THE MEDIUM-RANGE VARIATIONS OF THE SUMMER MONSOON CIRCULATION SYSTEM OVER EAST ASIA

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ABSTRACT

The Asian monsoon circulation system can be divided into two subsystems, i.e., the East Asian monsoon system (EAMS) and the Indian monsoon system (IMS). In this paper the main elements including the Indian monsoon trough, the South Asian high, the upper easterly jet etc. and the interactions between EAMS and IMS are dealt with. The basic emphasis is put on the medium-range variations of the EAMS. Some significant results are obtained.

I. INTRODUCTION

For a long time, many meteorologists are used to studying the monsoon system over eastern Asia with the same idea of Indian monsoon system. In recent years, it is found that there exist many differences between these two monsoon systems. For example, the activities of monsoon over East Asia, such as ITCZ and typhoon, are frequently reverse as compared with that over India [1-2]. This fact reveals that the structure and the main elements of the monsoon system over East Asia are independent of the India monsoon system even if there exist some interactions. That is to say, the vast Asian monsoon circulation system can be divided into two subsystems which are independent of each other but have some interactions.[3] So we call them respectively the Indian monsoon system (IMS) and the East Asian monsoon system (EAMS). So far as we know, the IMS has been discussed so much and it was found that its main elements are the Indian monsoon trough, the south Asian high (the upper anticyclone over South Asia), the upper easterly jet and its cross-equatorial current, the Mascareine cold high and the Somalia's lower cross-equatorial jet.[4] As for the EAMS, we also have found some elements similar to that in IMS.[3] The purpose of this paper is to discuss the main elements in EAMS and its interaction, and the interactions between EAMS and IMS. Our discussions mainly concern the medium-range fluctuations of summer monsoon.

II. THE FLOW PATTERN AND THE FEATURE OF OSCILLATION OF THE EAST ASIAN MONSOON SYSTEM

In this part, we are going to discuss the medium-range variations of flow pattern of the EAMS and its features of oscillation. The flow pattern of the East Asian monsoon region has been studied by many Chinese meteorologists.[5,6]

Based on the stream-line map at 850 mb and 200 mb during summer, a model of flow pattern for the active/weak ITCZ in the EAMS is made[6] (see Fig. 1.). During the active period of ITCZ in East Asia, most of the main elements in the EAMS, such as ITCZ, the southern easterly jet and its upper cross-equatorial current, the Australian cold high, the lower-layer cross-equatorial current in East Asia and the monsoon meridional cell, are rather strong, the position of the subtropical high is northward. However, they are reverse during the weak period of ITCZ. At that time, the subtropical high spreads southwest wind into the South China Sea.

