The Characteristics of 30–60 Day Oscillation and Its Relations to the Interannual Oscillations①

Song Yi (宋 毅) and *Chen Longxun* (陈隆勋)
Chinese Academy of Meteorological Sciences, Beijing 100081
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ABSTRACT

The characteristics of 30–60 day oscillation (hereafter called LFO) of the outgoing longwave radiation data (OLR) and its relations to the interannual oscillations of the sea surface temperature (SST) are investigated by using the daily OLR data for the period from January, 1979 to December, 1987 and the corresponding monthly SST data. It is found that the LFO the band the interannual oscillations of the SST monthly anomaly (SSTA) interact each other and they all relate to the occurrence and development of El Nino events closely. Before E1 Nino event happens, it contributes to the SST's warming up and to the SST's quasi–biennial oscillation (called QBO for brevity) and three and half years oscillation (called SO for short) being in warm water phase in the equatorial central and eastern Pacific (ECP and EEP) that the LFO in the equatorial western Pacific (EWP) enhances and propagates eastward; When E1 Nino event takes place, the LFO, SSTA and SSTA's QBO and SO in the EEP interact and strengthen each other; But the warmer SST and the SSTA's QBO and SO in the warm water phase in the EEP contribute to the LFO's weakening in the equatorial Pacific. Moreover, these contribute to the SST in the EEP becoming cold and the SSTA's QBO and SO in the EWP being in cold water phase and then impel the E1 Nino event to end.

I. INTRODUCTION

In the early 1970s, Madden and Julian (1971) found the LFO by applying the power spectrum analysis to the Canton island's monthly sonde data for ten years. From then on, people become more and more interested in this periodical LFO. Many famous scholars and experts have done a lot of studies and analyses to this kind of LFO and made inspiring achievements. Yasunari (1980) first clarified the importance of this kind of LFO in the Northern Hemisphere summer and pointed out its northward propagation characteristics in South Asia. It originates from the equatorial Indian Ocean, propagates northward to the south edge of the Tibetan Plateau and contacts closely with the onset and withdrawal of the Indian monsoon. Murakami, Chen and Xie (1986a, b) discussed the eastward propagation characteristics of the LFO and showed that the correlation coefficients among LFO, the shorter time scale oscillations (the quasi–biweekly oscillation and 5 day oscillation) and the longer time scale oscillation and 5 day oscillation) and the longer time scale oscillation (the seasonal cycles) are remarkable. This indicates that the different time scale oscillations (the shorter time scale oscillations, LFO and the seasonal cycle et al.) interact each other. But they didn't discuss the correlation between the LFO and the interannual oscillations (the longer time scale). In this field, Lau (1988) pointed out the probability of their interaction; Chen, Xie and Murakami (1987) investigated the correlations between LFO's changes and the El

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Nino event in 1982 El Nino event. Recently, Chen and Shao (1991) analyzed in detail the changes of the wind's and the OLR's LFO around the El Nino event in 1982. They pointed out: It was probable that the LFO's enhancement and eastward propagation in the EWP stimulated the El Nino event in the EEP to take place; Oppositely, the LFO's enhancement and eastward propagation in the EWP stimulated the El Nino event in the EEP to take place; Oppositely, the occurrence of the El Nino event made the LFO strengthen in the EEP and the whole LFO's stream fied change obviously and further affected the climate in the western Pacific and China.

With the LFO being studied profoundly in the recent years, people become more and more interested in studying the interannual oscillation. Yasunari (1985) found the existence of the interannual oscillation in the equatorial upper wind. Chen Duo, Chen Longxun and Shen Rugui (1990) studied the spatial distribution of the upper wind's interannual oscillation. Chen, Yan and Wang (1989) and Yan, Chen and Wang (1988) analyzed the COADS data from 1950 to 1979 further. They found the QBO and the SO in all the sea surface temperature, the sea surface wind, the sea surface pressure and the cloudage data. Moreover, they found that the superimposition curve of the SSTA's QBO and SO approaches the practical sea temperature curve well in the EEP. These studies indicated: The QBO and SO of the elements in the air–sea system had their own laws, harmonized and interacted each other; The El nino event didn't occur until their oscillation centers emerged at same time.

On the basis of above studies, people pay close attention to whether there are correlations between the LFO and the interannual oscillations. For this reason, we study this issue by applying the COADS (from 1979 to 1987), the OLR (from 1979 to 1987) and other data. We found that there are relations between the two kinds of different time scale oscillations. Though the details of the relations are not distinct, it is enough to explain the issue.

