THE ASIAN SUMMER MONSOON AND ITS RELATIONS TO THE RAINFALL IN CHINA

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ABSTRACT

In this paper, four problems are discussed: (1) the monsoon circulation over southern Asia; (2) the seasonal variation of the general circulation of the atmosphere; (3) the influence of the monsoon on the rainfall in southwestern China; and (4) the source region of water vapor for the rainfall in the Changjiang valley.

I. INTRODUCTION

The monsoon circulation is one of the important problems in the prediction of summer weather. It is well known that the cause of monsoon formation is quite complex. The structure of monsoon and its relations to the rainfall in China are also complicated. Although it has long been recognized that there is an easterly jet in the upper troposphere over southern Asia and a SW low-level jet in the lower troposphere, intensive studies on the daily and seasonal variations of these jets over this region have not been performed until recently. In this paper, the above-mentioned problems are reexamined based on the aerological data gathered during summers from 1972 to 1976. We found that both the two upper easterly jets over southern Asia and the two low-level SW monsoon jets are frequently evident.

The onset of the easterly jets and SW monsoon as is known is associated with the seasonal change of the general circulation of the atmosphere. Tao and Chen (1957)[1] and Yeh et al. (1958)[2] have demonstrated that there is synchronous change in the onset of the Indian SW monsoon and the onset of the "plum rains" in China and its change is rather rapidly. In this paper, the problem of the seasonal variation is also studied. We found that the process of the seasonal variation from spring to early summer can be divided into two stages. During the first stage, the main features of the variation of circulation are the onset of the south branches of the upper easterly jet (SEJ) and the low-level SW monsoon jet (SWJ), as well as the beginning of the rainy season in Yunnan Province. During the second stage, the main features are the onset of the north branch of the upper easterly jet (NEJ) and the onset of the north branch of the low-level jet (NWJ) i. e., the onset of the Indian monsoon and the beginning of the rainy season in the Changjiang valley. Tao and Chen specially discussed the facts of the second stage.

Although the southern China is a place famous for its SW monsoon, a proved relationship between the SW monsoon and the rainfall in this region is still lacking. This is not surprising because of the complexity of phenomenon. Some early results have shown that the water vapor for the rainfall in the southern China and the Changjiang valley comes from the Bay of Bengal and is transported by SW monsoon, but the results of our investigation show that it perhaps comes from the South China Sea by the SW monsoon and the Pacific by the SE monsoon. So we come to the conclusion that the South

China Sea is an important source region of the water vapor for the rainfall in the Changjiang valley.

II. THE MONSOON CIRCULATION OVER EAST ASIA

The characteristics of the upper easterly jet over southern Asia was discussed by Flohn[3](1968). Besides, Koteswaram (1969)[4] constructed a mean cross section along 80°E for July. From this cross-section, two easterly jets are found over southern India, but another Indian meteorologist did not find two jets over this region. Chen and Luo (1976)[5] have shown in a paper concerning the feature of the ITCZ that there exists an easterly jet which lies between 0°N and 8°N and extends from the western Pacific to southern Malaysia during the active period of the ITCZ in the western Pacific. In this paper, we have constructed a series of monthly mean maps for wind at 200, 150 and 100 mb during July and August, 1971—1978. We also have constructed a series of the time cross-section for daily wind along 80°E and 105°E during July and August, 1974—1976. In those maps, one important feature which should be noticed is that there are two easterly jets over southern Asia. Fig. 1 shows the monthly mean wind pattern at 150 mb during July, 1974. It is shown that the feature of two jets dominates southern

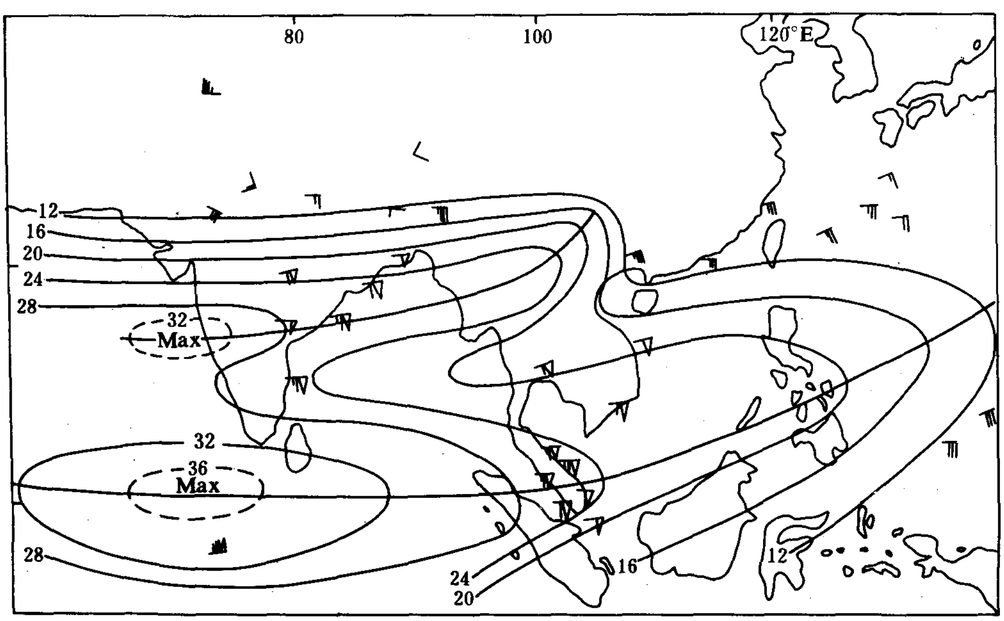


Fig. 1. The isotach at 150 mb for July 1974.

