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# Interdecadal Change in Extreme Precipitation over South China and Its Mechanism

NING Liang (宁 亮) and QIAN Yongfu* (钱永甫)

*Department of Atmospheric Sciences, Nanjing University, Nanjing* 210093

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**ABSTRACT**

Based on the daily precipitation data taken from 17 stations over South China during the period of 1961–2003, a sudden change in summer extreme precipitation events over South China in the early 1990s along with the possible mechanism connected with the anomalies of the latent heat flux over the South China Sea and the sensible heat flux over the Indochina peninsula are examined. The results show that both the annual and summer extreme precipitation events have obvious interdecadal variations and have increased significantly since the early 1990s. Moreover, the latent heat flux over the South China Sea and the sensible heat flux over the Indochina peninsula also have obvious interdecadal variations consistent with that of the extreme precipitation, and influence different months' extreme precipitation, respectively. Their effects are achieved by the interdecadal increases of the strengthening convection over South China through the South China Sea Summer Monsoon.

**Key words**: extreme precipitation, interdecadal change, South China, sensible heat flux, latent heat flux

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## 1. Introduction

Climate extremes are important in recent climate studies (Karl et al., 1996; Karl and Knight, 1998; Haylock and Neville, 2000; Brunetti et al., 2001; Frei and Schär, 2001; Xiong et al., 2003; Rasul et al., 2005; Zhao et al., 2006). The IPCC Third Assessment Report (Cubasch et al., 2001) pointed out that because of the increases of greenhouse gases and aerosols, the frequencies and intensities of the extreme weather and climate events would likely change. Also, the quantity and frequency of the extreme precipitation would increase in many areas all over the world. The increasing trends of the extreme precipitation have been testified by many previous studies (Zolina et al., 2005; Schmidli and Frei, 2005; Alexander et al., 2006; Boo et al., 2006; Gao et al., 2006).

Frich et al. (2002) pointed out that in many regions of the world there is an increase in the frequency of heavy precipitation events accompanied by changes in the drought frequency. Wilby and Wigley (2002) found out that the percent contribution of extreme precipitation would increase significantly in the future, namely, 2080–2099, in two General Circulation Models (HadCM2 and CSM). Kharin and Zwiers (2005) found that extreme precipitation increases almost everywhere, and the changes in the extreme daily precipitation rate are substantially larger than the changes in the annual mean precipitation rate. Moreover, they also found that the probability of the extreme precipitation events in the year 2000 is increased by a factor about of 2 at the end of the twenty-first century in the climate change simulations. In the second phase of the coupled model intercomparison project (CMIP2), the simulated changes of 20 model experiments showed that with increasing $CO_2$, the frequency of the precipitation extremes would grow larger over longer time scales (Räisänen, 2005). Similar conclusions were also reached by Barnett et al. (2006) in the simulations of the changes of daily extreme precipitation events in response to doubled atmospheric $CO_2$.

China suffers from the impacts of flood disasters, several of which, in the late 1990s, brought serious loss to the Chinese economy and society. Therefore, there have been a growing number of studies focusing on the extreme precipitation in China. Through the di-

*Corresponding author: QIAN Yongfu, qianzh2@mail.nju.edu.cn

agnoses and numerical simulations, Gong and Wang (2000) found that under the greenhouse effect, the extreme precipitation would increase over eastern China, but the extreme dry events would not likely decrease because they do not change symmetrically with the extreme wet ones. Gao and Zhao (2002) investigated the changes of extreme events due to greenhouse effects ($2\times CO_2$) over East Asia through a regional climate model (RegCM2) and found that besides the increases of the daily maximum and daily minimum temperature, the number of rainy days and heavy rain days increases over some sub-regions of China. Weng et al. (2004) also pointed out that the annual and interannual trends of the 500 hPa geopotential height and 850 hPa horizontal winds over the Eurasian continent had great effects on the China summer extreme wet and dry events. Zhai et al. (2005) found that the extreme precipitation over western China, the Yangtze River Valley, southwest China and the southern coast exhibited increasing trends, but those over northern China and the Sichuan Basin decreased. This is consistent with the result of Wang and Zhou (2005). Based on gridded daily rainfall and station daily rainfall for China for the period of 1951–2004, it is found that the interannual and interdecadal variations in the frequency of persistent heavy rainfall events were characteristic of China (Tang et al., 2006).

South China is affected by the vapor transported by the South China Sea Monsoon and the Indian Monsoon as well as the sensible heat flux and latent heat flux over the Tibetan Plateau, the Indochina peninsula and the South China Sea. Due to this, South China is one of the regions that experiences severe flood disasters in China. However, most of the previous studies focused only on the mechanism of the total rainfall (Liu et al., 2004; Ma and Wang, 2006; Ning and Qian, 2006). In this study, we are going to examine the interdecadal change of the summer extreme precipitation and investigate the possible mechanism associated with changes of the latent heat flux and sensible heat flux.

