Features of the Extremely Severe Drought in the East of Southwest China and Anomalies of Atmospheric Circulation in Summer 2006*

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ABSTRACT

The spatial-temporal features of the extremely severe drought and the anomalous atmospheric circulation in summer 2006 are analyzed based on the NCEP/NCAR reanalysis data, the characteristic circulation indices given by the National Climate Center of China, and the daily precipitation data of 20 stations in the east of Southwest China (ESC) from 1959 to 2006. The results show that the rainless period started from early June and ended in early September 2006 with a total of more than 80 days, and the rainfall was especially scarce from around 25 July to 5 September 2006. Precipitation for each month was less than normal, and analysis of the precipitation indices shows that the summer precipitation in 2006 was the least since 1959. The extremely severe drought in the ESC in summer 2006 was closely related to the persistent anomalies of the atmospheric circulation in the same period, i.e., anomalies of mid-high latitude atmospheric circulation, western Pacific subtropical high (WPSH), westerlies, South Asian high, lower-level flow, water vapor transport, vertical motion, and so on. Droughts usually occur when the WPSH lies anomalously northward and westward, or anomalously weak and eastward. The extreme drought in summer 2006 was caused by the former. When the WPSH turned stronger and shifted to the north and west of its normal position, and the South Asian high was also strong and lay eastward, downdrafts prevailed over the ESC and suppressed the water vapor transfer toward this area. At the same time, the disposition of the westerlies and the mid-high latitude circulation disfavored the southward invasion of cold air, which jointly resulted in the extremely severe drought in the ESC in summer 2006. The weak heating over the Tibetan Plateau and vigorous convective activities over the Philippine area were likely responsible for the strong WPSH and its northwestward shift in summer 2006.

Key words: the east of Southwest China, extremely severe drought, anomalous atmospheric circulation

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1. Introduction

In summer 2006, the east of Southwest China (ESC) suffered the most severe drought with a long duration and an extensive coverage since the initiation of meteorological records. The drought caused huge economical damage to this area. The ESC is frequently attacked by drought. It is important to study the characteristics of drought and its mechanism in order to improve the prediction and prevention of droughts in this area.

In recent years, extreme weather and climatological events such as flood or drought occur more and more frequently under the background of global warming (Filippo et al., 1996; Siegfried et al., 2004; Michelle et al., 2007; Ricardo et al., 2007; Diriba and Anthony, 2007; Tao and Xu, 1962; Huang and Wu, 1989; Wu et al., 2005; Ding and Hu, 2003; Luo et al., 1985; Yang, 2002; Sun and An, 2003; Wei, 2006; Liang et al., 2006; Niu and Li, 2007). Many studies on the causes and

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mechanisms of drought and flood have produced significant results (Tao and Xu, 1962; Huang and Wu, 1989; Wu et al., 2005; Ding and Hu, 2003; Luo et al., 1985; Yang, 2002; Sun and An, 2003; Wei, 2006; Liang et al., 2006; Niu and Li, 2007). However, most of these studies focused on East China, while only a few studies paid attention to Southwest China, which is hit by drought and flood frequently (Ma, 2002; Li, 2003; Liu et al., 2005). There have been some studies on the extreme severe drought in the ESC in summer 2006. For example, Peng et al. (2007) discussed the characteristics and mechanism of the drought with an emphasis on the abnormal activities of the western Pacific subtropical high (WPSH) and continent subtropical high, and the features of the westerlies and the tropical circulation. Zou and Gao (2007) pointed out that the extremely high temperature and drought in the ESC in summer 2006 was caused by both the weather system oscillations and global warming, in which the weather system oscillations such as the weak cold air from the north to the south, the northward and westward shifts of the ridge line of the WPSH, and the low snow cover over the Tibetan Plateau in the preceding winter played the major roles. Bao et al. (2007) also examined the relationship between the preceding Sea Surface Temperature (SST) and the 2006 drought. They found that the positive anomalies of SST between 20° and 40°S and the negative anomalies of SST at the equatorial eastern Pacific from January to March 2006 favored the severe drought in the ESC in summer 2006.

Since this event is caused by a range of factors, it deserves a further analysis. In this study, based on the previous results, we carry out a comprehensive analysis of this typical extreme drought in the ESC and the concurrent atmospheric circulation. We will also explore and identify its causes.

2. Data and method

In this study, the ESC is defined as the area 27°–32°N, 105°–110°E, covering the east of Sichuan Province, Chongqing, the north of Guizhou Province, and parts of western Hunan and Hubei provinces.

Table 1. List of 20 observation stations in the east of Southwest China

Station	Longitude	Latitude	Station	Longitude	Latitude	Station	Longitude	Latitude
Langzhong	105°58′	31°35′	Wanzhou	108°24′	30°46′	Youyang	108°46′	28°48′
Bazhong	106°46′	31°51′	Enshi	109°28′	30°17′	Jishou	109°44′	28°19′
Dazhou	107°30′	31°12′	Shapingba	106°28′	29°35′	Zhunyi	106°53′	27°42′
Fengjie	109°30′	31°03′	Fuling	107°25′	29°45′	Meitan	107°28′	27°46′
Shuining	105°35′	30°30′	Laifeng	109°25′	29°31′	Sinan	108°15′	27°57′
Nanchong	106°06′	30°47′	Tongzhi	106°50′	28°08′	Qianxi	106°01′	27°02′
Liangping	107°48′	30°41′	Xishui	106°13′	28°20′			

Global monthly NCEP/NCAR reanalysis data with a resolution of 2.5°×2.5° from June to August during 1959–2006 (some are daily data), daily precipitation of 20 observation stations in the ESC listed in Table 1, and the dataset of the characteristic atmospheric circulation from the National Climate Center (NCC) of China are used. Unless a special notice is given, the climatological period refers to 1971–2000.

