Strong/ Weak Summer Monsoon Activity over the South China Sea and Atmospheric Intraseasonal Oscillation[①]

Li Chongyin (李崇银), Long Zhenxia (龙振夏) and Zhang Qingyun (张庆云)
LASG, Institute of Atmospheric Physics, Chinese Academy of Science, Beijing 100029

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ABSTRACT

The circulation pattern corresponding to the strong / weak summer monsoon in the South China Sea (SCS) region and the associated characteristics of the abnormal rainfall in Eastern China have been studied by using the NECP reanalysis data and precipitation data in China. The results show that the climate variations in China caused by the strong / weak summer monsoon are completely different (even in opposite phase). The analyses of atmospheric intraseasonal oscillation (ISO) activity showed that the atmospheric ISO at 850 hPa near the SCS region is strong (weak) corresponding to the strong (weak) SCS summer monsoon. And the analyses of the circulation pattern of the atmospheric ISO showed that the strong / weak SCS summer monsoon circulation (200 hPa and 850 hPa) result mainly from abnormal atmospheric ISO.

This study also reveals that the atmospheric ISO variability in the South China Sea region is usually at opposite phase with one in the Jiang-huai River basin. For example, strong (weak) atmospheric ISO in the SCS region corresponds to the weak (strong) atmospheric ISO in the Jiang-huai River basin. As to the intensity of atmospheric ISO, it is generally exhibits the local exciting characteristics, the longitudinal propagation is weak.

Key words: The SCS summer monsoon, Atmospheric intraseasonal oscillation, Circulation pattern

1. Introduction

Asian monsoon activity and its anomaly directly affect the economy and the life of the people in that area, and they also have important effect on the global climate through atmospheric circulation teleconnection. In addition, the monsoon anomaly will impact the occurrence of the important climate events such as ENSO (Li et al., 1989), which is strongest signal of interannual climate variation. Thus, the research on the Asian monsoon has become one of important components in the Climate Variability and Predictability Programme (CLIVAR) (WMO et al., 1995).

During the middle of the 1980s, some Chinese scholars have pointed out clearly that the Asian monsoon is composed of the two related but some kind of independent monsoon subsystems, that is the South Asian (Indian) monsoon system and East Asian monsoon system (Tao and Chen, 1987; Jin and Chen, 1983; Zhu et al., 1986). They also notice that Asian monsoon breaks out in the SCS region first. Since 1990s', the attention has been paid to the SCS summer monsoon research, such as the outbreak of the SCS summer monsoon (He e al., 1997; Liu et al., 1998; Li and Qu, 2000) the activities and the impacts of the SCS summer monsoon. Especially, some studies have indicated the good relationship between the anomaly

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of the SCS summer monsoon and the rainfall in the Jiang–huai River basin during the flood season (Xu and Tao, 1996; Li and Zhang, 1999). Strong (weak) SCS summer monsoon corresponds to the deficient (sufficient) rainfall in the Jiang–huai River basin during the flood season.

On the other hand, the ISO activity is an important characters of the monsoon variability, and the ISO has its own obvious interannual variation (Li, 1993). Thus the relationship between the monsoon variability and atmospheric ISO activity has been paid much attention, which includes the impacts of the atmospheric ISO on the onset of the summer monsoon and on seasonal and interannual variations of the monsoon (Lau and Yang, 1996; Vernekar and Ji, 1999; Zhu and Xu, 1999). But in order to understand the relationship between atmospheric ISO and monsoon variability very well, there are many problems need to be studied.

This work will be carried out along this way to show the relationship. The main task is to compare the feature and activity of the atmospheric ISO in strong SCS summer monsoon years with those in the weak SCS summer monsoon years.

2. Composite pattern in strong and weak SCS summer monsoon years

According to the previous studies (Li and Zhang, 1999; Zhang et al., 2000), we choose following years as strong (weak) SCS summer monsoon years: 1981, 1984, 1985, 1986, 1990, 1992 and 1997 (1980, 1983, 1987, 1989, 1991, 1993 and 1998). We will make composite analyses to strong summer monsoon years and weak summer monsoon years respectively and compared their fundamental differences.

Figure 1 shows the composite wind fields (averaged in JJA) at 850 hPa for the seven strong monsoon years and seven weak monsoon years and their difference field. It can be shown that the stream pattern at 850mb in strong year (Fig. 1a) is primarily similar to the pattern in weak year (Fig. 1b), there still exist obvious differences (Fig. 1c). The main differences are shown: during strong monsoon year, there is strong westerly between 5°N and 20°N, stronger easterly between 5°S and 20°S and anomalous cyclonic circulation in the northeast region of the SCS indicating stronger monsoon trough. Above characteristics can suggest that Strong (weak) SCS summer monsoon is related to 1) the strong (weak) westerly wind over the tropical Indian Ocean; 2) the strong (weak) Somali cross–equatorial flow; 3) the northward (southward) displacement of the ridge of subtropical high over western Pacific.