## 2. Data and methods

The precipitation data adopted in our analysis are the observed daily precipitation data from 17 stations over South China during the period of 1961–2003, provided by the Chinese Meteorological Administration. The 17 stations are Xiamen, Meixian, Shantou, Shaoguan, Heyuan, Guangzhou, Yangjiang, Zhanjiang, Haikou, Guilin, Liuzhou, Wuzhou, Nanning, Beihai, Baise, Fuzhou and Yong'an (see Fig. 1). Since station relocation is the main reason for the data's temporal inhomogeneities (Zhai et al., 2005)

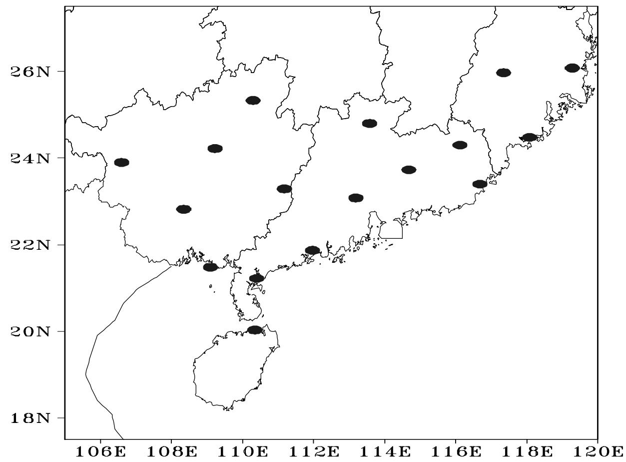


**Fig. 1.** Locations of the 17 stations over South China.

and these 17 stations did not change their locations after 1961, the precipitation data are expected to have few inhomogeneities. On the other hand, through our analysis, the extreme precipitation of these 17 stations has changed uniformly in the last decades and can be considered as a representative of South China as a whole. The outgoing longwave radiation (OLR) data during 1975–2003 and the latent heat flux and sensible heat flux during 1969–2003 from the National Center for Environment Prediction/National Center for Atmospheric Research (NCEP/NCAR) reanalysis monthly mean data are also adopted in our analysis. The OLR data are based on grids of $2.5^\circ \times 2.5^\circ$. The original NCEP/NCAR data are based on Gauss grids, and they are interpolated to normal grids of $1^\circ \times 1^\circ$. Notably, the OLR data from April 1978 to December 1978 are missing, so in the following analysis, all the OLR data of 1978 are removed.

The definition of extreme precipitation as those that exceed a certain threshold percentile of daily precipitation is a popular method in current climate extremes research (Frich et al., 2002; Bell et al., 2004; Zhai et al., 2005; Wang and Zhou, 2005). In order to define the extreme precipitation event, an extreme precipitation threshold is first determined according to the 95th percentile of the cumulative frequency of daily precipitation amount for all precipitation days during the period of 1961–2003. Then, the day with precipitation equal to or more than the threshold is taken as an extreme event. It is evident that each station has its own threshold, which mainly ranges from 35 mm to 65 mm (Table 1). The monthly, seasonal and annual extreme precipitation amounts can be obtained by the number of days with the extreme event multiplied by the amount in the corresponding days in the selected durations. Each station's average monthly extreme

**Table 1.** The thresholds and average monthly extreme precipitation amounts for each station in the period of 1961–2003 (mm).

| Stations | Threshold | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Xiamen | 41.7 | 1.1 | 11.6 | 19.1 | 40.3 | 33.4 | 80.1 | 65.4 | 99.7 | 61.1 | 21.5 | 9.0 | 3.3 |
| Meixian | 40.1 | 8.8 | 12.5 | 38.4 | 57.5 | 66.3 | 77.9 | 39.2 | 79.4 | 45.1 | 21.7 | 7.9 | 7.5 |
| Shantou | 53.1 | 0 | 6.7 | 18.0 | 50.1 | 69.7 | 126.8 | 89.9 | 119.0 | 64.8 | 26.4 | 8.7 | 2.9 |
| Shaoguan | 38.6 | 8.9 | 7.4 | 44.4 | 62.8 | 91.0 | 104.1 | 58.1 | 34.4 | 25.3 | 22.5 | 13.8 | 8.4 |
| Heyuan | 52.3 | 8.4 | 6.3 | 32.6 | 76.1 | 136.5 | 170.7 | 72.2 | 63.0 | 49.5 | 9.3 | 2.8 | 6.2 |
| Yangjiang | 65.2 | 3.2 | 1.9 | 14.7 | 89.9 | 202.6 | 202.7 | 146.4 | 141.4 | 96.5 | 30.2 | 13.8 | 3.8 |
| Zhanjiang | 55.0 | 1.7 | 2.8 | 10.7 | 54.3 | 88.1 | 126.5 | 88.6 | 120.0 | 130.4 | 56.4 | 9.0 | 3.2 |
| Haikou | 46.6 | 0 | 0 | 8.7 | 23.6 | 51.1 | 78.5 | 100.8 | 116.9 | 130.6 | 103.2 | 35.4 | 6.5 |
| Guilin | 45.9 | 0 | 6.4 | 20.9 | 80.9 | 165.0 | 193.3 | 91.6 | 42.8 | 22.7 | 19.1 | 10.7 | 2.6 |
| Nanning | 38.4 | 3.7 | 2.5 | 9.0 | 21.4 | 84.4 | 108.1 | 103.3 | 79.7 | 54.2 | 20.9 | 5.2 | 6.2 |
| Beihai | 57.1 | 1.4 | 0 | 5.2 | 18.5 | 56.9 | 133.4 | 229.5 | 189.8 | 70.3 | 20.7 | 10.9 | 0 |
| Baise | 38.0 | 0 | 0 | 5.1 | 13.3 | 68.3 | 92.6 | 91.1 | 71.3 | 25.6 | 15.2 | 6.5 | 2.5 |
| Fuzhou | 36.8 | 4.2 | 3.2 | 23.3 | 34.6 | 60.9 | 84.7 | 38.6 | 93.3 | 78.9 | 13.1 | 8.5 | 2.2 |
| Yong'an | 36.2 | 4.9 | 9.5 | 46.7 | 50.0 | 99.1 | 122.5 | 27.5 | 48.1 | 27.9 | 16.3 | 4.1 | 4.9 |
| Guangzhou | 46.9 | 9.7 | 7.3 | 12.1 | 58.3 | 117.1 | 102.1 | 79.9 | 75.0 | 89.6 | 24.2 | 6.7 | 0 |
| Liuzhou | 40.7 | 2.2 | 2.5 | 9.1 | 55.0 | 106.9 | 123.8 | 77.9 | 78.8 | 15.0 | 23.8 | 9.4 | 5.5 |
| Wuzhou | 37.7 | 11.8 | 7.8 | 12.6 | 83.5 | 96.7 | 92.8 | 63.2 | 67.5 | 31.1 | 20.0 | 6.9 | 3.3 |

