ADVANCES IN APPLIED RESEARCH OF THE OUTGOING LONGWAVE RADIATION IN CHINA

Jiang Shangcheng (蒋尚城)

Department of Geophysics, Peking University, Beijing 100871

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ABSTRACT

The outgoing longwave radiation (OLR) observed by NOAA satellite series has widely applied in various research fields since the 1980s in China. In this paper, advances of the applied research of OLR are described in the following respects:

(1) Studies of the global ITCZ;

(2) Climatology of the subtropical high over northern Pacific;

(3) Studies of the tropical cyclone over West Pacific;

(4) Characteristics of the intraseasonal variation (ISV) of tropical convective activities;

(5) Divergence wind and large scale circulation over the tropics;

(6) Studies of the air-sea interaction;

(7) Estimation of precipitation over the Tibetan Plateau and the Yangtze River (Changjiang River) basin during the rainy season;

(8) Analyses of regional climates of China;

(9) Studies of prediction of the severe and disastrous weather and climate;

(10) Atlas of OLR.

The distinctive features of these advances are reviewed and the focal points of the OLR applied research in future are also suggested.

Key words: outgoing longwave radiation (OLR), intertropical convergence zone (ITCZ), subtropical high, precipitation, regional climate

I. INTRODUCTION

The OLR is abbreviated from the outgoing longwave radiation of the earth-atmosphere system observed by weather satellites. It implies much information about the cloudiness, rainfall, convection intensity, condensation latent heat, divergence wind, large-scale vertical circulation and air-sea interaction etc. The satellite observation has advantages of the whole globe, well homogeneous distribution, continuity and high resolution. Therefore the OLR has been widely applied to the research of general atmospheric circulation, air-sea interaction, climate change and the medium- and long-range forecast etc. (Jiang and Zhu, 1990). Like the 500 hPa geopotential height and sea surface temperature (SST), the OLR mean and anomalous map has been applied to the operational analysis and presented in Climate System Monitoring Monthly Bulletin issued by WMO and Climate Diagnostics Bulletin printed by Climate Analysis Center in U.S.

The research of the OLR application in the world began at the initial stage of the weather satellite (late 1960s). In China it started lately (Jiang, 1987) but was developed and applied widely. The remarkable advances have been gotten in recent years. In this paper, the principal study results on it will be reviewed in the following ten aspects.

II. STUDIES OF THE GLOBAL INTERTROPICAL CONVERGENCE ZONE (ITCZ)

Based on the OLR data, the climatic characteristics of the ITCZ all over the globe and different regions in tropics (the eastern, central and western Pacific; the eastern, western Indian Ocean and the Atlantic; the Africa and southern America continents) are analyzed. It is revealed that there are prominent latitudinal seasonal oscillations of the mean longitudinal position of the double ITCZ in the Pacific (Fig.1a). It is caused by the southern Pacific convergence zone (SPCZ) existing in WP (West Pacific) all the year round, which has an outstanding seasonal variation both in intensity and location. In summer (refer to the Northern Hemisphere, but winter for Southern Hemisphere), it is the weakest and its eastern edge reaches the westernmost position. From summer to winter it intensifies and extends gradully toward the east and reaches its easternmost position (150°W) and from winter to summer it weakens and shifts westly. Corresponding to that the northern ITCZ exists in central and eastern Pacific throughout the year, from winter to summer it intensifies and shifts westward and formes the longest latitudinal ITCZ over the globe. On the contrary from summer to winter, the northern ITCZ disappears over WP and the SPCZ extends to the farthest east. In consequence, the position of the double ITCZ oscillates latitudinally with the seasonal variation. Obviously it is caused by the seasonal latitudinal supersession of the old ITCZ by the new one over both sides of equator. Based on the analysis of the SST in the same periods, it is found that this is closely related to the seasonal latitudinal oscillation of the warm pool in WP. Figure 1b shows the climatic monthly variation of the characteristic isotherm (SST = 28℃) of the warm pool over the southern Pacific. Its seasonal latitudinal movement is well consistent with the oscillation of the double ITCZ. It indicates that there is good relationship between them. By means of the OLR data, we have gained an up-to-date and more complete understanding of the climatic characteristics of the ITCZ over the whole globe (Jiang, 1987; 1988; Ma and Hu, 1991).

