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Teleconnections and Features of Circulation of the Pentad Mean 500 hPa Height Field during Northern Hemisphere Summer

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In this paper, the teleconnections of the pentad mean 500 hPa height field during the Northern Hemisphere summer are analysed based on the ten years data (1980–1989), and two teleconnection patterns (eastern Asia / Pacific (EAP) pattern and western Europe (WE) pattern) and western Asia / Pacific / Atlantic Oscillation are summed up. The spatial and temporal distribution features of general circulation at 500 hPa in summer are studied with the method of principal component analysis.

Key words: pentad mean 500 hPa height field; summer; teleconnections; principal component analysis; features of general circulation.

1. INTRODUCTION

The variations of general circulation in the Northern Hemisphere play an important role in the distribution of drought and flood in China. The temporal and spatial variations of rainband and intensity of Meiyu depend on the features of general circulation in summer. Therefore, it is meaningful to study the temporal and spatial variations of circulation, especially, subtropical circulation. The theory and numerical experiments show that the dispersion of quasi–stationary planetary waves excited by SST anomalies at low latitude, i.e., latent heating anomalies, which propagate toward middle and high latitude on the sphere leads to the circulation anomalies in extratropical zone in summer[2,4]. At present there are many papers on the teleconnections of the general circulation in winter such as Refs.[1–3,7], but there are only a few papers about summer at home and abroad. To estimate qualitatively the trend of medium–range change and seasonal variations on large–scale circulation, especially subtropical high, the teleconnection patterns and temporal and spatial variations of the pentad mean 500 hPa height field during the North Hemisphere summer are discussed in this paper.

2. DATA AND METHOD OF CALCULATION

By utilizing daily data of $5^\circ \times 10^\circ$ latitude–longitude grid point height at 500 hPa in 10–85°N (576 grid points in all) from June to August for 1980–1989, which are provided by National Meteorological Center of China, the pentad mean 500 hPa height fields in the Northern Hemisphere are calculated. There are 180 samples at a grid point because of 18 pentads every year from June to August. Local significance at 99% level is given by absolute correlation of 0.25. In order to ensure the stable correlation, the phenomena of teleconnection are only discussed while the correlation coefficient is greater than 0.30 in this paper. First, one-point correlation maps are computed between this grid point and others in the Northern Hemisphere, and the teleconnection value of this grid coefficient is obtained in one-point correlation map. Further, the map of teleconnection value is obtained[1,3], too. The teleconnection patterns are defined by the strongest correlation pattern. Second, the principal component analysis (PCA) is performed for the pentad mean 500 hPa height field during the Northern Hemisphere summer to discuss the temporal and spatial features. All the data are standardized by local standardizing deviation but the seasonal variations are not filtered. Based on 79 grid points with even distribution:

10–40°N, $10^\circ \times 30^\circ$ (beginning from 30°E)
50–70°N, $10^\circ \times 40^\circ$ (beginning from 40°E)
80°N, select four grid points at 90°, 180°, 270°, 360°

the 79 eigenvectors (spatial distribution patterns and the value of the principal component (time series) corresponding to every pentad are given. The eigenvectors with bigger contribution of variance and stability are regarded as the basic spatial distribution patterns of height fields. The composite maps of circulation anomalies are obtained by averaging pentad mean height field with greater (smaller) values of the principal component.

3. TELECONNECTIONS

Figure 1a is a sketch map showing two kinds of strongest correlative patterns obtained by means of correlation analysis for the pentad mean 500 hPa height field during the Northern Hemisphere summer. Figure 1b is a distribution map of the teleconnection value which is computed with the ten-year data (180 pentads in all).

