On the Onset of the South China Sea Summer Monsoon in 1998[①]

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ABSTRACT

Through analyzing the NCEP / NCAR reanalysis data, the satellite observational data and the ATLAS-2 mooring buoy observational data, it is shown that May 21 is the onset date of the South China Sea summer monsoon in 1998. There were abrupt variations in the general circulation pattern at the lower troposphere and the upper troposphere, in upper jet stream location and in the convection and rainfall over the South China Sea region corresponding to the outbreak of the South China Sea summer monsoon. It is also indicated that there was rainfall in the southern China coastal region before onset of summer monsoon, but it resulted from the (cold) front activity and cannot be regarded as the sign of summer monsoon outbreak in the South China Sea.

Key words: Onset, South China Sea summer monsoon, General circulation pattern, Jet stream, Convection

1. Introduction

Chinese scientists have pointed out since the 1980s that the Asian summer monsoon is composed of the South Asian (Indian) monsoon system and the East Asian monsoon system, which have their particular characteristics respectively but also interact on each other; and the Asian summer monsoon breaks out in the South China Sea (SCS) region at first, then spreads northwestward and northward respectively, finally the South Asian summer monsoon and the East Asian summer monsoon are set up (Tao and Chen, 1987; Jin and Chen, 1985; Zhu et al., 1986).

Much attention has been paid to the South China Sea summer monsoon from different aspects since the 1990s, especially more about the onset of the South China Sea summer monsoon (Xie and Zhang, 1994; He et al., 1996; Matsumoto, 1997; Yan, 1997), but the results were different. Since Webster's monsoon index fits only for the Indian monsoon but not for the East Asian (South China Sea) monsoon activity, we offered a new monsoon index (the differentiation of divergence between the upper troposphere and the lower troposphere), which is advantageous for representing East Asian monsoon activity, and studied the characteristics of the South China Sea summer monsoon activity and its impacts (Li and Zhang, 1999). We also analyzed the circulation characteristics in association with the onset of the South China Sea summer monsoon and the spreading of onset dates. It has been suggested that May 16 is the mean onset date of the South China Sea summer monsoon system. Before the establishment, the southwesterly wind in the southern China coastal region is not real

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summer monsoon, even though this kind of southwesterly wind and rainfall play an important role in the onset of the South China Sea summer monsoon, especially in the withdrawal of the subtropical high ridge (Li and Qu, 1999).

This work analyzed the onset and its characteristics of the South Chine Sea summer monsoon in 1998 and suggested further that it is not appropriate to divide the onset of South China Sea summer monsoon into two parts—north part (early) and south part (late). The NCEP / NCAR reanalysis data, the satellite observational data and the ATLAS buoy observational data are used in this work.

2. The wind field at 850 hPa

The wind field at 850 hPa during May 15–May 24, 1998 is shown in Fig.1. It is clearly shown that although there had appeared southwesterly wind in the southern China coastal region from May 15 on, the principal winds over the large area of the South China Sea were southeasterly and southerly until May 20. A clockwise subtropical high ridge controlled the South China Sea region from the start. From May 21 on, the southwesterly wind and southerly wind were principal winds controlling the South China Sea region and the subtropical high ridge had been out of the South China Sea completely. Therefore, the evolution of the circulation pattern at 850 hPa indicates that the onset date of the South China Sea summer monsoon in 1998 should be May 21, which was later than normal.

It is also clear in Fig.1 that the southwesterly wind in the southern China coastal region before May 21 was caused by strong northwesterly flow over the Indian peninsula, but on just May 21 and after it, the southwesterly wind in the southern China coastal region resulted from the strong westerly wind over the equatorial Indian Ocean, which is caused by the cross–equatorial Somali flow. The property of flow in the southern China coastal region is different between the days before and after the onset of SCS summer monsoon (May 21). Therefore, the local southwesterly wind is not enough to define the onset of SCS summer monsoon, the origin of the flow is also important.

Fig. 2 showed the temporal evolution of the average zonal wind at 850 hPa in the South China Sea region (5–20°N, 105–120°E). It is clearly indicated that during May 19–21 not only the zonal wind speed increased abruptly, but also the wind direction changed steadily to westerly. On May 19 it was easterly wind with about 0.5 m / s, but westerly wind with speed speed about 4 m / s on May 21. It can also be suggested that May 21 is the onset date of the South China Sea summer monsoon. During May 12–18, there was westerly wind, but it was very weak and not steady, they cannot be regarded as the signal of the summer monsoon onset.

