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THE RELATIONSHIP OF THE PRECEDING WINTER MJO ACTIVITIES AND THE SUMMER PRECIPITATION IN YANGTZE-HUAIHE RIVER BASIN OF CHINA

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Abstract: The first two series (RMM1 and RMM2) of RMM Index (all-Season Real-time Multivariate MJO Index) are computed to obtain the interannual variation of the preceding winter (preceding December to current February) MJO strength, according to which active (or inactive) years of preceding winter MJO are divided. By utilizing the data provided by NCEP/NCAR, CMAP and China's 160 stations from 1979 to 2008, we studied the preceding winter MJO strength and discovered that the summer precipitation in the basin are of significantly negative correlation, i.e. when the preceding winter MJO is relatively active, the summer precipitation in the basin decreases, and vise verse. We also analyzed the causes. When the preceding winter MJO is relatively active, its release of potential heat facilities Inter-Tropical Convergence Zone (ITCZ) to strengthen and locate northward in winter and propagate northeastward. This abnormal situation lasts from winter to summer. In mid-May, ITCZ jumps northward to the South China Sea, the western Pacific subtropical high withdraws eastward, and the South China Sea summer monsoon sets off and strengthens. In summer, ITCZ propagates to South China Sea-subtropical western Pacific, the zonal circulation of subtropical Pacific strengthens, and a local meridional circulation of the South China Sea to the basin area forms, giving rise to the East Asia Pacific teleconnection wave-train. An East Asian monsoon trough and the Meiyu front show opposite features from south to north, the East Asian summer monsoon strengthens and advances northward. As a result, the summer monsoon is weakened as the basin is controlled by the subtropical high continually, with less rain in summer. On the contrary, when the preceding winter MJO is inactive, ITCZ weakens and is located southward, the subtropical high is located southward in summer, and the basin is in a region of ascending airflow with prevailing southwest wind. The East Asian monsoon trough and EASM weaken so that summer monsoon is reduced in the basin where precipitation increases.

Key words: winter MJO; summer precipitation in the basin; ITCZ; East Asia wave train; East Asian Summer Monsoon

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1 INTRODUCTION

In the 1970s, the MJO (Madden–Julian oscillation) was proposed by Madden and Julian[1-2] who first discovered the phenomena of large-scale cyclical oscillation of 40-50 days in wind field and pressure field of tropical atmosphere. Now it has been studied as the strongest signal of 7-90 day oscillation in tropical atmosphere activities, and its laws of structure, propagation, variation and dynamical mechanism have been established after a series of studies at home and abroad[3-12]. MJO activities impact significantly on the weather and short-term climate in many areas of the globe. For its quasi-periodic characteristic of intra-seasonal oscillation[13], it can be used as an a forecast signal of short term climate anomalies and an important approach to improve the prediction of the East Asian area.

The forecast of precipitation during summer flood periods is a central topic of China's climatic prediction services. Studies in resent years discovered that MJO or known as the atmospheric ISO (Intra-Seasonal Oscillation) has intensive influence on the strength and distribution of summer precipitation in different areas, especially the eastern part of China[14-17]. As a typical area of the East Asian Monsoon processes, the basin is an important topic of

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research for the impact of MJO activities to summer precipitation in middle latitudes, with marked achievements achieved. As Li and Li[18] pointed out, among multi-time-scale anomalous circulations, ISO (especially in the lower troposphere) plays a significant role in summer drought and flood in the basin. The study of Huang et al.[19-20] indicated that convective systems in the Philippines and South China Sea that are closely related to MJO have important influence on the western Pacific subtropical high and summer precipitation in the basin by modulating the continuation and intensification of the rainy season in eastern China. Lu and Ding[21] discovered that warm and moist air can be transported in the mode of low frequency oscillation (LFO) from the low latitudes to the basin, leading to heavy rain there. Liang et al.[22] suggested that obvious LFO of 30-60 days exists in meridional moisture transport in the basin from May to August during flood years, but it is unnoticeable during drought years. Ding and Liang[13] pointed out that MJO can be used as an extended range forecast signal for summer precipitation in the basin, precipitation and heavy precipitation events increase obviously when MJO is in the third and forth phases. Ju and Cao[23] and Ju and Chao[24] put forward the concept of "monsoon surge" which spreads northward with time in East Asian summer monsoon (EASM) region; its magnitude at different latitudes could well describe the process of local large-scale precipitation. The summer precipitation in the basin and South China always presents opposite phase characteristics, which reflects longitudinal propagation of ISO in EASM at wave peak and valley in the above two regions respectively. The analysis by Li et al.[25] emphasized the influence of ISO in South China Sea on the basin: the abnormal ISO will arouse a sudden change of atmospheric circulation and EASM onset in the basin so to influence the summer precipitation there.

Previous research displays that the activities of MJO can be referred for forecast of summer precipitation. Therefore, this paper will further explore the relation between the preceding winter MJO activities and summer precipitation in the basin, and look for the causes from the viewpoint of tropical convection activities, the strength and seasonal propagation of Inter-tropical Convective Zone, meridional and zonal circulation, the East Asia-Pacific teleconnection (EA, or EAP) wave train and EASM, with an attempt to provide some forecast reference for the precipitation in the basin.

2 DATA AND METHODS

The data adopted by this paper mainly include daily or monthly averaged OLR data, reanalysis data of geopotential height field, wind field and ω (vertical velocity) provided by National Centers for Environmental Protection/National Center for Atmospheric Research (NCEP/NCAR, USA), monthly averaged precipitation data provided by CMAP (CPC Merged Analysis of Precipitation Enhanced), with the resolution being 2.5°×2.5°, and precipitation data from China's 160 stations, during 1979 to 2008. According to the 26 stations in the middle and lower reaches of the basin defined by the Forecast Office of National Climate Center of China Meteorological Administration[26], and deleting the stations with incomplete data, we selected 21 stations (Nanjing, Hefei, Anqing, Tunxi, Zhongxiang, Yueyang, Yichang, Changde, Wuhan, Shanghai, Hangzhou, Guixi, Quzhou, Nanchang, Xuzhou, Bengbu, Fuyang, Xinyang, Nanyang, Dongtai and Xinpu) and computed their daily observed precipitation to represent summer (June-August) precipitation in the basin.

This paper adopts the All-Season Real-Time Multivariate MJO Index (RMM), which is now extensively used in the world, to reflect the activities characteristics of MJO. It is an independent daily index to describe the observed MJO facts established by Wheeler and Hendon[24] in 2004. A pair of eigenvector of functions (EOFs) can be obtained in composite fields of the averaged 850 hPa and 200 hPa zonal wind and outgoing longwave radiation (OLR) close to equator. After elements of annual circulation and interannual variation are removed, projection of daily data can be obtained on multivariate EOFs, and a pair of principal components (PCs) time series close to intra-seasonal time scale of MJO are produced, which are called Real-time Multivariate MJO series 1 and 2 (RMM1 and RMM2). The phase diagram defined by RMM1 and RMM2 shows the daily special evolution of MJO, and the value of $\sqrt{\mathrm{RMM1}^2+\mathrm{RMM2}^2}$ can describe the daily strength of MJO. As an effective MJO filter, the projection avoids using traditional time filtering methods so that the PC time series become an effective real-time index.