II. DATA AND METHOD

We chose the OLR data from 1 January 1979 to 31 December 1987 to investigate the LFO. The original data were 2.5° longitude and 2.5° latitude from 90°N to 90°S global grid data. Due to the limitation of our compnter facility, we simplified them to be 5° longitude and 5° latitude from 70°N to 70°S grid data. We think that the 5° longitude and 5° latitude grid data are enough to be used for investigating the large scale characteristics.

According to Yan, Chen and Wang (1988), we filled up the day and night observed OLR data respectively. Then the two OLR data sets per day were averaged to be one data set to represent this day's OLR value. Only few lack observed value being in the OLR, we filled few.

In order to get the continuous low frequency oscillation spectrum of OLR for ten vears, we employed the method of Murakami, Chen and Xie et al. (1986a). We also used the method introduced by Yan Jinghua, Chen Longxun and Wang Gu (1988) to fill up the COADS data.

III. THE CHARACTERISTICS OF THE BASIC FIELD AND THE 30–60 DAY OSCILLATION OF THE OLR DURING THE El NINO EVENTS IN 1982–1983 AND 1986–1987

In order to investigate the characteristics of the basic field of the OLR during the two El Nino events, we make the time–longitude cross–sections of 5–day running mean OLR anomaly in 1982, 1983, 1986 and 1987 along the equator (0–5°S) (Figs.1a–d). The OLR anomalies are obtained by being minus the average values of 1979–1987. We find the following similarities and differences:

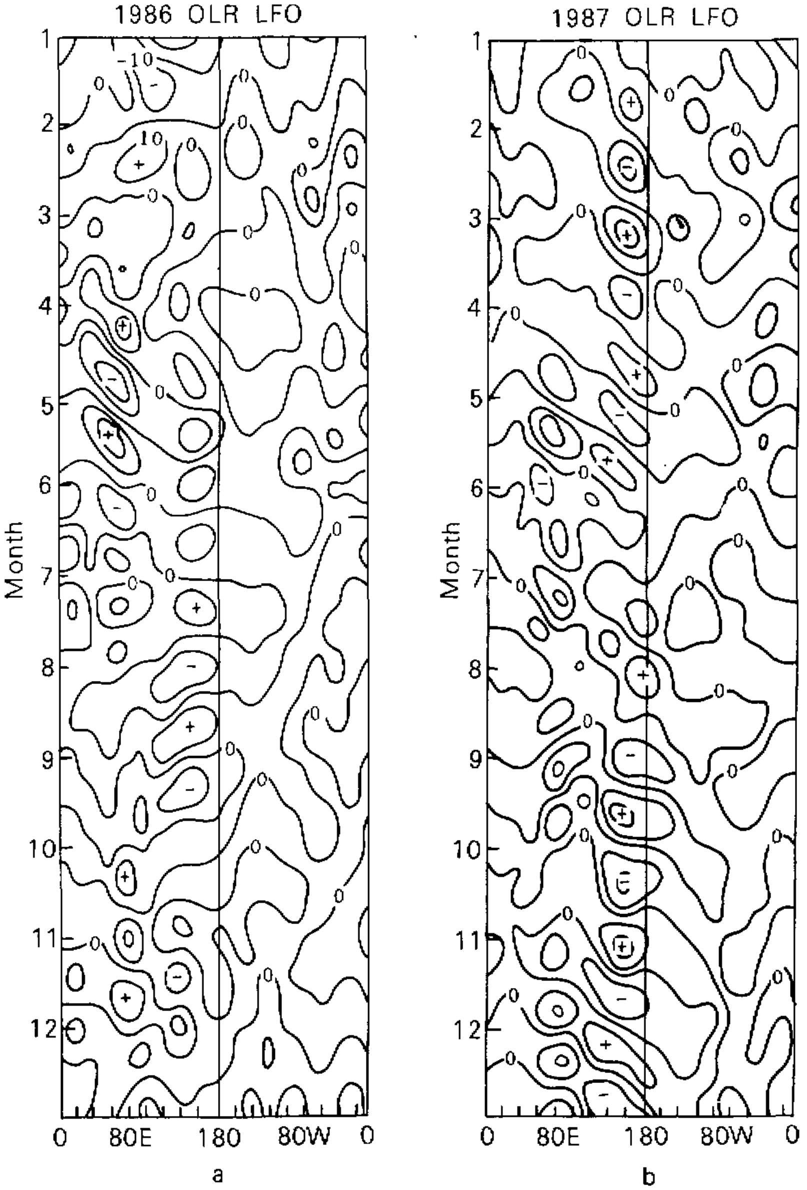

Fig.1. Time–longitude cross–sections of 5–day running mean OLR anomaly along the equator (0–5°S). 1a: 1986. 1b: 1987. The interval is 10 w / m^2. Negative values are dashed.

