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IMPACTS OF MONTHLY ANOMALIES OF INTRASEASONAL OSCILLATION OVER SOUTH CHINA SEA AND SOUTH ASIA ON THE ACTIVITY OF SUMMER MONSOON AND RAINFALL IN EASTERN CHINA

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Abstract: The impact of strong (weak) intraseasonal oscillation (ISO) over South China Sea (SCS) and South Asia (SA) in summer on the SCS and SA summer monsoon and the summer rainfall in Eastern China are studied by using the NCEP-NCAR analysis data and the rainfall data of 160 stations in China from 1961 to 2010. It is found that the impacts are significantly different in different months of summer. The study shows that in June and July cyclonic (anticyclonic) atmospheric circulation over SCS and SA corresponds to strong (weak) ISO over SCS. In August, however, strong (weak) ISO over SCS still corresponds to cyclonic (anticyclonic) atmospheric circulation over SA. In June and August cyclonic (anticyclonic) atmospheric circulation over South Asia corresponds to strong (weak) ISO over SA while a strong (weak) ISO corresponds to anticyclonic (cyclonic) atmospheric circulation over SA in July. Besides, in June the strong (weak) ISO over SA corresponds to cyclonic (anticyclonic) atmospheric circulation over SCS, while in July and August the atmospheric circulation is in the same phase regardless of whether the ISO over SA is strong or weak. The impacts of the strong (weak) ISO over SCS on the rainfall of eastern China are similar in June and July, which favors less (more) rainfall in Yangtze-Huaihe Rivers basin but sufficient (deficient) rainfall in the south of Yangtze River. However, the impacts are not so apparent in August. In South Asia, the strong (weak) ISO in July results in less (more) rainfall in the south of Yangtze River but sufficient (deficient) rainfall in Yangtze-Huaihe Rivers basin. The influence on the rainfall in eastern China in June and August is not as significant as in July.

Key words: ISO; atmospheric circulation; rainfall; South China Sea and South Asia

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1 INTRODUCTION

Atmospheric Intraseasonal Oscillation (ISO) is one of the important atmospheric circulation systems on a time scale from 20 to 90 days. A lot of studies have shown that the ISO has a significant impact on the change of weather and climate, especially in the tropical and subtropical atmosphere. Therefore, many scientists have done a series of researches on the ISO since its discovery in 1970s at home and abroad (Madden and Julian[1, 2]; Krishnamurti and Subrahmanyan[3]; Murakami[4]; Lau and Chan[5]; Li[6, 7]; Dong and Li[8]).

The Asian monsoon is the strongest and most typical monsoon system in the globe. Having experienced a long history, the research on the Asian monsoon has been significantly improved since the 1980s. One of the important signs was the finding of the 30-60-day oscillation of monsoon. The Asian monsoon is composed of two related but somewhat independent subsystems; one being the South Asian (Indian) monsoon system and the other the East Asian monsoon system. The South China Sea (SCS) summer monsoon is not only an important part of the East Asian summer monsoon, but also plays an important role on the establishment of the East Asian summer monsoon and the South Asian summer monsoon. Previous studies notice that the Asian summer monsoon breaks out in the SCS region first, and then propagates northwestward and northward, making the south Asian summer monsoon and the East Asian summer monsoon established (Tao and Chen [9]). Since the 1980s, more and more scholars have paid attention to the research of the SCS summer monsoon, such as the outbreak of the SCS summer monsoon activities and the impacts of the SCS summer monsoon. Some studies have indicated a good relationship between the anomaly of the SCS summer monsoon and the rainfall in Yangtze-Huaihe Rivers basin during the flood season. Strong (weak) SCS summer monsoon corresponds to the

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deficient (sufficient) rainfall in the Yangtze-Huaihe Rivers basin during the flood season (Li and Zhang[10]; Yang and Li[11]).

The ISO of the tropical atmosphere is most active in the Asian summer monsoon area, which has a close relationship with the onset and the strength of the SCS summer monsoon. Thus, scientists gradually studied the monsoon and the ISO together, including the impact of ISO on the onset of the summer monsoon, as well as the influence on the change and the anomaly of the summer monsoon (Lau et al.[12]; Vernekar and Ji[13]; Li et al.[14]; Wu and Liang[15]; Xu and Zhu[16]; Li et al.[17]; Chen et al.[18]; Ju and Zhao [19]). Analysis of the ISO activity showed that the atmospheric ISO at 850 hPa in the SCS region is strong (weak) corresponding to the strong (weak) SCS summer monsoon (Li et al.[20]). They also showed that the strong/weak SCS summer monsoon circulation (200 hPa and 850 hPa) result mainly from abnormal atmospheric ISO. Qi et al.[21] analyzed the role of the atmospheric ISO in the establishment and the interannual variability of the Indian summer monsoon, and found that the ISO has an important effect on the establishment of the Indian summer monsoon, as well as on the seasonal variability of the Indian summer monsoon. They also revealed that the contribution of the ISO to the monsoon is mainly reflected in the nonlinear dynamic effects, which affected the seasonal change of monsoon by the convergence or divergence of the horizontal transportation of the low-frequency west disturbance momentum in seasonal time scale. The correlation analysis indicated that the mean seasonal intensity of the ISO has a significant negative correlation with the interannual change of the intensity of the monsoon in the Indian summer monsoon region. When the ISO is strong (weak), there is anticyclonic (cyclonic) anomaly of the circulation in the low troposphere on the Indian subcontinent, corresponding to weak (strong) monsoon.

Indeed, most of the previous studies have aimed at the average of summer. However, not only the activity of the monsoon and the atmospheric ISO but also the precipitation in Eastern China has remarkable monthly variation (Xuan et al.[22]). In addition, the relation between atmospheric ISO and the summer monsoon is also different in different months of summer. In order to understand the relationship between atmospheric ISO and monsoon variability very well, it is necessary to analyze the cases of June, July and August, respectively. In this paper, the impacts of the monthly anomalies of intraseasonal oscillation over SCS and South Asian on the activity of the summer monsoon and the summer rainfall in Eastern China will be analyzed month by month.

2 DATA AND METHODOLOGY

The daily mean variable fields for the period of 1961 to 2010 on a 2.5°×2.5° mesh from the National Centers for Environmental Prediction and National Center for the Atmospheric Research (NCEP/NCAR) reanalysis are the basic data used in this study. Also used is the precipitation data of 160 stations from 1961 to 2010 in China derived from the National Climate Center. In this study, the last days of February in leap years were excluded, so 28 days are chosen in every year. In the analysis, the South China Sea (SCS) domain is chosen to be 105°–120°E, 10°–20°N, and the South Asia 60°–100°E, 5°–25°N.

Band-pass Butterworth filter and synthetic analysis are used in this paper.

3 MONTHLY VARIABILITY OF THE MONSOONS AND SELECTION OF STRONG (WEAK) YEARS OF ISO

In order to get the field of the 50-year average low-frequency kinetic energy in summer and in June, July and August respectively from 1961 to 2010, the meridianal wind u and zonal wind v data at 850 hPa were filtered through a 30-60-day band-pass filter. Then, the kinetic energy distribution of the atmospheric ISO can be obtained easily. Fig.1 shows that the kinetic energy of ISO in SCS has significant monthly variation on average. The monthly variation of the ISO kinetic energy is not remarkable in SA, because it is much smaller than in SCS. The average of the ISO kinetic energy is 3.47 m^2/s^2 in SCS but only 2.47 m^2/s^2 in SA in June (Fig. 1a). In July the ISO kinetic energy in SCS increases to 4.15 m^2/s^2 (Fig.1b). The ISO kinetic energy in SCS keeps increasing in August to 5.39 m^2/s^2 (Fig.1c). The ISO kinetic energy in SCS is stronger than in SA at 850 hPa in summer, and the ISO kinetic energy in SCS is strongest in August while the strongest ISO kinetic energy in SA is in July.

