An Observational Study of the 30–50 Day Atmospheric Oscillations Part I: Structure and Propagation

Li Chongyin (李崇银)
LASG, Institute of Atmospheric Physics Academia Sinica, Beijing 100080
and *Wu Peili*
Space and Atmospheric Physics Group, Department of Physics,
Imperial College, London SW7 2BZ
Received August 17, 1989

ABSTRACT

Features of structure and propagation of the 30 to 50 day atmospheric oscillations are investigated using the ECMWF analysis of 1980–1983. Evidence is provided to confirm the characteristics of the oscillation in the equatorial region. Those in the mid–high latitudes, however, are revealed to be very different from the tropics and pose a strong barotropic structure. Horizontal coherence shows teleconnection patterns which can be identified as EAP and PNA. The wind field of the specified time scale of the oscillation appears as long–lived vortices and vortex pairs. Mid–latitude perturbations propagate clearly westwards, especially during the winter season. In the high latitudes, they propagate westwards in the winter but eastwards in the summer. Meridional propagations are rather different from region to region.

I. *INTRODUCTION*

The 30 to 50 day (intraseasonal) atmospheric oscillation has been a popular topic in recent years. It is considered being directly relating to the long term weather modification and short climatic variation as well as the occurrence of ENSO.

This intraseasonal variability was first detected in zonal wind in the tropical Pacific by Madden and Julian (1971). One year later, they (Madden and Julian, 1972) asserted it is a global phenomenon around the tropics. Yasunari (1979) pointed out that the cloud–cover rate in monsoon region varies with a period of 30–40 days during the Northern summer. Then the 30–50 day monsoon oscillation in southern Asia Was further revealed by Krishnamurti (1982) and Murakami (1984) with the analysis of MONEX data. They also noticed the northward slow propagation. More arguments for propagations can be found from the analysis of OLR (outgoing longwave radiation) in Lau (1985) and Murakami (1984). Twelve years' GCM model output was used to investigate the three–dimensional structure and time variation of the tropical intraseasonal oscillations by N.C. Lau and K. M. Lau (1985).

Up to now, plenty of evidence supports the existence of the 30 to 50 day oscillations in the tropical area. In both stream field and temperature, the oscillations are dominated by zonal wavenumber 1 around the equatorial region. Its vertical structure shows a grear tilting with a 180° phase–shift from the low to the upper troposphere. It propagates eastwards with a slow move to the north. Theoretical studies (Li, 1985; K. M. Lau and Peng, 1987) relate the tropical intraseasonal oscillations to cumulus convection.

The angular momentum analysis carried out by Anderson and Rosen (1983) reminds us the existence of the specified oscillations apart from the tropics. A global analysis using the existence of the specified oscillations apart from the tropics. A global analysis using $FGGE_{IIIb}$ data by Krishnamurti et al. (1985) shows that the 30–50 day oscillation gets maximum amplitude in high latitudes and the summer monsoon region. Supporting points can be found from Li and Xiao (1989). Li et al. also pointed out the possible relations between the tropics and the mid–high latitudes.

Further research work is needed to reveal the features of the intraseasonal variability of the mid–high latitude atmosphere and its relationship with that in the tropics.

A detailed global investigation to the 30 to 50 day oscillations has been carried out recently with the 1980–1983 ECMWF data. Band–pass filtering technique is employed to isolate the variations of the specified time scale and correlation scheme is used to estimate its coherence. As the first part of the study, we focus on the structure and propagation in this paper. Comparison between mid–high latitudes and the tropics is made as well when necessary. Sections 2 and 3 present the vertical structure and horzontal coherenl patterns respectively. The propagations are discussed in section 4 and concluding remarks are given in Section 5.

