MEDIUM-RANGE OSCILLATIONS OF SYNOPTIC SYSTEMS IN SUMMER

Qiu Yongyan (仇永炎) and *Zhu Yafen* (朱亚芬)

Department of Geophysics, Peking University, Beijing

Received February 18, 1986.

ABSTRACT

Using summer data of seven years (1973 to 1979), the authors investigated the medium-range oscillations of the parameters which represent the circulation and synoptic scale systems of tropical atmosphere in the area between 30°E and 130°W and the parameters in the area of the middle and high latitudes of the Northern Hemisphere, with more attention paid to the interannual steadiness of parameters with periodic oscillation. Though the parameters investigated are as many as 148, only a few have been found to have medium-range oscillations of which the interannual variability is relatively small. These oscillation systems are characterized by regional distribution. Relations among those parameters with annually steady oscillations have also been investigated.

I. INTRODUCTION

In recent years, much emphasis of the tropical meteorology research has been laid on the periodic variation of synoptic systems in the SW monsoon region and in the Asian-Pacific-Oceanian region. It has been found that a lot of elements and synoptic systems have periodic oscillations with medium-range time scale, i.e. from 10 to 40 days. For example, Krishnamurti et al. (1976) have investigated periodic variations of nine parameters in the Indian monsoon region and found a quasi-biweekly oscillation system. Wang Xingdong et al. (1984) have studied the oscillations of the cross-equatorial jet stream at 105°E, the Asian surface pressure and the Australian surface pressure, and found that they also have quasi-biweekly oscillations. But to the authors' knowledge, most previous studies were based on only one or two particular years' data. Moreover, some of the systems have hardly been studied. The purpose of this paper is to use more years' data to study the oscillations of more parameters which represent the circulations and synoptic systems in the area between 30°E and 130°W, attempting to find some oscillational systems in which interannual variabilities are small.

Comparatively, attention paid to research on the oscillation of synoptic systems in the middle and high latitudes of the Northern Hemisphere was inadequate in the past. Another purpose of this work is to find the oscillation systems in these latitudes. The final aim is to get a relatively comprehensive understanding of medium-range oscillation of circulation systems in summer, thus providing some effective parameters for summer medium range weather forecasting for China.

II. DATA, PARAMETERS, AND METHODS

The data sets as determined by operational analyses at the U.S. National Meteorological Center (NMC) were utilized. One kind of raw data is the 72×23 NMC tropical grid from

