A STUDY OF THE RELATIONSHIP OF ZONAL WIND OSCILLATION BETWEEN EAST AUSTRALIA AND NORTHWESTERN PACIFIC TROPICAL AREA

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ABSTRACT

The spectral analysis of zonal wind at two stations in East Australia has been studied. It is confirmed that the oscillation with period between 40—50 days and 21—25 days do exist at both high and low levels. These oscillations are closely related with that of zonal wind with the same period over the Truk Island of the northwestern Pacific. The oscillation with a 40—50 day period over East Australia is 8—11 days earlier than that over the NW Pacific. But the oscillation with a 21—25 day period over the NW Pacific is about 3 days earlier than that over East Australia.

I. INTRODUCTION

In recent years, the mutual action of two Hemispheres has been emphasized in the study of tropic circulation and weather systems. Many authors focused their attention on the generation and behavior of the summer southwest monsoon south of ITCZ in the northwestern Pacific tropical area. Concerning the source of this monsoon, Li[1] and Tao[2] have pointed out that it is a cross-equatorial current during the period of a strong cold air activity in the Southern Hemisphere. Some results of synoptic analyses and spectral analyses[3,4] have shown that the strongest current is nearly at 150°E. There is a close relationship between the intensity of this cold air and long wave activity in the Southern Hemisphere[5]. If a meridional circulation exists in the Southern Hemisphere in a region from 90°E to 180°E, there usually is a strong cold air activity over the east coast of Australia, and the cross-equatorial current becomes stronger near 150°E and turns, after crossing the equator, to a southwest current under a favourable circulation pattern over the Northern Hemisphere. This leads to the intensification of southwest monsoon in the northwestern Pacific tropical area. In another paper[6], Tao et al. have indicated that the intensity of westerly jet over the Australian east coast can be used as an index to express the strong cold air activity in the same area. Five to ten days after the strengthening of the westerly jet over East Australia the southwest monsoon over the northwestern Pacific tropic area begins to intensify. In the analysis of the impact process of the Northern Hemisphere circulation on the summer circulation of the Southern Hemisphere, Yang et al.[7] revealed that the cold air outbreak over East Asia in winter could lead to the increase of westerlies over the southwestern Pacific equator. Love[8] has also studied the influence of winter hemisphere weather pattern on the summer hemisphere weather. All these studies mentioned above are mostly limited to case studies.

Madden and Julian[9] analyzed the spectrum of the ten-year Canton Island data and discovered the oscillations with the period of 40 to 50 days in the tropospheric zonal winds and temperature and the surface pressure over the central Pacific. Instead of being the Kelvin waves, they were probably a local reflection of the circulation change in the zonal cross-secton along equator. Madden and Julian further indicated[10] that these oscillations had some global characteristics and could propagate from the east Indian Ocean to the East Pacific.

All these phenomena are very important for us to study the tropical circulation and the monsoon. One may ask: is there any relationship between the large-scale low frequency oscillation near equator and the variation of mid-latitude circulation over both Hemispheres? We are going to study these problems by means of spectral analyses of observed wind data.

II. DESCRIPTION OF THE COMPUTATION

The data used here are observed winds and temperature at 200 hPa and 850 hPa of the Truk Island[1)] and two other stations[2)] at east coast of Australia. All the data were taken from National Center for Atmospheric Research, dated from Jan. 1, 1960 to Dec. 31, 1976 at 0000 GMT. There are 6210 records for each station. The numbers of interpolated data account for about 3% at low level and about 5% at upper level.

Using the spectral analysis subroutine of NCAR (by courtesy of B. Lackman), we computed the U, V and T spectra and cross-spectra of these three stations. In smoothing process, the N (6210) data are divided into K sections with number $M=N/K=51$. Then the Bartlett filter with a bandwidth $b=b_1/M=1.5/51=0.0294$°C/day and a freedom degree $\nu=2(N/M)b_1=2(6210/51)\times 1.5=365$ is used where b_1 is the standardized bandwidth and equals 1.5 in the case of using Bartlett filter. The confidence is set to be 95% and its limit is shown in Figs. 1 and 4.