To isolate the strong and weak years of ISO kinetic energy in the three months of summer respectively, Fig.2 shows the interannual change of the 50-year average ISO kinetic energy in SCS and SA in June from 1961 to 2010. A specific value is defined to extract the strong (weak) years. If the monthly average ISO kinetic energy is more (less) than this value in a year, then the year is assumed as a strong (weak) year, or as a normal year. According to the aforementioned definition, we choose the following 14(11) years as strong (weak) ISO kinetic energy years of June in the SCS monsoon region: 1967, 1972, 1974, 1979, 1981, 1982, 1984, 1985, 1991, 1992, 2003, 2004, 2006 and 2009 (1965, 1968, 1970, 1977, 1978, 1983, 1989, 1993, 1995, 1997 and 2000). And we also choose the following 14 (11) years as strong (weak) ISO kinetic energy years of June in the SA monsoon region: 1971, 1972, 1975, 1979, 1980, 1984, 1985, 1986, 1987, 1992, 1996, 2004, 2005 and 2007 (1961, 1965, 1966, 1969, 1970, 1976, 1995, 1999, 2000, 2009 and 2010). Analogously, we select 13 (15) years as strong (weak) ISO kinetic energy years of July in the SCS monsoon region and 11 (12) years as strong (weak) ISO kinetic energy years of July in the SA mon-

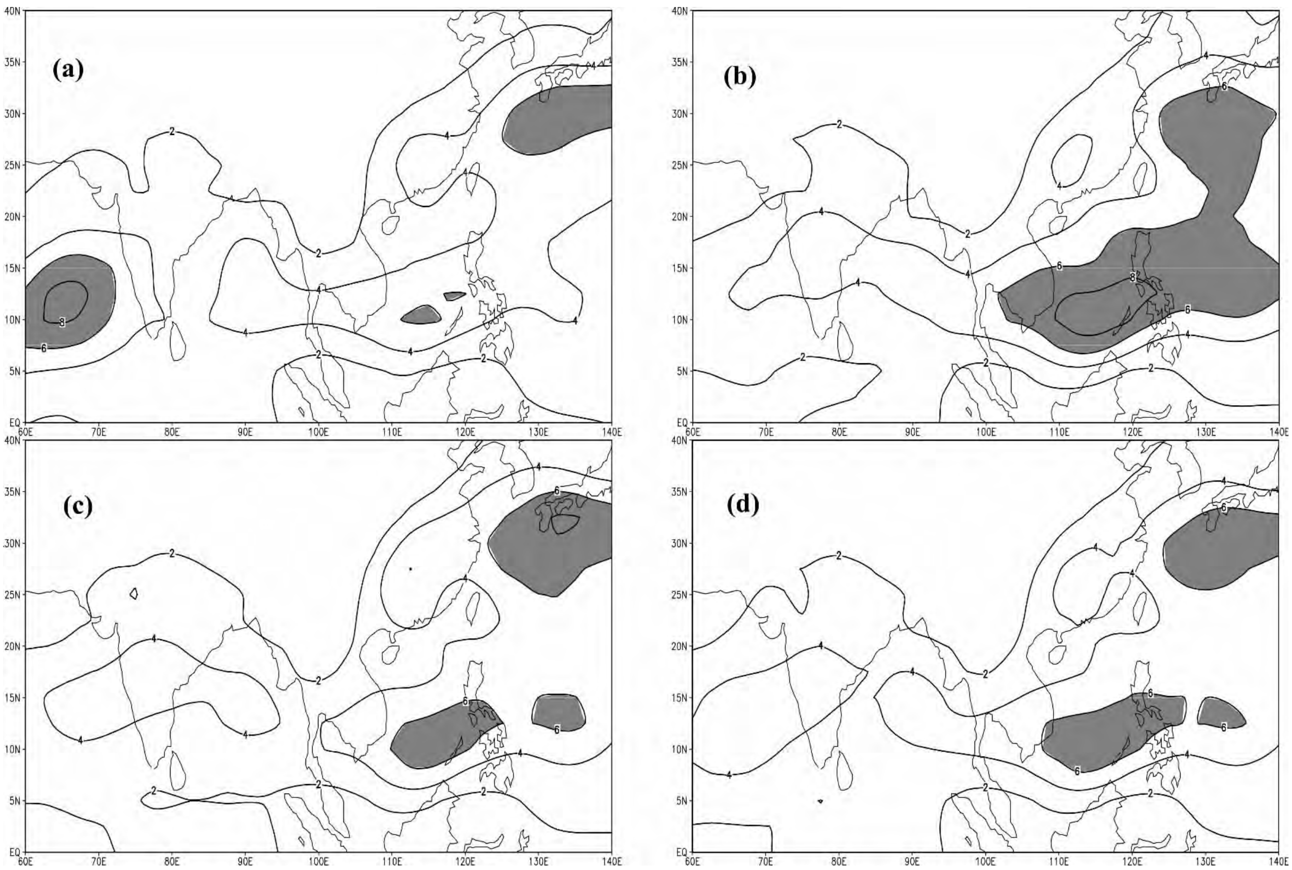

Figure 1. 50-year average ISO kinetic energy (m^2/s^2) of June (a), July (b), August (c) and the whole summer (d) from 1961 to 2010, with the grey areas indicating the value bigger than 4.

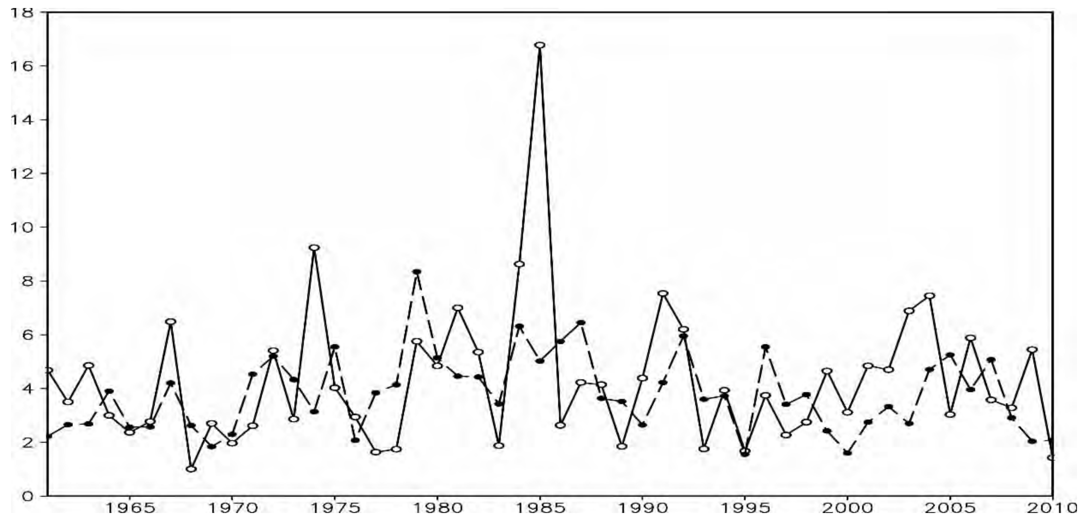

Figure 2. Interannual change of the ISO kinetic energy of June in SCS (solid line) and SA (dashed line) from 1961 to 2010.

soon region. 12 (15) years are also selected as strong (weak) ISO kinetic energy years of August in the SCS monsoon region and 11(12) years as strong (weak) ISO kinetic energy years of August in the SA monsoon region.

We find that the ISO kinetic energy in SCS of the three months in summer has a positive correlation with that in SA, with the correlation coefficient being 0.48, 0.56 and 0.66 respectively, which have all passed the significance test of 99%. Therefore, the same strong (weak) years of SCS and SA will be excluded in the following analysis of the impacts of the monthly anomalies of ISO over SCS and SA on the activity of the summer monsoon. As a result, only the independently strong (weak) years in the two areas will be chosen.

4 IMPACT OF MONTHLY ANOMALIES OF ISO OVER SCS ON THE ACTIVITY OF SUMMER MONSOON AND RAINFALL IN EASTERN CHINA

4.1 *Impact in June*

Composite wind anomaly fields at 850 and 200 hPa for the strong ISO years and weak ISO years over SCS in June are shown in Fig.3. It can be shown that in strong ISO years, there is east wind anomaly over South China and west wind anomaly over SCS and Philippine waters at 850 hPa (Fig.3a), so a cyclonic anomaly circulation is formed over SCS. Meanwhile, west wind anomaly controls the southern area of SA and weaker east wind anomaly controls the area from the northern part of the Bay of Bengal to the North Arabian Sea, so there is the same cyclonic anomaly circulation over SA. Otherwise, in weak ISO years (Fig.3b), weak west wind anomaly prevails over both South China and the northern area of SCS while strong east wind anomaly over the southern area of SCS and Philippine waters, so that there is an anticyclonic anomaly circulation over SCS. However, in weak ISO years of SCS, most part of the Bay of Bengal is controlled by east wind anomaly and the circulation over SA does not present an opposite circulation with strong ISO years.

In addition, in strong ISO years of June over SCS, there is an anticyclonic anomaly circulation at 200 hPa over China (Fig.3c), with the ridge line at 35°N. While in weak ISO years (Fig.3d), west wind anomaly controls the 30°–35°N zone from the Arabian Sea to the Bay of Bengal and Eastern China at 200 hPa, with east wind anomaly over the Arabian Sea to the Bay of Bengal and SCS at the 15°–30°N zone. Therefore, there is an anticyclonic anomaly circulation over the 15°–35°N zone.

As we know, the SCS summer monsoon is mainly composed of southwesterlies while the SA summer monsoon is mainly composed of zonal wind. Thus, aforementioned characteristics of the anomaly wind at 850 and 200 hPa can suggest that in strong ISO years of June over SCS, a cyclonic anomaly circulation prevails over both SCS and SA with a stronger South Asian high and the location of the high is northward. While in weak ISO years of June over SCS, an anticyclonic anomaly circulation prevails over both SCS and SA, and the South Asian high is still stronger with southward location.