3. The upper tropospheric circulation

The temporal evolution of the geopotential height field at 200 hPa (figure not shown) shows that a barometric high center had the characteristic of propagation from the neighborhood of (10°N,105°E) northwestward to the neighborhood of (15°N,95°E) before May 20 and its center intensity increased obviously on May 20 and May 21. The temporal evolution of the geopotential height field at 100 hPa (Fig.3) has an evident characteristic of a barometric high center moving eastward from North Arabian Sea to the Tibetan Plateau before May 20 and its center intensity increased obviously on May 21 and May 22. Such temporal evolution characteristics of the upper tropospheric circulation clearly indicated that the thermodynamic

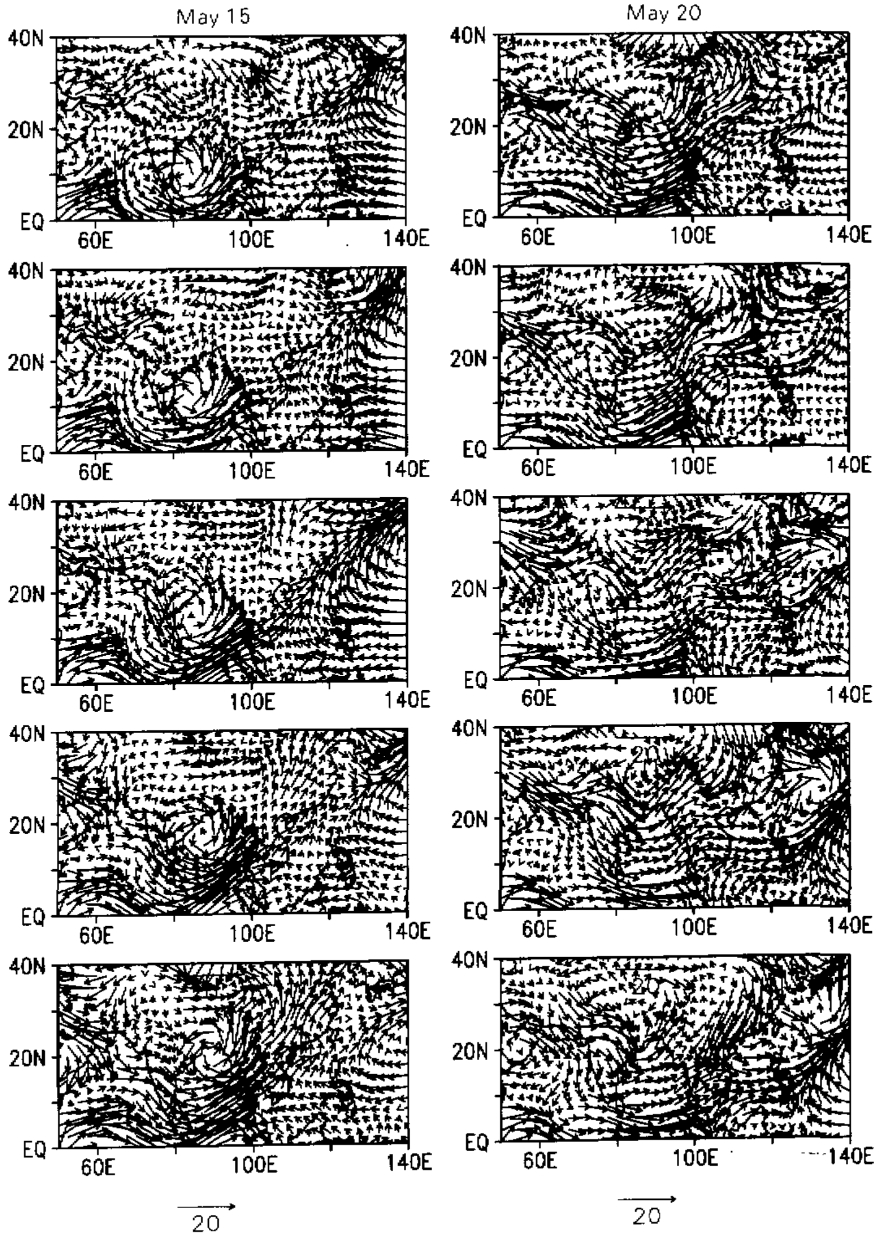


Fig. 1. Wind field at 850 hPa during May 15–24, 1998.

state variations of the Plateau and the circulation variability caused by the thermodynamic variation of the Plateau reached the biggest value on May 21.