1. Before the two El Nino events happen (before April 1982 and August 1986), the abnormal strong negative OLR anomaly areas (meaning strong convective area) always appear in the EWP. In the strong convective area, the strong convective center whose period is about 45 day always appears, and this shows the LFO existing. Chen, Xie and Murakami et al. discussed the appearance of the strong LFO in the western Pacific before the El Nino event happened in 1982–1983. This fact shows that the abnormal strong convection and the strong LFO can be the factor to stimulate the El Nino event to happen.

2. From the lst to 2nd month after the El Nino event happens, all the strong convective areas appear in the ECP and the strong convective centers with about 45 day period are found in the strong convective area. There are eight centers from July, 1982 to June, 1983 in 1982 El Nino event and seven centers from December, 1986 to October, 1987. The periods with which the centers existed are 45 day and 47 day respectively. The fact, that the strong convections take place after the SST becomes warm, shows that the strong convections are stimulated by the warm SST.

3. During 1982 El Nino event, the strong convective centers gradually shift to 140°W–120°W and stay there after the strong convections are formed in July, 1982 over the ECP. The EWP is conquered by the positive OLR anomaly while the equator from Africa to Indian Ocean is conquered by the second strong convections. During 1986 El Nino event,

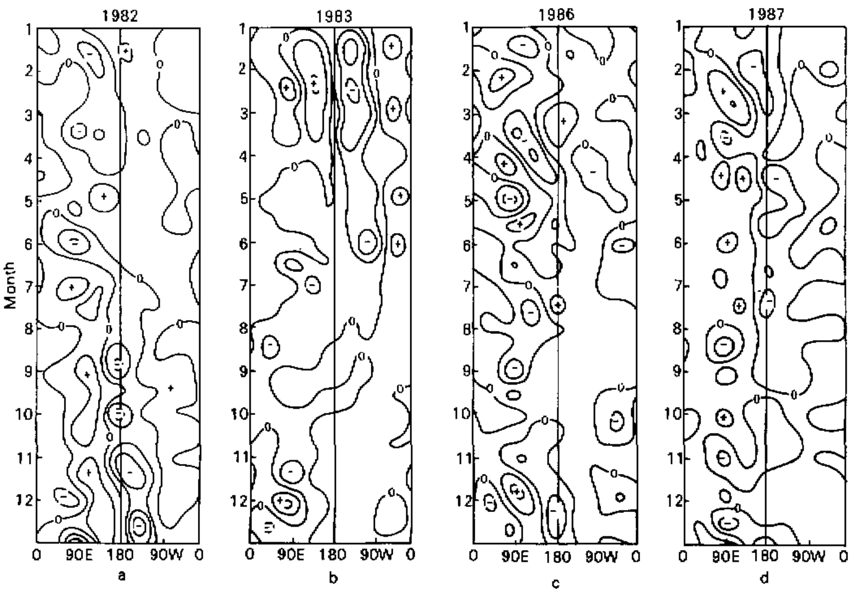

Fig.2. Time–longitude cross–section of the OLR's LFO along the equator (0–10°S). a: 1982; b: 1983; c: 1986; d: 1987. The interval is 20 w / m^2. Negative values are dashed.

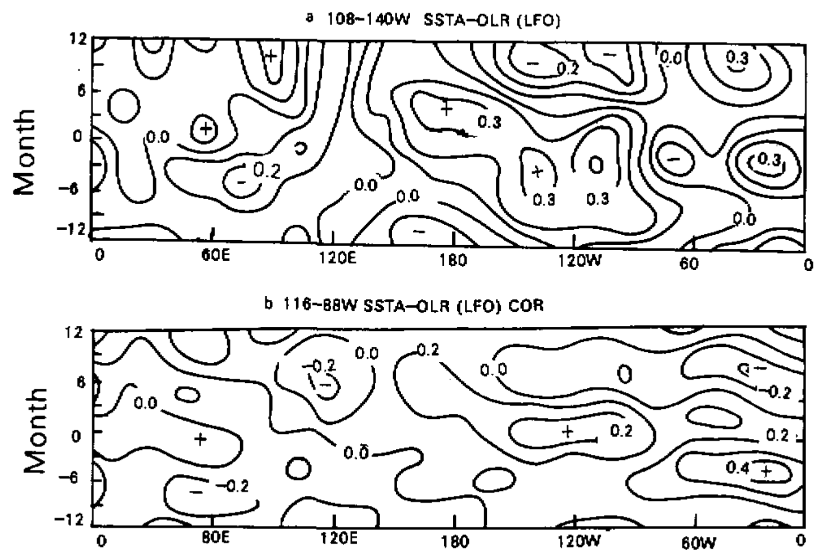

Fig.3. The time lagged correlation between the OLR's LFO and the SSTA in the equator. Negative values are dashed. a: the SSTA in 168°W–148°W; b: the SSTA in 116°W–88°W.

the strong convections continuously keep in the ECP and the center of the positive OLR anomaly keeps in the Bay of Bengal near 90°E. The EWP is the juncture of the two areas, and the positive and negative OLR anomalies can always take place there. The climatic influences of the two different El Nino events on East Asia, especially on China, are different.

