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THE CHARACTERISTICS OF LOW-FREQUENCY OSCILLATIONS OVER THE SOUTH CHINA SEA[1]

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ABSTRACT

Using 1975-1993 (with 1978 missing) data of the outgoing longwave radiation (OLR), characteristics of seasonal variation of low-frequency oscillations in the South China Sea and its relation to the establishment and activity of the summer monsoon there are studied. As is shown in the result, the low-frequency oscillation in the South China Sea is much stronger in the period of summer monsoon than in that of winter monsoon and the summer monsoon there usually begins to set up in a negative phase of the first significant low-frequency oscillation for the early summer. The study also reveals that the circulation for the low-frequency oscillation during the summer monsoon in the Sea is embodied as north-south fluctuations of the ITCZ and east-west shifts of western ridge point of the West Pacific subtropical high, suggesting close correlation between the low-frequency oscillation and the active and break (decay) of the South China Sea monsoon. In the meantime, the work illustrates how the low-frequency oscillation in the South China Sea are superimposed with the seasonal variation of the general circulation, so that the summer monsoon covers the establishment of the 1st, intensification of the 2nd and 3rd the low-frequency oscillations and decay of the 4th oscillation.

Key words: South China Sea, summer monsoon, low-frequency oscillation

I. INTRODUCTION

It has been confirmed in quite a number of observations that there is 30-60 day (low-frequency, in this work) oscillation in the tropical atmosphere (Li, 1993). It is directly related with large-scale anomalies of weather and climate. Its importance lies in the significant interactions with variations on time scale other than it in addition to the oscillation itself (Chen, Zhu and Luo et al. 1991). It is, therefore, helpful for more understanding of variation mechanisms of the general circulation and improving the medium and long-term forecasts by studying the low-frequency oscillation. Much more knowledge was acquired in the 1980's for the activity of Asian summer monsoon, being manifested by the research on the 30-60 day oscillation of the monsoon (Li, 1993). Based on analyses of the MONEX data, Krishnamurti (1993) isolates 30-60 day oscillation in the South Asian trough and ridge during the gradual northward movement and argues that low-frequency waves are present in the summer monsoon in the region. In the aspect of low-frequency oscillation in the East Asian summer monsoon, Chinese researchers are among those who first indicated its existence by what they called medium term or 5-7 week quasi-periodic oscillation (Zhang and Wang, 1976; Chen and Ke, 1981). Its presence is also confirmed by Chen and Jin (1982) and Jin and Chen (1982) in addition to a study of its origin and propagation features with significant findings. It should be noted that the above-stated work is all based on observations of 1 or 2 years long. The limitation in the knowledge and data is made worse by the fact that there is no clear-cut definition of monsoon between the tropics and subtropics in the

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[1] The work is one of the research projects for the criteria of outbreak of South China Sea summer monsoon.

research of summer monsoon over East Asia. Two different monsoon regimes are active in the East Asian monsoon region, one being the South China Sea–West Pacific Tropical Monsoon, the other East Asia Continent–Japan Subtropical Monsoon (Zhu and He, 1985). As shown in a study using 8-year OLR data for northern Australia and region of the Bay of Bengal, the summer monsoon is set up by the low-frequency oscillation when the condition is right, or, the specific date of establishment is dependent on the phase of the latter (Chen, Xie and Murakami, 1986). Then, what is the relationship between the establishment and activity of the South China Sea summer monsoon and the low-frequency oscillations? It is an issue that is going to be discussed in this work using the 18-year OLR data.

II. TREATMENT OF DATA AND DEFINITION

The data used in the work is a 18-year long daily OLR data set that covers the period from January 1975 to December 1993 (with year 1978 missing). Pentad-averaging is done before the computation for a domain of 40°S–40°N, 40°E–160°E, with a resolution of 2.5 longitudes × 2.5 latitudes. The region of the South China Sea is defined to be within the boundary of 10°N–20°N and 110°E–120°E. Without a standard index for monsoon at present, the period when the regional mean value of OLR is less than 240 W/m^2 is defined to be one with summer monsoon, for the summer monsoon is always with convection in the tropics. Following the definition and examining the 18-year mean chart of OLR in the longitude-time section, one finds that the summer monsoon is established in the 4th pentad of May over the South China Sea (110–120°E) but on a much later date (approximately in the 1st pentad of June) over India (80°E). It is consistent with results obtained with other techniques (Tao, Zhu and Zhao, 1988; Shen, Tao and Lai et al., 1982).

