Temporal Variations of the Spring Persistent Rains and South China Sea Sub-high and Their Correlations to the Circulation and Precipitation of the East Asian Summer Monsoon*

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ABSTRACT

National Meteorological Information Center (NMIC) rainfall data and NCEP/NCAR daily circulation reanalysis data are employed to establish the onset-pentad time index of the spring persistent rains (SPR) and the decay-pentad time index of the South China Sea (SCS) sub-high. These indexes are used to study the relationship between the factors in SPR period and their relations to the circulation and precipitation of the East Asian summer monsoon (EASM). Results show that, the summer rainfall over southeastern China decreases when SPR onset is late. For then EASM strengthens and the cyclonic circulation around the Tibetan Plateau (TP) strengthens, which makes abnormal anti-cyclonic circulation (cyclonic convergent circulation weakens) appear over southeastern China. When the decay of SCS sub-high delays, abnormal flood prevails over the middle and lower reaches of the Yangtze River (MLYR) and to the south. That is mainly caused by EASM weakening while SCS sub-high strengthening, then the abnormal southwesterly over South China and the abnormal northerlies of anti-cyclonic circulation around the TP converge over the Yangtze Valley. The two indexes have high correlations with multivariate ENSO index (MEI) in March, indicating that the climate abnormity in East Asia is related to global climate abnormity tightly. The two time indexes are independent of each other, which is favorable for the prediction of the anomalies of the circulation and precipitation of EASM. From this point of view, we must take the global climate background into account when we analyze and predict the East Asian summer circulation and precipitation.

Key words: spring persistent rains (SPR), East Asian summer monsoon (EASM), the South China Sea (SCS) sub-high, correlation analysis, time indices

1. Introduction

The circulation and precipitation of the East Asian summer monsoon have remarkable interannual and decadal variabilities. They often induce severe flood or drought disasters and affect the livings of the people in the monsoon area very badly. Thus they are the study focus of many meteorologists and the short-term climate prediction operators through all the ages. There are also many studies of the telecorrelations between leading sea surface temperature (SST), snow cover or winter circulations and the precipitation and circulation of EASM. For example, Yu et al. (2000) used the leading global SST as a predictor for the EASM precipitation, Huang et al. (2004) used sub-high and polar vortex, Peng et al. (2005) used the snow cover over the Tibetan Plateau (TP) and the ENSO index, Yang et al. (2007) used the first pattern of the SST of spring Indian Ocean, and so on. All these studies may find more or less notable factors, but on account of the large temporal or spatial distance, the affecting mechanisms are hard to find. Gao and Wang (2007) noticed that, ENSO, as a main predictor index to the EASM precipitation, its hint effect has been weakened for recent 20 years. Furthermore, Wu and Qian (2003) analyzed the effect of the snow cover over the TP on the EASM precipitation. Duan et al. (2004) analyzed the relations of leading

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meridional temperature gradients in mid-high troposphere levels and the temperature over the TP to the onset time of EASM. They also brought forward possible mechanisms. On the other hand, there are lots of studies of the contemporary correlations between the circulation of the EASM and its precipitation. For example, Sun and Ding (2003) studied the physical mechanism of the abnormal activities of the EASM in 1999. Wu et al. (2003) presented the statistical correlations between the intensity of the South China Sea (SCS) summer monsoon and the summer precipitation in China. These studies mainly focused on the possible affecting mechanisms between the states of the EASM and the contemporary precipitation. They are helpful for us to understand the EASM circulation and its precipitation. Nevertheless, how to predict the EASM precipitation appears to be extremely difficult.

In the late 1990s, Tian and Yasunari (1998) introduced the climatic conception of the spring persistent rains (SPR). Wan and Wu (2007) used data analyses and numerical modeling experiment to prove that it is the mechanical and thermal forcing of the giant TP that induces the southwesterly jet at the southeastern flank of TP and then results in SPR. Therefore, SPR is not a transient synoptic phenomenon but a climatic phenomenon with profound climatic background. The study of the temporal and spatial distributions of SPR (Wan and Wu, 2008) showed that, SPR appears ahead of the onset of EASM and is located at the hinterland of the north flank of the SCS sub-high. Consequently SPR is very close to EASM in temporal and spatial distributions. As a result, there may be some relations between them and the affecting mechanism may be clearer and more reliable. Therefore, this study focuses on the relationships between the circulation and precipitation of SPR and those of EASM and their possible mechanisms.