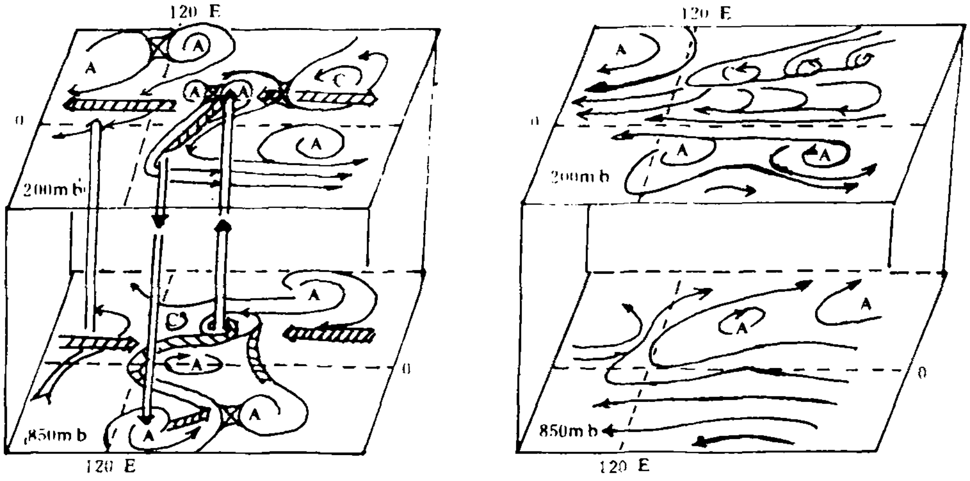

Fig. 1 Model of flow pattern.
(a) active ITCZ (b) weak ITCZ

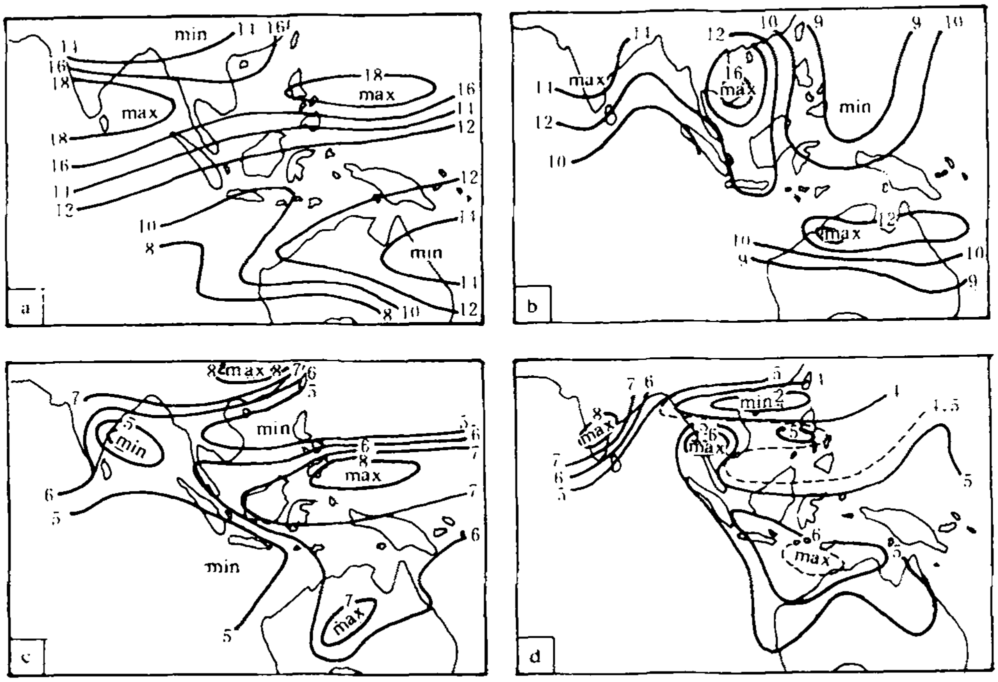

Fig. 2. The distributions of the power spectral density of the 14-day and 40-day oscillations for *u* and *v* components at 850 mb during summer, 1980. (*a*) *u*, 40-day; (*b*) *v*, 40-day; (*c*) *u*, 14-day; (*d*) *v*, 14-day.

In mid-summer, there also exist some quasi-periodic oscillations in the EAMS. Like that in the IMS,[4,8,9] it also can be found in the EAMS that there exist the 4–5 day, 14–19 day[6] and 40–50 day[3,7] oscillations. These oscillations appeared in the variations of the lower-layer monsoon, the surface pressure in the equatorial region[7] and the ITCZ. Fig. 2. shows the horizontal distribution of the density of the power spectrum of u and v components in 14-day and 40-day periods at 850 mb in summer, 1980. For the two spectra of v oscillation, there also exists a belt of maximum power spectrum located from the northern seaside of Australia to the middle and western parts of the South China Sea. For the 40-day oscillation, there exists a belt of maximum power spectrum for u just to the eastside of the center of maximum spectrum for v in the South China Sea. Besides, northern Australia is also a region of the center of maximum spectrum of u for the 40-day oscillation. This fact probably shows that this oscillation originates from the SE trade wind in northern Australia, so the spectrum changes from the v component near the equator to the u component in the eastern part of the South China Sea. For 14-day oscillation, the features of power spectrum are similar to that for 40-day oscillation in many ways, but the position of the center of u spectrum is near the equator as compared with that for 40-day oscillation. We have also computed the power spectrum of the geopotential height at 850 mb in summer 1980 and found that its position of the center of the maximum geopotential height in the EAMS coincided very well with the center maximum of v spectrum and the center minimum of u spectrum is located over the middle part of the South China Sea.

