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VARIATION OF PRECIPITATION DURING WINTER AS A CAUSE OF SUSTAINED DROUGHT IN GUANGDONG DURING THE PAST 50 YEARS

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Abstract: The variation characteristics of precipitation during the winter (between October and the following March, to be referred to as just "the winter" hereafter) in Guangdong province during the past 50 years (from 1957 to 2006) and the relationship with Pacific SST are studied using the methods of Empirical Orthogonal Function (EOF) analysis, wavelet analysis, and correlation analysis. The results show that The Guangdong precipitation during the winter exhibits quasi-periodic significant oscillations of 40 years and 2 years; rainfall is less from the end of the 1950s to the start of the 1970s and from the end of the 1990s to the present than from the mid 1970s to the mid 1990s. The frequency of sustained drought is more than sustained flooding during the winter. The Guangdong precipitation during this time period is in significantly positive correlation to the equatorial central and eastern Pacific SST, but in a significantly negative correlation with the western and northern Pacific SST east of the Philippine Sea. 61.5% of the sustained drought occurred in the phase of negative anomalies of the Niño3.4 index and 38.5% in the phase of positive ones. A composite analysis of atmospheric circulation is performed for the positive and negative phases of the Niño3.4 region associated with the sustained drought. The results showed that a weak polar vortex, a strong trough in Europe and a ridge near Balkhash Lake, active cold air and consistent northerly wind anomalies controlling Guangdong at low levels, an inactive westerly low disturbance in the low-mid latitude of the Asian continent, and a weak southern branch westerly trough, are all mutual causes for the sustained drought.

Key words: Guangdong precipitation; variation characteristics; winter; cause for sustained drought

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1 INTRODUCTION

On the one hand, precipitation is abundant in Guangdong Province as it adjoins the South China Sea, on the other hand, the yearly precipitation is notably variable and concentrates from April to September. This is primarily influenced by the winter monsoons from October to the following March. The precipitation is less than other time of year and has great variability [1] and often results in different degrees of drought, which continues from autumn all through spring in the worst case. Serious effects of the drought in Guangdong were experienced from 2003 to the beginning of 2005, with most of the province exposed to sustained drought successively from autumn to winter and then spring to the point of extreme dryness; the reservoirs lacked water, which had a negative impact on local production. The Xijiang, Dongjiang and Hanjiang Rivers and other freight waterways appeared to be at their lowest water level; there was salt water intrusion (salty tides) in coastal areas, and the water supply situation was grim in Zhongshan, Zhuhai and other coastal cities. All of these examples had an adverse effect on the development of the national economy of Guangdong Province.

Since drought is one of the most important climate-related disasters in our country and also a worldwide concern that the people pay attention to, recent years have witnessed a considerable amount of research conducted regarding drought variation and

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trends, causes, preceding signals and predictions. Wang et al.[2] studied climatological changes in drought over the north of China during 1950－2000. Ma [3] worked on the interdecadal dry/wet trends and shifts in the north of China and their relationship to the Pacific Decadal Oscillation (PDO). Yan et al.[4] investigated into the cause of severe drought events over Yunnan in spring 2005. Wei et al.[5] examined the climatological background and preceding strong signals of anomalous drought over the north of China. Zhang et al.[6] predicted aridification tendency in that part of the country. A great deal of achievement in the study of change and prediction of droughts and floods in Guangdong has been made in recent years [7-11]. These achievements have concentrated mainly on the variation, causes, and prediction of the annually first and second rainy seasons, and yet have not involved the winter drought, especially the sustained drought from autumn to spring.