Therefore, the upper tropospheric circulation was also changed corresponding to the

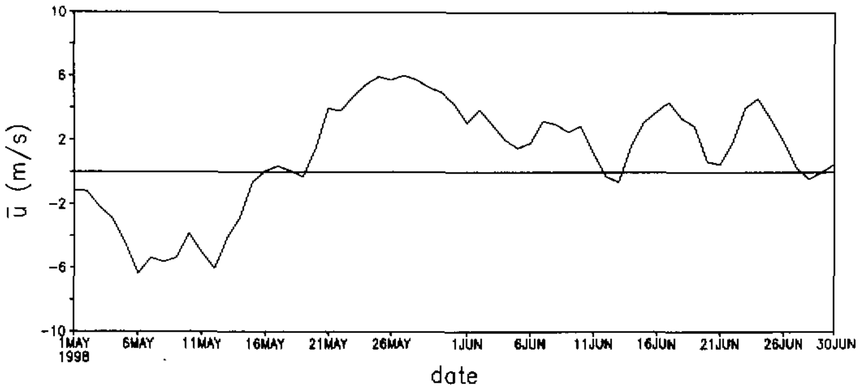


Fig. 2. Temporal evolution of mean zonal wind in the South China Sea region (5–20°N, 105–120°E) at 850 hPa.

outbreak of the SCS summer monsoon, and the greatest variation occurred on May 21—the onset date of summer monsoon.

4. The variation of upper jet stream

Early study pointed out that the upper jet stream axis jumps suddenly northward in June in association with the seasonal variation of northern hemisphere general circulation pattern from winter to summer (Ye et al., 1959). How about the upper jet stream activity in association with the onset of the South China Sea summer monsoon? The altitude–latitude section of the zonal wind in the South China Sea region (105–120°E) during May 12—30, 1998 is shown in Fig. 4. The most interesting thing is that the jet center was located at about 25–28°N before May 20, but it suddenly jumped northward to 35–40°N during May 20—21. The variation of latitude location reached 10 degrees only within two days. It suggested that not only the location of jet in East Asia had an obvious northward jump in association with the establishment of the South China Sea summer monsoon, but also the onset date of the South China Sea summer monsoon was on May 21 in 1998.

The above result shows that the sudden northward jump of the upper jet stream axis exists not only in June corresponding to the seasonal variation of northern hemisphere circulation pattern from winter to summer, but also in May in association with the onset of SCS summer monsoon, though it is shown in the East Asian region. It can be suggested that the seasonal variation of atmospheric circulation is completed in different stages and the onset of SCS summer monsoon is an important variation stage from winter to summer.

5. Convection activity in the South China Sea region

The convection activity and rainfall are important characteristics of the outbreak of summer monsoon. The satellite observational data and the ATLAS buoy observational data indicated clearly that obvious variations occurred in the convection in the South China Sea region before and after May 21. The time–latitude section of the mean TBB in region 105–120°E is shown in Fig. 5 (black area: TBB > 280K, no convection; greyish area: strong convection). It shows that there is no strong convection before May 21 but after that day the convection becomes stronger in the South China Sea region.