2. Data and method

A set of rainfall data from 730 stations in China for the period 1951–2003, newly released by the National Meteorological Information Center (NMIC), were processed into pentadly and monthly data and interpolated onto a $0.5°\times0.5°$ grid through professional meteorological graphical software GRADS so as to construct SPR rain indexes and analyze its interannual variation.

NCEP/NCAR reanalysis daily mean data (1951–2003), including geopotential height and horizontal wind at 850 hPa, were also used. All data are on a $2.5°\times2.5°$ grid. The data were transferred to pentadly and monthly data too.

3. Correlations between the onset time of SPR and the circulation and precipitation of EASM

Climatologically, the SPR spans from the 13th pentad (hereafter referred to as P13, the rest may be deduced by analogy) to the 27th pentad in calendar year and distributes over southeastern China (areas south of the middle-lower reaches of the Yangtze River, about 23°–30°N, 110°–120°E; SEC for short) according to Wan and Wu (2008). Its onset time, spatial distribution and intensity have remarkable interannual variations. Its abnormal temporal and spatial distributions often indicate the abnormal condition of the atmospheric circulation and may have vital significance to the prediction of the onset of the SCS summer monsoon and the circulation and precipitation of the EASM.

The onset of SPR symbols the end of cold and dry winter and the start of warm and wet spring. Then the southwesterly at the southeastern flank of the TP strengthens rapidly, and the precipitation over SEC increases notably. Therefore, these dynamical and thermal variables can be used to construct the onset time index of SPR. In January, the winter circulation is on its peak phase. At that time, the southwesterly over South China and the rain over SEC may increase occasionally but cannot keep stable. Consequently we consider that, from P7 (the first pentad of February) on, the pentadly mean rain over SPR region (A: 23°–30°N, 110°–120°E, Fig.1) exceeds 4 mm day^{-1}, and the southwesterly over upstream area (B: 20°–25°N, 110°–115°E; Fig.1) exceeds 4 m s^{-1} contemporarily, and these two conditions are met at least in one pentad among the following three pentads. The pentad which meets all the above conditions is considered as the onset time of SPR. Thus the series of SPR onset

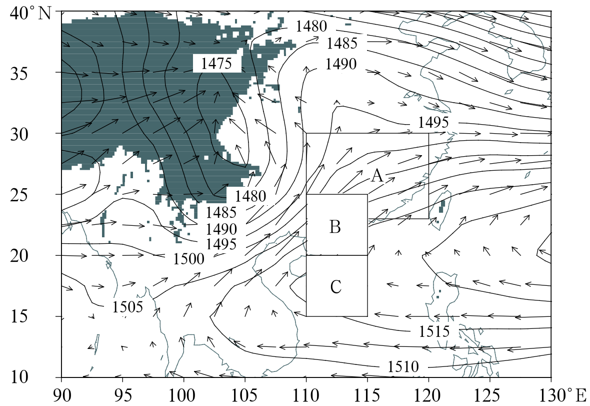

Fig.1. The fields of the wind vector and geopotential height (unit: gpm) at 850 hPa in SPR period over southeastern China and SPR region (A: 23°–30°N, 110°–120°E), upstream southwesterly region (B: 20°–25°N, 110°–115°E), and SCS west ridge region (C: 15°–20°N, 110°–115°E).

time index is constructed accordingly.

Figure 2a displays the interannual variations of the onset time index of the SPR ($T_{\rm spr}$). As we can see, $T_{\rm spr}$ has great interannual variations. The earliest is P7 (1959, 1992, 1997, and 1998) and the latest is P27 (1971, in fact it is vain SPR). The 53-yr mean pentad is P13.8. That is close to P13 and is corresponding with the remarkable increase of the southwesterly velocity and rain over the SEC. Thus it can be seen that, the construction of the $T_{\rm spr}$ index is reasonable.