As we know, the strong Tibetan anticyclone is also a typical characteristic of Asian summer monsoon circulation at the upper troposphere (200 hPa). Thus, it should be understand what is the pattern of the Tibetan anticyclone in strong summer monsoon or weak summer monsoon case. Figure 2 shows the composite summer (Jun. to Aug. average) stream patterns and their difference field at 200 hPa in strong monsoon years and weak monsoon years. To compare Fig. 2a with Fig. 2b, it is shown that there are all strong anticyclone on the Tibetan Plateau both in strong and weak monsoon years. But Fig. 2c shows that the intensity of the Tibetan anticyclone in the strong SCS summer monsoon year is obviously stronger than that in the weak SCS summer monsoon year. The location of the Tibetan anticyclone is relatively northwestward in strong SCS summer monsoon year.

It is known that the activity and the anomaly of the summer monsoon have important effects on the summer climate in China, particularly on the rainfall during the flood season. We have analyzed the circulation patterns corresponding to strong monsoon year and weak monsoon year. Now our attention will be devoted to the precipitation distribution corresponding

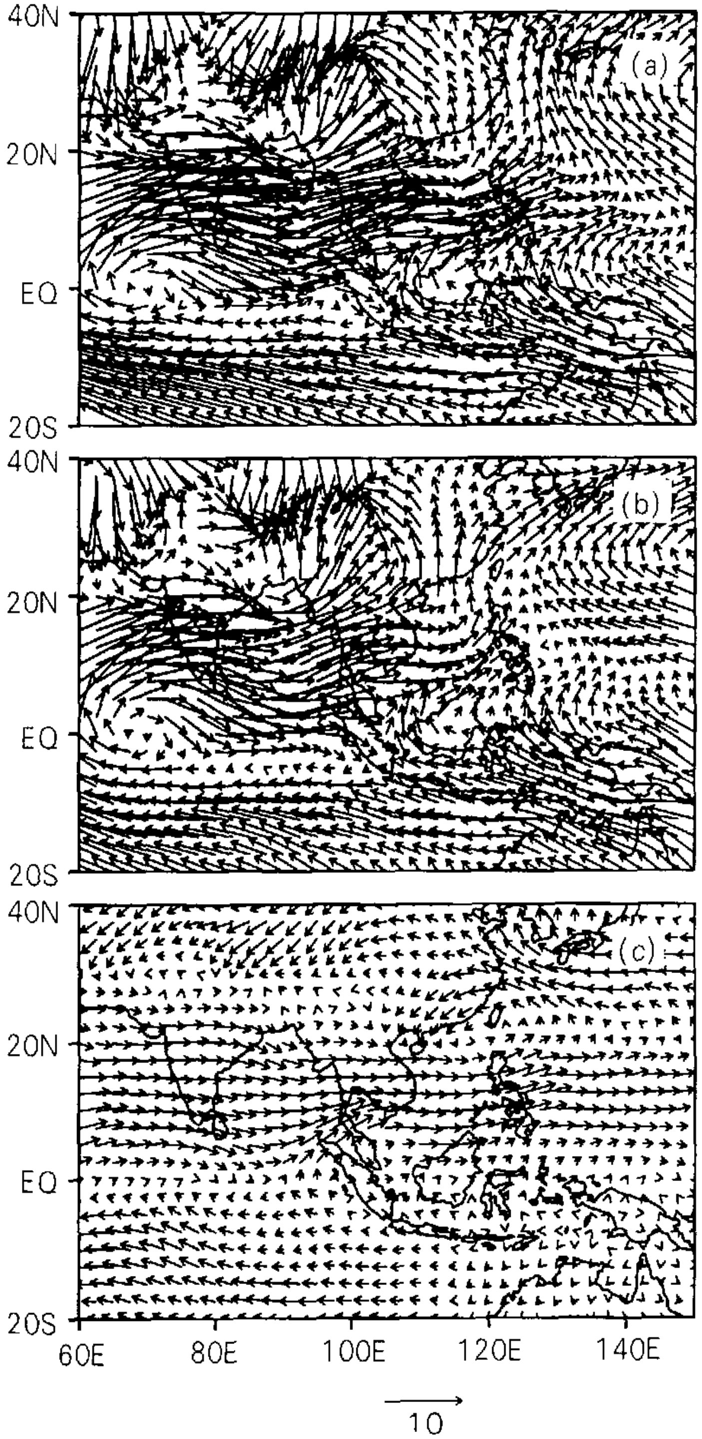

Fig. 1. Composite circulation pattern at 850 hPa (averaged in JJA) for strong SCS summer monsoon years (a) and weak SCS summer monsoon years (b) and their differences (c).

