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AN ANALYSIS ON INTERDECADAL VARIATIONS OF TROPICAL CYCLONE PRECIPITATION IN GUANGDONG PROVINCE OF CHINA

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Abstract: The interdecadal variations of tropical cyclones (TCs) and their precipitation over Guangdong Province are investigated using the observational data of TCs and precipitation from 26 observational stations in the province from 1951 to 2005. The results show that the TCs precipitation shows an oscillation with a peak value of about 25 years, with both the numbers of the Guangdong-influencing TCs and TCs formed in the western North Pacific oscillating with a peak value of about 23 years. The correlations are highly positive between the interdecadal variation of TC precipitation over the province and these numbers. The interdecadal variation of TC precipitation in the province shows significant negative correlations with the interdecadal variation of annual mean SST in some parts of the western North Pacific and the interdecadal variation of annual mean 500 hPa geopotential heights in some parts of the middle and high latitudes over the North Pacific. In general, there are high mean SSTs on the equator from central to eastern Pacific, low mean SSTs in the middle and high latitudes over the North Pacific and a main strong East Asian trough over the North Pacific in the period of less TC precipitation as compared with the period of more TC precipitation over the province.

Key words: interdecadal features of precipitation; statistical analysis; tropical cyclones affecting Guangdong Province

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1 INTRODUCTION

Tropical cyclones (TCs) have important impacts on the summertime precipitation in the coastal area of southern China[1-3]. As shown in some studies[4-6], the interdecadal variations of the TCs making landfall in China are associated with those of the South Asia high, subtropical high in western North Pacific and summer monsoon in East Asia. These TCs are significantly correlated with the sea surface temperature in the equatorial eastern Pacific and a main trough in East Asia (Ye et al.[7]). The TCs affecting China from the 1950s to the 1970s show a mildly increasing trend while those from the early 1970s to 2004 tend to decrease significantly (Wang et al.[8]).

Located next to the western North Pacific and South China Sea, Guangdong is the province that witnesses the most TC landfall in China, averaging at three to four annually and taking up about 40% of the national total. The landfall TCs are mainly distributed in June to October with the peak in summer. Precipitation in summertime takes up 70% to 80% of the yearly total for the province while precipitation brought about by TCs takes up 30% to 40% of the yearly total. It is then clear that TC precipitation is an important part of the summer precipitation for Guangdong. As shown in Lin et al.[9], precipitation from TCs making landfall in the south of China is mainly distributed, in a quasi-symmetric manner, on the right and left sides, in the right portion of these sides and in the front and rear portion, of the TC track. Close relationships are found to exist between the number of landfall TCs in the south of China and the ENSO episode (Yang et al.[10]). By examining the TCs and the precipitation data of Guangdong, He et al.[11] found that the total number of TC landfalls is similar in the tendency of variation to the accumulative rainfall of July through September in the province. Some other studies[12, 13] also suggested significant interannual variations of landfall TCs and precipitation they bring to Guangdong. In this study, the 1951-2005 observations of TCs and precipitation from stations across the province are used to study the

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interdecadal variations of the TC precipitation and their causes.

2 DATA AND METHODS

The TC data used in this study are from the *Typhoon Yearbook* for 1951−1988 and *Tropical Cyclone Yearbook* for 1989−2005. Daily precipitation data are from the records from 730 observation stations across China, which are compiled by China Meteorological Administration. The global 2.5°×2.5° reanalysis from National Centers for Environmental Protection / National Center for Atmospheric Research (NCEP/NCAR, U.S.A.) are used as monthly atmospheric data. The 2.0°×2.0° Extended Reconstructed Sea Surface Temperature (ERSST) by National Oceanographic and Atmospheric Administration (NOAA, U.S.A.) serve as monthly mean sea surface temperatures. ENSO indexes and Pacific Decadal Oscillation (PDO) index are respectively from NOAA and Washington University.

In this work, a precipitation index, the Lanczos filter[14], wavelet analysis and the Pearson correlation are the main methods for analysis.

3 TEMPORAL VARIATIONS OF TCS FOR GUANGDONG

In this study, the TC centers affecting Guangdong are located over the same area as those in Yuan and Zheng[13]. Figure 1 shows how they are distributed at 6-hour intervals over the period 1951–2005. Apart from it, only tropical storms or stronger TCs (with maximum wind speed V_{max} at 17.2 m/s) are included in the study. Figure 2 shows the variation of the annual number of TCs affecting the province from 1951 to 2005. There are one to six TCs that affect Guangdong on a yearly basis, with significant interannual variations and some degree of interdecadal changes.