Wolter and Timlin (1998) brought forward the multivariate ENSO index (MEI) on the six main observed variables over the tropical Pacific. These six variables are: sea surface temperature (SST), sea level pressure (SLP), zonal (U) and meridional (V) components of the surface wind, surface air temperature (T), and total cloudiness fraction of the sky (C). They reflect the states of the atmosphere and sea surface over the tropical Pacific on the whole. Positive MEI values represent the warm ENSO phase (El Niño), while negative MEI values represent the cold ENSO phase (La Niña). The correlation between $T_{\rm spr}$ and MEI in March is –0.43 for a period of 53 yr (1951–2003), exceeding the 99% significance level in t-test. This indicates that the onset time of SPR and ENSO are related to each other closely. SPR onset time is prone to be early when ENSO is in its warm state, and vice versa.

Figure 2b shows the field of the correlations between $T_{\rm spr}$ and the rain of China in summer (June-August) based on the 30 yr of 1971–2000 in view of the reliability of the prophase data of NCEP and the climatic base time 30 yr used currently. We can see from this figure that there are remarkable negative values over SPR region with the center at the Wuyi Mountains. The correlation values exceed the significance level 95% or 99%, respectively. This indicates that, when SPR establishes later (earlier), the summer rain over SEC tends to be less (more).

Figure 2c displays the compositive vector field of the correlations between $T_{\rm spr}$ and the u, v components of the 850-hPa wind in summer. It can be seen that there are notable abnormal southwesterly at the southeastern flank of the TP, and southeasterly at the northeastern flank, northeasterly at the north flank, and westerly at the southwestern flank, respectively. They form an abnormal cyclonic circulation surrounding the TP. This indicates that, the later (earlier) the SPR establishes, the stronger (weaker) the EASM is, and the more north (south) the summer rain is. At the same time, it is noticeable that, there is an abnormal anticyclonic circulation over SPR region, right corresponding to the high negative correlations area in Fig.2b. This makes it clear that the strengthening of the cyclonic circulation surrounding the TP weakens the cyclonic circulation and decreases the rain over the SEC in summer. This is the same reason as that the rain over the SEC does not increase but decreases when the height of TP increases exceeding 6 km and results in the weakening of the cyclonic circulation over the SEC in numerical sensitivity experiments (Wan and Wu, 2007).

4. Relationships between the decay time of the SCS sub-high and the circulation and precipitation of EASM

The analyses of the climatic causes of SPR (Wan and Wu, 2007) made it clear that, at 850 hPa, the geopotential height at the northwestern flank of the SCS sub-high (representing the intensity of the west ridge of the SCS sub-high) reaches its peak phase in the end of December, starts to decrease slowly in