III. THE OSCILLATION OF THE MID-LATITUDE ZONAL WIND OVER EAST AUSTRALIA

In order to study whether the 40—50 day periodic oscillation of the Pacific tropical zonal wind is related to the mid-latitude zonal wind variation over East Australia, we should know wether there is an oscillation with the same period in mid-latitude circulation over East Australia. For this purpose a spectral analysis of winds at these three stations (Brisbane, 94578 and Williamtown, 94776 and Truk, 91334) has been made, obtaining the following results:

1. *Upper Level Winds*

The spectra of zonal winds at 200 hPa (hereafter referred to as $U200$) of the two Australian stations are nearly the same as the spectra of the zonal winds at 850 hPa (hereafter referred to as $U850$) over the Truk Island. The maximum spectral peaks for East Australia stations occur between 40—50 days (Fig. 1). The 40—50 day periodicity does exist in the intensity of mid-latitude zonal winds over East Australia in the Southern Hemisphere. In addition, from Fig. 1 it can also be seen that the secondary wind spectral peaks of these

1) Truk (station number 91334, 7.27°N, 151.50°E).

2) Brisbane (station number 94578, 27.26°S, 153.05°E) and williamtown (station number 94776, 32.49°S, 151.59°E).

two stations are very close to that of Truk, the period being nearly between 21—25 days.

Madden and Julian[10] have studied the characteristics of the zonal wind oscillation with

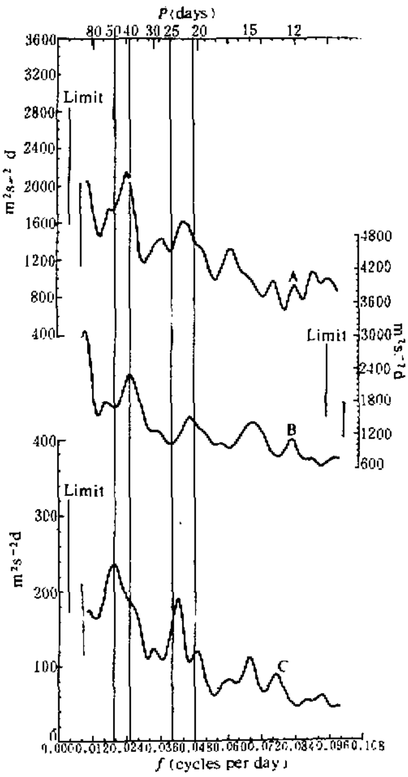

Fig. 1. Power spectra of 200 hPa and 850 hPa zonal wind.
Curve A— power spectrum of 200 hPa *U* for Williamtown station (94776, left ordinate value);
B— power spectrum of 200 hPa *U* for Brisbane station (94578, right ordinate value);
C— power spectrum of 850 hPa *U* for Truk Island (91334, left ordinate value);
95% confidence limits of 40—50 day and 21—25 day period ranges are indicated by the vertical lines.

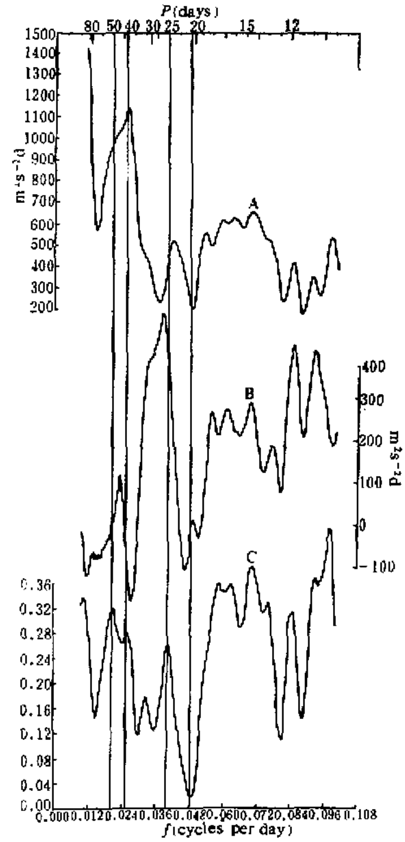

Fig. 2. Cross-spectra of 200 hPa zonal wind for Brisbane station and Williamtown station.
Curve A— cospectrum (left ordinate value);
B— quadrature (right ordinate value);
C— coherence (left ordinate value).

