An Observational Study of the 30–50 Day Atmospheric Oscillations Part II: Temporal Evolution and Hemispheric Interaction across the Equator

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ABSTRACT

In this part, the temporal evolution and interaction across the equator of 30–50 day oscillation in the atmosphere are investigated further. The annual variation of 30–50 day oscillation is quite obvious in the mid–high latitudes. In the tropical atmosphere, the obvious interannual variation is an important property for temporal evolution of 30–50 day oscillation. The low–frequency wavetrain across the equator over the central Pacific and central Atlantic area, the movement of the long–lived low–frequency system across the equator and the meridional wind component across the equator will obviously show the interaction of 30–50 day oscillation in the atmosphere across the equator.

I. INTRODUCTION

In Part I (Li, et al., 1990), some characteristics in relation to the structure and propagation of 30–50 day oscillation have been shown. We focused on the differences of the structure and propagation of 30–50 day oscillation in the mid–high latitudes from that in the tropical atmosphere. It is clear that the 30–50 day oscillation in the mid–high latitudes has typical barotropics structure and mainly propagates westward.

The 30–60 day oscillations have been regarded as a global low–frequency system. But the study in relation to the temporal variation and interaction across the equator is not quite ample yet. Based on the analysis of 30–50 day motion fields at 850 hPa and 200 hPa for 1980–1984 ECMWF data and FGGE (1979) data, Mehta and Krishnamurti (1988) initially investigated the interannual variability of 30–50 day oscillation. They found that the northward propagation speed of the trough and ridge systems over Indian summer monsoon region is different in 1979, 1982 and 1983 from that in 1980, 1981 and 1984. The amplitude of the divergent wave was found to be variable from one year to the next. But it is very clear that the characteristics of interannual variation of 30–60 day oscillation, especially its relationship with ENSO event are not clearly understood; and the characteristics of annual variation are not sufficiently studied too.

The possible relation of the quasi–40 day oscillation of the summer monsoon in East Asia to the atmospheric circulation in Australia has been indicated by analyzing the data in May–August, in 1980 (Chen et al., 1982). The meridional propagation of the quasi–40 day oscillation was studied by He (1990) and Li (1990). But the propagational feature of 30–50 day oscillation across the equator from one hemisphere to another is not studied very well.

According to the analyses using the ECMWF data, temporal evolution of 30–50 day oscillations and their hemispheric interaction across the equator will be investigated further in this part.

II. ANNUAL VARIATION OF 30–50 DAY OSCILLATION IN THE ATMOSPHERE

The 30–50 day oscillation is a universal feature of the atmospheric motion. As well as the regional differences, the temporal variation of 30–50 day atmospheric oscillation is also very important. In this section, we focus on the annual variation of 30–50 day oscillation in the atmosphere.

Fig.1 shows the kinetic energies of 30–50 day oscillation at 850 hPa along 55°S latitude averaged in January and July, 1981, respectively. It is very clear that the kinetic energy in July is much larger than that in January. This means the 30–50 day atmospheric oscillation in winter is much stronger than that in summer along 55°S.

Is the annual variation a general feature of 30–50 day oscillation, as shown in Fig.1 that it is stronger in winter and weaker in summer? In order to investigate this question, the temporal variation of 30–50 day band–pass filtered u^2 at 200 hPa in the region (30°–50°N, 80°–180°E) is given in Fig.2. It is able to represent the temporal variation of 30–50 day oscillation in the mid–high latitudes. We can find in Fig.2 that the maximum u^2 is in the wintertime and the minimum u^2 in the summertime. In other words, the 30–50 day oscillations in the mid–high latitudes of Northern Hemisphere are stronger in the wintertime but weaker in the summertime.

In other regions of the mid–high latitudes, the 30–50 day band–pass filtered u^2 has a similar temporal variation as shown in Fig.2 (figures are not given). Therefore, according to the results shown in Fig.1 and Fig.2, it can be suggested that the 30–50 day oscillations in the mid–high latitudes have obvious annual variation and they are stronger in the wintertime but weaker in the summertime.