This paper uses such statistical methods as composite analysis, correlation and differential significance computation and test.

3 RELATIONSHIP BETWEEN PRECEDING WINTER MJO ACTIVITIES AND SUMMER PRECIPITATION IN YANGTZE-HUAIHE RIVER BASIN

We average the above daily MJO strength values in every preceding winter (from the previous December to the current February) to obtain yearly preceding winter MJO strength to describe its annual variation. A year with the strength value >0.2 (or <–0.2) is defined as an active (or inactive) year of preceding winter MJO. They are 1985, 1980, 1990, 1997, 2001, 2004 and 2008 (or 1980, 1981, 1983, 1996 or 2000) during 1979–2008.

As shown in Figure 1, the annual variation of preceding winter MJO strength and summer precipitation in the basin (both standardized) from 1979 to 2008 reflects opposite variation characteristics with correlation coefficient of –0.62, which passes the reliability test of 99%, indicating that there is significant negative correlation between preceding winter MJO strength and summer precipitation in the basin. Figure 2 is the daily precipitation composite for the summers of the basin in the preceding active winter MJO years and the inactive years respectively during 1979–2008. As shown in the figure, the value in the preceding inactive winter MJO years is much larger than that in the inactive years, which is quite significant from June 20 to July 5, which is just a principle Meiyu flood period in the basin. Figure 3 is the correlation coefficient distribution between the preceding winter MJO strength and summer precipitation (CMAP precipitation data) in East Asia during 1979–2008, among which the light and heavy shadow areas have passed reliability test of 90% and 95% respectively. In this figure, the basin is a significant negative correlation region, while the southeastern part of South China and South China Sea-Western Pacific are a significant positive correlation region. This distribution situation not only verifies the negative correlation between the preceding winter MJO activities and summer precipitation in the basin again, but also complies with the opposite phase distribution feature of summer precipitation in Yangtze–Huaihe River Basin and South China.

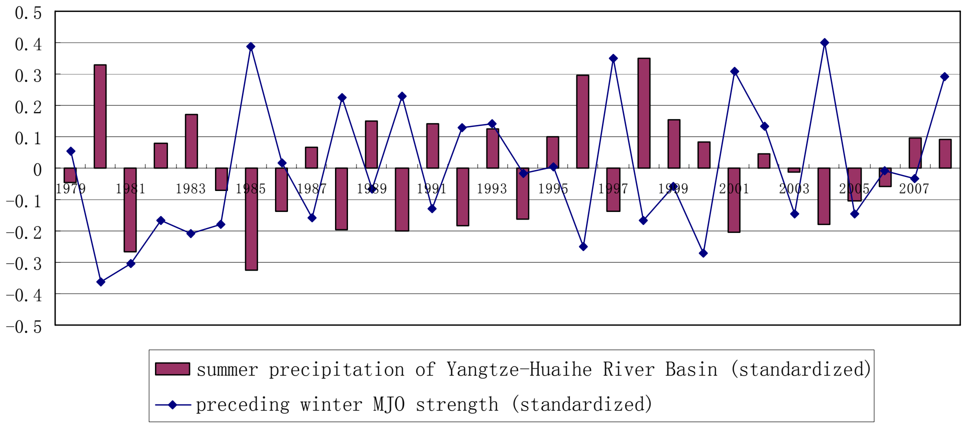


Figure 1. Year-to-year variations of preceding winter MJO strength and summer rainfall of the basin in 1979–2008 with correlation coefficient at –0.62, surpassing the 99% confidence test.

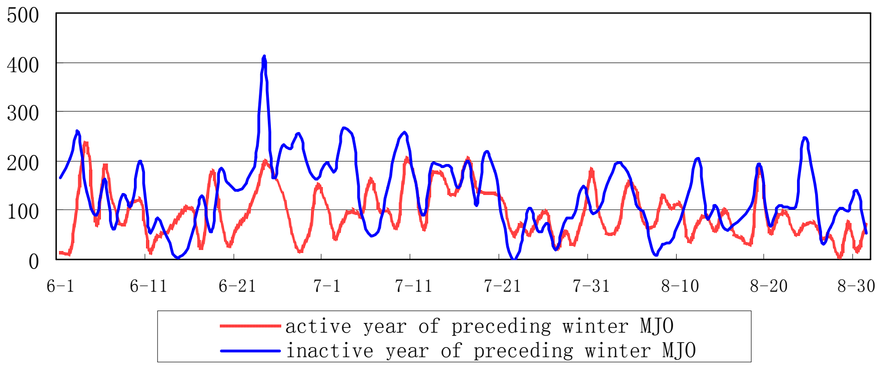


Figure 2. Composite day-to-day summer rainfall for the basin during the active and inactive years of MJO from 1979 to 2008 (Units: mm).

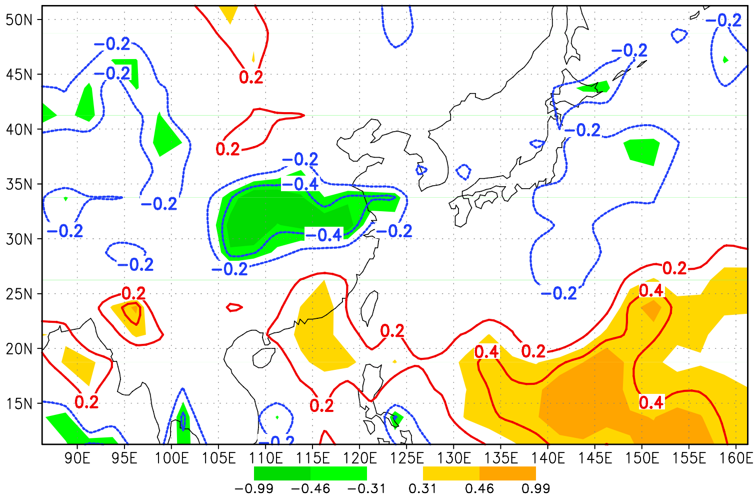


Figure 3. Distribution of the correlation coefficients between the MJO intensity of the preceding winter and rainfall (from CMAP) of East Asian summer from 1979 to 2008, with the light and heavy shades indicating the passing of 90% and 95% confidence tests, respectively.

Moreover, as shown in Figure 1, the year of 1998 is the extreme flood year, while 1985 is the extreme drought year, during the 30 years. We take these two years for instance to draw up the phase diagram of preceding winter MJO (Figure 4). The abscissa and ordinate in the figure respectively represent RMM1 and RMM2, the position of each point represents the daily phase of MJO, the distance away from the origin represents daily strength of MJO, and circle radius $R=\sqrt{RMM1^2+RMM2^2}=1$ i.e. the daily strength of MJO is 1. As shown in the figure, the points formed by the preceding winter daily RMM indexes of 1998 (Figure 4a) only appear near the circle. Their actual averaged value (not standardized yet, same below) is 1.11, less than 1.33, i.e., the average value of the 30 years, indicating that the preceding winter MJO activities of this extreme flood year (1998) is weaker than normal. However, most points formed by the preceding winter daily RMM indexes of 1985 (Figure 4b) are far away from the circle, except for some days from 13 December 1984 to 6 January 1985 within the circle. Their actual averaged value is 1.85, higher than 1.33, indicating that the preceding winter MJO activities of this extreme draught year (1985) are stronger than normal.