There are three centers of stronger teleconnection over western Asia at low latitude, the

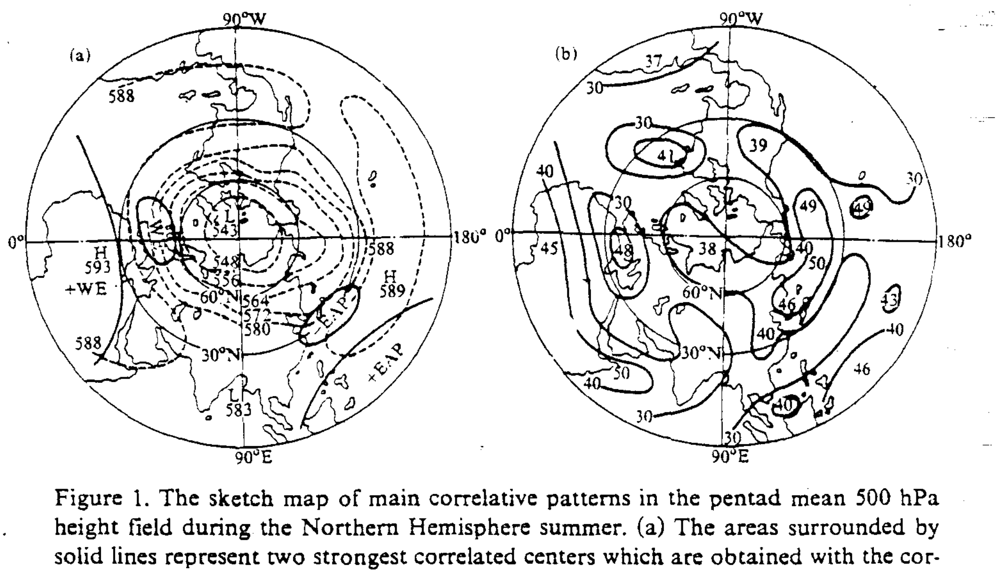

Figure 1. The sketch map of main correlative patterns in the pentad mean 500 hPa height field during the Northern Hemisphere summer. (a) The areas surrounded by solid lines represent two strongest correlated centers which are obtained with the correlation analysis: EAP -- eastern Asia / Pacific pattern, WE -- western Europe pattern. The dashed line represent mean 500 hPa height field during the Northern Hemisphere summer. (b) The map of teleconnection value. (The values have been multiplied by 100, the contour is only given more than 30, and its interval is 10.)

central part of the Pacific Ocean and the Atlantic Ocean in Figure 1b, their values are 50, 50 and 41 respectively. Figure 2 is a one-point correlation map corresponding to reference point at 15°N,45°E. There is a strong negative correlation center in central part of the Pacific Ocean and western Atlantic Ocean respectively (see Figure 2a). It is an approximate symmetry on pole between these two centers of negative correlation and reference point, and the contours appear even zonal distribution. This significant oscillation is defined by western Asia / Pacific / Atlantic Oscillation that may the caused by a stationary wave.

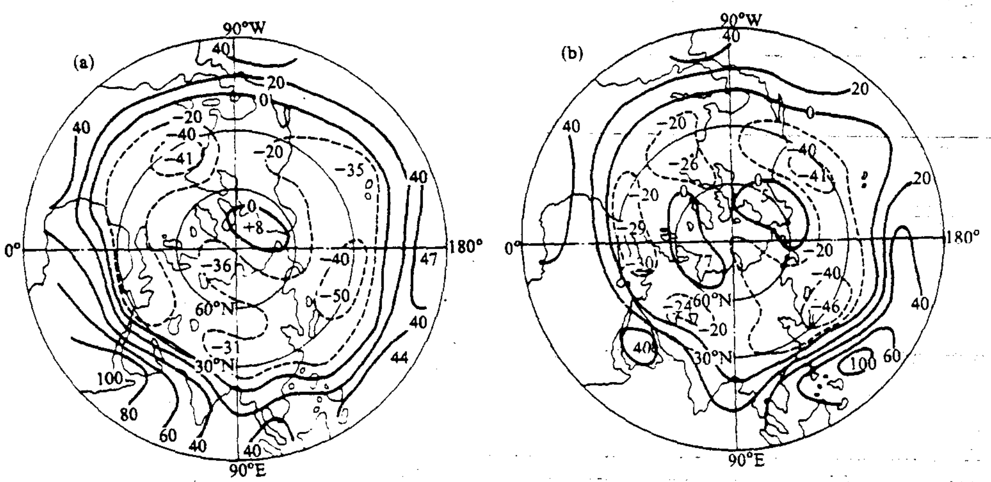

Figure 2. One-point correlation maps for the pentad mean 500 hPa height field in summer. (a) Reference point at 15°N, 45°E; (b) reference point at 15°N, 135°E. The correlation coefficient has been multiplied by 100, and the contour interval is 20.