precipitation is given in Table 1. It can be concluded that the amount of the monthly extreme precipitation in summer for each station is around 100 mm. And the total monthly number of the extreme precipitation events for each station is given in Table 2, which shows that the numbers have a similar annual distribution as the extreme precipitation amount. The area amount is computed by adding all amounts over the 17 stations. The sudden changes are found by use of the Mann-Kendall Test. The interdecadal changes of the latent heat flux and sensible heat flux are examined by the composite analysis.

## 3. The interdecadal changes of the extreme precipitation over South China

Figure 2 shows the time series of the annual and summer (June, July, August; JJA) extreme precipitation amounts, their variance-normalized anomalies and their Mann-Kendall tests' results. The summer extreme precipitation accounts for a large part of the annual one (about 40%–50%), especially in the wet years (about 60%), and both of them have similar increasing trends after the early 1990s (Figs. 2a and 2d). The normalized anomalies in Fig. 2b and Fig. 2e show that both the annual and summer extreme precipita-

**Table 2.** The total monthly number of the extreme precipitation events for each station in the period of 1961–2003.

| Stations | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Xiamen | 1 | 9 | 14 | 25 | 23 | 48 | 37 | 54 | 38 | 8 | 6 | 3 |
| Meixian | 7 | 9 | 28 | 44 | 47 | 56 | 27 | 49 | 32 | 14 | 6 | 6 |
| Shantou | 0 | 4 | 11 | 26 | 37 | 63 | 45 | 57 | 30 | 13 | 5 | 2 |
| Shaoguan | 7 | 7 | 31 | 50 | 63 | 68 | 41 | 26 | 19 | 17 | 10 | 6 |
| Heyuan | 5 | 4 | 20 | 44 | 69 | 84 | 39 | 36 | 26 | 5 | 2 | 4 |
| Yangjiang | 2 | 1 | 8 | 37 | 58 | 75 | 55 | 58 | 36 | 13 | 5 | 2 |
| Zhanjiang | 1 | 2 | 6 | 26 | 40 | 55 | 39 | 51 | 53 | 30 | 5 | 2 |
| Haikou | 0 | 0 | 6 | 15 | 32 | 42 | 53 | 57 | 68 | 47 | 16 | 4 |
| Guilin | 0 | 4 | 14 | 47 | 93 | 102 | 49 | 28 | 14 | 13 | 7 | 2 |
| Nanning | 3 | 2 | 7 | 17 | 62 | 73 | 63 | 56 | 37 | 16 | 4 | 5 |
| Beihai | 1 | 0 | 2 | 8 | 24 | 55 | 81 | 79 | 29 | 10 | 3 | 0 |
| Baise | 0 | 0 | 5 | 12 | 48 | 59 | 59 | 51 | 20 | 12 | 6 | 2 |
| Fuzhou | 4 | 3 | 21 | 30 | 47 | 61 | 30 | 59 | 48 | 10 | 7 | 2 |
| Yong'an | 5 | 9 | 39 | 44 | 76 | 91 | 22 | 38 | 21 | 12 | 4 | 5 |
| Guangzhou | 7 | 5 | 9 | 34 | 64 | 59 | 44 | 47 | 15 | 24.2 | 4 | 0 |
| Liuzhou | 2 | 2 | 6 | 38 | 71 | 81 | 49 | 50 | 9 | 18 | 8 | 4 |
| Wuzhou | 8 | 7 | 11 | 57 | 71 | 63 | 40 | 45 | 20 | 13 | 4 | 3 |

