, with the significance at 0.001 level. The sum of u components for seven points in the region (25–30°N, 70–100°E) is defined as the index 2 of the south branch of jetstream, and this region is defined as the jetstream region 2. The correlogram (Fig. 3) is made by using the data of index 2 and the rainfall of 160 stations in April–June. It is shown that the rainfall for these stations in the vast area from Yibin to Hangzhou is significantly positively correlated to index 2. The maximum correlation coefficient is 0.51. The twelve stations in the middle part of this area are indicated in Fig. 3 with solid circles, they are Changde, Changsha, Yueyang, Jiujiang, Nanchang, Anqing, Tunxi, Juxian, Hangzhou, Guixi and Pucheng. The curves of mean rainfall for the twelve stations in spring (April–June) and index 2 during 1951–1990 are shown in Fig. 4. The variations in these two series are often in good coincidence. When the index 2 > 140, it is defined as strong jetstream and index $2 < 110$, defined as weak jetstream. In the seven years with strong jetstream in January the mean rainfall for southern twelve stations in spring is 884.3 mm (+31.9%), among these years, in 1954 and 1964, the spring rainfall all are more than 1000 mm; in the eight years with weak jetstream, the mean rainfall in spring is only 542.6 mm (−19.1%). The significance for difference between the spring rainfall series in the years with strong jetstream and weak jetstream is examined as above. The result shows that it is significant at 0.01 level. The calculated result shows that spring rainfall for the most stations in the south of the Changjiang River during these years with strong jetstream is above

20% than those years with weak jetstream. Among them some stations spring rainfall differences are above 40%. The maximum difference is 73% occurred at Yueyang. The significance for spring rainfall difference for every station is examined with t test too. The results show that stations with difference more than 20%, the significances are in common at 0.01 or 0.05 level. So that, either mean rainfall for southern twelve stations or rainfall for every station in spring all are excessive during these years with strong jetstream, and deficient during these years with weak jetstream.

The regression equation from index 2 is:

$$y = -6.619 + 5.397x \ , \tag{4}$$

where y is the estimate value for the mean rainfall of the southern twelve stations, x is the index 2 for south branch of jetstream. The root-mean-square error is 142.7 mm. The standard deviation of southern twelve stations mean spring rainfall is 163.3 mm. So the error is less than 87% of the error for climate forecast. The index 2 series and southern spring rainfall series are classified into three ranks (i.e. more, normal and less), it is seen that there are 65% of the forty years spring rainfall and jet index 2 in the same rank. The root-mean-square error of Eq.(4) is larger than Eq.(3), but for the rainy years, such as 1954, 1962, 1964, 1967, 1973, 1977, 1989 and the rainfall deficit years, such as 1963, 1965, 1972, 1981 and 1982, the estimate values are suitable.

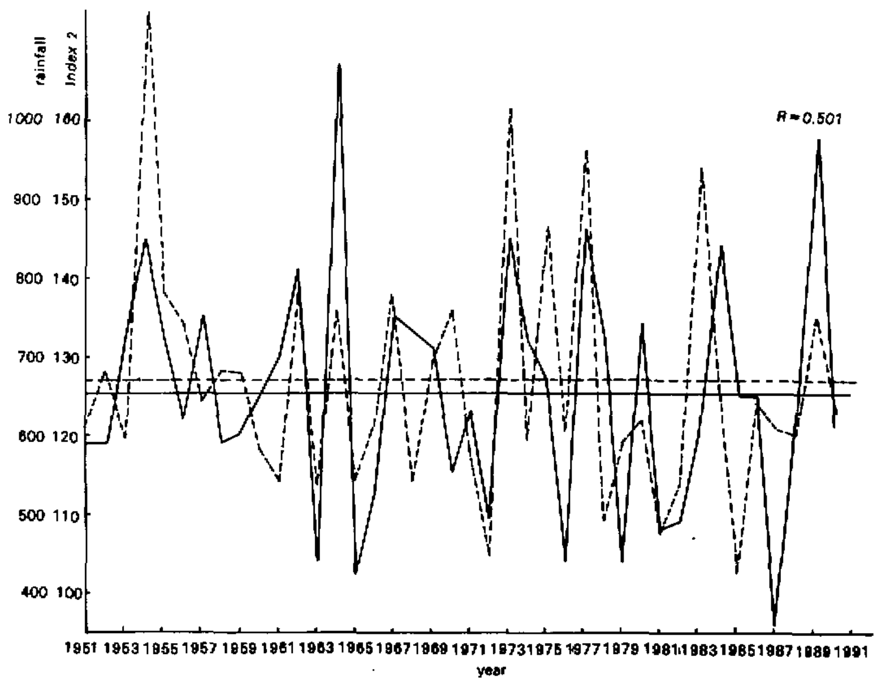

Fig. 4 The curves of mean rainfall (dashed line) for southern twelve stations in spring (April–June) and index 2 (solid line) during 1951–1990.

IV. DISCUSSION AND SUMMARY

From the above analysis it should be clear that spring rainfall in South China and summer rainfall in North China all are closely related to the south branch of jetstream in winter. The correlation coefficients between them are shown in Table 2, where * indicates the significance at 0.05 level, ** at 0.01 level, *** at 0.001 level. It is seen that spring rainfall in South China is significantly positively correlated to the summer rainfall in North China, whereas spring rainfall in South China and summer rainfall in North China all are correlated to Indian summer monsoon. These three rainy seasons all are significantly positively correlated to the south branch of jetstream (including region 1 and region 2). These events arranged in time sequence are:

1) The south branch of jetstream in winter is stronger / weaker→the subsequent spring rainfall in South China will be more / less→ and the subsequent summer rainfall in North China will be more / less.

2) The south branch of jetstream in winter is stronger / weaker→the subsequent spring rainfall in South China will be more / less→ and the subsequent Indian summer monsoon rainfall will be more / less.

3) Indian summer monsoon rainfall is more / less→simultaneously the summer rainfall in North China is more / less.

Table 2. Correlated Coefficients between Spring Rainfall in South China and Summer Rainfall in North China and Indian Summer Monsoon Rainfall and Index for South Branch of Jetstream in Winter

	Summer rainfall in North China	Spring rainfall in South China	index 1	index 2
Summer rainfall in North China (June–Sep.)	1.00	0.422**	0.666***	0.355*
Spring rainfall in South China (April–June)	0.422**	1.00	0.455**	0.501***
Indian summer monsoon rainfall (June–Sep.)	0.561***	0.425**	0.600***	0.370**

The above series reveal the long-range process for the south branch of jetstream in winter associated with the subsequent major rainy seasons in East China which indicates that they are not isolated each other.

In the present paper we have shown that the index of south branch jetstream can be utilized to make reliable forecasts of the major rainy seasons in the eastern China. According to this indicator, the forecasts for Tianjin summer rainfall in 1990, 1991 and 1992 are all right.

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