Asia. The southside jet (SEJ) prevails between 5°N and 8°N and northside jet (NEJ) lies between 15°N and 20°N. It is shown in Fig. 1 that the original region of the SEJ is the western Pacific and it extends to southern Malaysia and southern India, while the NEJ originates from south-western China and extends from Tailand to the north Bay of Bengal, the northern Arabian Sea and Iran. The distance between the two jets over Southeast Asia is longer than that over India, so that the feature of the two jets is quite evident over there. Fig. 2 presents the wind cross-section along 105°E in July, 1972 and 1974. The feature of the two jets can be noted in this figure, The core of the NEJ is located at 100 mb over Tailand and the core of the SEJ is situated at 150 mb over southern Malaysia. It shows that the intensity of the two jets are nearly equal at 200 mb and the SEJ is stronger than the NEJ at 150 mb. Above 150 mb, the velocity of the SEJ is weakening rapidly and disappears at 100 mb, while the NEJ is strengthening upward until 100 mb. Fig. 3 (a) presents the time cross-section at 200 mb along 105° in July and August,

1974. This figure shows the following features:

(1) The feature of the two jets at 200 mb by daily data is also as evident as that in the monthly mean map (see Figs. 1 and 2).

(2) The position and the intensity of SEJ are rather steady as compared with those of the NEJ.

(3) The variation of the NEJ is well connected with the activity of the upper Tebitan anticyclone.

Because the height of the NEJ core is higher than that of the SEJ and its change is well related to the Tibetan anticyclone, it is believed that one of the important causes of the NEJ formation is the heat source over the Tibet. The change of the NEJ is possibly connected with the thermal contrast

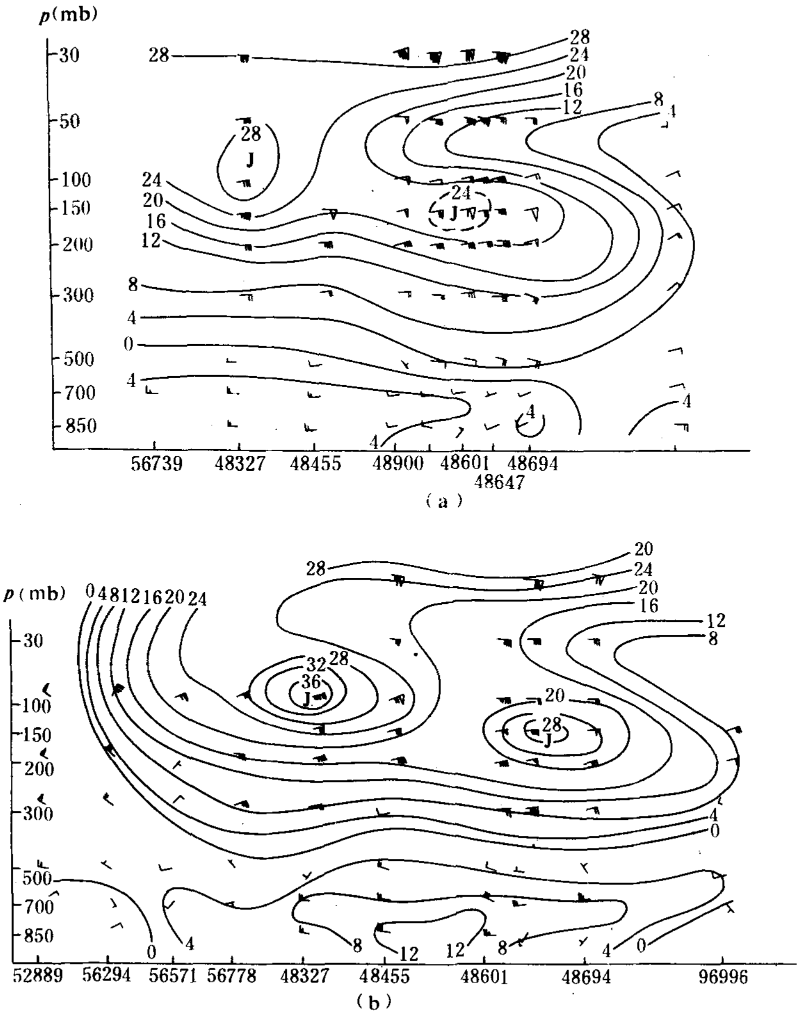


Fig. 2. The vertical cross-section of wind along 105°E for July 1974(a), 1972(b).

between the Tibetan Plateau and the Indian subcontinent, while the change of the SEJ is possibly connected with the thermal contrast between the continent and the ocean.

The low-level flow over the Arabian Sea is discussed in detail by Findlater.[6] From Fig. 1 of his paper, we can notice that the Somali low-level monsoon jet is divided into two branches from the west of 55° E. The southern branch (SWJ) lies between 5° and 10°N and seems to join the Bay of Bengal branch in vicinity of Sri Lanka. Cadet (1977) also shows the same result by the trajectories of superpressure constant-level balloons which were released within the tropical boundary layer from the