4. In one or two months before the El Nino event finishes, the negative OLR anomaly areas first appear in the EWP. It needs to be further investigated that whether the warm SST has occurred there before the strong convections appear.

Figs.2a, b are the time–longitude cross–section of the OLR's LFO along the equator (0–10°S) in 1986 and 1987. The characteristics of the LFO in 1986–1987 and 1982–1983 are similar on the whole. During 1986–1987 El Nino event, there ofter is an oscillation center near the dateline and the center propagates westward (for example from June to October 1986). The result is similar to that in Chen and Shao's paper (1991). They found that the LFO of the equatorial and tropic upper wind propagated westward from 180°during 1982 El Nino event. Moreover, the LFO near the dateline in 1986–1987 seems to be stronger than in 1982–1983.

IV. THE CORRELATIONS BETWEEN THE SST AND THE OLR'S MLFO IN THE EQUATOR

In recent years, Chen, Yan and Wang (1989), Yan, Chen and Wang (1988), Shao and

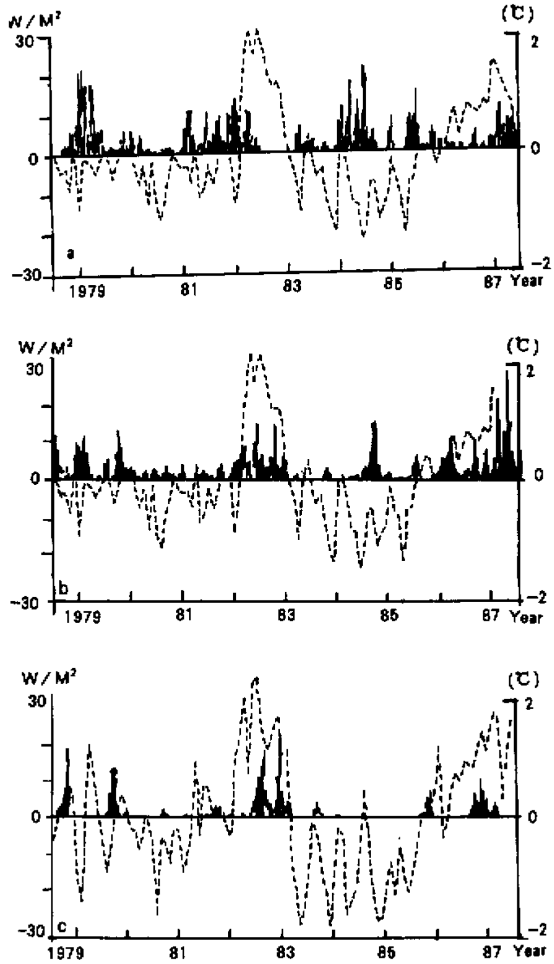

Fig.4. The temporal variations of the SSTA and the absolute value if the OLR's LFO in the equator, the dashed line is the SSTA, the solid line is the LFO's absolute value. a: the SSTA in 156°W–136°W, the LFO in 160°E–180°. b: the SSTA in 156°W–136°W, the LFO in 155°W–135°W. c: the SSTA in 120°W–104°W, the LFO in 120°W–105°W.

Chen (1991) have further studies the SST's interannual oscillations. Here we apply the SSTA data from 1979 to 1987, which they have treated, to study the correlations of the OLR's LFO to the SSTA and the SSTA's QBO and SO in the equator. Because the SST is monthly data, the LFO's intensity is measured by monthly average value of the absolute value of the OLR's

LFO (called MLFO for short). This MLFO represents the mean absolute amplitude value of the OLR's LFO in this month. We calculate the correlation coefficient of the SSTA to the MLFO in the equator. In the correlation analysis, the critical correlation coefficients which pass the test of the confidence levels of 0.05 and 0.01 are 0.189 and 0.246, respectively.

1. *The Correlations between the SSTA and the OLR's MLFO in the Equator*

We have made the 12 month lagged correlation analyses of the SSTA in 168°W–148°W ECP and in 116°W–88°W EEP to the equatorial OLR's MLFO (Figs.3a, b). The +12 in the coordinate represents that the SSTA lags for 12 months and the −12 in the coordinate represents that the SSTA advances for 12 months.

