THE INTERANNUAL VARIATION OF MEDIUM-RANGE OSCILLATION CHARACTERISTICS IN THE UPPER TROPOSPHERE OVER THE SUBTROPICAL REGION

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ABSTRACT

By using the power spectrum analysis, the interannual variation of medium-range oscillation characteristics in the upper troposphere over the subtropical region in China during June-August, 1966—1981 is studied. The quasi-two and quasi-one week oscillations are the two major oscillations generally existing in the subtropical region, and their intensities have obvious quasi-triennial variation period. These medium-range oscillation characteristics are closely related to the South Asian high, and in some degree to the summer precipitation in China. The quasi-two week oscillation is probably a display of the inherent oscillation of the south Asian high itself, and the quasi-one week oscillation is probably that of the forced oscillation from westerly disturbances.

In recent years because most of the studies of the medium-range oscillation characteristics in the tropical and subtropical regions, used only one year data and the objects of study were also different, therefore the results of these studies can not be mutually compared and the interannual variation of these oscillation characteristics can not be revealed either. In this paper, the spectral analyses are made for daily height data for 100 hPa level at 12 GMT over Lhasa, Chengdu, Wuhan and Shanghai in June—August, 1966—1981. The interannual variation of the medium-range oscillation characteristics in the upper troposphere over the subtropical region in China is examined, and the synoptic process corresponding to the medium-range oscillation is discussed. The method used in this paper is the same as in Ref.[1]. The 5-day running mean and difference filter for the raw departure series are made for filtering small disturbances and linear trends. In calculating spectrum estimates, Tukey window having the maximum lag being 1/3 of the length of series is used and according to the method of Ref.[1],the frequency points of calculating spectrum estimates are densified with the purpose of improving the resolution of the spectrum estimates in the low frequency region. Finally, we employ Zangvil's method to determine the dominant scale of all kinds of oscillations and the product of power and frequency is expressed as spectrum charateristics[2].

I. MEDIUM-RANGE OSCILLATION CHARACTERISTICS AND THEIR INTERANNUAL VARIATIONS

There exist two major oscillations (i. e. quasi-one and quasi-two week oscillations) in the tropical and subtropical regions. For example, the medium-range oscillation periods of the Indian summer monsoon in 1962 were about 5 days and 15 days[3]; all elements of the monsoon system in 1967 had almost the quasi-two week oscillation period[4]; but in 1979, there appeared almost an oscillation of quasi-8 day period for the ground thermal characteristics in the Qinghai-Xizang (Tibetan) Plateau, for the height and temperature at the isobaric level, for the South Asian high and the easterly jet[1].

Table 1 Dominant Scales of 100 hPa Height Oscillations over the Subtropical Region in China in Summer, 1966—1981

	Lhasa	Chengdu	Wuhan	Shanghai
1966	7.5	12.6	9.2	7.7*
1967	10.9	9.6	12.0	12.0
1968	9.6*	14.1*	8.6*	8.0
1969	7.1	10.4*	21.0	12.6*
1970	7.7	9.6*	11.4*	12.0*
1971	13.3*	17.1	7.7	14.1*
1972	16.0	7.3	10.9*	12.6*
1973	10.4*	9.2	9.2	10.0
1974	8.3*	12.0*	11.4*	9.2*
1975	12.6*	12.6*	8.9*	14.1*
1976	10.4*	9.6*	6.9	12.6*
1977	9.6*	8.9	12.0	11.4
1978	13.3*	14.1*	14.1*	8.0*
1979	7.5	9.6*	10.0	12.6
1980	10.9	8.3	10.4	10.9*
1981	12.6*	12.0*	16.0	8.6

Asterisk (*) denotes that these data passed the red noise test in a confidence limit of 0.05.

Table 1 gives the dominant scales of the 100 hPa level height oscillations over Lhasa, Chengdu, Wuhan and Shanghai in the subtropical region in China in summer, 1966-1981. All of them passed the non-dominant scale hypothesis test of confidence limit 0.05, and among them the data with asterisk (*) passed additionally the red noise test in a confidence limit of 0.05. It can be seen from Table 1 that there generally exist two major oscillations with the periods of quasi-one week and quasi-two weeks in the upper troposphere over Lhasa, Chengdu, Wuhan and Shanghai, this means that the quasi-one and the quasi-two week oscillations are the major oscillations in the upper troposphere over the subtropical region in China. Over Lhasa, Chengdu and Wuhan, the frequency of quasi-one week oscillations is larger than that of quasi-two week oscillations, but over Shanghai the frequency of quasi-two week oscillations is larger than that of quasi-one week oscillations.