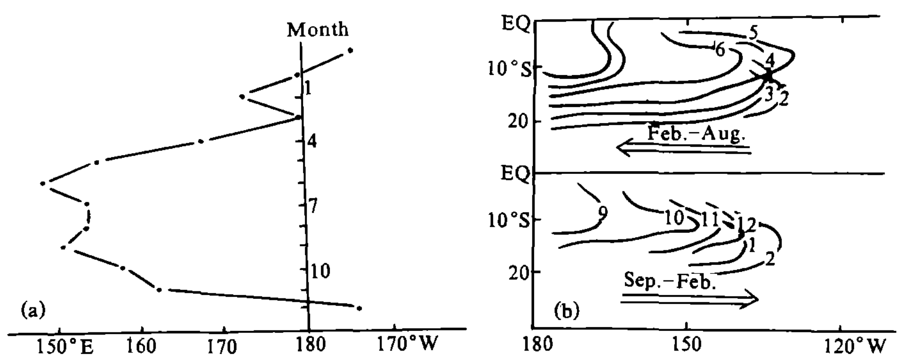


Fig. 1. The latitudinal oscillation of the double ITCZ and the warm pool in the Pacific. (a) The monthly variation of the mean longitude position of the double ITCZ in the Pacific; (b) The monthly variation of the characteristic contour of SST (= 28℃) in the southern Pacific.

III. CLIMATOLOGY OF THE SUBTROPICAL HIGH (SH) OVER NORTHERN PACIFIC

With ten years OLR data, the climatic characteristics of the longitudinal shift of the SH over WP and its relation to the ITCZ in the summer half year were analyzed (Jiang and Dai, 1990). Figure 2 shows that there are two abrupt northward shifts of SH in WP during the summer half year, which coincide with the starting dates of Meiyu (plum rain) in the Yangtze River basin and the rainy season in North China. The seasonal northward displacement of SH over WP is closely related to the northward shift and the intensifying of convective activities of the ITCZ to the south. It is first confirmed by satellite observation that the seasonal abrupt northward shift of the SH in WP during the summer season is closely related to the variation of the Hadley cell. Therefore, it is suggested that the researches on droughts and floods in China and the anomalies of the SH in WP should be focused on the study of the anomalies of tropical convection activities which is easier to observe and monitor by satellites.

The climatic characteristics of the SH over the northern Pacific (NP) revealed by OLR show that there is striking latitudinal oscillation of the SH over WP both in position and intensity (Jiang and Zhang, 1993a). The central position of the SH over NP is over the eastern Pacific in summer and the western Pacific in winter. The direction of the seasonal movement is similar to that of the SH in the Atlantic (Verneka, 1981) and contrary to that of the double ITCZ over the Pacific. The latitudinal oscillation of the intensity forms a dipole —— strong in the west and weak in the east in winter and vice versa in summer. It is resulted from the seasonal variation of the longitudinal and latitudinal circulation which affects the SH over the Pacific. In addition, the OLR data can well revealed the characteristics of main part of the SH over the Pacific but poor for the western edge of SH. This implies that there is different structure between the main part and the western edge of the SH over the NP. It is often rainy and cloudy (upward motion) in the western edge of the SH and stable (downward motion) in the main part. Therefore the OLR field can not well represent the height field over the western edge of the SH in WP , so we must be very carefull in analyses.

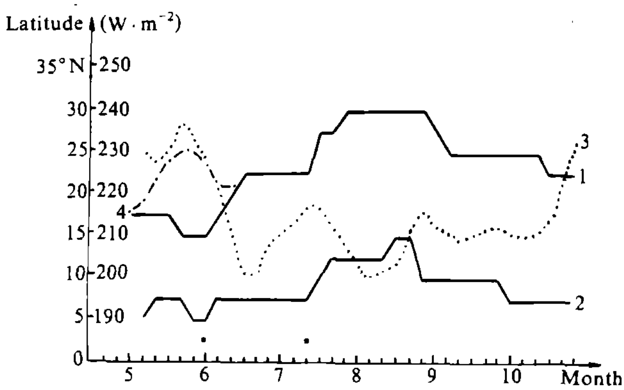


Fig. 2. The variations of the 10-year mean (1975—1985, except 1978) position of the ridge line of the SH over WP (the axis of the maximum OLR, line 1) and the position of ITCZ (the axis of the minimum OLR, line 2) and the intensity of the ITCZ (line 3 for the northern ITCZ, line 4 for the southern ITCZ).

IV. STUDIES OF THE TROPICAL CYCLONE OVER WP

The analyses of the OLR data indicate that there is close relationship between the low-frequency oscillation (LFO) of OLR and the activities of tropical cyclones over WP (Xie and Ye, 1987). Based on the analysis of the 30—60 day filtered components of OLR and activities of tropical cyclones over WP in 1979, it is found that the LFO (with a period of 40—50 days, or called low-frequency disturbance) occurred three times during Junuary—September, 1979. During this period all the tropical cyclones emerged in the active phase (negative anomalies) of the LFO of OLR and the stronger the LFO, the more frequently the tropical cyclones occurred. It means that the active phase of the LFO of OLR corresponds to the forming stage of the tropical cyclone group. This enables us to predict the appearing periods of the tropical cyclone group over WP according to the period, phase and amplitude (intensity) of the LFO of OLR over the associated area. In addition, It is found that for the different stages of tropical cyclone evolution there are remarkable prediction features of the OLR pattern over the SE part of the tropical cyclone center which is closely related to the cross-equatorial flow (Xiao, 1990). The axis of the low OLR is a good indicator of the displacement of the tropical cyclones in the future 6 hours (Jiang and Chen, 1992). These provide a new approach to the forecasting of the formation, development and movement of the tropical cyclones.