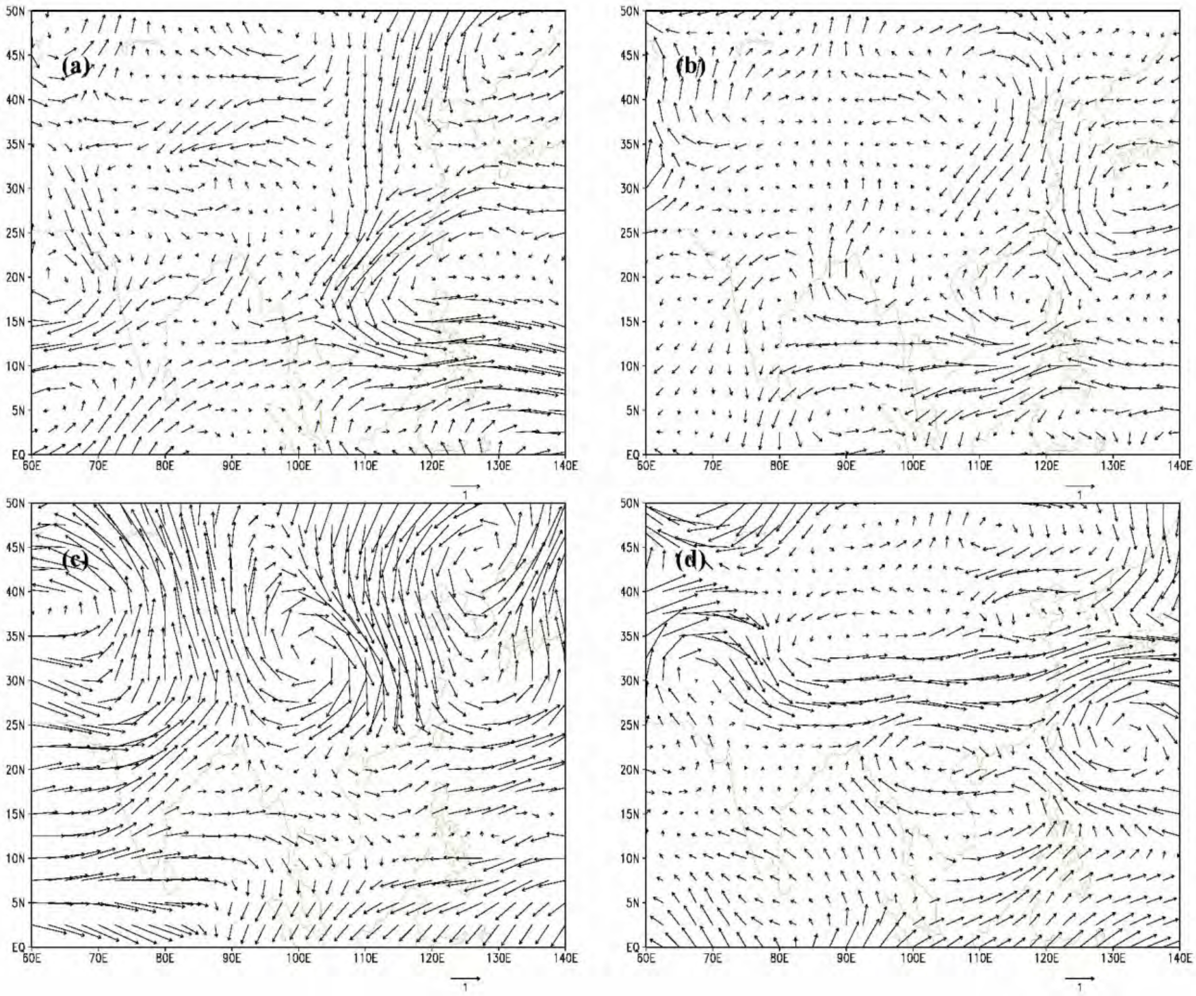

Figure 3. Composite wind anomaly fields at 850 hPa (a and b) and 200 hPa (c and d) for the strong ISO years (a and c) and weak ISO years (b and d) over SCS in June.

The precipitation anomaly shown in Fig.4 indicates that in strong ISO years of June over SCS, the rainfall is deficient in the Yangtze-Huaihe Rivers basin, but sufficient in the south of Yangtze River basin and South China. On the other hand, in weak ISO years of June over SCS, the rainfall is sufficient in the Yangtze-Huaihe Rivers basin while deficient in the south of Yangtze River basin and South China.

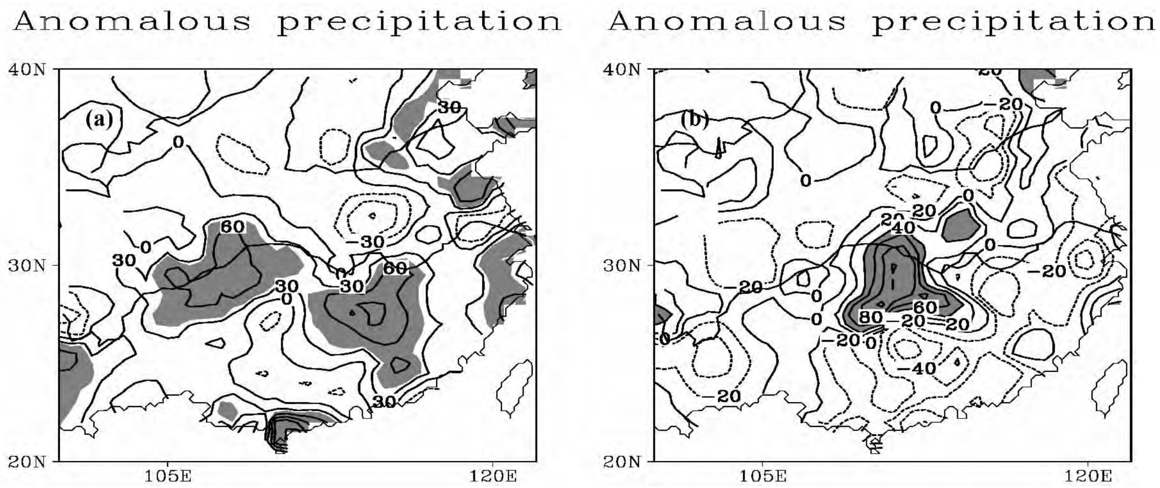

Figure 4. Composite rainfall anomaly of June in China in strong (a) and weak (b) ISO years over SCS, with the grey areas indicating values larger than 40 mm.

According to the analysis above, we can know that in strong (weak) ISO years of June over SCS, both SCS and SA are controlled by a cyclonic (anticyclonic) anomaly circulation and the South Asian high is strong with northward (southward) location. The rainfall is deficient (sufficient) in Yangtze-Huaihe Rivers basin but sufficient (deficient) in the south of Yangtze River basin and South China in strong (weak) ISO years of June over SCS.

4.2 *Impact in July*

Similarly, composite analysis is used in the study of July in strong and weak ISO years over SCS. It is found that the circulation in July is different from that in June. In strong ISO years of July over SCS (Fig.5a), west wind anomaly controls SCS and the southern area of South China at 850 hPa, with east wind anomaly controlling the northern area of South China and the south of Yangtze River basin, so there is a cyclonic anomaly circulation over SCS and South China. Meanwhile, there is also a huge cyclonic anomaly circulation over the area from the Bay of Bengal to the North Arabian Sea. Otherwise, in weak ISO years of July over SCS (Fig.5b), east wind anomaly prevails over SCS and west wind anomaly over the south of Yangtze River basin and South China. Therefore, an anticyclonic anomaly circulation is formed over SCS and South China. The southern area of the Bay of Bengal and the Arabian Sea are controlled by weak west wind anomaly, while the Bay of Bengal and the North Arabian Sea are controlled by weak east wind anomaly. As a result, there is also an anticyclonic anomaly circulation over SA.

The wind anomaly at 200 hPa (Fig.5c and 5d) shows that in strong ISO years, most areas of East Asia are controlled by an anticyclonic anomaly circulation. In weak ISO years, an east-west anticyclonic anomaly circulation over middle latitudes of Asia is very obvious, because east wind anomaly prevails over the area south of 30°N and west wind anomaly over the area of 30°–40°N.

Therefore, according to the analysis above, we can conclude that strong (weak) ISO years of July over SCS correspond to a cyclonic (anticyclonic) anomaly circulation over SCS and SA. Regardless of strong or weak ISO years of July over SCS, the South Asian high is strong, which is similar to the case of June.

The rainfall anomaly of July shown in Fig.6 indicates that in strong ISO years of July over SCS (Fig.6a), the rainfall is deficient in the Yangtze-Huaihe Rivers basin but sufficient in the south of Yangtze River basin and South China. In weak ISO years of July over SCS (Fig.6b), the rainfall in Yangtze-Huaihe Rivers basin and the east of Yangtze River basin is sufficient but deficient in South China.