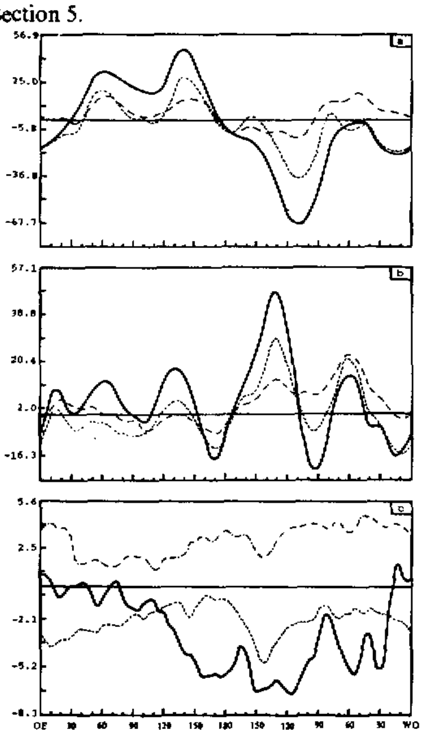

Fig.1. Longitudinal variation of the 30–50 day band–pass filtered geopotential height field in the winter Solid–lines represent 200 hPa, dot–dashed lines 500 hPa and 850 hPa. (a) 55°N–65°N, (b) 25°N–35°N, (c) 10°S–0°.

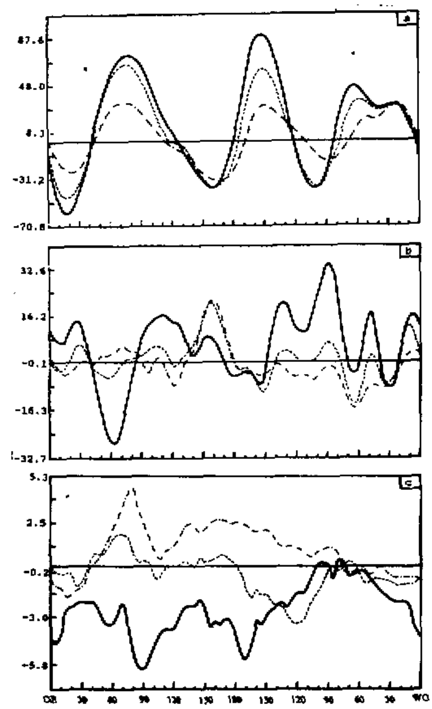

Fig.2. As Fig.1 but in summer.

II. VERTICAL STRUCTURE

In the equatorial area, it is known that the 30–50 day oscillations have a wavenumber 1 structure in horizontal and change sign from the lower to upper troposphere in vertical. For those in mid–high latitudes, although krishnamurti (1985) has mentioned its barotropic property, are still far from clear.

Based on the band–pass filtered data, structure of the oscillations is examined for different latitudes. We refer to (55°–65°N) as high latitudes, (25°–35°N) as mid–latitudes and (Equator–10°S) as equatorial region. Fig.1 and Fig.2 present the zonal structure of geopotential height perturbations of the oscillations for winter (November to April) and summer (May to October) season respectively. In the equatorial region (Figs.1c and 2c), the oscillation mainly has a zonal wavenumber 1 structure and changes sigh in the troposphere (the critical level is above 500 hPa). This is quite consistent with the known facts.

In the high–latitudes of Northern Hemisphere, the characteristic wavenumbers are 1–3, 1 and 2 in winter and 2 and 3 in summer. Barotropic structure can be readily seen from Figs.1a and 2a. Figs.1b and 2b show that in the mid–latitudes the oscillations are dominated by wavenumbers 3–4. Generally speaking, it is barotropic in the vertical direction, but the summer oscillations in area 50°E–135°E change sigh from the lower to the upper levels, similarly to the tropical 30–50 day oscillations. This is due to the monsoon action which modifies the zonal flow structure in the region.

The filtered vorticity field is presented in Fig.3. Vertical distribution of the perturbation vorticity field shows similar structure at different levels in mid–high latitudes. This, again, indicates the barotropic nature of the 30–50 day oscillations in mid–high latitudes. In the equatorial area it changes sigh in the vertical direction. Namely, high–level anti–cyclonic (cyclonic) vorticity is located over the low–level cyclonic (anti–cyclonic) vorticity. As is noticed before, the sign–changing level for geopotential height field is above 500 hPa. For vorticity field, however, in some regions they are above 500 hPa and others below. Another difference is that the zozal scale of vorticity field increases towards the polar region. Computational figures show that strong vorticity is placed in high latitudes and upper levels.