The above facts illustrate that preceding winter MJO activities are in significantly negative correlation to the summer precipitation of the basin, i.e. when the preceding winter MJO is relatively active, the summer precipitation of the basin will decrease, and otherwise it will increase. Then, how does winter tropical atmospheric condition influence the summer precipitation in the basin? We will analyze it further in the following sections.

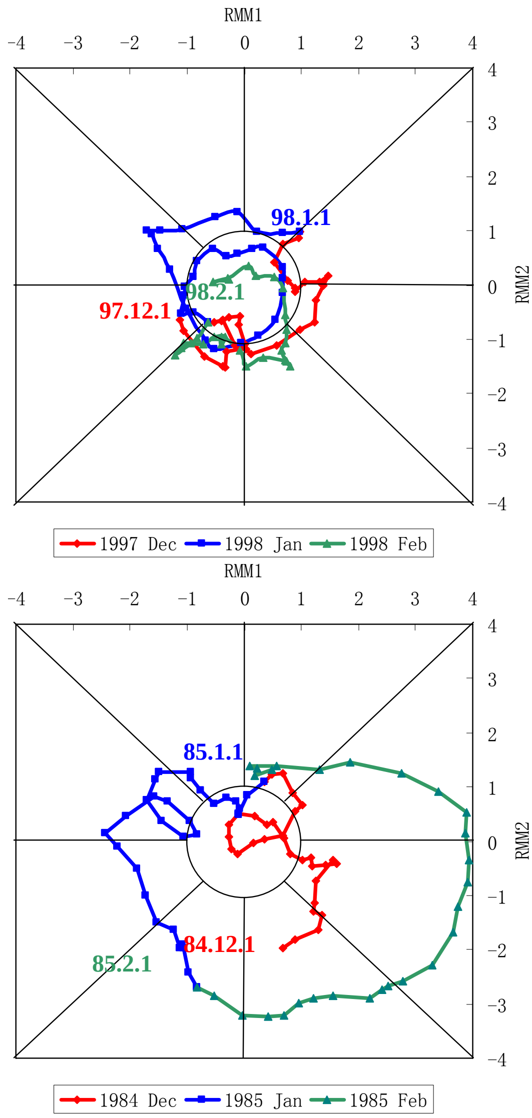
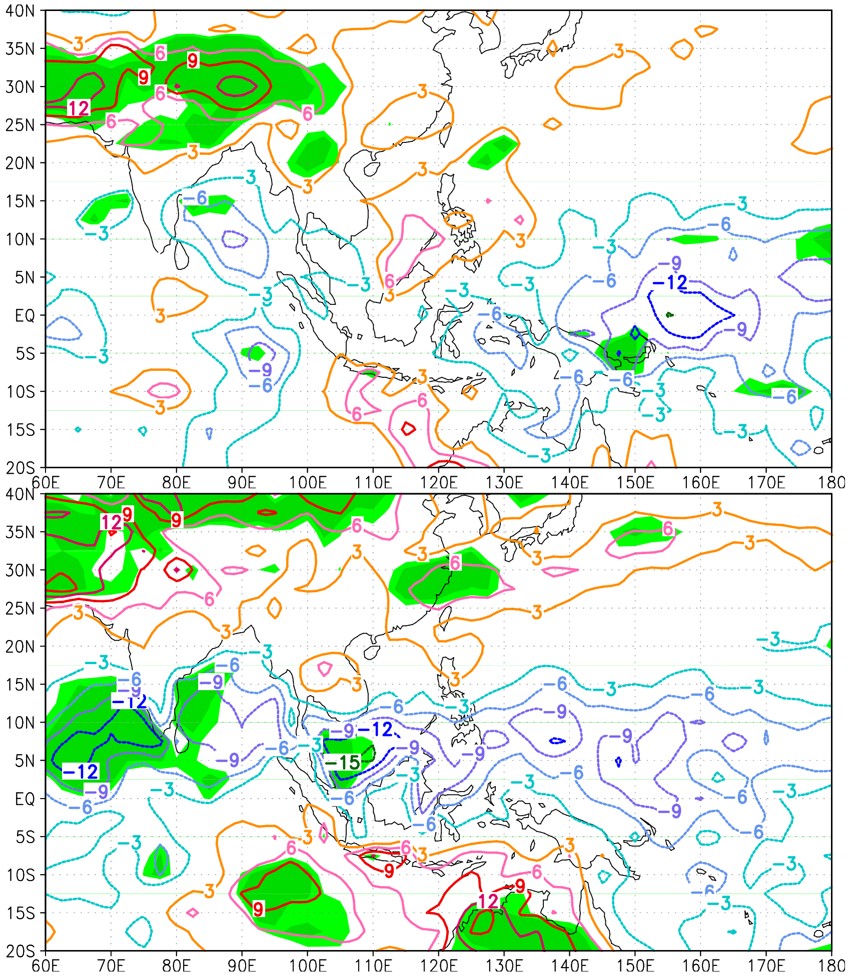


Figure 4. Daily phases of the preceding winter MJO in 1998 (a) and 1985 (b).

4 INFLUENCE OF PRECEDING WINTER MJO ACTIVITIES ON ITCZ AND CONVECTIVE ACTIVITIES

As OLR data can well reflect large-scale convective activities of tropical atmosphere, and ITCZ just corresponds to the large-scale convective ascending region of tropical atmosphere, so the position and value of central axis in a low OLR value area (for instance, an area ≤225 Wm^{-2}) can be used to describe the position and strength of ITCZ[28]. We use the distribution of composite differential OLR value in different seasons in preceding winter MJO active years deducting inactive years in 1979–2008 (Figure 5) to display the influence of preceding winter MJO activities on the change of ITCZ (the light and heavy shadow areas have passed differential significance test of 90% and 95% respectively). As shown in the figure, in the preceding winter MJO active years compared to the inactive years: in winter (Figure 5a), ITCZ is stronger in the equatorial Indian Ocean north of Indonesia and equatorial western Pacific and wider in western Pacific, expanding northward to the tropical area of the Northern Hemisphere, and convection strengthens obviously in eastern Arabian Sea and middle of Bay of Bengal; in spring (Figure 5b), ITCZ is relocated northward to northern Indian Ocean to about 5°N with larger strength, and a strong convection center is produced in southwestern South China Sea and convection strengthens significantly in middle Arabian Sea and northern part of Bay of Bengal. In summer (Figure 5c), ITCZ shifts northward to approach 20°N, and strong convection centers exist in northern Bay of Bengal, South China Sea and subtropical Pacific. In particular, the convection in South China Sea-subtropical western Pacific is strengthened while that in the basin is weakened, forming EA wave train, leaving the basin in a descending airflow area with high temperature and less rain in summer. We will make further analysis of it later.