There are two stronger correlation centers, both of the teleconnection values are 46 over eastern Philippines and from eastern China to Japan. Figure 2b is a one-point correlation map corresponding to the reference point at 15°N, 135°E. In Figure 2b, there is a strong negative correlation center with the value −46 from eastern China to Japan, which reflects the propagating approach of dispersion of quasi-stationary planetary waves excited by heating anomalies over the eastern Philippines on the sphere. This teleconnection pattern is defined by eastern Asia / Pacific pattern (EAP), which is similar to that of monthly mean height field suggested in Ref.[2]. In addition, there is a pair of teleconnection centers with negative correlation each other over northern africa and western Europe, and their teleconnection values are 45 and 48 respectively, which is regarded as western Europe (WE) pattern.

As indicated above, there are two obvious teleconnection patterns in the pentad mean 500 hPa height field during the Northern Hemisphere summer: eastern Asia / Pacific (EAP) and western Europe (WE) pattern. Their physical mechanism is somewhat different from the teleconnection pattern in winter[1,3,7]. In summer, the teleconnection patterns caused by planetary waves exited by heating over the Asian summer monsoon at low latitude propagate toward middle and high latitudes on the sphere (through stronger meridional cell), which reflects the effect of the tropical circulation on the circulations of middle and high latitudes[2,4]. Compared with the map of teleconnection value in Ref.[3] the teleconnection values are smaller in summer than in winter. This is due to the fact that the westerlies barotropical Rossby waves propagate in extratropical zone in winter but the quasi-stationary planetary waves excited by heating anomalies at low latitude propagate toward middle latitudes in summer on the sphere. The latter is both of zonal and meridional propagation with complicated relation of circulation systems between middle and low latitudes.

In brief, the teleconnection patterns in the pentad mean 500 hPa height field during the Northern Hemisphere summer show the relationship between low latitude, especially the region of Asian summer monsoon, and other regions in the hemisphere, which reflect the relation of circulation systems between middle and low latitudes. However, the negative zonal teleconnection is dominant in winter.

4. THE FEATURES OF CIRCULATION

With the principal component analysis (PCA)[5], the data of the pentad mean 500 hPa height field during the Northern Hemisphere summer are analysed to discuss the temporal and spatial variations of circulation. The method of PCA has the properties of extracting the main information from meteorological fields with random obstruction and excluding the statistical analytic method with random obstruction. It can best reflect the information of original variables with a few variables, in which the eigenvector is related to sample size. The stable eigenvectors with bigger contribution of variance indicate the fundamental spatial distribution patterns of meteorological fields. The even 79 grid points within the scope of the Northern Hemisphere and the ten-year data in summer (180 pentads) are used. The basic results are presented in Table 1 and Figure 3. Table 1 lists the first five eigenvalues and the contribution of variance to the principal component analysis. Figure 3 is the spatial distributions of the first and second eigenvectors; the contribution of variance is at the upper right.

Table 1 shows that the contributions of variance of the first and second eigenvectors are

Table 1. The first five eigenvalues and contribution of variance with principal component analysis.