Guangdong is mainly affected by winter monsoons in the winter, with which the variation of precipitation in winter is closely related. Over the past 10 years, the relationship between the East Asian winter monsoons and precipitation has been studied and with results mainly on the impact of El Niño/Southern Oscillation (ENSO) events. Guo et al. [12] studied the relationships between the winter monsoon activity over East Asia and the El Niño events, and discovered that in the winters of an El Niño (La Niña) year, the path of cold waves over the East Asian continent migrates to the east (west) in comparison to the normal situation and the precipitation increases (decreases) in southern China. Tao et al.[13] compared the response of the Asian winter and summer monsoons to ENSO events, and found that the winter in El Niño (La Niña) years in East Asia is unfavorable (favorable) for the southward outbreaks of cold air leading to weak (strong) winter monsoons and that there is above normal (below normal) precipitation in the south of China, including the Tibetan Plateau. He et al.[14] also studied the cause of the anomalous precipitation in southern China during the winters of 1997/1998 and 1998/1999, which corresponded to two typical El Niño and La Niña episodes, respectively. However, from 2003 to the beginning of 2005, Guangdong suffered a serious drought from autumn to spring. According to the monitoring results from the United States Center of Climate Prediction (CPC[15]), the sea surface temperature (SST) of the Niño3.4 region is positively anomalous during the winters in 2003 and 2004; this also reflects the complexity of ENSO events impacting precipitation variability in Guangdong. It is therefore necessary to restudy the relationship between precipitation and ENSO events during this period and look for the causes of sustained drought. The paper first studies the interannual and decadal variability of precipitation in winter and then establishes a relationship with the SST field in the Pacific during the same period. By choosing the years with sustained, anomalous drought during this period, the method of synthetic analysis is used to analyze the atmospheric circulation characteristics corresponding to positively and negatively anomalous SST in the Niño3.4 region and to identify the causes of the sustained winter drought.

2 DATA

The data are as follows: (1) Monthly precipitation data of 19 representative stations from October 1957 to March 2007 (Climate Center of Guangdong Province); (2) The 2.5° × 2.5° monthly mean reanalysis data of 500-hPa geopotential height from National Centers for Environmental Protection (NCEP) / National Center for Atmospheric Research (NCAR); (3) Sea surface temperature data of Extended Reconstructed SST (ERSST)[16, 17] with intervals of 2° ×2°(ftp://ftp.ncdc.noaa.gov/pub//data/ersst-v2).

3 VARIATION CHARACTERISTICS OF GUANGDONG PRECIPITATION DURING WINTER

The method of EOF analysis is used to analyze the anomalous precipitation fields of 19 stations in Guangdong during the winter from 1957 to 2006, with the first principal component of variance contributing up to 71.0%. It can be seen in Fig. 1 that the precipitation shows three distinctive stages of change during this study period and exhibits very clear characteristics of interdecadal variation. This is presented in more detail in Point 1 of the summary.

Figure 2 shows that the Guangdong precipitation exhibits quasi-periodic significant oscillations of quasi-2－3 years, 6－8 years and 40 years. The periods of quasi-2 years and quasi-40 years can pass the test of 0.05 significance level in the power spectra chart; the quasi-2 year period is consistent with the winter monsoon[18].

4 THE RELATIONSHIP BETWEEN GUANGDONG PRECIPITATION AND PACIFIC SST DURING WINTER

Figure 3 shows two wide ranges that pass the test of 0.05 significance level; one significant positive correlation center is in the equatorial eastern Pacific (5°S－5°N, 170－80°W), the other significant negative correlation center is in the western North

Pacific (0° – 20°N, 135°E – 180°) that locates east of the Philippine Sea. The latter is probably caused by positive (negative) anomalous SST in the equatorial eastern Pacific that caused the development of anti-cyclone (cyclone) that had a positive feedback to SST and so resulted in negative (positive) SST anomalies in the area east of the Philippine Sea[19-20].

