Vol.12 No.2 JOURNAL OF TROPICAL METEOROLOGY December 2006

Article ID: 1006-8775(2006) 02-0121-09

# THE VARIATION OF THE SPRING PRECIPITATION IN GUANGZHOU AND ITS PRECURSORY SIGNALS

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ABSTRACT: Guangzhou spring rainfall mainly exhibits interannual variation of Quasi-biannual and interdecadal variation of 30 yrs, and is in the period of weak rainfall at interdecadal time scale. SST anomalies (SSTA) of Nino3 are the strongest precursor of Guangzhou spring rainfall. They have significant positive correlation from previous November and persist stably to April. Nino3 SSTA in the previous winter affects Guangzhou spring rainfall through North Pacific subtropical high and low wind in spring. When Nino3 SSTA is positive in the previous winter, spring subtropical high is intense and westward, South China is located in the area of ascending airflow at the edge of the subtropical high, and water vapor transporting to South China is intensified by anticyclone circulation to the east of the Philippines. So Guangzhou spring rainfall is heavy. When Nino3 SSTA is negative, the subtropical high is weak and eastward, South China is far away from the subtropical high and is located in the area of descending airflow, and water vapor transporting to South China is weak because low-level cyclonic circulation controls areas to the east of the Philippines and north wind prevails in South China. So Guangzhou spring rainfall is weak and spring drought is resulted.

**Key words:** Guangzhou spring rainfall; spring drought; precursor; subtropical high; low-level wind

**CLC number:** P426.61.4 **Document code:** A

## 1 INTRODUCTION

Guangzhou is located in south China and affected by the East Asia monsoon, especially by the summer monsoon. Its climate can be divided into two seasons, i.e. wet and dry season by precipitation. There are many studies on the precipitation in wet season, particularly for the early and late raining periods. Wu and Liang[1] studied the spatiotemporal distribution of drought/rain in the early raining period of south China. Wu et al.[2] studied the interannual variation of the precipitation in the late raining period in south China. Ji et al.[3] studied the multiple time scale characters of the precipitation in the early and late raining periods of Guangzhou. There are also many studies[4-10] on the factors affecting the precipitation during the south China raining period, such as the subtropical high, sea surface temperature and low-latitude circulation systems. However, few studies on the spring precipitation in south China can be found so far. Since the spring is the planting and growing season of crops in south China and has a significant influence on agriculture, it has important practical meaning. Natural precipitation is the main source of water needed by crops, so it is suitable to use rainfall as the represent and analyze the aridity of climate. Spring drought happens from February to May with features of large extension and strong synchronization in time, which is resulted from the anomaly of the large-scale circulation[11]. The spring drought usually happens under two patterns of weather situation, one being

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**Received date:** 2005-09-196; **revised date:** 2006-06-23

**Foundation item:** Research on the Technologies of Predicting Drought Prospects in Guangdong, a planned project for Guangdong Province (2005B32601007)

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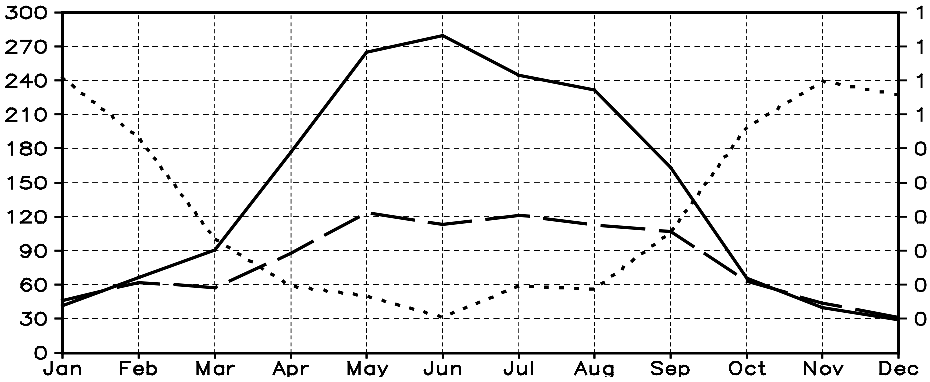

Fig.1 The variation of monthly mean rainfall of 1908-2004 in Guangzhou. The real line is the mean value, long dash line is the variance (left vertical axis in mm) and the dot line is the variance coefficient (right vertical axis).

characterized by northwesterly dominating the upper level with divergence and without a frontal zone, the other by a stronger subtropical high than normal that governs south China. Either of the patterns has very large spatial scales. And a certain pattern brings weather with the same amount of rainfall. This large-scale feature also gives two suggestions to our research: the first one is that data of a single station can be quite representative; the second one is the sea surface temperature field of the earlier period possibly contains quite good precursory signals. By using precipitation data for the past 100 years or so observed at the Guangzhou weather station, this paper is devoted to analyzing the characters of historical variation of the spring (February- May) precipitation, seeking their precursory signals in the sea surface temperature field of the earlier raining period and giving the reasons for their formation in terms of the general circulation anomaly.