j	1	2	3	4	5
λ_j	15.31	8.28	3.34	3.13	3.09
λ_j / 79.0%	19.4	10.5	4.2	4.0	3.9

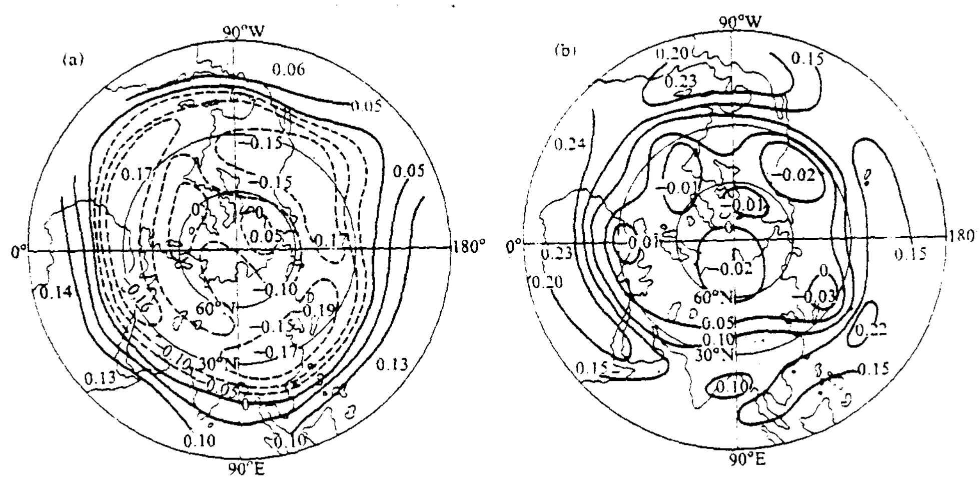

Figure 3. The spatial distribution of eigenvector for standardizing pentad mean 500 hPa height field during the Northern Hemisphere summer. (a) The first eigenvector; (b) the second eigenvector; and the contour interval is 0.05.

19.4% and 10.5% respectively, and the rest are less than 5%. The stability of the eigenvectors is examined by using the absolute value of cosine on the angle of intersection between the frrst three eigenvectors for different sample sizes (n = 180, n1 = 144, n2 = 108). The first two eigenvectors are more stable for the absolute value of cosine on the angle of intersection between vectors greater than 0.95, so these two kinds of basic spatial distributions exist in the pentad mean 500 hPa height field during the Northern Hemisphere summer.

Table 2. The absolute value of cosine on the angle of intersection between eigenvectors for different sample sizes.

No. \ sample size	between n and n_1	between n and n_2
1	0.99182	0.97933
2	0.98362	0.95450
3	0.67262	0.38708

4.1 *The Spatial Distribution Pattern of Eigenvector*

The spatial distribution of the first eigenvector in Figure 3a is as follows: The contours appear zonal distribution, and its variations of the tropics and subtropics are opposite to those of middle and high latitudes. There are three centers of positive maximum respectively located near the Philippines, western Asia and northern Africa at low latitude, and six centers of negative maximum near eastern China, eastern Japan, eastern Pacific Ocean, northern America, Atlantic and western Asia at middle latitude. The values of extreme center are great (absolute value is larger than 0.10). The above analysis leads us to conclude that the decrease (increase) of the pentad mean 500 hPa height of the region at low latitude is related to the increase (decrease) of that at middle latitude. This spatial distribution pattern is consistent with the teleconnection pattern given above, in which the meridional negative teleconnections are predominant. And this reflects the relationships between the heating in low latitude and meridional cell as well as the intensity and position of subtopical high. For spatial distribution of the second eigenvector, the contours are not zonal distribution at low latitude and its variation is smaller at middle and high latitudes (see Figure 3b). There are five centers of positive extreme value respectively located near northern Africa, eastern Atlantic, the Caribbean Sea, the eastern Philippines and the Bay of Bengal at low latitude; the last one is the minimum center. Besides, there exist six centers of smaller negative values in the regions at middle and high latitudes. As mentioned above, the second eigenvector reflects that the variation of high fields is caused by unseasonal adjustments of circulation, which may be related to ENSO and the 30-50 day low frequency oscillation.

Hence, the distribution of the pentad mean 500 hPa height field in the Northern Hemisphere summer depends mainly on these two kinds of spatial distribution patterns with even and uneven zonal distributions. Meanwhile, this means that the teleconnection pattern is the reflection of the seasonal variations of 500 hPa height field from June to August, and the features of circulation at 500 hPa are represented by these two eigenvectors before, during and after the period of Meiyu.

