Tropical cyclone activity over Western Pacific Associated with Tibetan Plateau Heating forcing

Liu Xin and Huang-Hsiung Hsu
Department of Atmospheric Sciences, National Taiwan University

中文摘要

本文利用 1958-1997 年 NCAR/NCEP 重分析資料研究了青康藏高原加熱與西北太平洋地區的熱帶,副熱帶氣旋活動的關係.

夏季青康藏高原地區是北半球中緯度的加熱源區.很多研究表明高原加熱強迫在東亞打氣環流和夏季風建立中扮演著重要角色.本研究結果指出青藏高原加熱與西北太平洋地區熱帶氣旋活動的密切關係.高原加熱強迫會在亞洲大陸太平洋沿岸地區產生出類似 Rossby 波列.此波列當加熱強時,有利於西太平洋副熱帶高壓西伸,導致東亞海域35度以南熱帶氣旋活動減少.反之當高原加熱弱時,則熱帶氣旋活動增加.

關鍵詞:熱帶氣旋,青藏高原熱力強迫

Abstract

This paper presents the results of an investigation on the variations of tropical and sub-tropical cyclone (TC) activity over the western North Pacific (WNP) associated with the variation of Tibetan Plateau heating force (HTP) during boreal summertime. The study is based on the activity of TC in summer time (June to August) during the period 1958-1997.

The diabatic heating over the Tibetan Plateau is a significant diabatic heating area in mid-latitude of North Hemisphere in boreal summertime. There are recent indications that HTP forcing plays impotent role to the eastern Asia atmospheric circulation and the Asian summer monsoon. In this paper, it is investigated that the relationship between the HTP and East Asia circulation by using correlation and composition methods. It is found that the HTP is stronger than normal, which induced a Rossby Wavelike train in the region of the eastern coast of Asia to western Pacific Ocean. The wave train will intensify a positive geopotential height anomaly (negative relative vorticity anomaly) in the region of southern China to the western Pacific at 15 to 30°N latitude. It will intense the subtropical anticyclone stronger than normal near east Asian area, and induce the western Pacific subtropical anticyclone extending westward to approach eastern coast of Eurasian continent. It led to the sub-tropical cyclone activity is below normal years. Especially occurred in neighbor region of Taiwan. In conversely as the HTP is weaker than normal, the western Pacific subtropical anticyclone also weak and contract eastward, the sub-tropical cyclones activity is invigorated in neighbor region of Taiwan.

Keywords: tropical cyclone, Tibetan Plateau heating forcing

Introduction

East Asian summer monsoon rainfall (EASMR) is greatly affected by the tropical cyclone (TC) activity over the Western North Pacific (WNP). This TC and EASMR variability is well correlated with the El Niño-Southern Oscillation (e.g., Weng et al. 1999, Chen 2000, Lau and Weng 2001). Other studies found that the EASMR variability is associated with a north-south·

circulation oscillation called the Pacific-Japan pattern and suggested that this pattern is forced by the anomalous sea surface temperature (SST) in the tropical Western Pacific (Nitta 1987, Lau 1992, Huang and Sun 1992). It has also been suggested that the Tibetan Plateau (TP) heating effect might also affect the TC activity and EASMR. However, the possible link between the TP and the TC activity variability is not as well studied as in the SST anomaly effect. This study reveals the close relationship between the TP heating and the TC activity and suggests that external conditions other than the SST anomaly should be considered to understand the interannual summer tropical cyclones activity variability.

Data

The monthly NCEP/NCAR reanalysis (Kalnay et al., 1996) from 1958-1997 were used in this study. The diabatic heating rate H, defined in the following equations, was estimated on a 1.875°×1.875° grid at 28 σ levels.

$$Q(\sigma)=SH(\sigma)+LH(\sigma)+RD(\sigma) \qquad (1)$$

where $SH(\sigma)$ denotes the vertical diffusion heating rate, $LH(\sigma)$ denotes the sum of latent heat released in deep and shallow convection and large scale condensation, and $RD(\sigma)$ denotes the net radiative heating at every σ level. The column heating is defined as

$$H=\frac{c_p p_s}{g}\int_0^1 Q(\sigma)d\sigma \qquad (2)$$

where c_p is the specific heat at the constant pressure, p_s is the surface pressure and g is the gravitational acceleration. An examination of the contribution from each heating component indicates that the column heating H is dominated by the latent heating. Other NCEP data were used on a 2.5°×2.5° grid. The Unisys weather hurricane/tropical data (http://weather .Unisys.com/hurricane) used in this study covers only the western North pacific area. The data during the 1958-1997 period were used to match the NCEP reanalysis.