In the correlation distribution of the SSTA in the ECP to the equatorial OLR's MLFO (Fig.3a), near 160°E, the positive correlation coefficient is the biggest at 4–month, above 0.3; and it begins to become negative at −7–month; then the correlation center propagates eastward repidly, arrives in the Pacific in the area east of 140°W after about 7 months and makes the positive correlation coefficient become the biggest at −2–month near 140°W–100°W, above 0.3. This indicates that the LFO in the EWP becomes abnormal strong at the 4th month before the SST in the ECP becomes warm and the LFO in the ECP and EEP becomes abnormal strong at the 2nd month after the SST in the ECP becomes warm. We also find that the negative correlation center appears near 80°E at 0–month. This shows that the LFO in the equatorial Bay of Bengal weakens when the SST becomes warm in the ECP.

The correlation distribution of the SSTA in the EEP to the equatorial OLR's MLFO (Fig.3b) is similar on the whole to Fig.3a, but the correlation coefficient is more remarkable. To the east of 140°E, the positive correlation coefficient is the biggest from the 7–month to 2–month, above 0.2. This indicates that the LFO in the EWP is abnormally strong from the 7th to 2nd month before the SST in the EEP becomes warm. Near 100°W–140°W, the positive correlation coefficient is the biggest in 0–month, above 0.4. This means that the LFO in the EEP begins to strengthen at the same time when the SSt in the the EEP becomes warm. We also find that the area of the strongest correlation coefficient propagates eastward from the EWP. This indicates that the strenfthening LFO area in the EEP comes from the eastward propagating LFO in the EWP after the SST in the EEP becomes warm.

Comparing Fig.3a with Fig.3b, we find: The negative correlation center of the MLFO to the SSTA in the ECP is at 80°E, but the negative correlation center of the MLFO to the SSTA in the EEP is at 100°E; The negative correlation area expands to 140°E in the former case and expands to 160°E in the later case. This indicates that the weakening LFO area from the former to the later shifts to the South Asia from the East Asia.

Figs.4a, b, c are the temporal variations of the SSTA and the absolute value of the OLR's LFO in some equatorial areas. The dashed line is the SSTA, the solid line is the LFO's absolute value per day. We can find: The LFO in 160°E–180° advances the SSTA in 156°W–135°W, the LFO in 155°W–135°W is synchronous with the SSTA in 156°W–136°W on the whole and the LFO in 120°W–105°W lags the SSTA in 120°W–104°W. These results coincide with the above correlation analysis.

This indicates: it contributes to the SSTA in the ECP and EER becoming warm that the

LFO in the EWP strengthens and propagates eastward before the SSTA in the ECP and EEP becomes warm; and it further contributes to the LFO in the ECP and EEP strengthening that the SSTA in the ECP and EEP becomes warm. This coincides with the changes that the LFO in the equator and the SST in the ECP and EEP took place about the El Nino events in 1982–1983 and 1986–1987.

2. *The Correlations of the SSTA's QBO and SO to the OLR's MLFO in the Equator*

We have further made the 12 months lagged correlation analyses of the SSTA's QBO in 80°W–120°W (ECP) and in 140°E–160°E (EEP) to the equatorial OLR's MLFO (Figs.5a,b). The +12 in the coordinate represents that the SSTA's QBO lags for 12 months and the −12 in the coordinate represents that the SSTA's QBO advances for 12 months.

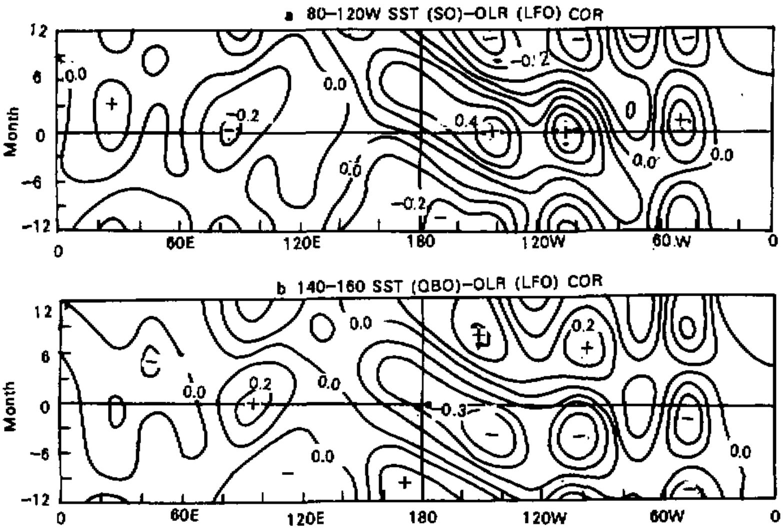

Fig.5. The time lagged correlation between the OLR's LFO and the SSTA's QBO in the equator. Negative values are dashed.a: the SSTA's QBO in 80°W–120°W; b: the SSTA's QBO in 140°E–160°E.