It is different from obvious annual variation in the mid–high latitudes that the 30–50 day oscillations in the tropical atmosphere do not have significant annual variation. Fig.3 shows the longitudinal distribution of mean kinetic energy at 500 hPa for 30–50 day oscillation

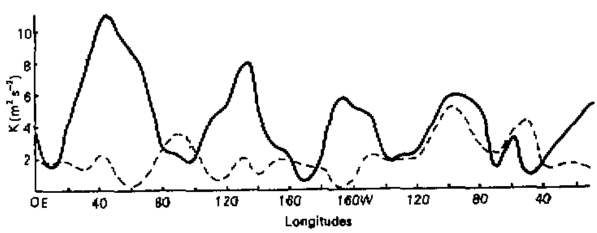

Fig.1. Longitudinal distribution of kinetic energy at 850 hPa for 30–50 day oscillation in January (dashed line) and July (solid line), 1981 along 55°S latitude.

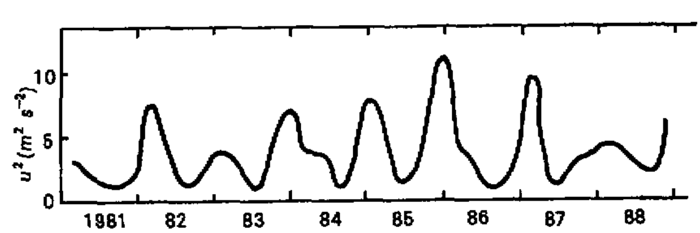

Fig.2. Temporal variation of 30–50 day band–pass filtered u^2 at 200 hPa in (30°–50°N, 80°–180°E) region.

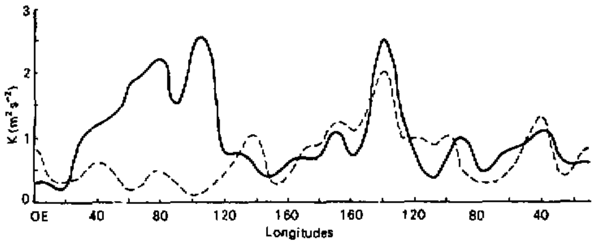

Fig.3. Longitudinal distribution of kinetic energy at 500 hPa for 30–50 day oscillation in January (dashed line) and July (solid line), 1981 along 10°S–10°N latitudes.

along 10°S–10°N latitudes in January and July, 1981. We can clearly see that kinetic energies of 30–50 day oscillation in the tropical atmosphere have nearly the same magnitude except in South Asia monsoon region. In other words, the 30–50 day oscillations in the most tropical area have the same strength and no obvious annual variation. In South Asia region, there is clear seasonal variation of 30–50 day oscillation and this seasonal variation is different from that in the mid–high latitudes, i.e., the 30–50 day oscillation is stronger in summer but weaker in winter. This seasonal variation feature of 30–50 day oscillation in South Asia is a significant reflection of the monsoon activity. In summer, there are stronger summer monsoon and the cumulus convection in South Asia. So that the stronger 30–50 day atmosphere oscillation can be excited.

III. INTERANNUAL VARIATION OF 30–50 DAY OSCILLATION IN THE ATMOSPHERE

Mehta and Krishnamurti (1988) analyzed the zonal winds at 850 hPa over the Arabian Sea in the period 1979–84 and showed that the 30–50 day oscillations were stronger during 1979 and 1983. The temporal–longitude sections of the 200 hPa velocity potential, averaged between 30°S and 30°N for 1979–1984, showed more obvious eastward propagating waves during 1979 and during October 1982 to October 1983. Because 1982–1983 was the El Nino year and 1979 was characterized by weak warm anomalies of SST in the eastern equatorial Pacific Ocean, they suggested a possible connection between the 30–50 day oscillation and El Nino activity.

According to the analyses of interannual variations of 30–50 day oscillation before and after 1982–1983 and 1986–1987 El Nino events, the connection between the 30–50 day oscillation and El Nino event will be revealed more clearly. The temporal variation of u^2 of 30–60 day oscillation at 200 hPa along the equatorial middle–western region is given in Fig.4. It is very clearly shown that the seasonal variation of 30–50 day oscillations in the tropics is not obvious, with clear difference from that in the mid–high latitudes. And the interannual variation of 30–50 day atmospheric oscillations in the tropics is closely related to El Nino event. We can see in Fig.4 that there are the maximum u^2 over the middle–western equatorial Pacific Ocean in the Spring of 1982 and Spring–Summer of 1986, before the occurrence of El Nino event. Lau and Chan (1987) have suggested that the increasing amplitude and the decreasing frequency of 30–50 day atmospheric oscillation over the equatorial Pacific Ocean can excite El Nino event. The observational analysis in this paper gives an obvious affirmation to Lau's perspective.