## 2 DATA AND APPROACHES

Three kinds of data are utilized in the present paper: 1) Monthly rainfall data from 1908 to 2004 in Guangzhou station obtained from datum branch of Guangdong Meteorological Bureau. 2) Reconstructed sea surface temperature ERSST[12-13] starting from 1854 provides sea surface temperature field of a corresponding long time period (ftp://ftp.ncdc.noaa.gov/pub/data/ersst-v2/). Its horizontal resolution is 2 °×2 °. 3) Monthly mean global NCEP/NCAR data of 2.5 °×2.5 °[14].

Approaches involved in the present research are wavelet transform with Mexican hat as the mother wavelet analysis, correlation analysis and composite analysis. Wavelet transform is employed in the study of the oscillating characters of the spring precipitation of Guangzhou, while correlation analysis is for the study of the relationship between the anomaly of the spring precipitation of Guangzhou and earlier sea surface temperature field, and composite analysis for the composition of the atmospheric circulation using the anomaly of the sea surface temperature as the reference.

## 3 CLIMATOLOGICAL CHARACTERS OF THE PRECIPITATION IN GUANGZHOU

As the averaged annual rainfall over 1908-2004 is about 1694 mm, but the distribution within a year is highly inhomogeneous. Fig.1 gives the monthly rainfall, its variance and variance coefficient[15] averaged over 1908-2004. It shows that averaged monthly rainfalls of April-September exceed 150 mm, and those for the remaining months are below 90 mm. The maximum rainfall appears in June with a mean value over 270 mm, while the minimum appears in December with a mean value of about 30 mm. The variance of rainfall in May-September has large values between 110 and 120 mm, but that in January-March and October-December has small values. Variance coefficient is a ratio of variance to mean value, which reflects the magnitude of the variability of an observed series after removing the influence of the scale of the variable. Variance coefficient is large in January-April and September-December and becomes small in May-September, which indicates a strong variability of rainfall of Guangzhou in autumn, winter and spring and also frequent droughts of different degree or even a long-lasting drought through these three seasons. Since the amount of spring (February-May) precipitation has significant influence on the planting and growing of the crops, in this paper we analyze the variation characters of the spring precipitation by using a long time series (97 years) of rainfall of Guangzhou.

## 4 CHARACTERS OF THE INTERANNUAL AND INTERDECADAL VARIABILITY OF THE SPRING RAINFALL IN GUANGZHOU

In order to reflect illustratively how the spring precipitation varies, its time series is normalized. The result of calculation does not show any significant linear trend of change. Fig.2 gives the normalized time series of spring (February-May) rainfall of Guangzhou in 1908-2004 and its wavelet analysis. From the distribution of wavelet coefficient, significant interannual and interdecadal variability of the spring rainfall in Guangzhou can be seen. Among which, interannual variability contains quasi-biennial and 5 –7 year oscillations, and interdecadal variability contains oscillations of 10-15 and 25-35 years. Quasi-biennial oscillation is mainly seen around the years of 1910, 1920, 1930 and 1960 and in the late 1970's. Oscillation of about 7 years is found around 1920. Oscillation of 10-15 years exists from 1920's to the end of 1940's; Up to now from the 1950's, there is an oscillation of about 25-35 years. From the power spectrum in Fig.3, one may find that although no period reaches the confidence level of 0.05, there are significant peaks that can be regarded as the main periods of the time series. Primary long period is 30 year, while short periods are 7.5, 4.3, 3.5, 2.7 and 2.3 years, which are consistent with the period of ENSO, i.e. 2-7 years. The variance analysis of wavelet also demonstrates the primary periods of oscillation are quasi-biennial and quasi-30 years (no shown). Fig.2 also gives a series of interdecadal scale reconstructed from the inverse wavelet transform (as shown by the thick dash line). It is shown that 1908-1917, 1929-1939, 1946-1949, 1960-1972 and 1994-till now are dryer periods, while 1919-1928, 1939-1945, 1950-1959 and 1973-1993 are wetter periods, of the interdecadal scale. A dryer period lasts 5 years at least