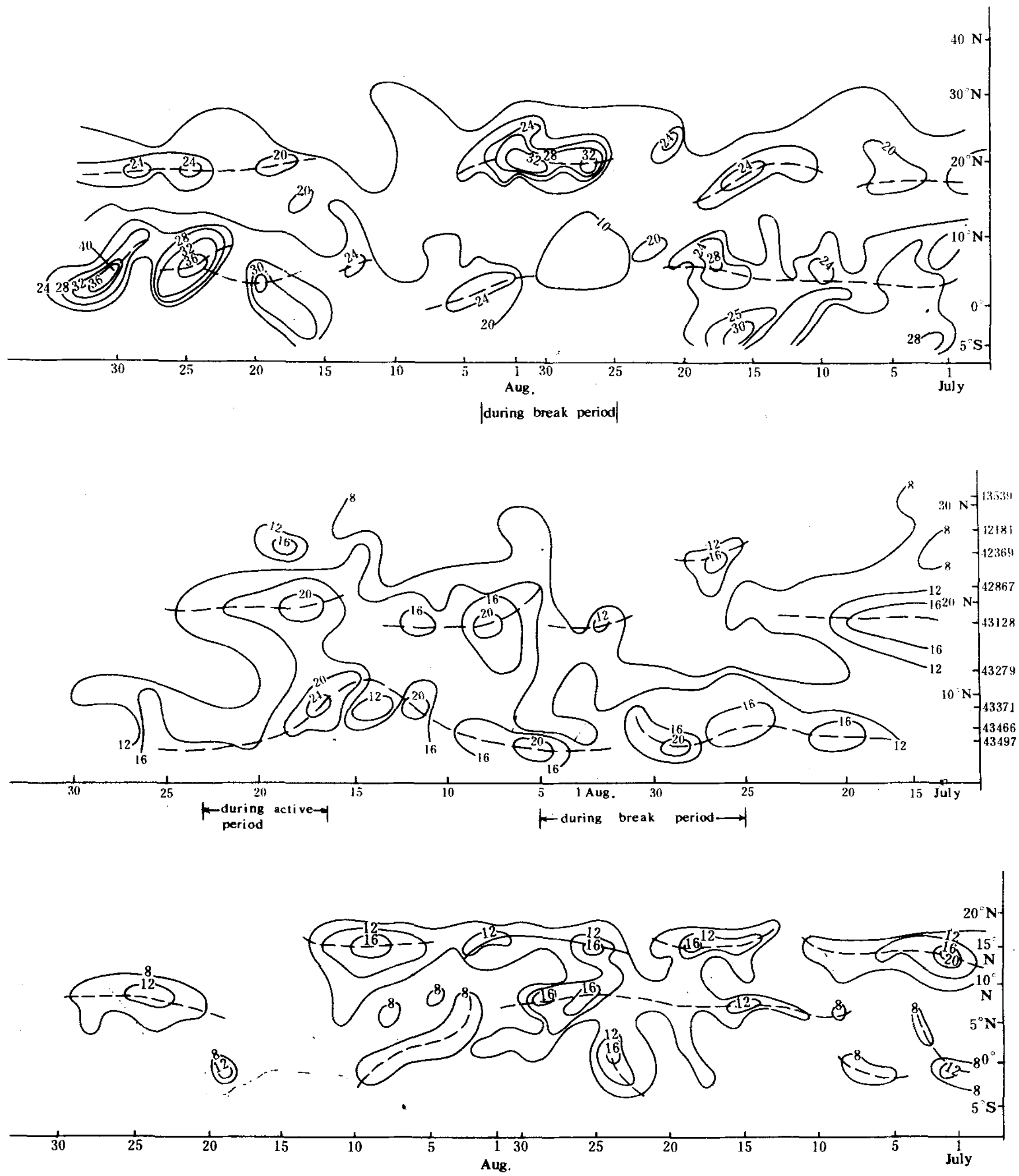


Fig. 3. The time cross-section of daily aerological wind for July and August, 1974.

(a) along 105°E at 200 mb ;

(b) along 80°E at 850 mb;

(c) along 105°E at 850 mb.

Seychelles islands during the summer, 1975. The northern branch (NWJ) is the so called low-level jet of the Indian monsoon which lies between 15°N and 20°N. A series of time cross-sections at 850 mb along 80°E and 105°E are made for July and August, 1973—1976. Figs. 3 (b), (c) are two of these maps which indicate the feature of the two low-level jets in this region. Fig. 3 (b) shows the cross-section along 80°E for 1974 and Fig. 3 (c) presents the cross-section along 105°E for 1976. For 80°E, the position of the SWJ is much steady and lies in the south of 7°N. We found that the SWJ lies just under the SEJ and the NWJ lies just under the NEJ. The intensity of the SEJ exceeds 16 m/s in general and is rather steady as compared with NWJ. It is shown in Fig. 3 (b) that the NWJ disappears when the Indian monsoon breaks down and regenerates over northern India. From daily tropical maps, the two low-level jets are confluent from the western part of the Bay of Bengal. The feature mentioned above generally occurs when the Indian monsoon is active.

III. RELATIONSHIP BETWEEN THE APPEARANCE OF THE UPPER JETS AND THE LOWER JETS AND THE SEASONAL CHANGES OF THE GENERAL CIRCULATION

In the above, we have discussed the structure of the flow field over southern Asia. In this part, we shall discuss the problems of the appearance processes of these jets and their relation with the seasonal variations of the general circulation during the transitional period from spring to early summer. We have found that the seasonal variation during the above-mentioned period is accomplished through two rapid changes rather than in a single process. We have selected lots of circulation indices and decided the appearance date for which the circulation indices coincide with the pre-defined standard based on the acrological data for 1971—1976. These indices are as follows:

(1) The appearance date for the SWJ (DSWJ): the first day when the velocity of the westerly wind at 850 mb over southern India south of 10°N exceeds 12 m/s for three-day running.

(2) The appearance date for the NWJ (DNWJ): the first day when the velocity of the westerly wind at 850 mb over India between 15°N and 20°N exceeds 12 m/s for three-day running.

(3) The appearance date for the SEJ (DSEJ): the first day when the velocity of the easterly wind at 200 mb over South-Eastern Asia south of 10°N exceeds 16 m/s for three-day running.

(4) The appearance date for the NEJ (DNEJ): the first day when the velocity of the easterly wind at 200 mb over South-Eastern Asia between 15°N and 20°N exceeds 16 m/s in succession.

(5) The appearance date of the SWJ in the Bay of Bengal (DSWJ in the Bay of Bengal): the same as DSWJ, i.e. the date when wind is rising in Port Blair.

(6) The onset day of the SW monsoon over Bombay (ODMB): the day when the north limit line of the SW monsoon defined in the Indian daily map arrives at Bombay.

(7) The onset date of "plum rains" in the Changjiang valley (ODMYY): following the definition of the long-range prediction group, Center of Forecasting, State Meteorological Administration.

(8) The date of the beginning of the monsoon rainy season in Yunnan Province (DRSY): following the definition of You, et al. (1979).

Following the above-mentioned difinitions, we have constructed a table (Table 1) for 1971—1976. It can be seen from this table that the seasonal variation can be divided into two stages. The major features during the first stage are as follows:

(1) the SWJ and the SEJ appear;

(2) the monsoon rainy season of Yunnan Province begins;

(3) the onset of the monsoon in the Bay of Bengal occurs;

(4) the axis of the anticyclone at 100 mb over southern Asia suddenly moves northwards from 20°N to about 25°N and the axis at 200 mb also moves from 17°N to 22°N.