V. CHARACTERISTICS OF THE INTRASEASONAL VARIATION (ISV) OF TROPICAL CONVECTIVE ACTIVITIES

The considerable research on the ISV or 40—60 day oscillation has been conducted with OLR data in the world. The resent research in China is concentrated on the WP and Tibetan Plateau. It is found that the oscillation exhibits the maximum strength near the northern Philippines (15°N) in summer. It propagates eastward along the equator and then turns northwestward between 15—30°N (Dai and Jiang, 1990). In the East Asia (120°E), it propagates northward from the tropics and southward from the high latitudes then converges at the subtropics and sometimes it can move across the subtropics to the high latitudes or to low latitudes (Chen and Xie, 1988). It is revealed that there is a wave train with positive and negative centers from the equator via Philippines to the Yangtze River basin. It is suggested that the droughts and floods in the Yangtze River basin are closely related to the ISV of the tropical convective activities over WP (Jiang, 1992).

In Tibetan Plateau, The LFO does exist in summer but not as significant as over WP and Indian Ocean. The features of the propagation are that some move latitudinaly across the plateau and some shift northward from the equatorial Indian Ocean. This differs from the results based on the traditional weather observation data, i.e. the LFO does exist in the Tibetan Plateau but the plateau is not the source and sink region (Xie et al., 1989).

The characteristics of the LFO in spring over WP were first studied by Shi and Zhu (1991). The results show that the characteristics of the LFO in spring and in summer are different both in source and in the propagation direction, which possess the features of the transition season from winter monsoon to summer monsoon. The bandpass-filtered analysis of 30-day OLR was carried out in special periods (May—March 1975—1983) and regions (80—105°E, 5°N—10°S, the location of the west oscillation center of OLR and the corresponding ITCZ center). The filtered curve of the LFO of OLR is divided into four stages: A. low; B. transitionion from low to high; C. high and D. transition from high to low. Figure 3 shows the mean OLR and ITCZ in above stages. It can be seen that there are pronounced variations both in the intensity and the location of the longitude of the west edge of the ITCZ with phase change of the LFO. Generally, the ITCZ extends to the westernmost position (55°E) and the convection is the strongest at the low stage (A), and it moves eastward to 85°E and the convection decreases at the transition stage from low to high (B). At the high stage (C) the ITCZ is the weakest and shifts to the easternmost location (90°E), and at the transition stage from high to low (D) it extends westward again to 75°E and its intensity increases. It is interesting that the low and high stages of the LFO of the tropical OLR are coincident with the continuous overcast and rainy weather and sustained fine weather in spring over the Yangtze River basin. This result can expand our thoughts in forecasting and enable us to put the prediction of the continuous overcast and rainy weather in spring season in the Yangtze River basin under the wider temporal and spacial background.

VI. DIVERGENCE WIND AND LARGE SCALE CIRCULATION OVER THE TROPICS

The proportion of the divergence wind in the total stream field in the tropics is larger than in the extratropics due to the ageostrophic motion resulted from the active convection motion. In tropics the radiowind observation both in quality and quantity can not satisfy the demands of the divergence wind measurement. For this reason, it greatly affects the precision of the initial fields of numerical forecasting and the further study of tropical circulation. OLR can reflects indirectly the divergence field of the atmosphere because it can well represent the convective intensity over the tropics. Julian (1984) and Krishnamurti et al. (1986) have made respectively experiments on the calculation of the divergence wind with the OLR data and put forward the associated schemes. Based on their schemes, we made experiments on the divergence wind in