III. THE SYNOPTIC SUBSTANCE OF THE 14-DAY AND 40-DAY OSCILLATIONS IN THE EAST ASIAN MONSOON SYSTEM

The propagation direction and the synoptic substance of the oscillations in the EAMS have been studied in different aspects by some Chinese meteorologists. To sum up, it can be suggested that one of the oscillation propagates from the Southern Hemisphere into the Northern Hemisphere in the lower layer, while the other one propagates in a reverse direction in the upper layer. For the 14-day oscillation, it mainly reflects the oscillation intensity of ITCZ, but for the 40-day oscillation it reflects the activity or break of the large-scale monsoon.

Fig. 3 shows the distribution of phase angle of u and v components at 850 mb computed by the cross-spectral analysis with the Singapore station as a reference point in the summer 1980. The data

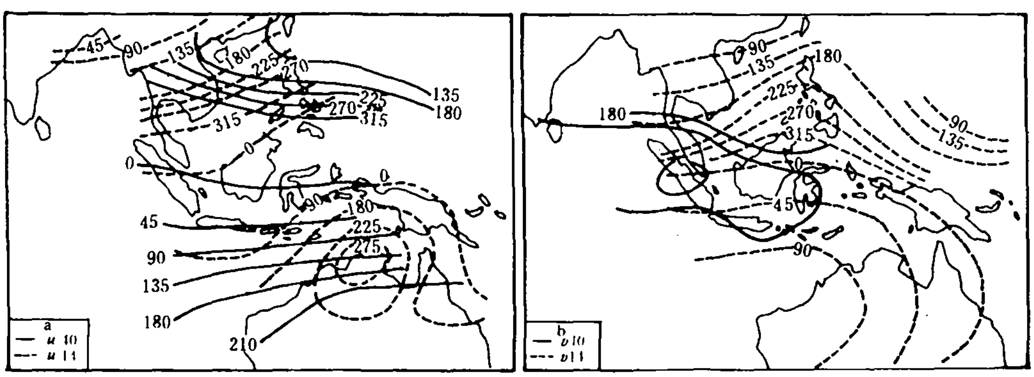

Fig. 3. The distribution of phase angle of the cross-spectrum of u and v components at 850 mb with the Singapore station as a reference point in the summer, 1980.

from 40 stations are taken into account and only the values of coherence larger than 0.5 are considered in the analytical process.

As we can see in this figure except the 40-day oscillation of v spectrum, both the 14-day and 40-day oscillations of u and v components in the lower layer originate from the northern part of Australia and spread toward the Northern Hemisphere and finally to the northern part of the South China Sea. Fig. 4. shows the same analysis, but at 200 mb, the Kuching station is taken as the reference point, the sources of the two oscillations are located over the northern ITCZ, and the oscillations propagate southward to the Southern Hemisphere. According to the analyses in different years, although most of lower layer oscillations originated from the Southern Hemisphere, a few oscillations originated in a northern developing ITCZ or after typhoon developed, and then the strengthening of the lower and upper cross-equatorial currents appeared. So the northern ITCZ is another source of oscillations.

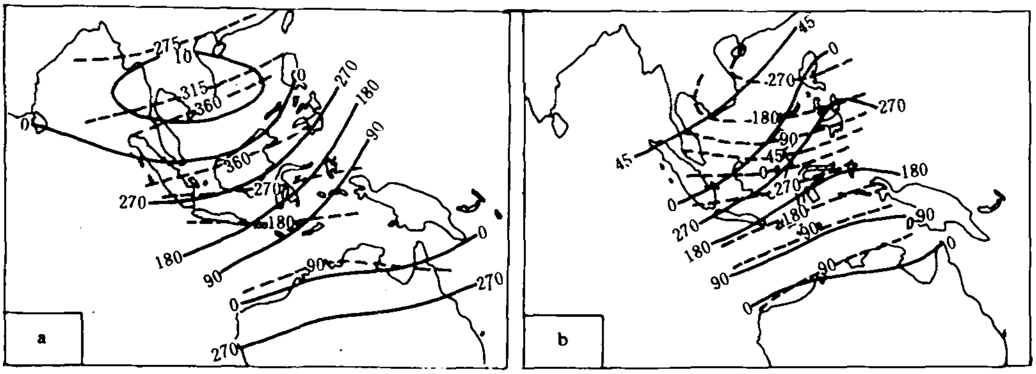

Fig. 4. The distribution of phase angle of the cross-spectrum of u and v components at 200 mb with the Kuching station as a reference point in summer, 1980.