Results

A heating index (hereafter referred to as HTP) was computed to represent the diabatic heating over the Tibetan Plateau. It is defined as the area average of the H for those grid points where the altitude is above 3000 meters. The tropical cyclone tracks number is calculated in western North Pacific area, it is expressed as the monthly total number of tropical cyclone tracks passage into a 5°X5° longitude-latitude grid box with 4 times observation per day. We also compute a similar index ,TCI, based on tropical cyclone tracks number over 20°N-30°N, 115°E-130°E, near Taiwan region.

The correlation and composite method is used in this work, the result indicates that the correlation between the two indices based on the heating and TCI is about -0.4, which is significant at the 0.01significant level. The HTP represents the collective heating effect, while the precipitation could only reflect the amount of latent heat release. The HTP, which can be used as a forcing in the dynamical framework, is therefore chosen for this study.

The June-August (JJA) time series shown in Figure 1 fluctuates between 60 and 140 Wm^{-2} and exhibits multiple time scales. The inter-decadal fluctuation was marked by a dramatic shift in the late 1970s, which occurred concurrently with the well-documented climate regime shift. The HTP fluctuates between negative and positive values before the shift, but remains mostly positive afterward. The fluctuation before the shift exhibits larger amplitude and a longer period than its counterpart after the shift. We also can find the TCI fluctuation appears opposite phase against HTP. Quasi-biennial fluctuation is evident in the 1990's.

Eight strong and weak heating summers with the JJA HTP anomalies larger than or equal to one standard deviation were chosen for composite purpose to reveal the relationship between the TP heating, the tropical cyclone activity in western North Pacific and circulation in East Asia. Figure 2a presents the differences between the 200 hPa geopotential height composites for eight strong and weak cases. A wave-like structures emanate northeastward on the coast region of Euro-Asian continent. This wave-like pattern was also documented by Liu et al. (2002). Similar distribution is observed in the lower layers, the figure 2b indicates the difference composition on 500 hPa, and figure 2c indicates the difference of surface layer pressure. On figure 2b, we can find positive anomaly near Taiwan area, it benefits the western Pacific anticyclone westward extended. The westward extended anticyclone will extremely affect the tropical cyclone activity in the region. The large-scale circulation anomaly apparently modulates the interannual TC activity fluctuation.

Figure 3 shows the difference of tropical cyclone track number. It is found that summer tropical cyclone activity is more invigorative in weak TP heating years. A similar tropical cyclone activity distribution also exists in spring season, which is presented in Figure 3a.

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Figures:

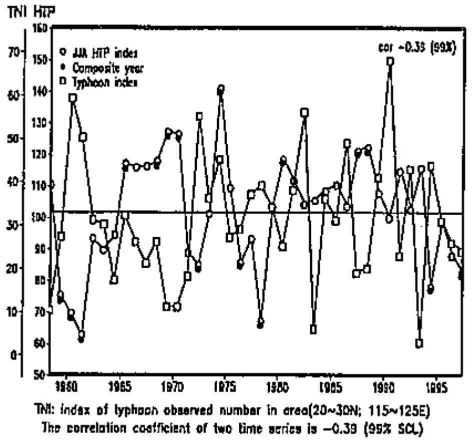

fig. 1

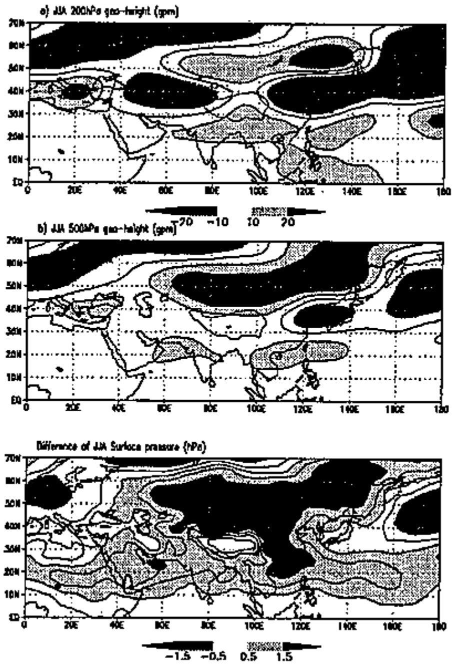

fig. 2

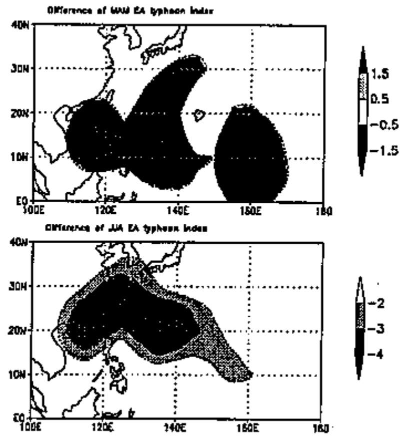

fig.3