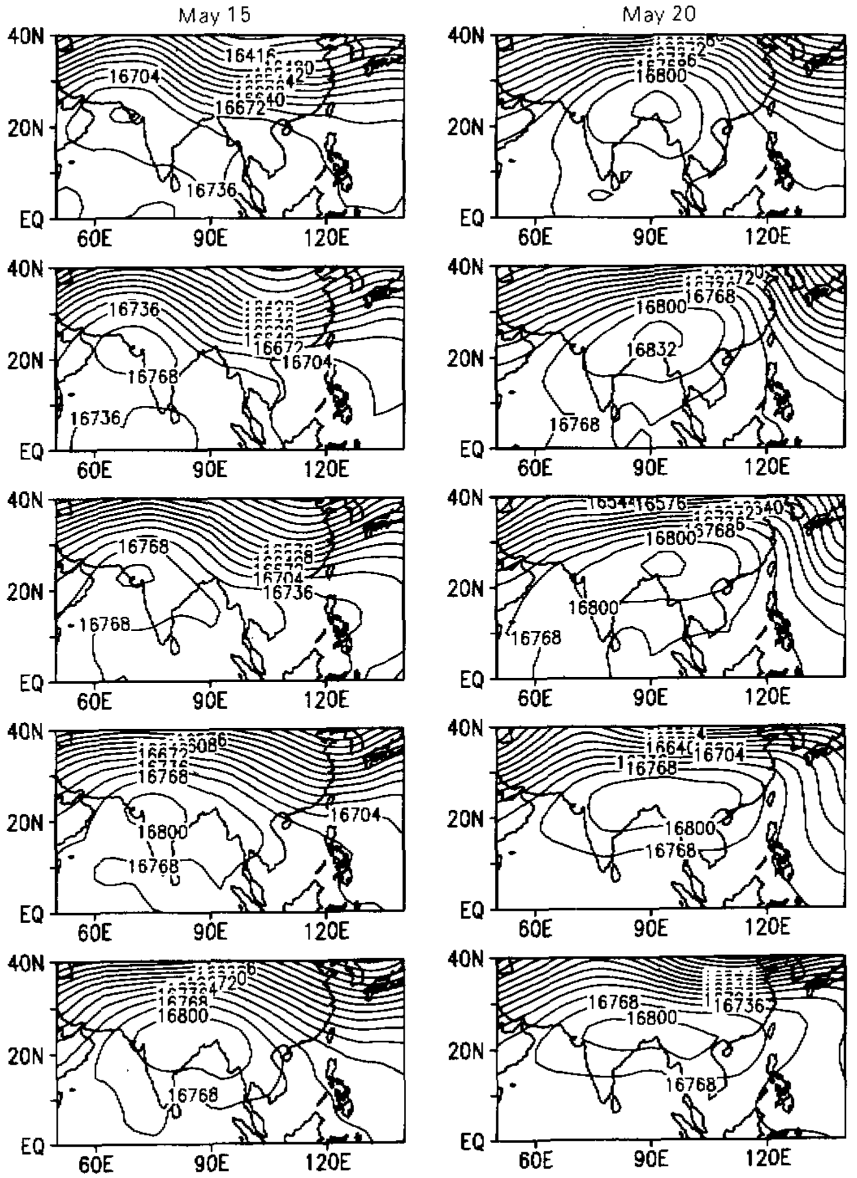


Fig. 3. Geopotential height pattern at 100 hPa during May 15–24, 1998.

The ATLAS–2 buoy observational data at (12°N,114°E) are given in Fig. 6. Both mean daily rain ratio (a) and mean radiation (b) indicated that the atmospheric state changed obviously before and after May 21 in the South China Sea region, the rainfall increased obviously and radiation intensity decreased from 550 W / m^2 to 200 W / m^2.