III. SEASONAL VARIATION OF LOW-FREQUENCY OSCILLATION IN SOUTH China SEA

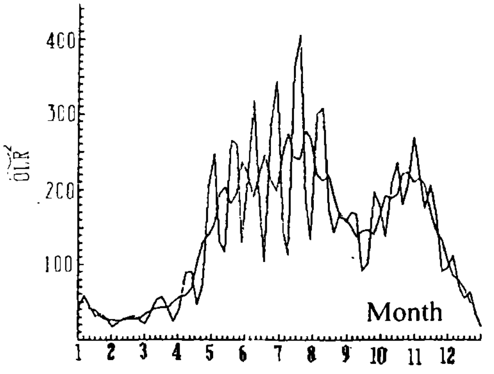

Fig.1. The variability of low-frequency oscillation and its running average over a period of 18 years in unit of W^2.

To express the intensity of low-frequency oscillation, the OLR data are first through band-pass filter of 6–12 pentads for low-frequency components$(\widetilde{OLR}$. Its square $(\widetilde{OLR})$is then derived to indicate the intensity of the low-frequency oscillation. Studying the region of the South China Sea on a yearly basis, the low-frequency oscillation is usually found to be stronger in the summer monsoon than in the winter monsoon, though that in the winter of 1976 and 1986 and the spring of 1988 being among the strongest of all. Fig.1 is the curve of mean intensity of low-frequency oscillation and 5-pentad running mean over the 18 years. It shows that the low-frequency oscillation begins to increase at the end of April and starts to decrease in the beginning of November, acquiring the strongest in July.

In an earlier work of the author, the OLR data is used to study the relationship between the low-valued OLR regions in the low latitudes of the East Hemisphere (ITCZ) and high-valued variance regions of low frequency (strong regions of low-frequency oscillation). The result reveals high consistence in terms of their seasonal transition. With the change in seasons, the strong low-frequency regions are moving north (south) in phase with ITCZ at a more advanced location than the latter. It suggests that the usually strong low-frequency oscillation during the summer monsoon over the South China Sea is virtually a reflection of the oscillatory characteristics of tropical systems.

On the other hand, low-frequency oscillation remains inactive during the period of winter monsoon in the South China Sea. Is it contradictory to Li's concluding remarks (1993) that the winter monsoon in East Asia is marked by significant 30-60 day oscillation? The answer is negative. As the low-frequency oscillation in mid and high latitudes of the Eurasian continent propagates southeastwards along the EUP wave train of low frequency towards the equatorial central Pacific, its periodicity or transfer will not be obvious if the profile taken is off the direction of EUP or PAN wave train. It is naturally expected that the low-frequency oscillation for the winter monsoon act weakly in the South China Sea, which is not on the wave trains mentioned above.

IV. ESTABLISHMENT OF SOUTH CHINA SEA SUMMER MONSOON AND RELATIONSHIP TO LOW-FREQUENCY OSCILLATION

Fig.2 plots the temporal evolutions of OLR values after subtraction of 240 averaged over 18 years for the region of the South China Sea. The evolutionary tendency is basically the reversed with that shown in Fig.1. The point at which the low-frequency oscillation sharply increases (6th pentad of April) is shown to appear earlier than that at which the OLR value drastically drops (4th pentad of May). In other words, the intensification of low-frequency oscillation is about four pentads earlier than the outbreak of the summer monsoon, or about half a period of oscillation. It should be noted that the former is also later than the occurrence of convection (about the 3rd pentad of April) in the Indochina Peninsula (around 105°E).