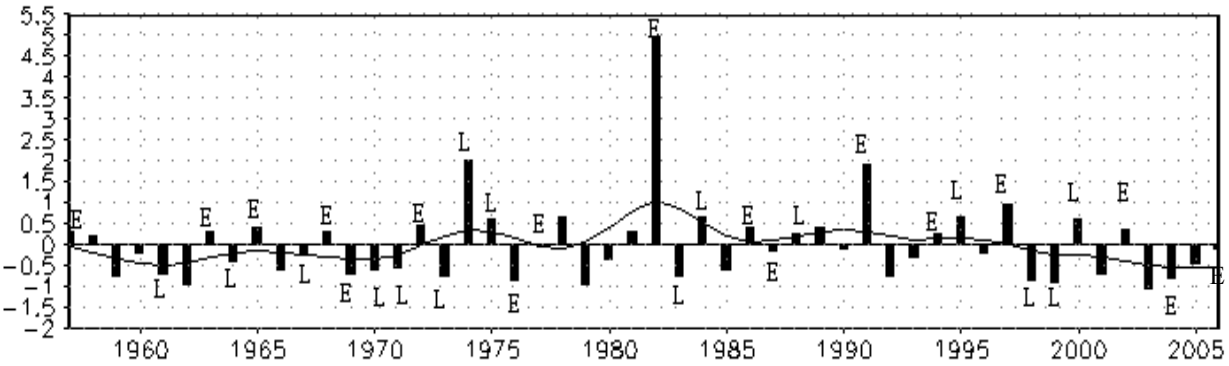

Fig.1 Standardized principal component PC1(bar) of EOF1 for the Guangdong precipitation during winter and 9-point Gaussian running mean (solid line) . E and L represent El Niño and La Niña years, respectively; determined by CPC[15].

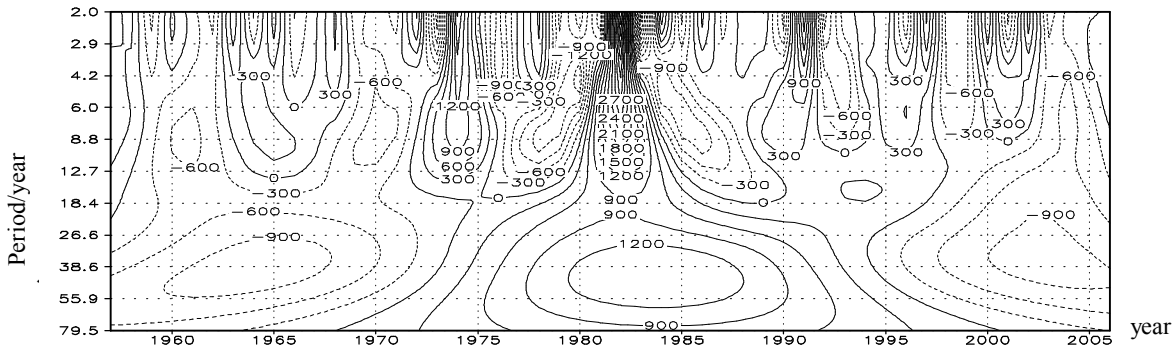

Fig.2 Wavelet analysis for standardized principal component PC1 of EOF1 for the Guangdong precipitation during winter.

