STABILIZATION OF SUMMER MONSOON IN MIDDLE AND LOWER REACHES OF THE CHANGJIANG RIVER AND SEASONAL TRANSITION OF EAST-ASIAN CIRCULATION PATTERN IN EARLY SUMMER

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ABSTRACT

Using data of 850 hPa pentadal mean θ_{se} and composite wind fields in East China, characteristics of the mean circulation are examined with summer monsoon (SM) stabilized over the Changjiang middle and lower reaches (CMLR). The onset of steady SW monsoon consistent over the CMLR is marked by a considerable northward jump of the pentadal position of the 340 K θ_{se} isoline. This is considered as a seasonal change-over of South-China SM in its northward movement. Moreover, it is found that, when low-level SM becomes stabilized over the CMLR, an evident northward shift occurs of the high-level jet center along 115°E, indicating a certain relation between the seasonal variation of the East-Asian circulation pattern in early summer and the steadiness of SM in the CMLR.

I. INTRODUCTION

As early as the 1950's the relationship was discussed in detail between early-summer Meiyu over East Asia and the seasonal transition of the circulation pattern over Asia[1], and in the early 1980's research was made of SM activity in East China relative to the drought and flood typical of the Changjiang reaches[2]. As indicated in these studies, a relation exists of such large-scale weather processes as the rainy season and drought/flood in early summer over the CMLR to the seasonal variation of the circulation pattern as well as the lower SM behavior, a major problem our meteorologists have been showing concern for. Based on the data on SM behavior from April to July 1971—80 over the CMLR[3] further exploration is made of variations of pentadal mean flow and θ_{se} fields over these years at 850 hPa along with their seasonal change around SM stabilization in these areas. In addition, on the basis of 3 sets of data for different onset time of Meiyu (1978—80) the relationship is studied between SM stabilization over the CMLR and the seasonal transition of the East-Asian circulation pattern in early summer with an attempt of further investigating the association among the onset of Meiyu period, SM stabilization and the seasonal transition of the circulation pattern over East Asia.

II. SOME MAIN FEATURES OF THE SM NORTHWARD ADVANCEMENT OVER EAST CHINA

By analyzing facts of circulation pattern change-over in low latitudes and tropics, many studies[3,4] indicate that summer SW monsoon affecting East China advances progressively from south to north instead of sudden outbreak. On an average basis, when SM begins to have influence upon the CMLR but is easily disturbed by westerly trough/ridge systems owing to its geographical location (nearly 30°N), the swing occurs across the River in the

northward course[3]. Only in the first half of June does the SM become steady gradually with the SW wind blowing all over the CMLR. This significant change is clearly shown in the development of mean flow and θ_{se} fields at the 850 hPa level. The main features are as follows:

1. *Characteristics of 850 hPa Pentadal Mean Flow Field Variations before or after the SW Monsoon Stabilization*

Analysis of the 5-day mean flow field at 850 hPa for the area of East China south of 40°N from April to July, 1971—80 shows that in April the CMLR are often affected by the transformed cold air from the north which still extends to the south side of the Changjiang River (figure omitted). In the 4th pentad of May (Fig. 1 (a)), however, the winter monsoon becomes strongly weakened and can retreat to the north side and SW airflow originated in South China Sea or regions even further south of it can reach the place at this time of year, only with insufficient stability so that in the 1st pentad of June (Fig. 1 (b)), northerly wind can still be observed to the south of the River. The alternate occurrence of these south and north winds is just what we refer to as the swing. It is worth noting