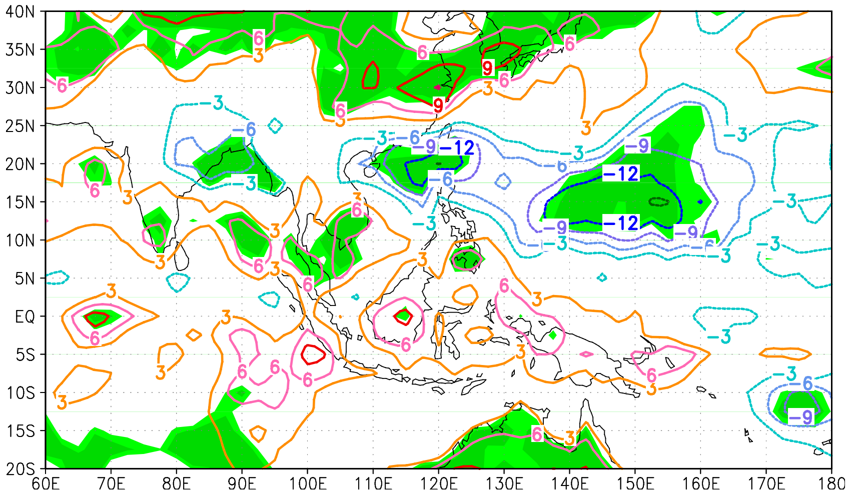


Figure 5. Distribution of seasonal averages of composite OLR differences for winter (a), spring (b), and summer (c) as determined by subtracting active MJO years from inactive MJO years in the preceding winters of 1979–2008 (units: m s^{-1}), with the light and heavy shades indicating the passing of 90% and 95% significance tests, respectively.

To more vividly describe how the strength and propagation path of ITCZ are changed under the influence of preceding winter MJO activities, we show the latitude-time cross-section of the composite OLR differential value averaged in 105–120°E from January to October in the preceding active winter MJO years deducting the inactive years during 1979–2008 (Figure 6a), where the light and heavy shadow areas have passed differential significance tests of 90% and 95% respectively. As shown in the figure, in the preceding active winter MJO years compared to the inactive years, ITCZ is stronger from the late January to mid-May in Indonesia-southern and middle South China Sea; in mid-May, the strengthened area of ITCZ jumps northward to middle South China Sea-southern South China and lasts until early September. Its abnormal strengthening and seasonal northward trend makes the subtropical high move eastward in mid-May and withdraw from South China Sea, so that South China Sea Summer Monsoon (SCSSM) begins and strengthens, and influences EASM. After entering summer, the part of the basin north of 25°N is controlled by the subtropical high and remains in a lasting and stable descending airflow, turning this region into one with high temperature and less rain in summer.

Figures 6b and 6c show the latitude-time cross-section of the OLR anomaly averaged in 105–120°E from January to October in 2004 and 1980 (i.e. the years corresponding to the maximum and minimum value of preceding winter MJO strength in the 30 years respectively). In 2004 (Figure 6b), since the preceding winter MJO is quite active, ITCZ strengthens in Indonesia and its southern sea area at the end of winter till the beginning of spring, and gradually propagates northward. In mid- and late-April, it arrives in the South China Sea, forcing the subtropical high to withdraw from South China Sea and SCSSM starts in advance. After entering summer, ITCZ continues propagating northward and a strong convection area remains in the middle of South China Sea- southern South China from mid-June to mid-July. The subtropical high jumps northwards to the basin, making this region less rainy in summer under control of the subtropical high. As shown in Figure 1, the summer precipitation of this year is the second lowest during the 30 years, i.e. it is a significant drought year in the basin. However, in 1980 (Figure 6c), the situation is totally different. Since the preceding winter MJO strength is quite weak, ITCZ in Indonesia-South China Sea is obviously weak during the beginning of February-mid May but strong in South China Sea in late May, resulting in a weakened SCSSM and a delayed onset; after mid-July ITCZ withdraws southward to the southern South China Sea-Indonesia. Due to the southward location and weakened ITCZ, the subtropical high is located southward in South China Sea-southern South China for most of the time during May-August, the basin remained in the northern edge of the subtropical high with the southwest wind prevailing, which is beneficial to water vapor transport. Meanwhile, it remained in a large-scale convective ascending area that possesses excellent uplifting condition. As a result, sufficient water vapor and strong convection make the summer of the basin more rainy in summer, and as shown in Figure 1, the summer precipitation in this year is the second largest during the 30 years, i.e. it is a significant flood year in the basin.