The quasi-one and quasi-two week oscillation intensities in the upper troposphere over the subtropical region in China have obvious interannual variations. Fig. 1 shows the power spectrum of the 100 hPa level height oscillations in Lhasa in June—August, 1966—1981. In Fig. 1, the solid lines are the various iso-confidence limits of non-dominant scales[2], the region of the oblique lines denotes that with a confidence limit more than 0.05, the circle the major period of the medium-range oscillations in those years and the dot the major period which passed the red noise test in a confidence limit of 0.05. It is shown in Fig. 1 that the interannual variations of oscillation characteristics over Lhasa are very clear and that the variation cycles of dominant scales and the intensities of quasi-one and quasi-two week oscillations are three years or so.

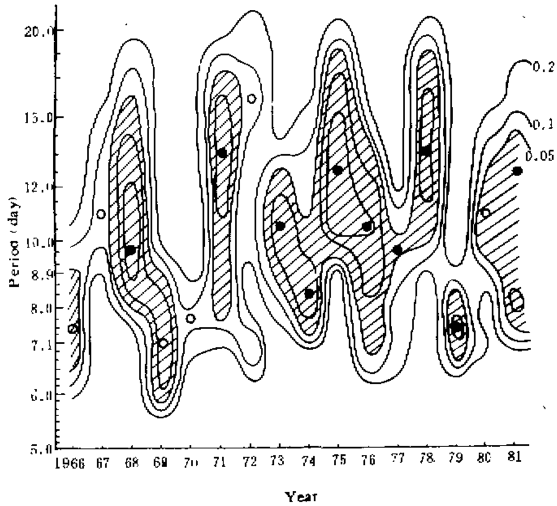

Fig. 1. The power spectrum of 100 hPa level height oscillations in Lhasa in June-August, 1966–1981.

In order to understand further the interannual variations of medium-range oscillations over the subtropical region in China, we have calculated the spectrum of the variations of the dominant scales and the intensities of quasi-one and quasi-two week oscillations at

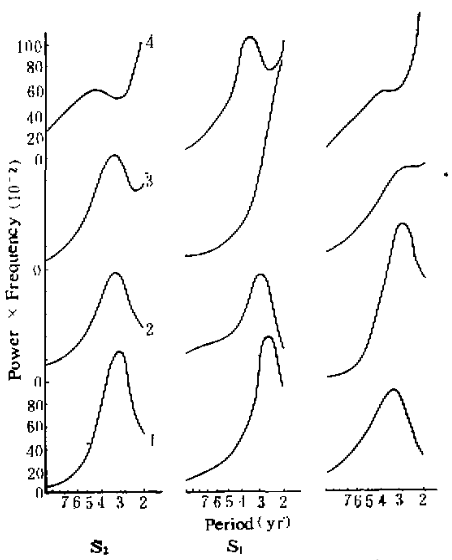

Fig. 2. The autospectrum characteristics of the mediumrange oscillations in the upper troposphere over the four stations in the subtropical region in China.
1—Lhasa; 2—Chengdu; 3—Wuhan; 4—Shanghai.

100 hPa level over Lhasa, Chengdu, Wuhan and Shanghai during the period of 1966—1981. In calculations, the intensity of quasi-two week oscillations is denoted by the percentage of the 12—16 day oscillation variance to the total one, the intensity of quasi-one week oscillation by the percentage of 7.5–10.0 day oscillation variance to the total one. It can be seen from Fig. 2 that there exists an obvious quasi-triennial variation in the dominant scales and the intensities of quasi-one and quasi-two week oscillations over Lhasa and Chengdu. The Quasi-triennial variation of the dominant scales over Wuhan and Shanghai is not quite obvious, but the quasi-triennial oscillations of quasi-two week oscillation intensities over Wuhan and quasi-one week oscillation intensities over Shanghai are still obvious. It indicates that the time variation of the medium-range oscillations in the upper troposphere over the subtropical region in China is regular, the medium-range oscillation for each year is related to the long-range oscillation to a certain extent. In the next section, we will discuss the phase relationship between the medium-range oscillation and the long-range oscillation. Moreover, it can be seen from Table 1 and Fig. 2 that the time variations of the medium-range oscillations in various regions are different. As far as the four stations mentioned above are concerned, the quasi-triennial variation of medium-range oscillation characteristics in western China is more significant than that in eastern China. This phenomenon shows that the medium-range oscillation in the upper troposphere over the subtropical region in China has definite space distribution feature.