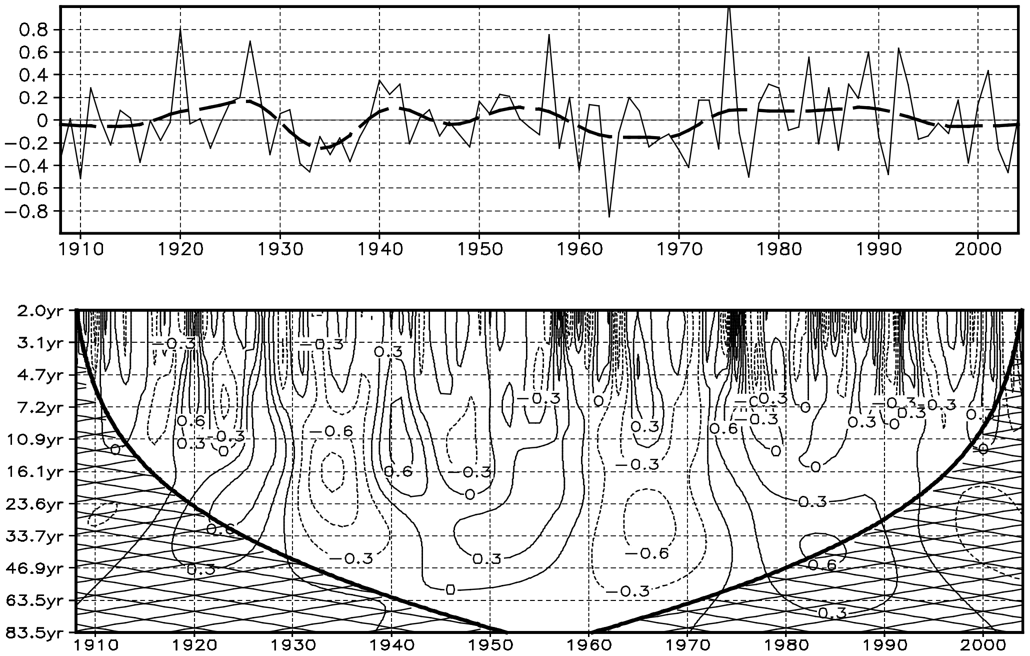

Fig.2 Normalized time series of the spring (February-May) rainfall (upper panel) and its wavelet transform (lower panel). Shadows indicate regions affected by the outside of the boundary.

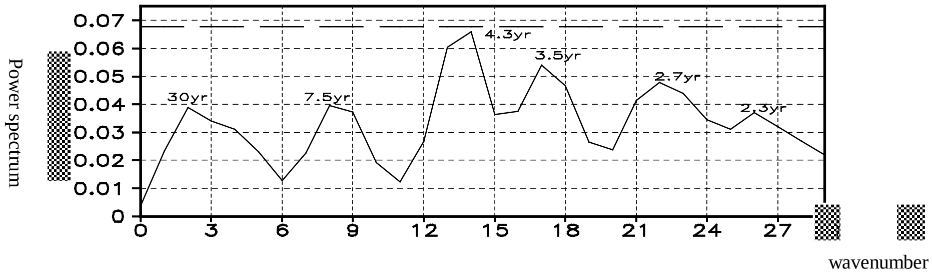

Fig.3 The spectrum of the normalized time series of the spring rainfall in Guangzhou. Periods corresponding to the peaks are indicated in the figure.