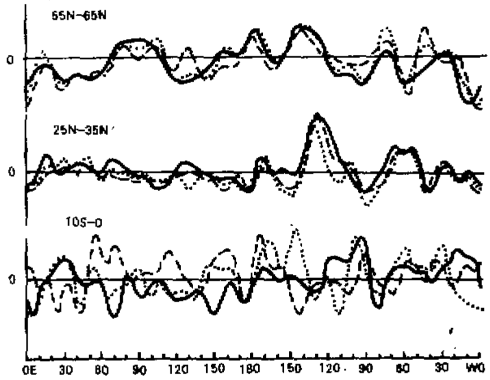

Fig.3. As Fig.1 but for vorticity.

The divergence compensation principle is well known in the atmosphere. The vertical structure of divergence field of the 30–50 day oscillations (the figure is not given) shows that in mid–low latitudes the upper layer divergence (convergence) is balanced by the lower layer convergence (divergence) and the vertical scale is small. But in high latitudes, divergence at the three levels seems to have a same sigh, This makes to hard to interpret. Presumably, the whole troposphere divergence (convergence) is compensated by the boundary layer convergence (divergence) supposing it is strong enough. In general, large divergence is at 200hPa and stronger in low latitudes. At 850 hPa, high latitude divergence is slightly stronger. Computations also show that the vorticity is five times (less than one order of magnitude) larger than the divergence.

III. HORIZONTAL COHERENT PATTERNS AND WIND FIELD

Teleconnections in atmospheric circulations (see Wallace and Gutzler, 1981) have been of major interest in the study of low frequency variability. The dispersion theory of two–dimensional Rossby waves is applied to interpret the wavetrain–like coherent patterns by Hoskins and Karoly (1981), whose computations show great circle routines of the wave trains for stationary modes. The 30 to 50 day oscillations are not yet exactly steady motion, nevertheless, great circle routine theory may be in great help for understanding the correlation patterns.

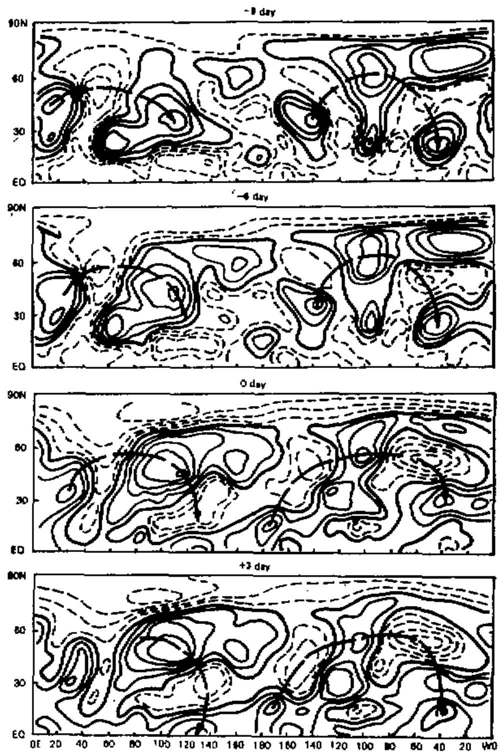

Fig.4. Coherent patterns of the filtered geopotential height at 500 hPa with referee point at (115°E, 45°N) corresponding lag–time from −9 day to 9 day. The contour interval is 0.2.

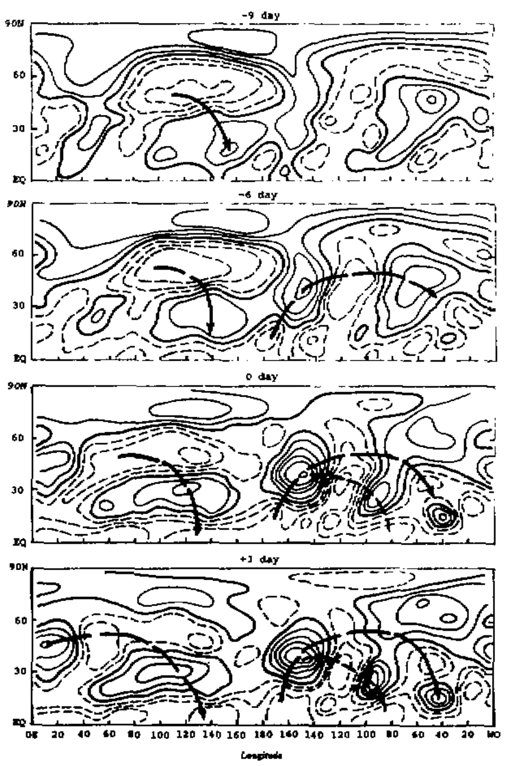

Fig.5. As Fig.4 but with referee point at (150°W, 40°N).