4.2 *The Temporal Variations of Circulation Anomalies*

Figure 4 shows the curves of the change of principal component series with every pentad during the summers of 1980-1989. The change of the first principal component (solid line)

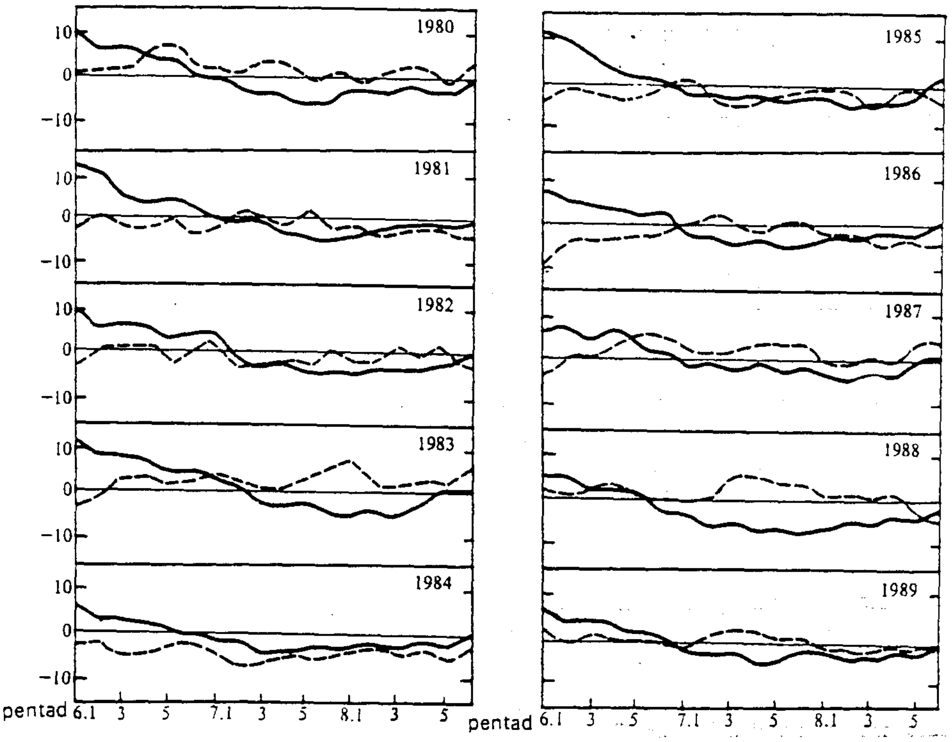

Figure 4. The curves of the change of principal component series with every pentad. The solid (dashed) line is the first (second) principal component.

indicates the difference of zonal distributions for seasonal variation every year because the seasonal variations of data are not filtered. In fact, it shows that the seasonal variations of the subtropical high and meridional cell are closely related to the solar radiation and the change of meridional temperature gradient caused by heating. But the change of the second principal component (dashed line) mainly reflects the change of the pentad mean 500 hPa height fields distributed along the zone caused by the change of circulation at low latitude. It reflects the complex nonlinear interaction between SST along the zone (uneven heating) and the circulation systems at low latitude.

The composite maps of circulation anomalies are constructed by averaging the pentad mean height field with the values of the second principal component being greater than or equal to 3.0 and less than or equal to −3.0. There are two kinds of different situation maps in Figure 5.

In Figure 5a, the subtropical high assumes band distribution and stronger intensity, but it is weaker in Figure 5b, in which there is only a smaller closed center surrounded by 588 dagpm contour. These two kinds of situation correspond to different distributions of pentad rainband and temperature in China (zonal distribution is dominant). It is found that the variations of the principal component with time generally possess the persistence features of medium−range evolution of circulation.

The smaller absolute value of negative value of the first principal component and greater positive value of the second principal component indicate that the stronger zonal difference of temperature is caused by heating at low latitude, resulting in stronger and slight southward subtropical high and obvious Indian monsoon, and bringing about rare rainfall in northern