a 40—50 day period over the Truk Island and pointed out that it is a local reflection of large-scale zonal circulation change near the equator. To further study the character of this oscillation of East Australia, cross spectral analysis is given in Fig. 2, showing a peak between 40—50 days which means a good relationship between the two stations. The zero phase difference shows that these two oscillations are in phase. The other coherence peak is between 23—25 days, which is consistent with the peaks shown in Fig. 1. These higher frequency oscillations have a good relationship as well. By judging from the phase difference, the oscillation over Brisbane (94578) is 1.5 days earlier than that of Williamtown (94776).

There are 17 waves with an average period of 43 days from January 1, 1960 to December 31, 1961 (see Fig. 3).

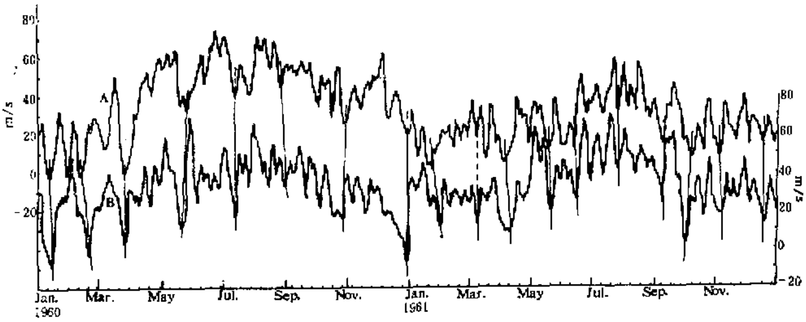

Fig. 3. Five-day running mean curve of 200 hPa zonal wind for Brisbane station (A, left ordinate value) and Williamtown station (B, right ordinate value).

2. *Low Level Winds*

The spectral peaks (Fig. 4) of low level zonal winds (U850) over East Australia are similar to those of *U*850 for the Truk Island, whereas Williamtown *U*850 peaks have slightly lower frequency and are not so concentrated as *U*200 of the same station.

The comparison of corresponding *U*850 and *U*200 cross-spectra between the two East Australia stations (Figs. 5 and 2) shows that the largest spectral peak of low level zonal wind is located between 45—55 days, and its period is longer than that of upper level. There is a 1.3 days lag at Williamtown in relation to Brisbane. This can be considered nearly in phase compared with the period length concerned.

Similar to the *U*850 spectral analyses, the cross-spectra between these two stations also have a secondary peak (Fig. 5), the period being nearly between 21—25 days. There is a 0.8 day lag at Williamtown in relation to Brisbane.

3. *Relationship between Winds at High and Low Levels*

The zonal wind oscillations with a 40—50 day period at two East Australian stations are nearly in phase at both high and low levels. Thus, we have computed the cross-spectra of the mean value for these two stations (referred to as 94*U*850 and 94*U*200) and found out that the cross-spectral peaks move slightly to lower frequency (Fig. 6), i. e. the peaks are located between 40—55 days with the same phase (the phase difference is only 0.5 day). We can also find out a 21—25 day secondary spectral peak with the same phase.

