Dynamics of Climatological monsoon break over the Indochina Peninsula in northern summer.

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Abstract

The climatological pentad mean annual cycle derived from 32 stations located in Thailand shows a rainfall dip in the middle of rainy season around Julian pentad 34 to 36 (June 14-29). The Indochina rainfall system can be divided into two subsystems in the vicinity of climatological monsoon break (CMB). The rainfall subsystem of the former is characterized as a monsoon southwesterly system, while that of the latter is characterized as a tropical depressions system. The CMB is an important monsoon singularity event on the monsoon seasonal march over the entire Asian-Pacific region.

Key words: climatological monsoon break, topographic effect, rainfall system

1. Introduction

In the last decade, there has been a surge of interests in study of the monsoon over Indochina. The Indochina summer monsoon exhibits many peculiar features that distinguish it from the adjacent Indian and the western North Pacific (WNP) (including the South China Sea (SCS)) monsoons.

Matsumoto (1997) noted that before the Thailand monsoon onset in mid-May, there are many significant rainy events, which are referred to as pre-monsoon rain. From the pre-monsoon rain to the summer monsoon onset, the local rainfall normally increases progressively heavier so that the onset is more a gradual process rather than an abrupt onset from very dry conditions such as the ones over India or the SCS. Based on analysis of the rainy season characteristics, Wang and Lin (2002) pointed out that the rainy season over the Indochina region differs in many essential aspects from adjacent Indian and the WNP summer monsoons, thus this region might serve as a transition zone (boundary) between the two tropical monsoon (the Indian and the WNP) subsystems.

A peculiar feature of the Indochina monsoon rainy season is the significant bimodality with a major rainy peak in September and a minor peak in late May (P28-32) (Fig. 1). Around P35 (late June) there exists a notable monsoon break in the climatological annual cycle of Thailand rainfall (Fig.1). This mid-summer break will be referred to as climatological monsoon break (CMB) in this study. Examination of each year of rainfall indicates that the CMB has strong tendency to occur in late-June. Thus the CMB is an important monsoon singularity event on the monsoon seasonal march. To the authors' knowledge, the cause of the CMB over Indochina has not been studied. The primary purpose of this study is to document the circulation changes before, during, and after the CMB and to

understand the basic processes that are responsible for the Indochina CMB.

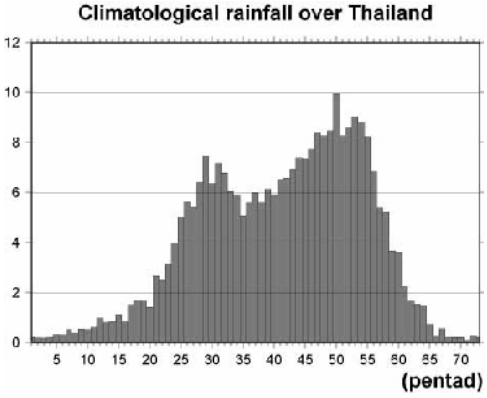

Figure 1: Pentad climatological time series of rainfall index for 50 years in units of mm/day. The index was averaged rain gauge observations at 32 stations.

2. Data

The rainfall data, which consist of 32 stations in Thailand from 1951 to 2000 compiled by Thai Meteorological Department (TMD) are used for this study. The percentage of missing data for each station is less than 1 percent.

To analyze large scale rainfall distribution, CMAP (Climate Prediction Center (CPC) Merged Analysis of Precipitation, Xie and Arkin, 1997) was used. This dataset covers global domain and is available for the period from 1979 to 2000 on 2.5 X 2.5 grids.

The National Center for Environmental Prediction (NCEP)/ National Center for Atmospheric Research (NCAR) reanalysis data were used to derive zonal and meridional wind (u, v) and geopotential height (z) at 850hPa at 2.5 x 2.5 each grid.

To describe climatological sub-seasonal variability, pentad data were calculated from daily data for each field.

Tropical cyclone tracks archived by the Typhoon Center of JMA for 20 years from 1981 to 2000 are also used.

3. Atmospheric circulation associated with Indochina rainfall

3.1 CMB

To investigate the atmospheric circulation fields associated with the CMB, difference in 850hPa wind and geopotential fields (upper panel), and rainfall (lower panel) between before CMB (P31-33) and during CMB (P34-36) are shown in figure2, respectively. In general, the monsoon westerly is dominant in this period (not shown). In the transition period to CMB, the monsoon westerly is enhanced along the latitudinal belt centered on 15N-20N, especially over Indian monsoon section. An anti-cyclonic ridge is located over the west of Indochina Peninsula (Bay of Bengal, BOB) and the western Indochina Peninsula. In the lower troposphere the anti-cyclonic ridge is clearly fixed with the mountain ranges. The anti-cyclone coincides with the decreased rainfall over the western Indochina Peninsula. At the same time, a cyclonic circulation and a cyclonic trough appear over the SCS to the WNP. In that area, rainfall reasonably increases. Thus the enhancement of the low-level monsoon westerly along 15N-20N is likely responsible for the CMB, because the intensified monsoon westerly flows over the north-south oriented Indochina mountain range, generating topographic Rossby waves. The increased rainfall over the SCS is considered as the downstream impact of the stationary-Rossby waves. Therefore the CMB is not a local phenomenon, it is significant for monsoon seasonal march.