Fig.4 and Fig.5 show the correlation coefficients of the filtered geopotential height data at 500 hPa, which are computed by using all points corresponding with the reference point at (115°E, 45°N) and (150°W,40°N) respectively. The lag–time is marked in the figures, in which 0 day lag implies instantaneous correlation. The dominant coherent patterns in both figures are recognized as EAP (Eurasia Pacific) and PNA (Pacific North America) patterns. Careful analysis reminds us the interaction of the two patterns. Normally, at the first phase, EAP is stronger than PNA; then EAP is weakened and PNA is developed; afterwards, EAP is strengthened again. This is not only an illustration of the wave energy dispersion along the wave trains, but also hints the energy exchange between the mid–high latitudes and the tropics. It strongly suggests the influence of mid–high latitudes perturbations on the tropics in the low frequency domain. Emphasis should not only be placed on the tropical forcing, anomalies like blocking events in the mid–high latitudes are very important as well.

The isolated wind field of the oscillations illustrates the existence of the long–lived vortices. Fig.6 presents the oscillation wind fields of January 1982 at 200 hPa, from which we can see the clearly–outlined vortices. The lifetime of such vortices is about 20 days. They move very slowly. Stronger vortices are usually located over the middle Pacific and Atlantic ocean during the winter time. In summer they are negligible. The fascinating thing is that the stronger vortices frequently appear as robust vortex pairs, especially in the middle Pacific (150°E–160°W). Moreover, they efficiently affect the vortices in northern America and Atlantic Ocean as well as in the Southern Hemisphere.

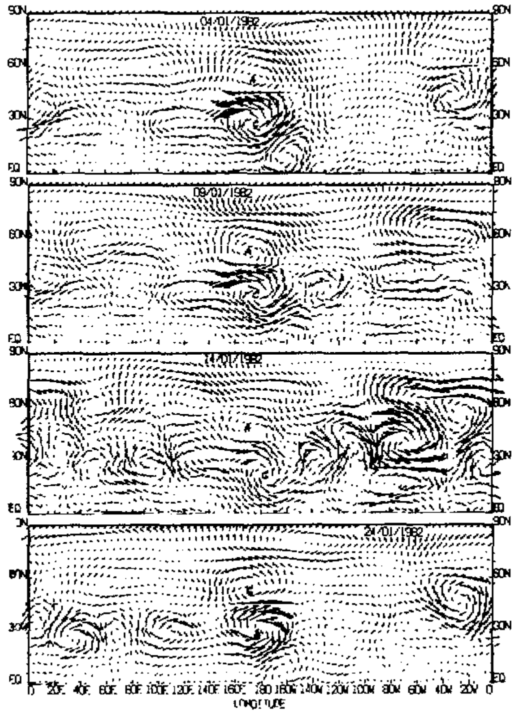

Fig.6. The vortex structure of the 30–50 day oscillation.

The analysis above reminds us to realize the importance of the middle Pacific area (it is called a "transfer station" in one of our former papers) in connecting the 30–50 day oscillations of mid–high latitudes and the tropics, and connecting those of the two hemispheres. This will be specially discussed in another paper.

IV. PROPAGATION

It is known that the tropical low–frequency oscillations slowly propagate eastwards and also northwards in Asian monsoon region. But far less attentions have been paid to those apart from the tropics. It is, therefore, not clear that how the mid–high latitudes 30–50 day oscillations propagate. In this section, interests are mainly in zonal propagation of mid–high latitudes, for contrasting, tropical versions are presented together when needed.