The features of the second stage are as follows:

(1) the onset of the Indian monsoon occurs;

(2) the NWJ and the NEJ appear;

(3) the axis of the anticyclone at 100 mb moves northwards further to about 30°N and starts to maintain steadily at that latitude and the axis at 200 mb moves northwards from 25°N to about 30°N;

(4) the onset of plum rains in the Changjiang valley occurs.

Table 1. The Appearance Date for the Seasonal Variation of the General Circulation over Eastern Asia

Item \ Year	1971	1972	1973	1974	1975	1976
(1)	25 May	8 June	5 June	23 May	1 June	21 May
(2)	27 May	8 June	8 June	23 May	1 June	25 May
(3)	27 May	2 June	9 June	26 May	6 June	26 May
(4)	22 May	7 June	8 June	26 May	4 June	26 May
(5)	23 May	19 June	10 June	24 May	4 June	25 May
(6)	1 June	21 June	8 June	28 June	17 June	4 June
(7)	1 June	24 June	8 June	29 June	18 June	4 June
(8)	8 June	19 June	19 June	26 June	19 June	5 June
(9)	5 June	18 June	12 June	25 June	20 June	8 June
(10)	9 June	20 June	16 June	10 June	16 June	21 June

(1) The appearance date for the SWJ over southern India.
(2) The appearance date of the SW monsoon over the Bay of Bengal
(3) The appearance date for the SEJ at 200 mb.
(4) The first variational date of the anticyclone at 100 mb.
(5) The beginning date of the monsoon rainy season of Yunnan Province.
(6) The onset date of the SW monsoon over Bombay
(7) The onset date for the NWJ over India.
(8) The onset date for the NWJ at 200 mb.
(9) The second variational date of the anticyclone at 100 mb.
(10) The onset date of the "plum rains" in the Changjiang valley.

It can be seen in Table 1 that on an average, the date for the first stage is about 25 May and is about 10 June for the second stage. Although the occurrence dates for the circulation indices are different from each other, the time difference is limited in a period of five days for the first stage and in a period of ten days for the second stage .

On an average, the onset of the Indian monsoon is three days earlier than the beginning of "plum rains", so we can only say that the processes of the seasonal variation are rather rapid and the occurrence dates of circulation indices are nearly at the same time. It can be noticed in Table 1 that the onset of the monsoon in the Bay of Bengal is four days later than the beginning of rainy season in Yunnan Province for 1971, and the onset of "plum rains" is eighteen days earlier than the onset of the Indian monsoon for 1974. These results mean that: (1) The precipitation mechanism in the Changjiang valley and Yunnan Province is very complicated and the monsoon is merely one of the important causes. Other causes such as the influence of the cold air are also important for the rainfall in these regions. (2) There does not exist a direct relationship between the onset of the Indian monsoon and the onset of "plum rains", but these two features are the results of the seasonal variation of the general circulation. On an average, the occurrence date of the first stage is 15 days earlier than that of the second stage, but it has a great difference from 1971 to 1976. For example, the difference between the two stages is about one month for 1974 and one week for 1973. This feature means that it can be divided definitely into two stages in these years, but in some years, the changes of the two stages appear in a continuous sequence.

In a paper discussing the relationshiop between the seasonal variation of the general circulation