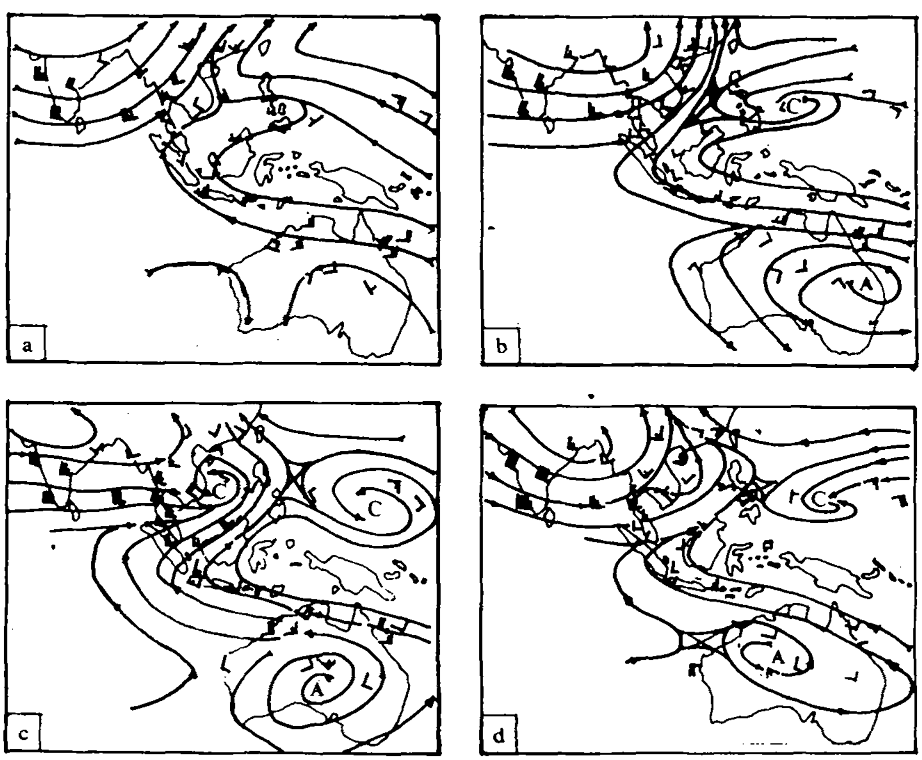

Fig. 5. The composite 850 mb flow pattern of four phases for the 14-day oscillation of surface pressure in the middle part of the South China Sea in summer, 1980. (a) phase of high pressure; (b) phase of high to low pressure; (c) phase of low pressure; (d) phase of low to high pressure.

Fig. 5 shows the composite flow pattern at 850 mb for the four phases of the 14-day oscillation of the surface pressure in the middle part of the South China Sea in the summer, 1980. Fig. 6 is the same as Fig. 5 but for 200 mb. In the composite process, we take three day's data for every phase, so that about 15 day's data are used in a composition pattern. The surface pressure over the middle of the South China Sea indicates the weakening and strengthening of ITCZ. In general, the ITCZ is weakening during the period of high pressure and is strenthening during the period of low pressure (see Fig. 5). As we can see in Fig. 5, during the phase of high pressure, most of the main elements of the EAMS, such as ITCZ, the cold high in Australia, the upper and lower cross-equatorial currents, the southern easterly jet are weakening and the upper trough in the Southern Hemisphere is located over the western part of Australia. On the contrary, all the above-mentioned monsoon elements are strengthening during the phase of low pressure in the middle part of the South China Sea. In that period, the upper trough