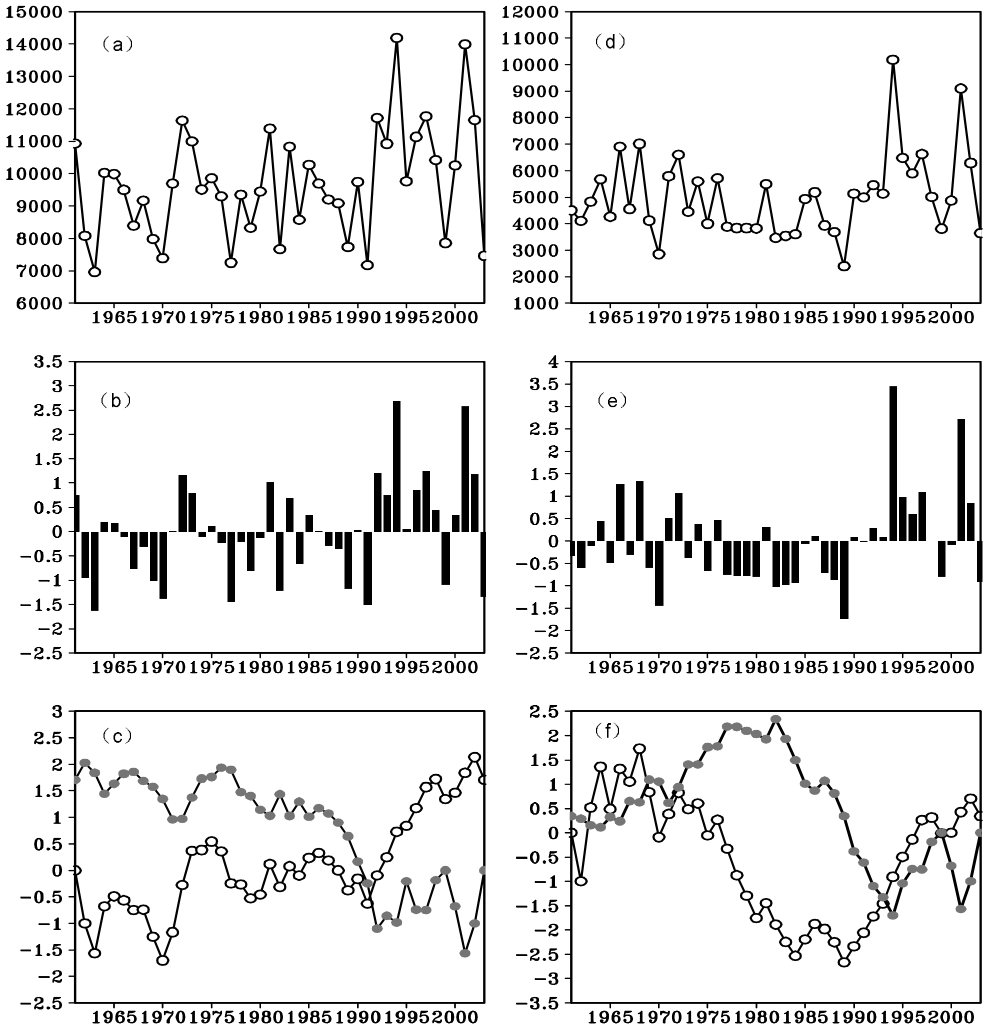


**Fig. 2.** Time series of the (a) annual and (d) summer extreme precipitation amount (mm); standard anomalies of the (b) annual and (e) summer extreme precipitation amount; Mann-Kendall tests' results for the (c) annual and (f) summer extreme precipitation amount. In (c) and (f), the lines with open (solid) circles represent the $U_F$ ($U_B$) curves.

tion time series have interdecadal changes in the early 1990s. For the annual extreme precipitation, the dry spell lasts from the early 1960s to the early 1990s, while that for the summer precipitation starts in the early 1970s and ends in the 1990s. These are also confirmed by the results of the Mann-Kendall tests (Figs. 2c and 2f).

The Mann-Kendall test is a method to detect a time series' trends and sudden changes (Hirsch et al., 1982; Wei, 1999). For any time series $x_i$, the rank series is produced by the following method:

$$S_k = \sum_{i=1}^{k} r_i \quad (k = 2, 3, \ldots, n)\,, \tag{1}$$

where, $r_i = 1$, when $x_i > x_j$ or $r_i = 0$. $i$ and $j$ ($j = 1, 2, \ldots, i$) are the sequence numbers of time serias $x_i$.

Then, the statistical variable $U_F$ is defined:

$$U_{F_k} = \frac{S_k - E(S_k)}{\sqrt{V_{ar}(S_k)}}\,, \tag{2}$$

where $U_{F_1} = 0$. And $E(S_k)$ and $\sqrt{V_{ar}(S_k)}$ are the average value and standard variance of the time series $s_i$ given from Eq. (1). Similarly, the statistical variable $U_B$ for the reversed time series $x$ is also calculated by the method above.