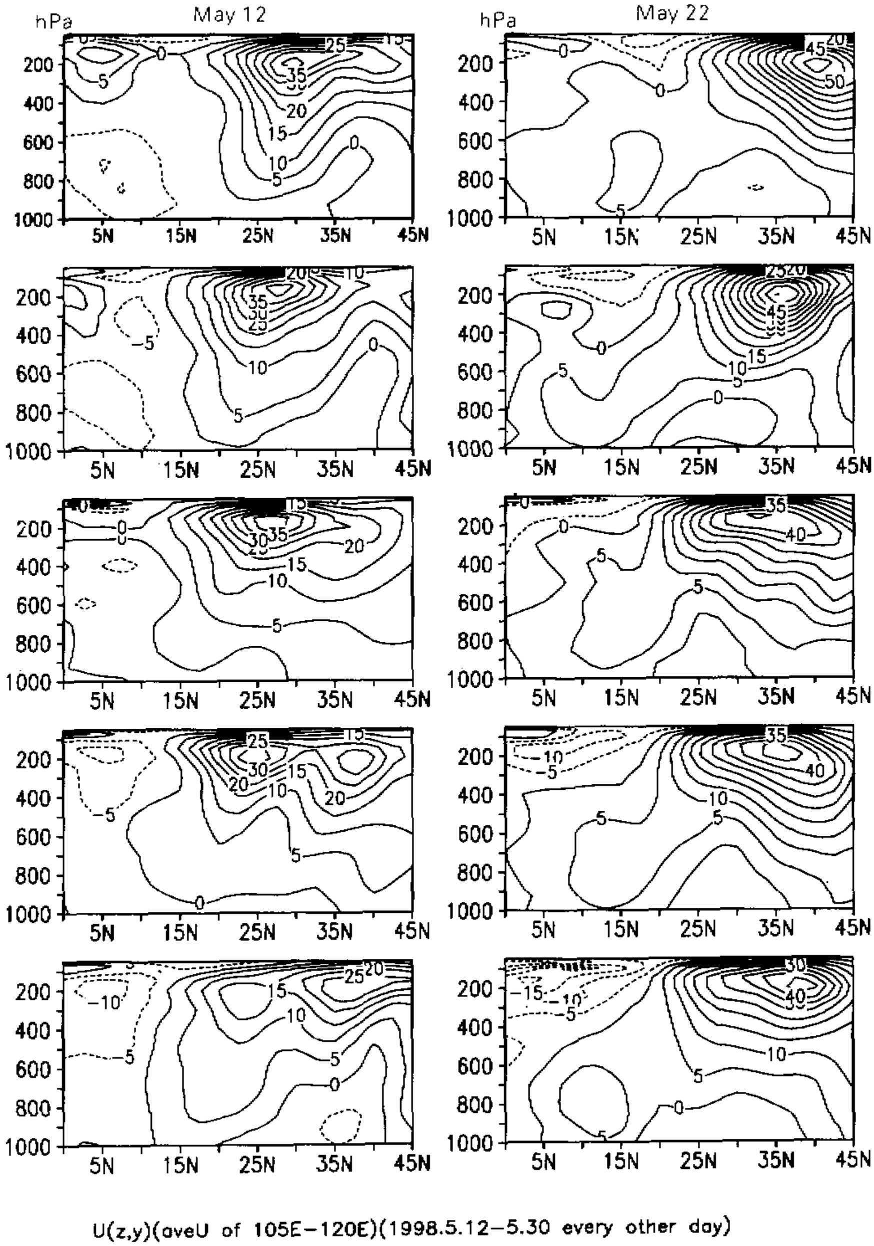


Fig. 4. Temporal evolution of time–latitude section of the zonal wind in the South China Sea region (105–120°E) during May 12–30 (every other day), 1998.

Thus, it can be suggested from the variations of the convection activities in the South China Sea region that May 21 is the onset date of the South China Sea summer monsoon in 1998.

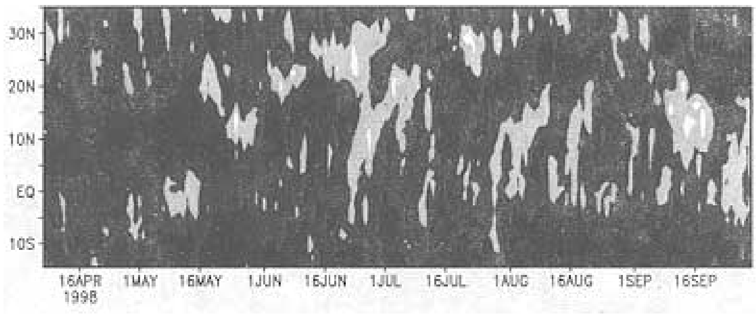


Fig. 5. The time–latitude section of the mean TBB in region (105–120°E).