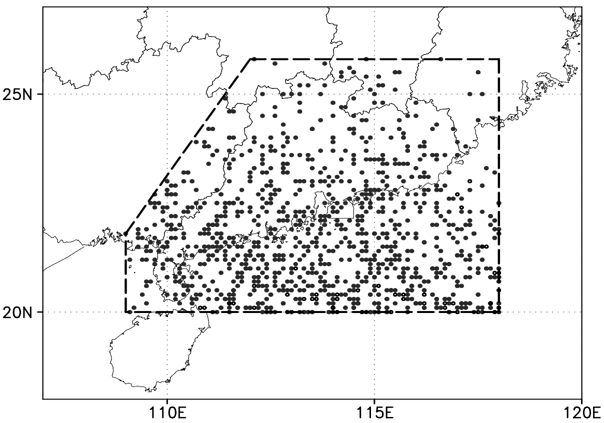


Figure 1. Distribution of the centers of the TCs observed every six hours to affect Guangdong from 1951 to 2005.

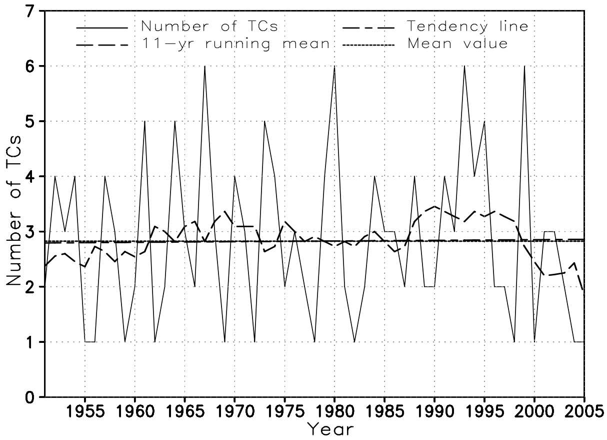
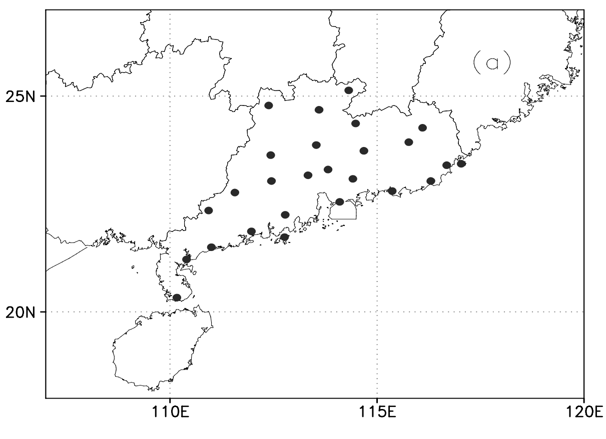


Figure 2. Variation of the number of TCs affecting Guangdong from 1951 to 2005 (solid curve). Long dashed line: 11-year running mean; short dashed line: multi-year mean; long and short dashed line: tendency.

4 ANALYSIS OF INTERDECADAL VARIATION OF GUANGDONG-AFFECTING TCS AND THEIR PRECIPITATION

4.1 *Temporal and spatial variation of the precipitation*

To study the interdecadal variation of the TC precipitation for the province, rainfall data from 26 of its stations are used. Figure 3a shows the spatial distribution of these stations, which are quite evenly distributed across the province. According to their distribution covering the period 1951−2005, the annual mean rainfall from the TCs is gradually decreasing from the southeast coast to the northwest with the maximum over the coastal area around the estuary of Pearl River (Figure 3b). Figure 4 gives the variation of the annual mean rainfall with time, which shows some degree of interdecadal variation.