In order to summarize the characteristics of the rainfall in the ESC and compare with the historical records, we calculate the regional rainfall index during the period 1959–2006 based on the method adopted by the climate prediction office of NCC:

$$\gamma = (\frac{1}{n}\sum_{i=1}^{n}\frac{R_i}{\overline{R_i}} + \frac{n^+}{n}) \times 100, \qquad (1)$$

where n is the number of the observation stations, R_i is the total precipitation from June to August, $\overline{R_i}$ is the climatology of the precipitation, i is the index of the observation station (i=1,2, ..., n), n^+ is the number of n observation stations with the anomaly of the precipitation $\Delta R \geqslant 0$. The rainfall index γ can well depict the strength of the precipitation in the region:

the larger the value, the more the precipitation in the region. The average value is 150. We use a ratio correction method to interpolate the series in order to fill in the missing values for a few observation stations in some years.

3. Distribution of rainfall in the ESC in summer 2006

3.1 Characteristics of the spatial distribution

Figure 1 shows the distributions of precipitation anomalies in June, July, August, and the whole summer (June–August) 2006 in the ESC. It can be seen that both the monthly precipitation and the summer total precipitation were smaller than normal values. In June (Fig. 1a), except for the west of Guizhou Province and parts of Laifeng region in Hunan Province, rainfall in other regions is small. There were large negative anomaly regions in Sichuan, northwest of Chongqing, and north of Guizhou. These regional centers were located in Dazhou, Wanzhou, Zhunyi, and Meitan, where the rainfall decreased by more than 80%. In July (Fig. 1b), the precipitation was large in Youyang and Chongqing but small in other regions, where the rainfall decreased by more than 80% in Shuining, and more than 70% in Langzhong, Sichuan Province and Fuling City. In August (Fig. 1c), the rainfall was scarce in the whole ESC. The decrease of precipitation was more than 50% in the major part of the region; especially, it was more than 90% in Shuining, Nanchong and Bazhong, Sichuan Province and more than 80%

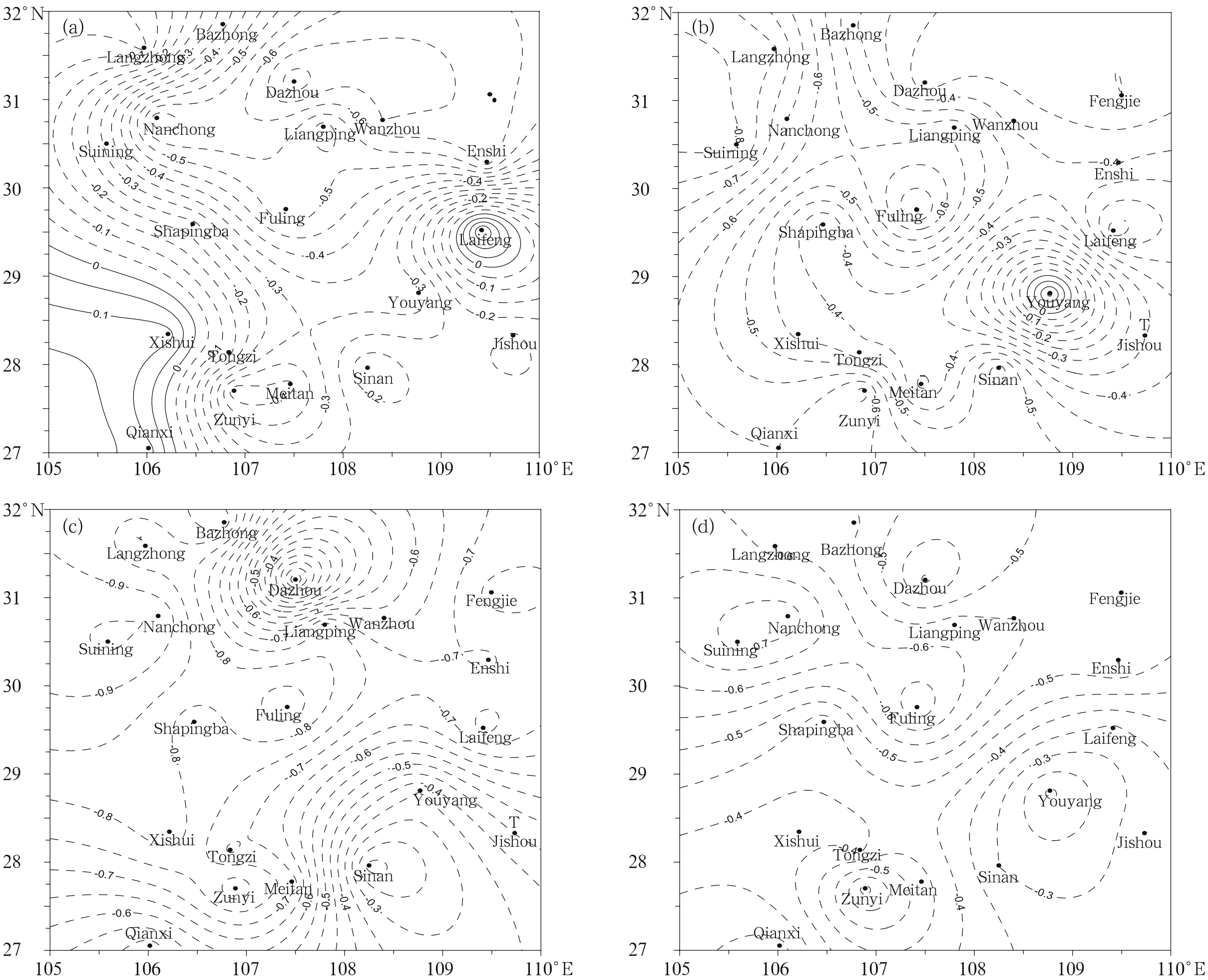

Fig. 1. Spatial distributions of the precipitation anomaly percentage in the ESC for (a) June, (b) July, (c) August, and (d) the summer of 2006. Dashed lines denote negative anomaly and solid lines denote zero or positive anomaly.