4.3 *Impact in August*

The impact of the anomalies in August over SCS on the activity of summer monsoon and rainfall is very different from that in June and July. In Fig.7a, it is clear that in strong ISO years of August over SCS, east wind anomaly prevails over South China and the Yangtze River basin, while west wind anomaly prevails over SCS, so there is a cyclonic anomaly circulation over SCS and South China at 850 hPa. However, in weak ISO years of August over SCS (Fig.7b), west wind anomaly controls the south area of South China, while the area from SCS to Philippine waters is controlled by east wind anomaly. Therefore, an anticyclonic anomaly

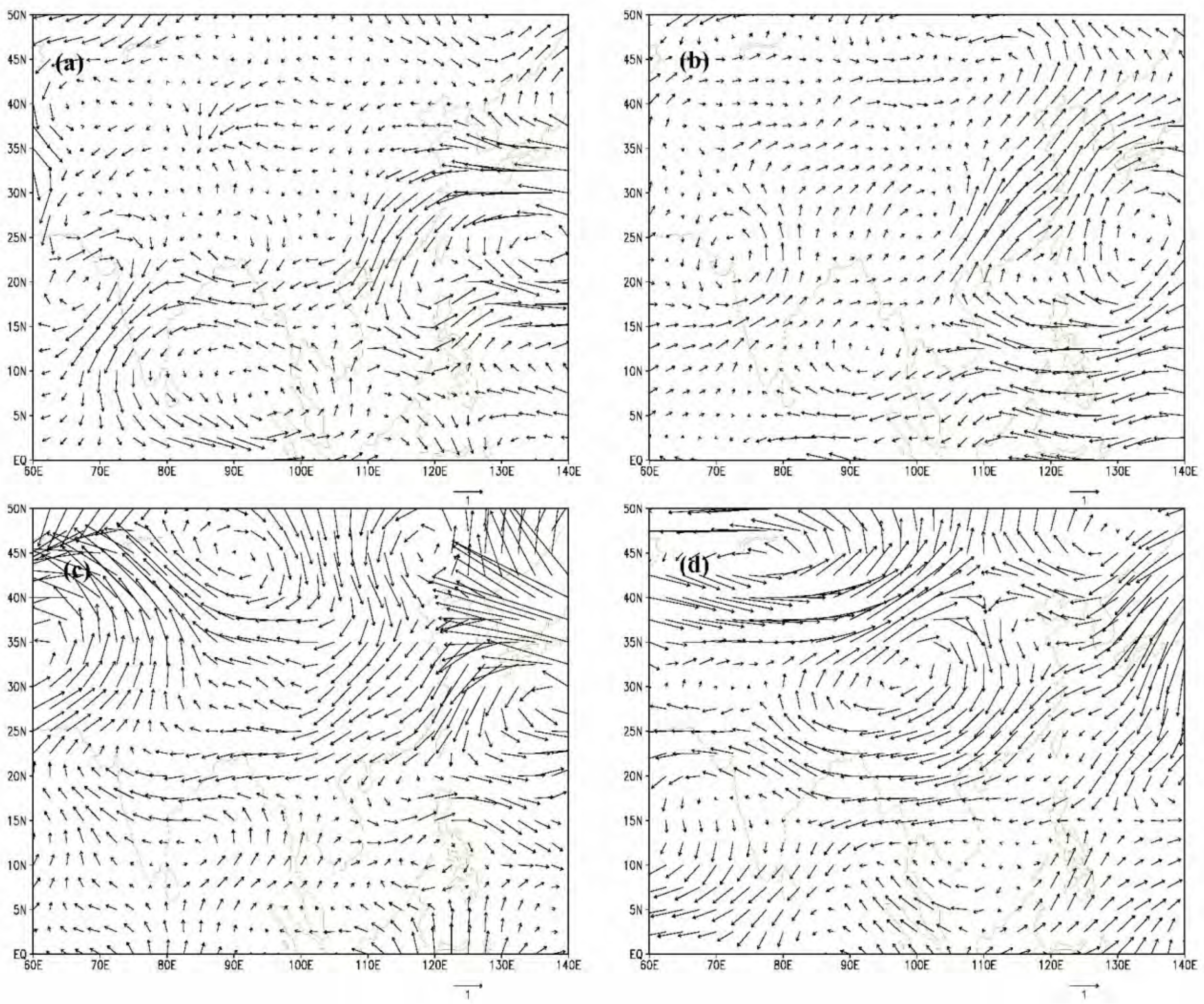

Figure 5. Same as Fig.3 but for July.

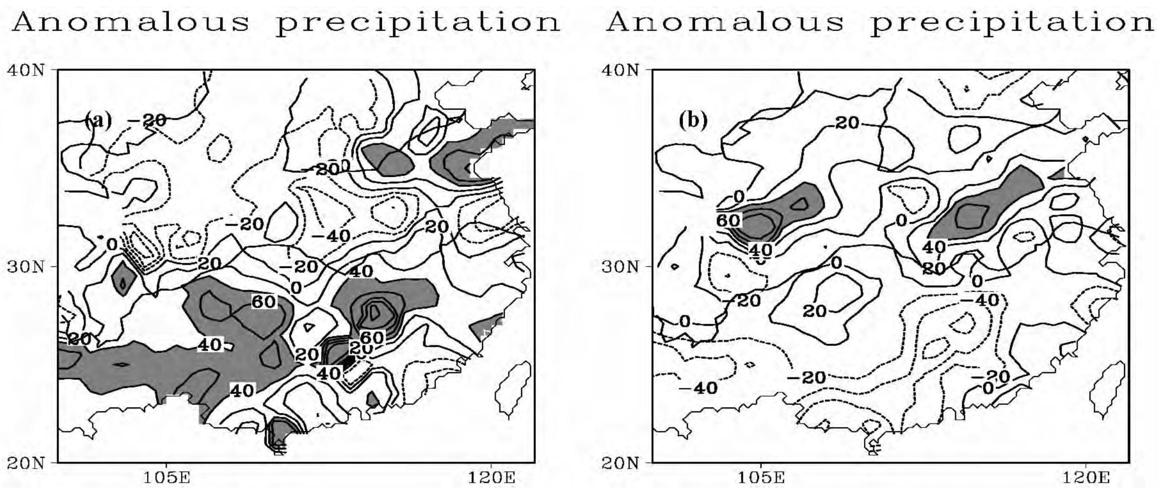

Figure 6. Same as Fig.4 but for July.

circulation is formed over South China and SCS at 850 hPa. We can also see in Fig.7a and 7b that there is an anticyclonic anomaly circulation over the north of the Bay of Bengal at 850 hPa in strong ISO years of August over SCS while a cyclonic circulation in weak ISO years. Besides, the wind filed at 200 hPa shows different distribution in ISO anomaly years of August over SCS. In strong ISO years, an easterly belt controls the area of 30°–40°N while a westerly zone controls the area of 15°–25°N from the Arabian Sea to SCS, which results in a powerful cyclonic anomaly circulation at 200 hPa. In weak ISO years, the area from South China