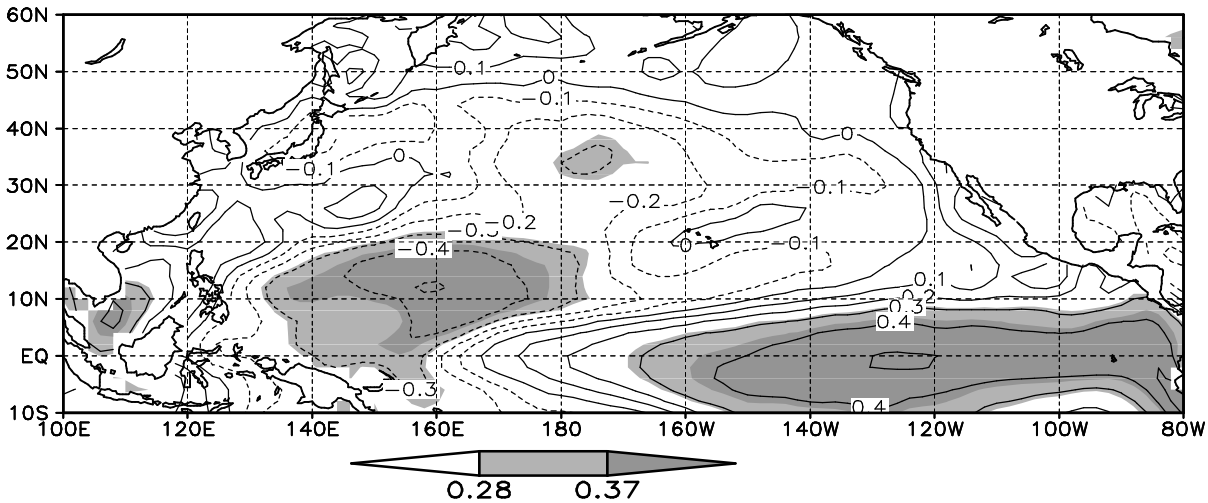

Fig.3 Correlation coefficients between the principal component PC1 of the precipitation during winter in Guangdong and SST field in the same period from 1957 to 2006. (The shadows indicate the passing of the 0.05 level of significance.)

Table 1 indicates that eight out of the 13 sustained drought years (accounting for 61.5%) are with negatively anomalous SST in the Niño3.4 region (only four years are in the La Niña episodes), and five years (accounting for 38.5%) are with positive anomalies (only two years are in El Niño episodes).

5 ATMOSPHERIC CIRCULATION CHARACTERISTICS IN SUSTAINED

DROUGHT YEARS IN GUANGDONG DURING WINTER

It can be seen from Fig. 4 that with positively anomalous SST in the Niño3.4 region, the polar regions, Russia and most of the Asian continent and the Eastern Hemisphere south of 20°N are dominated by significant positive anomalies; areas east of Japan and the Northwest Pacific (130°E – 170°E) are also controlled by significant positive anomalies. Most parts of Europe (40°N – 70°N，0° – 40°E) and the Sea of Okhotsk and the region east of it are of obvious negative anomaly. When the SST of the Niño3.4 region is negatively anomalous, the polar region, the Sea of Okhotsk, areas west of the Asian continent, Balkhash Lake, Baikal Lake, and most of the southern Asian continent are controlled by a significant positive anomaly, while the remaining regions are controlled by a negative anomaly. See more in Point 3 of the summary.

Table 1 Guangdong sustained drought years and the corresponding SST anomalies of Niño3.4 region (°C).

	1959	1962	1966	1969	1973	1979	1985	1992	1998	1999	2001	2003	2004
SST	−0.3	−0.5(L)	−0.4	0.6(E)	−1.7(L)	0.3	−0.3	0.1	−1.4(L)	−1.5(L)	−0.1	0.2	0.7(E)

Notes: E and L stand for the El Niño and La Niña years, respectively, which are determined following CPC[15].