In the Mann-Kendall test, the positive $U_{F_k}$ indicates that the time series has an increasing trend at that time, and the negative one indicates the opposite trend. If the absolute value of $U_{F_k}$ exceeds the certain significance level, the increasing or decreasing trend is significant. Moreover, if the $U_F$ and $U_B$ curves inter-

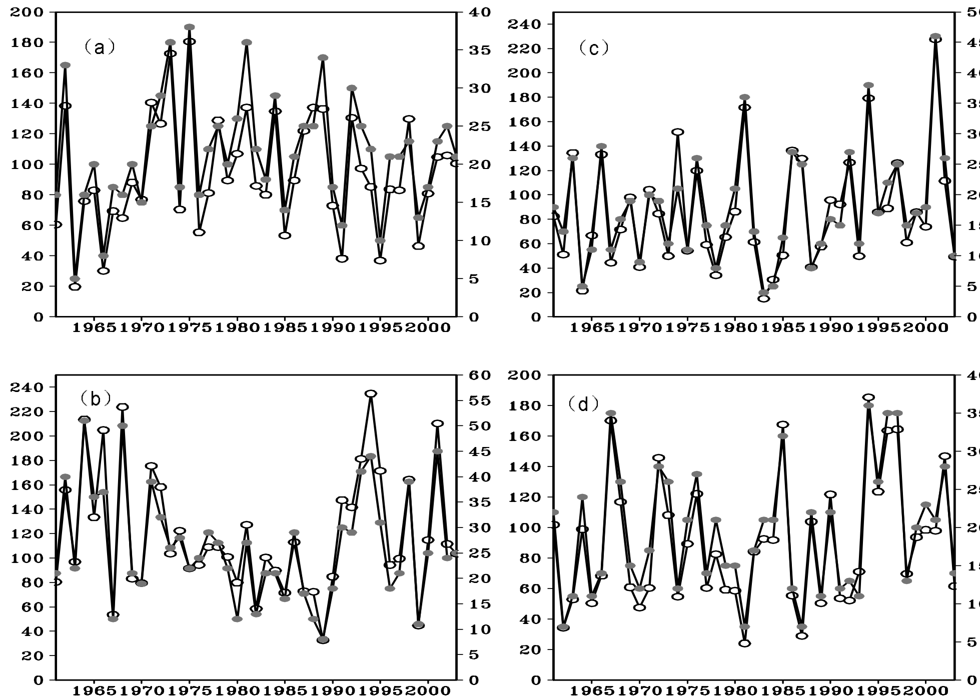


**Fig. 3.** Time series of the station-averaged extreme precipitation amounts (left $y$-axis; units: mm) and frequencies (right $y$-axis; units: d) from (a) May, (b) June, (c) July and (d) August. The lines with open (solid) circles represent the extreme precipitation amounts (frequencies).

sect between the significance values, the time series has a sudden change at that time. So, from the intersections of the $U_F$ and $U_B$ curves, we can find that the exact transition years for the annual and summer extreme precipitation are 1991 and 1993, respectively. The results all exceed the 95% ($U_{0.05}$=1.96, 95% significant level), even 99% ($U_{0.01}$=2.56, 99% significant level) significance level. Moreover, the $U_F$ and $U_B$ curves also overlap in the year 1999 for the summer extreme precipitation (Fig. 2f), but for the most part, they do not really overlap. The years 2001 and 2002 are wet years. So we still classify the years after 1999 as being in the wet spell.

Many previous studies have proved that South China has a flood season lasting from May to August (Ma and Wang, 2006) according to the temporal variation of the multi-yearly averaged annual cycle of precipitation. This is also true for the extreme precipitation which, in our analysis, also has a similar seasonal variety (figures not shown). The averaged extreme precipitation amounts and frequencies over all stations in May, June, July and August are presented in Fig. 3. The extreme precipitation amounts change coherently with the frequencies, indicating that the changes are caused by the changes of frequency rather than intensity of the precipitation. During the four months, only the extreme precipitation in May exhibits a slight decreasing trend since the mid-1970s. For the other three months, the extreme precipitation increases since the mid-1970s with obvious changes in the early 1990s, especially in June and August. Therefore, it could be concluded that the interdecadal change of the annual extreme precipitation is mainly the result of the summer extreme events, especially in June and August.

As shown in Fig. 4, the outgoing longwave radiation (OLR) has obvious interdecadal decreases after 1993, which are obtained from the difference between the wet spell (1994–2003) and dry spell (1975–1993), over South China and the South China Sea in the four months from May to August, especially in June and July. The OLR reflects the intensity of the tropical convection, and the less the OLR is, the more vigorous the convection is. So, the interdecadal decreases indicate that the numbers of convection have increased in the four months since the early 1990s over South China. In May (Fig. 4a), the area with the interdecadal decrease over 90% significance level is located in the South China Sea rather than South China. However, the areas are located over South China in June, July and August (Figs. 4b–d). These indicate that the interdecadal decreases of the OLR over South China are significant and that the interdecadal increase of the extreme precipitation results from the increase of the convection after 1993.