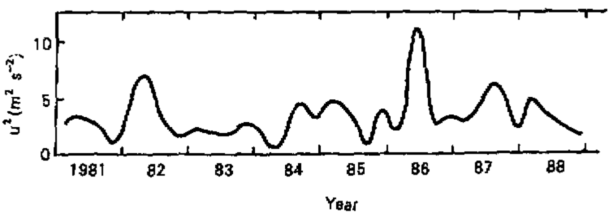

Fig.4. Temporal variation of 30–50 day band–pass filtered u^2 at 200 hPa in (10°S–10°N, 110°–180°E) region.

There is stronger 30–50 day atmospheric oscillation over the mid–western equatorial Pacific prior to the El Nino event. What process could enhance the 30–50 day atmospheric oscillation over the mid–western Pacific? Our studies have indicated that the anomalously stronger winter monsoon (cold waves) in East Asia in the wintertime prior to the El Nino event is capable of enhancing the cumulus convection over the middle–western equatorial Pacific and then enhancing the 30–50 day oscillation there (Li, 1989; Li, 1990). Comparing Fig.2 with Fig.4, it can be seen that there are stronger 30–50 day oscillation u^2 in 30°–50°N latitudes of East Asia–western Pacific area in the spring of 1982 and the winter of 1985–86, prior to the enhancement over the middle–western equatorial Pacific, although not as obviously as those in the tropics. In other words, the stronger 30–50 day atmospheric oscillations over East Asia mid–high latitudes in the wintertime propagate with the cold wave activity into the middle–western Pacific area and enhance the 30–50 day atmospheric oscillations over there, then the El Nino event could be excited.

IV. INTERACTION OF 30–50 DAY OSCILLATION ACROSS THE EQUATOR

Based on the 1979 FGGE IIIb data in (30°S–30°N, 30°E–150°W) area, the transfer of sensible and latent heat and momentum for the quasi–40 day oscillation in a cross–equatorial meridional section is investigated (He, 1988). It suggested an interaction of 30–50 day oscillation across the equator. But it is not understood what are the avenues for the interaction of 30–50 day oscillation across the equator? According to the analyses in the ECMWF data, some avenues for the interaction of 30–50 day atmospheric oscillation across the equator are explored.

There are 30–50 day low–frequency wavetrains in both the Northern Hemisphere and the Southern Hemisphere. We will indicate further that the 30–50 day low–frequency wavetrains are able to cross the equator in some places and produce the cross–equatorial wavetrains. These cross–equatorial low–frequency wavetrains obviously show an interaction of 30–50 day oscillations across the equator because the low–frequency energy will propagate along the wavetrains from one hemisphere to another.

In Part I (Li and Wu, 1990), the low–frequency wavetrains in the Northern Hemisphere are noted. There we focus on the cross–equatorial parts of low–frequency wavetrains, especially over the central equatorial Pacific. Fig.5 shows the correlation coefficients of the filtered geopotential height at 500 hPa based on the reference points (115°E, 45°N) and (150°W, 40°N), respectively. According to the distributions of the correlation coefficients, it is very clear that there are two major cross–equatorial wavetrains over the central equatorial Pacific. Because the correlation coefficients over the central equatorial Pacific area are quite large, the cross–equatorial low–frequency wavetrains are obviously existential. Although it is no more

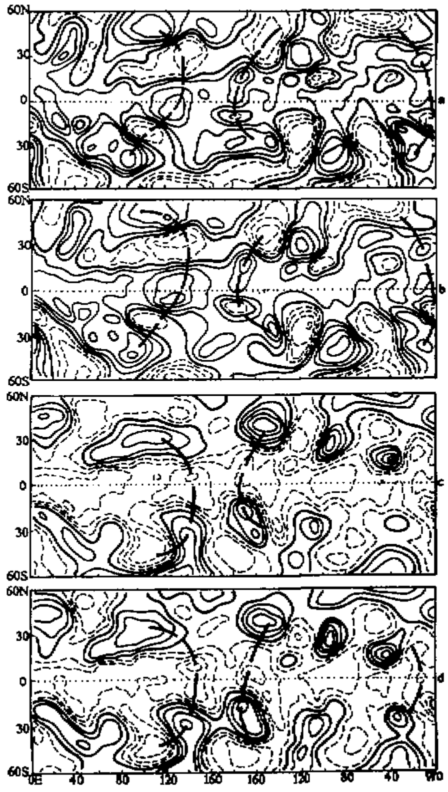

Fig.5. Distributions of the correlation coefficients of the filtered geopotential height at 500 hPa. The contour intervals are 0.2. a. The reference point at (115°E, 45°N); 3 days lag b. The reference point at (115°E, 45°N); 6 days lag c. The reference point at (150°W, 40°N); 3 days lag d. The reference point at (150°W, 40°N); 6 days lag.