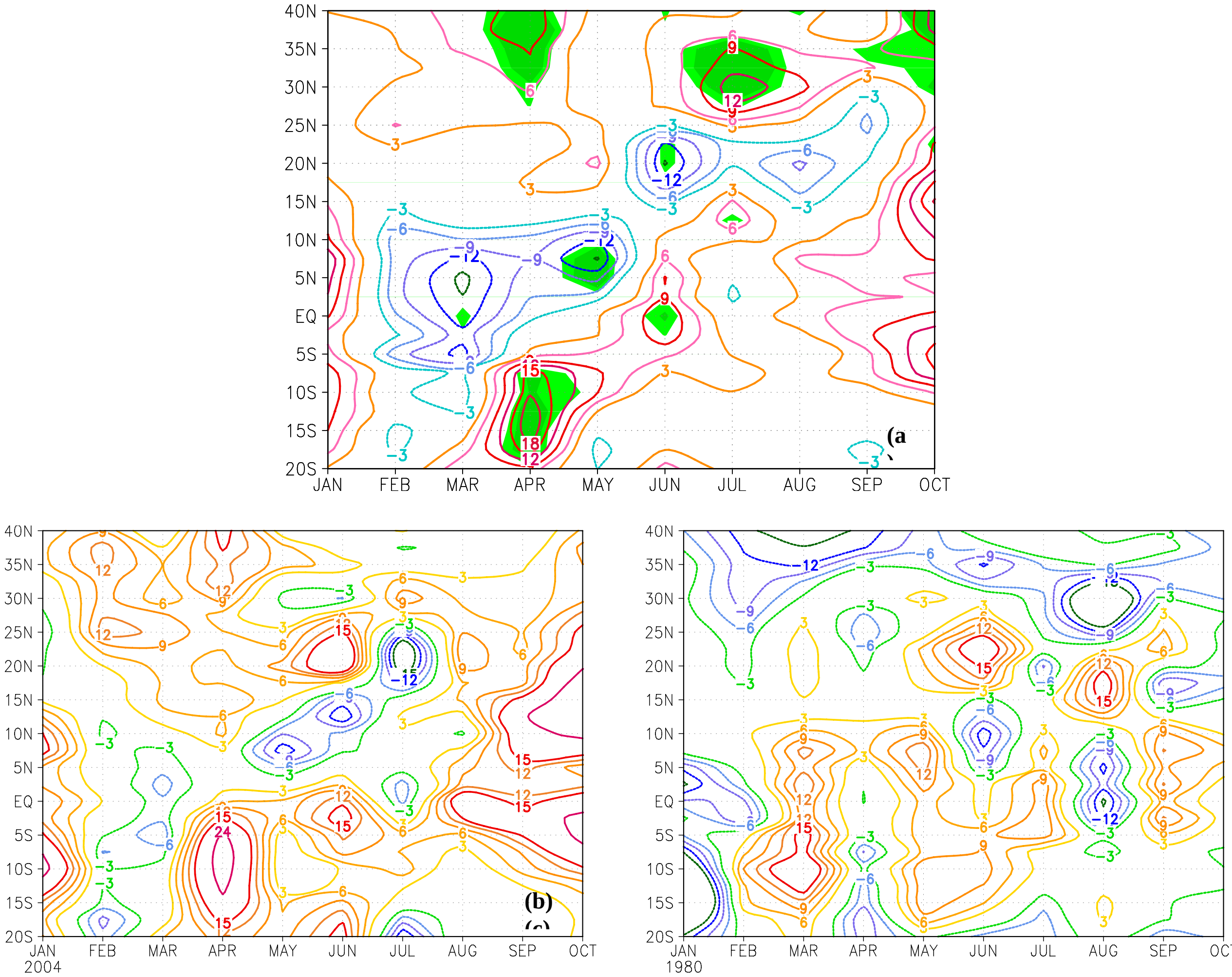


Figure 6. Latitude-time evolutions of the composite OLR differences, as determined by subtracting the active MJO winters from the inactive ones (a), January to October OLR anomalies averaged over 115–120°E for 2004 (b) and 1980 (c), with the light and heavy shading indicating the passing of 90% and 95% significance tests, respectively.

From the analysis above, the influence of preceding winter MJO activities to ITCZ will last from winter till summer, which changes the position of the subtropical high and the convection field of East Asia in summer and influences the summer precipitation in the basin. To further describe the relationship between the abnormal convection of East Asia and the summer precipitation in the basin, we show the distribution figure of correlation coefficients between summer precipitation in the basin and summer averaged OLR during 1979–2008 (Figure 7), in which the light and heavy shadow areas have passed reliability test of 90% and 95% respectively. As shown in the figure, significant negative correlation between OLR and precipitation in summer exists in the basin, i.e. when convection in this region strengthens, the precipitation there will increase accordingly. Meanwhile, correlation is significantly negative in the region of Indonesia, significantly positive in South China Sea-subtropical Western Pacific, significantly negative in the basin and Sea of Japanese Sea, while Okhotsk Sea is significant positive, which is just the distribution of EA wave train. As Huang and Sun [19, 20] proposed, in summer convection field, when active convection exists near the Philippines, an alternative opposite phase distribution of active and suppressed convection areas will be produced in East Asia, forming the propagation similar to Rossby wave train, that is the EA wave train. It will cause the basin-Japanese islands to be controlled by descending airflow with high temperature and less precipitation in summer. This theory can be used to explain our analysis and conclusion above.

It can be concluded from the analysis above that, when the preceding winter MJO is relatively active, corresponding convection produced in tropical atmosphere gets strengthened, and the release of its potential heat facilitates ITCZ strengthening and propagating northward in winter. The abnormally strengthened situation of ITCZ lasts from winter to summer and gradually propagates northeastward to South China Sea-subtropical western Pacific, which has remarkable influence on the summer convection of East Asia and position of SH, and forms the EA wave train. Therefore, it changes the water vapor transport and convection in the basin and changes summer precipitation there correspondingly.

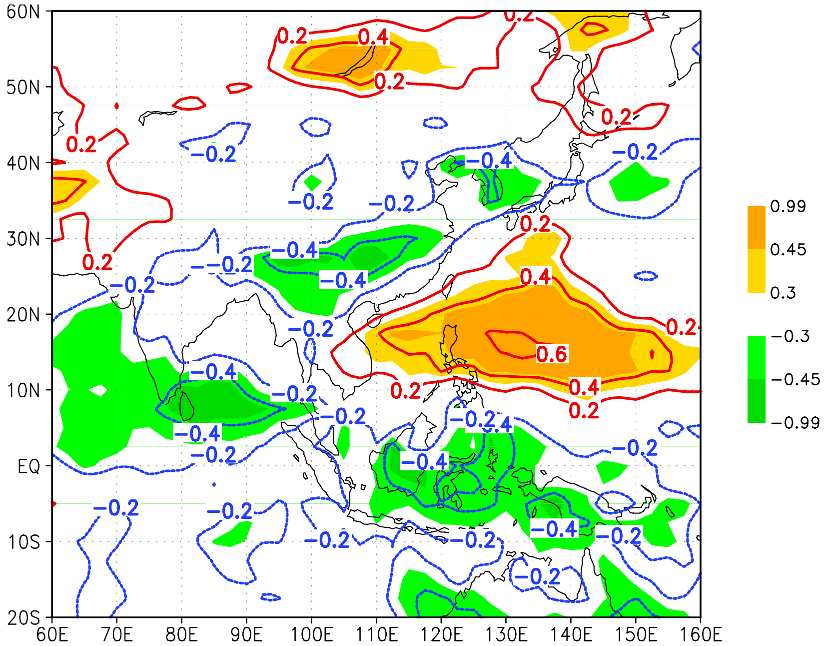


Figure 7. Distribution of the correlation coefficients between the summer rainfall of the basin and summer average OLR in East Asia from 1979 to 2008, with the light and heavy shades indicating the passing of 90% and 95% confidence tests, respectively.

5 INFLUENCE OF PRECEDING WINTER MJO ACTIVITIES TO THE MERIDIONAL AND ZONAL CONVECTION AND EASM

As shown in the analysis above, the preceding winter MJO activities have remarkable influence on the strength and position of ITCZ, which closely relates to the atmospheric circulation. The following section will further analyze how the atmospheric meridional and zonal convection in East Asia is changed when preceding winter MJO strength changes.