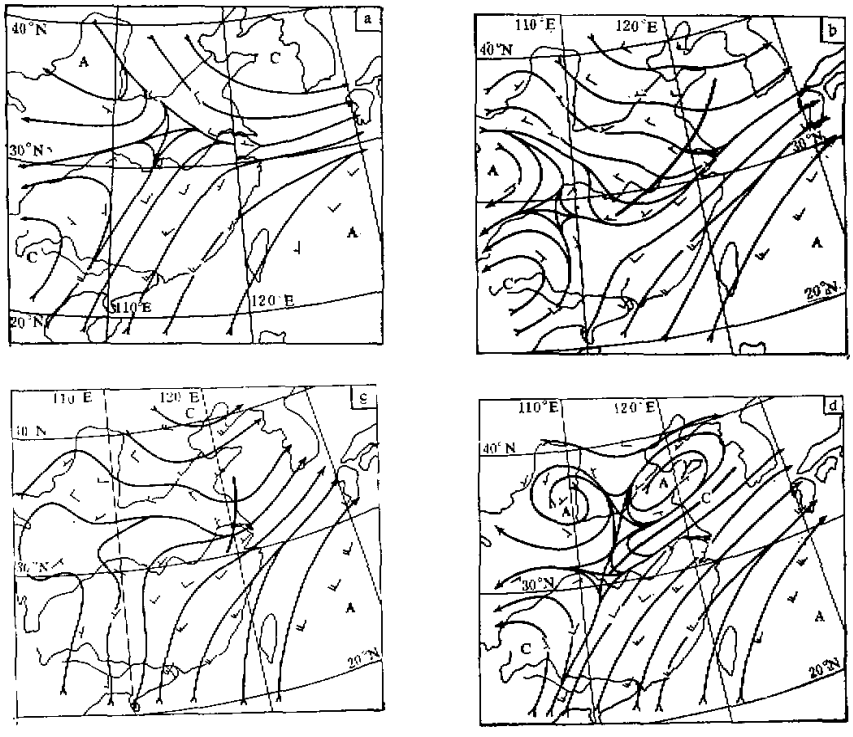

Fig. 1. Pentadal mean flow fields at 850 hPa for May–June, 1971—1980.
(a) for the 4th pentad of May, (b) for the 1st pentad of June,
(c) for the 2nd pentad of June and (d) for the 4th pentad of June.

that over western-Sichuan east of the Qinghai-Tibet Plateau there is a more evident dynamical anticyclone (Fig. 1 (b)) which is progressing southeastward, merging into the western North Pacific subtropical high during the 2nd pentad of June (Fig. 1(c)), and it happens to joint the seasonal westward-extending ridge of the high, thus making the extension strengthened with more stability. After this, SW airflow of the CMLR no longer retreats southward, leading eventually to steady SW wind all over the CMLR (Fig. 1 (d)).

The transitional feature from unstable to stable SW wind over the CMLR is marked by a sudden increase of southerly wind speed at 850 hPa from the CMLR to the Ryukyu Islands. To account for the variations in detail 3 regions are presented for discussion, namely Region I for the Ryukyu Islands with Stations Naze,Naha and Ishigakijima,Region II for Provinces Zhejiang, Jiangxi and Fujian with Stations Quzhou, Ganzhou and Fuzhou and Region III for the CMLR with Stations Shanghai, Nanjing and Wuhan. Fig. 2 illustrates pentadal variations vs the sum of southerly and northerly components at the 3 stations of each region.

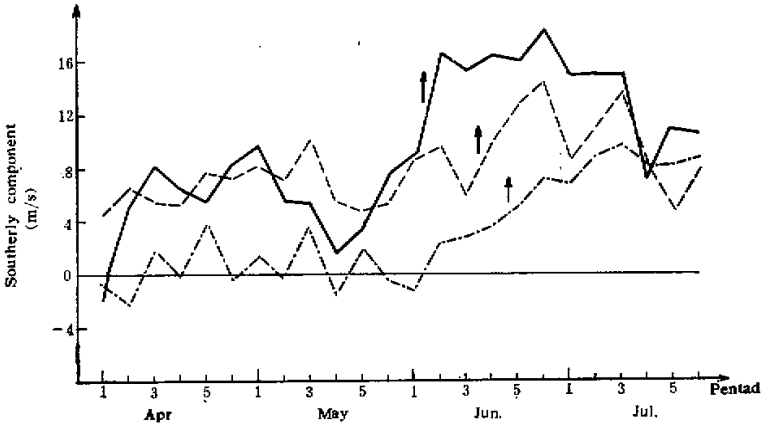

Fig. 2. Pentadal curves of V components for these regions. Solid line for region I, dashad line for II and dot-dash line for III.