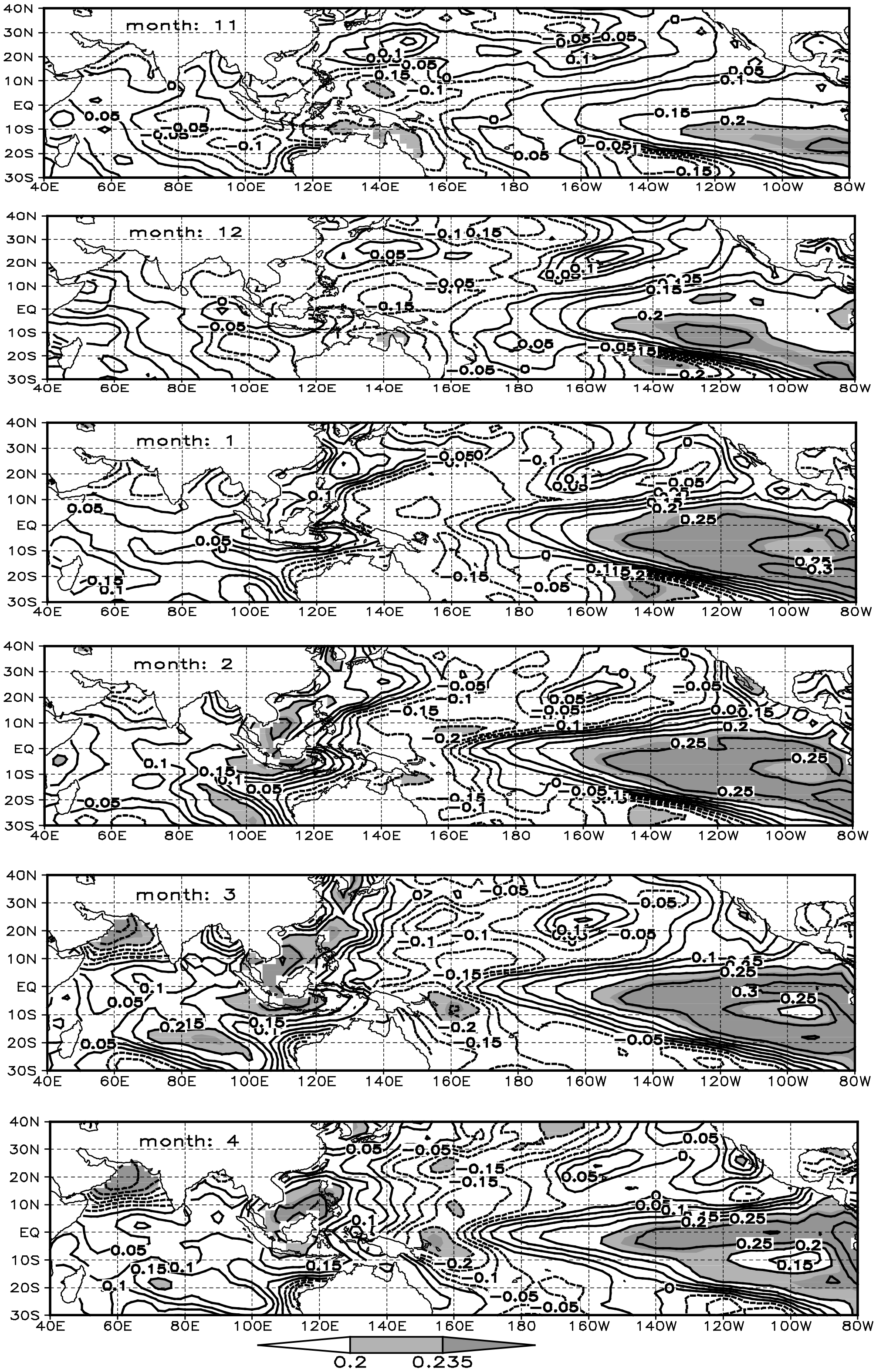

Fig.4 The distribution of the correlation coefficient between Guangzhou spring rainfall.

and 13 years at most; a wetter period lasts 6 years at least and 21 years at most. It is also found that wetter periods and dryer periods following them occur in pairs almost periodically. For instance, in 1919-1928, 1929-1939, 1939-1945, 1946-1949, 1950-1959 and 1960-1972. This pattern of pairs for the main periods can also be found in the wavelet coefficient chart. Now, Guangzhou is within a dryer period with an interdecadal scale of about 35 years. If history can repeat itself, Guangzhou will remain in this dryer period in the coming few years and have a high possibility of less rainfall than normal.

## 5 RELATIONSHIP BETWEEN GUANGZHOU SPRING PRECIPITATION AND EARLIER STAGE SST/ATMOSPHERIC CIRCULATION

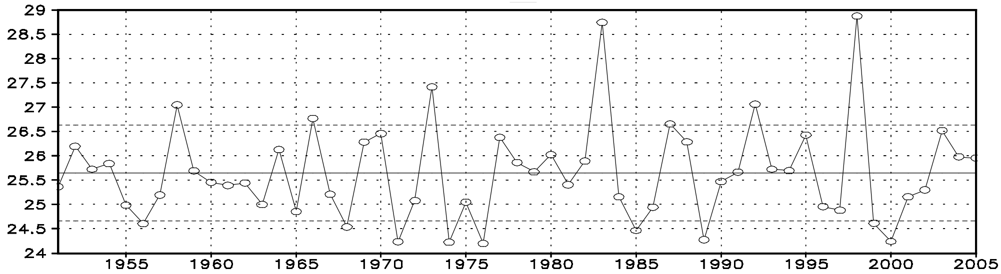

Fig.5 Niño3 SST of the previous winter (December-February) during 1951-2005. Dash lines are the standard deviation in unit of °C.