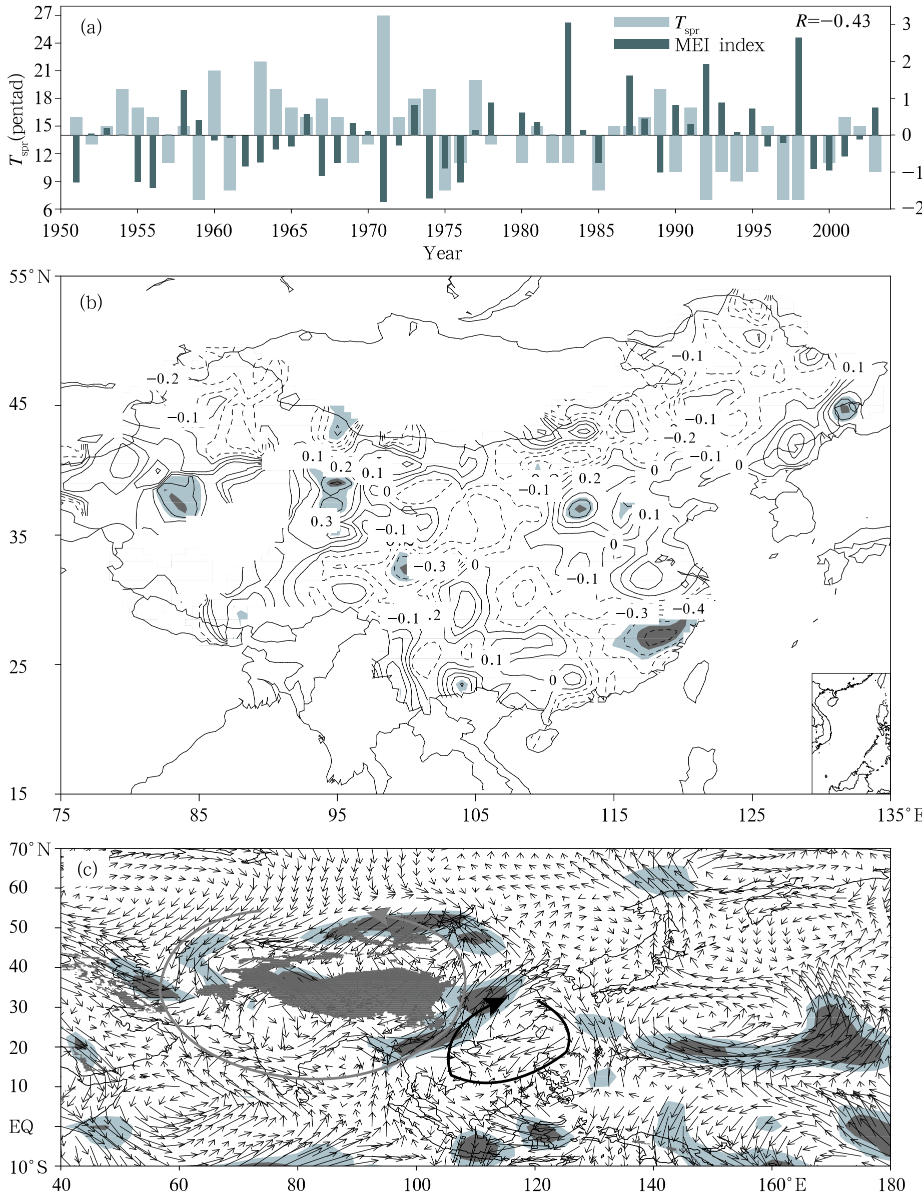

Fig.2. (a) Interannual variations of the SPR onset time T_{spr} (unit: pentad) and standardized MEI index in March, (b) correlation field between T_{spr} and the summer precipitation (June-August) over China mainland within 1971–2000, and (c) compositive vector field of the correlations between T_{spr} and the u, v components of the wind at 850 hPa (June-August) within 1971–2000. Grey shaded areas are the t-test significance at the 95% or 99% levels, respectively. Black shaded regions are over the 1800-m elevation.

in January, maintains in February or even increases slightly in the end of February while decreases rapidly in March. The rate of the decrease of the geopotential height keeps up with the rate of the intensifying of the southwest warm low so as to maintain the southwesterly jet. That is, around the onset of SPR, there is a remarkable inflexion in the seasonal evolution curve of the geopotential height. The inflexion can be taken as a symbol of the onset of SPR. Thus we select the decay time of the geopotential height as an index T_{hgt}. Just like T_{spr}, from P7 on, the pentadly mean geopotential height of the SCS sub-high west ridge (C: 15°–20°N, 110°–115°E; Fig.1) is below 1525 gpm (the climatological mean value of the inflexion), and the condition must be met at least in one pentad among the following three pentads. The pentad which meets all the above conditions is taken as the decay pentad of the SCS sub-high. Accordingly, the series of $T_{\rm hgt}$ index is constructed within 1951–2003.

Figure 3 shows the interannual variations of $T_{\rm hgt}$ and the fields of its correlations to the circulation and precipitation of EASM. In Fig.3a, the decay time of SCS sub-high has remarkable interannual variations too. The earliest is P7 and the latest is P20 (1998). The average time within 53 yr is P9.5, quite different from the climatological mean SPR onset time P13. The reason needs further studying.