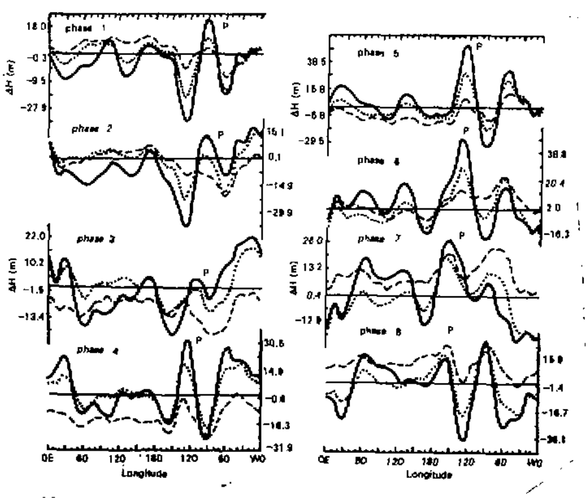

Fig.7. Zonal distributions of the 30–50 day geopotential height perturbations averaged over 25°N–35°N latitude belt in winter season for different composite phases. The solid lines represent 200 hPa, dotted lines 500 hPa and dashed lines 850 hPa.

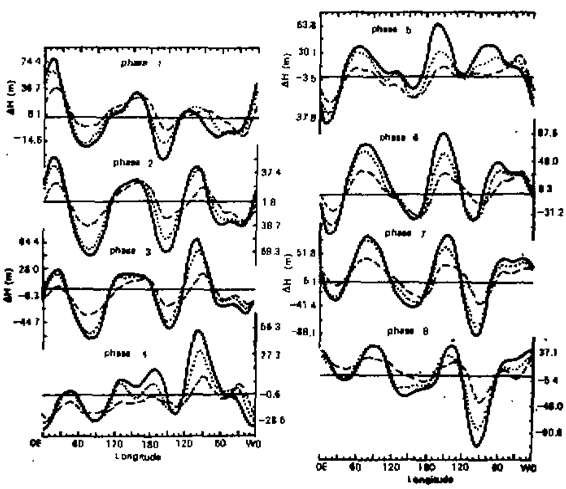

Fig.8. As Fig.8 but averaged over 55°N–65°N in summer.

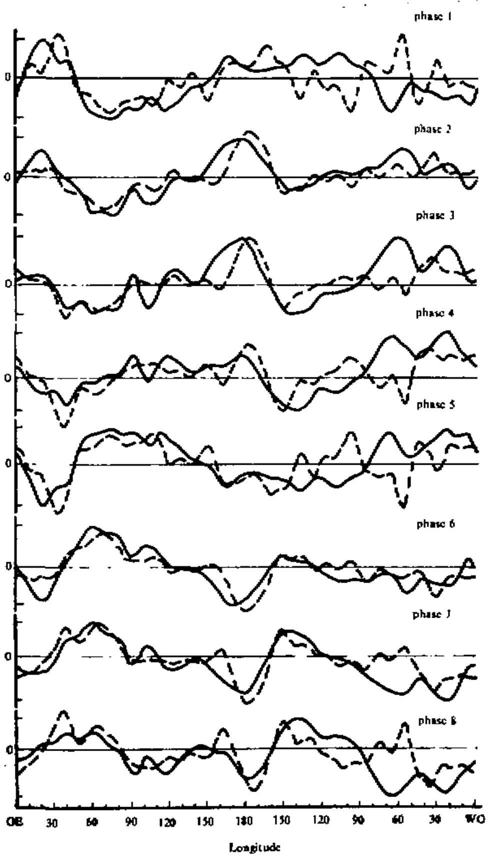

Fig.9. As Fig.8 but for vorticity in winter.

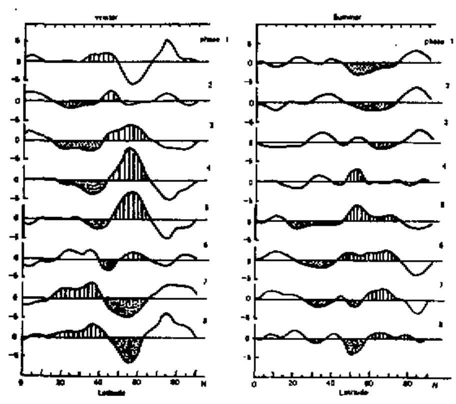

Fig.10. Latitudinal distribution of 500 hPa zonal wind perturbation at zero longitude.