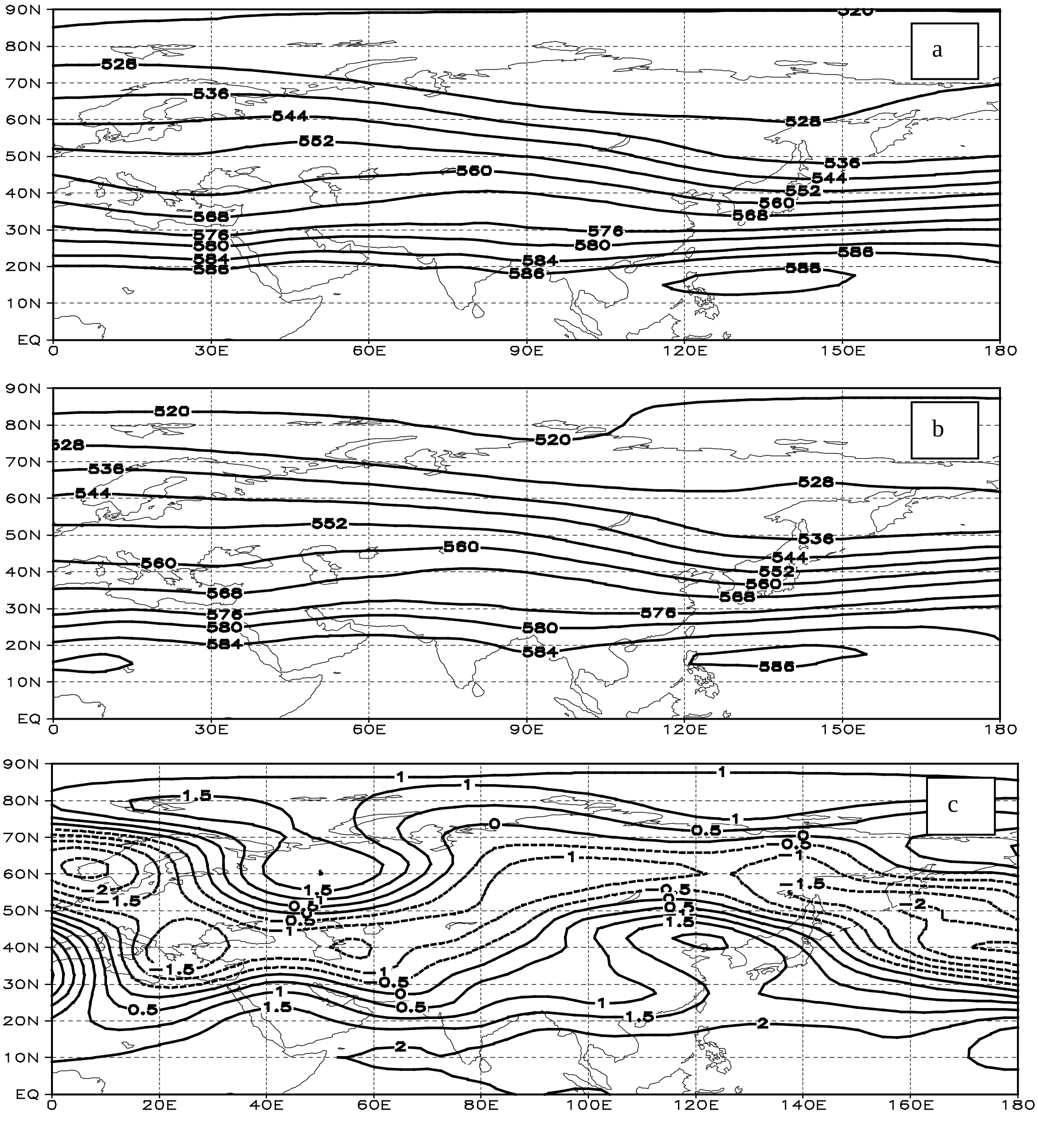

Fig.6 The mean 500 hPa geopotential of the March-May following winters with positive (a) and negative (b) Niño3 SST anomaly and their difference (c) (×10gpm).

The amount of the spring precipitation of Guangzhou is closely related to the spring drought of south China, so it has significant influence on the agricultural production. Hereafter, we will seek precursory signals from the sea surface temperature and analyze the reason for its formation in terms of atmospheric circulation.