Figure 8 is the meridional-vertical cross-section in 1000–100hPa of different seasons of the composite differential ω value (the isoline, multiplied with (–100) to facilitate, the same below) and differential zonal-vertical wind vector in the preceding winter MJO active years deducting the inactive years during 1979–2008, in which the light and heavy shadow areas have passed differential significance testing of 90% and 95%. In the preceding winter MJO active years compared to the inactive years (Figure 8a), 5°S of winter (Figure 8a) is corresponding to two strong convection centers on ITCZ (Figure 5a), strong ascending airflow in Indonesia-tropical western Pacific in the vertical circulation field, and strong descending airflow over the eastern Pacific. In other words, Walker circulation strengthens, together with both of the east wind in the lower layer and the west wind in the high layer in the middle and western Pacific. Meanwhile, there is ascending airflow over the ocean west of Indonesia. For 5°N of spring (Figure 8b), due to ITCZ strengthening and propagating northward and a strong convection center in southwestern South China Sea (Figure 5b), the ascending motion is strong from the ocean in northwest of Indonesia to tropical western Pacific, being most significant in northern Indonesia and western Pacific in 140–150°E, with strong Walker circulation and an ascending branch that expands eastward. Both of the east wind in the low layer and the west wind in the high layer east of 150°E strengthen. For 20°N of summer (Figure 8c), there are three strong convection centers of ITCZ in northern Bay of Bengal, South China Sea and subtropical western Pacific (Figure 5c), the convective ascending motion from northern Bay of Bengal to subtropical western Pacific strengthens, and strengthened descending airflow appears in subtropical central and eastern Pacific to form a strong zonal circulation. It is the most obvious in subtropical western Pacific in 140–150°E, which is beneficial to the successive control of the subtropical high to the basin and less summer precipitation there.

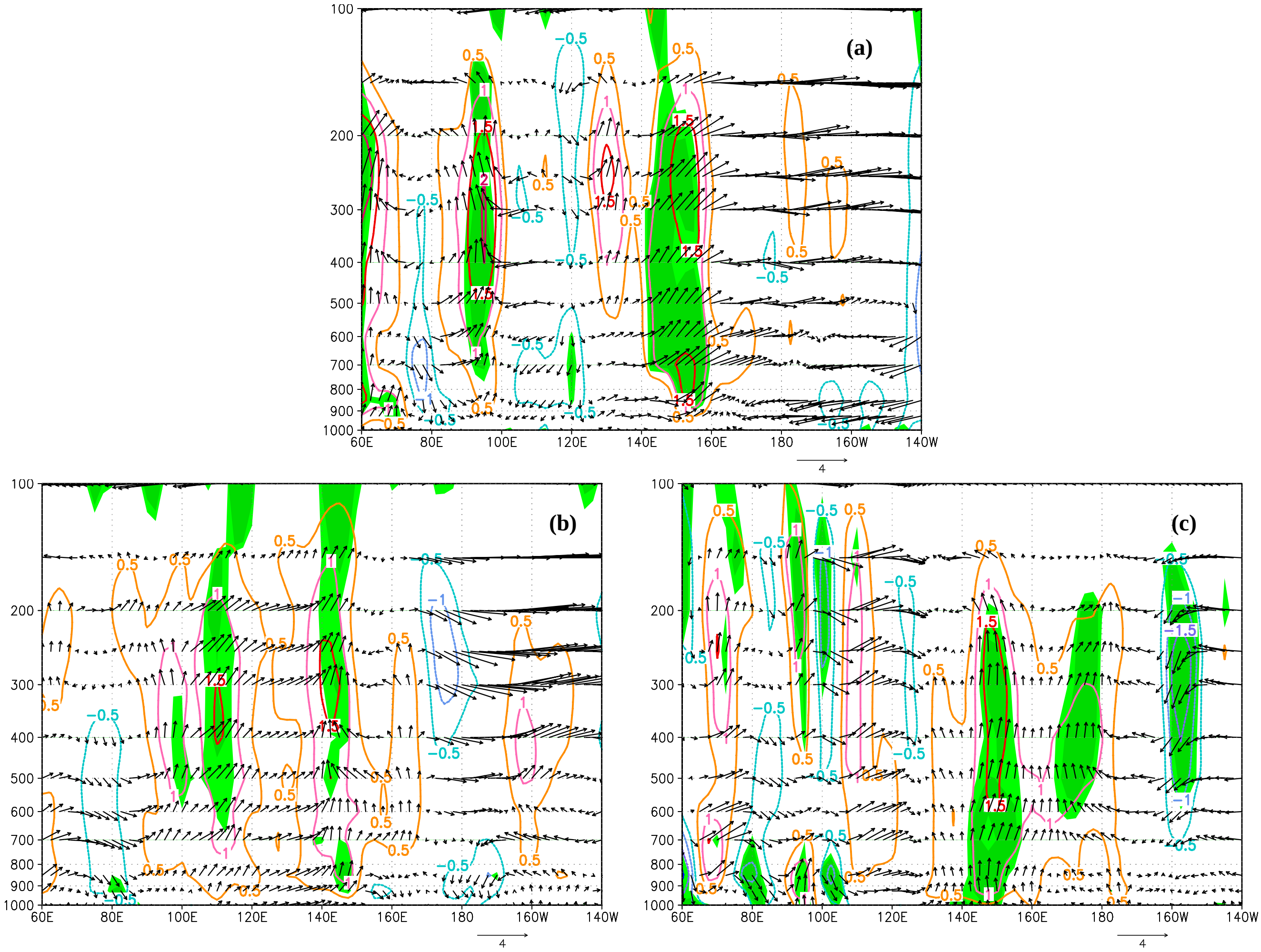


Figure 8. Composite ω differences determined by subtracting active preceding winter MJO years from inactive MJO years (contours, which are multiplied by (–100) in the unit of 100 Pa s^{-1}, with the light and heavy shades indicating the passing of 90% and 95% significance tests, respectively and the longitudinal-vertical cross-sections in 1000-100 hPa of latitudinal-vertical vector wind differences on 92.5°E in winter (a), 115°E in spring (b), and 120°E in summer (c), from 1979 to 2008. Unit: m s^{-1}

Figure 9 is the zonal-vertical cross-section in 1000-100hPa of different seasons of the composite differential ω value and differential meridional-vertical wind vector in the preceding winter MJO active years deducting the inactive years during 1979–2008, in which the light and heavy shadow areas have passed significance tests of 90% and 95%, respectively. As shown in the figure, in the preceding winter MJO active years compared to the inactive years, 92.5°E of winter (Figure 9a) is corresponding to an ITCZ strengthening and expanding northward and a strong convection area in the sea area southwest of Indonesia (Figure 5a), the ascending airflow strengthens remarkably in the tropic Indian Ocean and western Indonesia, i.e. the ascending branch of Hadley circulation strengthens. In 115°E of spring (Figure 9b), with ITCZ strengthening and locating northward and its strong convection center in southwestern South China Sea (Figure 5b), both of the ascending airflow in Indonesia-southwestern South China Sea and the descending airflow in northern South China Sea-South China is strong, a local meridional circulation circle is formed and the north wind in the low layer in South China Sea strengthens obviously, further maintaining activities of ITCZ. In 120°E of summer (Figure 9c), due to the strong convection center of ITCZ in South China Sea (Figure 5c), both of the ascending airflow in northern South China Sea-southern South China and the descending airflow in the basin are strengthened to form a strong local meridional circulation, an EA wave train at intervals of "+, – , +" out-of-phase distribution is formed in South China Sea, the basin and the region north of 35°N, and the precipitation in the basin reduces due to the control of descending airflow.