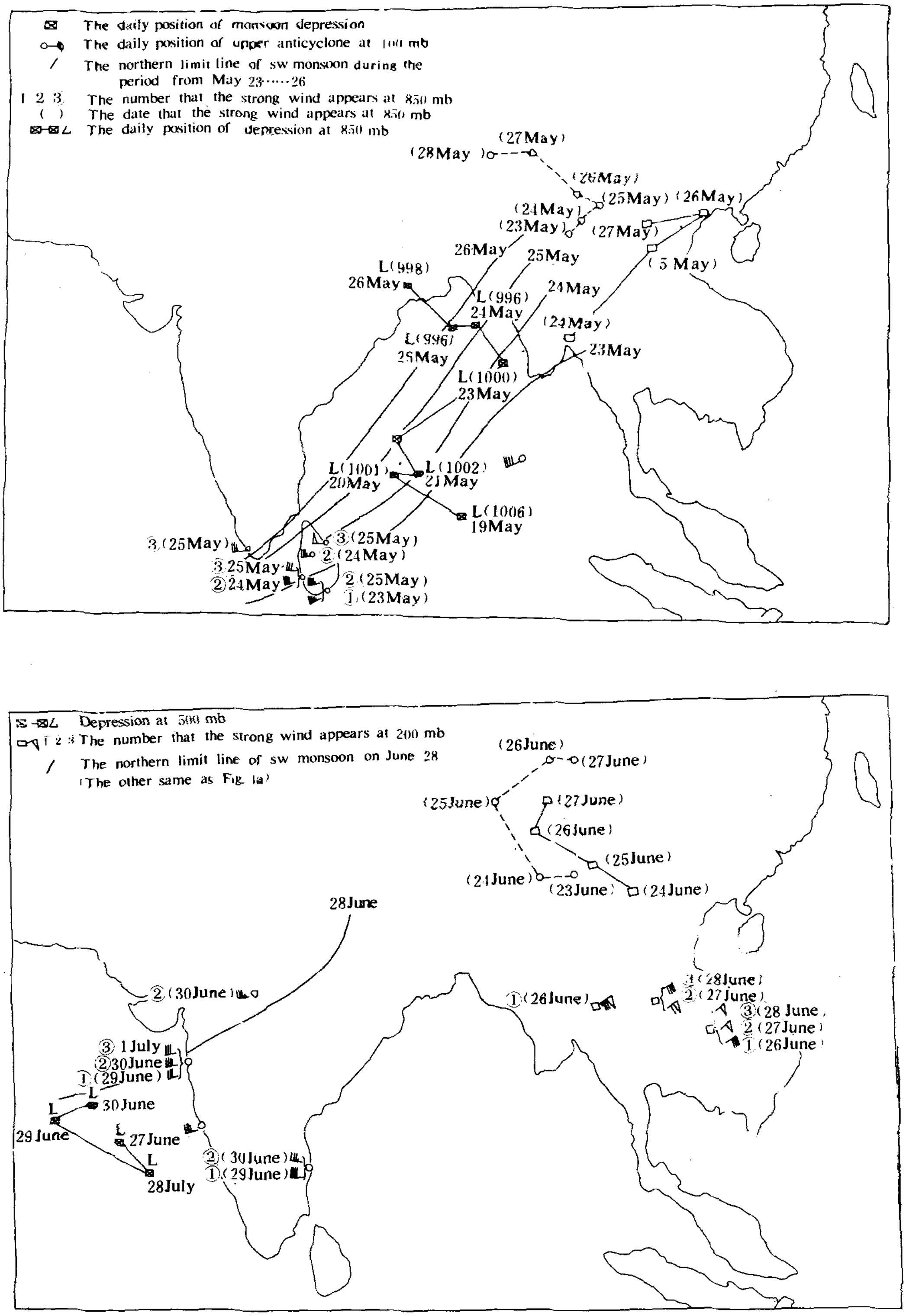


Fig. 4. (a) The first process of seasonal variation from spring to early summer 1974.

(b) The second process of seasonal variation from spring to early summer 1974.

and the beginning of rainy season in Yunnan Province, one of the authors pointed out that the onset of the monsoon over the Bay of Bengal was frequently connected with a developing process of the monsoon low over there and the occurrence date of the SWJ in southern India was 2—4 days earlier than that of the formation of that monsoon low. In the second stage, we also can see that the onset of the Indian monsoon over the Arabian Sea is also usually connected with a developing process of the monsoon low over there. Figs. 4(a) and (b) are the composite maps for the process of the seasonal variation in 1974. Fig. 4(a) shows the process of the first stage. We can see from this figure that the wind velocity at 850 mb in the southside of Sri Lanka exceeds 20 m/s on 25 May. At the same time, the monsoon at Port Blair at 500 mb is also intensive and its velocity exceeds 16 m/s on 23 May. During the period before 20 May, the wind velocity at 850 mb over the above-mentioned region is smaller than 12 m/s. The monsoon low develops on 19 May over the Bay of Bengal and arrives near the Burma coast on 23 May. The central pressure of the monsoon low is about 1000 mb before 23 May and suddenly develops to 996 mb on 23 May. It seems that the onset of the monsoon in the Bay of Bengal is one day earlier than the developing day of the monsoon low. During the same period, the velocity of the SEJ is strengthened to 16 m/s at 200 mb on 26 May over South-Eastern Asia, whereas the same feature appears on 31 May over southern India, so the strengthening of the SEJ in the eastside of southern Asia is about 5 days earlier than that in the westside during the first stage. Besides, the center of the

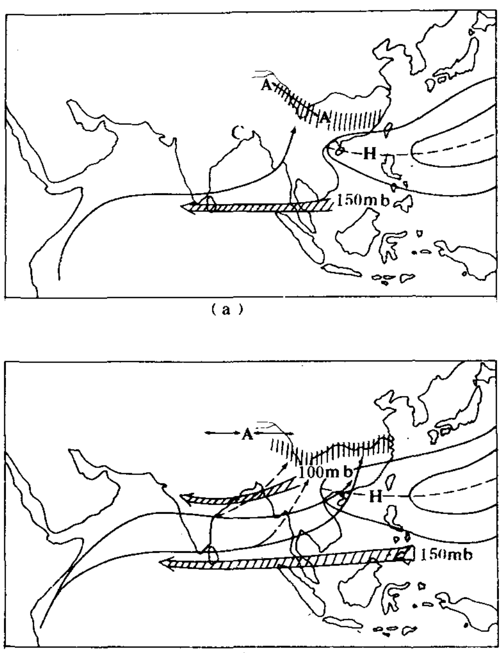


Fig. 5. The scheme of circulation process of seasonal variation from spring to early summer

(a) The first process. (b) The second process.

A: Anticyclonic center at 100 mb

C: Center of monsoon depression over the Bay of Bengal

Axis of easterly jet at 150 mb.

Lower-layer jet of SW monsoon.

---H--- Axis of subtropical high at 500 mb.

Rainfall area in China.

anticyclone at 100 mb moves northwards from 23.5°N to about 29°N during 23—28 May, so the occurrence of the SEJ over southern India on 23 May is about 4 days earlier than that of the anticyclone.

Fig.4(b) shows the process of the second stage for 1974. The north limit line of the monsoon arrives in Bombay on 28 June. In the same period, a monsoon low develops over the Arabian Sea. The velocity of the NEJ at 200 mb over Southeast Asia between 15°N and 20°N is being strengthened to 16 m/s on 26 June. In the same day, it is 32 m/s over the Changmai station. The center of the anticyclone at 200 mb moves northward from 25°N to 31°N during 25—27 June and arrives at 34°N at 100 mb on 25 June.

Following the above-mentioned features, we can draw a composite figure to illustrate the two processes. Fig. 5 presents the composite scheme.

IV. INFLUENCE OF THE MONSOON ON THE RAINFALL IN SOUTH-WESTERN CHINA

As discussed in the preceding section, the beginning of rainy season in Yunnan Province is connected with the invasion of the SWJ. Shen et al. (1980) pointed out that during mid-summer, the rainfall period in the main-land of China caused by the low vortex coming from south-western China and the break period of the Indian monsoon usually coincided with each other. This feature especially dominates in south-western China. In this paper, we want to discuss two problems. The first is what the rainfall pattern caused by the monsoon is. The second focuses on the source region of the water vapor which causes the rainfall in China during the break and active periods of the Indian monsoon.