### 5.1 The relationship between Guangzhou spring precipitation and SST

Fig.4 yields the distribution of the correlation coefficient between Guangzhou spring rainfall and earlier (November-April) SST. It demonstrates that a significant positive correlation region appears in the south of the tropical eastern Pacific from November of the previous years (not significant before, not shown). In December, the significant correlation region moves northwestward and approaches the equator with the most significant correlation center located at around the point (120°W, 10°S). In January, the whole Niño3 region reaches the significant level of 0.01, and a large area of the southeast tropical Pacific reaches a significant level of 0.05. In February, significant positive correlation in this large area of the southeast tropical Pacific remains unchanged, while another large region with significant positive correlation appears in the South China Sea and its adjacent area. In March, the significant positive correlation in east tropical Pacific Ocean and South China Sea gets intensified, and a significant negative correlation region appears in the Arabian Sea. In April, the significant positive correlation region in east tropical Pacific Ocean and the South China Sea contracts and the significant negative correlation in the Arabian Sea are intensified slightly.

We know from the analysis above that the Niño3 SST anomaly in east tropical Pacific is the strongest precursory signal of the spring precipitation of Guangzhou, a significant positive correlation between it and the spring precipitation of Guangzhou appears in November and remains stable until April. There is a significant positive correlation between the SST of February-April in the South China Sea and the spring precipitation of Guangzhou, and there is also a significant positive correlation between the SST from March to April in the Arabian Sea and spring precipitation of Guangzhou.

Since the SST anomaly can affect the anomaly of the atmospheric circulation of successive stage, and that the precipitation anomaly is the result of the atmospheric circulation anomaly, hereafter we will analyze how SST in strong precursory signal region, i.e. Niño3 region affects the successive atmospheric circulation and thus the spring precipitation of Guangzhou.

### 5.2 The influence of the SST anomaly on the atmospheric circulation

Fig.5 gives the variation of the mean SST of the previous winter (December -February) in Niño3 region during 1951-2005. The horizontal dash lines indicate the level of variance. It is obvious that the SST in the seven years of 1958, 1966, 1973, 1983, 1987, 1992 and 1998 has significant positive anomalies, while that of the nine years of 1956, 1968, 1971, 1974, 1976, 1985, 1989, 1999 and 2000 has significant negative anomaly. Comparing with the variation of the Guangzhou spring precipitation in Fig.2, we find that among the seven years with significant positive SST anomaly, six years have positive anomaly of spring precipitation in Guangzhou except for 1958, accounting for 6/7; among the nine years with significant negative SST anomaly, six years have negative anomaly of spring precipitation in Guangzhou except for 1985, 1989 and 2000, accounting for 6/9. These strongly suggest the SST anomaly in Niño3

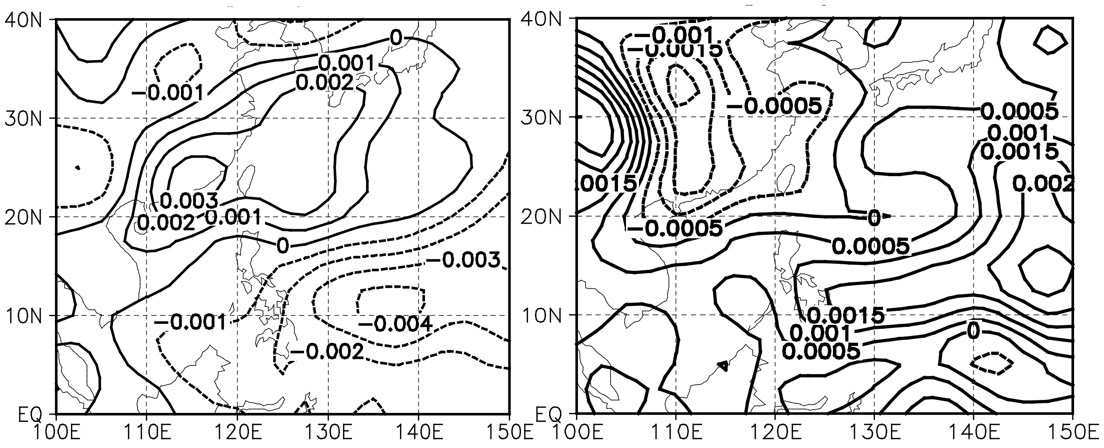

Fig.7 The composed differences of the mean 500-hPa vertical velocity (m/s) over the March-May following winters with positive (left) and negative (right) SST anomaly.

region be a very good precursory signal for spring precipitation in Guangzhou. In the following parts, we will perform a composite analysis for the successive atmospheric circulation of the positive/negative years of the Niño3 SST so as to identify the atmospheric circulation anomaly resulted from it.

