15C.3 ENSO AND ATMOSPHERIC ENERGETICS ALONG THE TROPICAL STORM TRACK

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1. INTRODUCTION

ENSO, a highly air-sea coupled system, has fluctuations both on ocean and atmosphere, and it can affect activities of weather and climatic systems by altering the thermodynamic and dynamic states of environment. Most of studies found that the interannual variability of tropical storm over the Western North Pacific (WNP) can be explained by the El Nino-Southern Oscillation (ENSO) phenomena. In other words, the year-to-year variation of SST over the Central-Eastern Pacific has a teleconnection with tropical activities over the WNP. Chen et al. (1998), Chia and Ropelewski (2002) and Wang and Chan (2002) all noticed that the locations of tropical cyclones (or tropical storms) genesis over the WNP tend to shift southeastward during the El Nino years. In contrast, tropical cyclones are formed in the northwest region over the WNP during the La Nina years. Because the ENSO forcing is strongest in the end of a year, most studies had focused the large-scale variabilities associated with ENSO in the period of winter seasons. Recently, the interannual variabilities of tropical storms over the WNP were found to have a highly relationship with summertime SST anomalies over the Eastern Pacific (Wand and Chan 2002; Chan 2005). It is worth to note how the SST and flow patterns change during the TS peak season (July to September) in the ENSO developing year. This study will investigate the activities of tropical storms in the viewpoint of energetics. Examining the processes of the atmospheric energy cycle is a vital way to understand the large-scale atmospheric dynamics (Kung 1966), as well as the growth and decay of synoptic-scale disturbances (e.g. Norquist et al. 1977; Lau and Lau 1982).

2. Data and Analysis Method

The 6-hourly best track data of tropical cyclones published by the Joint Typhoon Warning Center (JTWC) from 1979 to 1998 is obtained online from JTWC website (www.npmoc.navy.mil/jtwc.html/best_tracks). The tropical cyclones with a maximum wind that reaches at least 17m/s (intensity of tropical storms) are included in the tropical storm data sample for analyzing the frequency and intensity of tropical storms. The National Centers for Environmental Prediction (NCEP) / National Center for Atmospheric Research (NCAR) reanalysis data (Kalnay et al. 1996) from 1979 to 1998 are used to examine circulation and energetic analysis. The monthly Sea Surface Temperature (SST) for the period 1979 to 1998 obtained from the NCEP/NCAR (Reynolds and Smith 1994) is also adopted in this study. The interannual classifications in this study are stratified by the July-September SSTA in Nino3.4 region: warm years (SSTA > 0.8 standard deviation), cold years (SSTA < -0.8 standard deviation) and normal years (-0.8 standard deviation ≦ SSTA ≦ 0.8 standard deviation). Table 1 shows the results of stratifications.

3. RESULTS

Fig. 1 shows the frequency and intensity of TS, as well as the location and strength of monsoon trough, for warm and cold years, respectively. During warm years, the monsoon trough extends near 30° farther eastward from it climatological position (not shown), and over 40° eastward compared with cold years composite (Fig 1a and 1b). The warm year composite of TS frequency shows a maximum center over the Philippine Sea/ WNP with the value of over 5 TSs occurrence per year. The distribution of the TS frequency during warm years is similar with climatology (not shown), but the maximum value of TS occurrence of climatology is about 4 TS per year. The axis of the most frequent occurrence of tropical storms over the WNP tilts from southeast toward northwest and it is coincided with the monsoon trough. The increased number of TS occurs near the dateline is also accompanied with the eastward extension of convergent region and monsoon trough (Fig. 1 a). In contrary, the monsoon trough retreats westward and weakens during cold years (Fig 1a and 1b). A region of

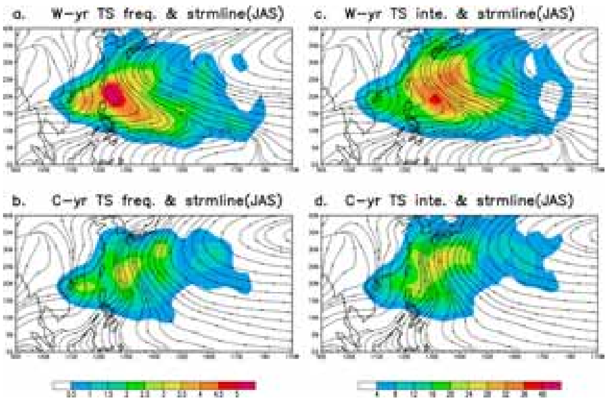

Fig 1

＊Corresponding author: Chih-Hua Tsou, Department of Earth Sciences, National Taiwan Normal University, Taipei, Taiwan. Email: chi@ ntnu.edu.tw tropical storms genesis from 150°E-180° in the tropics is absent and the averaged numbers of TS frequency along the storm track are decreased during cold years.

The differences of the total, mean flow and eddy kinetic energy during July to September between warm and cold years are showed in Fig. 2. The kinetic energy and tropical storm activity both increase over the Western Pacific when the Nino3.4 has a higher SST. The difference (warm years minus cold years) in the vertical averaged JAS mean flow kinetic energy (Fig. 2 b.) reveals that there are two jet-like structures of positive anomalies centered along 10°-20°N and 30°-40°N, and two negative anomalies over the Central Pacific and the adjacent area of Indonesia. Although the mean flow kinetic energy is enhanced during warm years over tropical storm activity regions, its magnitude is much smaller than the positive anomalies of the eddy kinetic energy (Fig. 2 c.). The eddy kinetic energy over almost the whole Western-North Pacific, where more frequency of tropical storm occurs, largely increases during warm years.