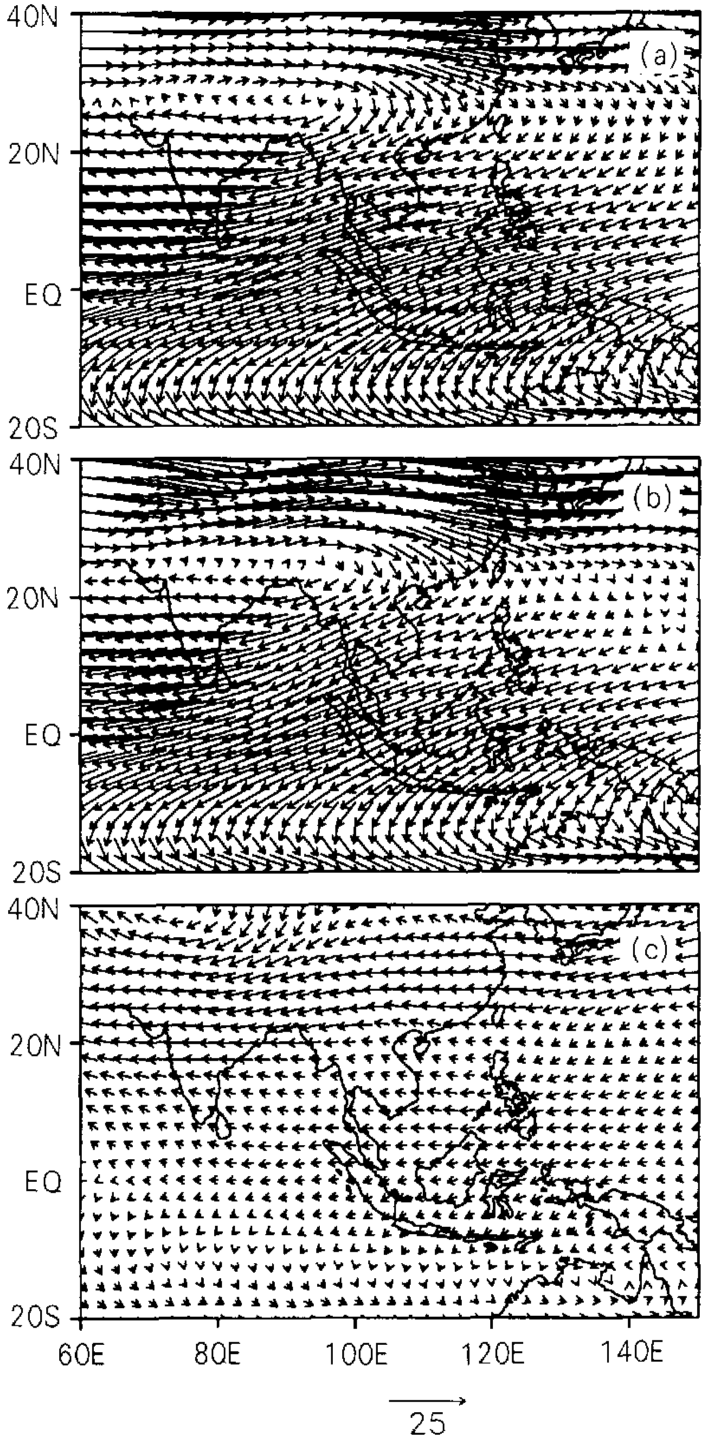

Fig. 2. Composite wind fields (averaged in JJA) at 200 hPa for strong SCS summer monsoon year (a) and weak SCS summer monsoon year (b) and their differences (c).

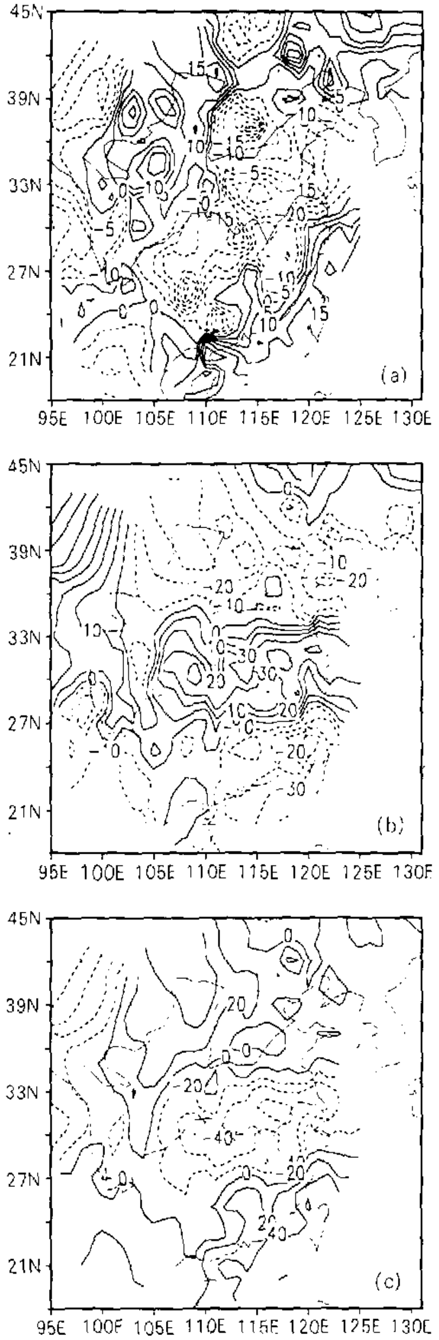

Fig. 3. Composite summer precipitation anomalies (%) for strong summer monsoon year (a) and weak monsoon year (b) and the differences between the two cases (c).

to the strong summer monsoon years and the weak monsoon years. Figure 3 shows the composite distribution of the summer precipitation anomalies (%) in eastern China for the strong monsoon year, the weak monsoon year and their differences, respectively. It is clearly shown that there is sufficient precipitation in the southeast littoral region of China and the region from the great bend of the Yellow River to the south areas of Northeast China in the strong SCS summer monsoon year (Fig. 3a); but the rainfall is deficient (average reach to 10%–20%) in the middle and lower reaches of the Yangtse River and the south areas of Northern China. The rainfall in the weak monsoon year is sufficient (average reach to 20%–40%) in the middle and low stream of the Yangtse–Huaihe River basin (Fig. 3b); but in South China and North China the rainfall is deficient (average reach 10%–30%). Fig. 3c can show more obviously the influences of summer monsoon activity on the summer rainfall in eastern China. That means strong summer monsoon leads to the sufficient rainfall in the southeastern China, South China, North China and south areas of the Northeast China and the deficient rainfall in the middle and low stream of the Yangtse–Huaihe river basin. The weak SCS summer monsoon has the opposite impacts.