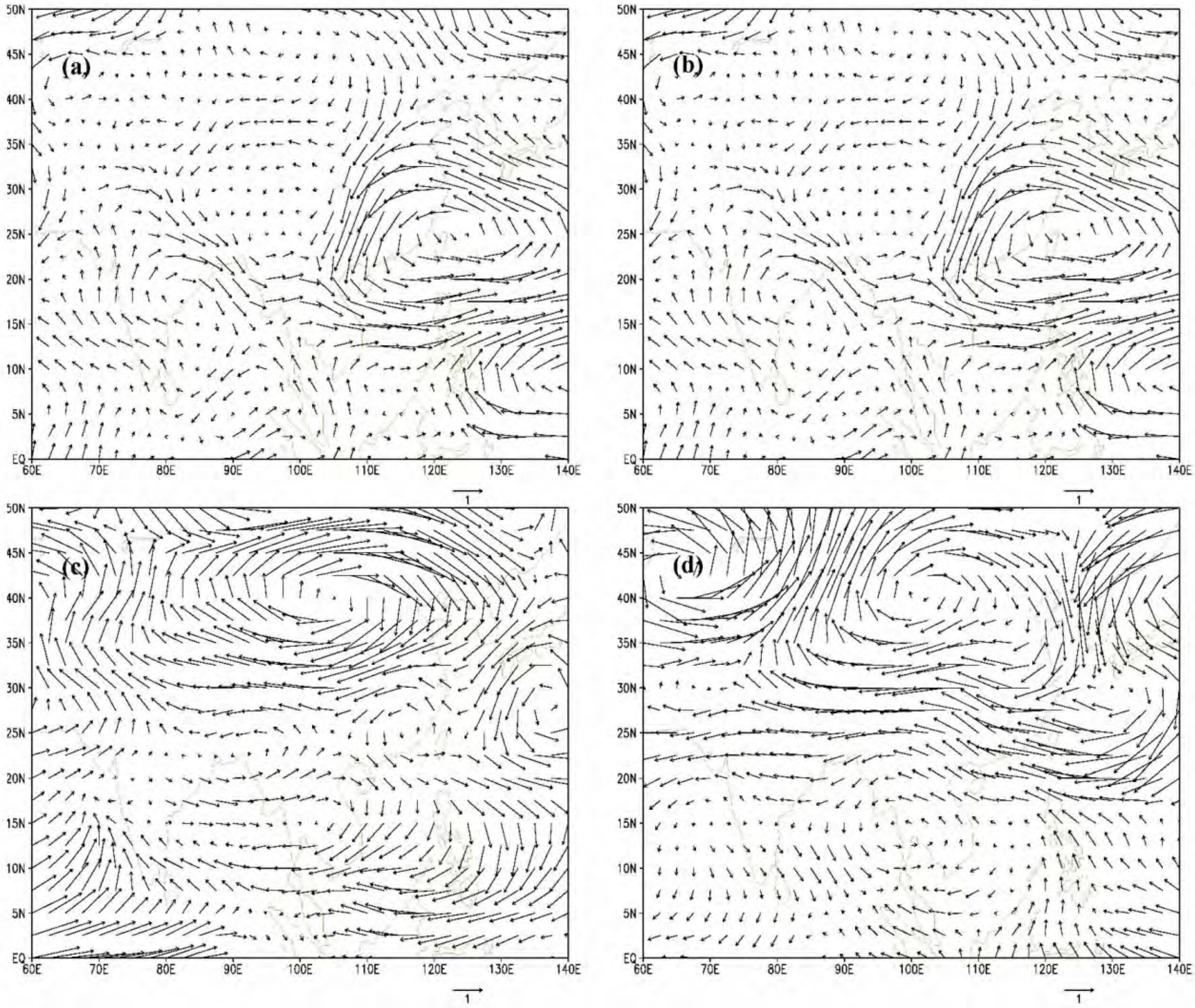

Figure 7. Same as Fig.3 but for August.

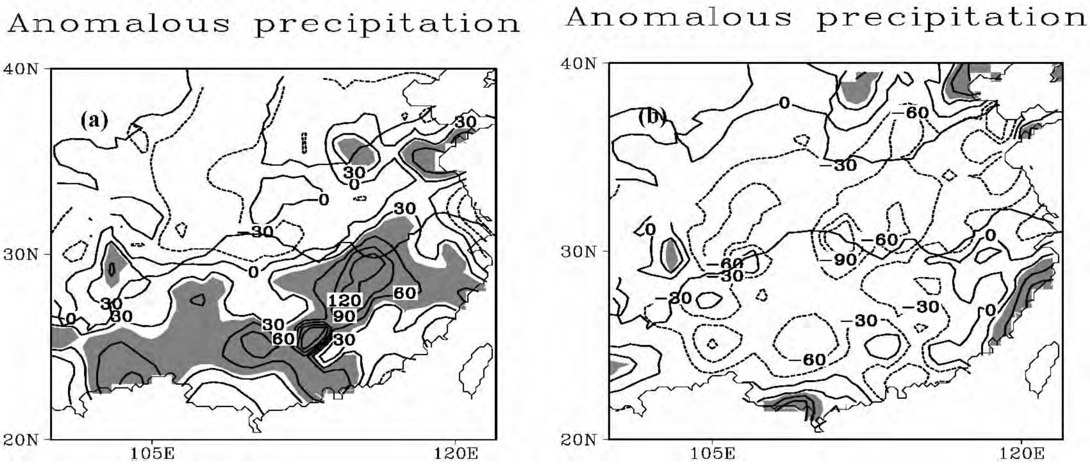

Figure 8. Same as Fig.4 but for August.

to Yellow River-Huaihe River basin is controlled by east anomaly wind with west anomaly wind over the north area, so there is an anticyclonic anomaly circulation at 200 hPa. The center of the anticyclonic circulation in weak ISO years is more northward than the center of the cyclonic circulation in strong ISO years.

Above all, in strong (weak) ISO years of August over SCS, a cyclonic (anticylonic) circulation prevails over SCS, and an anticyclonic (cyclonic) circulation prevails over SA. The South Asia high is weaker and more southward in strong ISO years than in weak ISO years. The precipitation anomaly in August shows that in strong ISO years, the rainfall is sufficient in most areas of Eastern China. In weak ISO years, however, the rainfall is sufficient in the south of Yangtze Rive basin and the east of South China but it is deficient in Yangtze-Huaihe Rivers basin. The rainfall anomaly in August is corresponding to the atmospheric circulation anomaly, but it is very different from that in June and July. This is why the current study is done on a monthly basis.

5 IMPACT OF MONTHLY ANOMALIES OF ISO OVER SA ON THE ACTIVITY OF SUMMER MONSOON

Having studied the impact of monthly anomalies of ISO over SCS on the activity of summer monsoon and the rainfall in Eastern China, we found that the impact in different month is different. Does the SA summer monsoon have the same characteristics? In the following part, the relationship between the strength of the ISO over SA and the activity of Asia summer monsoon will be studied month by month.

5.1 *Impact in June*

We can see in Fig.9 that in strong ISO years of June over SA, there is a cyclonic anomaly circulation over the Bay of Bengal and the Arabian Sea at 850 hPa. There is also a cyclonic anomaly circulation over SCS at 850 hPa. On the contrary, in weak ISO years of June over SA, there is an obvious anticyclonic anomaly circulation over the area from the north of SCS to Yangtze River basin, and the Bay of Bengal is also controlled by an anticyclonic anomaly circulation. In other words, in strong (weak) ISO years of June over SA, a cyclonic (anticyclonic) anomaly circulation is over both SCS and SA at 850 hPa. Besides, in strong ISO years of June over SA, a huge anticyclonic anomaly circulation controls the area from Eastern China to Tibetan Plateau. In weak ISO years of June over SA, the anticyclonic anomaly circulation still exists, but it is stronger and more eastward than in strong ISO years.

The precipitation anomalies of China in ISO anomaly years of June over SA (Fig.10) shows that in strong ISO years, the rainfall is deficient in the south of Yangtze River basin and South China in June but it is sufficient in the basins of Yangtze-Huaihe Rivers and