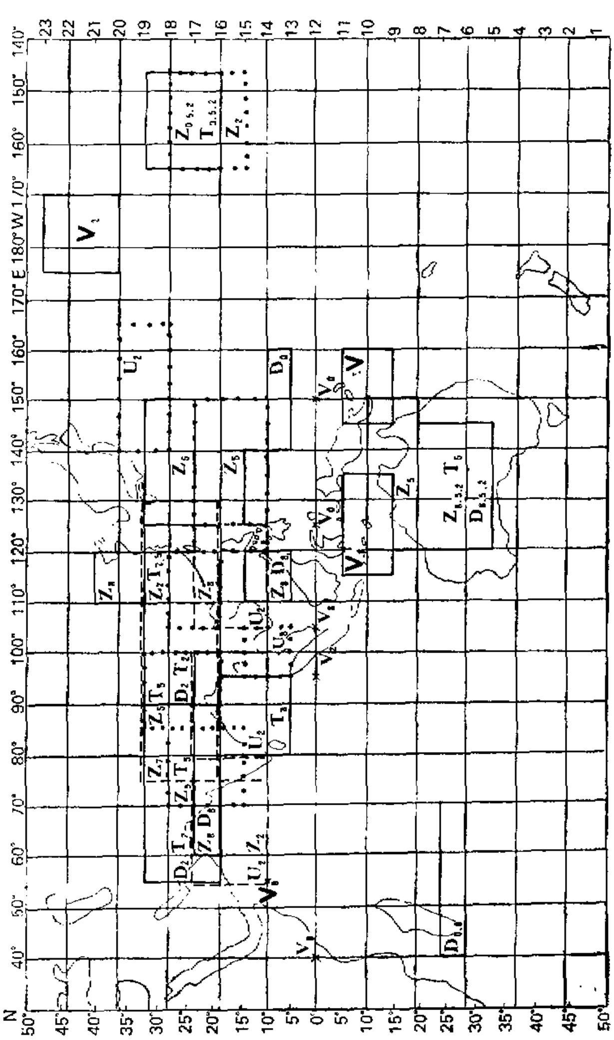

Fig. 1. Distribution of parameters and the domains occupied by them, not including those representing the zonal mean quantities.
——or——or…… denotes boundaries of domains over which data are averaged;
X denotes a single gridded parameter;
Z, D, T, U, V, V denote vorticity, divergence, temperature, westerly, south and resultant winds, respectively;
Subscripts 0, 8, 5 and 2 denote 1000, 850, 500 and 200 hPa levels, respectively.

48.1°S to 48.1°N, approximately 5° longitude-latitude resolution, including temperature and wind fields at seven levels. We used only the data at 200, 500, 850 and 1000 hPa. From the wind fields, the fields of vorticity and divergence (denoted by Z and D respectively) were computed and put on the grid. Thus, five element fields, i.e. U,V,Z,D,T, at the four levels were utilized.

The NMC operational analyses of 500 hPa level geopotential height fields were used as data in the middle and high latitudes in the Northern Hemisphere. From the height field (denoted by H), we calculated the vorticity field (denoted by Z) using the geostrophic approximation. Both the height field and the vorticity field were put on a 5° longitude × 5° latitude grid.

The defining of synoptic systems is carried out mainly in two ways: For some synoptic systems, each is defined using only one parameter, while for most of them, each is defined using several different parameters. So the total number of parameters used for tropical systems is as many as 107. These parameters generally represent four groups of systems: synoptic systems in the SW monsoon region (from the Mascarene Islands to the Tibetan Plateau), synoptic systems in the trade wind region from Australia to North China, parameters presenting the zonal mean quantities in the area between 48.1°S and 48.1°N parallels, and parameters associated with the E–W circulation systems. All of these are tentatively referred to as tropical parameters. Fig. 1 shows the distribution of parameters and the domains over which the elements selected are averaged, not including those parameters which define the zonal mean quantities

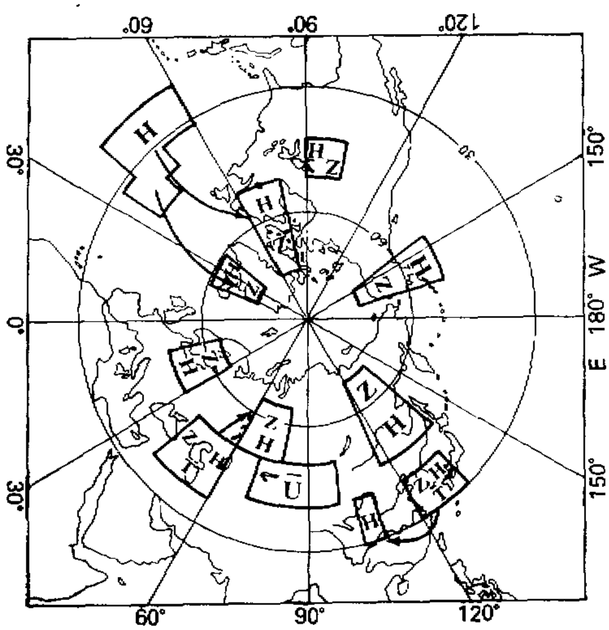

Fig. 2. 500 hPa parameters in the Northern Hemisphere, not including the zonal indexes. ——or··· boundary of domain;
A ↗ B denotes the averaged value in domain A minus that in domain B; Z, H, T and U denote respectively vorticity, geopotential height, temperature and westerly wind.

We took the parameters in the northern middle and high latitudes from the fields of 500 hPa geopotential height and vorticity. A total of 47 parameters have been defined. They can be divided into two sets: one includes the zonal indexes in the middle and high latitudes and the amplitudes of wavenumbers 1, 2 and 3 at 45°N, and the other, the parameters defining the synoptic systems which are constantly concerned with routine forecasting. Figure 2 shows the distribution of parameters in the second set.