in Fuling, Zhunyi, Guizhou Province and Xishui and Langzhong, Sichuan Province. The total precipitation from June to August was smaller than the usual in the whole ESC where the total rainfall decreased by more than 70% in the low center located in Nanchong and Shuining, Sichuan province, and Fuling city.

In summary, the extreme drought in the ESC occurred with the total precipitation in summer 2006 much smaller than the usual, and the precipitation decreased significantly in the major part of the region in each month during the summer.

3.2 Characteristics of the temporal variation

In order to catch the comprehensive features of rainfall in the ESC in summer 2006, we conduct a further analysis on the temporal variation of the rainfall.

Figure 2a shows the time series of the regional rainfall indices by useing Eq. (1) in the ESC in summer during 1959–2006. It is seen that the rainfall in the region was obviously above normal in 1980, 1993, and 1998, while it was much less than the normal in 1972 and 2006, with the rainfall being minimum in 2006 since 1959.

In order to analyze the temporal variation and duration of the extreme drought in detail, we calculate the daily precipitation in the ESC from June to September (Fig. 2b). It can be found that the duration of the precipitation below normal extended from the second ten days of June to the first ten days of September, a total of more than 80 days, among which the rainfall from the last ten days of July to the first ten days of September was scarce.

4. Features of the atmospheric circulation in East Asia in summer 2006

The drought is attributed to the long duration and development of the abnormal atmospheric circulation. In the following sections, we will analyze the high- and mid-latitude atmospheric circulations, WPSH, westlies (cold air activities), South Asian high, the flow pattern in the lower troposphere, water vapor transport, and the vertical motion.

4.1 Characteristics of the high- and mid-latitude atmospheric circulations and WPSH

WPSH and the high- and mid-latitude atmospheric circulations have significant influences on the precipitation in the ESC. Figure 3 shows the geopotential height and its anomalies at 500 hPa in June–August 2006. It is seen that the atmospheric circulations in high to mid latitudes were smooth. The ridge near the Ural and the shallow European trough were insignificant. The atmospheric circulation in North China was also very smooth. The East Asian trough was shallow with a prevailing zonal circulation. WPSH was much stronger and situated in a larger area. Its ridge line shifted northward and extended westward obviously. Consequently, the ESC was under the control of WPSH.

Since WPSH is a very important system affecting the rainfall in the ESC, we list the chracteristic indices of WPSH in summer 2006 and their climatological values in Table 2. It can be seen that the area size of WPSH was much larger in June and July 2006 with much larger strength values, and the ridge line shifted northward and westward. In August, the area of WPSH was slightly larger but its strength was

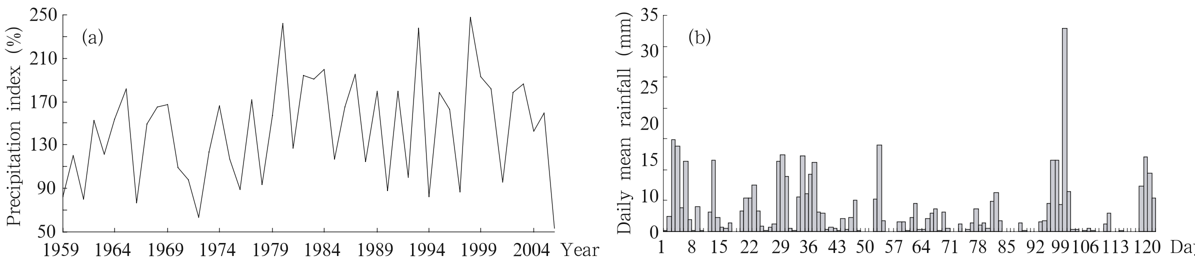

Fig. 2. (a) Changes of precipitation indices from 1959 to 2006 and (b) daily mean rainfall from June to September in 2006 in the ESC.

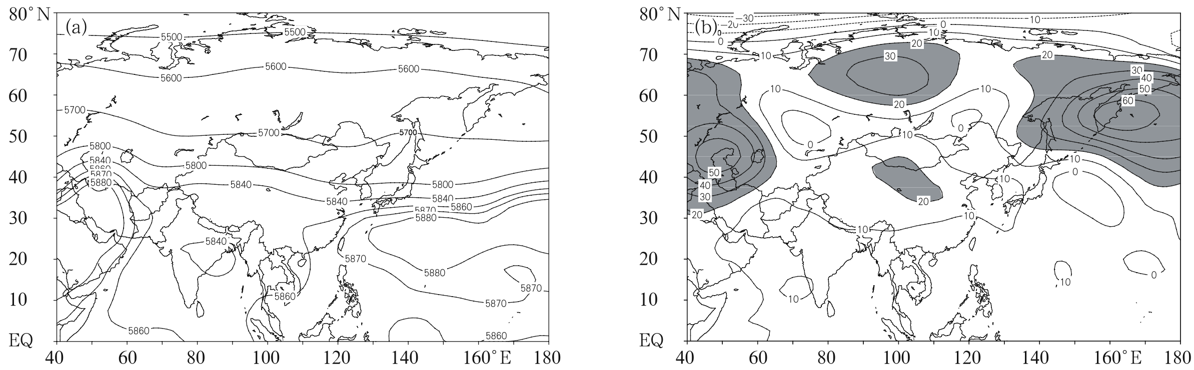

Fig. 3. The geopotential height (gpm) field (a) and its anomalies (b) at 500 hPa in summer 2006. Shaded areas denote positive anomaly.