It can be seen in Fig. 2 that the southerly component has a sharp increase in the period from late May to early June over Region I, leading to the sharp growth of wind speed of three stations from below 8 to 16 m s^{-1}, increasing roughly twice as much, and since then the value has been maintained around 15 m s^{-1}. The increase shows that the enhancement of SW wind speed over the northwestern brim of the subtropical high in the lower level (Fig. 1 (a—c)) implies a seasonal westward extension of the high. This is about the case with Region II, but with the sharp increase happening only in the 3rd—4th pentads of June. As for Region III, before early June the southerly component is less than 4 m s^{-1}, even with the north one for a particular pentad. Entering the 2nd pentad, the southerly component exhibits steady increase,especially for the 4—6th pentads.Based upon the above analysis, it can be inferred that the abrupt increase of the southerly component of the wind from the Ryukyu Islands to our coastal provinces and the southeastward movement

of the western-Sichuan anticyclone are the cause of the subtropical high westward extension and getting more stable. In addition, the extension occurs, according to the sharp increase in wind-speed over Region I (see Fig. 1 (a—c)),2—3 pentads earlier than SW monsoon becomes stabilized over the CMLR, as indicated in Fig. 2 This would be of value to medium-range forecasting.

In short, either by the wind field or by the circulation pattern these changes described above can be considered as a seasonal transition for South-China SM advancing from the south to the CMLR. The transition is, on the average, about the 3rd pentad of June, which is totally coincident with the multi-annual mean onset of Meiyu over the CMLR[5].

2. *Developmental Features of Pentadal Mean θ_{se} Isoline at 850 hPa for 1971—1980*

To characterize variations of temperature and humidity regimes of the lower atmosphere in East China (east of 110°E) in summer months, pentad-to-pentad mean θ_{se} fields are analyzed for 1971—1980. Fig. 3 (a) indicates changes of pentadal mean 340 K θ_{se} isopleth for May-July, 1971—1980.

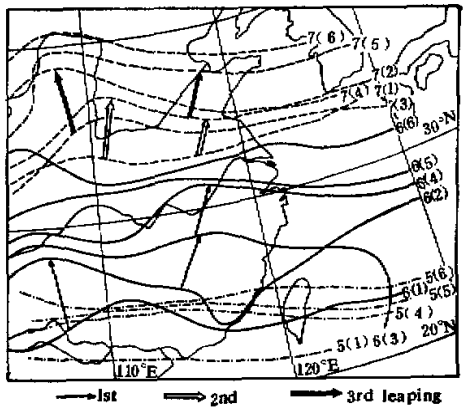

Fig. 3 (a). Pentadal variation of the mean 340 K θ_{se} isopleth at 850 hPa for May-July, 1971—1980.

It is clearly shown in Fig. 3 (a) that the 340 K isopleth appears in early May along the coastal areas of South China and in its subsequent northward advancement 4 relatively stable stages and 3 jumps are distinguished for May to July. These stages are the 4th of May to the 2nd pentad of June (in northern South China), the 4th of June to the 1st pentad of July (over the Changjiang-Huaihe Valleys), the 2nd to 4th pentads of July (in the Huanghe-Huaihe Basins) and the 5th to 6th pentads of July (over North-China Plains). They are primarily consistent with the northward advancement of the rain belt over East China. Each stable stage corresponds, on a multi-annually average basis, to a rainy period. The corresponding rainy seasons are the crest of the pre-flooding in South China, Meiyu over the CMLR, the crest of the rainy spell in the Huanghe-Huaihe Basins and the period of excessive rain over North China. Consequently, it is of primary significance to explore the relationship

between the SM advancement and the northward shift of the rain band by the spatial and temporal distribution of the 340 K θ_{se} isopleth.