The correlation between $T_{\rm hgt}$ and MEI (in March) within 53 yr is 0.64, much higher than the 99% significance level in t-test. This indicates the close relationship between them. That is, when ENSO is in its warm (cold) state, the SCS sub-high tends to decay

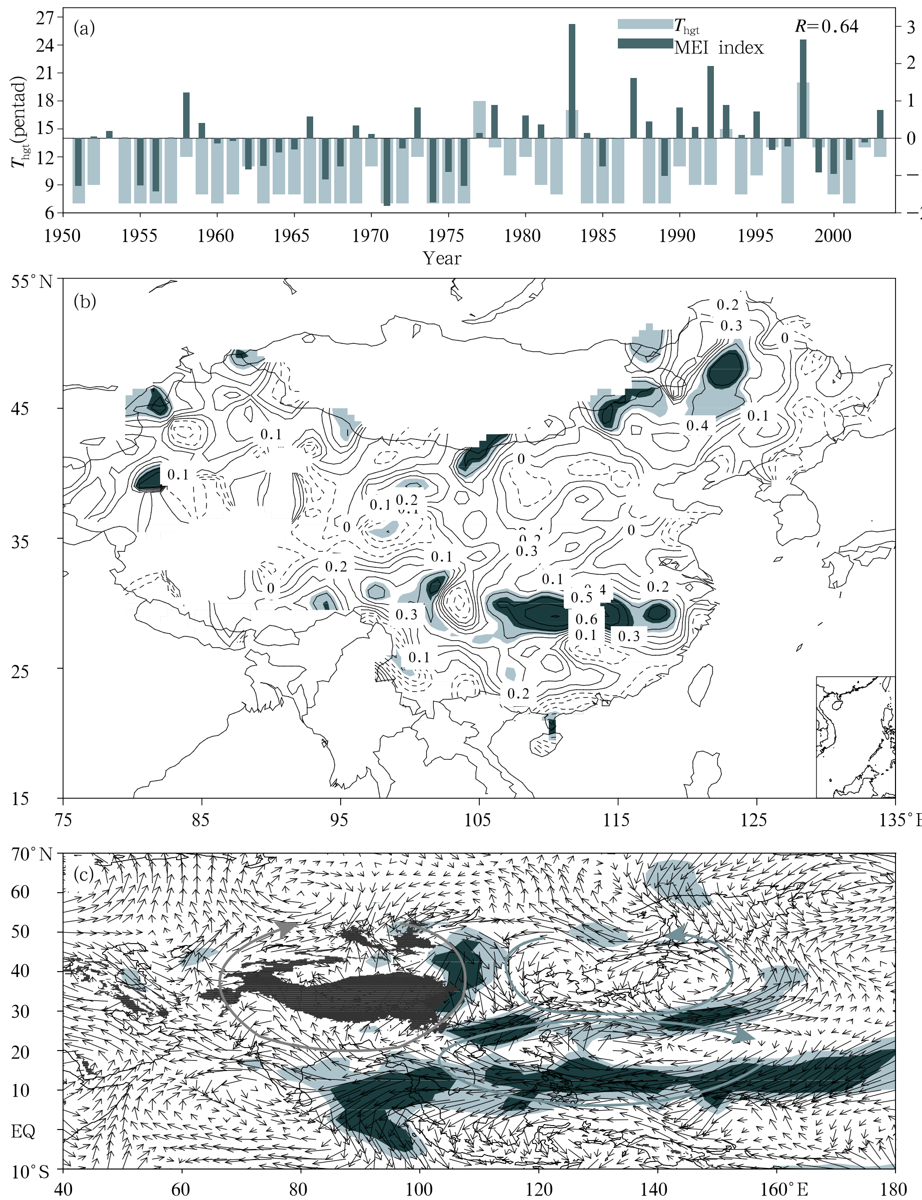

Fig.3. (a) Interannual variations of the west ridge decay time $T_{\rm hgt}$ (unit: pentad) of the SCS sub-high and standardized MEI index, (b) correlation field between $T_{\rm hgt}$ and the summer precipitation (June-August) over China mainland within 1971–2000, and (c) compositive vector field of the correlations between $T_{\rm hgt}$ and the u, v components of the wind at 850 hPa (June-August) within 1971–2000. The shaded area indicates the same as Fig.2.

later (earlier). This result is consistent with the case statistics of the effect of the intensity of SCS sub-high on summer rain in China (Chen, 1998).