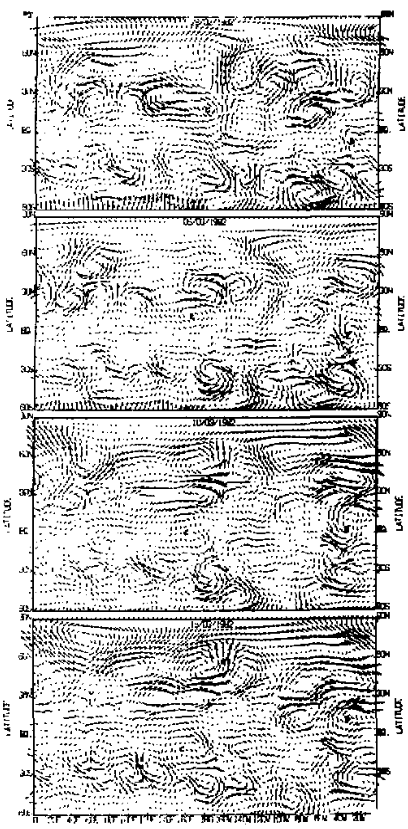

Fig.6. The isolated wind fields of 30–50 day oscillations at 200 hPa from February 28 to March 15, 1982.

obvious than that over the central equatorial Pacific area, the cross–equatorial wavetrain can also be seen over the central equatorial Atlantic area.

The long lasting low–frequency systems (" storms") have been found to propagate meridionally northwards from the equator during the Northern winter season (Krishnamurti et al., 1985). Are there the long lasting low–frequency systems to propagate across the equator? We have indicated the existence of the long–lived vortices in Part I. In fact, the low–frequency vortex, shown in Fig.6 of Part I, propagates from the Northern Hemisphere to the Southern Hemisphere over the central Pacific area. In that figure, the cyclonic vortex "C" located near 25°N on January 4, 1982 has already moved near the equator on January 24. Then that cyclonic vortex propagated into the Southern Hemisphere. Fig.6 presents the isolated wind fields of the oscillations at 200 hPa from February 28 to March 15, 1982. It is also

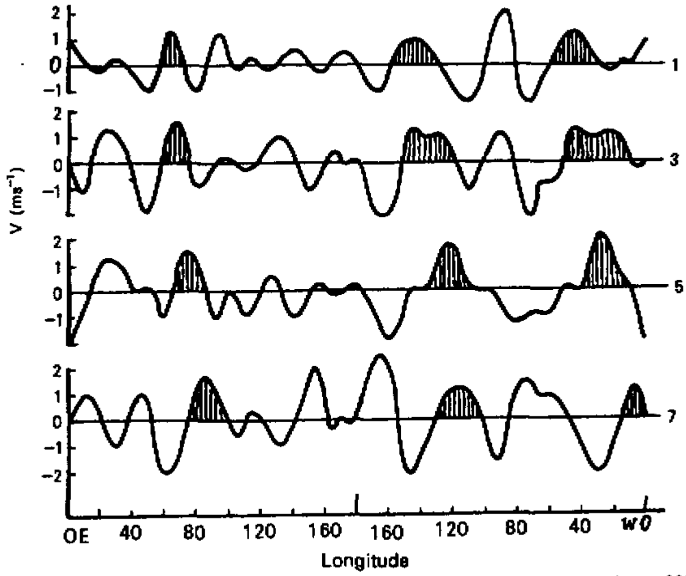

Fig.7. Longitudinal distributions of meridional wind components of 30–50 day oscillation at 200 hPa along the equator for the wintertime in 1980. Numerals 1, 3, 5 and 7 represent 4 oscillation phases in total 8 phases, respectively.

shown that a cyclonic vortex marked with "C" propagates from Northern to Southern Hemisphere over the central equatorial Pacific area. In the same time, a cyclonic vortex marked with "D" in the Southern Hemisphere obviously propagates into the Northern Hemisphere over the central equatorial Atlantic area.

It is clearly presented that the cross–equatorial propagation of the low–frequency vortex is an important avenue for the interaction of 30–50 day atmospheric oscillations between the two hemispheres. The central Pacific area and central Atlantic area are major regions for the cross–equatorial propagation of the low–frequency vortex, especially in the wintertime.