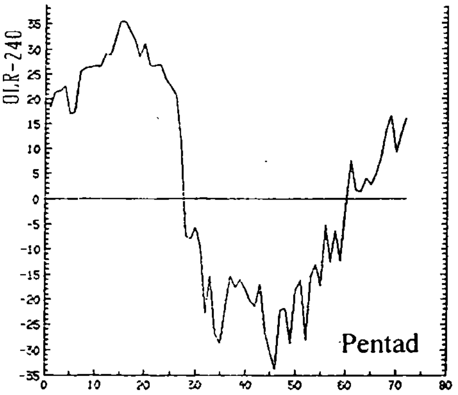

Fig.2. The intraseasonal variability of (OLR-240) value averaged over 18 years.

The climatological mean is shown above for the 18 years and the year-to-year details are listed in Table 1. It shows that there is certain degree of interannual variation among the date of establishment of summer monsoon and of intensification of low-frequency oscillation over the South China Sea and the occurring time of convection in the Indochina Pen. The relationship is fixed in that the convection first appears over the peninsula, then the low-frequency oscillation begins to grow and then the summer monsoon is established. Comparing the yearly OLR curves and low-frequency filter curve (Figure omitted), one finds that the negative phase of the first strong low-frequency oscillation in early summer is usually the period when the summer monsoon breaks out in the South China Sea. Being consistent with the work of Murakami et al., the finding is sufficient enough in stating that the activity of low-frequency waves acts as a significant trigger for the outbreak of the South China Sea summer monsoon.

Being possibly associated with the cross-equatorial current at 105°E, convection first occurs over the Indochina Pen., from which convection-associated low-frequency oscillation transfers east to the South China Sea (as shown clearly in Fig.1a of Chen et al., 1982). The intensification of low-frequency oscillation and outbreak of summer monsoon are in different phases (the first strong low-frequency oscillation starts to intensify in the positive phase in the early summer in the Sea while the summer monsoon there appears in its negative phase). On the average, they are active by a difference of about 4 weeks (approximately half a cycle). Further study remains to be done as regard to why the low-frequency oscillation is with the positive phase, though it is estimated to link with the horizontal propagation features such as the direction, wavelength, and phase, etc.

Table 1. The time of generation of convection over Indochina Pen., strengthening of intraseasonal oscillation and establishment of summer monsoon over the South China Sea.

Yr	Convection in Indochina	Low-freq. Oscillation strengthened.	Monsoon. established.	Yr	Indochina Convection	Low-freq. oscillation strengthened	Monsoon established
1975	4th pen. Apr.	3rd pen. May	6th pen. May	1986	4th pen. Apr.	6th pen. Apr.	4th pen. May
1976	5th pen Apr	5th pen. Apr.	5th pen. May	1987	5th pen. Apr.	3rd pen. May	1st pen. Jun.
1977	2nd pen. May	6th pen. May	3rd pen. Jun.	1988	2nd pen. Apr.	5th pen. Apr.	5th pen. May
1979	4th pen Apr	5th pen. Apr.	3rd pen. May	1989	4th pen. Apr.	6th pen. Apr.	4th pen. May
1980	2nd pen Apr	4th pen. Apr.	4th pen. May	1990	4th pen. Apr.	5th pen. Apr.	3rd pen. May
1981	2nd pen Apr	2nd pen. Apr.	2nd pen. May	1991	5th pen. Apr.	2nd pen. May	6th pen. May
1982	6th pen. Mar	2nd pen. Apr.	1st pen. Jun.	1992	6th pen. Apr.	5th pen. May	6th pen. May
1983	3rd pen Apr.	4th pen. Apr.	4th pen. May	1993	2nd pen. Apr.	5th pen. Apr.	4th pen. May
1984	6th pen. Mar.	6th pen. Mar.	6th pen. Apr.	M.	3rd pen. Apr.	6th pen. Apr.	4th pen. May
1985	3rd pen Apr	2nd pen. May	6th pen. May	—	—	—	—

V. LOW-FREQUENCY OSCILLATION OF SOUTH CHINA SEA AND MONSOON

As indicated in the preceding sections, the low-frequency oscillation is active during the summer monsoon in the South China Sea, which leads to necessity of investigating the relationship between the low-frequency oscillation and summer monsoon. For this purpose, the OLR filter curve is based to select 4 consecutive waves beginning from the point of intensification in annual low-frequency oscillation. Four phase points are selected for each wave (Phase A corresponds to the shift point from low value to high value, Phase B to that of the highest value, Phase C to that from high value to low value and Phase D to that of lowest value). A composite field of OLR distribution is consecutively and separately made for each of the phases in every wave so as to avoid mixture of both seasonal and low frequency variations that would have been resulted if all of the waves were indiscriminately composed.