3. The atmospheric ISO in strong and weak monsoon years

To study the ISO, the 30–60 days band–pass filter is used for obtaining the zonal wind and meridianal wind of the ISO. Then, the stream pattern and the kinetic energy distribution of the atmospheric ISO can be gotten easily. The distributions of the atmospheric ISO kinetic energy at 850hPa show that there is strong ISO activity corresponding to the strong monsoon years; the strongest kinetic energy center locates in the middle of the SCS and Philippines. But corresponding to weak monsoon years, atmospheric ISO is relatively weak and strong kinetic energy center locates over the northwestern Pacifica (20°N, 140°E).

Figure 4 clearly shows that strong (weak) SCS summer monsoon corresponds to the strong (weak) atmospheric ISO, the biggest difference can reach to twice. Thus a question is naturally put forward: Does the activity of the atmospheric ISO in the SCS and nearby region play an important role in the SCS summer monsoon anomaly? The answer will be obtained in the following analyses.

The composite stream patterns of the ISO at 850 hPa for strong monsoon years and weak monsoon years and their difference are shown in Fig. 5, respectively. It is clearly that there are strong ISO over the SCS and the western Pacific regions corresponding to strong summer monsoon year; but corresponding to weak summer monsoon year, the atmospheric ISO stream field is very weak. Especially, a strong cyclonic circulation pattern occurs over the SCS and the western Pacifica corresponding to the strong summer monsoon; however, there is weak anticyclonic circulation corresponding to the weak summer monsoon. This means that the intensity of monsoon trough is closely related to the activity of cyclonic (anticyclonic) circulation of the ISO in the SCS and nearby regions. Thus, it can be suggested that the activity and its cyclonic circulation of the atmospheric ISO play an important role in the formation of the strong cyclonic circulation which is the important character of strong SCS summer monsoon. In other words, the activity of the atmospheric ISO in the SCS and nearby regions plays an important role in the formation of the strong SCS summer monsoon.

The atmospheric ISO stream patterns in the upper troposphere (200 hPa) also show evident difference corresponding to the different situation of summer monsoon (Fig. 6). It is clearly that the biggest difference of the ISO at 200 hPa exists over the Tibetan Plateau with a relative strong anticyclonic circulation for strong monsoon year. Comparing Fig. 6c to Fig. 2c, it can be suggested that the atmospheric ISO, especially the anticyclonic circulation of low frequency oscillation over the Tibetan Plateau, also play an important role in the onset and maintenance of the strong SCS summer monsoon.