Table 2. Comparison of the characteristic indices of WPSH in summer 2006 with their climatological values

Types of indices	June		July		August		June–August	
	Climatology	2006	Climatology	2006	Climatology	2006	Climatology	2006
Area	22	32	22	32	22	30	22	31
Strength	45	60	40	89	38	31	41	60
Ridge line (°N)	21	21	25	26	27	29	24	25
Northern boundary (°N)	26	25	31	31	32	33	30	30
Westmost point of the ridge line (°E)	118	110	124	120	124	100	122	110

reduced a little. The ridge line still shifted northward and westward significantly. Therefore, the larger, stronger and northward and westward shifted WPSH controlled the ESC. The associated descending airflows prevailed in this area and resulted in the high temperature and the scarcity of the rainfall.

4.2 Characteristics of the westerlies

The strength of the cold air is another important factor affecting the flood or drought in the ESC. The southward movement of the cold air from the westerlies maintains the Meiyu front and induces the rainfall directly. Figures 4a and 4b show the distributions of average zonal wind and its anomalies at 200 hPa during June–August 2006. It can be seen from Fig. 4 that the activity area of the westerlies was larger and the westlies shifted northward. The jet in the upper troposphere also moved five degrees northward. The stronger zonal circulation in summer 2006 made the cold air inactive, and the cold air was unable to reach the Yangtze River valley and the ESC. Consequently, these regions suffered the scarcity of the rainfall and the drought.

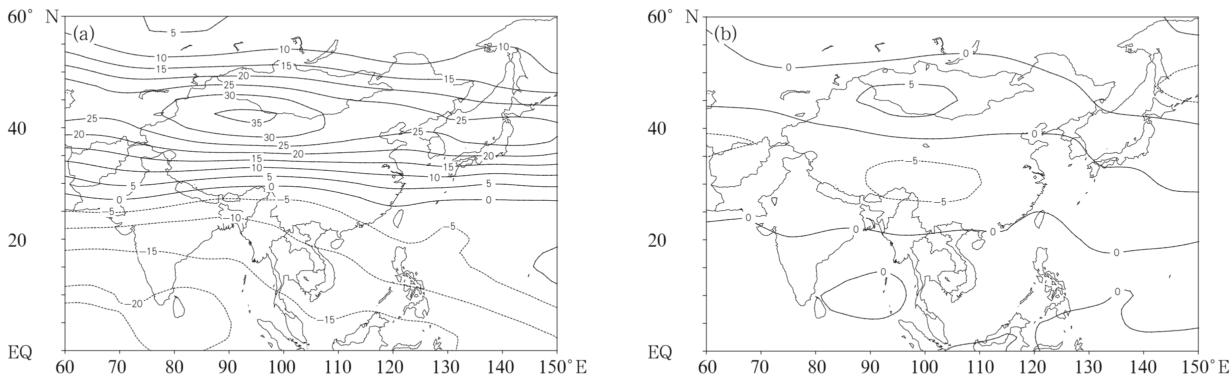

Fig. 4. The zonal wind (m s^{-1}) field (a) and its anomalies (b) at 200 hPa in summer 2006.

4.3 Characteristics of the South Asian high

The South Asian high is dominant in the upper troposphere in summer with the maximum center at 100 hPa. It plays an important role in the atmospheric circulation of the Northern Hemisphere and the weather and climate of Asia, especially the distribution of the flood and drought in China. Figure 5 demonstrates the geopotential height and its anomalies at 100 hPa during summer 2006. We see that the ridge line of the South Asian high was located near 32°N. It shifted northward and eastward while the South Asian high was getting stronger. The main body of the South Asian high controlled West Asia and the major part of China, especially the ESC in the entire summer. Previous studies (Zhang and Wu, 2001; Tao and Zhu, 1964) found that the South Asian high is negatively correlated with the WPSH in their zonal movement: they normally move toward each other and retreat backward away from each other. In summer 2006, a stronger South Asian high with eastward and northward shifts favored the northward and westward shifting of the WPSH. This resulted in the significant decrease of rainfall in ESC, and then the extreme drought occurred.