Figure 3b displays the correlation field between $T_{\rm hgt}$ and the summer rain in China. It can be seen clearly that there is an abnormal significant positive correlation belt over MLYR. The center of the belt is located near the Three Gorges of the Yangtze River and most of the correlation values are higher than the 99% significance level. This indicates that the later (earlier) the SCS sub-high decays, the more (less) rain will be over MLYR. Besides, another high significant positive area appears over the middle-north part of Northeast China. The two high significant positive areas just superpose the maximum variation areas of the summer rain in China (figure omitted). The above correlations are much higher than the correlations between MEI and the summer rain over MLYR (figure omitted). Thus it can be seen that, comparatively, the SCS sub-high decay time index is a better leading signature to the summer rain over MLYR. Therefore, it can be considered as an important operational forecast factor for the EASM.

Figure 3c displays the compositive vector field of the correlations between $T_{\rm hgt}$ and the u, v components of the 850-hPa wind in summer. This figure suggests, when the SCS sub-high decays late, the West Pacific sub-high strengthens and results in abnormal anti-cyclonic circulation. At the same time, there are cyclonic circulations in middle latitudes and anti-cyclonic circulations in Mongolia and the Okhotsk Sea of the middle-high latitudes. Thus the southwesterly from the strengthening of the SCS sub-high and the northerlies from the anti-cyclonic circulation in the middle-higher latitudes construct an abnormal cyclonic circulation over MLYR and induce more rain there. And the more rain over the reaches of Nenjiang River is owing to the abnormal southeasterly between the cyclonic circulation in middle latitudes and the anti-cyclonic circulation over the Okhotsk Sea. The abnormal circulation pattern at the low level troposphere in East Asia is consistent with the study of Wu et al. (2003) who disclosed that the abnormal geopotential height at 500 hPa presents "$+-+$" pattern in meridian direction when EASM weakens.

In addition, the northerly from the abnormal anti-cyclonic circulation over Mongolia appears at the east flank of the TP, abnormal easterly appears at the subcontinent south to the TP, and abnormal southerly appears at west flank of the TP. Thus there is an abnormal anti-cyclonic circulation surrounding the TP. This indicates that the later (earlier) the SCS sub-high decays, the weaker (stronger) the EASM is.

It is notable that, at the tropical convergence zone near 10°N, there is an abnormal significant easterly belt with a length of 10000 km or more prevailing from the middle Pacific to the east of South Asia. What causes it? It is well known that the strongest climatic external forcing is abnormal sea temperature, and ENSO is the most important coupled ocean-atmosphere phenomenon to cause global climate variability on interannual time scales. The intensity of EASM is also related to ENSO. When ENSO is in cold phase, the West Pacific water is prone to be warmer, the West Pacific sub-high is prone to be weaker, and the EASM is prone to be stronger so as to strengthen the cyclonic circulation in EASM region. The abnormal cyclonic circulation in Fig.2c is mainly relates to it. On the contrary, when ENSO is in warm phase, the above variables tend to be reverse, the abnormal anti-cyclonic circulation in Fig.3c is mainly related to it. At the same time, the extra strong West Pacific sub-high forms planetary-scale abnormal easterlies at its south flank and thus weakens the westerly in the tropical convergent zone of EASM. Besides, it induces abnormal cross-equatorial southward flows near 90°E.

The two abnormal circulations similarly surrounding the TP indicate that the circulation surrounding the TP is sensitive to the precedent spring climatic features. Thus it is necessary to study the precedent thermal state of the TP and its relationships to the circulation and precipitation of EASM. Such studies have been a few. For example, Wu and Qian (2003) pointed out that the precedent winter and spring snow cover of the TP has important effects on the EASM. Duan (2004) found, in March, the temperature of middle-high troposphere over the TP is highly correlated to the onset date of the summer monsoon in the Bay of Bengal.

In addition, it can be seen in above two circulation correlation fields that, the strong anti-cyclonic circulation appearing over the SCS often favors more rain over MLYR, while that over SEC favors less rain over SEC. Thus the position of the abnormal sub-high is very important and it is closely related to ENSO. On the other hand, the same abnormal southwesterly has different characters. The southwesterly in Fig.2c is mainly caused by abnormal sensible heating pumping of the TP while the southwesterly in Fig.3c is mainly caused by the pressure gradients between the abnormal SCS sub-high and the southwest warm low. The former induces less rain over SEC while the latter induces more rain over MLYR and they form the completely different abnormal distributions of circulation and precipitation over East Asia. Obviously, the TP plays a vital role in the abnormal distribution of the summer rain over East Asia.