Twice daily records in three summer months form a sequence of 184 data for each parameter. The raw data of seven years (1973 to 1979) have been used, and each of the parameters mentioned above has seven sequences for calculating the density of power spectrum. None of the sequences have been filtered. Confidence $\alpha=0.05$ was taken for the significance test. Cross-spectra for a pair of sequences can give a good relationship in frequency domain. The phase angle and coherence squared for each pair of the selected parameters have been computed. The significance test for coherence squared was generally performed by taking confidence $\alpha=0.05$.

The results of computation of the seven years' data showed that periodic oscillations occur in most of the parameters, but this did not remain constant. In other words, most of the parameters may, in some individual years, had a certain period at which the spectral peak exceeded the 95% significance level, but in other years they did not have this period. As concerns parameters in the SW monsoon region, their oscillations have an obvious interannual variation. In the Somali low-level jet, there existed a 23-day oscillation in two of the seven years, while a 15.4-day oscillation only existed in one year. The vorticity in the Indian monsoon trough had two modes of oscillation—a 23-day mode and a 15.4-day mode, but they occurred in two different years, respectively. In order to find the parameters of which the oscillations are rather steady, we need to count the frequency of each parameter at a particular period. In doing this, we adopt the definitions shown in Table 1.

The frequencies have been counted in the light of the following four period lengths: 46 days, 23 days, quasi-biweek (15.4–11.6 days) and quasi-week (9.2–6.6 days). Finally, in accordance with the frequencies during the seven years, we can classify the selected parameters into five grades which are defined in Table 2.

Table 1. Frequency Counting Criteria

Spectral Peak	Exceeding Significance Level	Count
Revealed	95%	1 time
Revealed	90%	0.5 times
Not Revealed	95%	0.5 times

Table 2. Definitions of Grades

Frequency during the Seven Years		Grade
$\leqslant 2$	times	1
$>2, \leqslant 3$	times	2
$>3, \leqslant 4$	times	3
$>4, \leqslant 5$	times	4
$>5,$	times	5

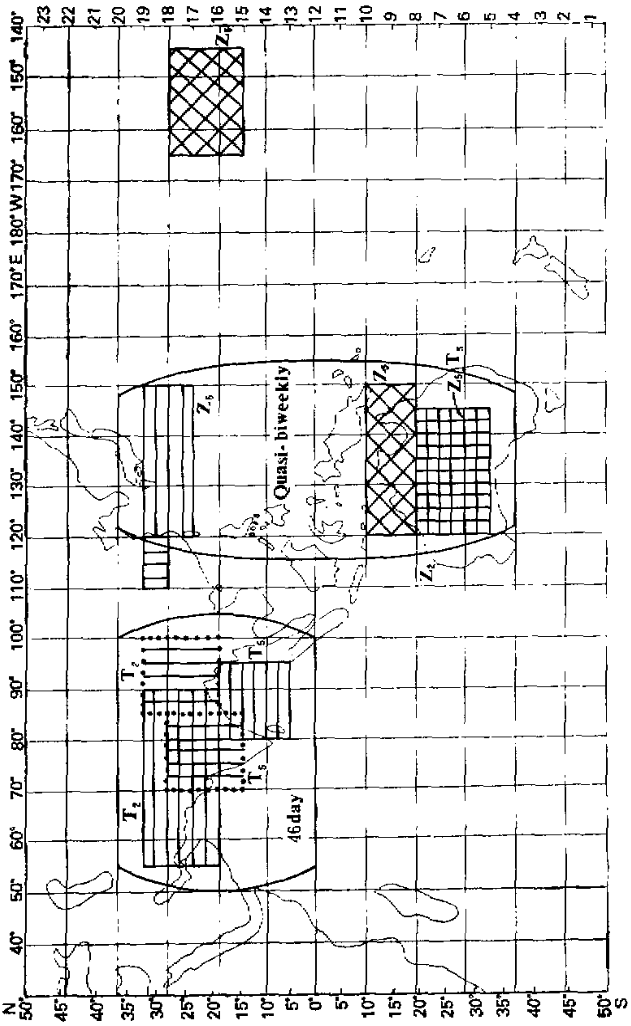

Fig. 3. Distribution of parameters of oscillation with interannual steadiness in the tropical atmosphere (not including the zonal mean quantities).
×××, |||, ≡ denote the domains of Grade 5, 4 and 3, respectively. (see Text)

If a parameter falls into Grade 3 or above, it may be considered a steady oscillation parameter, for its periodic oscillation occurs in more than half of the seven years. In the following we will only discuss this kind of oscillation parameter.