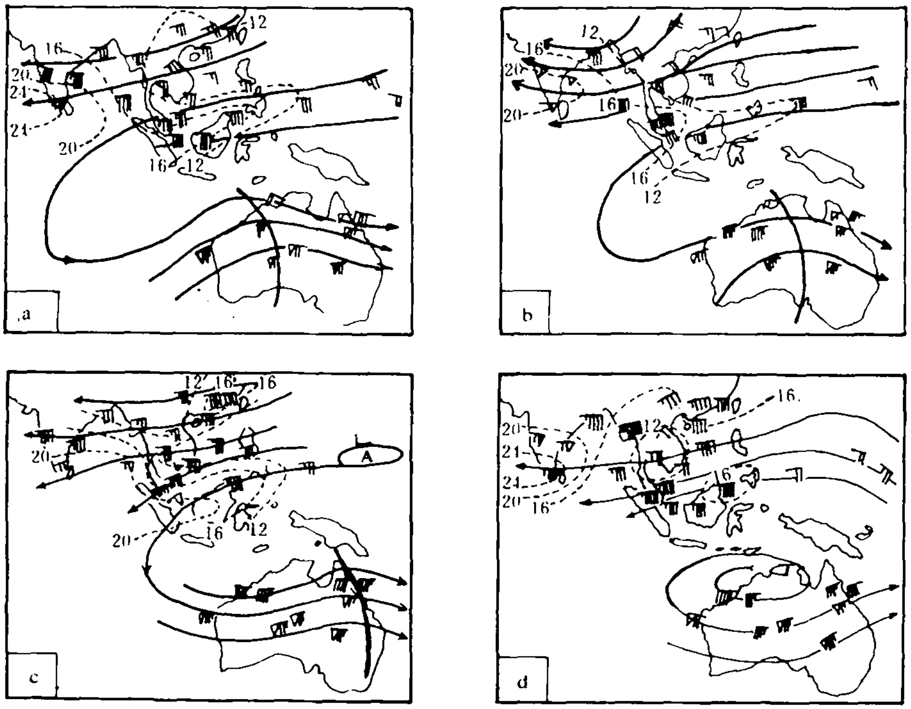

Fig. 6. Same as Fig. 5 but for 200 mb

Table 1. Values of Phase Angle of Cross Spectrum for the Surface Pressure along 12.5 N in the Summer, 1979*

Days	L	70	75	80	85	90	95	100	105	110	115	120	125	130	135	140	E
40	Phase( )	32	28	23	14	7	4	357	359	355	0	1	0	0	2	350	
	Coherence	0.79	0.77	0.74	0.83	0.89	0.89	0.95	0.96	0.98	1.0	0.98	0.94	0.94	0.88	0.73	
13.4	Phase( )	194	222	255	289	285	334	349	350	353	0	11	29	53	30	49	
	Coherence	0.71	0.73	0.74	0.67	0.65	0.52	0.48	0.75	0.74	1.0	0.85	0.66	0.52	0.46	0.14	
5	Phase( )	144	199	224	273	332	322	268	329	325	0	21	73	87	146	143	
	Coherence	0.13	0.16	0.05	0.17	0.24	0.15	0.18	0.25	0.48	1	0.73	0.28	0.23	0.22	0.28	

* The reference point is at 115 E.

in the Southern Hemisphere is located over the eastern part of Australia. We also can see that for the 14-day oscillation, the axis of the subtropical high of the Western Pacific merely moves back and forth between the northern part of the South China Sea and South China, but can not spread into the middle and southern parts of the South China Sea. In this situation, the ITCZ is maintained all the time, but has an oscillation of its own intensity. The monsoon in the south side of ITCZ also shows an oscillation of intensity without break.

The Indian monsoon reaches its maximum intensity of state in the phase of low to high pressure (Fig. 5(d)),i.e. it lags behind the strongest phase of the monsoon in the South China Sea by one-fourth of an oscillation. In fact, the strengthening of the monsoon in the South China Sea can not be simply explained by the strengthening of the Indian monsson.