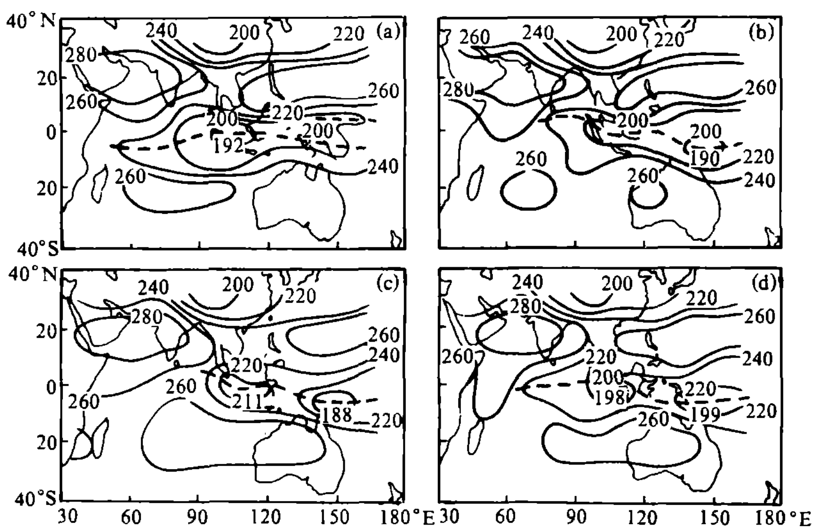


Fig. 3. The features of the ITCZ and the mean OLR pattern at different stages of the LFO in spring (a) stage A, (b) stage B, (c) stage C and (d) stage D. The solid line is OLR contour (W m^{-2}) and the dashed line represents the ITCZ.

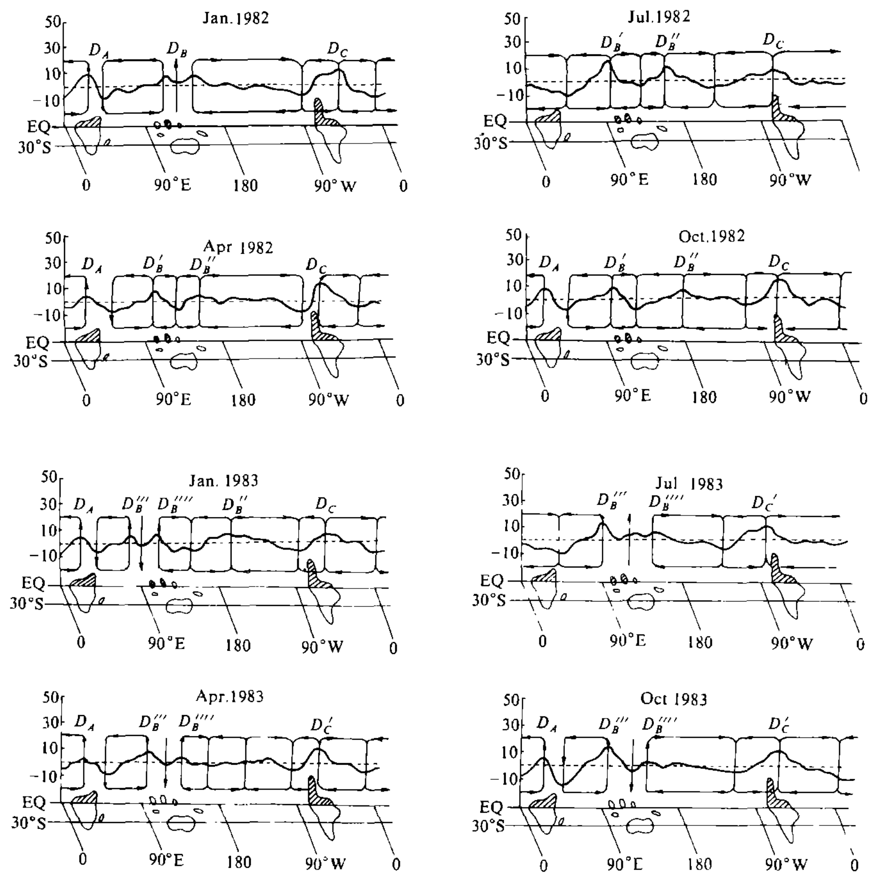


Fig. 4. The evolution of the latitudinal vertical circulation along equator (10°S—10°N) during 1982—1983 ENSO calculated with OLR data. The curves denote the variation of the latitudinal components of mean vertical velocity derived from OLR. D is the divergent center at 200 hPa.

tropics with OLR data. The results is better than that from radiowind data (Xie and Bai, 1993; Jiang and Zhang, 1993b). Therefore a new tropical stream field can be formed by means of the OLR and radiowind data, which can increase the proportion of the divergence wind in the total wind field and in the mean time keep the total kinetic energy constant. These results would well improve the initial fields of numerical weather prediction and the diagnostic research in tropics.

The evolution of the Walker cell along the equator (10°S—10°N) and the local Hadley cell over the Pacific were investigated for 1992—1993 ENSO with the divergence wind in 200 hPa and 850 hPa calculated from OLR (Jiang and Zhang, 1993b). It is found that during the developing periods of the ENSO, the number of the divergent centers on the 200 hPa increased from 3 (the normal case) to 4—5 with the gradual eastward displacement of the latitudinal circulation cell. While the ENSO developing, not only the latitudinal circulation cell moved but also the number of the cells changed (Fig.4) and in the mean time the local longitudinal circulation cell varied too, i.e. the Hadley cell weakened over WP and enhanced abruptly in the central-east Pacific. The adjustment of tropical latitudinal vertical cell, the correlation between the latitudinal and longitudinal cell variations and its dynamic causes need further studies. The OLR data reveals the variation of the tropical vertical circulation in detail which can not be found out with the traditional wind observations. It provides a new approach for the research of the interaction between the middle and low latitude circulations.