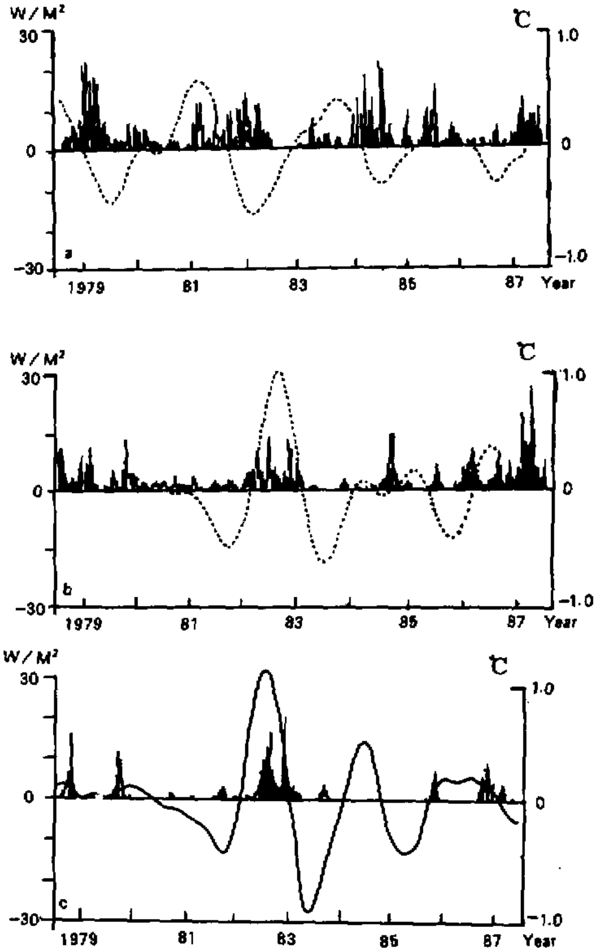

Fig.6. The temporal variations of the SSTA's QBO and the absolute value of the OLR's LFO in the equator. The dashed line is the SSTA's QBO, the solid line is the LFO's absolute value. a: the QBO and the LFO in (140°E–150°E, 10°N). b: the QBO and the LFO in 180°–160°W. c: the QBO in 120°W–104°W, the LFO in 120°W–105°W.

In the correlation distribution of the SSTA's QBO in the EEP to the equatorial OLR's MLFO (Figs.5a), near 160°E, the positive correlation coefficient is the biggest at 6–month, above 0.3; and it begins to become negative at −1–month; then the correlation center propagates eastward rapidly, arrives in the Pacific in the east of 140°W after about 7 months and