All meridional wind spectral analyses show that there are no apparent peaks. In

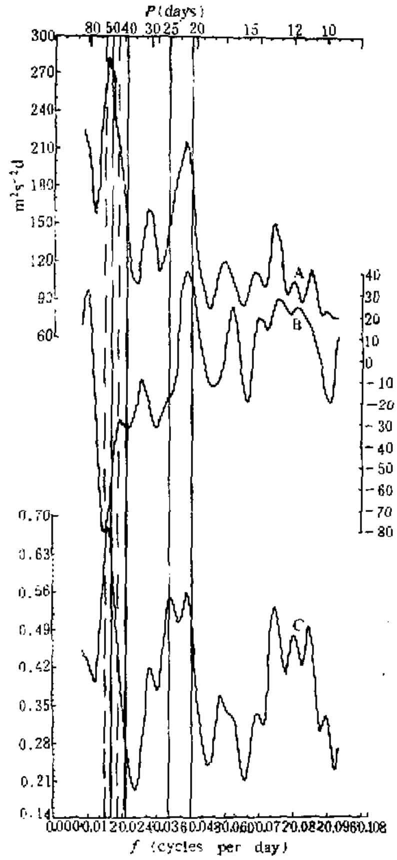

Fig. 4. As in Fig. 1, except for 850 hPa.

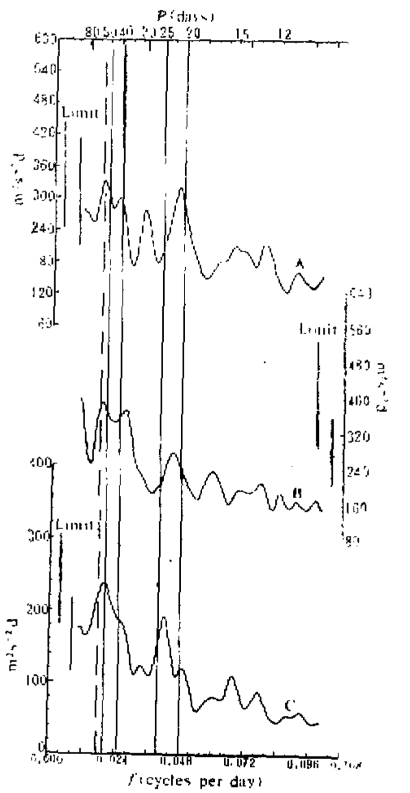

Fig. 5. As in Fig. 2, except for 850 hPa.

summary, we can confirm that there is a 40—50 day mid-latitude zonal wind oscillation over East Australia. It exists at both high and low levels, and has the same phase. Besides, the 21—25 day oscillation is also very clear in spectra or cross-spectra analyses. The oscillation of *U*200 or *U*850 over Brisbane (94578) is about 1 day earlier than that of Williamtown (94776), and the oscillation between high and low levels is in phase.

Tao et al[6]. (1982) pointed out that the variation in intensity of mid-latitude jet stream in the Southern Hemisphere is closely related to the south-north temperature gradient in the troposphere. For a further statistical study, we have computed the cross-spectra between

94*U*200 and the difference of the mean temperature $\bar{T}$[3] (referred to as DRTAT) over Townsville[4] and Williamtown[5] (Fig. 7). It shows that several obvious peaks occur between 40—50 days, and the phase angle difference vanishes. From this we would believe that the 40—50 day oscillation of mid-latitude zonal wind over East Australia is closely related to that of the south-north tropospheric temperature difference with the same period in the same area.

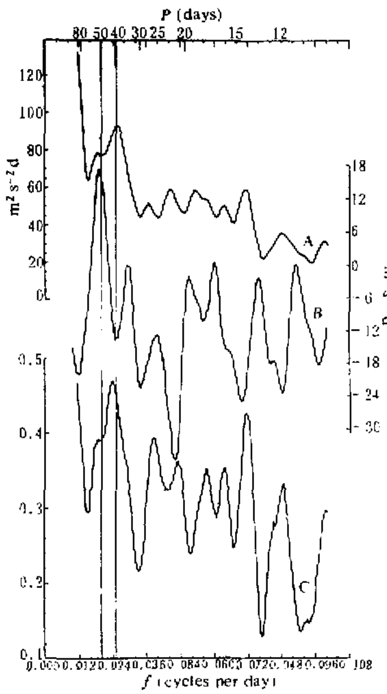

Fig. 6. Cross-spectra of mean 200 hPa zonal wind (94*U*200) and mean 850 hPa zonal wind (94*U*850) for Brisbane and Williamtown stations, the rest being the same as in Fig. 2.