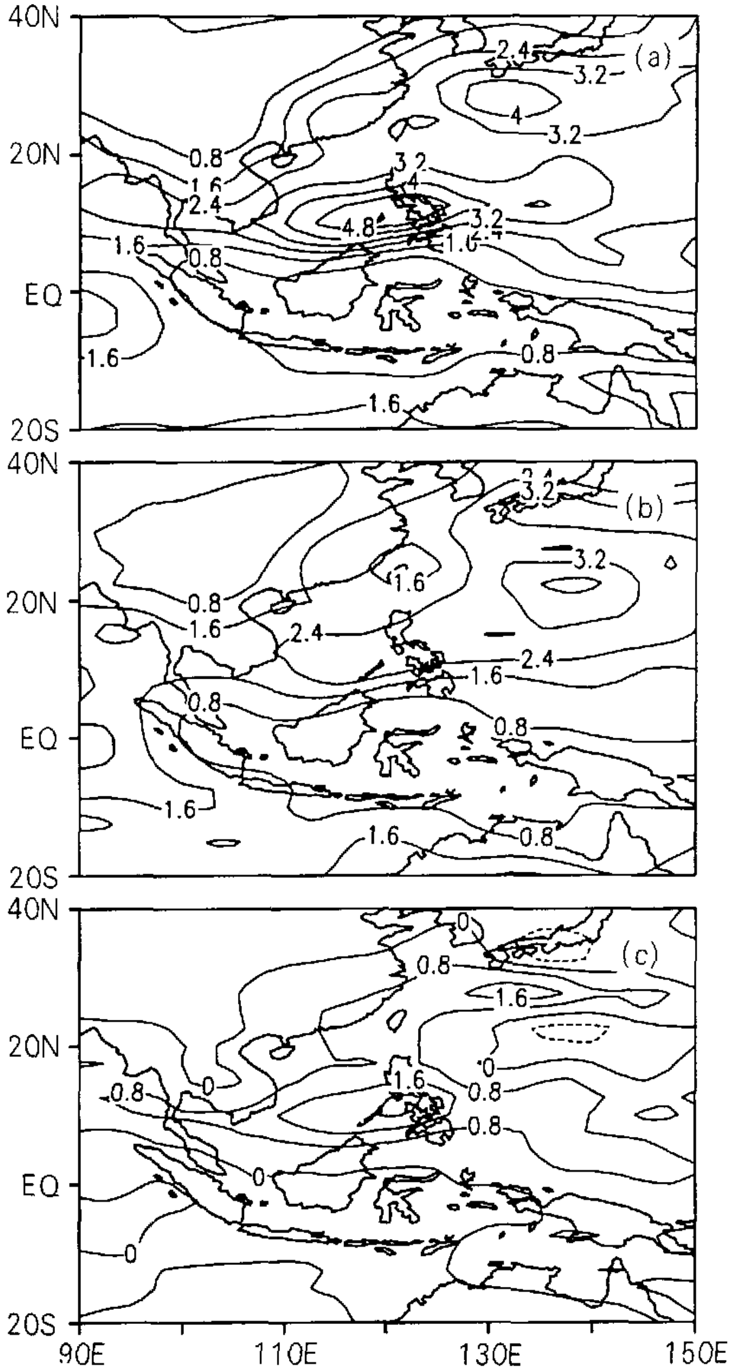

Fig. 4. The kinetic energy ($m^2 s^{-2}$) distribution of atmospheric ISO in summer (Jun.–Aug.) (a) for seven strong SCS summer monsoon years, (b) for seven weak SCS summer monsoon years, (c) the differences between (a) and (b).

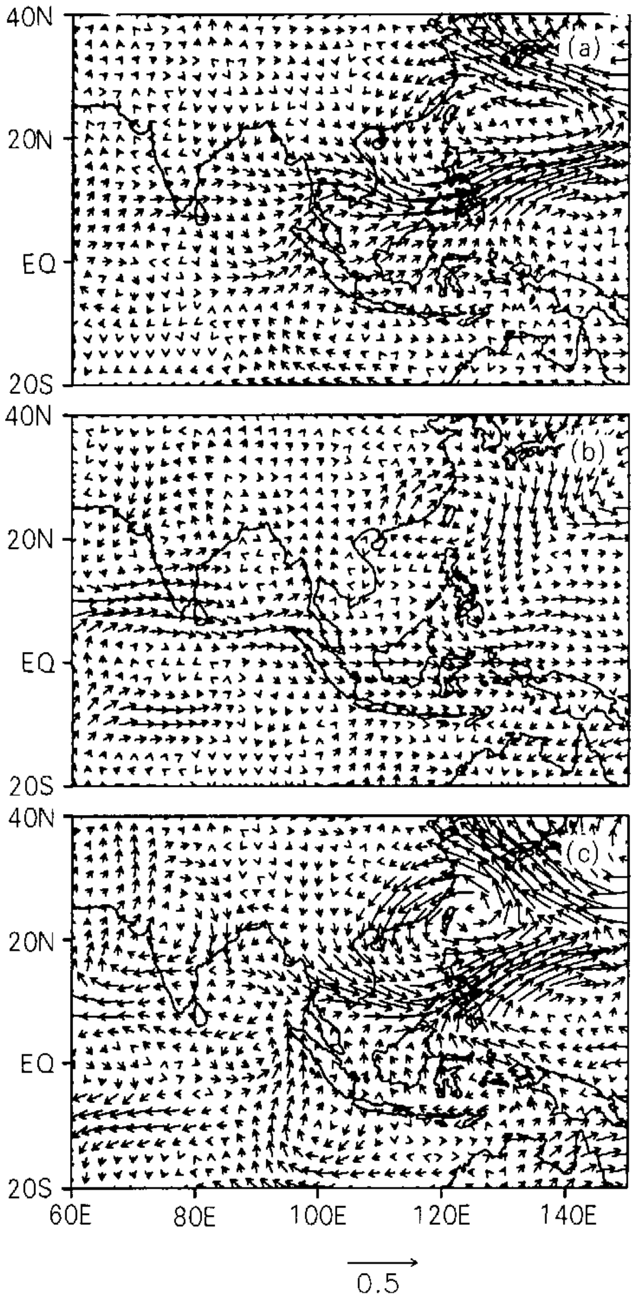

Fig. 5. Composite summer stream fields of the atmospheric ISO at 850 hPa (a) For strong SCS summer monsoon years, (b) for weak SCS summer monsoon years, (c) the difference field between (a) and (b).