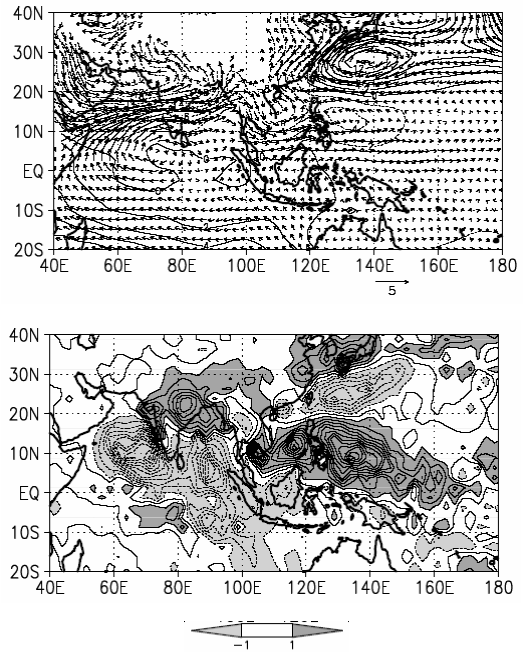

Figure 2: Difference in 850hPa winds and geopotential height (upper panel) and precipitation rate (lower panel) between P31-33(before CMB) and P34-36 (CMB). Contours show geopotential height and precipitation rate at an interval of 2gpm and 1mm/day, respectively. In the lower panel, light shading denotes rainfall decreased and heavy shading denotes rainfall increased.

3.2 The difference in rainfall system between before and after the CMB

Figure 3 shows the difference in 850hPa winds and geopotential height between P28-32 (the 1st peak) and P47-P51 (the 2nd peak). The monsoon westerly is dominant during both the periods. The cyclonic circulation is observed over the SCS and the WNP, which suggest that the rainfall system of 2nd peak is characterized as tropical depressions. During the 1st peak, the increase rainfall is likely to be caused by the intensification of the monsoon southwesterly. Thus the rainfall system of the 1st peak is characterized as the monsoon southwesterly from BOB.

Figure 4 shows the tracks of tropical cyclones over the WNP. Figure 4 clearly shows that the 1st peak has little tropical depressions, whereas the 2nd peak has numerous tropical depressions.

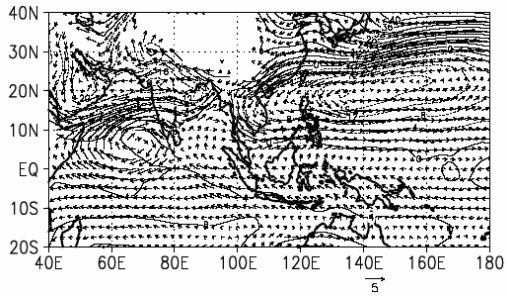

Figure 3: Difference in 850hPa winds and geopotential height between P28-32 (the 1st peak) and P47-51 (the 2nd peak). Contours show geopotential height at an interval of 4gpm.

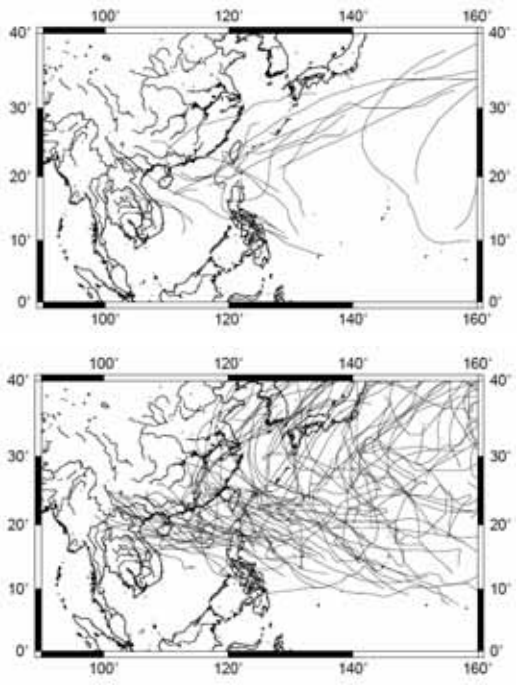

Figure 4: Tracks of tropical depressions (including typhoons) from 1981 to 2000 during the 1st peak (upper panel) and the 2nd peak (lower panel).

4. Conclusions and remarks

Major findings obtained in the study are summarized as follows;

1) Climatological 50-years mean pentad values of rainfall clearly show distinct climatological monsoon break (CMB) occurring over Thailand in late-June. It is found that CMB occurs in p34-36. The CMB has strong tendency to occur in late-June, which indicates the CMB is an important monsoon singularity.

2) The decreasing rainfall is associated with an anti-cyclonic circulation over the Bay of Bengal with decent northerly wind into the Indochina Peninsula. When the monsoon westerly is enhanced along the band centered on 15N-20N, the anti-cyclonic circulation is enhanced over the west of Indochina Peninsula. The enhancement of monsoon westerly is probably associated with northward expansion of the monsoon westerly, as a part of intraseasonal variation.

3) CMB corresponds to the anti-cyclonic circulation in the lower troposphere on just the western mountain range over the Indochina Peninsula. We suggest that the formation of anti-cyclonic anomaly over the Indochina Peninsula is affected by the topographic effect, which is like stationary-Rossby wave caused by a coupling of the monsoon westerly and topographic effect. At the same time, the cyclonic circulation is enhanced over the South China Sea and Philippine Sea, which corresponds to the onset of rainy season over Philippine Sea and the drastic increase of the rainfall over the South China Sea.

4) We can identify that the Indochina rainfall system can be divided into two subsystems in the vicinity of CMB. The former has a peak rainfall in late-May to early-June that is caused by the intensification of monsoon southwesterly along 10N. While the latter that has a peak rainfall in early-September that is caused by the appearance of active tropical depressions. Moreover the latter is also associated with CMB, because the CMB propagates eastward active rainfall area to SCS and the WNP. The CMB plays a significant role as bridge to transfer active rainfall area to the SCS and the WNP regions. Moreover Indochina rainfall is affected from the transferred active rainfall area as tropical depressions.

Reference

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