Fig.3 is the composite chart of all phase points of the low-frequency oscillation. In Phase A (Fig.3a) and Phase B (Fig.3b), the South China Sea – West Pacific are dominated by the subtropical high and the Indochina Pen. is controlled by an area of convection. By Phase C (Fig.3c), the high has moved out of the South China Sea, turning it into an area of weak convection with the OLR value ranging from 240 to 250. In Phase D (Fig.3d), the ITCZ moves northward into the South China Sea–Bay of Bengal and a center of deep convection appear over the Philippines. It is one of the strongest monsoon phases in the first low-frequency cycle in early summer. It is at Phases C or D or somewhere between Phases C and D that the summer monsoon sets in every year in the South China Sea. A weak area of weak convection is shown on the composite chart of the South China Sea because the summer monsoon has already set up in some years and the subtropical high remains active in others as far as Phase C is concerned. The summer monsoon has solidly established and grown strongly by Phase D in most o f the years except in 1981 and 1982, which witness establishment after Phase D.

The composite distribution of Phases B and D are described for the 2nd to 4th low-frequency oscillation without giving any details of each phase due to limitation of text. At Phase B of the 2nd oscillation, the ITCZ is located more southward and the monsoon weakens in the South China Sea (OLR value increases to 240 and more); at Phase D, the monsoon becomes active again and is stronger than at Phase D (with a lower OLR value). At Phase B of the 3rd oscillation, the West Pacific subtropical high is split into more than a cell, giving rise to the appearance of a separated South China Sea high (with OLR value larger than 250 there). The ITCZ moves more southward in regions east of 110°E and the monsoon comes to a break in the Sea; at Phase D, however, the high disappears from the South China Sea and the ridge of the subtropical high has a significant northward movement in the West Pacific with more vigorous monsoon in the Sea. The convection spreads (with the northernmost contour of 220 locating more northward) as compared to the cycle of the 2nd low-frequency oscillation. The lowest axis of OLR (or the ITCZ) is also more to the north. At Phase B of the 4th oscillation, the subtropical high ridge shifts to the south in the West Pacific and the monsoon weakens in the South China Sea (with the OLR value being about 240). By Phase D, the monsoon grows again in the Sea, but with weaker intensity than that in the 2nd and 3rd cycles of oscillation. The center of convection also disappears in the Philippines and the subtropical high keeps moving southward in the West Pacific.

It is then drawn that in the South China Sea the low-frequency oscillation is closely related to the establishment, prevalence and break (decay) of the monsoon, and its primary circulation body is shown as the north-south fluctuation of ITCZ and east-west oscillation of the western ridge point of the West Pacific subtropical high. Additionally, such low-frequency oscillation is actually one that superimposes on the seasonal variation of general circulation, including north-