For the study of the first problem, we have constructed a series of rainfall maps for the break periods of the Indian monsoon, 1971—1976. It is shown in these maps that there exist two kinds of rainfall patterns, one is purely influenced by the Indian monsoon and the other is influenced by combination of the monsoon and the cold air. We have found that the rainfall of the first kind is merely limited in the region of the central and eastern Tibet, western Sichuan, Yunnan Province and west Guangxi. Therefore, the rainfall pattern is in an arc form. Fig. 6 (a) is a typical map for the first kind. This figure illustrates the total rainfall amount during 25—31 August 1974 and the flow pattern at 850 mb on 27 August 1974. In this figure, the rainfall amount observed by the satellite is presented in the Bay of Bengal. We can see in Fig. 6 (a) that it is a typical break period of Indian monsoon and it has

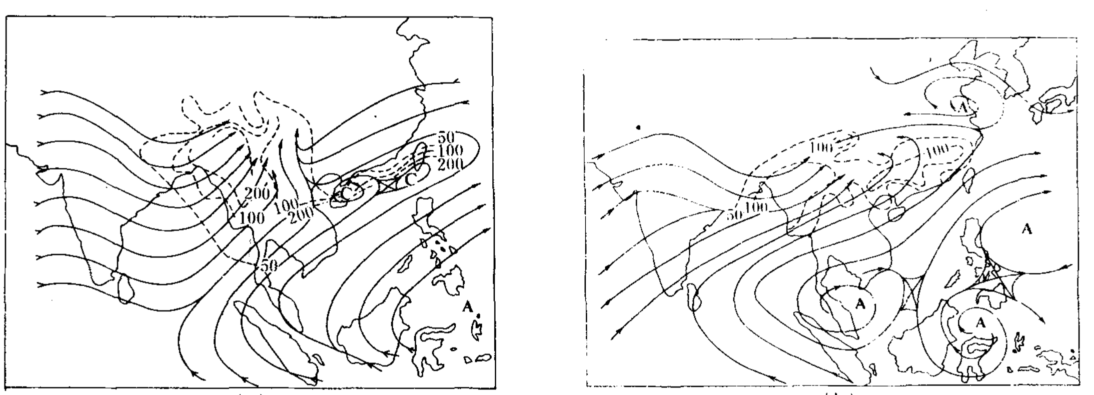


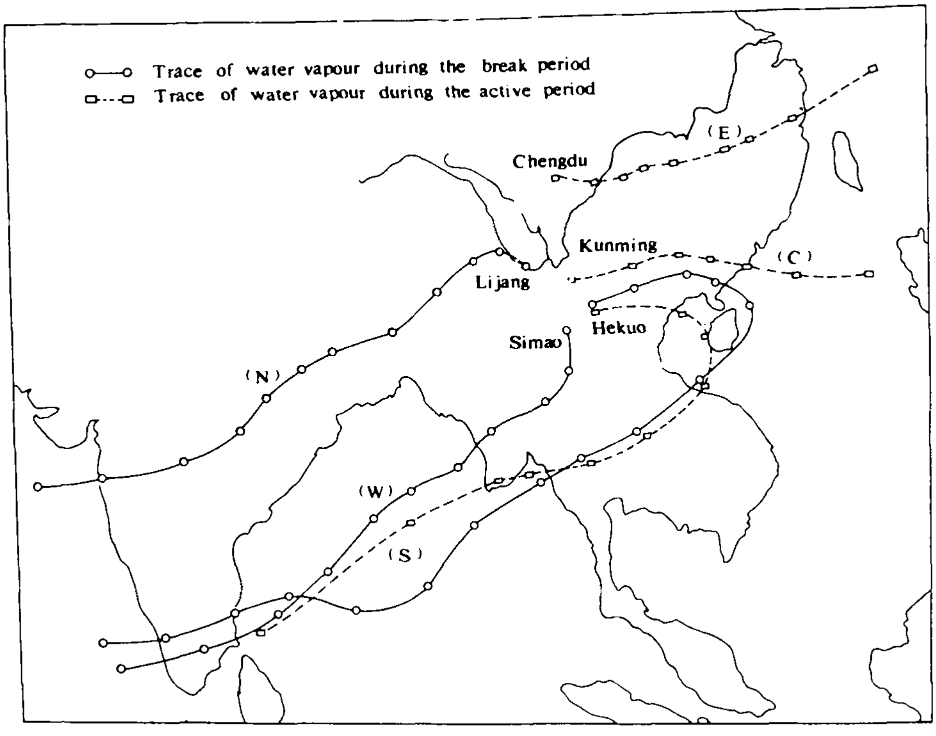
Fig. 6. (a) The stream line at 850 mb for 27 August 1974 and the total amount of rainfall during the period 25 31 August 1974.
Full line: stream line,
Dashed line: Isohyet (mm).
(b) Same as (a), but for 7 July 1976 (stream line) and for 3—12 July 1976 (rainfall)

not strong cold air in the main-land of China. In the Bay of Bengal, there are two current confluent near the Islands of Andama, one is the SWJ and the other comes from the Southern Hemisphere and crosses the equator at Sumantara. After confluence, the SWJ flows through Burma and finally arrives in the main-land of China. In the break period, there is the third monsoon current. This current originates from the river southside of the Plateau and flows through the Yarlungzangbo-Brahmaputra valley, then arrives at western Yunnan. Generally speaking, the daily rainfall amount caused by the monsoon is smaller than 8 mm. According to our statistics, there are nine break periods of Indian monsoon in summer 1971—1976, which appear to be four processes of pure monsoon rainfall similar to Fig. 6 (a) (the first pentad of August 1971, the fourth pentad of July 1972, the first pentad of July 1974 and the sixth pentad of August 1974). Fig. 6 (b) illustrates only a typical rainfall pattern for the combination kind. In this figure, the total rainfall amount for 3—12 July 1976 and the flow pattern at 850 mb for 7 July 1976 are presented. It shows that there exists a equatorial anticyclone at 850 mb over the eastside of the South China Sea and moves to the westside on 5 July, then the SWJ is being strengthened and moves into the main-land of China. In the meantime, the cold air invades into western Sichuan on 3 July and then spreads into the eastern main-land of China. Due to the combination effects of the monsoon and the cold air, there exist two rainfall regions, one is the typical pattern for the pure monsoon as same as that in Fig. 6 (a), but the rainfall amount is larger than that in Fig. 6 (a). Because of the influence of the cold air in Sichuan, a heavy rain region appears in Sichuan and Yunnan Provinces. The other lies in the south of the Changjiang valley caused by the combination effects.