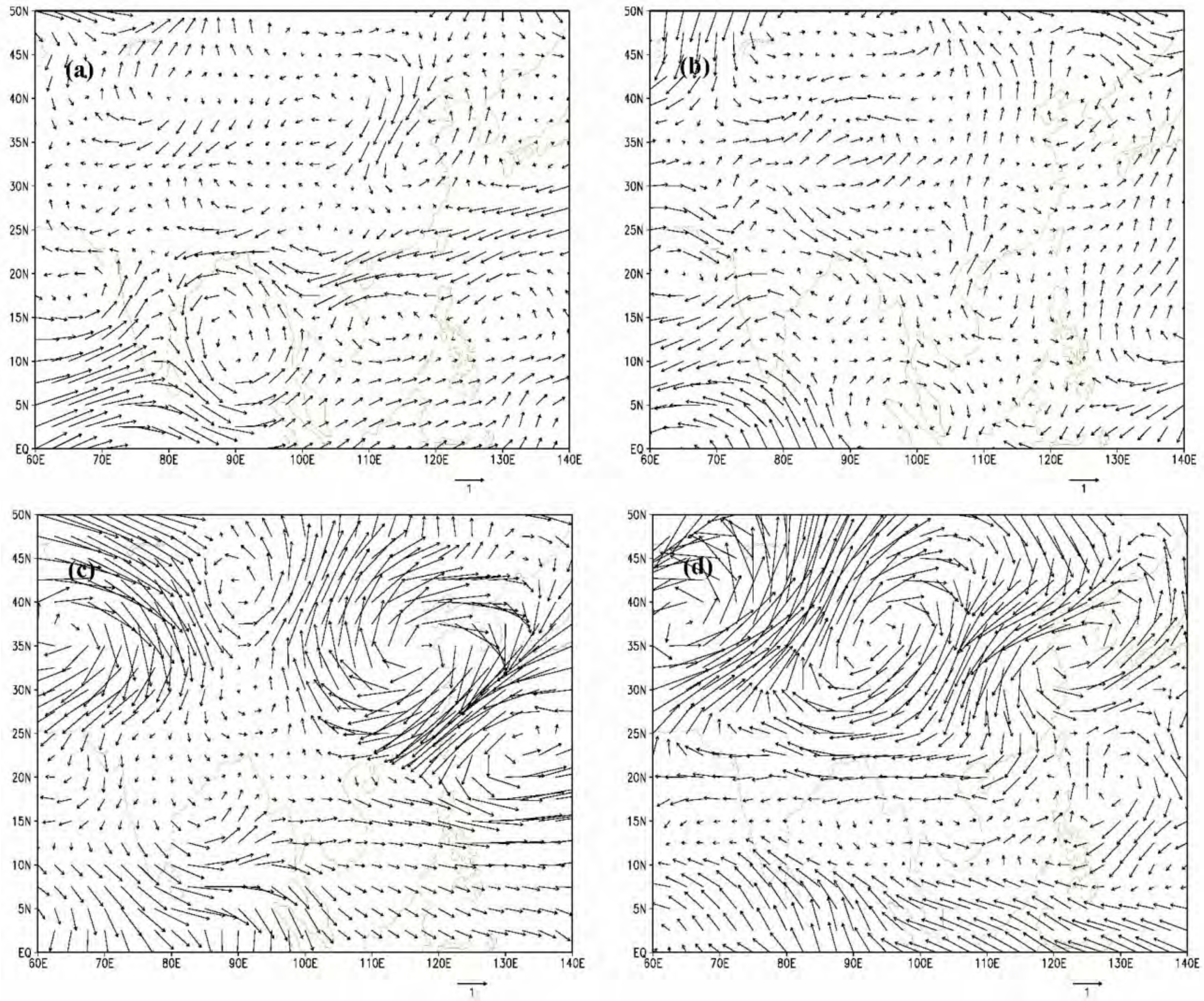

Figure 9. Composite wind anomaly fields at 850 hPa (a and b) and 200 hPa (c and d) for the strong ISO years (a and c) and weak ISO years (b and d) over SA in June.

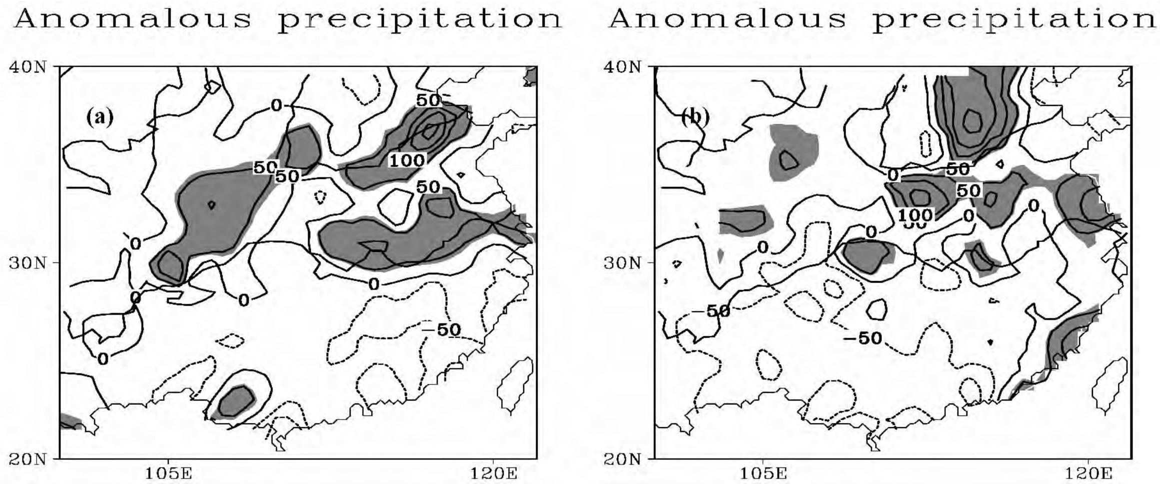

Figure 10. Composite rainfall anomaly of June in China in strong (a) and weak (b) ISO years over SA, with the grey areas indicating the value bigger than 40 mm.

Yellow River-Huaihe River. In weak ISO years, the rainfall is sufficient in Yangtze-Huaihe Rivers basin, Yellow River-Huaihe River basin and the east of South China but deficient in the south of Yangtze River basin and the west of South China.

According to the analysis above, we can conclude that in strong (weak) ISO years of June over SA, both SCS and SA are controlled by a cyclonic (anticyclonic)

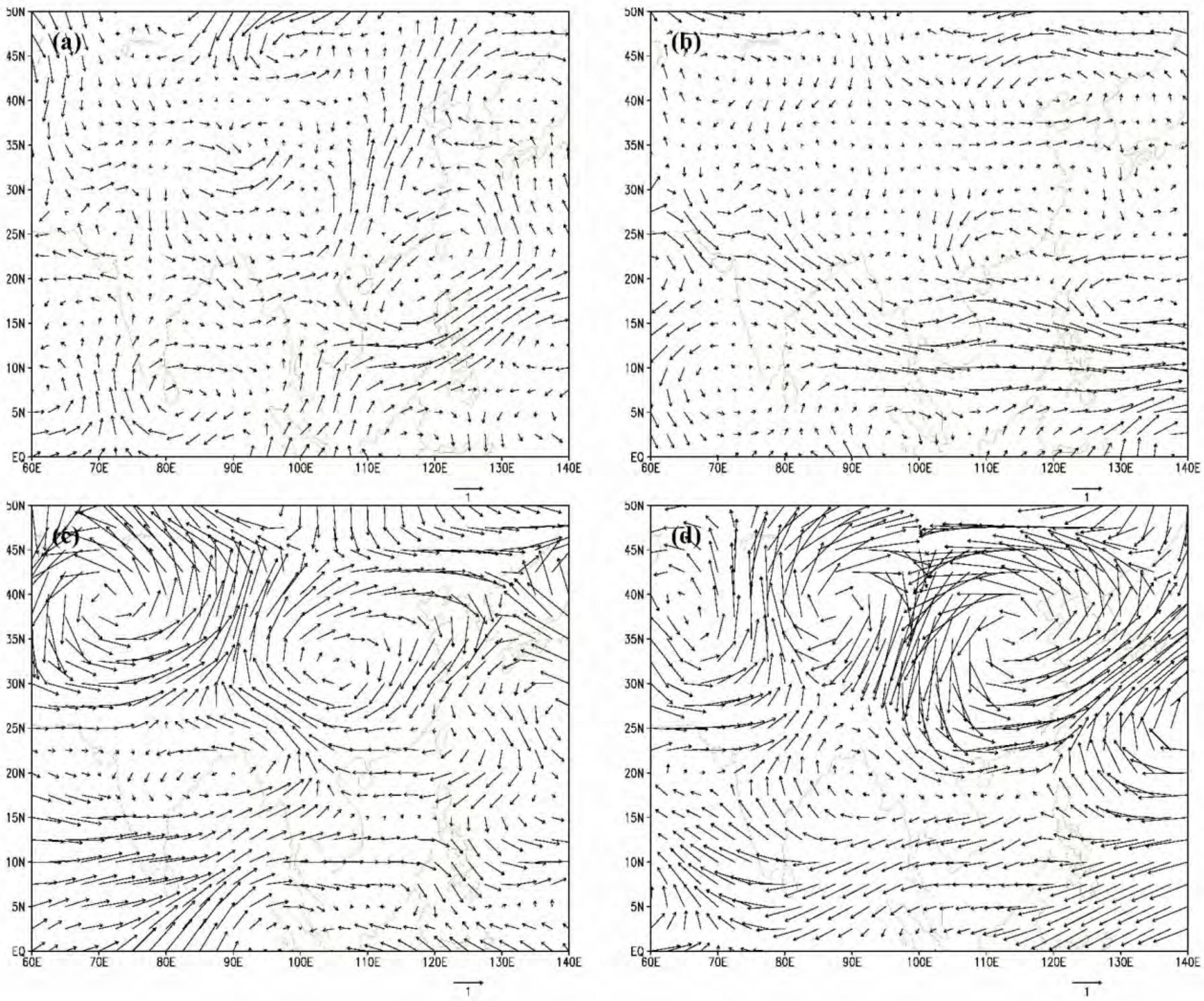

Figure 11. Same as Fig.9 but for July.

anomaly circulation at 850 hPa, and the South Asia high is stronger (weaker). The rainfall is deficient in the south of Yangtze River basin and South China in June but sufficient in Yangtze-Huaihe Rivers basin, Yellow River-Huaihe River basin in strong ISO years. However, the rainfall is sufficient in Yangtze-Huaihe Rivers basin, Yellow River-Huaihe River basin and the east of South China but still deficient in the south of Yangtze River basin and the west of South China in weak ISO years.