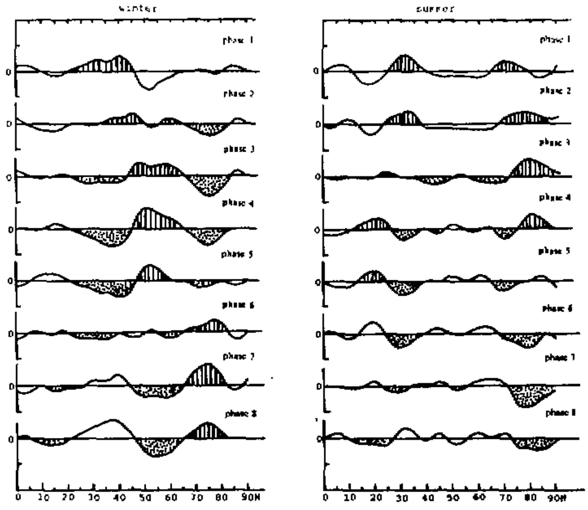

Fig.11. As Fig.10 but at 130°E.

In the equatorial region, it is quite clear that the geopotential height oscillations of zonal wavenumber 1 slowly propagate eastwards all year round. This is fairly consistent with the known facts. It is also noticed that the subscale disturbances superimposed on the wavenumber 1 oscillations do not do the same all the time (figures are not given here). In mid–high latitudes the oscillations propagate differently in summer and in winter, particularly in high latitudes. As can be seen from Fig.7, the midlatitude height perturbations clearly move westwards, but faster in winter season. In high latitudes (Fig.8) they propagate westwards *in winter but eastwards in summer.* The westward propagation of the oscillations seems to be related to the retrogression of the ultra–long waves.

The zonal distributions of oscillation vorticity and divergence fields for different composite phases are analyzed. Fig.9 shows the situation of vorticity and the divergence is similar to the vorticity. First of all, it should be noticed that the zonal scales of vorticity and divergence are much smaller than that of the geopotential height. Even in the equatorial region, the wavenumber 1 structure is not evident. The movement in winter, however, show a consistent propagation with geopotential height field: eastward move in the equatorial region and westward move in the mid–high latitudes. In summer, the propagation is not as clear as that of the geopotential height field, only in the high latitudes, eastward move can be recognized.

In spite of certain differences, the dominant propagations of the 30–50 day oscillations shown by geopotential height, vorticity and divergence are generally consistent with each other. In the equatorial area, the perturbations propagate eastwards. The midlatitude perturbations propagate westwards. In high latitudes, they propagate westwards in the winter but eastwards in the summer.

With the analysis of MONEX data, Krishnamurti (1985) and Murakami (1986) pointed out the northward propagation of the low–frequency oscillations in Asia monsoon region. This is further confirmed in our study. We have made more detailed analyses to show the meridional movement of the low–frequency oscillations, especially in the mid–high latitudes. It is found that at different longitudes the perturbations show a big difference in direction of meridional propagation. Fig.10 and Fig.11 are examples at zero longitude and at 130°E. From Fig.10, it can be seen that the perturbations propagate northwards all year round. At 130°E, however, it includes both southward and northward propagations.

V. CONCLUDING REMARKS

The following points are remarkable from all above:

1). Consistent with other authors, we have found that in the equatorial region the 30–50 day oscillations pose a dominant zonal wavenumber 1 structure in geopotential height perturbations and propagate eastwards. It changes sign from the lower to upper troposphere in the vertical direction.

2). In middle latitudes, especially the high latitude perturbations show a definite barotropic structure. In Asia summer monsoon region, the oscillations have a quite similar vertical structure to the equatorial perturbations. The different structural characteristics suggest different mechanisms behind in different latitudes. The spherical coherence of the isolated perturbations shows teleconnection patterns, the major wavetrains of which can be identified as EAP (Eurasian Pacific) and PNA (Pacific North America) pattern.

3). Long–lived vortices are found in its wind field and frequently the vortices appear as vortex pairs. Strong and robust vortex pairs are often located over the middle Pacific Ocean.