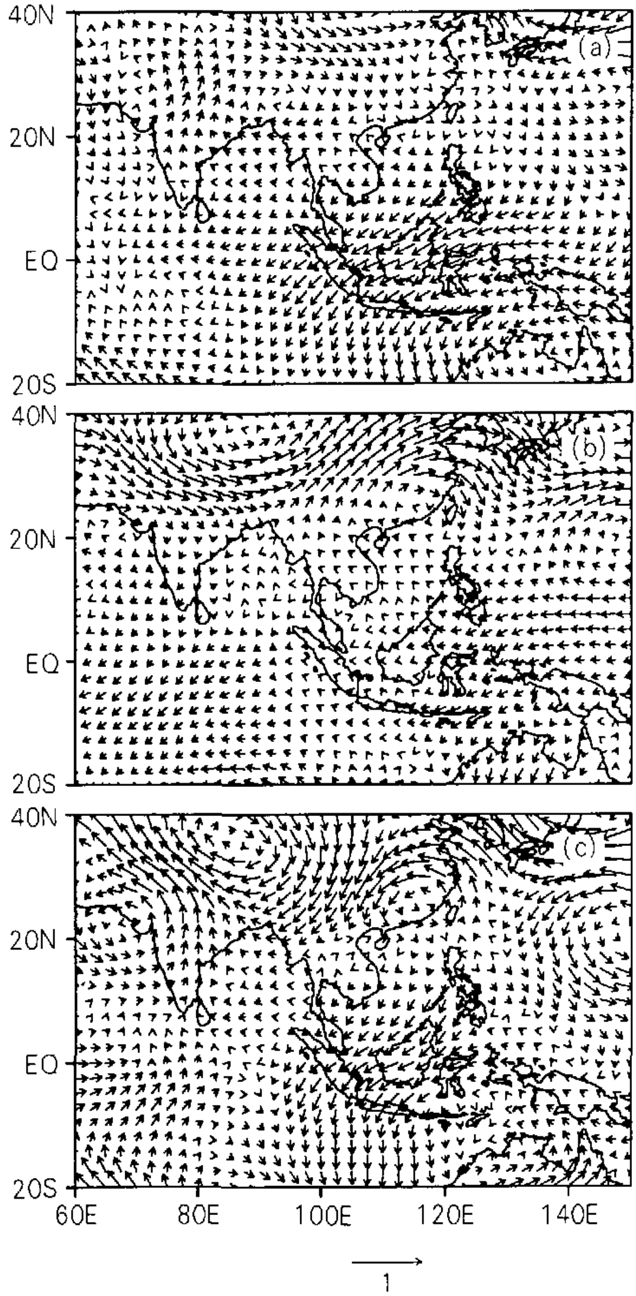

Fig. 6. The same as in Fig. 5, but at 200 hPa.

4. Case analysis of the activity of the atmospheric ISO

We have studied the composite results about the influence of the atmospheric ISO on the SCS summer monsoon. And it is still shown that both the activity and the stream pattern of

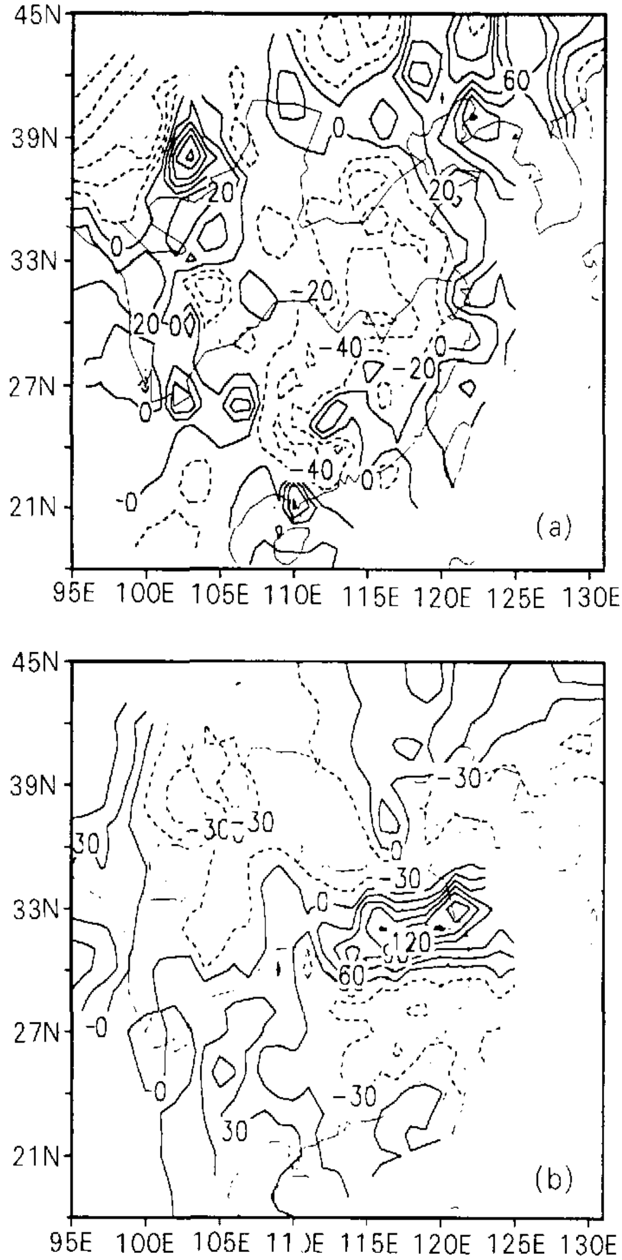

Fig. 7. The summer precipitation anomalies (%) in China in 1985 (a) and 1991 (b).