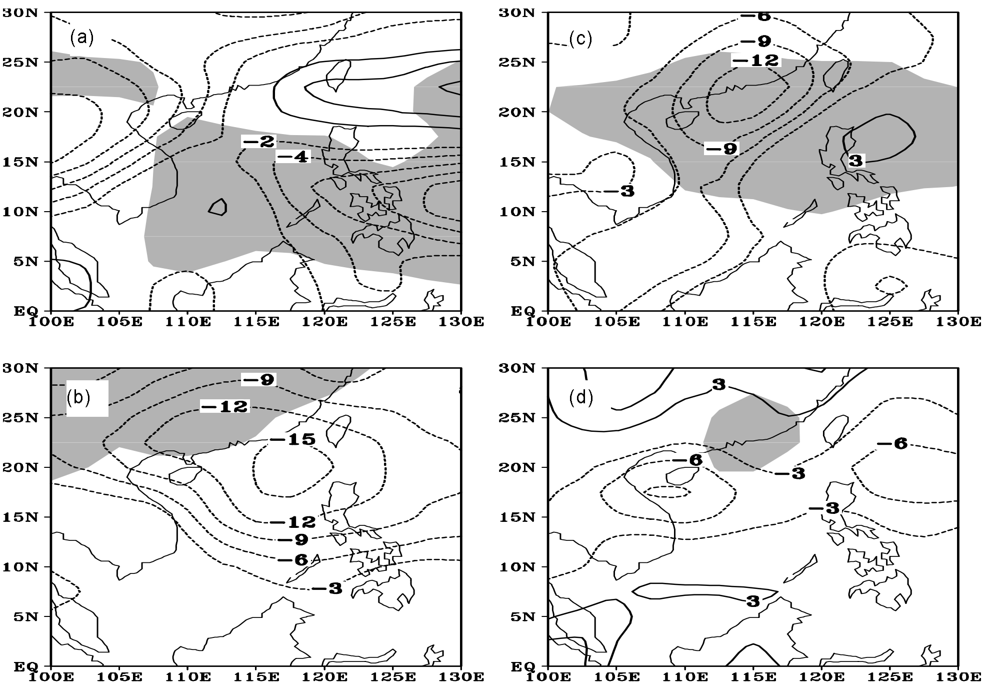

**Fig. 4.** The interdecadal changes of the outgoing longwave radiation (W m$^{-2}$) of (a) May, (b) June, (c) July, and (d) August after 1993 against before 1993. Regions over the 90% significance level in the $t$-test are shaded.

## 4. The interdecadal changes of the latent and sensible heat flux

The increase of the extreme precipitation in various regions can be attributed to contributions from both dynamic and thermodynamic processes associated with global warming. The dynamic change is due to the change in atmospheric motion, while the thermodynamic change is due to the change in atmospheric moisture content (Emori and Brown, 2005). Between the two processes, Trenberth (1999) argued that the increase of extreme precipitation is mainly caused by the enhancement of atmospheric moisture content, because all weather systems, which feed on the available moisture through storm-scale moisture convergence, are likely to produce correspondingly enhanced precipitation rates. The IPCC Fourth Assessment Report (Meehl et al., 2007) showed that the greater increase in extreme precipitation compared to the mean is attributed to the greater thermodynamic effect on the extreme occurrences due to increases in water vapor, mainly over the subtropical areas. Meehl et al. (2005) also pointed out that the general increases in water vapor associated with positive SST anomalies in the tropics produce increased precipitation intensity over most land areas. So the possible thermodynamic mechanism for the interdecadal increase of the extreme precipitation over South China will be discussed in the following parts.

### 4.1 *The interdecadal changes of the latent heat flux over the South China Sea*

Following the result of the Mann-Kendall test on the summer extreme precipitation, we define the period of 1969–1993 as the dry spell and the period of 1994–2003 as the wet spell. Through the correlation analysis between the latent heat flux and the summer extreme precipitation over South China (figures not shown), it is found that the latent heat flux in April, May and June over the South China Sea have evident positive relationships with the extreme precipitation June. The interdecadal changes of the latent heat flux of April, May and June after 1993 (Figs. 5a–c), which are obtained from the difference between the wet spell (1994–2003) and dry spell (1969–1993), indicate that the latent heat flux of the three months over the South China Sea have obvious interdecadal increases with the maximum centers located over the Philippine Sea. The areas whose interdecadal increases can exceed 90% significant level are located at the centers with large interdecadal increases.

