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COMPARISON OF THE EFFECTS OF ANOMALOUS CONVECTIVE ACTIVITIES IN THE TROPICAL WESTERN PACIFIC ON TWO PERSISTENT HEAVY RAIN EVENTS IN SOUTH CHINA

BAO Ming (鲍名)

(Center for Monsoon System Research, IAP, CAS, Beijing 100080 China)

Abstract: The different effects of anomalous convective activities in the tropical western Pacific on two persistent heavy rain events in South China in 2005 and 2006 have been compared in this study. The data used consist of NOAA Outgoing Longwave Radiation (OLR) data, the NCEP-NCAR reanalysis and precipitation from meteorological stations in South China. Results show that the persistent heavy rain in 2005 was related to the 10-25-day westward propagation of convective activities in the tropical western Pacific from about 150 °E. The physical mechanism is interpreted as a Gill-type response of subtropical anticyclone westward extension during weak convective activities period over the Philippine Sea. Our researches also show that the persistent heavy rain in 2006 has longer period than that in 2005, and the subtropical anticyclone persists westward in the earlier summer which is possibly related to the lasting anomalous strong convective motion in the southern branch of Intertropical Convergence Zone (ITCZ) in the tropic western Pacific. The anomalous convective activities affect the local Hadley circulation over the western Pacific with anomalous ascending motion south of the equator and anomalous descend motion north of it, in favor of the westward extension of the subtropical anticyclone for a long time. Comparison between the two persistent heavy rain events indicates different physical effects of convective activities in the tropical western Pacific, though both effects are helpful to the subtropical anticyclone westward extension as a common character of large-scale circulation backgrounds for persistent heavy rain events in South China.

Key words: annually first rainy season in South China; persistent heavy rain; convective activities; tropical western Pacific; physical effects

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1 INTRODUCTION

Subject to monsoon climate, the low-latitude south of China has abundant rainfall from April to September, in which the time from April to June is the yearly first raining season. Due to the difference in monsoon systems, the wetness in the raining season changes significantly on the interannual scale [1 – 3]. Interannual anomalies of the season have drawn much attention. To determine its causation, previous work used to focus on the signals and roles of perpetual snow in winter and spring in the Tibet-Qinghai Plateau [4, 5], SST anomalies in tropical oceans, like El Nino [6], Indian Ocean – equatorial Pacific[7] and offshore SST[8], and tropical convection in preceding and current time[9] in the interannual variation of drought and flood in the southern parts of Yangtze-Huaihe River basins. Work has also been done on the anomalies of the circulation of monsoon systems associated with the wetness anomalies of South China during the raining season [10 – 11]. They have all increased the understanding of the causation of drought or flood in the area for this time of the year and helped in the forecasting the climatic anomalies of the season.

In China, the frequency of summertime heavy rains is closely correlated with the total rainfall on the interannual scale for the monsoon area [12]. The heavy rain is an important trigger of floods, which can happen over extensive areas if the rain is regional and sustainable [13]. Recently, an objectively defining

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Biography: BAO Ming, male, assistant researcher, Ph.D., mainly undertaking the research on monsoon dynamics.

E-mail: baom@mail.iap.ac.cn

method has been used to study sustaining heavy rains in China and their large-scale background from 1951 to 2005[14]. It enables successful retrieval and statistical determination of the episodes of sustaining heavy rain, which include a typical case of 2005 that is going to be studied in this work. Though a process on the synoptic scale, the sustaining heavy rain causes floods with climatic significance due to high rain rate, long duration and large area.

In view of a previous finding that the sustaining heavy rain of South China in 1994 has good correspondence with the northward transportation from the South China Sea of the 30- to 60- low-frequency oscillation of tropical convection [15], this work will study the relationship further between this type of rain and convection over tropical western Pacific in 2005 and 2006 and the physical processes by which convection affects the generation of the sustaining heavy rain in South China. On the basis of that, attempts will be made to link the sustaining rain with the large-scale background via the tropical convection.