VII. STUDIES OF THE AIR-SEA INTERACTION

OLR is an important parameter in the research of the air–sea interaction. Generally the positive correlation between OLR and SST implies that the atmosphere affects the sea principally and the negative correlation means the sea affects the atmosphere mainly. Based on the correlation analysis of the multiple-year anomalies of OLR and SST, we reveal the climatic features of the air–sea interaction in different regions and seasons in tropics and suggest that the state of the air–sea interaction would be linked to the distribution of the general atmosphere circulation systems and the atmospheric heat sources and sinks (Jiang and Chen, 1993). It provides us the useful information in understanding of the climatic background of the air–sea interaction. Besides, analyzing the relation between the axses of the maximum SST and the minimum OLR (the ITCZ), it is revealed that there is good relation between them only in some regions (the East Pacific and the Atlantic) and the striking difference exists in WP and Indian Ocean (Jiang and Guo, 1992). This is in contradiction with the Saha's results (1973) —— the cloud band (ITCZ) basically coincides with the axis of the maximum SST and is located on the polartward side. It indicates that the ITCZ does form in the warm water regions (SST > 27℃), but the intensification of the convection is not sensitive to the increase of the SST; therefore, the location of the ITCZ does not depend on the axis of maximum SST.

VIII. ESTIMATION OF SUMMER PRECIPITATION IN THE YANGTZE RIVER BASIN AND THE TIBETAN PLATEAU

The estimation of precipitation over the tropical ocean with OLR data has been succeeded (Arkin, 1983) and used in operation (CAC in U.S.). Recently the experiments on the estimation of the precipitation in the Yangtze River basin and the Tibetan Plateau are also succeeded respectively (Jiang and Winston, 1989; Xu, Li and Jiang, 1990). With 9 years (1974—1983, except 1978) OLR data and the rainfall records of 95 stations in the Yangtze River basin and 83 stations over the Tibetan Plateau, experiments are carried out on various the temporal and spatial scales. The results show that there is linear correlation between the monthly anomalies of the precipitation and OLR on the $2.5^\circ \times 2.5^\circ$ network in the Yangtze River basin. The correlation coefficient is -0.53 on the whole and -0.64 over the main stream region and it increases with the increasing temporal and spatial scales. The good relation is also found in the experiment on the Tibetan Plateau. The spatial ($2.5^\circ \times 2.5^\circ$) correlation coefficient between the climatic monthly mean OLR and precipitation is about -0.80 and the temporal correlation is -0.5—-0.9 over the main body of the plateau with a confidence level of 0.001. It indicates that the linear correlation between OLR and precipitation on the Asia mid-latitude monsoon continent in rainy season is as well as on the tropical oceans. The effect of the temporal and spatial scales, topography, rainfall and the density of the rainguadges on the correlation coefficients is also analysed. These results are of great significance to agriculture and hydrology and to estimation of latent heat over the Tibetan Plateau.

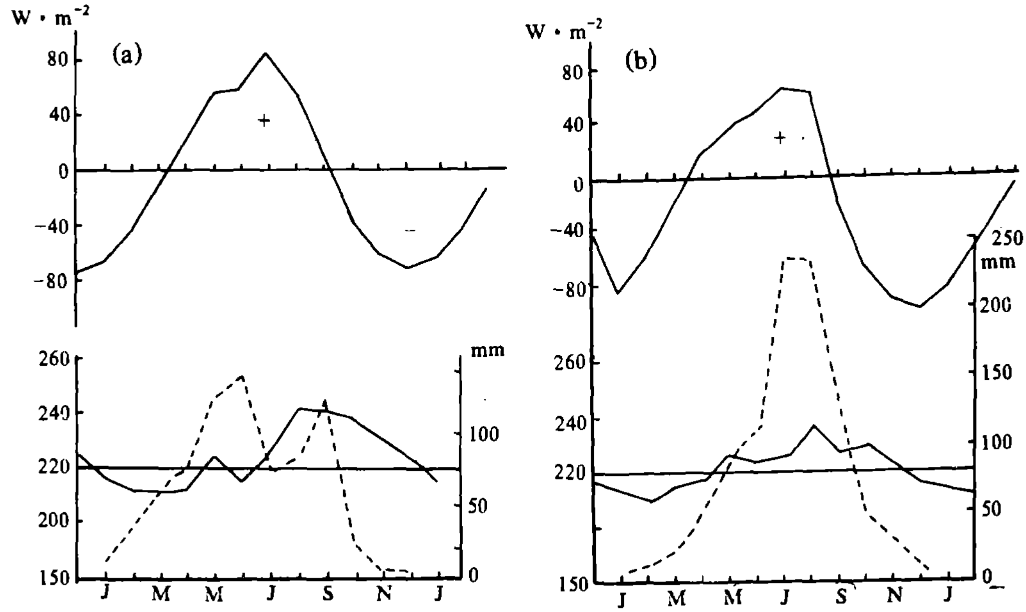
IX. ANALYSES OF THE REGIONAL CLIMATOLOGY IN CHINA