5.2 *Impact in July*

Is the impact in July similar to that in June? In Fig. 11, it is shown that in strong ISO years of July over SA, east anomaly wind prevails over SCS, the Bay of Bengal and the Arabian Sea at 850 hPa, while South China and middle and lower reaches of the Yangtze River are controlled by west anomaly wind. Therefore, an anticyclonic anomaly circulation is formed over East China, South China and SCS. Besides, the Bay of Bengal and the Arabian Sea are controlled by an anticyclonic anomaly circulation. In weak ISO years of July over SA, an anticyclonic anomaly circulation prevails over the area from the sea east off the island of Taiwan to Southeast China with a cyclonic anomaly circulation prevailing over the central and northern area of the Bay of Bengal and the Arabian Sea at 850 hPa. The wind anomaly field at 200 hPa also exhibits an opposite situation correspondingly. In strong ISO years of July over SA, there is an anticyclonic anomaly circulation over the area from East China to the Tibetan Plateau at 200 hPa. However, in weak ISO years of July over SA, the latitude zone from 15°N to 35°N is controlled by a cyclonic anomaly circulation, the center of which is more westward and southward than the center of the anticyclonic anomaly circulation in strong ISO years.

Thus, in strong ISO years of July over SA, both SCS and SA are controlled by anticyclonic anomaly circulation and the South Asia high is strong. In weak ISO years of July over SA, SCS is still controlled by an anticyclonic anomaly circulation, but SA is controlled by a cyclonic anomaly circulation and the South Asia high is weak. We can see in Fig.12 that in strong ISO years of July over SA, the rainfall is deficient in the south of the Yangtze River but sufficient in the western coastal region of South China and Yangtze-Huaihe Rivers basin. On the contrary, in weak ISO years of July over SA, the rainfall is deficient in Yangtze-Huaihe Rivers basin but sufficient in most part of the south of the Yangtze River.

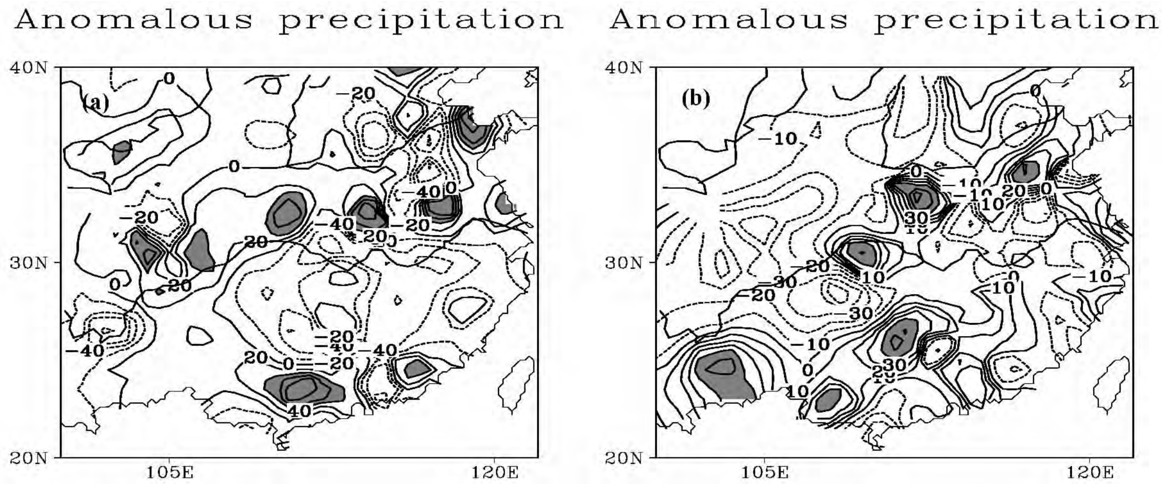

Figure 12. Same as Fig.10 but for July.

5.3 *Impact in August*

The situation in strong/weak ISO years of August over SA is shown in Fig.13. We can see in Fig.13 that in strong ISO years of August over SA, west anomaly wind controls the east costal region of China, South China and SCS at 850 hPa, but the Bay of Bengal and the Arabian Sea are controlled by cyclonic anomaly circulation. In weak ISO years of August over SA (Fig. 13b), the coastal region of South China and SCS are controlled by cyclonic anomaly circulation at 850 hPa, however, the circulation in the Bay of Bengal is contrary to that in strong ISO years. That is to say, the Bay of Bengal and the Arabian sea are both controlled by anticyclonic anomaly circulation at 850 hPa in weak ISO years of August over SA. Therefore, in strong (weak) ISO years of August over SA, SA is controlled by cyclonic (anticyclonic) anomaly circulation. However, SCS is controlled by anticyclonic anomaly circulation in both strong ISO years and weak ISO years. Besides, in strong ISO years of August over SA, west anomaly wind prevails over South China and the south of Yangtze River at 200 hPa with east anomaly wind prevailing over Huang-huai River basin and Yangtze-Huaihe Rivers basin, so there is a huge cyclonic anomaly circulation. Meanwhile, the east anomaly wind prevailing over the south of SCS and the east of

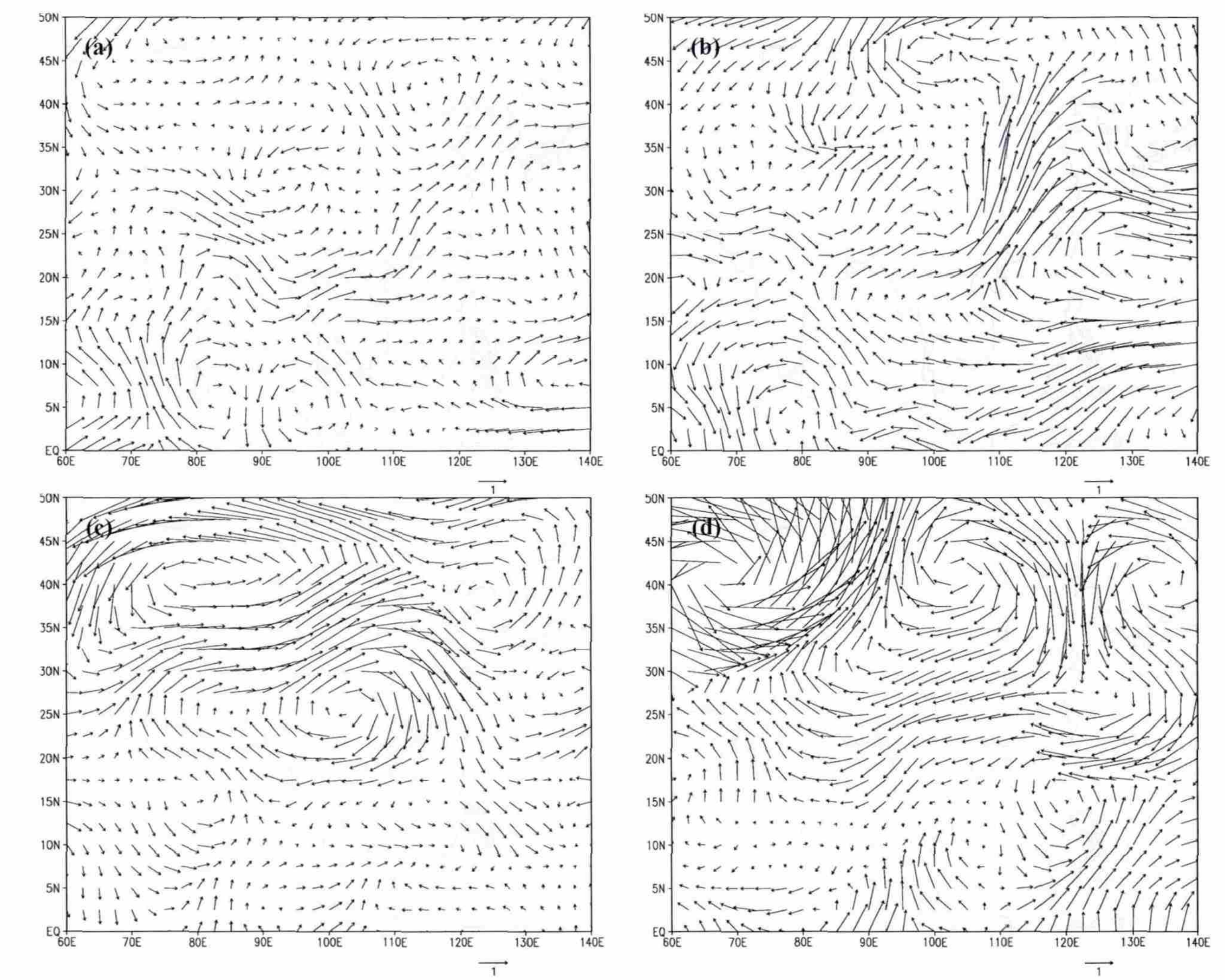

Figure 13. Same as Fig.9 but for August.

the Bay of Bengal, combined with the west anomaly wind in the north, constitutes an anticyclonic anomaly circulation over the plateau, the center of which is southward. In weak ISO years of August over SA, the west anomaly wind prevailing over the area from the Arabian sea to South China, combined with the east anomaly wind over Yangtze-Huaihe and Yellow River-Huaihe River basin, constitutes a cyclonic anomaly circulation over the Tibetan Plateau at 200 hPa.