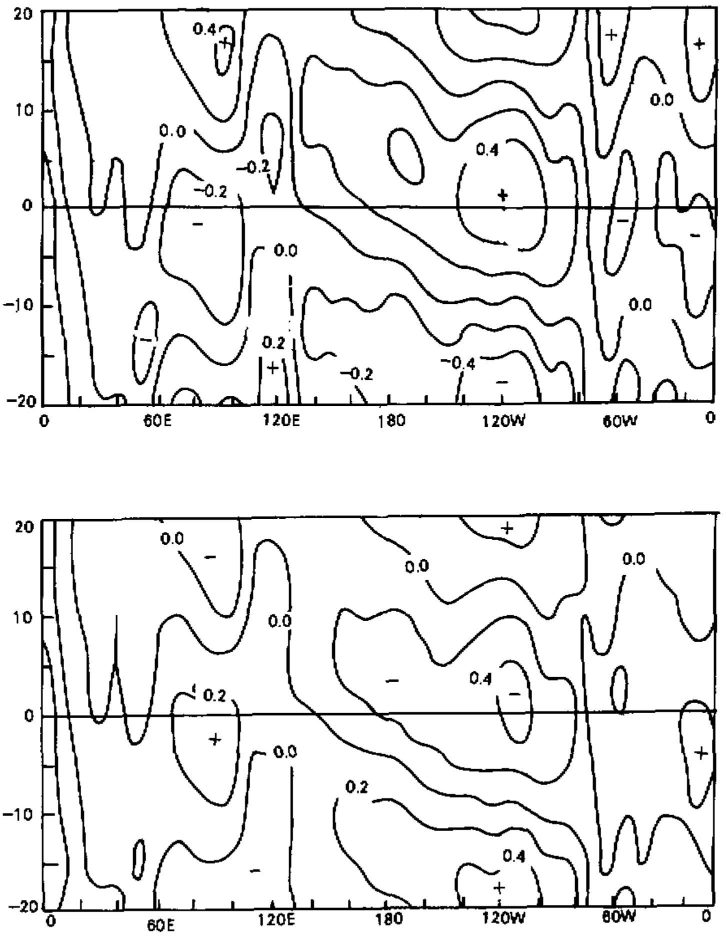

Fig.7. The time lagged correlation between the OLR's LFO and the SSTA's SO in the equator. Negative values are dashed. a: the SSTA's SO in 80°W–120°W; b: the SSTA's SO in 140°E–160°E.

makes the positive correlation coefficient become the biggest at −1–month near 140°W–100°W, above 0.3. This indicates: The LFO in the EWP becomes abnormally strong at the 6th month before the SSTA's QBO in the EEP becomes warm; the LFO in the EWP begins to weaken and the LFO in the ECP and EEP becomes abnormally strong at the 1st month after the SSTA's QBO in the EEP becomes warm.

The correlation distribution of the SSTA's QBO in the EWP to the equatorial OLR's MLFO (Fig.5b) is similar on the whole to Fig.5a. The difference is that the signs of the correlation coefficient in Fig.5b and Fig.5a are opposite. Near 160°E, the correlation coefficient is the negative biggest at 3–month, above −0.2, and begins to become positive at −4–month. Near 140°W–100°W, the correlation coefficient is the negative biggest at −4–month, above −0.3. This indicates: At the 3rd month before the SSTA's QBO in the EWP becomes cold, the LFO in the EWP becomes abnormally strong; at the 4st month after the SSTA's QBO in the EWP becomes cold; the LFO in the EEP becomes abnormally strong and the LFO in the EWP also begins to weaken.

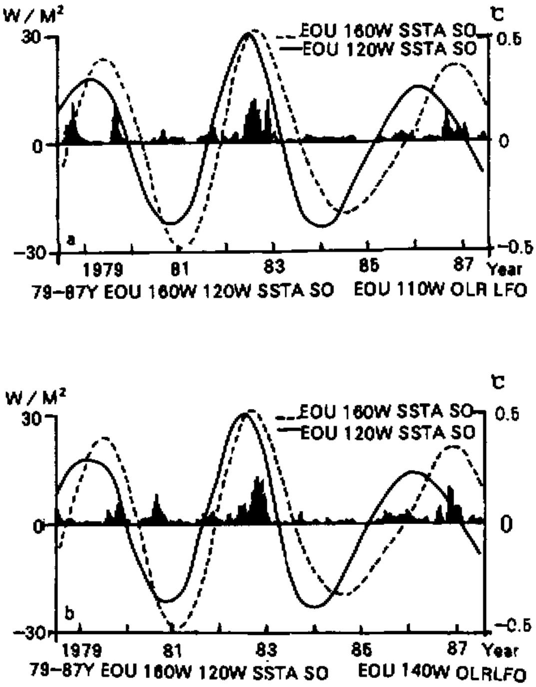

Fig.8. The temporal variations of the SSTA's SO and the absolute value of the OLR's LFO in the equator. The dashed line is the SO in 120°W, the solid line in the SO in 160°W. a: The thick dashed line is the LFO in 110°W. b: The thick dashed line is the LFO in 140°W.

From Fig.5, we can find: The signs of the correlation center in the equatorial Pacific and in the equatorial Indian Ocean are opposite; With the SSTA's QBO advancing and lagging, the correlation center changes in the opposite direction in the ECP and EEP; At about 12th month before or after the correlation center appeared, there exists a correlation center with the opposite sign. Therefore, there probably exists the QBO which propagates eastward in the LFO over the ECP and EEP.

Figs.6a, b, c are the curves of the SSTA's QBO and the absolute value of the OLR's LFO in some equatorial areas. The dashed line is the SSTA's QBO, the solid line is the LFO's absolute value per day. We can find: In (140°E–150°E, 10°N), the LFO advances the SSTA's QBO, but their phases are opposite; In 180°–160°W, the LFO is synchronous with the SSTA's QBO; In 120°W–105°W, the LFO lags the SSTA's QBO. Moreover, each of the LFO's curves demonstrates the characteristics of QBO. These results coincide with the above correlation analyses.