4.4 Characteristics of the flow field in the lower troposphere

Figure 6 shows the flow field and its anomalies at 850 hPa in summer 2006. It is seen that the flow over the ESC originated from the cross-equatorial flow and the Indian Ocean flow, which converged into one flow from nearly the south to the north after they flowed through the Bay of Bengal or through the Indo-China Peninsula and South China Sea. The converging flow separated into two branches: one climbed over the Tibetan Plateau and converged there with the cold air from north; the other flowed northward. Fig. 6b reveals that there was an abnormal anticyclone over both Mongolia and South China. The ESC was under

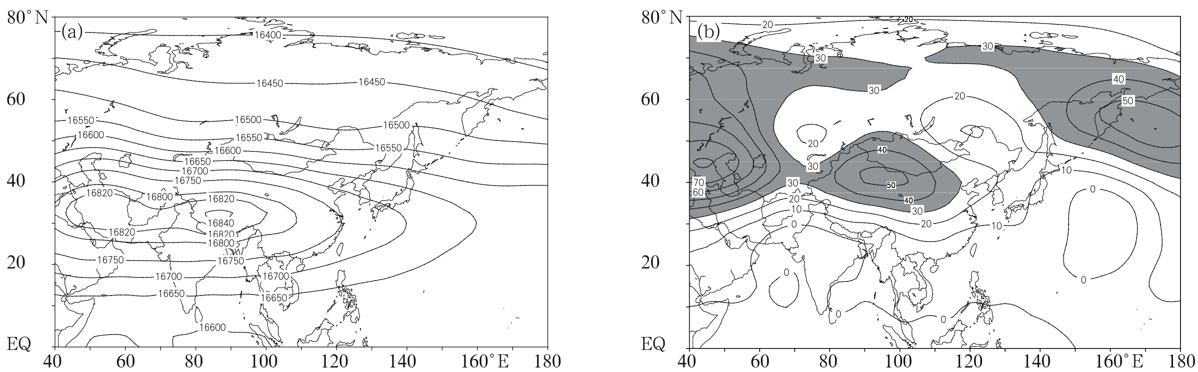

Fig. 5. The geopotential height (gpm) field (a) and its anomalies (b) at 100 hPa in summer 2006.

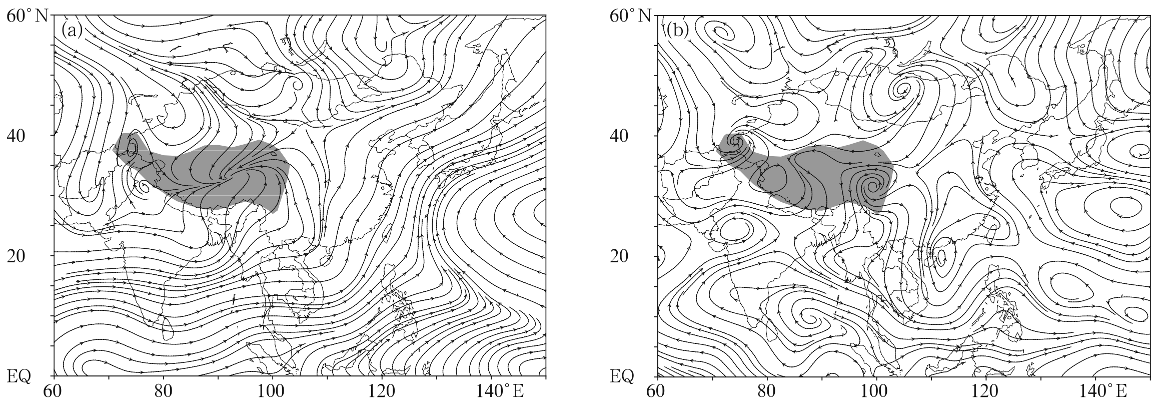

Fig. 6. The streamline field (a) and its anomalies (b) at 850 hPa in summer 2006.

the control of the outflow from both anticyclones from the north to south. This indicates that the atmospheric circulation in the lower troposphere disfavored the warm and moisture air transport from the south to the north, which disadvantaged the convergence of cold and warm airs over the ESC, and the water vapor transport decreased enormously (for details, see Section 4.5). Therefore, the rainfall over this region in summer 2006 was much less than that in the normal year.

4.5 Characteristics of the water vapor transport

The water vapor transport and its budget are important elements in the maintenance and variation of the global atmospheric circulation because water vapor is one of the necessary conditions of rainfall. Figure 7 shows the climatological water vapor transport flux of the whole column and its anomalies in summer 2006, and those at 850 hPa.

It is seen from Fig. 7a that the main source of water vapor over the ESC comes from two branches. One originates in the Indian Ocean and flows through the Bay of Bengal and Indo-China Peninsula, and the other comes from the South China Sea and West Pacific. The two branches converge over the ESC and form a new water vapor transport channel from southwest to northeast. Figure 7b shows that in summer 2006, weak anomaly vectors from northeast to southwest appeared over the ESC region. This indicates that the water vapor supply to the ESC decreased because the water vapor transport diminished. From Fig. 7c, we see that the climatological water transport at 850 hPa in summer was similar to that of the whole column. This also demonstrates that the main branch comes from the Indian Ocean and flows across the Bay of Bengal and Indo-China Peninsula or across the South China Sea. This branch merges with the