Figs.6a-6c give the mean 500 hPa geopotential of the March-May following winters with positive/negative Niño3 SST anomaly and their difference in the Northern Hemisphere. It demonstrates that in the positive phase of the Niño3 SST anomaly, the subtropical high over the northwest Pacific is intensified with its position shifted westwards, the contour line of 588 extends westward to the central and eastern South China Sea, and Guangdong is situated in the southwesterly of the northwest edge of the subtropical high; In the negative phase of the Niño3 SST anomaly, the subtropical high over the northwest Pacific is weakened, the contour line of 586 is to the east of the South China Sea, and the subtropical high is far apart from Guangdong (Fig.6b). This is consistent with the previous study that states the response of the subtropical high to the tropical SST has a 1-2 season lag in time and a significant positive correlation. Chen[16] suggests that it take about 4 months for the subtropical high to adapt to the tropical SST. It indicates that the earlier stage SST anomaly, by affecting the change of the late stage subtropical high, produces a significant correlation between Guangzhou spring precipitation and the SST of November of the previous years. From the distribution of the 500-hPa geopotential difference in Fig.6c one may find that, in the high-latitude region around and to the north of the Ural mountains there is significant positive anomaly, and from the east Europe and the Atlantic, the Mediterranean Sea, the Black Sea, Lakes Balkhash and Baikal to the east of it through the Okhotsk Sea and the Pacific to the east there is significant negative anomaly. To the south of them is a large-scale region of positive anomaly. Especially, from north China to Japan is a region of significant positive anomaly. It can be found that by comparing the 500-hPa geopotential high in Fig.5a and Fig.5b, in the positive phase of the Niño3 SST anomaly the ridge in high latitudes around the Ural mountains is slightly enhanced, around Okhotsk Sea there is a significant trough, another significant trough is situated over the middle latitudes of the Mediterranean Sea and the Black Sea. The Southeast