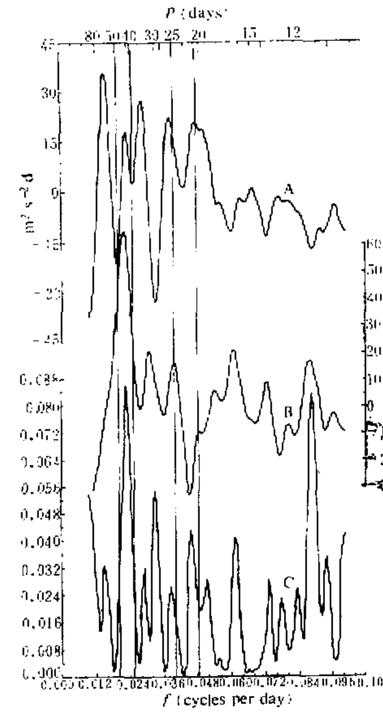

Fig. 7. Cross-spectra of 94*U*200 and the mean temperature difference (DRTAT) of Townsville and Williamtown stations, the rest being the same as in Fig. 2. (Note: the unit of ordinate should be corrected as m s^{-1} ℃ d)

IV. RELATIONSHIP BETWEEN THE ZONAL WIND OSCILLATION OVER EAST AUSTRALIA MID-LATITUDE AREA AND NORTHWESTERN PACIFIC TROPICAL AREA

For this purpose, we have calculated the cross-spectra between winds over Truk *U*850 and 94*U*200 and 94*U*850 (the mean winds of Brisbane and Williamtown).

Concerning the high level, the cross-spectra of winds over Truk *U*850 and 94*U*200 (Fig. 8)

3) $\bar{T}=(T_{850}+T_{500}+T_{200})/3$;
4) Station number 94294 (19.16°S, 146.46°E);
5) Station number 94776 (32.49°S, 151.59°E).

show that there is a maximum between 40—50 days and a $-65°$ phase lag, which means that high-level zonal wind oscillation in mid-latitude over East Australia develops 8 days earlier than the low-level zonal wind oscillaton over northwestern Pacific tropical area. In addition, the maximum of coherence (Fig. 8) is found between 21—25 days. It means that the oscillation with secondary peaks shown in Fig. 1 is also closely related. According to the phase angle analysis, low-level zonal wind oscillation with a 21—25 day period over northwestern Pacific tropical area is 3.5 days in advance of high-level zonal wind oscillation over East Australia mid-latitude area.

In Fig. 9, the cross-spectra of Truk $U850$ and $94U850$ are nearly the same as the cross-spectra between Truk $U850$ and $94U200$ except that the phase angle difference is $-90°$. It shows that the low-level zonal wind oscillation over East Australia is in advance of that over northwestern Pacific tropical area by 11 days. Similarly, another peak with 21—23 days is consistent with the secondary peak in Fig. 4, and the oscillation over northwestern Pacific tropical area is in advance of that of East Australia by 3 days.

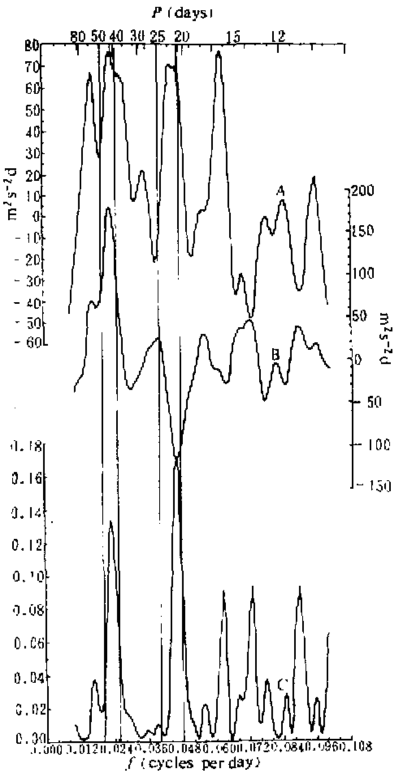

Fig. 8. Cross-spectra of 850 hPa zonal wind for Truk Island and $94U200$, the rest being the same of Fig. 2.