The South China Sea monsoon usually has an outbreak in May (Qian et al., 2005), and after its onset the prevailing wind in the lower troposphere over the South China Sea turns from southeasterly to the southwesterly. In June, the subtropical high retreats

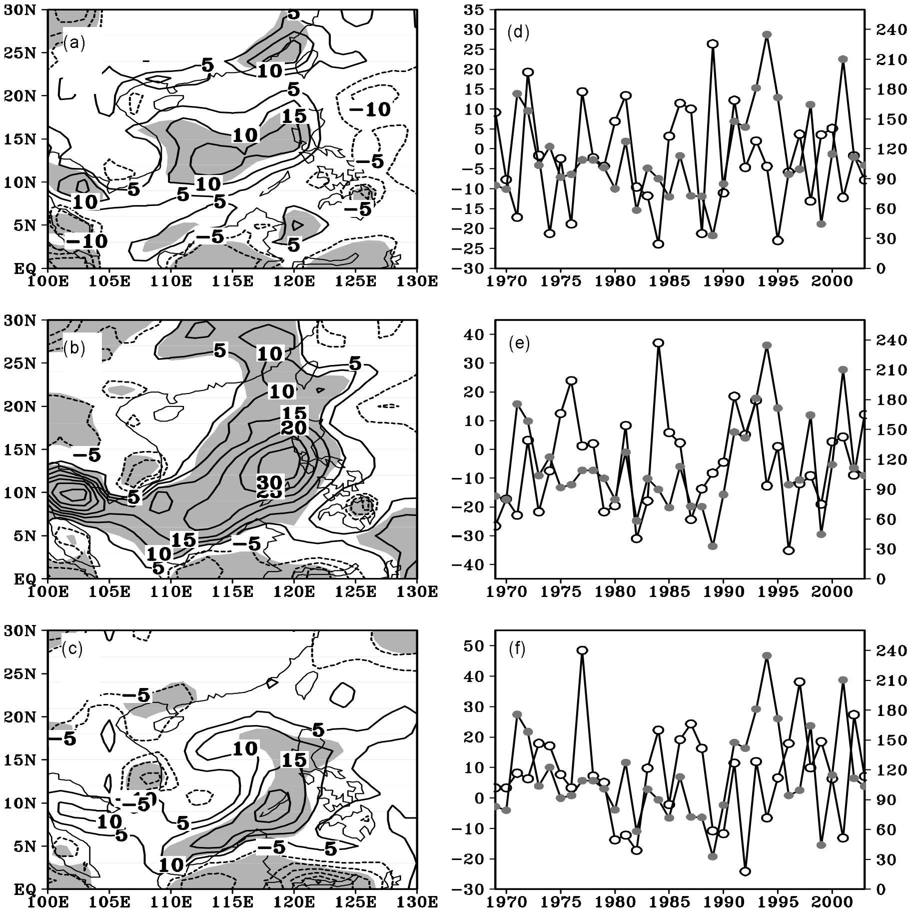


**Fig. 5.** The interdecadal changes of the latent heat (W m$^{-2}$) of (a) April, (b) May, and (c) June after 1993 against before 1993; and the time series of the June's extreme precipitation (right $y$-axis; units: mm) and the latent heat anomalies (left $y$-axis; units: W m$^{-2}$) over the key regions for (d) April, (e) May, and (f) June. In (d)–(f), the lines with open (solid) circles represent the time series of latent heat anomalies (extreme precipitation). Regions over the 90% significance level in the $t$-test are shaded.

from the South China Sea and the South Asia High proceeds to the Tibet Plateau. Then, South China is located to the east of the South Asia High and there is much strong convection over South China. Therefore, the convection takes the place of the fronts and become the main weather systems that affect the extreme precipitation over South China in June (Chi et al., 2005). One major resource of the water vapor that affects the extreme precipitation over South China is the northern South China Sea (Simmonds et al., 1999). Combining with the correlation analysis shown before, we select the key latent heat flux areas affecting June's extreme precipitation as follows: April: 10°–16°N, 117°–123°E; May and June: 12°–18°N, 112°–118°E. The area-averaged time series of the latent heat flux anomalies over the three key regions (Figs. 5d–f) show that they all increase significantly after the early 1990s and have evident positive correlations with June's extreme precipitation. The correlation coefficients are, respectively, 0.41, 0.32 and 0.36, which can all exceed 95% significant level.

The interdecadal increase of the latent heat flux indicates an enhancement of evaporation over the key regions after the early 1990s, which provides more water vapor from the surface to South China by circulation in the lower troposphere. Under the same atmospheric conditions, the increase of the water vapor content will increase the CAPE (Convective Available Potential Energy) and reduce the CIN (Convective Inhibition), and this would make the convection occur much easier. After the convection is induced, the positive vorticity and vapor convergence in the lower troposphere are strengthened by the latent heating. The upward movement and transport of the vapor and en-