The climatic characteristics of various regions in China are revealed by using annual cycle curves of OLR and net radiation in ten representative cities from Mohe to Haikou (Jiang et al., 1991). Figures 5a—5c show the variation curves of the multi-year mean OLR and net radiation derived from the NOAA satellite observation and the precipitation observed on the ground at Hangzhou, Chengdu and Lhasa along the 30°N over China. It can be seen that the features of the annual cycle of radiation at Hangzhou (Fig.5a) represents the climatical pattern on the dalta of Yangtze River, in which there are two valleys on April and June and a peak on August in the OLR curve. It corresponds to the spring rainy weather, Meiyu (plum rains) and the summer drought —— the typical climatic pattern of the southern Yangtze River basin. It differs from the single peak of "V" pattern in summer in North China. The negative area of the net radiation is almost equal to the positive area and the relatively low net radiation occurs on June (Meiyu season). It implies that the effect of cloud albedo is greater than greenhouse effect. The annual amplitude of OLR is less in North China. It reflects the annual range of the temperature is less in North China and the precipitation is not as variable as in North China. Comparing with Hangzhou and Lhasa along the same latitude, the OLR curve of Chengdu in Sichuan Basin is most irregular with a smaller amplitude. It corresponds to climatic features of cloudy, foggy, less sunshine and continuous rainy in autumn. The annual radiation budget in the Sichuan Basin is negative. Differing from the Sichuan Basin and the Yangtze dalta, it is positive at Lhasa in the plateau and reaches 480 W m^{-2} (which is the highest in China). That is, there is much sunshine in Lhasa (so sometimes it is called sunshine city). Its OLR curve is similar to that in North China —— a distinctive "V" pattern in summer, i.e. the rains are concentrated in summer. But the annual mean OLR is less in Lhasa than in Beijing to the north, obviously because it is affected by the altitude of the plateau.

Ohring and Gruber (1983) applied the satellite radiation observation data to the study of the world regional climate and achieved successful results. We conducted the further research on the regional climate of China with satellite data. The results show that the two parameters (OLR and net radiation at top of atmosphere) can be and should be applied to the fields of the regional climatology. It is well known that the research on the classification of the climate or the regional climatology has a long history. Such parameters observed on the ground as temperature and rainfall are adopted in traditional methods. The OLR and radiation budget of earth-atmosphere system contain the message of energy budget (the major cause of the climate) and a variety of climatic information such as temperature, precipitation, cloud amount, sunshine and vegetation etc. Therefore, The introduction of the two new parameters to the field of the regional climatology may enable us to break through the limitation of the conventional surface observation and combine with the space observation. It is of great significance both in theory and in practice.

X. STUDIES OF DIAGNOSIS AND PREDICTION OF THE SEVERE AND DISASTROUS WEATHER AND CLIMATE

The diagnosis and prediction of the disastrous weather and climate with OLR data have been widely studied in China such as summer precipitation (Zhu et al., 1987; Wu et al., 1990; Li



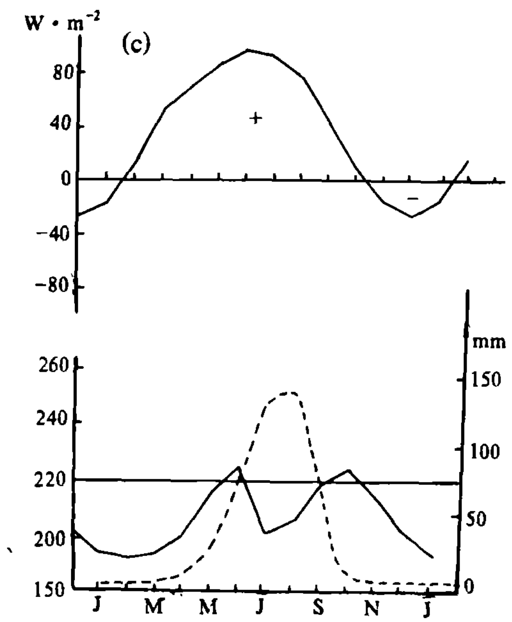


Fig. 5. The annual cycle of radiation budget (the upper solid line), OLR (the lower solid line) of the earth–atmosphere system, and precipitation (dashed line) over (a) Hangzhou (30°N, 120°E); (b) Chengdu (30°N, 105°E); (c) Lhasa (30°N, 90°E).