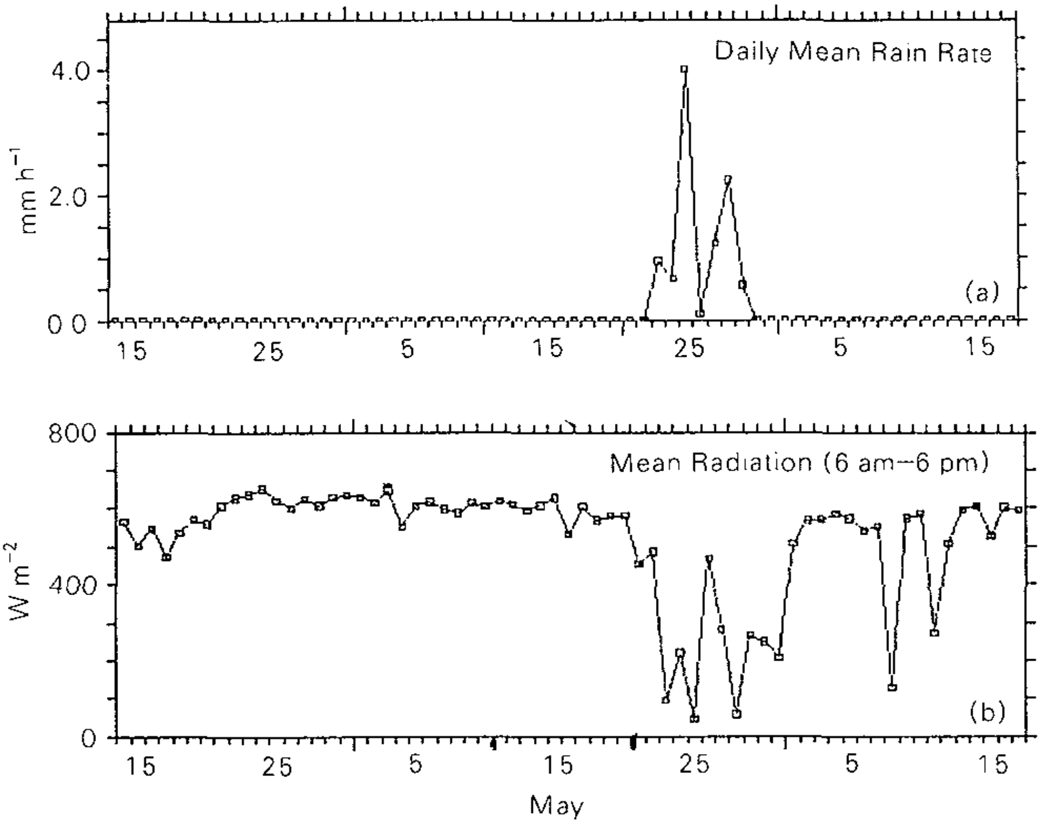
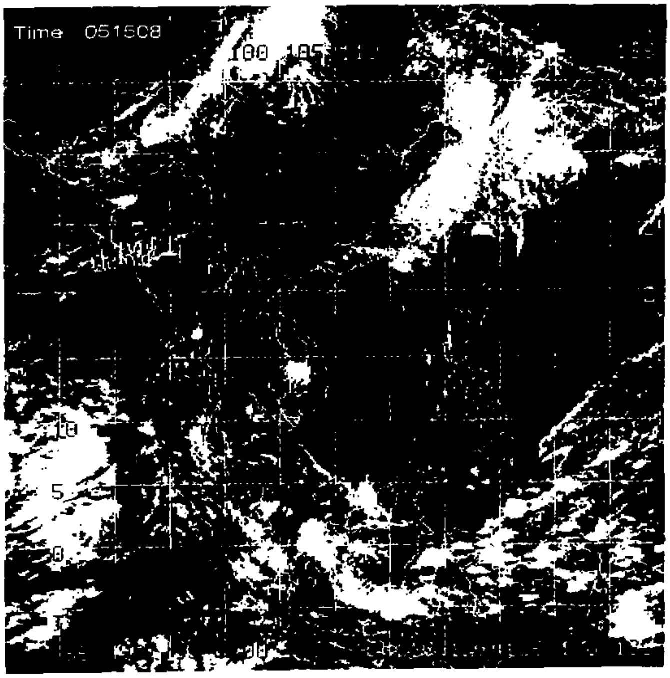


Fig. 6. ATLAS–2 observational data at (12°N,114°E). (a) Mean daily rain ratio, (b) Mean radiation.