4). Geopotential height perturbations show a zonal scale of wavenumber 3–4 in middle latitudes and 1–3 in high latitudes. For all latitudes, the perturbation scales of vorticity and divergence are much smaller, and smallest in the tropics.

5). Midlatitude perturbations propagate westwards all year round and faster in winter. High latitude perturbations propagate westwards in winter but eastwards in summer. The meridional propagations of the disturbances are rather different at different longitudes.

We are grateful to Dr. John Marshall of Imperial College for reading the first English version and his valuable comment, and Mr. Wu Zhengxian of the Institute of Atmospheric Physics, Chinese Academy of Sciences, for his help in part of computer work.

REFERENCES

Anderson, J. R., and R. D. Rosen, (1983), The latitude–height structure of 40–50 dar variations in atmospheric angular momentum, *J. Atmos. Sci.*, **40**: 1584–1591.

Hoskins, B. J., and D. J. Karoly, (1981), The steady linear response of a spherical atmosphere to thermal and orographic forcing, *J. Atmos. Sci.*, **38**: 1179–1196.

Krishnamurti, T. N., and D. Subrahmanyam, (1982), The 30–50 day mode at 850 hPa during MONEX, *J. Atmos. Sci.*, **39**: 2088–2095.

Krishnamurti, T. N., and S. Gadgil, (1985), On the structure of the 30 to 50 day mode over the globe during FGGE, *Tellus* (A), **37**: 336–360.

Lau, K. M., and L. Peng, (1987), Origin of low–frequency (intraseasonal) oscillations in the tropical atmosphere, Part I: Basic theory, *J. Atmos. Sci.*, **44**: 950–972.

Lau, K. M., and P. H. Chan, (1985), Aspects of the 40–50 day oscillation during the Northern winter as inferred from outgoing longwave radiation, *Mon. Wea. Rev.*, **113**: 1889–1909.

Lau, K. M., and P. H. Chan, (1986), Aspects of the 40–50 day oscillation during the Northern winter as inferred from outgoing longwave radiation, *Mon. Wea. Rev.*, **114**: 1354–1367.

Lau, N. C., and K. M., Lau, (1986), The structure and propagation of intraseasonal oscillations appearing in a GFDL general circulation model, *J. Atmos. Sci.*, **43:** 2023–2047.

Li Chongyin, (1985), Actions of summer monsoon troughs (ridges) and tropical cyclones over South Asia and the moving CISK mode, Scientia Sinica (B), **28:** 1197–1206.

Li Chongyin and Xiao Ziniu, (1987), The actions of the 30–50 day oscillation at 500 hPa in the Northern Hemisphere, submitted to Chinese *J. Atmos. Sci.*.

Madden, R. D., and P. Julian, (1971), Detection of a 40–50 day oscillation in the general wind in the tropical Pacific, *J. Atmos. Sci.*, **28:** 702–708.

Madden, R. D., and P. Julian, (1972) Description of global scale circulation cells in the tropics with 40–50 day period, *J. Atmos. Sci.*, **29:** 1109–1123.

Murakami, M. T. Nakzawa and J. He, (1984), On the 40–50 day oscillations during the 1979 Northern Hemisphere summer, Part I: Phase propagation, *J. Meteor. Soc. Japan*, **62:** 440–468.

Murakami, T., L. Chen and A. Xie, (1986), rrelationship among seasonal cycles, low–frequency oscillations, and transient disturbances as revealed from outgoing longwave radiation data, *Mon. Wea. Rev.*, **114:** 1456–1465.

Murakami, T., L. Chen, A. Xie and M. Shrestha, (1986), Eastward propagation of 30–60 day perturbations as revealed from outgoing longwave radiation data, *J. Atmos. Sci.*, **43:** 961–971.

Wallace, I. M., and D. S. Gutzler, (1981), Teleconnections in the geopotential height field during the Northern Hemisphere winter, *Mon. Wea. Rev.*, **109:** 784–812.

Yasunari, T., (1979), Cloudiness fluctuation associated with the Northern Hemisphere summer monsoon, *J. Meteor. Soc. Japan*, **57:** 227–242.