By the daily analysis of the dew-point deficit, it can be seen that the isoline whose $(T\text{-}T_d)$ equals 2° spreads from the central Bay of Bengal to Burma, so it shows that the water vapor for the rainfall in south-western China is coming from the Bay of Bengal and is tansported by the SWJ. To solve this problem furthermore, we have selected five typical break periods of the Indian monsoon from 1971 to 1976. The total number of these five periods is 38 days. In these days, we have selected one rainfall point per day in south-western China and have evaluated its trajectory. There exist three typical trajectories (Fig. 7 (a)). This firgure shows the transfer path of the water vapor which causes the rainfall in the above-mentioned region. We call the first path the northern path and its original region can be traced back to the Arabian Sea near 20°N. From the original region, it moves eastwards through the central India and the northern Bengal and finally arrives in the main-land of China. This path usually occurs in the early stage of the break period because India just situated in the active period when we traced back to the rainfall region of central India. It can also be noticed that it causes a heavy rain in the westside of the mountain when the monsoon flow crosses the mountain along this path. The second path is so called the central path. We can trace it back to the southern India. The water vapor is transported by the SWJ and arrives at southern Yunnan and southwestern Yunnan, then spreads northwards or eastwards. The arc form of the rainfall region is caused by this process. As is well known, the rainfall is larger when the cold air is invading. This is the cause that a heavy rain region is formed in the dividing region of Sichuan and Yunnan Provinces when the cold air combines with the monsoon. The third path for the break period lies by south, so we call it the south path. Its original region is the same as that of the central path , i. e, southern India. From its original region, it moves eastwards through the Bay of Bengal, Tailand and the South China Sea then enters into Guangxi and finally arrives at eastern Yunnan. It appears frequently during the end stage of the break period.

The central path is the most important one statistically, its occurrence frequency is 24/31. We can say that the water vapor for the rainfall in south-western China is mainly coming from the Bay of Bengal and is transported by the SWJ.

In the active periods of the Indian monsoon, there is also much rainfall in south-western China, but on an average, its intensity is smaller than that in the break period. Statistically, the break periods of rainfall in south-western China always occur in the active period of the Indian monsoon. Because the



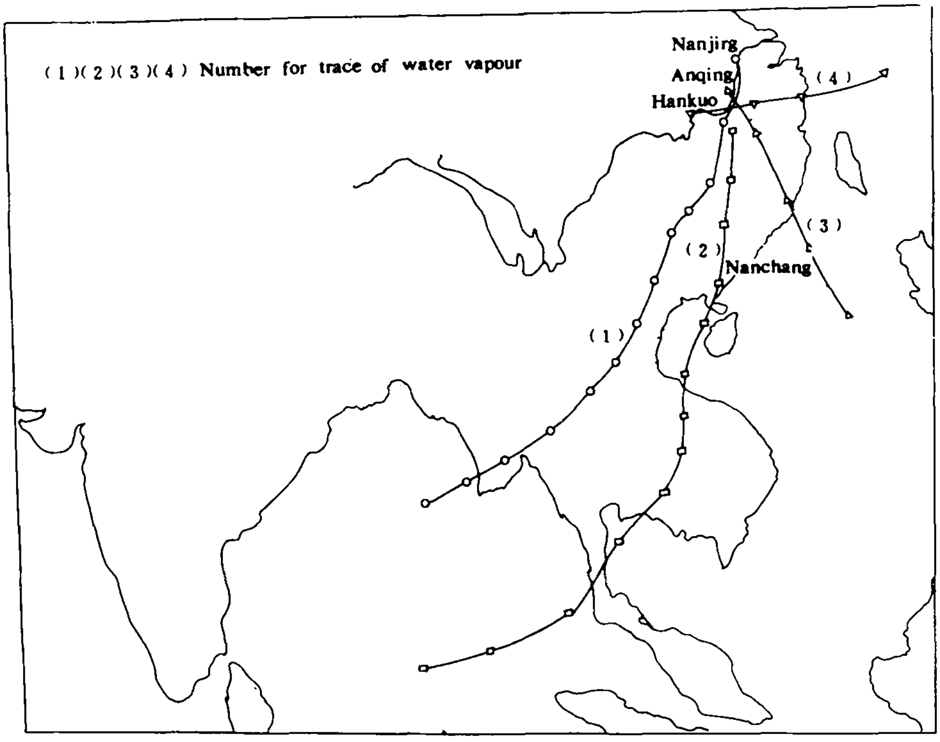


Fig. 7. (a) Trace of water vapour that caused the rain in the south-western path of China.

o——o Trace of water vapour during the break period.

□—□ Trace of water vapour during the active period.

(b) same as Fig. 7 (a), but for the Changjiang valley. Numbers 1, 2, 3 and 4 denote traces of water vapour.

number of active monsoon day is larger than that in the break monsoon day, the total amount of rainfall in southwestern China during the active period of Indian monsoon still can be larger than that in the break period. For the active periods, we also have selected four typical periods (34 days) and evaluated the trajectories for these days. The dotted line in Fig. 7 (a) shows the typical trajectories. We call the first path the western-path which is the same as the southern path during the break period. The second path is the central path. It can be traced back to the South China Sea and arrives in southwestern China through Guangdong Province or eastern Guangxi. The third is the eastern path and its original place is the Pacific. The total occurrence frequency of the central and eastern path is 16/22, so these two paths are important. From the abóve-mentioned statistics, we can see that for the rainfall in southwestern China the water vapor originating from the South China Sea is more important than that originating from the Bay of Bengal during the active period, and the rainfall in that region is mainly influenced from the eastern-side. It can be seen in the climate map of rainfall for July and August in China that the dividing region between Guangxi in China and Viet Nam is a maximum region of the rainfall and this region spreads westward to the south-eastern Yunnan (monthly amoumt exceeds 500 mm). There is another rain belt lying from western Guangxi to eastern Yunnan. These two belts coincide closely with that of the central path and the eastern path during the active period, so they are possibly caused by the water vapor originating from the South China Sea. From the above results, we conclude that the water vapor for the rainfall in south-western China mainly comes from the Bay of Bengal during the break period of the Indian monsoon and from the South China Sea during the active period.