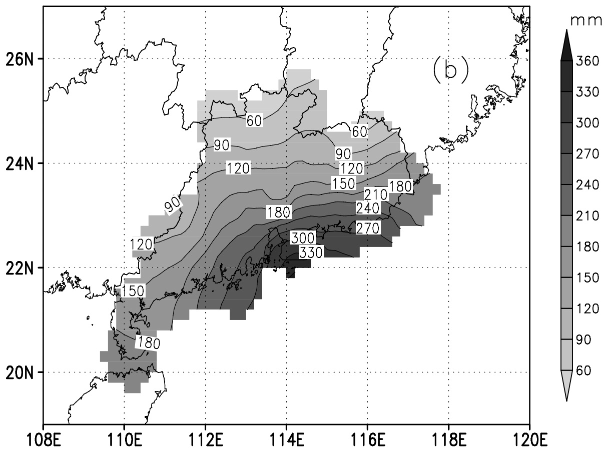


Figure 3. Spatial distributions of the 26 Guangdong stations (a) and of the annual mean TC precipitation (b).

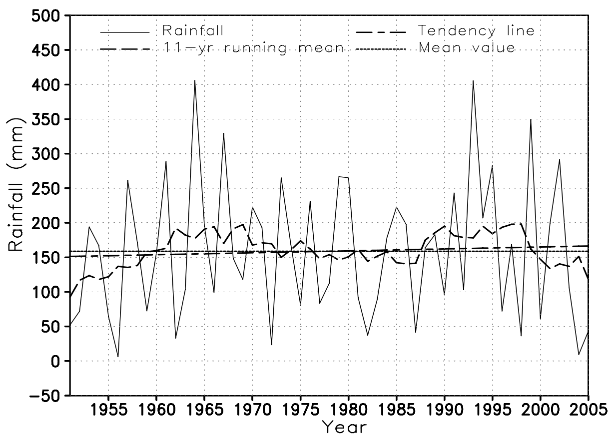


Figure 4. Temporal variation of the annual TC precipitation averaged for the 26 Guangdong stations from 1951 to 2005 (solid line). Other captions are the same as in Figure 2.

To make it convenient to study the variation of the TC precipitation, an index is introduced as in

$$\gamma = \left(\frac{1}{n}\sum_{i=1}^{n}\frac{R_i}{\overline{R}_i} + \frac{n^+}{n}\right)\times 100 - 150 \qquad (1)$$

where R_i is the annual rainfall, $\overline{R}_i$ the multi-year mean, n the number of stations within the region, and n^+ the number of the stations with the anomaly of the annual rainfall $\Delta R \geqslant 0$ among the region's n stations. The first term on the right hand side of the equation is for the mean rain rate, the second term for the range of anomalously more rainfall within the region, and the third term shows that the normal value is 150. A $\gamma>0$ index indicates anomalously more rainfall within the area while a $\gamma<0$ index points to anomalously less rainfall. The index is able to give good description of the anomalous variation of mean rainfall with time in a particular region. The variation of the index with time (figure omitted) is highly consistent with that of the annual TC rainfall averaged over the 26 stations in Guangdong. What this index shows is basically the anomalies of annual mean rainfall for these stations.

4.2 *Wavelet analysis*

Figure 5 presents the Mexican hat wavelet analysis of the index for TC precipitation in Guangdong, which shows significant interannual and 20-30 year interdecadal variations. To further examine the interannual variations of the variables, the Lanczos filter is used in this work to remove some disturbances on scales less than 10 years while retaining and highlighting information on the interdecadal scale. For the variables used below, they are all been filtered. Treated first with the Lanczos filter and then the wavelet analysis, the index is found to oscillate periodically with a peak of about 25 years (Figure 6). By contrast, the interdecadal variation of the annual number of TCs for Guangdong oscillates periodically with a peak of about 23 years (Figure 7) and that of the number of TCs forming over the western North Pacific also oscillates at a peak of about 23 years (figure omitted).

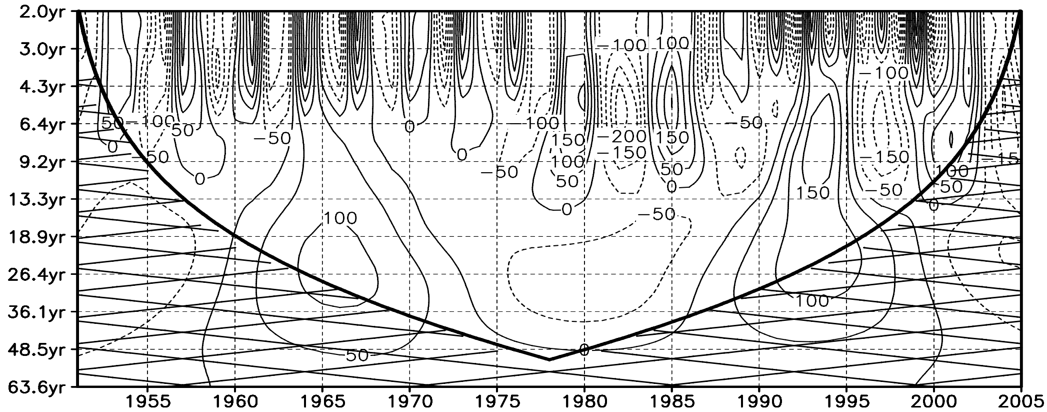


Figure 5. The Mexican hat wavelet analysis of TC precipitation index for Guangdong. The abscissa is for the year.