6. The southwesterly wind and rainfall in the northern South China Sea prior to the onset of SCS summer monsoon

Sometimes there are southwesterly wind and rainfall in the northern South China Sea region prior to the onset of SCS summer monsoon, so that the onset of SCS summer monsoon is considered over the northern part at first in some studies. In 1998, the onset of SCS summer monsoon is also suggested on May 17 over the northern part in the discussion, but it is not true. The detailed analyses are shown in this section.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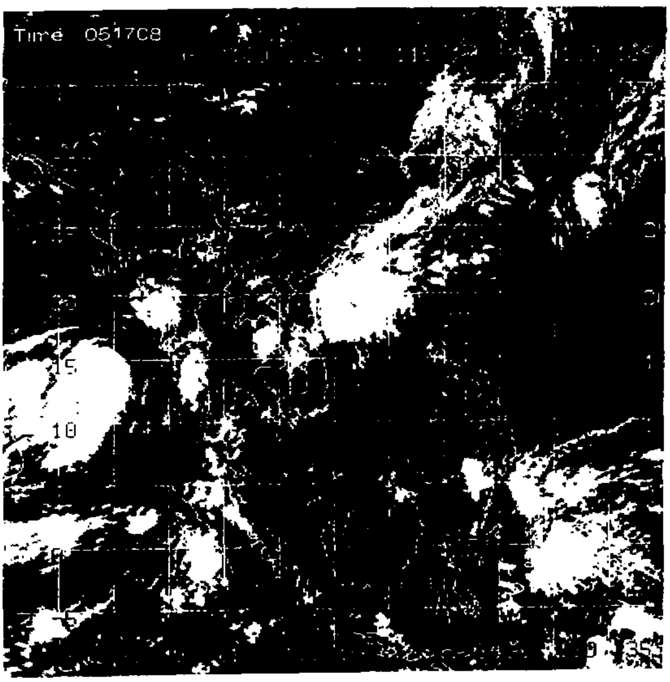
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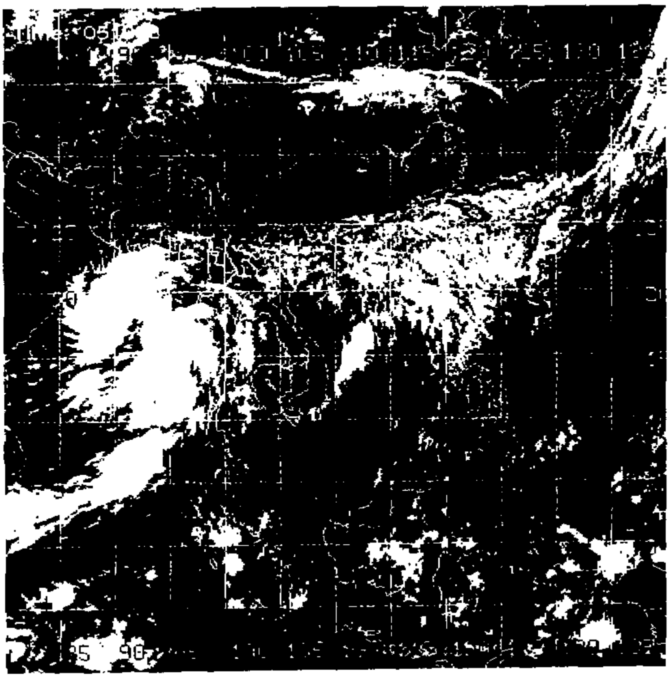

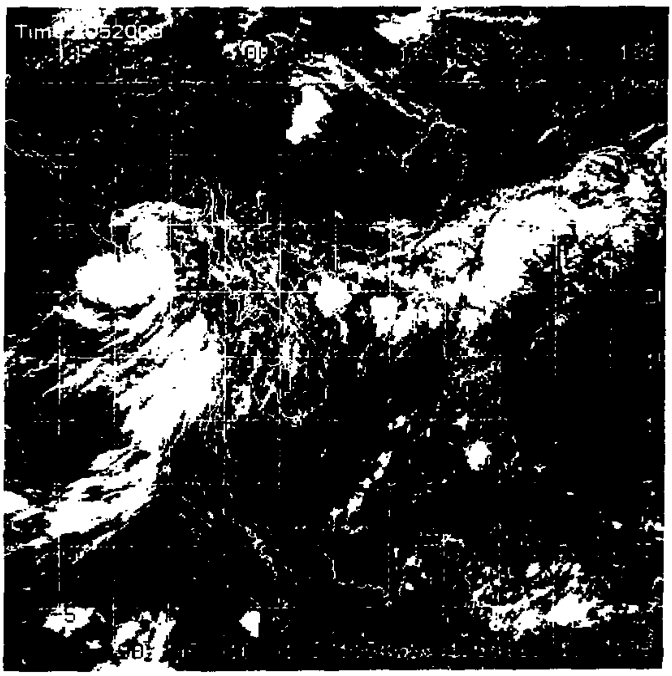

Fig. 7. Satellite photographs on May 15 (a), May 16 (b), May 19 (c) and May 20 (d), 1998, respectively.