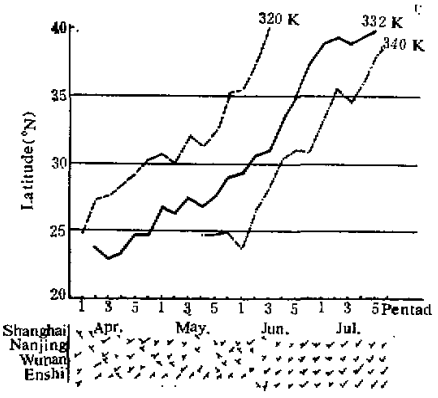

Fig. 3 (b). Pentadal variations of locations of θ_{se} isopleths of 320, 332 and 340 K between 110—122.5°E and composite wind fields for the same period.

Additionally, Fig. 3 (a) illustrates that, similar to the displacement of the 500 hPa western North Pacific subtropic high ridge, the θ_{se} isoline experiences a profound northward ump as indicated by the arrow in this figure when the transition takes place from one stable stage to another. During the first leap it covers 6° latitudes (between northern South China to the CMLR) only in about 2 pentads, compared with 2°—3° latitudes respectively in the next and 3rd leap. The first jump can, therefore, be regarded as a sharp event, which matches the stabilization of SW monsoon in the CMLR (the 3rd pentad of June), as shown in Fig. 3b.

Fig. 3 (b) indicates that during April to May when summer SW monsoon is not steady over the CMLR pentadal south-north swings occur of the 320 and 332 K θ_{se} isopleths between 110—122.5°E and each southward swing coincides with a northerly wind occurrence, implying that transformed cold air from the north can still occupy the CMLR and it stops intruding only when the 332 K isoline is beyond 31°N. And it is just the time when SM becomes stabilized in the CMLR for the multi-annually average condition. The following table gives details for each of the years. The table shows that SM becomes steady over the CMLR 2 pentads after or simultaneously with the isopleth over 31°N in 8 out of 10 cases with exceptions of 2 cases (1974 and 1976). Thus, by taking 31°N as a critical latitude and the abrupt northward jump of the 340 K isoline into account, the SM stabilization in these regions can be diagnosed. This would be reasonably of value to weather forecasting.

3. *Mean Features of Behavior of the 500 hPa Subtropical High Ridge Line*

In order to reveal the relationship between the variations of the mid-tropospheric western North Pacific subtropical high and those of 850 hPa θ_{se} and composite wind fields, the

10-yearly mean pentadal variational characteristics are examined of the ridge of the high at the 500 hPa level (125—140°E), as illustrated in Fig. 4.

Table 1 The 332 K θ_{se} Isopleth across 31°N Relative to the Start of the SM Stabilization

Year	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Pentad for Isopleth across 31°N	6th*	3rd**	4th**	4th**	4th**	4th**	2nd**	3rd**	4th**	2nd**
Pentad for SM Stabilization	6th*	5th**	4th**	2nd**	4th**	3rd**	3rd**	5th**	4th**	2nd**
Difference in Pentad	0	+2	0	−2	0	−1	+1	+2	0	0

* denotes May.
** denotes June.

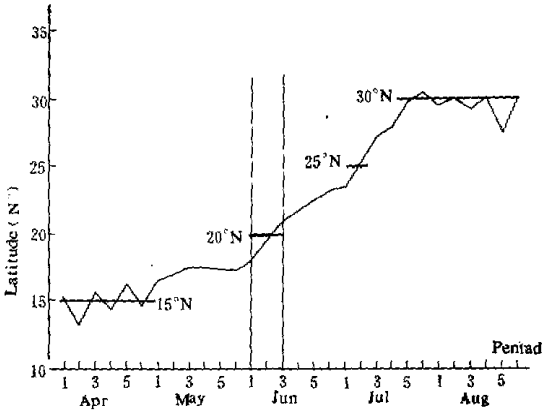

Fig. 4. Developmental curves of the 500 hPa ridge line of the subtropical high (125—140°E) based on pentadal means for 1971—1980.