We have made a series of time cross-section of cloudiness. Fig. 7 shows the cross-section along 132 – 140 E. We can see in this figure that there exists a 40-day oscillation of cloudiness. The propagation direction is from the Southern Hemisphere to the Northern Hemisphere. The original area is located over the northern coast of Australia and propagates to about 8 N with a velocity of 0.8 latitudes day. Fig. 8 shows the cross-section along equator. We also can see in this figure that there exists a 40-day oscillation of cloudiness which propagates westward from the eastern part of the Bay of Bengal to the West Pacific along the equator. So we can conclude that there exists the 40-day oscillation and it propagates from the Southen Hemisphere to the Northern Hemisphere and from the Bay of Bengal to West Pacific. The propagation direction is very similar to that in the Indian monsoon system, so that this type of oscillation has a global scale and has some stimulation regions, such as the western Indian Ocean and the northern coast of Australia.

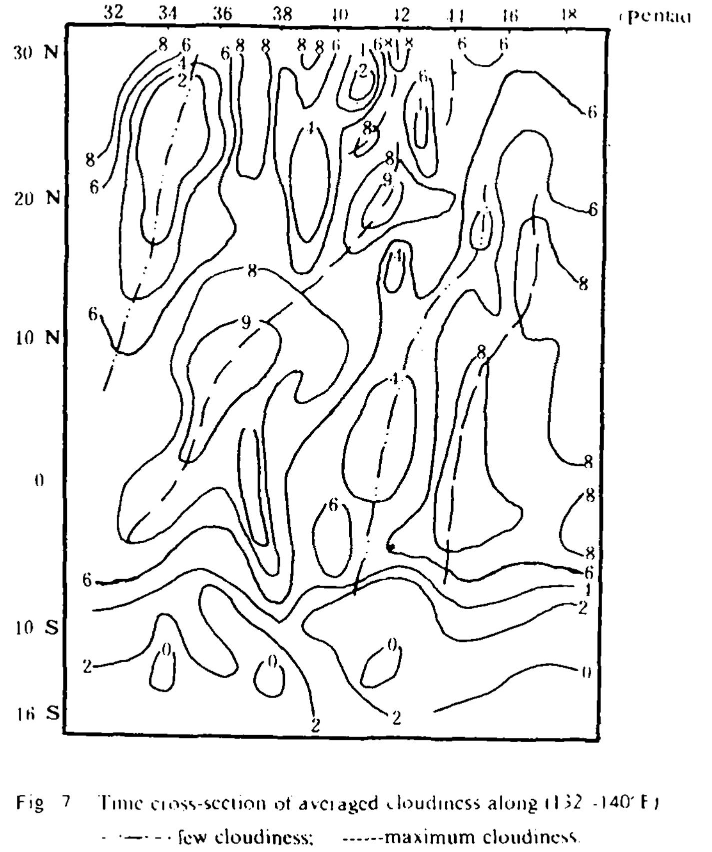

Fig 7 Time cross-section of averaged cloudiness along (132 -140° E)

- ·—· - - few cloudiness; ------maximum cloudiness.