Figs.7a, b are respectively the time cross–sections of the lag correlation analyses of the SSTA's SO in 80°W–120°W (ECP) and in 140°E–160°E (EEP) to the equatorial OLR's MLFO. The +20 in the coordinate represents that the SSTA's QBO lags for 20 months and the −20 in the coordinate represents that the SSTA's QBO advances for 20 months. We can find: It is very similar to Figs.5a, b. The difference is that the correlation center in the ECP and EEP demonstrates the characteristics of the eastward propagating SO. This means that there probably exists the eastward propagating SO in the LFO in the ECP and EEP.

Figs.8a, b are the curves of the SSTA's SO and the absolute value of the OLR's LFO in two areas EEP. The solid line is the SSTA's SO in 120°W and dashed line is the SSTA'sSO in 160°W, the thick dashed line is the LFO's absolute value per day. The SSTA'sSO in 160°W is synchronous with the LFO in 110°W and 140°W, the SSTA's SO in 120°W advances the LFO in 110°W and 140°W. Moreover, each of the LFO's curves demonstrates the characteristics of SO.

Therefore, the correlatios of the SSTA's QBO and SO to the MLFO in the equtor are remarkable, especially in the EEP. The correlation centers propagate eastward from the EWP. The signs of the correlation center in the Pacific are opposite to those in the Indian Ocean and there exists a seesaw structure between these two correlation centers. In the ECP and EEP, the correlation centers show the characteristics of eastward propagating QBO and SO.

The above analyses indicate: It contributes to the SST and the SSTA's QBO and SO in the ECP and EEP becoming warm that the LFO strengthens and propagates eastward before the SST and the SSTA's QBO and SO in the ECP and EEP become warm; And it contributes to the LFO in the ECP and EEP enhancing and the LFO in the EWP weakening and propagating eastward that the SST and the SSTA's QBO and SO in the ECP and EEP become warm. These coincide with the changes of the LFO in the equator, the SST in the ECP and EEP and the SSTA's QBO and SO in the ECP and EEP during the El Nino events in 1982–1983 and 1986–1987.

V. CONCLUSIONS

At present, the interactions among different time scale oscillations in sea–air system are an important issue in the mchanisms which the low frequency oscillation and the lower frequency oscillations form. In this paper, we make a try at this issue. The continuous OLR data are only for 10 years and the results we obtained can only give a probability to it, but the results are exciting. The following results are obtained:

(1) In the EEP and EWP or in the equatorial Indian Ocean,the correlations of the SSTA's interannual oscillations to the OLR's LFO are remarkable. It shows that the LFO and the interannual oscillations interact each other and the powerful LFO occurs in the warm phase of the SSTA's interannual oscillations.

(2) Before SSTA in the ECP and EEP is in the warm phase, the LFO in the equatorial Pacific has an abnormally powerful phase. Soon afterward, this kind of powerful LFO center propagates eastward and becomes the powerful LFO in the warm phase of the SSTA's interannual oscillations in the ECP and EEP. With the center of the strong LFO propagating eastward, the LFO in the EWP and equatorial Indian Ocean begins to weaken. The changes of the LFO in strength in the ECP and EEP form a seesaw structure with those in the EWP and the Bay of Bengal.

(3) The locations where the warm centers of the SSTA's interannual oscillations in the warm phase arise contact closely with the locations where the LFO's correlative centers from the western Pacific to the Bay of Bengal arise. When the warm SST center arises in the EEP, the negative correlative center (meaning the weak LFO) appears in the East Asia equator; When the warm SST center arises in the ECP, the LFO's negative correlative center appears in the equator of the Bay of Bengal. In the former case, the cold sea water center,weak convection area and weak LFO area keep in the East Asia equator. In the later case, a transition area keeps in the East Asia equator. As a result, in the two cases, the influences on the East Asia climate are very different. We must classify the two kinds of interannual oscillations.

(4) The results that we obtained by analyzing the two El Nino events in 1982–1983 and 1986–1987 coincide with the above–mentioned results.

According to the above–mentioned results, when the SSTA or SSTA's interannual oscillations are in the warm phase and the poweerful convection arises in OLR, the powerful LFO appears. It coincides with that the instantaneous powerful convection appears in the LFO's powerful convective phase and the powerful LFO appears in the powerful convective phases of the seasonal LFO appears in the powerful convective phases of the seasonal cycle and the interannual oscillations. This shows that the energy of the various time scale oscillations in the tropics mainly comes from the convective condensation heat. Furthermore, the short time scale oscillations depend upon the energy supply that the long time scale oscillations release in the convective phase, but the convective phases of the long time scale oscillations are often stimulated to appear by the surrounding strong LFO (For example, the unusual powerful LFO in the western Pacific can stimulate the El Nino event to happen). For this reason, the different time scale oscillations interact each other. It means that the long time scale oscillations are stimulated to form by the short time scale oscillations and then influence the latter.

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