et al., 1991; Jiang et al., 1991), winter low temperature (Zhu and Tao et al., 1989), chilling damages in Northeast China and in Ningxia (Mao et al., 1988; Kang and Wu, 1989), droughts and floods in the Yangtze River basin (Jiang and Winston, 1986; Li and Liu, 1991; Jiang, 1992; Jiang et al., 1993) and in North China (Li and Liu, 1991) and snow in Tibetan Plateau (Shangguan, 1990). These can be divided into three kinds: First, the diagnosis of the characteristics of the OLR and the climate anomalies in China, such as the research on the lag correlation between the global OLR and winter temperature or summer precipitation at selected stations in China. It was found that the Australia and the Tibetan Plateau are key areas that affect the summer rainfall in China, and nine sensitive regions that influence the winter temperature in China correspond to the centers of the 500 hPa teleconnection patterns of EU, PNA and EA and to the descending and ascending branches of the Walker circulation cell in tropics. Consequently some useful clues to the long-range forecasting are found. Based on the diagnosis of droughts and floods over Yangtze River basin with OLR, it is also revealed that in the flood year the characteristics of OLR in tropics are that the intensities of SH in WP and ITCZ in Indian Ocean and WP are greater than the normals and their positions are to south of the normal; and at the earlier stage, the negative anomalies continuouly present in the two key areas on the south side of the ITCZ in the Indian Ocean and the Pacific in spring (May—March) and the Australia High and the East Pacific SH in the Northern Hemisphere develop anomaly in winter. The long-range forecast scheme for the floods in Yangtze River basin based the above results is shown as Fig.6.

Second, the OLR pattern is considered as a new field in analyzing, such as the research on the formation, development and shift of tropical cyclones and the 3— 5 day forecast of rainstorms in Yangtze River basin in which the predictors are summed up from the analysis of the OLR pattern and its evolution features. Third, the establishment of the prediction formula with various predictors derived from the diagnostic results such as the severe cold summer prediction in Ningxia and snow prediction in the Tibetan Plateau.

XI. THE ATLAS OF OLR

An atlas of OLR has been published by Peking University (Jiang and Zhu, 1990) in China. Comparing with the atlas of the same kind published by NOAA in U.S. (1986), there are some improvements in our atlas. The axes of ITCZ identified from the minimum OLR are added in the OLR monthly charts and the global ITCZ atlas derived from satellite data is presented. Figure 7a shows the climatic mean ITCZ over the globe. Moreover, the SST anomalies are superimposed on the OLR anomaly charts and it is more convenient to analyse the situation of

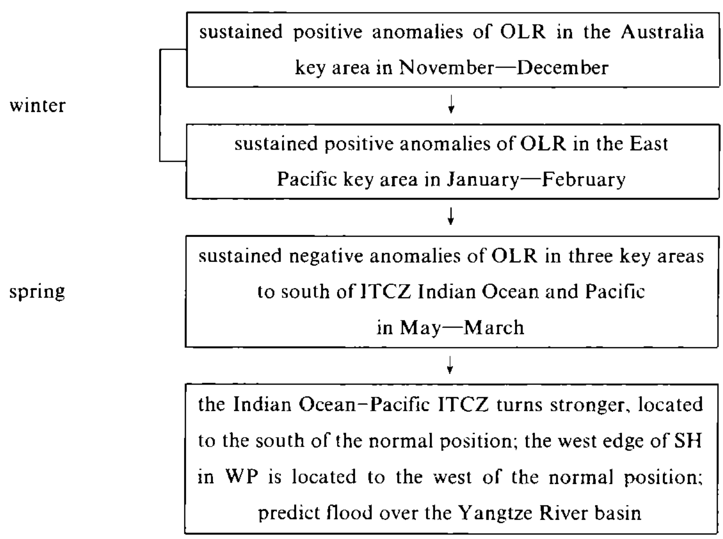


Fig. 6. The long-range forecasting scheme for the floods in the Yangtze River basin.