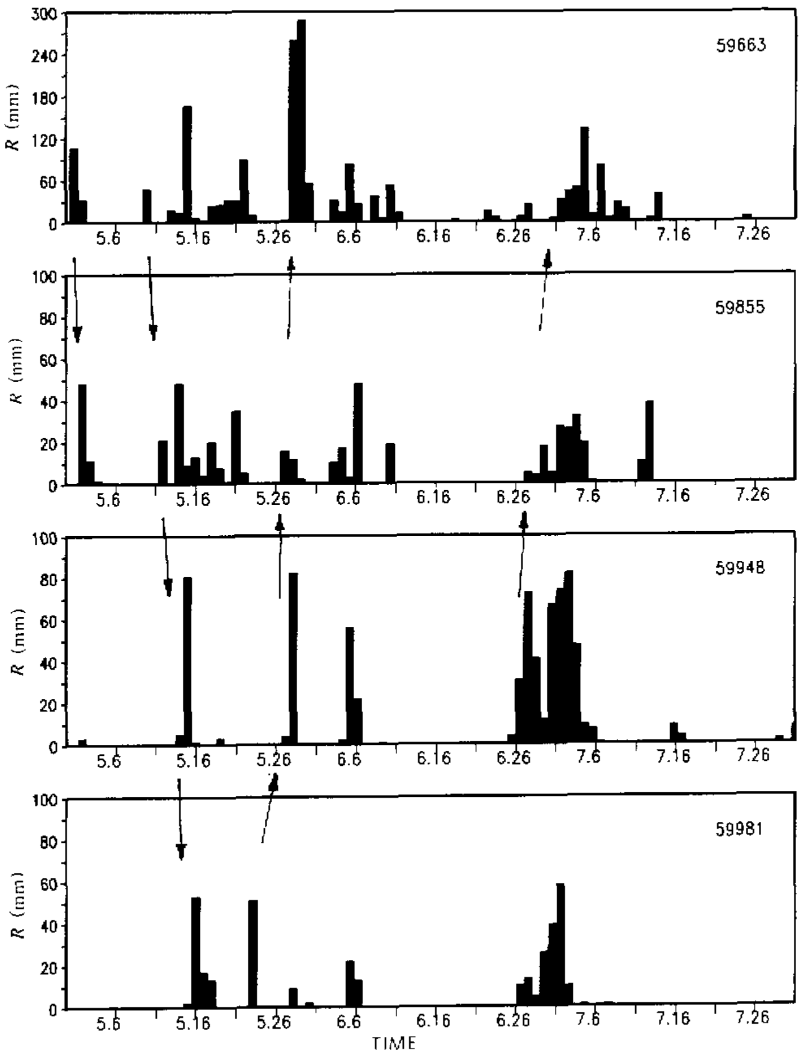

Fig. 8. Daily precipitation at 4 stations during May 1—July 31, 1998.

We have indicated that there was southwesterly wind in the southern China coastal region before May 21, but it could not be the sign of SCS summer monsoon onset because this southwesterly wind resulted from strong northwesterly flow over the Indian peninsula. The regional southwesterly wind is not enough to define the onset of SCS summer monsoon, and the flow origin should be considered.

Secondly, the satellite photographs showed that there were frontal activities over the northern South China Sea region from May 15 to May 20. The frontal activities not only caused the rainfall over the southern China coastal region, but also caused the southwesterly wind to the south of the front. In Fig. 7, some satellite photographs on May 15, 17, 19 and 20 are shown respectively, two frontal processes are clear over the northern South China Sea region. In general, the frontal rainfall cannot be regarded as the summer monsoon precipitation. In order to expose the rainfall feature in the northern South China Sea region during May 1–July 31, the temporal variations of daily precipitation at Yangjiang (59663), Qionghai (59855), Sanya (59948) and Xisa (59981) are shown in Fig.8. It is evident that the *systematic rainfall propagated from north to south before the onset of SCS summer monsoon* (May 21) corresponding to the southward movement of the front. But after May 21, the northward propagation of the systematic rainfall is clearly shown. Therefore, the rainfall in the northern South China Sea region was the frontal feature just before May 21, but the summer monsoon feature after that day.

7. Conclusions

Through analyzing and comparing the NCEP / NCAR reanalysis data, the TBB satellite observational data and the ATLAS buoy observational data, it is clear that May 21 is the onset date of the South China Sea summer monsoon in 1998.

There were abrupt variations of the troposphere general circulation, especially that of the lower troposphere stream in association with the onset of the South China Sea summer monsoon. The subtropical high ridge moving out of the South China Sea, southwesterly wind controlling the South China Sea and westerly jet axis jumping from infra 30°N to ultra 35°N are most important characteristics of the summer monsoon onset in the South China Sea.

Before the onset of the South China Sea summer monsoon, there were rainfall and the southwesterly wind in southern China coastal region, but they did not mean that the summer monsoon first broke out in the northern South China Sea region. The rainfall there was caused mainly by the front and the southwesterly wind came mainly from strong northwesterly wind in Indian peninsula.

The onset of SCS summer monsoon is an important stage and component of the seasonal variation of atmospheric circulation, which occurs in the East Asian monsoon region. Studying on the onset of SCS summer monsoon should investigate the features of large–scale circulation and their changes.

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