The above changes of vertical circulation in different seasons are in accord with the convection situation in Figure 5, i.e. when the preceding winter MJO is active, ITCZ strengthens and locates northward in winter, spring and summer, with convection centers distributed abnormally and the meridional and zonal circulation changing accordingly. When summer comes, the zonal circulation in subtropical Pacific strengthens, and its abnormal ascending airflow in subtropical western Pacific helps it control the basin for quite a long time. Meanwhile, a strengthened local meridional circulation exists in northern South China Sea-the basin, which intensifies the descending airflow in the basin, forming the EA wave train and making this region one with high temperature and less rain in summer.

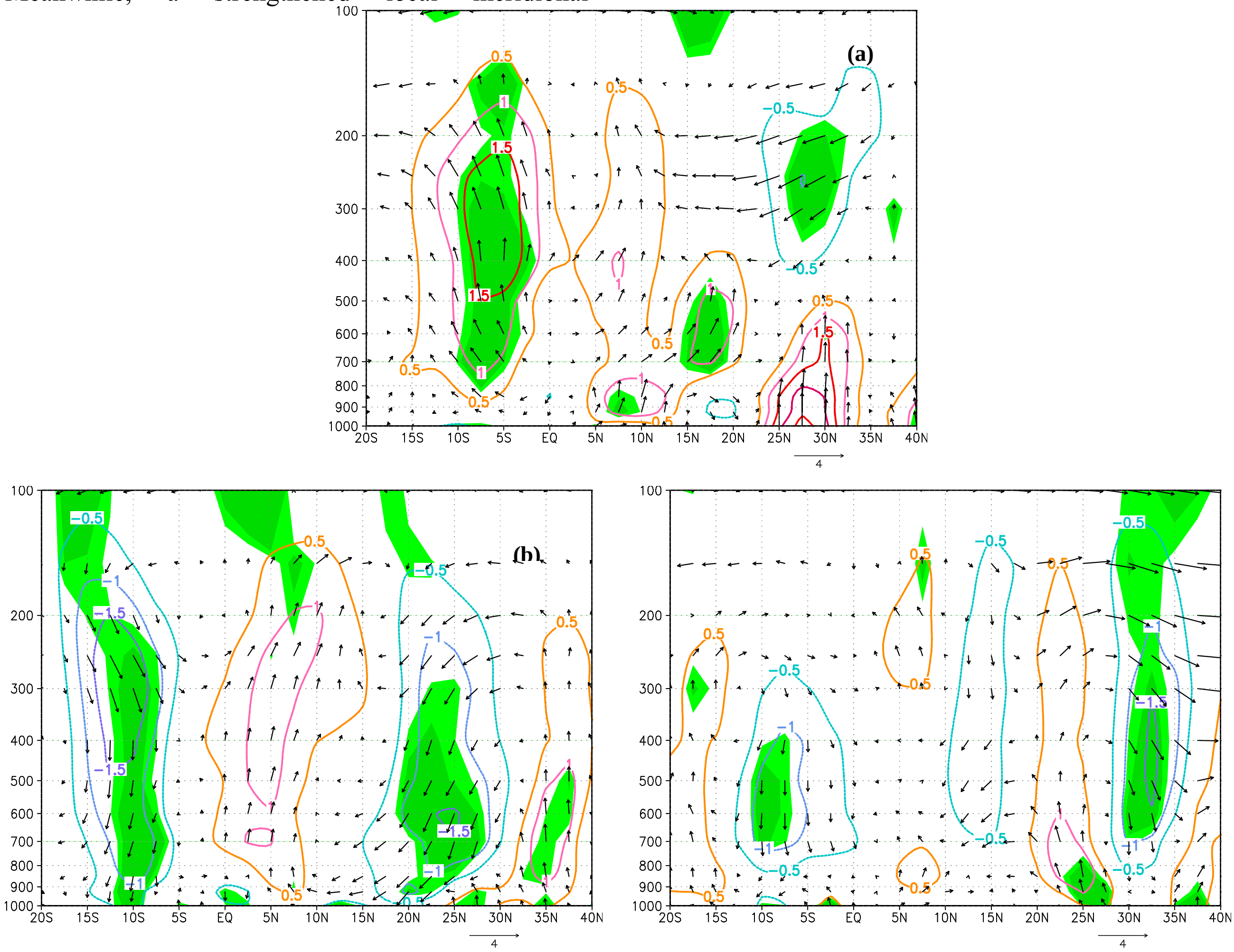


Figure 9. Same as Figure 8 but for the longitude-vertical cross-sections of latitudinal-vertical vector wind differences.

Figure 10 is the summer geopotential height and horizontal wind anomalies at the 850 hPa level that are composite for preceding winter MJO active years (a) and the inactive years (b). As shown in Figure 10a, when the preceding winter MJO is relatively active, the EA wave train of "–, +, –" distribution is formed in the summer geopotential height field of 850 hPa in South China Sea-subtropical western Pacific, the region north of the basin to Japanese islands, southern Okhotsk-Bering Sea; the geopotential height in South China Sea-subtropical western Pacific is relatively low while that in the north of the basin is relatively high, making the subtropical high located northward to the basin, where successive descending airflow remains, being not beneficial to the formation of ascending condition for precipitation. Meanwhile, the east wind prevails in the basin, which prevents the southwest wind from transporting water vapor to this region in summer, thereby reducing the precipitation. The situation in Figure 10b is just opposite. When the preceding winter MJO is inactive, South China Sea-the basin belongs to a positive region with the subtropical high located southward. The basin remains at the northwestern edge of the subtropical high with the southwest wind prevailing, which is beneficial to water vapor transport. As a result, the summer precipitation in the basin increases.

Besides, from the angle of EASM, when the preceding winter MJO is relatively active (Figure 10a), the negative geopotential height area in South China Sea-subtropical western Pacific indicates strong convection there, i.e. the East Asian monsoon trough deepens; while the positive area north of the basin-Japanese islands indicates weak convection there, i.e. the Meiyu front weakens. Both of them form opposite features from north to south, beneficial to the EASM strengthening. Meanwhile, the circulation field in the low layer also coordinates with above features. Strengthened east wind prevails in the Meiyu front region north of 30°N, while strengthened west wind prevails in the subtropical East Asia monsoon trough region. As Zhang et al.[29] pointed out, as a vital basis for the strength of EASM, East Asia monsoon trough is deepening corresponding to strengthened west wind in the low layer, being beneficial to EASN strengthening. Therefore, the powerful EASM directly enters eastern China and surpasses the basin. So EASM in the basin is relatively weak, which is controlled by the subtropical high with high temperature and less rain in summer. However, when the preceding winter MJO is inactive (Figure 10b), the subtropical East Asia monsoon trough is in an abnormally positive area, suggesting a weakened East Asia monsoon trough. The situation of east wind prevailing in the though area and west wind prevailing in the Meiyu front region corresponds to EASM weakening. A weaker EASM enters the basin along the external edge of the subtropical high and remains in this region for a long duration, with sufficient water vapors allocated with uplifting condition to lead to more summer precipitation.