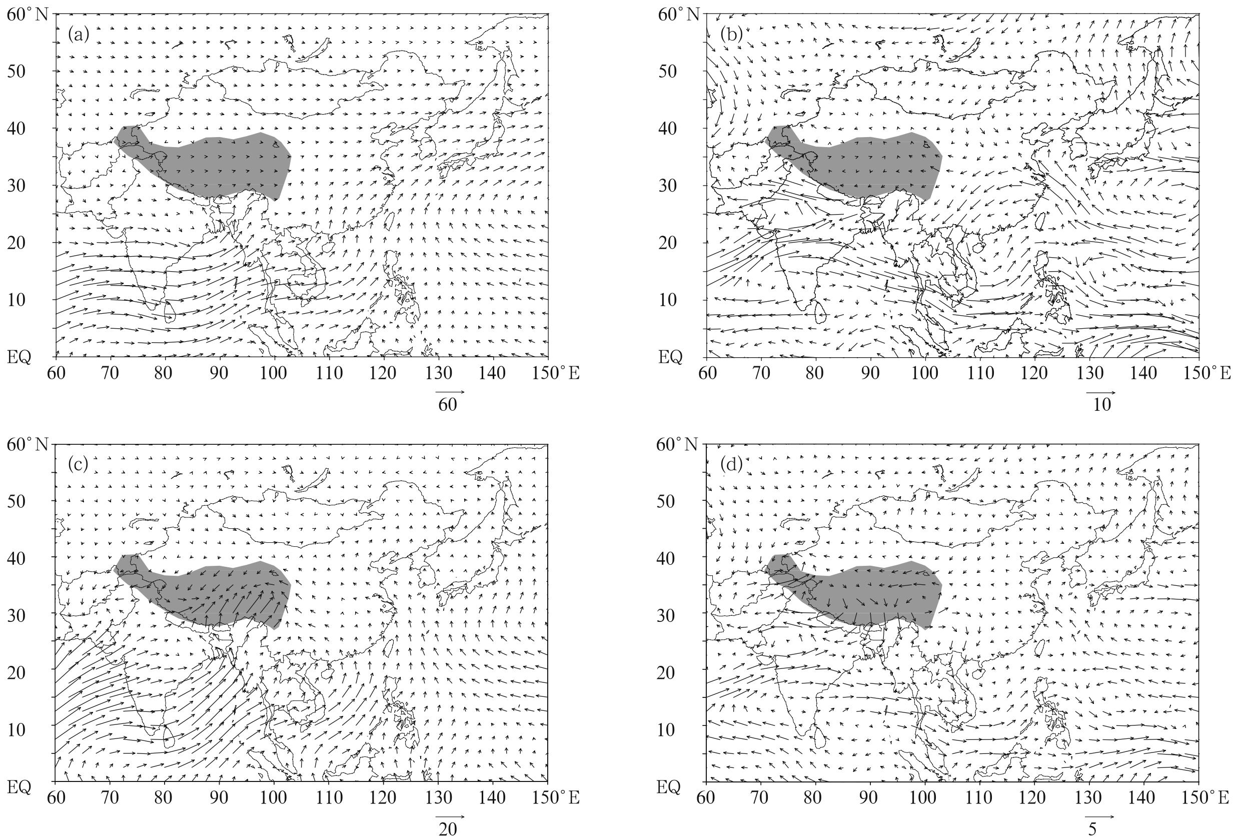

Fig. 7. The multi-year average whole column moisture flux (a) and its anomaly in summer 2006 (b), and those at 850 hPa (c, d) (unit: kg cm^{-1} s^{-1}). The shaded area denotes the Tibetan Plateau.

northward water vapor transport from the South China Sea into the ESC. Little water vapor over the region comes directly from the West Pacific. Fig. 7d illustrates that there was abnormal water vapor transport from the north to south over the ESC at 850 hPa in summer 2006, so the water vapor transport from the south over the ESC dwindled.

4.6 Characteristics of the vertical motion

Figure 8 depicts the time-height cross-section of the daily vertical velocity in summer 2006 (Fig. 8a), the climatological vertical velocity field at 850 hPa (Fig. 8b), and its anomalies in summer 2006 over the ESC (Fig. 8c). It can be seen from Fig. 8a that downward movement prevailed in this region and therefore the rainfall diminished. Comparing Fig. 8a with Fig. 2b finds that the vertical velocity field matchs the precipitation episodes very well. In the first ten days of June, the rainfall over this region occurred frequently and upward flow was widespread. But on other days of June, rainfall was scarce and downward flow prevailed. According to the climatology in Fig. 8b, under the mechanical and thermodynamic influences of the Tibetan Plateau, the ESC is a transition place for upward and downward motions, where weak upward flow is usually dominant. However, from Fig. 8c we see that there was a positive center over the ESC, suggesting that descending motion prevailed over this region in summer 2006. That is to say, the downdrafts strengthened while the updrafts weakened significantly, which disfavored the occurrence of rainfall over the ESC.