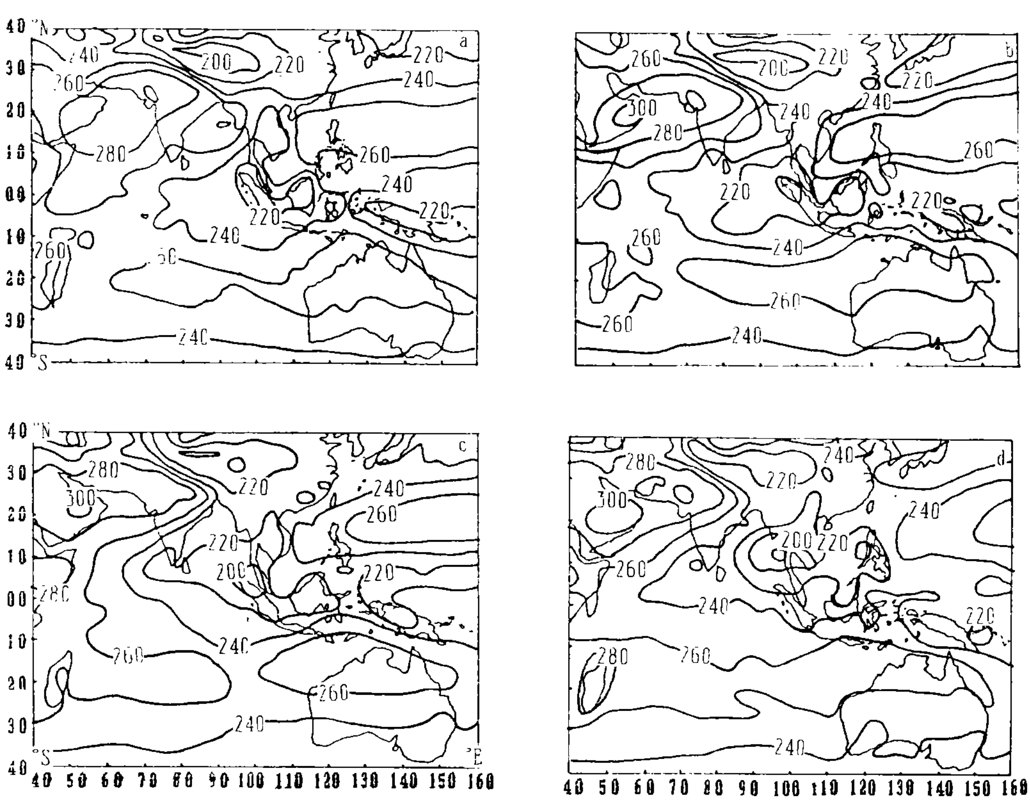

Fig.3. The composite diagram of phase points for the first intraseasonal oscillation in unit of W/m^2.

south shifts and intensity change in ITCZ and the West Pacific subtropical high. Seasonal variations are found in the period of prevalence, break (or decay). For the intensity of convection center, the 2nd monsoon prevalence period is the strongest (with central OLR value being 169). For the whole region of the South China Sea, however, the 3rd period is the strongest with the ridge line of the subtropical high locating the northernmost. It is at Phase B within this cycle of the oscillation that the high appears and the monsoon breaks over the South China Sea while the OLR values are all less than 250 for the Phase B in both the 2nd and 4th oscillatory cycles, i.e. the monsoon weakens rather than break completely. It is suggested that the monsoon is in its most intense period in the 3rd cycle of oscillation (with large variability, in other words). When the monsoon reappears in strong intensity in the 4th cycle of oscillation, the intensity is much weaker than in the previous two cycles, in which the center of deep convection also disappears in the Philippines.

It is concluded from the composite chart of all phases for all of the 4 waves that the medium term activity of the South China Sea monsoon is active in phases that are different from that of the Indian monsoon, being consistent with results by other researchers (Chen et al., 1991).

VI. CONCLUSIONS

a. The low-frequency oscillation in the South China Sea is stronger in the summer monsoon than in the winter monsoon. The former intensifies at a late or simultaneous time as compared to the convection over the Indochina Pen., but at an early time relative to the establishment of the monsoon in the South China Sea. The order of occurrence remains unchanged from year to year, and the mechanism of which is to be studied further.

b. The South China Sea summer monsoon begins to set up at the negative phase of the first strong low-frequency oscillation in early summer.

c. For the low-frequency oscillation in the South China Sea monsoon, the circulation body is the north-south fluctuations of ITCZ and east-west shifts of the western ridge point of West Pacific subtropical high. The low-frequency oscillation is closely associated with the prevailing and break (decay) periods of monsoon in the Sea.

d. The establishment of the 1st, intensification of the 2nd and 3rd , and decay of the 4th , low-frequency oscillation, are covered by the summer monsoon period, because the oscillation is superimposed by the seasonal variation of the general circulation.

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