III. PARAMETERS WITH STEADY OSCILLATION

1. *The Tropical Parameters*

According to the definition determining steady oscillation parameters, the spectra for the 107 parameters during the seven years have been analysed. The results are as follows: (part of the parameters with steady oscillation are shown in Fig. 3)

(a) There exists a 46-day mode in the various averaged temperatures in the Tibetan Plateau and its adjacent regions. This mode is probably characterized by seasonal variation.

(b) There is no 23-day mode occurring in our selected parameters.

(c) There exists a quasi-biweekly mode in Australia over which the averaged vorticity at either 500 hPa or 200 hPa has a steady quasi-biweekly oscillation. It is noteworthy that in the northernmost part of Australia and the ocean area adjacent to it (about 20°S–10°S, 120°E–150°E), this kind of mode in the averaged vorticity is steadier and exists nearly every year.

The averaged vorticity in the north-western part of the North Pacific Ocean, which represents the intensity of the west part of the Pacific Ocean subtropical high, also has a quasi-biweekly mode, but its steadiness is lower.

(d) A quasi-weekly mode occurs primarily in the southern part of the normal position of the Mid-Pacific Ocean trough (See Fig. 3).

In the zonal indexes and the momentum transports in the lower middle latitudes in both hemispheres, the quasi-weekly mode also exists (not shown in Fig. 3).

2. *The Parameters of the Northern Middle and High Latitudes*

At 500 hPa in the northern middle and high latitudes, steady oscillations have three variant period lengths: 23 days, quasi-two weeks and quasi-one week. The geographic locations and the domains of the steady oscillation parameters in the first two kinds (not including the zonal indexes in several local regions) are shown in Fig. 4.

Parameters of the 23-day periodic oscillation consist of the following: (a) the difference between the averaged geopotential height in the Mid-Atlantic Ocean and that in the Iceland-Greenland area, tentatively named Atlantic Ocean oscillation, (b) the difference between the averaged height in the Mid-Atlantic Ocean and that in the east coast of North America, tentatively named Atlantic Ocean oscillation I, (c) the averaged geopotential height in Europe, and (d) the local zonal index in the Atlantic-European area.

Parameters with a quasi-biweekly mode consist of the following: (a) the difference between the averaged geopotential height in the Caspian Sea and that in the area to the east of the Ural Mountains, tentatively named the Caspian-Ural height difference, (b) the averaged geopotential height in the summer resident position of Okhotsk Sea ridge (about 110°E–130°E, 50°N–65°N), and (c) the averaged geopotential height in the region neighbouring Alaska, tentatively being referred to as the Alaska ridge.

From Fig. 4, it seems that the parameters with 23-day mode and those with quasi-biweekly mode are distributed in a specific geographic position, respectively. In the Atlantic-European area the 23-day mode predominates, but in Asia and in the Pacific Ocean the quasi-biweekly mode is predominant.