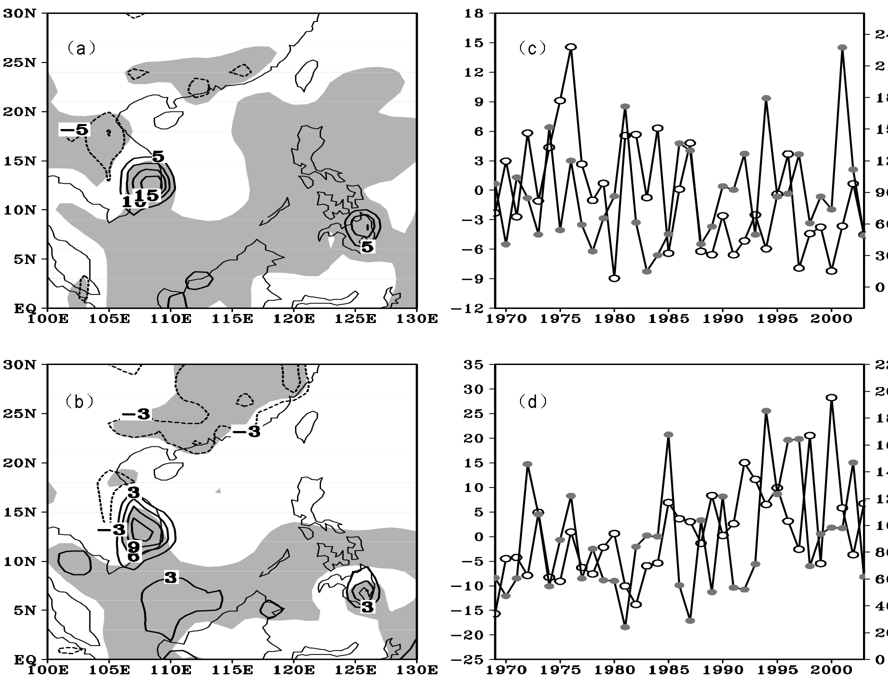


**Fig. 6.** The interdecadal changes of the sensible heat flux (W m$^{-2}$) of (a) July and (b) August after 1993; the time series of the extreme precipitation (right $y$-axis; units: mm) and the area-averaged sensible heat anomalies (left $y$-axis; units: W m$^{-2}$) over the key region for (c) July and (d) August. In (c) and (d), the lines with open (solid) circles represent the time series of latent heat anomalies (extreme precipitation). Regions over the 90% significance level in the $t$-test are shaded.

ergy help the convection systems' developments and persistence. Therefore, there has been more vigorous convection since the early 1990s, which confirms the results of the analyses of the OLR above and in turn induces the interdecadal increase of the extreme precipitation in June.

### 4.2 *The interdecadal changes of the sensible heat flux over the Indochina peninsula*

Figure 6 present the interdecadal changes of the sensible heat flux of July and August after 1993. Both of the two maximum centers in the two months are located over the southeast Indochina peninsula. The results of a $t$-test show that the interdecadal increases of the sensible heat flux over the southeast Indochina peninsula in the two months are significant. Thus, we select the area (10°–15°N, 105°–110°E) as the key region of the July and August sensible heat flux. The time series of the area-averaged sensible heat flux anomalies over the key region and the extreme precipitation in July and August exhibit similar interdecadal features and increase after the early 1990s. The correlation coefficient between the sensible heat flux and extreme precipitation in July is 0.31, which can exceed 90% significant level. While that in August is 0.46, which can exceed the 95% significant level.

On one hand, the interdecadal increase of sensible heat flux over the southeast Indochina peninsula increases the temperature of the southwest circulation and makes the air able to hold more moisture (Meehl et al., 2005). On the other hand, the interdecadal increase of sensible heat forms a warm center and enhances the local thermal contrast between the land and the ocean, and therefore the horizontal temperature gradient. To the horizontal circulation, the heating in the lower troposphere reduces the geopotential height to strengthen the geopotential height's gradient. The interdecadal enhancements of the horizontal temperature gradient and geopotential height gradient are helpful to maintain and strengthen the southwesterly winds brought by the South China Sea monsoon. Heating from the ground strengthens convergence in the lower troposphere and divergence in the upper troposphere, which are in favor of the transport of the vapor from the ground to the upper level. Therefore, the interdecadal increase of the sensible heat flux over the southeast Indochina peninsula strengthens the vapor transport from the Indochina peninsula and the north South China Sea to South China because of the two reasons analyzed above.

In July and August, South China is located to the south of the subtropical high, and the main extreme precipitation also resulted from the convections. However, at that time, the convections are mainly brought by the tropical weather systems, such as the typhoon from the Pacific, ITCZ and so on. Therefore, the increase of water vapor over South China will produce stronger convection, which confirms the results of the analyses of the OLR above, and confirm having more extreme precipitation as a result.

## 5. Conclusion

Through the analysis above, the following conclusions are reached:

(1) Both the annual and summer extreme precipitations over South China have obvious interdecadal changes and increase significantly after the early 1990s. Moreover, the sudden change of the annual extreme precipitation results mainly from the summer extreme precipitation, and the sudden change of the latter is due to the extreme precipitation brought by convection in June and August.

(2) The interdecadal increase of the latent heat flux over the Philippine Sea in April and over the northern South China Sea would provide more vapor to South China and consequently more vigorous convection happens.

(3) The interdecadal increase of the latent heat flux over the southeast Indochina peninsula plays an important role in the interdecadal increase of the convection in July and August, and the effect is carried through the southwestly winds of the South China Sea Monsoon.

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