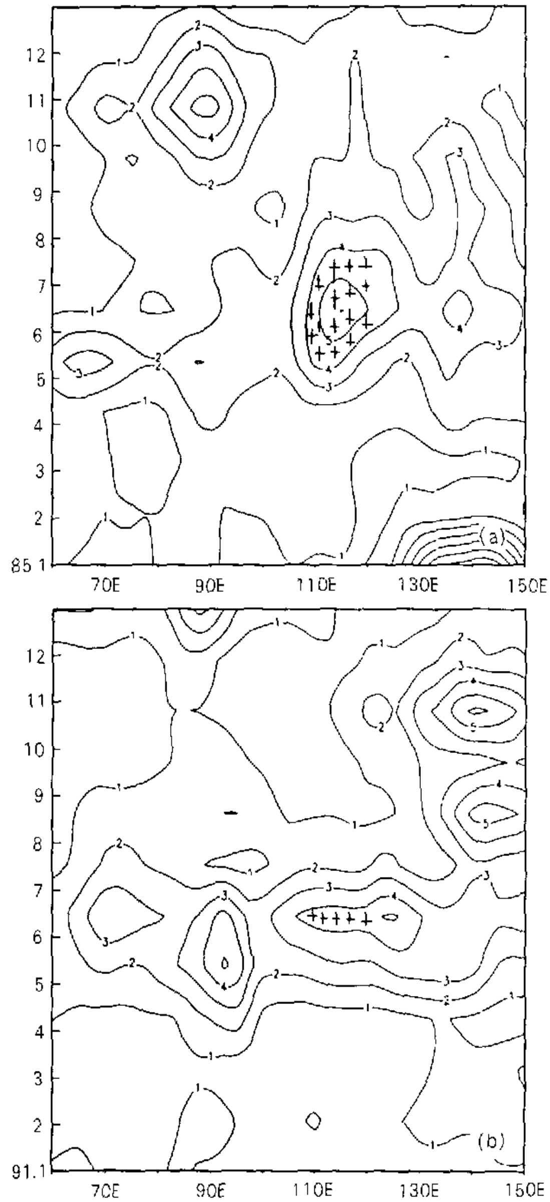

Fig. 8. Time–longitude cross sections of the averaged atmospheric ISO kinetic energy in (5°–20°N) region at 850 hPa for 1985 (a) and 1991 (b).

the atmospheric ISO can impact directly on the summer monsoon circulation not only at the lower troposphere (850 hPa) but also at the upper troposphere (200 hPa). For further details, 1985 is selected as strong summer monsoon case and 1991 as weak summer monsoon case. The result shows that the circulation pattern in 1985 is very similar to those in Fig.1a and Fig. 2a as the representative of the strong monsoon year, and the circulation in 1991 is very similar to those in Fig. 1b and Fig. 2b as the representative of the weak monsoon year. Figure 7 shows the summer precipitation anomalies in 1985 and 1991 respectively. In Fig. 7. the difference can be easily identified and It is clearly shown that the climate effects caused by strong and weak summer monsoon are different greatly and their patterns are very similar to Fig. 3.

In order to check whether the atmospheric ISO in the SCS region propagates eastwards from the Indian Ocean region. The time–longitude cross section of the averaged atmospheric ISO kinetic energy in (5–20°N) region at 850 hPa shows clearly that the atmospheric ISO in the SCS mainly didn't propagate eastwards from the Indian Ocean region (Fig. 8), but formed and strengthened mainly in the SCS region. The atmospheric ISO over the SCS is mainly independent to that over the equatorial Indian Ocean. Figure 8 also shows that the atmospheric ISO is strong (weak) corresponding to strong (weak) summer monsoon. But the strong (weak)

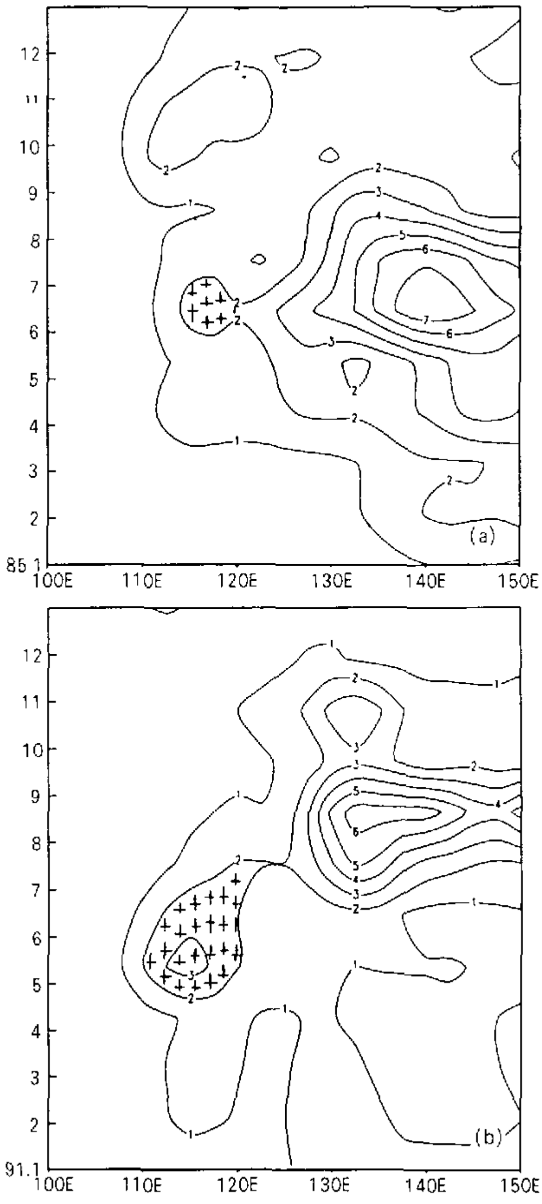

Fig. 9. The same as in Fig. 8, but averaged in the 25°–35°N region.

atmospheric ISO in Indian Ocean region is associated with weak (strong) Indian summer monsoon.