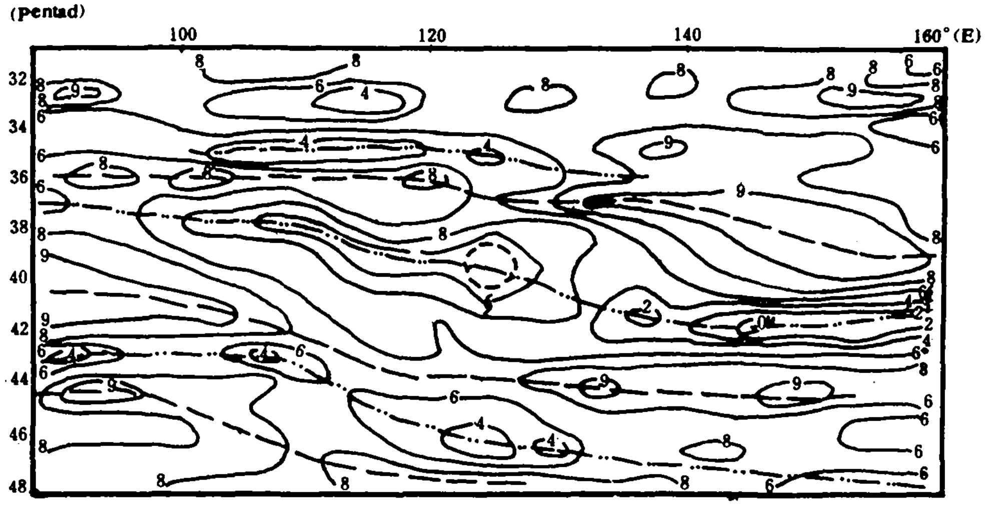

Fig. 8. Time cross-section of average cloudiness along equator (2 S 2 N) during summer 1980.

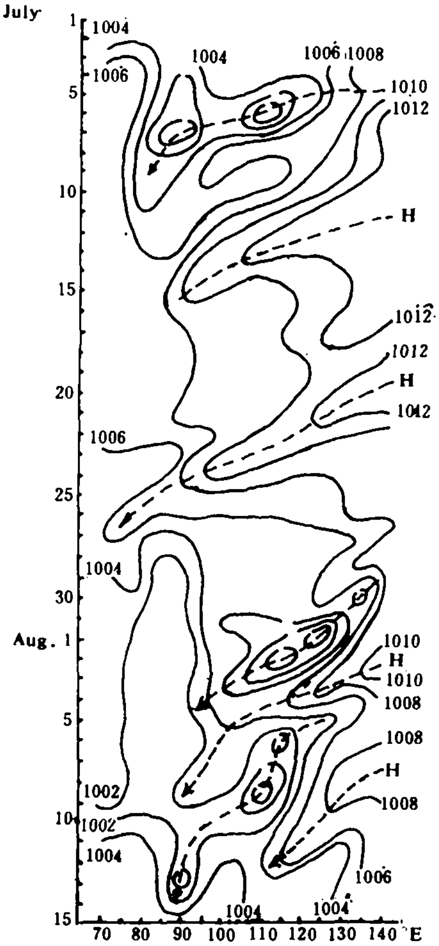

Fig. 9. Time cross-section of the surface pressure along 12.5°N during the summer, 1979.

IV. INTERACTION BETWEEN THE EAST ASIAN MONSOON SYSTEM AND THE INDIAN MONSOON SYSTEM

It has long been believed that the variation of the monsoon in the South China Sea and the West Pacific is caused by the Indian monsoon and the latter would propagate eastward to the South China Sea after strengthening. In recent years, we have found that the development of the depression in the Bay of Bengal caused by the activity of typhoon or the monsoon depression in the South China Sea can propagate westward from the South China Sea to the Bay of Bengal and finally influences the Indian monsoon. This fact is very obvious during the summer, 1979—1980. Fig. 9 shows the time cross-section of the surface pressure along 12.5°N during summer, 1979. We can see that during the summer of 1979, lots of pressure waves propagate from the West Pacific to the South China Sea and finally to the Bay of Bengal. Table I shows the values of phase angle of the cross spectrum and its coherence for the surface pressure along 12.5°N. In the calculation, we took the 115°E point as the reference point. We can see that for the 40-day oscillation, the phase angle in the east of 100°E (in the EAMS) is almost equal, but shows the eastward propagation in the region in the west of 100°E (in the IMS). So we can conclude that the boundary line of these two monsoon systems for the 40-day oscillation is located at 100°E. So far as the 14-day oscillation can propagate westward from the West Pacific to India, the situation in summer 1980 is the same. Fig. 10 shows the analysis of phase angle of cross spectrum for the geopotential height at 850 mb in the summer of 1980 in which the Xisha station was taken as a reference point. we have found that for the 40-day oscillation, the phase angle in the EAMS is almost