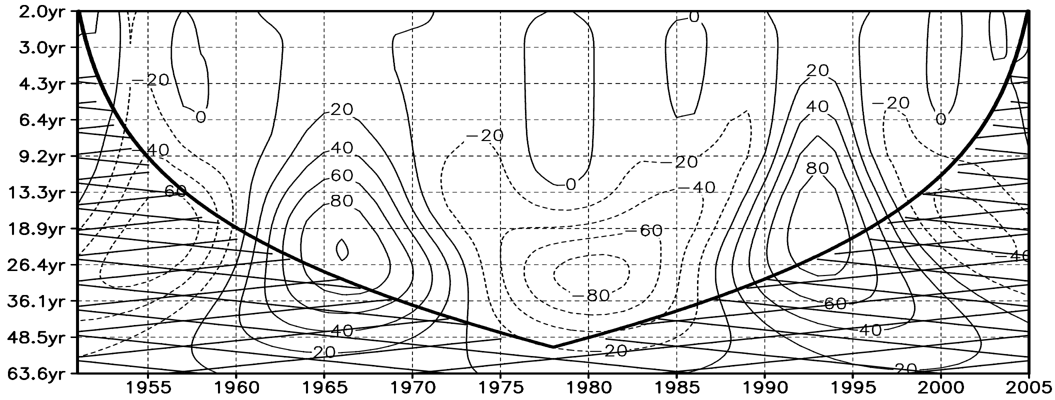


Figure 6. The Mexican hat wavelet analysis of the interdecadal variation of the TC precipitation index for Guangdong. The abscissa is for the year.

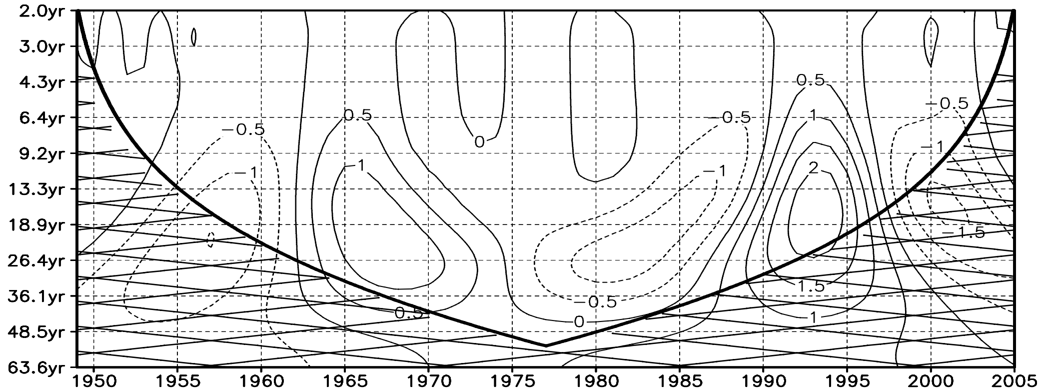


Figure 7. Same as Fig. 6 but for the number of TCs for Guangdong. The abscissa is for the year.

As shown in some studies[5, 15, 16], the TC activity of the Pacific is related to the ENSO event, PDO and East Asian summer monsoons. To further examine possible relationships between the interdecadal variation of this index with that of other indexes, this work conducts a wavelet analysis of the interdecadal variations of an index for the South China Sea summer monsoon[17] and an ENSO index. The former oscillates periodically with two peaks of around 13 and 40 years respectively while the latter with a peak of around 30 years (figure omitted).

4.3 *Correlation analysis*

Simultaneous correlation of the interdecadal variation is determined between the precipitation index and other variables (Table 1). The precipitation index is highly correlated with the number of TCs appearing over the western North Pacific (by more than a 99.9% confidence level) while being insignificantly correlated with the annually averaged intensity (maximum wind speed), ENSO index, PDO index and the index for the South China Sea summer monsoon.