II. RELATIONSHIP BETWEEN SYNOPTIC PROCESSES AND MEDIUM-RANGE OSCILLATION CHARACTERISTICS

In discussing the oscillation of the summer monsoon system, Krishnamurti suggested that the quasi-two week oscillations should be the inherent oscillations of the large scale monsoon system due to the dynamical process, th quasi-one week oscillations may be the reflection of the passage of local instability disturbances[4]. Murakami suggested that the quasi-5 day oscillations in the Indian monsoon region during 1962 be a westward disturbance, the 10—15 day oscillations seem to be related to the cycle of the monsoon activities[5].

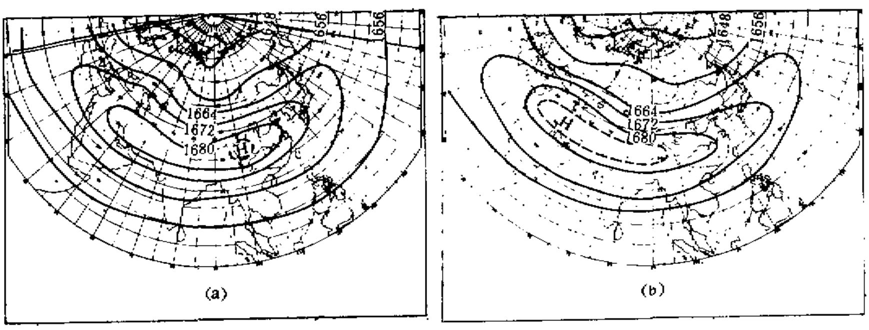

Fig. 3. Composite map of the different medium-range oscillation characteristics at 100 hPa over Lhasa in July.
(a) Obvious quasi-two week oscillations;
(b) Obvious quasi-one week oscillations.

The quasi-two and the quasi-one week oscillations over the subtropical region in China are closely related to the South Asian high. It can be seen from Fig. 3 and Table

2 that for the different medium-range oscillation characteristics the South Asian high has obvioutly different behaviours with the ridge line and main center at different locations. For the years when the quasi-two week oscillations (the dominant scales within 12—16 days) over Lhasa are of significance, the ridge line of the South Asian high over East Asia in July is to the north, the average ridge line between 110°—150°E reaches 35°N. At this time, the heights of 100 hPa mean isobaric surface over Beijing region from June to August is higher. The correlation coefficient of the intensities of the quasi-two week oscillations with the mean heights at 100 hPa isobaric surface over Beijing is $\gamma=0.52$ (for $\alpha=0.10$, $\gamma_\alpha=0.43$); the major center of the South Asian high is to the east. For the other years when the quasi-one week oscillation (dominant scale within 7—9 days) in Lhasa is significant, the major center of the South Asian high is to the west, its ridge line over East Asia is to the south of 30°N, the height of 100 hPa mean isobaric surface over the subtropical region in China from June to August is generally lower (see Table 2) and the corresponding correlation coefficients over Beijing and the others stations except Shanghai during June–August are all negative and larger than 0.40.

In the different phases of the quasi-two and the quasi-one week oscillations, the behaviours of the South Asian high are also different, Figs.4 and 5 show the 100 hPa mean height fields for the oscillation dominant scales over Lhasa, being quasi-two weeks (July, 1975) and quasi-one week (July, 1979), respectively. The high phase and the low phase are expressed by three days including one day before and after the peak and the valley, respectively.