As illustrated in the figure, the mean position of the ridge in April swings around 15°N; from late April to early May it is steadily advancing northward across the latitude; meanwhile between 110—122.5°E (see Fig. 3 (b)) the 332 K θ_{se} isopleth is north of 25°N and the 320 K line in its retreat crosses 30°N; the ridge line, after being about one month between 15—20°N, jumps again over 20°N in the 2nd pentad of June when the 340 K isopleth is just across 25°N and the 332 K over 31°N (see Fig. 3 (b)). As far as the composite wind field is concerned, the SW wind is formed all over the CMLR (Fig. 1 (c—d)) and getting steady, when Meiyu period begins to spread all over the CMLR.

In summary, SM in East China passes through a remarkable seasonal variation in its advancement towards the CMLR either from the composite wind and θ_{se} fields or from

displacement of the subtropical high ridge. It happens between the 2nd and 3rd pentad of June according to the average condition for these 10 yr. Therefore, it is of help to keep an eye on features of the northward movement of the 332 and 340 K θ_{se} isopleths and the seasonal northward shift of the 500 hPa high ridge line as well as the onset of Meiyu in judging the seasonal change-over of SW monsoon over the CMLR.

III. VARIATIONS OF LOCATION OF THE MAXIMUM JET CENTER IN WESTERLIES IN RELATION TO SEASONAL TRANSITION OF LARGE-SCALE CIRCULATION OVER EAST ASIA

Analysis of pentadal shift of the maximum jet center provides a basis for understanding seasonal variation of the large-scale circulation in East Asia. Three types of Meiyu onset are selected: the early type (1980), the normal (1979) and the later (1978), as indicated in the following table.

Table 2 The Pentad for Low-Level SM Being Stabilized Relative to the Onset of Meiyu in June, 1978—1980

Year	Pentad for SM Being Stabilized	Day for Meiyu Onset
1978	5th	23
1979	4th	18
1980	2nd	9

Besides, various vertical cross-sections are constructed for pentadal mean westerly components about 115°E prior or subsequent to SM stabilization in the CMLR. Here only the component for 1980 is cited for examination, which is shown in Fig. 5.

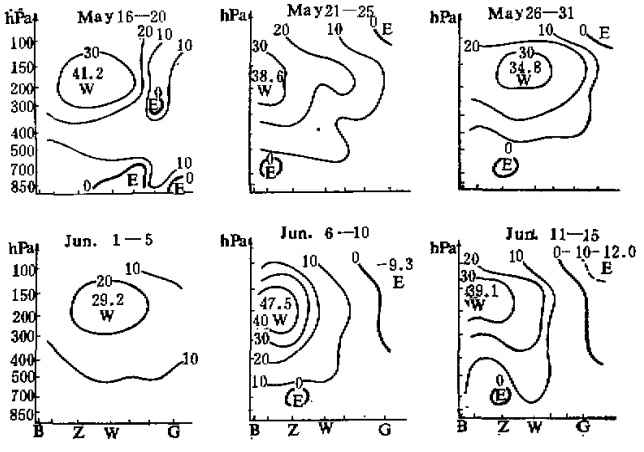

Fig. 5. The vertical cross-section of component U around 115°E from the 4th of May to the 3rd pentad of June, 1980. The letters B, Z, W and G represent Beijing, Zhengzhou, Wuhan and Guangzhou, respectively.

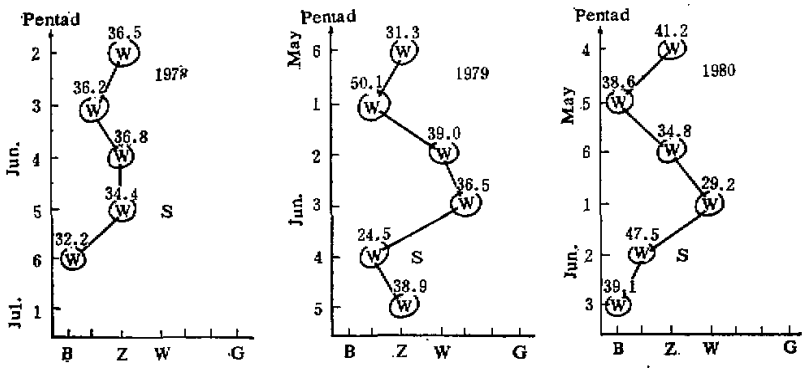

Fig. 6. Pentadal variations of maximum jet stream center position along 115°E before and after SM monsoon stabilization for 1978—1980. The letters B, Z, W, G are the same as in Fig. 5. The letter S represents the time when SW monsoon becomes stabilized over the CMLR.