The ISO over the SCS is not obvious zonal propagation, how about meridional propagation? The time–latitude cross section of the averaged atmospheric ISO kinetic energy in the (105°–120°E) region shows that there is no obvious propagation of the atmospheric ISO from the SCS to the Jiang–huai River basin, but the propagation of atmospheric ISO is evident from the Equator to the north region of the SCS (figure is omitted).

In previous study, Li and Li (1997) have indicated that the atmospheric ISO has opposite variation feature in summer over the SCS and the Jiang–huai River basin. Comparing the kinetic energy of the atmospheric ISO in the Jiang–huai River basin (25°–35°N, 112°–120°E) with that over the SCS, an opposite variation feature can be also found. The strong (weak) ISO over the South China Sea is associated to weak (strong) ISO in the Jiang–huai River basin. In Fig. 9, It is clear that the atmospheric ISO kinetic energy in the Jiang–huai River basin is weak in the strong SCS summer monsoon year (1985) but strong in the weak SCS summer monsoon year (1991). But it is difficult to find whether the atmospheric ISO in Jiang–huai River basin propagated from the west although there is little propagating signal from east to west. We can only see in Fig. 9a that the atmospheric ISO has the propagation character westwards in the 130°–150°E region. Therefore, it is possible that the ISO in these regions are mainly excited locally. Further, maybe there is a flexuous relationship between them: The strong atmospheric ISO in the SCS region will lead to an unfavorable circulation situation in the Jiang–huai River basin for the formation and activity of the ISO, vice versa.

5. Conclusion

Through composite and case analyses for two types (strong and weak) summer monsoon, this work reveals some relationship between the SCS (East Asian) summer monsoon and atmospheric ISO.

1) Although there exist some similarities in the general circulation during strong and weak SCS summer monsoon years, corresponding to strong SCS summer monsoon year, there is relatively strong westerly between 5°–20°N at 850 hPa and the cyclonic circulation over the north part of the SCS: the anticyclone over the Tibetan Plateau is strong and northwestward at 200 hPa.
2) The summer precipitation distribution in eastern China exhibits great differences between strong and weak monsoon years, even they are out–of–phase. In strong (weak) SCS summer monsoon years, the precipitation is deficient (sufficient) in the middle and lower reaches of the Yangtse–Huaihe River basin, but sufficient (deficient) in the southern China and region from the great bend of the Yellow River to the south of northeastern China.
3) Corresponding to the strong SCS summer monsoon year, there exists strong ISO activity at 850 hPa over the SCS with the strongest center located in the region from the middle of the SCS to the Philippines; corresponding to the weak SCS summer monsoon year, the atmospheric ISO over the SCS is relatively weak with a strong center located near the western Pacific region (around 20°N, 140°E).
4) The stream field of the atmospheric ISO shows that the atmospheric ISO at 850 hPa is also strong (weak) corresponding to the strong (weak) SCS summer monsoon and there is strong cyclonic circulation (weak anticyclonic circulation) in the SCS–western Pacific region. The stream field of the atmospheric ISO at 200 hPa exhibits anticyclonic circulation

(cyclonic circulation) over the Tibetan Plateau corresponding to the strong (weak) SCS summer monsoon. Thus, the activity of the atmospheric ISO in the SCS and nearby regions has important impacts on the anomaly of the SCS summer monsoon.

5) The variation of the atmospheric ISO kinetic energy over the SCS is opposite to that in the Jiang–huai River basin. Strong (weak) atmospheric ISO in the SCS associated to the weak (strong) atmospheric ISO in the Jiang–huai River basin.

6) The time–latitude and time–longitude cross sections of the atmospheric ISO kinetic energy indicated that the variation of the atmospheric ISO kinetic energy exhibits mainly local character both in the SCS region and the Jiang–huai River basin. There is a possible flexuous relationship between them: The strong atmospheric ISO in any place affects the atmosphere circulation at first, then the favorable or unfavorable circulation pattern to excite the ISO will be caused in another place, which leads to strong or weak atmospheric ISO.

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强弱南海夏季风活动及大气季节内振荡

李崇银 龙振夏 张庆云

摘 要

应用 NCEP 再分析资料和中国降水资料，分析研究了对应南海强、弱夏季风的环流形势及其与之相应的中国东部的降水异常。其结果表明，由强、弱夏季风所引起的中国气候异常是完全不同(甚至反相)的。分析大气季节内振荡(ISO)的活动还表明，对应大气强(弱)南海夏季风，南海地区 850 hPa 也有强(弱)大气 ISO；而强、弱南海夏季风环流(200 hPa 和 850 hPa)主要由异常的大气 ISO 所激发。本研究还揭示了南海地区大气 ISO 的变化往往与江淮地区大气 ISO 的变化反相，例如南海地区的强(弱)大气 ISO 常与江淮流域的弱(强)大气 ISO 相对应。对于大气 ISO 的强度，一般多表现出局地激发特征，经向传播相对较弱。

关键词: 南海夏季风，大气季节内振荡，环流形势(型)