In recent years, for domestic short-term climate forecasters, the most impressing thing was that, the year 1997/1998 was a typical strong El Niño year, and thus forecasting the Yangtze River and the Nenjiang River would have big floods in 1998. The forecast was extremely successful. However, year 1999 was a typical strong La Niña year, and thus forecasting the main rain belt very likely would move to the Yellow River Valley. Unfortunately, the fact was the main rain belt stayed in MLYR and south to it. The forecast was extremely false. Sun and Ding (2003) made particular analyses on this problem and pointed out that, the most abnormal warm SSTs in recent 20 years prevailed over the SCS and tropical West Pacific from spring 1998 to 1999. The persistence of the abnormal strong sea-air coupling made the local thermal forcing be the main external forcing factor on the abnormal monsoon and rain in East Asia and thus made the activities and rain of the summer monsoon in 1999 quite different from general. Nevertheless, Fig.3a shows that the decay time of the SCS sub-high in 1999 was not ahead of schedule on the effect of the La Niña. On the contrary, it was remarkably late, just corresponding to the summer flood over MLYR and SEC. The similar events occurred in 1977, 1996, and 2002. This demonstrates that it is not an occasional phenomenon and is worthy of further study.

5. The relationships between the factors in SPR period

According to Fig.1, the area mean rain over Region A represents the SPR rain intensity $I_{\rm spr}$. The area mean velocity in southwest direction over upstream region B represents the intensity of the southwesterly $I_{\rm vsw}$. And the area mean geopotential height at 850 hPa over Region C represents the SCS sub-high west ridge intensity $I_{\rm hgt}$. Table 1 shows the correlations between them within 1971–2000. The bold values are higher than the 95% significance level in t test.

Table 1. Correlations between the factors in SPR period within 1971–2000

	$T_{\rm spr}$	$T_{\rm hgt}$	$I_{\rm spr}$	$I_{\rm vsw}$
$T_{\rm spr}$	**1**	–	–	–
$T_{\rm hgt}$	−0.03	**1**	–	–
$I_{\rm spr}$	**−0.45**	0.23	**1**	–
$I_{\rm vsw}$	**−0.45**	−0.17	**0.45**	**1**
$I_{\rm hgt}$	−0.09	**0.58**	0.14	−0.19

Table 1 shows that the correlation value between $T_{\rm spr}$ and $I_{\rm spr}$ is −0.45, exceeding 95% significance level, indicating that the onset time of SPR is a profound leading factor to the following overall rain of SPR. In addition, the correlation between $I_{\rm spr}$ and $I_{\rm vsw}$ is 0.45, indicating that SPR rain will increase when the southwesterly over South China strengthens. This reflects the significance of the southwesterly to the climatic formation of SPR. On the other hand, the value between $T_{\rm hgt}$ and $I_{\rm hgt}$ is 0.58, higher than the 99% significance level, indicating that the west ridge will decay later when SCS sub-high strengthens. The relationship between $T_{\rm hgt}$ and $T_{\rm spr}$ is very weak and the value is −0.03, indicating that they are linearly independent. This is a very interesting phenomenon and needs further analyzing. Nevertheless, the linearly independence provides the convenience for the climate prediction.

6. Conclusion and discussion

This article constructs SPR onset time index and SCS sub-high decay time index and analyzes the relationships between the variables in SPR period and their connections to the circulation and rain of EASM. The analyses make it clear, when SPR rain comes late, the summer rain over SEC decreases, mainly because the strengthening of EASM and the cyclonic circulation surrounding the TP induces abnormal anticyclonic circulation over SEC (cyclonic circulation weakening) and leads to less rain over SEC. When the SCS sub-high decays late, it is prone to flood over the middle-lower reaches of the Yangtze River and to the south, mainly because the SCS sub-high is stronger and the EASM is weaker, the abnormal southwesterly from the stronger SCS sub-high and the abnormal northerly from abnormal anti-cyclonic circulation in North China converge over the middle-lower reaches of the Yangtze River and yield more rain there. Though they are all closely related to ENSO multi-variable index MEI, the SPR onset time index and the SCS sub-high decay time index are not related to each other obviously. The interesting linear independence is worthy of further study. After all, the significant correlations between the two indexes and the circulation and rain of EASM provide important forecast clues for the circulation and rain of EASM.