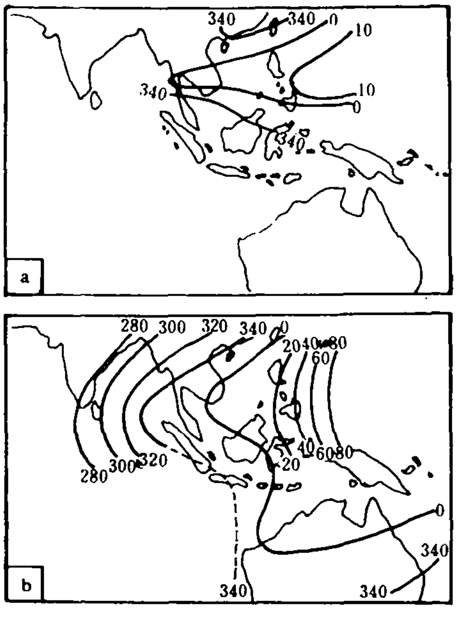

Fig. 10. Phase angle of cross spectrum for the geopotential height at 850 mb in the summer of 1980. The Xisha station is taken as a reference point. (a) 40-day oscillation. (b) 14-day oscillation.

equal but different in the IMS. However, the 14-day oscillation can propagate westward from the West Pacific to India. According to the above-mentioned results, we can conclude that during summer, the influence of the EAMS on the IMS is very important and the reverse influence is rather weak. Besides, the boundary line between these two monsoon systems seems to be located at about 100°E.

The above analyses are limited in the region to the north of 10°N. Because the number of aerological stations in the south of 10°N is too small to study, the main direction of the influence is not obvious. We have investigated a series of lag-correlation analyses (1 – 15 days) using the u component at 850 mb along 10°N (Madras, port Blare, Bangkok, Sisha and Clark air-base) taking Madras as a reference point (Fig. 11). We can not find any fact to show the eastward propagation of the Indian monsoon. In the region in the east of Bangkok, there is no correlation coefficient to satisfy the

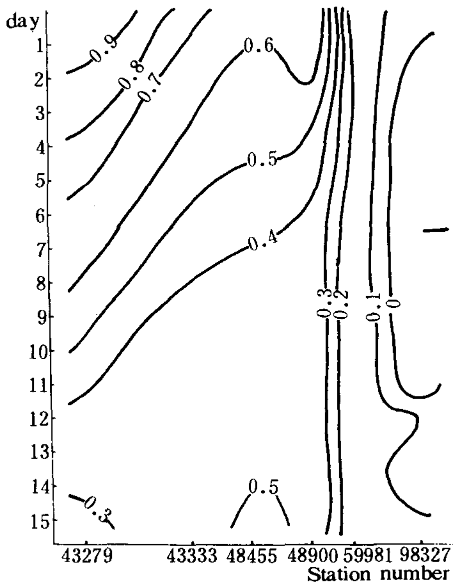

Fig. 11. Distribution of lag-correlation coefficient for u component at 850 mb during summer 1980. (the reference point is Madras station)

confidence 0.01. That is to say, we can not find sufficient evidence to indicate that the strengthening of the Indian monsoon may infleunce the east Asian monsoon. We think that this problem has not been resolved yet and is necessary to study continuously.

V. CONCLUSIONS

According to the above-mentioned discussion, it can be concluded that the EAMS is a rather independent system and is different from the IMS. Its features are as follows: (1) It has got its own main elements. They are the subtropical high in the western Pacific, ITCZ, the upper- and lower-layer cross-equatorial current, the southern upper easterly jet and the Australian cold high. When the ITCZ in the South China Sea and the western Pacific changes its intensity, all of these main elements vary correspondingly. In the lower-layer, the infleuence of the elements over the Southern Hemisphere on the northern monsoon is important, but it is reverse in the upper-layer. (2) The variations of the east Asian monsoon and the Indian monsoon usually are reverse. This fact shows that we can not attribute the variation of the east Asian monsoon to that of the Indian monsoon. On the contrary, some evidence suggests that the influence of the EAMS on the IMS should be important. (3) There exist the 14-day and 40-day oscillations in the EAMS. The 14-day oscillation is characterized by the intensity variation of ITCZ and monsoon, but the 40-day oscillation is charaterized by the large-scale break and activity of monsoon and its corresponding intense variations of the monsoon meridional cell and the subtropical high. According to the results obtained in this paper, the boundary of these two monsoon systems is located at about 100° E.

We think that up to now, many features of the EAMS remain unknown, therefore, a further investigation seems to be extremely necessary.

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