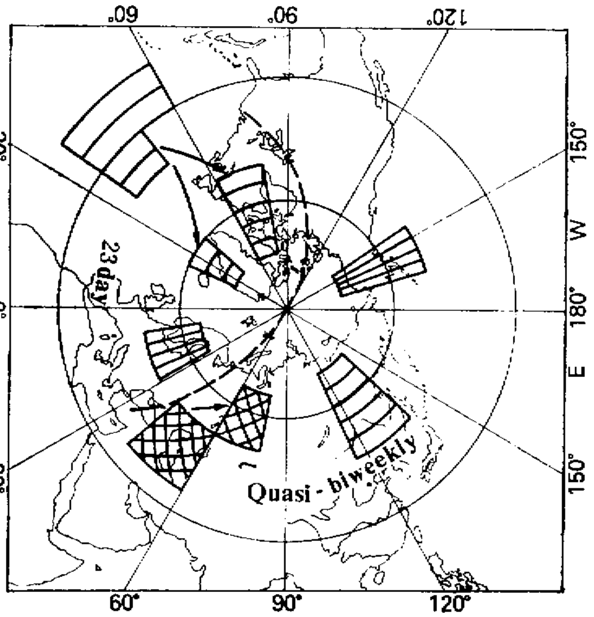

Fig. 4. Distribution of parameters of the 23-day oscillation and the quasi-biweekly oscillation in the northern middle and high latitudes (not including the zonal mean quantities).
Heavy broken line denotes the boundary line between the areas of the 23-day mode and the quasi-biweekly mode.

IV. INTERRELATION AMONG OSCILLATION SYSTEMS

Like others who investigated atmospheric periodic oscillation, we, too, dealt with the interrelation among oscillation systems by means of the cross spectra. Because of the requirement of the squared coherence exceeding the 95% level of significance and the consideration being given only to the parameters with interannually steady oscillation, it is very difficult to find a set of parameters which can form a phase cycle without much varying from year to year. But it is possible to find several of them in couples or even in triples, each parameter in the couple (or triple) in a relative phase relationship to its companion(s). This is often observed. We have obtained the following interesting results.

(1) Taking a maximum intensity of the Australian trough as the starting point in the quasi-biweekly mode, the following sequence is rarely one of the Southern Hemispheric parameters, but often one of the Northern Hemispheric parameters, such as the Alaska ridge, the subtropical high ridge, etc. Thus, it seems to denote that there is a quasi-biweekly wave mode in Australia and this mode propagates towards the Northern Hemisphere biweekly. It is found that during four of the seven years this mode was associated with the Alaska ridge, but the causes of the association are not known yet.

(2) Taking a maximum intensity of the Atlantic Ocean oscillation as the starting point in the 23-day mode, the following sequences always occur to the east of it. It is worth noting that in most of the seven years the 23-day mode was associated with the oscillation systems to its east and the easternmost system associated was the parameter representing the

Caspian-Ural height difference. The relative phase which often occurred is:

The maximum intensity of the Atlantic Ocean Oscillation,

$\xrightarrow[\text{about 6 days}]{90^\circ \pm 30^\circ}$ the minimum in the Caspian-Ural height difference

$\xrightarrow[\text{about 6 days}]{90^\circ \mp 30^\circ}$ the minimum in the Atlantic Ocean oscillation

Thus, the rate of propagation in the 23-day mode is about 14 longitudes per day.

(3) The Caspian-Ural height difference in a quasi-biweekly mode in most of the seven years was also associated with the systems to its east and the easternmost system associated was one over the Japanese Sea/Bohai Sea area. The maximum height in this area is reached about four days after the maximum in the Caspian-Ural height difference is found.

(4) The Alaska ridge in a quasi-biweekly mode in most of the seven years was associated with the systems to its west and the westernmost system associated was the summer resident position of the Okhotsk Sea ridge. The relative phase between the two ridges is:

The maximum height in the Alaska ridge,

$\xrightarrow{100^\circ—140^\circ}$ the maximum height in the Okhotsk Sea ridge

$\xrightarrow{80^\circ—40^\circ}$ the minimum height in the Alaska ridge.

V. CONCLUSION

Based on seven years' data in the tropics and the northern middle and high latitudes, power spectral analyses of large numbers of synoptic systems or parameters have been performed. Only a very few systems or parameters have medium-range oscillations in which interannual variability is relatively small. These oscillation systems are characterized by regional distributions, as are the interrelations among them.

The authors wish to express thanks to Mr. Xu Jianmin for providing the raw data recorded on tape.

REFERENCES

Krishnamurti, T.N. and Bhalme, H.H. (1976), Oscillations of a monsoon system, Part I: Observational aspects, *J. Atmos. Sci.*, **33**:1937–1954.

Wang Xingdong and Tao Shiyan, (1984), A preliminary investigation on the cross-equatorial stream in the western Pacific Ocean, *Acta Oceanological Sinica*, **6(2)**:160-173 (in Chinese).