The interdecadal variation of the precipitation index can be divided into two stages of evolution, one being the stage of relatively more rain and the other being the stage of relatively less rain (See Table 2). On the interdecadal scale, this index shows relatively small magnitudes in 1951–1959, 1976–1987, and 2000–2005, and relatively large magnitudes in 1960–1975 and 1988–1999.

Table 1. Simultaneous correlation of the interdecadal variation between the precipitation index for the TCs of Guangdong and other variables.

Variables	Pearson corr. coeff.	*p*-value
TC number in Guangdong	0.847	<0.001
TC number in western North Pacific	0.687	<0.001
TC intensity in Guangdong	0.261	0.064
ENSO index	0.232	0.109
PDO index	−0.033	0.823
South China Sea summer monsoon index	0.026	0.862

Table 2. Periods of interdecadal less and more TC precipitation in Guangdong.

Less rain/years	More rain/years
1951—1959	1960—1975
1976—1987	1988—1999
2000—2005	

There are not only significant differences in the sea surface temperature but also significant variations of large-scale atmospheric circulation between periods of more and less TCs in the western North Pacific (Yumoto et al.[18]). Differences in the mean SST between the periods of less and more TC rain in Guangdong during the TC season (from May to November) show that mean SST is usually higher in the equatorial central and eastern Pacific and southern Indian Ocean but lower in the middle latitudes of North Pacific in the period of less rain than in the period of more rain (Figure 8). Besides, the relatively low SST in the tropical western North Pacific makes it unlikely for TCs to form and develop, decreasing the Guangdong-affecting TCs and thus lessening the related rainfall.

Figure 9 gives the interdecadal differences of mean 500-hPa geopotential height between the two periods in the TC season. Compared to the period of more rainfall, the main East-Asian trough over the North Pacific and the upper-level trough over the mid-latitude South Pacific are usually stronger in the period of less rainfall. In association with relatively strong high ridges over North America, South Asia and Siberia, it results in relatively southward position of the subtropical high over the western North Pacific and increases the anti-cyclonic vorticity in the tropics. It is therefore unfavorable for TCs to form over the western North Pacific and TC precipitation to develop in Guangdong.

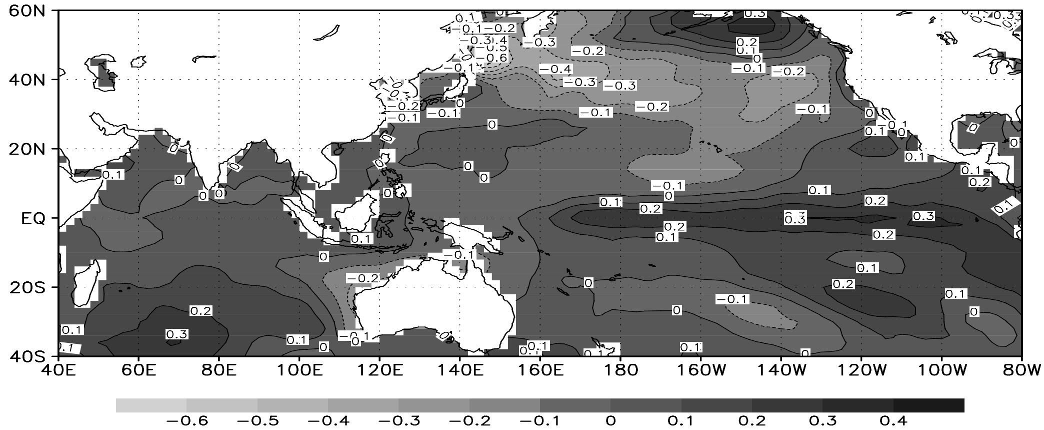


Figure 8. Differences of mean SST for the periods of less and more TC precipitation in Guangdong from May to November. Unit: °C.