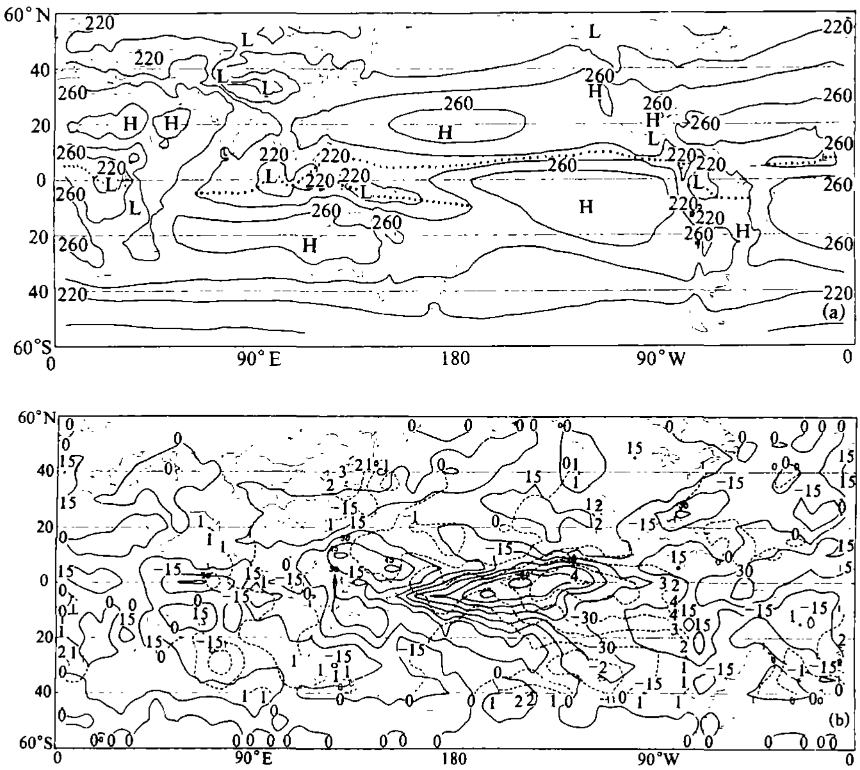


Fig. 7. (a) Annual average OLR (W m^{-2}) in the period of January 1975 to December 1985. Solid line: OLR (W m^{-2}), dashed line: ITCZ (minimum of OLR) axis; (b) Anomalies of OLR and SST in January 1983. Solid line: OLR anomaly (W m^{-2}), dashed line: SST anomaly (℃).

the interaction between ocean and atmosphere. For this reason, it is widely accepted by scientists in meteorology and oceanography. Figure 7b shows the anomalies of OLR and SST in January 1983. It can be seen that during the developing period of the 1982—1983 ENSO there is a strong negative OLR anomaly center (< -75 W m^{-2}) and a positive SST anomaly center (> 4℃) in the central and eastern Pacific. It indicats that the air–sea interaction is very strong but the two centers do not coincide each other. This can be explained by Marakami's research on relationship between OLR and SST on interannual scales (Marakami et al., 1988). The highest SST anomalies tend to occur about three months prior to lowest OLR perturbations. Because both of them propagate eastward, the OLR negative anomaly center lags behind the SST positive anomaly center.

XII. MAJOR FEATURES OF THE OLR APPLIED RESEARCH IN CHINA

1. *Extensiveness of the OLR Applied Research*

It can be seen from the above mentioned ten aspects that the range of the OLR applied researches is quite extensive in China and some of them are pioneering work. They play an active role in the disseminating and deepening of the OLR applied research.

2. *Emphases on the Tropical Oceans and the Tibetan Plateau*

The tropical oceans and Tibetan Plateau, where is scarce of the conventional observation data and there are with the active convection activities, greatly affect the general atmospheric circulation and climate anomalies in mid– and low–latitudes. The OLR data observed by satellites can enable us to take advantage of satellite data to make up for the inadequacy of the conventional observation.

3. *Discovery ofNew Facts*

Some new phenomena are revealed by OLR, such as the latitudinal oscillation of the double ITCZ and the SH in WP, the evolution of the Walker and local Hadley cells during ENSO and their relation, and the relation between the LFO of the ITCZ and droughts and floods over Yangtze River basin etc. All of these are of great significance in theory and practice.

4. *Close Relation with the Forecasting Practice in China*

A great deal of foundational work has been done in China in the disastrous weather and climate prediction, especially for serious summer chill, snow on the plateau, rainstorms, tropical cyclones, droughts and floods etc., and some of them have been used in the forecasting operation.

In the days to come, the emphasis will still be put on the tropical oceans and the Tibetan Plateau and we will combine OLR with the conventional data in analyses. The relationship of the convective activities and the heating anomalies over the plateau in summer to the anomalies of the East Asia monsoon and the general atmospheric circulation should be further studied. In the tropical oceans the emphasis should be put on the relationship of OLR to atmospheric heat sources and sinks, air–sea interaction and relation between the middle and lower latitudes. Besides, the application of OLR to the operational prediction should be enhanced. In the long–range forecasting OLR should be applied to the physical diagnosis as much as possible, so as to establish a reliable base, and the possibility of the establishment of the prediction systems in conjunction with the short and medium range forecasting should be explored. The OLR data should also be applied in the medium and short–range numerical weather forecast to improve the initial fields in tropics so as to further enhance our capability to predict severe weather and to reduce damages.

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