2 SUSTAINING HEAVY RAIN IN 2005 AND 10 – 25 DAY OSCILLATION OF CONVECTION IN TROPICAL WESTERN PACIFIC

2.1 *Variation of western Pacific subtropical high during the sustaining heavy rain*

Fig.1a gives the 500-hPa geopotential height averaged over 112.5°E – 122.5°E and day-to-day variation of 700-hPa meridional wind averaged over 115°E – 120°E. It can be known from the figure that there are four stages of daily variation of the geopotential field within the range of longitudes. Significant differences are identified from comparisons between contour 5880 at 500 hPa averaged over the four stages on the longitude/latitude plane. It is then known that the 20-some-day east-west oscillation is a main feature of the intraseasonal variation of the subtropical high in western Pacific during the early summer of 2005 while the strengthening and intensification of the subtropical high makes a favorable condition for the sustaining heavy rain in South China. Such large-scale circulation background agrees with the common characteristics retrieved in [14] and the June 17 – 24 hard rain process is also the typical episode retrieved in [14].

2.2 *Role of westward propagation of the 10-25-day oscillation of convection over tropical western Pacific*

There are not only MJO that oscillates on the scale of 30 to 60 days but also westward transportation of 10-25-day oscillation in the convection of tropical western Pacific [16 - 21]. Then, will the westward transportation provide the sustaining heavy rain with stable atmospheric circulation background by way of affecting the subtropical high? A time-latitude cross-section is made of OLR (Fig.2). From a comparison of Fig.1a and Fig.2, it is known that the intraseasonal variation of the subtropical high agrees well with that of convection at 10°N – 15°N, 120°E, especially around June 5 and between June 26 and July 7 (Fig.1a). In addition to the westward transportation of the 10-25-day low-frequency oscillation, there is also local variation near 110°E – 120°E. When examined carefully, it is also found to be closely related with the short-term change of the subtropical high between 10°N and 20°N. It is then clear that during the pause (Section C) between two processes of intense convection in Sections B and D propagating to the Philippines and South China Sea, convection weakens significantly while the subtropical high extends westward and intensifies, forming favorable large-scale circulation condition for the occurrence of the sustaining rain. Meanwhile, two waves of cold air advanced southward between June 14 and 22, which is also a favorable condition for this type of weather.

It is then known from the analysis above that the sustaining rain studied above is associated with the westward propagation of the 10-25-day oscillation of convection in tropical western Pacific and the Gill circulation response for the westward extension and intensification of the subtropical high is corresponding to a low-frequency break of the intense convection near 120°E.

3 SUSTAINING HEAVY RAIN IN 2006 AND ITCZ ANOMALIES IN TROPICAL WESTERN PACIFIC

3.1 *Variation of western Pacific subtropical high during the sustaining heavy rain*

Fig.1b gives the day-to-day variation of the subtropical high during the yearly first raining season in 2006, with the caption being the same as that of Fig.1a. Beginning from May 20, contours 5860 – 5880 stayed in South China until June 16, keeping the heavy rain there for almost a month, which was intermittent with two short breaks caused by the southward movement of the subtropical high and cold air, respectively. The subtropical high moved back northward after June 16, ending the rain in South China. In general, the subtropical high has been extending westward before the date except in the time with typhoon effect. It agrees with the common characteristics of such sustaining heavy rain [14]. It shows that the two rains have happened against the same background of large-scale circulation as far as