Table 2 The Relationships of the Medium-Range Oscillation Characteristics in the Upper Troposphere in Lhasa with the Circulation Features

	Circulation Features	Quasi-two Week Oscillation	Quasi-one Week Oscillation
100 hPa South Asian High (July)	mean ridge line (110—150-E)	35.6°N	29.6°N
	major center (°E)	101°E	54°E
Correlation Coefficients of the Oscillation Intensity with the Mean Height at 100 hPa Level for June-August	Beijing	0.52	−0.43
	Shanghai	0.24	−0.35
	Wuhan	0.07	−0.44
	Chengdu	0.08	−0.58
	Lhasa	−0.40	−0.58
500 hPa Western Pacific Subtropical High (July)	mean ridge line (110—150°E)	28.2°N	24.6°N
	area index	13.4	25.0
	year	1971, 1972, 1975, 1978, 1981	1966, 1969, 1970, 1974, 1979

It can be seen from Fig. 4 that in the high phase of the quasi-two week oscillation, the ridge line of the South Asian high obviously extends north-westward as far as 35°—40° N over the West Pacific, and the major center is to the east. In the low phase of the quasi-two week oscillations, this ridge line is in about 30°N over the West Pacific and is to the south relative to that in the high phase and the major center is to the west. It can be seen from Fig. 5 that in the high phase of the quasi-one week oscillations, the major center of the South Asian high is to the west. Its ridge line over East Asia is located to the south of 30°N. In the low phase of the quasi-one week oscillation, the major center is to the east, and the ridge line over East Asia is located at about 30°N.

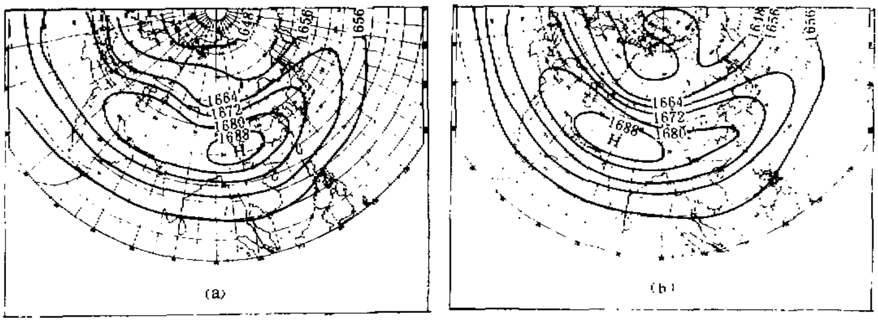

Fig. 4. 100 hPa mean map in the different phases of the quasi-two week oscillations (July 1975).
(a) High phase; (b) Low phase.

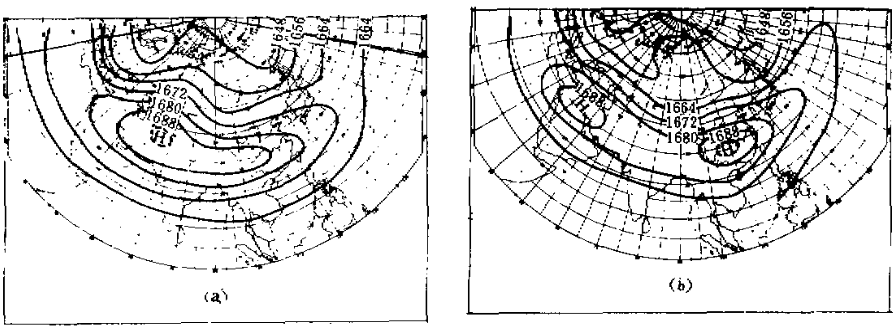

Fig. 5. 100 hPa mean map in the different phases of the quasi-one week oscillations (July 1979).
(a) High phase: (b) Low phase.