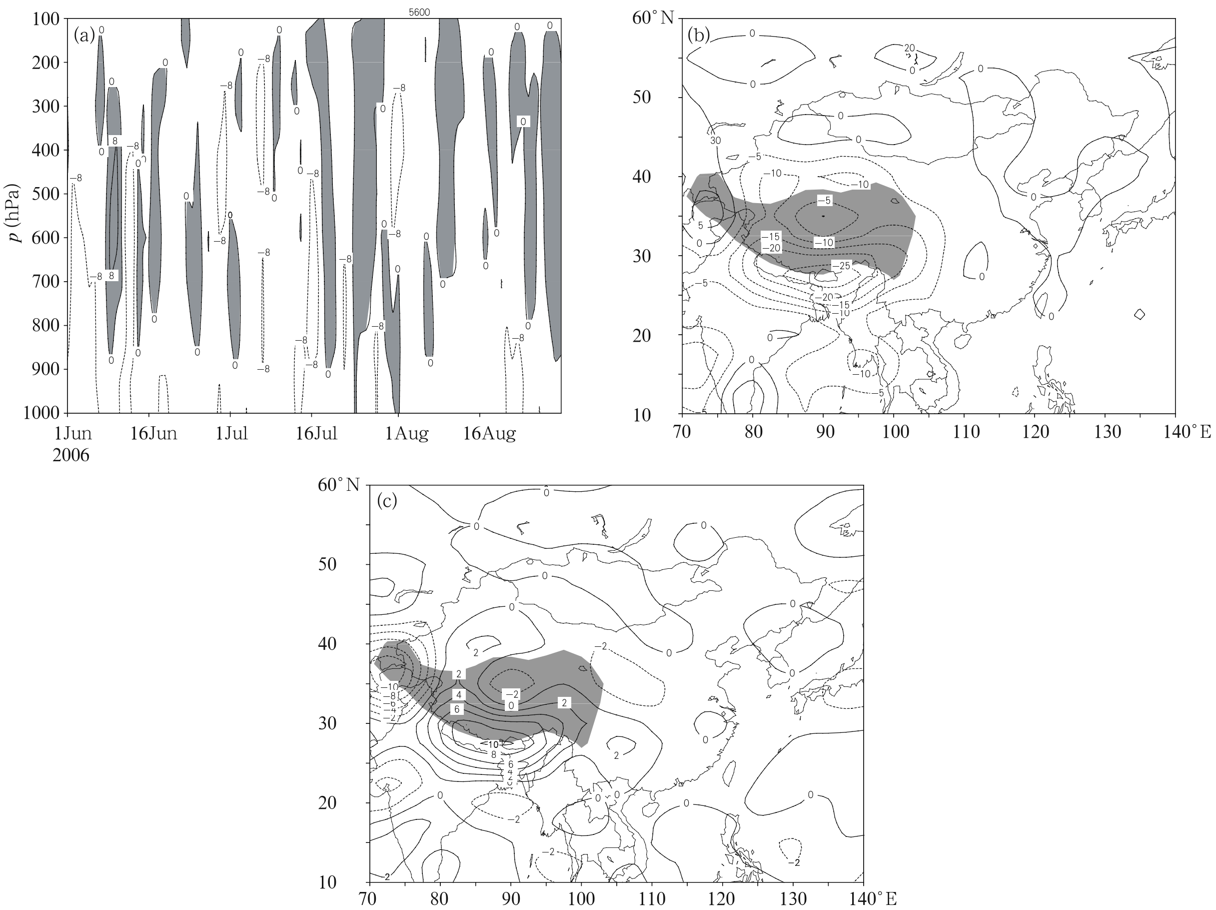

Fig. 8. The time-height cross-section of summer 2006 daily average vertical velocity over the ESC (a), and the multi-year average vertical velocity at 850 hPa (b) and its anomaly in summer 2006 (c) (unit: 10^{-2} Pa s^{-1}). The shading in (a) denotes downward motion.

5. Causes of the drought

The factors we analyzed in the previous section are inter-correlated. The more stable the atmospheric circulation, the less the precipitation in the ESC in summer. The extremely strong WPSH, which plays an active role during boreal summer, has important influences on both the westerlies and the adjustment of the subtropical atmospheric circulation. Its strength and location determines the venue and approach of the convergence of the warm air from the south and the cold air from the north and therefore the occurrence place of rainfall in summer. This is a direct reason for the extreme drought in ESC. Under the control of WPSH, water vapor transport into this region decreased and descending flow prevailed. This hindered the convergence of the warm air from the south and the cold air from the north. Therefore, the severe drought happened. In fact, the atmospheric circulation impacting the flood and drought in the ESC is of great complication. The circulation may change in different flood or drought years, and even change in the same flood or drought year. The circulation patterns associated with the WPSH are complicated.

Table 3 displays the characteristic indices of WPSH corresponding to the severe drought in different years in the ESC. It can be seen that the ridge line of WPSH was in the normal place or shifted northward for all the cases but the WPSH strength and the westmost point of its ridge line may vary in each case. There are two types of WPSH causing the severe drought in the ESC in summer. The first type of WPSH shifts northward and westward, producing high temperature and long-term drought in the ESC. The WPSH generating the severe drought in this region in summer 2006 belongs to this type. The second type of WPSH is weaker and shifts eastward, inducing low temperature and drought. It impedes the northward movement of the warm air from the south and the southward movement of the cold air from the north, and therefore leads to less rainfall and drought in ESC in summer. For example, the drought in 1972 belongs to this situation. This kind of drought is typical in the 1970s but much less happened than the drought triggered by the first type of WPSH. That is to say, the majority of droughts in ESC in summer occur in association with the first type of WPSH, with high temperature and long duration. This is consistent with the previous result (Song and Yang, 2003).

According to the above analysis, the ridge line of WPSH shifts northward during the drought. This is common for all drought cases, but no such a common feature is found for the indices of the strength and the westmost point of the ridge line. In fact, the analysis of the correlation between the rainfall index and each of the five chracteristic indices of WPSH reveals that the best correlation is between the rainfall and the latitude of the WPSH ridge line, with the correlation coefficient of –0.47, significant at the level of 0.001; while the correlations between rainfall and other WPSH indices are not significant at this level. This is consistent with the observations and Table 3. The location of WPSH determines the site and approach of the convergence of cold and warm airs. It disfavors

Table 3. Characteristic indices of the western Pacific subtropical high during the summers of ESC droughts

Drought year	Index of the strength (41)*	Index of the ridge line (24°N)*	West point of the ridge line (122°E)*	Characteristics of WPSH
1959	34	24	117	Weaker, to the west, and normal ridge line
1961	39	27	112	Weaker, to the north and west
1966	50	25	107	Stronger, to the north and west
1971	29	27	126	Weaker, to the north and east
1972	19	24	135	Weaker, to the east, and normal ridge line
1976	23	26	130	Weaker, to the north and east
1978	22	25	130	Weaker, to the north and east
1990	34	25	125	Weaker, to the north and east
1992	63	25	123	Stronger, to the north and east
1994	82	27	112	Stronger, to the north and west
1997	30	25	117	Weaker, to the north and west
2001	27	26	120	Weaker, to the north and west
2006	60	25	110	Stronger, to the north and the west