Therefore, regarding the prediction of the SPR rain and the summer flood-season rain in East China, firstly we need to pay attention to the evolution and developing trend of ENSO, the global climate background factor. Secondly, we need to analyze the evolutions and developing trends of SCS sub-high and the thermal character over the TP. The facts of the abnormal circulation of EASM surrounding the TP indicate that, as the biggest and steepest plateau on the Earth, the TP has a profound influence on the intensity of EASM. Its leading thermal conditions are especially notable. SCS sub-high, as a part of the West Pacific sub-high, is the ligament between the tropical and sub-tropical weather and climate anomalies. The interactions between it and TP are especially important to the weather and climate anomalies in East Asia. Therefore above two factors are worthy of wide attentions in the theoretical studies or operational forecasts. ENSO, as the biggest and strongest external forcing, has great and profound influences on the global weather and climate. The inconsistence between it and the SCS sub-high decay time needs thorough research. Moreover, many efforts in this article are preliminary, like selecting criteria of time indexes and so on, and wait for further studies.

REFERENCES

Chen Juying, 1998: The strengthening of the South China Sea subtropical high is the strong signal of the summer flood in the Yangtze River Valley. *Disaster Reduction in China*, **8**(3), 20–23. (in Chinese)

Duan Anmin, Mao Jiangyu, and Wu Guoxiong, 2004: Predictability analysis and preliminary application of the Bay of Bengal summer monsoon onset. *Plateau Meteorology*, **23**(1), 18–25. (in Chinese)

Gao Hui and Wang Yongguang, 2007: On the weakening relationship between summer precipitation in China and ENSO. *Acta Meteor. Sinica*, **65**(1), 131–137. (in Chinese)

Huang Jiayou, Liu Ge, and Zhao Xinyi, 2004: The influence of subtropical high indexes and polar vortex indexes on the summertime precipitation in China. *Chinese J. Atmos. Sci.*, **28**(4), 517–526. (in Chinese)

Peng Jingbei, Chen Lieting, and Zhang Qingyun, 2005: Multi-scale variations of snow cover over QXP and tropical Pacific SST and their influences on summer rainfall in China. *Plateau Meteorology*, **24**(3), 366–377. (in Chinese)

Sun Ying and Ding Yihui, 2003: A study on physical mechanisms of anomalous activities of East Asian summer monsoon during 1999. *Acta Meteor. Sinica*, **61**(4), 406–420. (in Chinese)

Tian, S.-F., and T. Yasunari, 1998: Climatological aspects and mechanism of spring persistent rains over central China. *J. Meteor. Soc. Japan*, **76**(1), 57–71.

Wan Rijin and Wu Guoxiong, 2007: Mechanism of the spring persistent rains over southeastern China. *Sci. in China (Ser. D)*, **50**(1), 130–144.

Wan Rijin and Wu Guoxiong, 2008: Temporal and spatial distribution of the spring persistent rains over southeastern China. *Acta Meteor. Sinica*, **66**(3), 310–319. (in Chinese)

Wolter, K., and M. S. Timlin, 1998: Measuring the strength of ENSO—how does 1997/98 rank? *Weather*, **53**, 315–324.

Wu Shangsen, Liang Jianyin, and Li Chunhui, 2003: Relationship between the intensity of South China Sea summer monsoon and the precipitation in raining seasons in China. *Journal of Tropical Meteorology*, **19**(S1), 25–36. (in Chinese)

Wu T. W., and Qian Z.-A., 2003: The relation between the Tibetan winter snow and the Asian summer monsoon and rainfall: An observational investigation. *J. Climate*, **16**(12), 2038–2051.

Yang Mingzhu, Ding Yihui, Li Weijing, et al., 2007: Leading mode of Indian Ocean SST and its impacts on Asian summer monsoon. *Acta Meteor. Sinica*, **65**(4), 527–536. (in Chinese)

Yu Rucong, Zhang Minghua, Yu Yongqiang, et al., 2000: Summer monsoon rainfall over mid-eastern China lagged correlated with global SSTs. *Advances in Atmospheric Sciences*, **18**(2), 179–196.