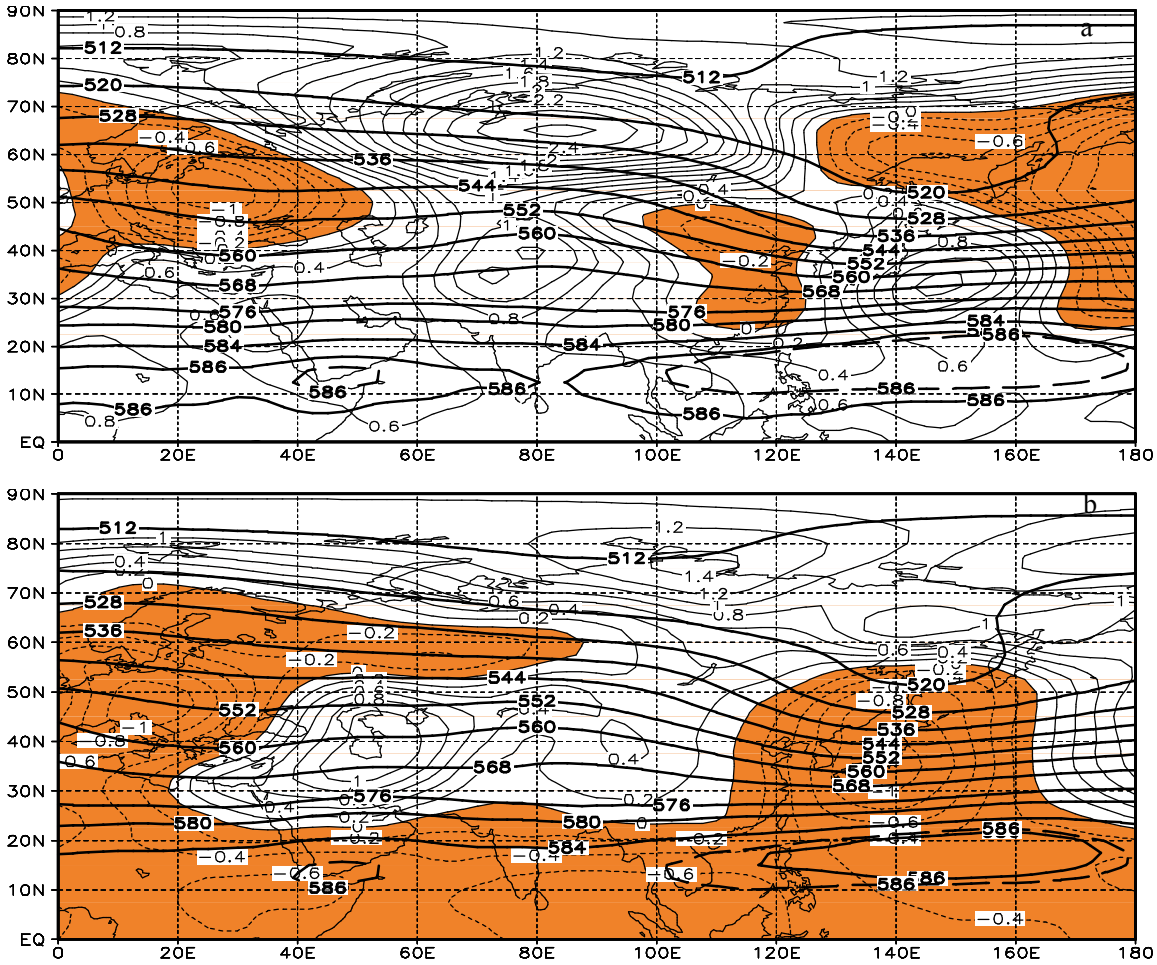

Fig.4 Composite 500 hPa geopotential heights and their anomalies corresponding to sustained drought years in Guangdong when the SST of Niño3.4 region is positive (a) and negative (b) anomalies. (Shaded areas: negative anomalies, Unit: 10 gpm)

6 SUMMARIES

(1) The Guangdong precipitation during the winter exhibits quasi-periodic significant oscillations of 40 years and 2 years; rainfall is less from the end of the 1950s to the start of the 1970s and from the end of the 1990s to the present than from the mid-1970s to the mid-1990s. The precipitation during this period has a high (or low) frequency of interannual anomalies of precipitation in Guangdong when it is in the high (or low) phase of decadal changes. The frequency of sustained drought is more than sustained flooding during the winter.

(2) The Guangdong precipitation during this period is in a significantly positive correlation with the equatorial central and eastern Pacific SST, but in a significantly negative correlation with the western and northern Pacific SST east of the Philippine Sea. When the SST in the equatorial eastern Pacific is of the El Niño (La Niña) pattern, the precipitation is more (or less). 61.5% and 38.5% of the sustained drought occurred in the phase of negative and positive anomalies of the Niño3.4 region, respectively.

(3) Among the mutual causes for sustained drought of Guangdong during the winter are the weak polar vortex, the strong trough in Europe and the ridge near Balkhash Lake, and the active cold air and consistent northerly wind anomaly controlling Guangdong at low levels, the inactive westerly low disturbance in the low- and mid-latitude of the Asian continent, and the weak southern branch westerly trough. The strength of the trough in East Asia and the subtropical high are not the root causes inducing a continually less rainfall.

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