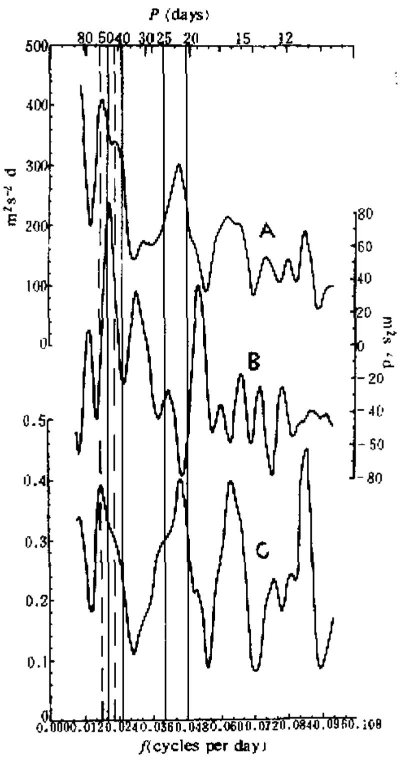

Fig. 9. Cross-spectra of 850 hPa zonal wind for Truk Island and $94U850$, the rest being the same of Fig. 2.

Why is the 40—50 day mid-latitude oscillation in advance of that over northwestern

Pacific tropical area by 8—11 days and why is the 21—25 day mid-latitude oscillation behind that by nearly 3 days? It is still not very clear yet. It might be resulted from the different seasons and scales of synoptic process. The oscillation of 40—50 days could be traced back to the strong cold air activity originated from the Southern Hemispere which can affect the weather in northwestern Pacific tropical through the momentum transportation from south to north. So the oscillaton over Australia is earlier by 8—11 days. This influence speed is nearly as large as that obtained by Tao et al[6]. in their case study. The oscillation of 21—25 days may be originated from some of synoptic processes over northwestern Pacific, which can affect the circulation of the Southern Hemisphere. Thus the oscillation over northwestern Pacific tropical area might be in advance of that of East Australia by 3 days.

V. CONCLUSIONS AND DISCUSSION

Conclusions:

(1) According to the zonal wind spectral and cross-spectral analyses at two stations and two levels in mid-latitude of East Australia, the 40—50 day and 21—25 day oscillations do exist. The oscillations of 40—50 days, either between the two stations or between the two levels, are in phase. On the other hand, the oscillations of 21—25 days observed at Brisbane in low latitude are nearly one day earlier than that of Williamtown.

(2) The mid-latitutde zonal wind 40—50 day oscillation over East Australia is closely related to the oscillatiŏn with the same period of the mean south-north temperature difference in troposphere and in the same area. This periodic oscillation of mid-latitude zonal wind may be the reflection of strong cold air outbreak over East Australia.

(3) The mid-latitude zonal wind 40—50 day and 21—25 day oscillations over East Australia are also closely related to the oscillations with the same period of zonal wind over northwestern Pacific. The oscillations of 40—50 days over Australia are 8—11 days earlier than those over northwestern Pacific. The oscillations of 21—25 days over NW Pacific are 3 days earlier than those over Australia.

Discussion:

A number of synoptic analyses have revealed that the mutual action between the two Hemispheres is different in winter from in summer. It is very complicated especially in the transition season but the statistics here included all cases of the two Hemispheres and the four seasons. The 40—50 day oscillations probably originate from strong cold air outbreak from the Southern Hemisphere which strengthen the baroclinicity over mid-latitutde area of East Australia and increase zonal wind at both high and low levels. The momentum of this process might be across equator and gives an impact on the increase of low-level zonal wind over northwestern Pacific tropical area after 8—11 days on average. Because the zonal wind 21—25 day oscillation over northwestern Pacific tropical area is about 3 days earlier than that of the same oscillation over East Australia area, it possibly has a certain influence of some synoptic processes on the circulation of the Southern Hemisphere.

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