The composite rainfall anomaly of August in China in strong and weak ISO years over SA (shown in Fig. 14), combined with the anomaly circulation, indicates that in strong ISO years of August over SA, cyclonic anomaly circulation prevails over SA, with a weak South Asia high. Besides, the rainfall is sufficient in the east of Yangtze-Huaihe Rivers basin, Yellow River-Huaihe River basin, the east area of the south of Yangtze River and South China, but deficient in the west of Yangtze-Huaihe River and Yellow River-Huaihe River basin. On the contrary, in weak ISO years of August over SA, anticyclonic anomaly circulation prevails over SA, with a strong South Asia high. The rainfall is sufficient in the east costal of South China but deficient in East China. No matter in strong ISO years or in weak ISO years, SCS is controlled by anticyclonic anomaly circulation. Although the strength of ISO in August over SA has no significant impact on the circulation over SCS, the anomaly circulation over SA affects the rainfall in China.

6 SUMMARY AND DISCUSSION

The impacts of the monthly anomalies of intraseasonal oscillation over SCS and SA on the summer monsoon and the rainfall in China are analyzed in this paper. The results show that the impacts of the monthly anomalies of intraseasonal oscillation over SCS and SA on the summer monsoon and the rainfall in China are different in different month, so they should be studied respectively.

(1) In strong/weak ISO years of June over SCS, both SCS and SA are controlled by cyclonic/anticyclonic anomaly circulation at 850 hPa, and the South A-

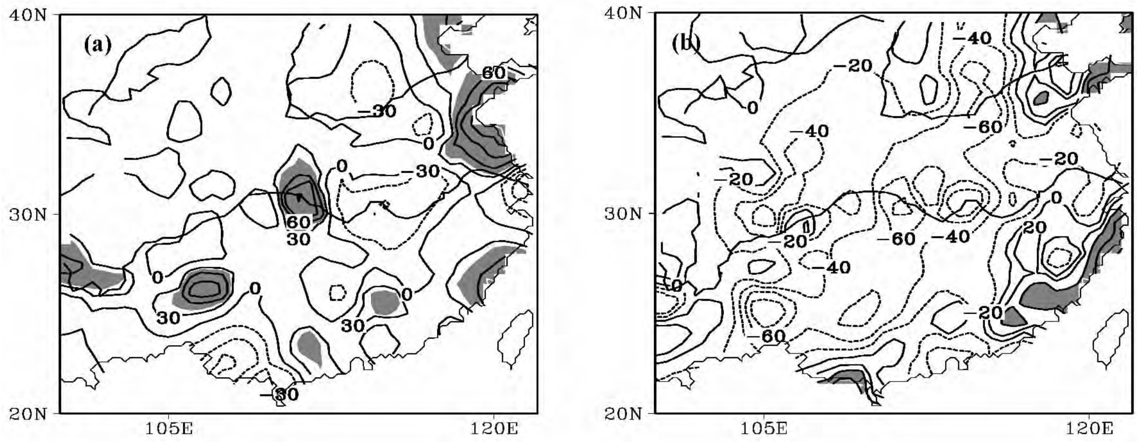

Figure 14. Same as Fig.10 but for August.

sia high is strong in both years, but the position of which is northward/southward. The rainfall is deficient/sufficient in Yangtze-Huaihe Rivers basin, while sufficient/deficient in the south of Yangtze River and South China, corresponding to strong/weak ISO years of June over SCS. In strong ISO years of June over SA, SCS and SA are both controlled by cyclonic anomaly circulation, and the South Asia high is strong. In addition, the rainfall is deficient in the south of Yangtze River and South China but sufficient in Yangtze-Huaihe Rivers and Yellow River-Huaihe River basin. In weak ISO years of June over SA, both SCS and SA are controlled by anticyclonic anomaly circulation, and the South Asia high is weak. The rainfall is sufficient in Yangtze-Huaihe Rivers and Yellow River-Huaihe River basin and the east of South China but still deficient in the south of Yangtze River and the west of South China.

(2) The impacts of the anomalies of ISO over SCS on the summer monsoon in July are similar to that in June, but the impacts on the rainfall of China are different. There is a/an cyclonic/anticyclonic anomaly circulation over both SCS and SA at 850 hPa, with a weak/strong South Asia high, corresponding to strong/weak ISO years of July over SCS. In strong ISO years of July over SCS, the rainfall is deficient in Yangtze-Huaihe Rivers basin but sufficient in the south of Yangtze River and South China. The rainfall in weak ISO years of July does not distribute in an opposite pattern to that in strong ISO years as the situation in June. Instead, in weak ISO years of July over SCS, the rainfall is sufficient in Yangtze-Huaihe Rivers basin and the east of the south of Yangtze River but deficient in South China. The impacts of the anomalies of ISO over SA on the South Asia summer monsoon and the South Asia high in July are similar to that in June, but the impacts on the SCS summer monsoon are not obvious. In strong ISO years of July over SA, both SCS and SA are controlled by anticyclonic anomaly circulation, and the South Asia high is strong. The rainfall is sufficient in the west coastal of South China and Yangtze-Huaihe Rivers basin but deficient in the other areas of the south of Yangtze River. However, in weak ISO years of July over SA, SCS is still controlled by anticyclonic anomaly circulation, but SA is controlled by cyclonic anomaly circulation instead, and the South Asia high is weak. The rainfall in the south of Yangtze River is sufficient except in the east local areas and deficient in the Yangtze-Huaihe Rivers basin.

(3) In strong ISO years of August over SCS, a cyclonic anomaly circulation prevails over SCS, but SA is controlled by an anticyclonic anomaly circulation at 850 hPa. The South Asia high is weak and southward, and the rainfall in East China is sufficient. On the contrary, in weak ISO years of August over SCS, SCS is controlled by an anticyclonic anomaly circulation while SA is controlled by a cyclonic anomaly circulation. The South Asia high is strong and northward, and the rainfall is sufficient in the South of Yangtze River and the east of South China but deficient in Yangtze-Huaihe Rivers basin. In strong ISO years of August over SA, SA is controlled by cyclonic anomaly circulation and the South Asia high is weak. In addition, the rainfall in the east of Yangtze-Huaihe and Yellow-River-Huaihe Rivers basins is sufficient, and the rainfall is also sufficient in the east of the south of Yangtze River and South China, but deficient in the middle region of Yangtze-Huaihe and Yellow-River-Huaihe Rivers basins. In weak ISO years of August over SA, SA is controlled by anticyclonic anomaly circulation and the South Asia high is strong instead. The rainfall is deficient in East China except in the east costal region of South China. SCS is controlled by anticyclonic anomaly circulation whether in strong or weak ISO years of August over SA. So the strength of ISO in August over SA has no impact on the circulation of SCS, but still affects the precipitation in East China. This is another example of South Asia summer monsoon affecting the precipita-

tion in China, which is consistent with the previous findings.

Through the above analysis, it can be concluded that the impacts of the monthly anomalies of intraseasonal oscillation over SCS on the SCS and SA summer monsoon are similar in June and July, while opposite in August. Cyclonic/anticyclonic anomaly circulation over both SCS and SA corresponds to strong/weak ISO years over SCS in June and July. Corresponding to strong/weak ISO years of August over SCS, SCS is still controlled by cyclonic/anticyclonic anomaly circulation, but SA is controlled by anticyclonic anomaly circulation instead. The impacts of the monthly anomalies of intraseasonal oscillation over SA on the summer monsoon and the rainfall of China are quite different from the impacts of the monthly anomalies of intraseasonal oscillation over SCS. In June and August, strong/weak ISO over SA corresponds to cyclonic/anticyclonic anomaly circulation over SA, but in July strong/weak ISO over SA corresponds to anticyclonic/cyclonic anomaly circulation over SA. Strong/weak ISO of June over SA also corresponds to cyclonic/anticyclonic anomaly circulation over SCS. However, whether in strong or weak ISO years of July and August over SA, anticyclonic anomaly circulation prevails over SCS. The precipitation anomaly shows that in strong/weak ISO years of June and July over SCS, the rainfall anomaly in the south of Yangtze River is positive/negative while negative/positive in Yangtze-Huaihe Rivers valley. But in August, the opposite characteristic of the rainfall anomaly in the south of Yangtze River and Yangtze-Huaihe Rivers valley is not obvious in strong/weak ISO years of August over SCS. In strong/weak ISO years of July over SA, the rainfall anomaly in the south of Yangtze River is negative/positive while positive/negative in Yangtze-Huaihe Rivers valley. The impact of the strength of ISO over SA in June and August on the rainfall of East China is not so apparent as that in July. The above results indicate clearly that the impacts of ISO in different months and different areas on the atmospheric circulation and the rainfall can be different. The internal atmospheric forcing has some dependencies on atmospheric base state like the external atmospheric forcing. In this paper, we only get some results of data analysis. Further research, especially research of numerical modeling, should be done in future work to understand the genesis and mechanisms.

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