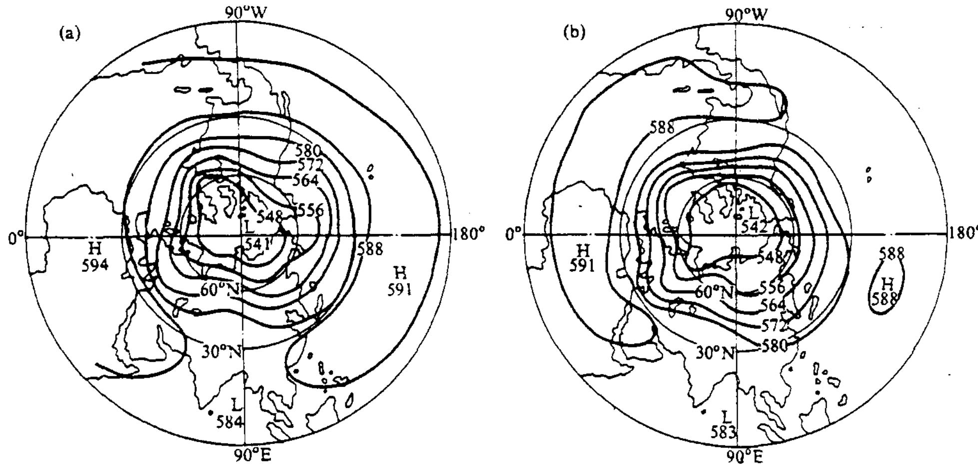

Figure 5. Two kinds of circulation patterns are represented by the second principal component. Its value (a) is greater than or equal to 3.0 and (b) is less than or equal to −3.0; the contour interval is 8 dagpm.

China, floods in the Huanghe valley and the middle and lower reaches of the Changjiang River, stronger Meiyu for the years 1980, 1982, 1987, 1989. But the opposite distributions of rainband and weaker Meiyu are formed by the opposite trend of variations of principal component (the second principal component takes negative value as dominant) for other years, as 1981, 1984, 1985, 1986. For 1983 (5–6 pentad for July) and 1988 (1–2 pentad for July), the variations of the second principal component with every pentad appearing significant catastrophe and greater positive value with greater absolute value of negative value for the first principal component at the same time, which results in the abrupt increase of the intensity of subtropical high, the position slightly to the north and west corresponding to unstable jumps of rainband, greater intensity and uneven distribution of precipitation. Particularly, the period with the second principal component greater than zero continued the longest in ten years leading to rare persistent weather of high temperature in the Changjiang River–Huaihe River valley and south of the lower reaches of the Changjiang River in China. The rainbands stayed in north of the Huaihe River. The theoretical research shows that the seasonal catastrophe of meridional cell or subtropical high may be caused by convective condensation heating anomalies at low latitude with change of solar radiation through nonlinear interaction[6]. It is remarkable that rates of convective condensation heating were obviously increased by the radical change of SST at low latitude, especially the western Pacific Ocean, thus causing the catastrophes of zonal and meridional circulations while SOI rapid increase from negative value to positive value during the recovering stage of ENSO for the summers of 1983 and 1988. At that moment it was easy to happen unstable jumps of rainband in China.

5. CONCLUSIONS

1) There are two kinds of main teleconnection patterns: eastern Asia / Pacific (EAP) and western Europe (WE) patterns in the pentad mean 500 hPa height field during the Northern Hemisphere summer. This reflects that quasi–stationary planetary waves excited by convective condensation heating anomalies at low latitude propagate toward extratropical re-

gions. The teleconnection patterns of the pentad mean 500 hPa height field take remote relations between the region of Asian summer monsoon and other regions in hemisphere as dominant. Meanwhile, there exists significant western Asia / Pacific / Atlantic Oscillation, reflecting the oscillation of zonal height fields. This may be the effect of stationary wave.

2) With the principal component analysis, two kinds of spatial distribution of stable eigenvectors are obtained for the pentad mean 500 hPa. For the first pattern, the contribution of variance is 19.4%, featuring that the contours appear zonal, the variations at low latitude are opposite to those at middle and high latitudes and the distribution of variation centers is similar to the teleconnection patterns, which reflect the change of 500 hPa height field caused by the variation of meridional cell and the intensity and position of subtropical high with seasonal variation of solar radiation. For the second pattern, the contribution of variance is 10.5%, featuring that the contours appear unzonal distribution, the rate is greater along the zone at low latitude and is smaller in middle and high latitudes, which reflect the effect of unseasonal variations of zonal circulation anomalies on 500 hPa height field due to uneven heating forcing along the zone at low latitude. It may be related to ENSO and tropical intraseasonal oscillation.

3) The variations of the first and second principal components with every pentad generally possess obvious persistence, reflecting the trend of seasonal variation and medium-range evolution of large-scale circulation. The catastrophes of the principal component caused by heating forcing in some intensity heating correspond to the seasonal catastrophes and intraseasonal adjustments of circulation for meridional, zonal circulations and subtropical high through nonlinear interaction.

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