It can be also seen from Figs. 4 and 5 that the 100 hPa mean situations at the different phases of the quasi-two and quasi-one week oscillations are almost opposite. In the high phase of the quasi-two week oscillations, the South Asian high over East Asia is stronger than that in high phase of the quasi-one week oscillations, In the quasi-one week oscillations, the mean ridge lines of the South Asian high over East Asia, either in the high phase or in the low phase, are to the south of that in the quasi-two week oscillations. During the years of the dominant quasi-one week oscillation shown in Fig. 3, the mean ridge line of the South Asian high over East Asia is to the south (5°) of that during the years of the dominant quasi-two week oscillation. It shows that the influence of westerlies on East Asia region in the quasi-one week oscillation is more significant than that in the quasi-two week oscillation, therefore, in discussing the physical cause of the quasi-two and the quasi-one week oscillations, this difference should be noted, It can be seen from Fig. 1 that in some years the quasi-two week oscillation is dominant and so is the quasi-one week oscillation in some other years. In addition to these two cases, there also exists the case that both oscillations are simultaneously stronger or weaker. It can be seen from Table 3 that the correlation coefficients between both oscillations in Lhasa station and other three are small, which shows that these two oscillations are independent on the whole.

Tabel 3 The Correlation Coefficients between the Quasi-two and the Quasi-one Week Oscillation

Lhasa	Chengdu	Wuhan	Shanghai
0.042	−0.060	0.006	−0.184

Owing to the fact that under the different oscillation patterns in Lhasa region, the behaviour of the South Asian high is obviously different and the influence of westerlies on East Asia is also different, as well as these two oscillations are independent, we may consider that the physical causes of the oscillations are probably different. The quasi-two week oscillation in the upper tropopshere over subtropical region in China is probably a display of the inherent oscillation of the South Asian high itself, and the quasi-one week oscillation is probably a display of the forced oscillation from westerlies disturbance. Thus, when the South Asian high is the east pattern, its location is to the north and has stronger intensity over East Asia, and the quasi-two week oscillation is dominant. When the South Asian high is the west pattern, its location is to the south, the intensity is weaker, the influence of the forced oscillation from westerlies disturbance is larger, and the quasi-one week oscillation is dominant. Whether this tentative idea is right or not still remains to be proved.

In the eastern part of China in summer, because the South Asian high in the upper troposphere tends to synchronously change with 500 hPa western Pacific subtropical high, the behaviour of the western Pacific subtropical high is different when the oscillation characteristic over Lhasa is different. It can be seen in Table 2 that when the height at 100 hPa level over Lhasa exhibits mainly the quasi-two week oscillation, the ridge line of 500 hPa western Pacific subtropical high is to the north and the area index of the subtropical high smaller, and that when the height at 100 hPa level over Lhasa exhibits mainly the quasi-

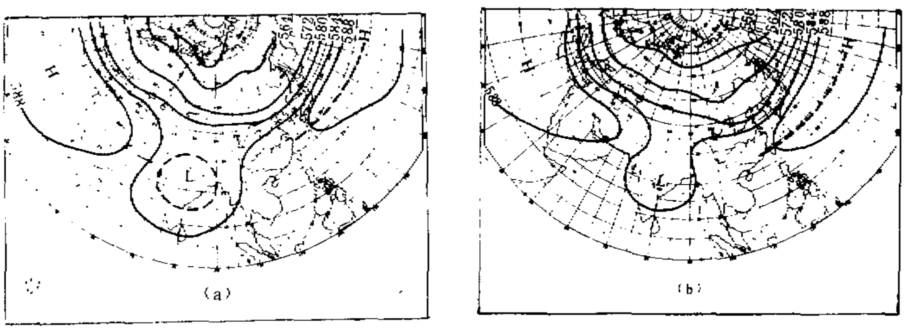

Fig. 6. The 100 hPa composite map of the 100 hPa different oscillation characteristics in Lhasa in July.
(a) Quasi-two week oscillation;
(b) Quasi-one week oscillation.

one week oscillation, the ridge line of 500 hPa western Pacific subtropical high is to the south and the area index of the subtropical high is greater. Fig. 6 shows 500 hPa mean field in July occurring with the different medium-range oscillations in the upper troposphere over Lhasa. It can be seen from Fig. 6 that with the different oscillation characteristics over Lhasa, the behaviour of the Indian depression has also obvious difference. The extent and intensity of the Indian depression in the case of the quasi-two week oscillation are larger than those in the case of the quasi-one week oscillation. This phenomenon may be related to the general intensity of monsoon. As a matter of fact, there was a weaker monsoon (with the quasi-one week oscillation over Lhasa) in 1979. And a stronger monsoon (with the quasi-two week oscillation over Lhasa) occurred in 1975.