V. THE SOURCE RÉGION OF WATER VAPOR FOR THE RAINFALL IN THE CHANGJIANG VALLEY

It has long been accepted by most of Chinese meteorologists that the water vapor for the rainfall in the Changjiang valley mainly comes from the Bay of Bengal. But as seen from the analysis of the daily synoptic chart, we have found that the point of view mentioned above must be reexamined now. In authors' opinion, the relationship between the rainfall in the Changjiang valley and the Indian monsoon is not so close. For example, the Indian monsoon was broken down in July, 1972 and the rainfall in the Changjiang valley was also weak. But for July, 1974, although it was also a break month of the Indian monsoon, the rainfall in the Changjiang valley was rather strong and the rain anomaly exceeded positive 100%. The causes of the rainfall in the Changjing valley are not purely created by the Indian monsoon. As a matter of experience of Chinese forecasters, the rainfall in that region is closely related to the activity of the cold air and the subtropical high. The latter means the activity of the SE monsoon in China. In recent years, it is well known that the rainfall caused by the SE monsoon dominates the Changjiang valley. We also have evaluated the trajectories starting from the rainfall region in the Changjiang valley. The days discussed here are the same as those in the above section. Table 2 shows the statistical feature of all trajectories and Fig. 7 (b) shows the four typical trajectories. The first path originates from the Bay of Bengal and is through Burma, southwestern Yunnan and finally arrives at the Changjiang valley. This path coincides with the central path during the break period for rainfall in south-western China. The second also originates from the Bay, but is through the South China Sea and finally arrives at the Changjiang valley. The third originates from the South China Sea but the fourth from the Pacific. Based on our statistics listed in Table 2, the second and the fourth are more important than the first and the third during the break period and their frequencies are 9/17 and 6/16 respectively. On the other hand, the third and fourth path are important during active period of Indian monsoon and their frequencies are 6/19 and 9/19, respectively. So the water vapor for the rainfall in the Changjiang valley mainly comes from the South China Sea and the Pacific during either the break period or the active period. According to the present authors' opinion, the SW monsoon causing the rainfall in the Changjing valley originates from two currents. One is coming from

Table 2. Statistical Table for Trace of Water Vapor

(a) During Break Period

Region / Path / Date	The SW Region			The Changjiang Valley			
	N	C	S	(1)	(2)	(3)	(4)
1—6 August 1971	1	6	1		3		
17—31 July 1972		5	2			1	5
25—31 July 1973		5	1		4	1	
21—28 July 1974	2	5			2		
25—31 July 1974							1
Total	3	24	4		9	2	6

(b) During Active Period

Region / Path / Date	The SW Region			The Changjiang Valley			
	W	C	E	(1)	(2)	(3)	(4)
5—19 August 1972		1	1				5
5—9 July 1973	4	1		1	1	3	
26—31 August 1973	2	1	3			3	1
13—31 August 1974		4	2		2		3
Total	6	7	9	1	3	6	9

N: The northern path.
C: The central path.
S: The southern path.
W: The western path
E: The eastern path.

(1) The first path
(2) The second path
(3) The third path
(4) The fourth path.

the Indian monsoon (the SWJ) and the other is coming from the Southern Hemisphere which crosses the equator between 90°E and 125°E.

VI CONCLUSIONS

There exist two upper easterly jets and two low-level jets. Over South Asia, the northside jets lie between 15°N and 20°N and the southside jets between 5° and 10°N. We suggest that the change of the northside jet should be connected with the thermal contrast between the Plateau and the continent and with the sea-continent contrast for the southside jet.

The process of the seasonal variation of the general circulation from spring to early summer can be divided into two stages. The variation of the first stage is closely connected with the appearance of the two southside jets, the rapid northward movement of the upper anticyclonic center, the onset of the monsoon in the Bay of Bengal and the beginning of the monsoon rainy season of Yunnan Province while the variation of the second stage is closely connected with the appearance of the two northside jets, the onset of the Indian monsoon and the beginning of "plum rains" in the Changjiang valley.

On an average, the intensity of rainfall in south-western China is larger during the break period of the Indian monsoon than that during the active period. The rainfall region is an arc form when the rainfall is caused by the monsoon only and lies in eastern Tibet, western Sichuan and Yunnan Province. During this time, the rainfall amount is smaller than that caused by the combination effect of the monsoon and the cold air. The water vapor for the rainfall in southwestern China comes from the Bay of Bengal during the break period and mainly from the South China Sea during the active period.

The causes of the rainfall in the Changjiang valley are quite complicated problem. They are influenced by three elements: (1) the SW monsoon coming from the India and Southern Hemisphere; (2) the SE monsoon; (3) the cold air. The water vapor for the rainfall in the Changjiang valley mainly comes from the South China Sea and the Pacific.

REFERENCES

[1] 陶诗言，陈隆勋，气象学报， **28** (1957), 234—246

[2] 叶笃正，陶诗言，李麦村，气象学报，**29** (1958), 249—263

[3] Flohn,H., *Contributions to a meteorology of the Tibetan highlands*, Dept. Atmos. Sci. Colorado state Univ. Atmos. Sci. No. 150.

[4] Koteswaram,p., *WMO Technical Notes*, **95** (1969), 218—228.

[5] 陈隆勋，罗绍华，中国科学院大气物理研究所集刊，科学出版社， 1979, 8:77—85.

[6] Findlater,J., *Quart.J.Met. Soc.*, **95** (1969), 362 380.

[7] 尤丽钰，霍义强，陈隆勋，长江流域暴雨文集，气象出版社， 1980.