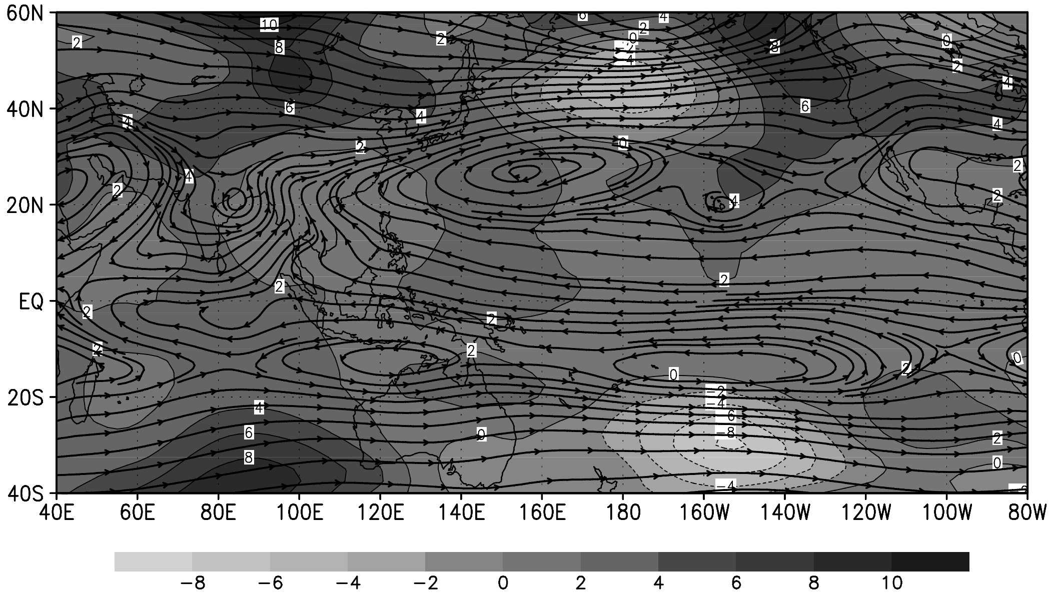


Figure 9. Differences of mean 500-hPa geopotential heights for the periods of less and more TC rain in Guangdong from May to November in the unit of geopotential meter. The streamlines are for the multi-year mean flow field.

Figure 10 presents the correlation of the interdecadal variations between the precipitation index and annual mean SST. The index is in significant negative correlation with the SST in part of the western North Pacific while being in significant positive correlation with it in mid- and higher-latitudes of the ocean. It is possible that relatively frequent TC activity over this part of North Pacific causes the upwelling of seawater, resulting in the reduction of mean SST there and making the interdecadal relationships between the SST to the province's TC precipitation complicated.

Figure 11 gives the correlation of interdecadal variations between the TC precipitation index for Guangdong and the annual mean 500-hPa geopotential height. In some parts of the mid- and higher-latitudes of the North Pacific, the former is in significant negative correlation with the latter, showing that the interdecadal variation of the TC precipitation is somewhat related to that of the atmospheric circulation in these parts of the North Pacific.

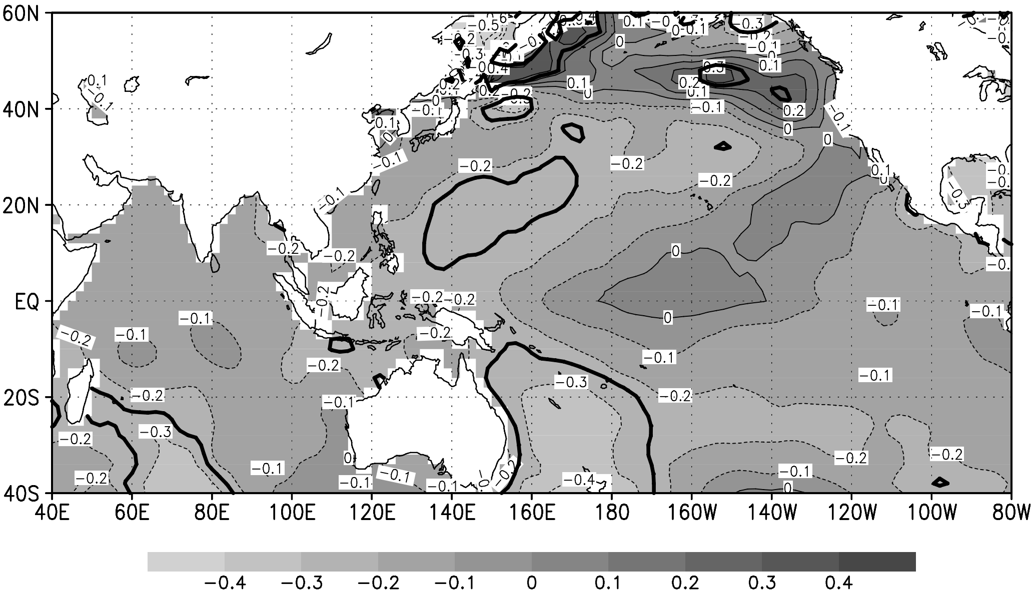


Figure 10. Correlations of the interdecadal variations of the precipitation index and annual mean SST. The solid, bold line indicates the area where the correlation reaches the 95% confidence level.