The medium-range oscillation characteristics in the upper troposphere are related to the summer precipitation in China. For example, the variations of medium-range oscillation characteristics in Lhasa during June-August, 1966—1981 are closely related to the precipitation of seven regions from all the fifteen regions of China (refer to Table 4), the correlation coefficients are larger than the critical value ($\alpha=0.10$, $\gamma_a=0.43$). When the quasi-

Table 4 The Correlation Coefficients between the Medium-Range Oscillations and the Precipitation of 15 Regions in China during June—August[1)]

	Intensity of Quasi-two Week Oscillation	Intensity of Quasi-one Week Oscillation	Dominant Scale
1. Xingan	Lhasa −0.59	Wuhan −0.46	Wuhan 0.50
2. Songliao			
3. Neimongol		Chengdu 0.46	
4. Huabei (North China)			
5. Huaihe River			Shanghai 0.48
6. Changjiang River			•
7. Jiangnan[2)]	Chengdu −0.48	Lhasa 0.60	
8. Huanan (South China)		Lhasa 0.67	Wuhan 0.55
9. Yunnan			Chengdu 0.51
10. Sichuan-Guizhou	Shanghai −0.44		Lhasa −0.66
11. Hetao[3)]			
12. Hexi[4)]		Chengdu 0.61	
13. northern Xinjiang		Lhasa −0.48	Wuhan 0.43
14. southern Xinjiang		Lhasa 0.63	
15. Qinghai-Xizang Plateau		Lhasa 0.45	Lhasa −0.58

1) The precipitation indexes of 15 regions are obtained from the Central Forecasting Office, State Meteorological Administration of China.
2) South of the lower reaches of the Changjiang River.
3) At the top of the Great Bend of the Huanghe River in the Inner Mongol Autonomous Region and Hui Autonomous Region of Ningxia.
4) The west of Hetao.

one week oscillation is dominant and the quasi–two week oscillation is weak in Lhasa, the precipitation in Xingan, to the south of the lower reaches of the Changjiang River, in South China, Sichuan and Guizhou, the southern Xinjiang, and the Qinghai–Xizang Plateau in June—August is more than normal, the precipitation in the northern Xinjiang tends to be less than normal. The medium–range oscillation characteristics in Chengdu, Wuhan and Shanghai are related to the summer precipitation in some regions, but they have less regions of significant correlation than Lhasa. To study the medium–range oscillation characteristics in the upper troposphere is useful for the medium–long range forecast of summer precipitation in China.

The quasi–triennial oscillation which acts as a major oscillation period in the subtropical region is more and more envisaged in recent years. In Ref.[5], we have made a preliminary summary for the quasi–triennial oscillation of the South Asian high. Not only have the height anomaly at low latitudes in the Northern Hemisphere and the area and ridge of the South Asian high the Quasi–triennial oscillations, but the area and ridge of 500 hPa west Pacific subtropical high, the sea surface temperature in the equatorial esatern Pacific and the frequency of the northwestern Pacific typhoon have ones. In addition, the major oscillations of precipitation in the western provinces of China[6] and temperature in the equatorial region[7] are quasi–triennial, too.

From the discussion mentioned above, the quasi–triennial variation of the medium–range oscillation characteristic is correspondingly related to the quasi–triennial oscillation of the South Asian high. When the quasi–two week oscillation in Lhasa is strong, the areas of the South Asian high and 500 hPa subtropical high are small, their ridges are to the north, and the sea surface temperature in the equatorial eastern Pacific is lower than normal. That is to say, the strong quasi–two week oscillation tends to be the high phase of the triennial oscillation of the ridge line of the South Asian high and the 500 hPa western Pacific subtropical high, and tends to be the low phase of the triennial oscillation of the area indexes of the South Asian high and the subtropical high and the equatorial SST. When the quasi–one week oscillation is strong, things are contrary to those mentioned above. This shows that the quasi–triennial oscillation is an important phenomenon in the tropical and subtropical regions, not only for the temperature, pressure and weather system but also for their medium–range oscillation characteristic. The mechanics of the quasi–triennial oscillation seems to be related to the interaction between the ocean and the atmosphere[5].

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