Fig.7 presents longitudinal distributions of the meridional wind components of 30–50 day oscillation at 200 hPa along the equator for the 1st, 3rd, 5th and 7th phases, respectively. The slow eastward propagation along the equator shows the basical property of 30–50 day oscillation in the tropical atmosphere. It is shown in Fig.7 that the cross–equatorial meridional winds along the equator are oscillational and the cross–equatorial effects are able to exist at any place. The longitudinal distributions of v^2 at 200 hPa along the equator averaged for 8 phases in the summertime and wintertime are given in Fig.8. We can find that there are three major cross–equatorial effect regions along the equator in the wintertime, i.e., the central Pacific area, the eastern Atlantic and western African area and the western Indian Ocean; there are two major cross–equatorial effect regions in the summertime, i.e., the eastern Pacific area and the central Atlantic area.

The discussions in this section show that the interaction of 30–50 day oscillations across the equator has three avenues. They are the cross–equatorial low–frequency wavetrains, the cross–equatorial low–frequency vortex and the cross–equatorial meridional winds. And, the major regions for the cross–equatorial interaction of 30–50 day oscillations are over the central–eastern Pacific and the central Atlantic.

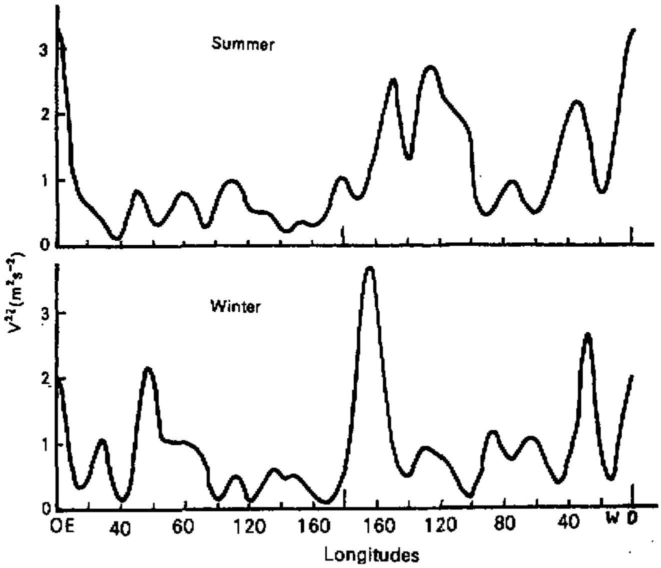

Fig.8. Longitudinal distributions of v^2 at 200 hPa along the equator averaged 8 phases.

It is well–known that there are three main avenues for cross–equatorial air. They are located in 50°–60°E, 105°E and 150°E regions along the equator. Specially, the famous Somali jet which crosses the equator through 50°–60°E avenue, is a significant circulation system for the Southern Hemisphere affecting the Northern Hemisphere. But for the 30–60 day oscillations, the above usual avenues are not apparent. On the contrary, the more important avenues are located over equatorial central Pacific and central Atlantic. This indicates that the cross–equatorial effect of 30–50 day oscillation has remarkable differences from that of general circulation.

V. CONCLUDING REMARKS

Based on the analyses in ECMWF data, some properties in relation to the temporal evolution and hemispheric interaction of 30–50 day oscillation across the equator are discussed in this part. Especially, the following conclusions should be indicated.

1. The 30–50 oscillations in the atmosphere have annual variation property. It is more obvious in the mid–high latitudes. In general, the 30–50 oscillations are stronger in the wintertime and weaker in the summertime for the mid–high latitude area. And, they are stronger in the summertime and weaker in the wintertime for the tropical atmosphere.

2. The interannual variation of 30–50 day atmospheric oscillation in the tropics is very clear and it is related to the El Nino event. There are stronger 30–50 day atmospheric oscillations over the mid–western equatorial Pacific prior to the El Nino event.

3. The cross–equatorial effect of 30–50 day atmospheric oscillation has three major avenues: the cross–equatorial low–frequency wavetrains, the cross–equatorial propagation of the low–frequency vortex and the cross–equatorial meridional wind. The cross–equatorial effects of 30–50 day atmospheric oscillation mainly occur over the central Pacific and the eastern Atlantic – western Africa. Sometimes, there are obvious cross–equatorial meridional wind of 30–50 day oscillation over the western equatorial Indian Ocean.

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