Some facts can be generalized from the chart.

(1) In general, the maximum jet stream center is situated between 200—150 hPa in the troposphere over East Asia. 1—2 pentads before SM stabilization (the 6th of May to the 1st pentad of June), the maximum center remains between Zhengzhou and Wuhan with a maximum of 30—35 m s^{-1}. But in the 2nd pentad of June when the SM becomes steady, the center makes a sudden retreat of 5° latitudes polewards, reaching Taiyuan, with a maximum of above 40 m s^{-1}. This abrupt northward shift is obviously associated with seasonal transition of the East-Asian circulation pattern.

(2) The above-described transition of the circulation occurs in all the years whether the stabilization takes place normally, earlier or later (1978 is among the type of later onset of Meiyu, leading to serious drought), as indicated in Fig. 6. It shows that 2—3 pentads prior to the onset of Meiyu or SW monsoon stabilization this transition gives its clue that 3—4 pentads before the stabilization the maximum center begins to move northwards and subsequently returns southwards in a steady and progressive way, and one pentad prior to or simultaneously with the stabilization of lower SW monsoon the center makes a considerable retreat northwards, greater than the previous in the distance covered. It follows that the previous retreat seems to be a seasonal change-over indicator of SW monsoon being steady and onset of Meiyu.

In short, facts discovered through analyses show that the stabilization of SM in the CMLR, the onset of Meiyu and the apparent poleward movement of the maximum west wind center about 115°E are various aspects of the seasonal transition of the East-Asian circulation from winter to summer pattern.

IV. SUMMARY

(1) Based on analyses of pentadal mean wind and flow fields for 1971—80, the 850 hPa circulation with SM steady over the CMLR is characterized primarily by seasonal westward

extension of the western North Pacific subtropic high to incorporate in itself the dynamic anticyclone east of the Qinghai-Tibet Plateau with the result of SM stabilized over the CMLR. The sharp increase in southerly components from the Ryukyu Islands to our coastal provinces can serve as a criterion for the seasonal extension of the subtropical high. It is also pointed out that sharp increase of south wind over the Islands takes place 2—3 pentads sooner than the SW monsoon becomes stable over the CMLR, which can be referred to in medium-range prediction.

(2) Analysis of pentadal changes in the spatial distribution of 10-yearly mean 340 K θ_{se} isopleth at 850 hPa indicates that during May-July 4 stages of SM stabilization and 3 jumps for the isopleth in its northward course are identified. These periods each coincide with the rainy seasons over East China to a greater extent. Among the jumps the most profound is the one from northern South China to the CMLR, which can be regarded as a seasonal abrupt change of the θ_{se} field, well coincident with summer SW monsoon steady in the CMLR.

(3) Analysis is made of variations of pentadal mean θ_{se} fields between 110—122.5° E for 1971—1980 with the result that the 332 K θ_{se} isoline across 31°N in conjunction with a sudden shift of the 340 K is a proper index for SM stabilization over the CMLR. Test results show that the 332 K isopleth beyond the critical latitude occurs 1—2 pentads earlier than or simultaneously with the stabilization over the CMLR in 8 out of 10 cases for 1971—80.

(4) Based on 3 cases of different onset time of Meiyu,analysis is done of pentadal variations of the maximum westerly center position along 115°E. It is found that, on the whole, they have a similar pattern in their position shift. For all these cases an apparent poleward retreat of the center location occurs one pentad before or simultaneously with SW monsoon being maintained. The retreat can be considered as a seasonal transition of the East-Asian circulation from winter to summer pattern. It must be noted that 3—4 pentads before the retreat a small northward advancement has made its appearance, which is indicative of the start of SW monsoon stabilization and the onset of Meiyu over the CMLR.

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