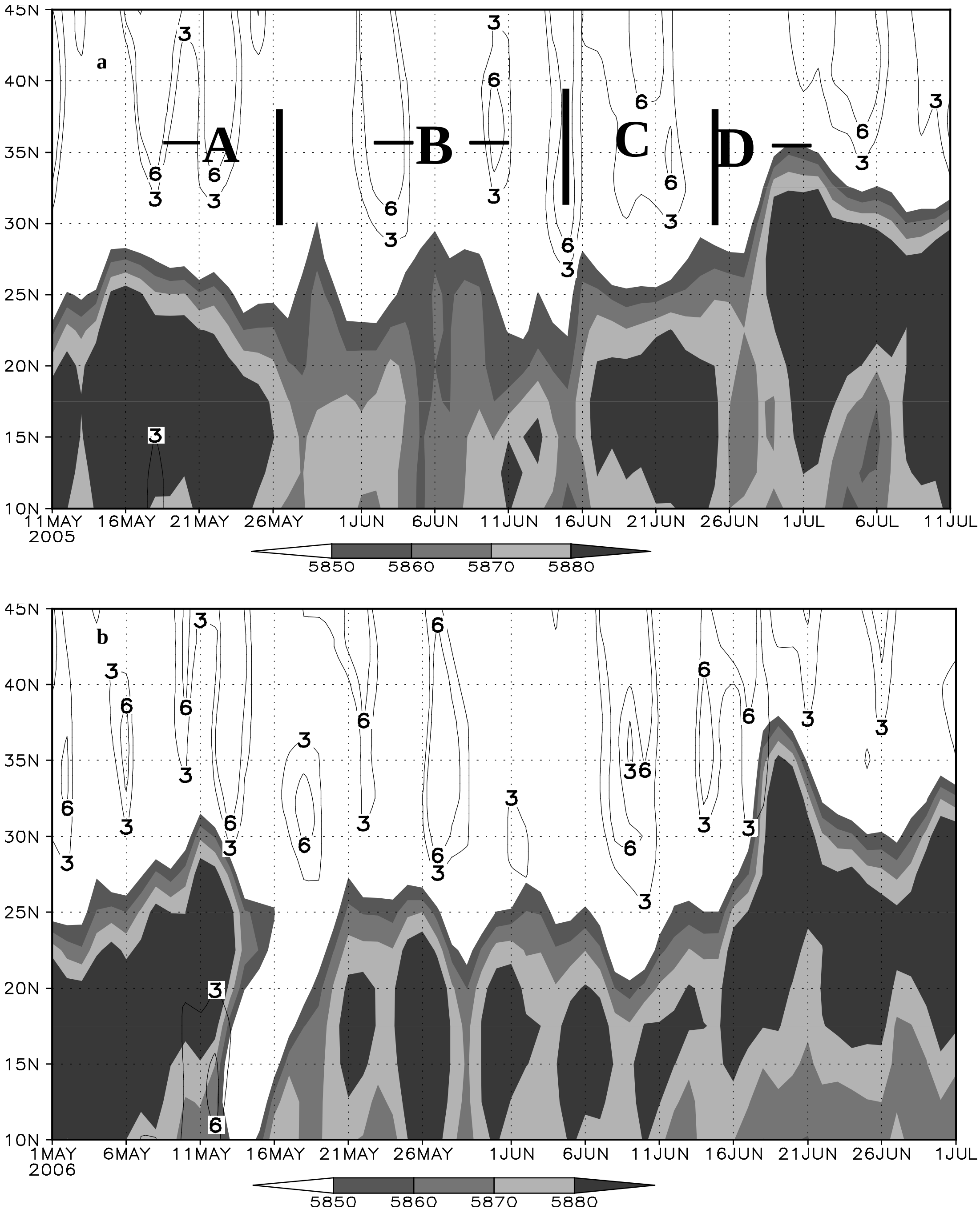

Fig.1 Day-to-day variation of 500-hPa geopotential contours averaged over 112.5 – 122.5 (shades) and 700-hPa meridional wind averaged over 115 – 120 (contours) in the early summer of 2005 (a) and 2006 (b). The shades are for range of variation of the contours 5850 – 5880 in the interval of 10 (unit: gpm); Negative contours indicate northerly wind and are assigned the values of 3 and 6 (unit: m/s).

the subtropical high is concerned. Compared with 2005, though, the rain of 2006 had a longer period of activity and the subtropical high had longer time of westward extension. In the last section, the westward propagation of the 10-25-day low-frequency oscillation of the tropical western Pacific convection in 2005 is shown to play a role by providing large-scale circulation background for the sustaining rain. The rain of 2006 is obviously different from that of 2005 and may be related with a longer westward extension of the subtropical high.