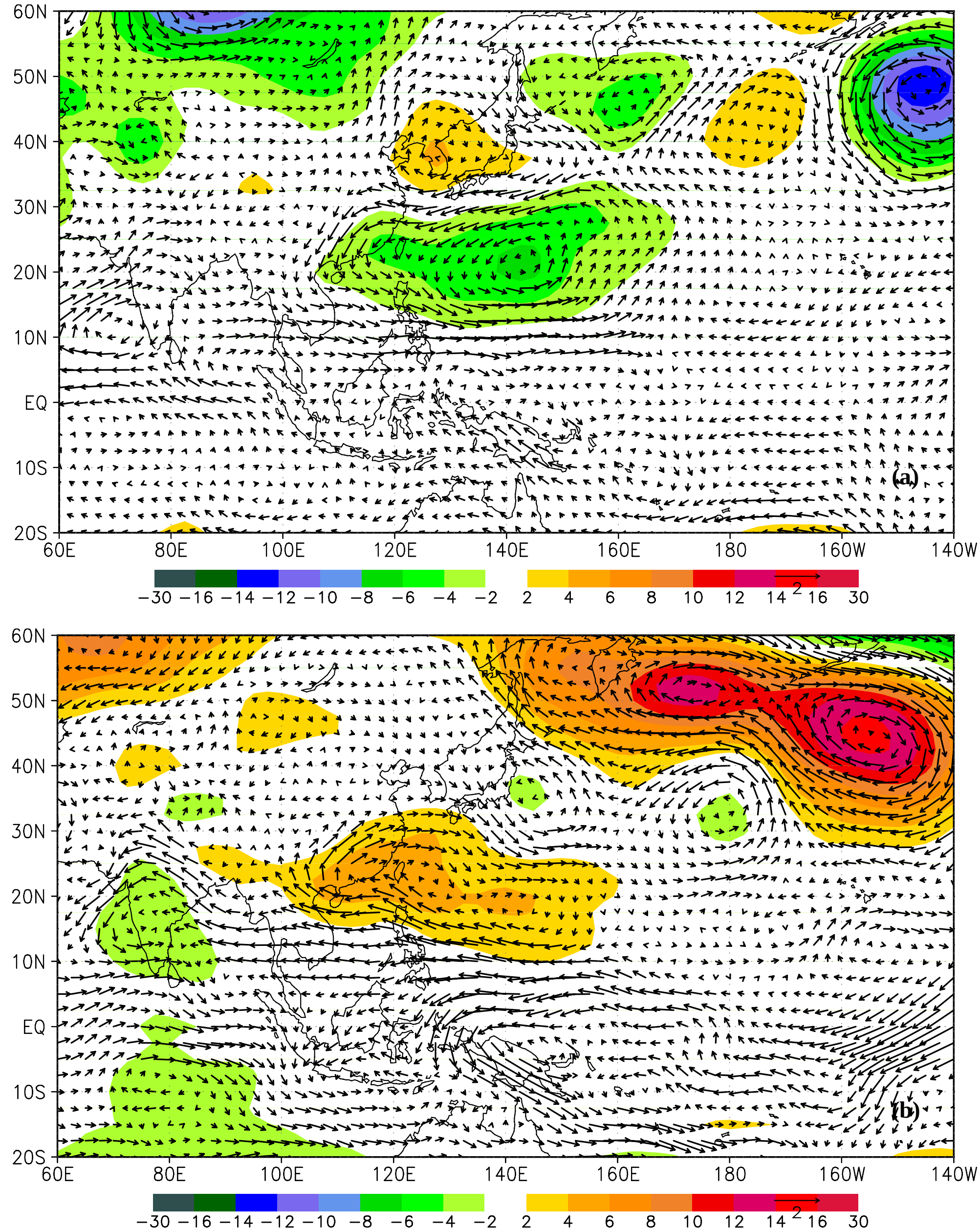


Figure 10. Composite 850 hPa geopotential heights (units: m) and horizontal winds (units: m s^{-1}) for active preceding winter MJO years (a) and inactive ones (b), averaged over the summers of 1979–2008.

It can be concluded that, by influencing the position and strength of ITCZ from winter to summer, the abnormal activities of preceding winter MJO has further impact on the atmospheric circulation and the strength and coverage of EASM, thereby influencing the summer precipitation in the basin.

6 CONCLUSION AND DISCUSSION

In this paper, the first two series (RMM1 and RMM2) of All-season Real-time Multivariate MJO Index (RMM Indexes) are computed to obtain the interannual variation of preceding winter MJO, according to which the active (or inactive) years of preceding winter MJO are divided. By utilizing the OLR data and reanalysis data of wind, geopotential height and ω provided by NCEP/NCAR, the CMAP precipitation data and the daily data of China's 160 stations from 1979 to 2008, we have learned that preceding winter MJO activities and summer precipitation in the basin is of significantly negative correlation, i.e. when preceding winter MJO is relatively active, the summer precipitation in the basin decreases, and otherwise it increases. Then, we analyzed the causes from the convection conditions, ITCZ, meridional and zonal circulations, EASM and EA wave train etc.

When the preceding winter MJO is relatively active, its release of potential heat facilities ITCZ to strengthen, locate northward in winter, and propagate northeastward. This abnormal situation lasts from winter to summer. In mid-May, ITCZ jumps northward to South China Sea, the subtropical high withdraws eastward, SCSSM sets off and strengthens. In summer, ITCZ strengthens and propagates to South China Sea-subtropical western Pacific, zonal circulation of subtropical Pacific strengthens, abnormal situation of ITCZ maintains, a local meridional circulation of the South China Sea- the basin forms, and the basin is controlled by descending airflow. Meanwhile the EA wave train forms in South China Sea-subtropical western Pacific, the basin-Japanese islands and Okhotsk-Bering Sea. The East Asian monsoon trough deepens and the Meiyu front weakens, an opposite feature forms from south to north, EASM strengthens and advances northward, so that summer monsoon is weakened in the basin which is controlled by the subtropical high continually, with less rain in summer.

On the contrary, when the preceding winter MJO is inactive, ITCZ weakens and locates southward, the subtropical high locates southward in summer, the basin remains in the northern edge of the subtropical high with the southwest wind prevailing and in a large convective ascending area, being beneficial to water vapor transport. Meanwhile, the East Asian monsoon trough weakens with the east wind prevailing while the Meiyu area is prevalent with the west wind and a weakened EASM, so that summer monsoon is weakened in the basin where precipitation increases.

Therefore, as an indicative signal, the preceding winter MJO can provide some forecasting basis for the precipitation in the basin.

Meanwhile, in our research we also find that when preceding winter MJO is strong, the sea surface temperature in tropical eastern Pacific is reduced obviously in winter i.e. during a La Niña event (Figure omitted). In other words, the abnormal SST of ENSO event in winter results in abnormal MJO activities in the same period and further influences the convection and circulation fields later. Since the response of tropical atmosphere to abnormal SST needs 2–4 weeks and that of subtropical atmosphere to abnormal tropical atmosphere needs more than 3 months[27], the change of MJO activities in winter will influence the subtropical and middle latitudes climate in subsequent summers. Further research on the influence and its mechanism is needed.

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