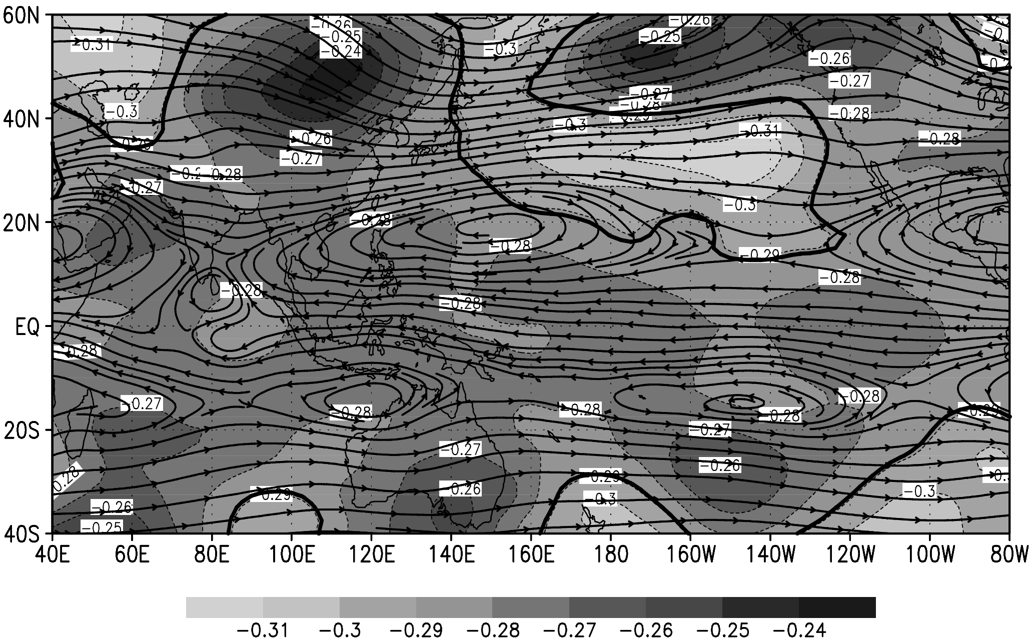


Figure 11. Correlation of interdecadal variations between the TC precipitation index for Guangdong and the annual mean 500 hPa geopotential height. The streamlines are for the multi-year mean flow field and the bold, solid lines are for the area where correlation is at the 95% confidence level.

5 CONCLUDING REMARKS

(1) The interdecadal variation of TC precipitation in Guangdong oscillates periodically at a peak of about 25 years and the number of TCs affecting the province and that of the TCs forming over the western North Pacific oscillate periodically at a peak of 23 years. The latter two are in significant positive correlation with the TC precipitation. The interdecadal variation of the TC precipitation is chiefly related to that of the number of TCs formed over the western North Pacific.

(2) Compared to the period of more rainfall, the mean SST is usually higher in the equatorial central and eastern Pacific but lower in the middle latitudes of North Pacific, the main East-Asian trough over the North Pacific and the upper-level trough over the mid-latitude South Pacific are usually stronger in the period of less rainfall, resulting in relatively southward position of the subtropical high over the western North Pacific and increased anti-cyclonic vorticity in the tropics. It is therefore unfavorable for TCs to form over the western North Pacific and TC precipitation to develop in Guangdong.

(3) The interdecadal variation of TC precipitation in Guangdong is in significant negative correlation with that of the mean SST in some parts of the western North Pacific but in significant positive correlation with the SST in the mid- and higher-latitudes of this part of the Pacific and in significant negative correlation with the interdecadal variation of the annual mean 500 hPa geopotential height field in some parts of the mid- and higher-latitudes of the North Pacific. It is therefore inferred that the interdecadal variation of TC precipitation in Guangdong may be caused mainly by that of the number of the TCs forming over the western North Pacific, which results from the changes in atmospheric circulation and oceans.

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