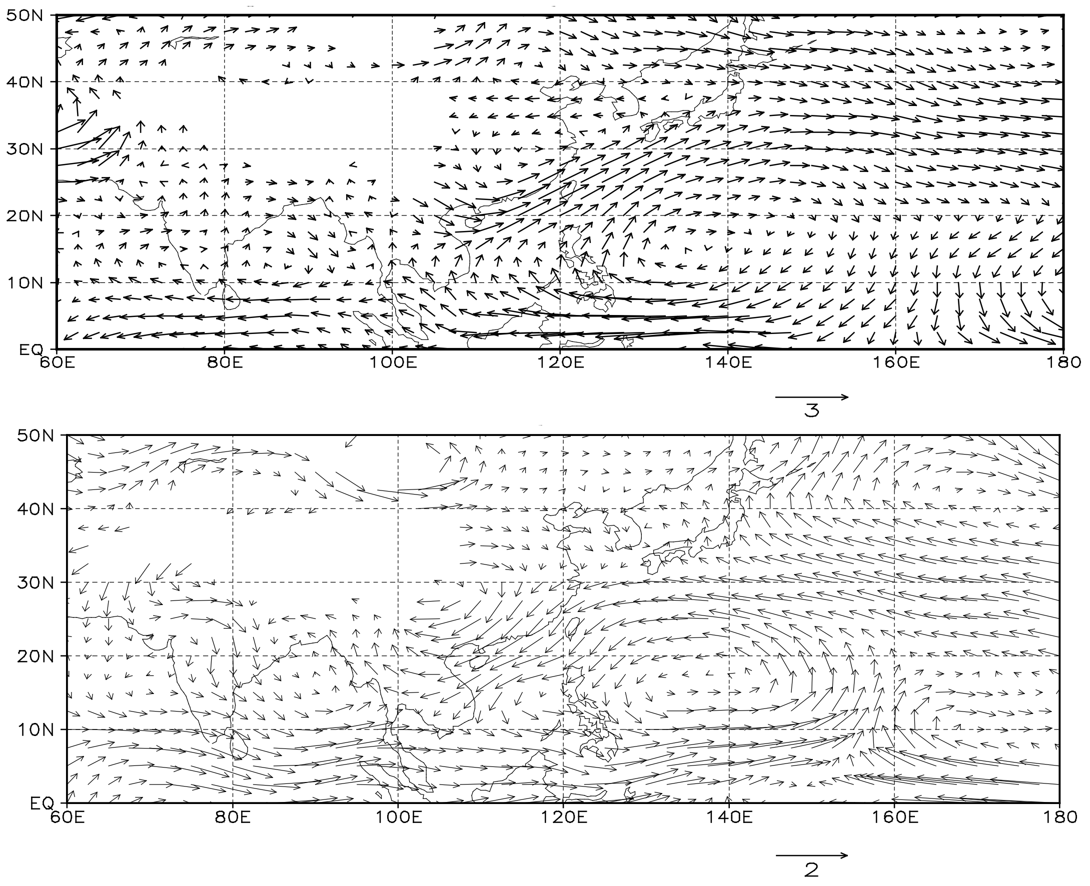

Fig.8 The composed differences of the mean 850 hPa wind field over the March-May following winters with positive (upper panel) and negative (lower panel) SST anomaly.

Asia trough is shifted eastward, the Bay of Bengal trough is shallow, and the subtropical high is strong. They indicate that the water vapor comes from the southerly of the northwest edge of the subtropical high. In the negative phase of the Niño3 SST anomaly the situation is contrary. Although the Bay of Bengal trough is intensified somewhat, the subtropical high remains weak, so cold flows cannot bring precipitation.

Fig.7 gives the composed differences of the mean 500-hPa vertical velocity over the March-May following winters with positive/negative SST anomaly. It shows that in the positive phase of the Niño3 SST anomaly, from the Pacific to the east of Philippines is a negative value region of the vertical velocity, while northern South China Sea, south China, north of the Yangtze River, east China, Japan and the Pacific to the south of it constitute a positive value region of the vertical velocity. Particularly, the Pearl River estuary, east Guangdong and its coastland are in the ascending anomaly center and in favor of the formation of precipitation. The situation corresponding to the negative phase of the Niño3 SST anomaly is contrary: the Pacific east of Philippines is a ascending region while south China and the most parts of east China belong to a descending region, which is unfavorable for the formation of precipitation. According to the distribution of the vertical velocity, the ascending and descending regions are of large-scale, reflecting that the spring precipitation of south China is controlled by large-scale circulation system, making precipitation in the whole region well synchronized.

Fig.8 gives the composed differences of the mean 850-hPa wind field over the March-May following winters with positive/negative SST anomaly. It shows that in the positive phase of the Niño3 SST anomaly, the region east of Philippines is dominated by an anticyclone of anomaly, which reinforces the southwesterly over south China and provides more water vapor. South China and the basins of Yangtze River and Huaihe River are dominated by cyclonic circulation, and Guangdong is situated at the meeting point of the northwesterly and southwesterly where more precipitation is produced, which leads to a rainy spring of south China. In the negative phase of Niño3 SST anomaly, the region east of Philippines is dominated by an anomaly of cyclonic circulation. Northerly prevails in south China and the south of the Yangzi River, extending to the central and northern parts of the South China Sea and Indo-China Peninsula. This goes against the northward transportation of water vapor, especially the production of precipitation, so spring drought is caused in south China. Moreover, the centers of anticyclone and cyclone in Fig.8 coincide with those of negative and positive values of vertical velocity in Fig.7a and Fig.7b.

## 6 CONCLUSIONS

(1) The spring precipitation in Guangzhou has inter-annual and inter-decadal variability of primarily about 2 and 30 years, respectively. Now it is in a dryer phase of inter-decadal time scale.

(2) The Niño3 SST anomaly of the previous winter is the strongest precursory signal of the anomaly of the spring precipitation in Guangzhou. The significant correlation between them appears in November of the previous year and is maintained stably until the April.

(3) The impact of Niño3 SST anomaly of the previous winter on the spring precipitation in Guangzhou is implemented by affecting north Pacific subtropical high and the low-level wind east of Philippines in spring. In the positive phase of the Niño3 SST anomaly, the subtropical high is strong and shifted westward. South China is in the ascending region of the edge of the subtropical high. The anti-cyclonic circulation east of Philippines reinforces the water vapor supply toward the south China. These make the spring precipitation in Guangzhou increase in amount. In the negative phase of Niño3 SST anomaly, the subtropical high is weak and shifted eastward and south China is far apart from the subtropical high and situated in the descending region of the vertical motion. The region east of Philippine is dominated by an anomaly of cyclonic circulation. Northerly prevails in south China and the south of the Yangtze River, going against the northward transportation of water vapor. They lead to a decrease to the precipitation of Guangzhou in spring and thus cause spring drought.

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