*The number in the bracket denotes the climatological value.

the convergence of cold and warm airs over the ESC when the WPSH shifts westward and northward or when a weaker WPSH shifts eastward. The WPSH was located to the south and west of its normal place in summer 2006. The drought was of long duration with high temperature under the control of WPSH. When the WPSH shifts westward and strengthens again, the South Asian high extends eastward and strengthens. Then, the ESC is under the control of both the WPSH and South Asian high. This situation does not help the convergence of water vapor and occurence of rainfall (Peng et al., 2007). Under the control of WPSH, surface friction causes the overlap between the ridge line of WPSH within the boundary layer and the downward movement above the top of the boundary layer. At the same time, the air streams converge in the upper troposphere and diverge in the lower troposphere. Since the divergence in the lower troposphere restrains the development of low cloud, and the adiabatic increase of temperature by downward motion decreases the relative humidity, the weather is often clear nearthe ridge line of the WPSH (Wu et al., 2004).

Why did the WPSH strengthen and shift northward and westward in summer 2006? Huang and Sun (1994) pointed out that when the convection over the Philippine area becomes stronger, the WPSH strengthens and shifts northward; when the convection over there becomes weaker, the WPSH weakens and shifts southward. Besides the influence of the tropical convective activity on the WPSH, the heat source of the Tibetan Plateau also plays an important role. The Tibetan Plateau is a huge heat source looming into the mid troposphere. Not only its mechanical forcing is significant, but also the thermodynamic forcing is vigorous. The heating by the Tibetan Plateau can bring about the atmosphere oscillation and therefore affect the East Asian and even the global atmospheric circulation (Wu et al., 2005; Duan et al., 2003; Liu et al., 2002). It is shown by numerical simulations (Zhao et al., 2003) that when the latent heat of condensation over the Tibetan Plateau weakens, the WPSH becomes stronger and shifts northward and westward; the WPSH weakens and shifts southward when the latent heat of condensation there strengthens.

The magnitude of outgoing longwave radiation (OLR) depends on the temperature of the cloud top and the underlying surface. Over the Tibetan Plateau, OLR reflects the thermodynamic conditions, while in the tropics, OLR reflects the strength of the convective activity. Figure 9 shows the anomalies of OLR in summer 2006. It can be seen that the anomalies of OLR were negative over the area around the Philippine. Convection was very active and the convection over the western Pacific warm pool was also strong in summer 2006. The stronger heat source over the tropical western Pacific strengthened the Hadley Circulation, whose downward branch shifted northward and westward. Then, the WPSH strengthened and shifted northward and westward as well. It is also shown in Fig. 9 that the OLR over the major part of the Tibetan Plateau, especially over the east of the Tibetan Plateau, was positive. Thus, the latent heat of condensation was weaker than usual, so the WPSH strengthened and shifted northward and westward. It is thus inferred that in summer, the anomalies of heat source over the Tibetan Plateau and the convection over the western Pacific warm pool can produce abnormal activities of WPSH. The weak heat source over the Tibetan Plateau and the extremely active convection over the area around the Philippine cause a stronger and northward and westward WPSH. This results in the extremely severe drought over the ESC in summer 2006.

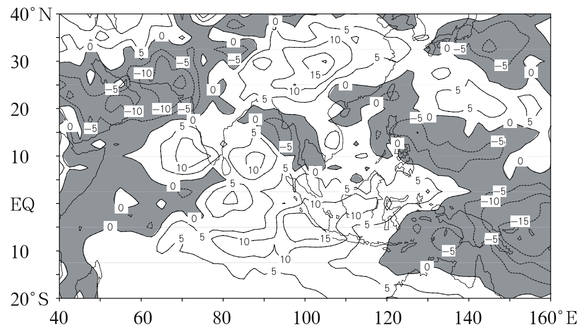

Fig. 9. The OLR anomaly field in summer 2006 (W m^{-2}). The climatology period is 1979–2006; shadings denote negative values.

6. Conclusions

In this study, we analyze the severe drought in the ESC in summer 2006, which has been the most severe with the least rainfall since 1959. The findings suggest that the severe drought was closely related to the abnormal atmospheric circulation. During the summer of 2006, there existed the long-term abnormity of mid- and high-latitude circulations, WPSH, westerlies (cold air activities), South Asian high, the flow in the lower troposphere, the water vapor transport, and the vertical motion. It is shown that this severe drought is of long duration with high temperature under the control of WPSH. The detailed physical mechanism is as follows: the weaker heat source over the Tibetan Plateau and the active convection over the area around the Philippine drove the WPSH to become stronger and to shift northward and westward; meanwhile, the South Asian high shifted eastward and became stronger. Since the ESC was under the control of WPSH, the downward movement of airflow prevailed in this region, and the water vapor transport was restrained. The westerlies and the atmospheric circulation in the high and mid latitudes also hindered the southward movement of the cold air. Consequently, scarce rainfall and the extreme severe drought occurred in the ESC.

In fact, the dynamical and thermodynamic interactions between the atmospheric circulations in high, mid, and low latitudes are very complex. It is especially challenging to investigate the causes of the flood and drought in the ESC and to improve the prediction, due to the special location of this region. A further analysis of the features and physical mechanism of the severe drought in the ESC will be conducted in order to find out the physical factors with predictive values. This would be expected to help improve the short-term climate prediction of the flood and drought in this region.

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