3.2 *Role of ITCZ in tropical westward Pacific*

Day-to-day variation of the convection on all

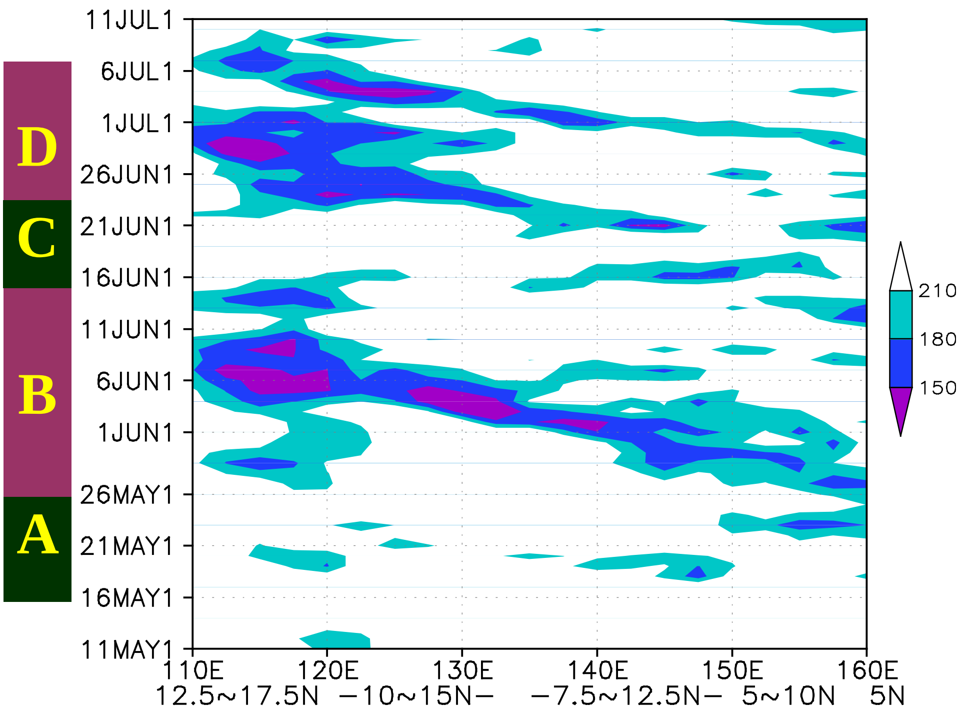

Fig.2 Time-latitude cross-section of day-to-day variation of OLR over western Pacific in the early summer of 2005. The shades indicate intense convection where OLR is lower than 210 W/m^2 at interval of 30 W/m^2.

latitudes is studied (figure omitted). Compared with the climatological mean, the year 2006 witnesses consistently intense convection near 5°S averaged over 120°E - 140°E. For the time after Typhoon Chanchu till June 16, however, convection averaged over the boreal 120°E - 140°E stays on a high level near 5°N - 10°N and a convergence zone of convection over the tropical western Pacific remains negatively anomalous in the southern branch over 120°E - 140°E. There is a pattern of being stronger in the south than in the north.

In 2006, cross-equatorial convergence at lower tropospheric levels is significantly weakened at 0 – 5°N. Consequently, the center of maximum ascending motion in local meridional circulation is over the Southern Hemisphere, restricting the vertical ascending motion over the area of the Philippine Sea while the ascending motion is weakened in western Pacific (115°E – 135°E, 5°N – 20°E), forming a circulation background favoring the persistence of the rain zone over South China.

For analyses of other aspects, refer to the Chinese edition of the journal.

5 SUMMARY

Taking two sustaining heavy rains in 2005 and 2006 as the objects of study, this work studies the convection of tropical western Pacific in terms of the physical role of large-scale circulation background or climatic background in the rains and compares the two typical rains. It is shown in diagnostic analysis that the 2005 heavy rain is associated with the westward propagation of the 10-25-day low-frequency oscillation of the convection in tropical western Pacific; A Gill-type circulation response of weak convection is shown when the subtropical high extends westward and strengthens during tow low-frequency breaks of the convection propagation. The heavy rain of 2006 is also related with persistent westward extension of the subtropical high. Because it is anomalously intense over extended period of time, the southern branch of the dual ITCZ in tropical western Pacific causes the local Hadley cell to shift southward, and with weakened northern branch of convection and ascending motion over the area of 115°E – 135°E, 5°N – 20°N, making it favorable large-scale background of circulation for the sustaining heavy rains. The two sustaining heavy rains of South China took place under a common large-scale circulation background of persistent extension of the subtropical high, which is also consistent with the common feature of a typical pattern in documentation [14]. What is different is that the two cases have different lengths of duration in response to different time of westward extension of the subtropical high. It is resulted from a different physical role of convection in tropical western Pacific. The finding is consistent with that of [15] that a sustaining heavy rain in 1994 is related with the northward propagation of the 30-60-day low-frequency oscillation of the tropical convection [15]. All of them have shown that the anomalies of tropical western Pacific convection can provide large-scale background of circulation for sustaining heavy rains in South China via multiple physical processes. It needs to be noted, however, large-scale or climatic background roles, instead of local scale roles, are emphasized in the current study.

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