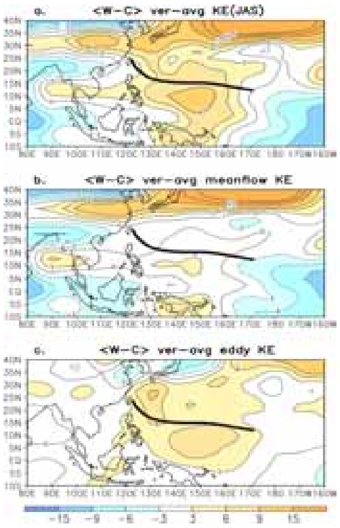

Fig 2

The vertically integrated summer–mean barotropic and baroclinic conversion are showed in Fig. 3. During warm years, the conversion from mean kinetic energy to eddy kinetic energy is positive over the Philippine Sea/tropical Western Pacific, but it is negative over the Central Pacific of Northern Hemisphere and the most Northwestern Pacific (Fig. 3 a.). However, during cold years, the barotropic conversion is negative over the Western Pacific where the tropical cyclones are formed and propagated (Fig. 3 b.). It seems that the barotropic conversion is not responsible for the growth of eddy kinetic energy in the formation region of tropical storms. During both warm and cold years, the barotropic energy conversion is negative over the subtropic regions of the Western Pacific. This might lead to the decrease of tropical storms intensity, as they propagated northward into subtropical regions over the Western Pacific. Fig. 3 c. shows the difference of barotropic conversion between warm and cold years, superimposed by the maximum interannual difference of occurrence of the frequency of tropical storms. Comparing with cold years, the barotropic conversion from mean kinetic energy to eddy kinetic energy is enhanced during warm years over Philippine Sea and the tropical Western Pacific, but decreased over Central Pacific and Northwestern Pacific. This result indicates that the barotropic energy conversion is beneficial for the development stages of tropical storms. However, the process of barotropic conversion is not responsible for the southeastward extension of the formation of tropical storms over the Central-Western Pacific.

The baroclinic conversion from eddy available potential energy to eddy kinetic energy is positive during both warm and cold years along the tropical storm track. Compared between warm years (Fig. 3 d.) and cold years (Fig. 3 e.), the most striking difference occurs in the southeast region of the Western-Central Pacific (Fig. 3 f.) where more tropical storm are generated during warm years. The positive baroclinic conversion extends eastward during warm years. It is suggested the growth of eddy kinetic energy, which might be account for the southeastward extension of the tropical storms formation, are mainly contributed by the baroclinic energy conversion. The enhanced eddy kinetic energy conversion from eddy available potential energy during warm years might be favorable for the enhancement of the activities of tropical storms over the Western Pacific.

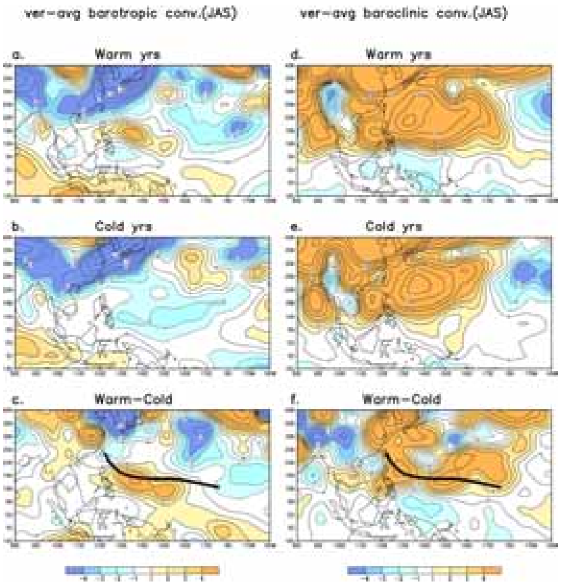

Fig 3

The interannual mean flow wind patterns, which are showed in Fig. 4, reflect the linkage between the eddy kinetic energy and summertime ENSO forcing through barotropic conversion. Fig. 4 a. shows that the tropical easterly is weak and strong westerly wind extends from the Bay of Bengal into the Western-Central Pacific along 5°-15°N during warm years. The tropical easterly and westerly along 5°-15°N converge near the along 130°-150°E, and a cyclonic shear occurs to the north of the westerly jet. As a result, the negative zonal and meridional gradient of zonal wind over tropical storms occurrence regions leads to the growth of eddy kinetic energy through barotropic conversion (Fig. 3 a.). In contrast, the easterly and southerly associated with subtropical high are enhanced, but the westerly confined in the Bay of Bengal/South China Sea during cold years (Fig. 4 b.). The wind pattern of cold year composite causes a negative barotropic conversion (Fig. 3 b.). Differences in the mean flow pattern between warm and cold years reveal the enhanced westerly jet which causes stronger wind shears and contributes to the growth of eddy kinetic energy (Fig. 4 c. and Fig. 3 c.). However, the anomalous anticyclonic circulation leads to a negative barotropic conversion over the subtropical Western Pacific.

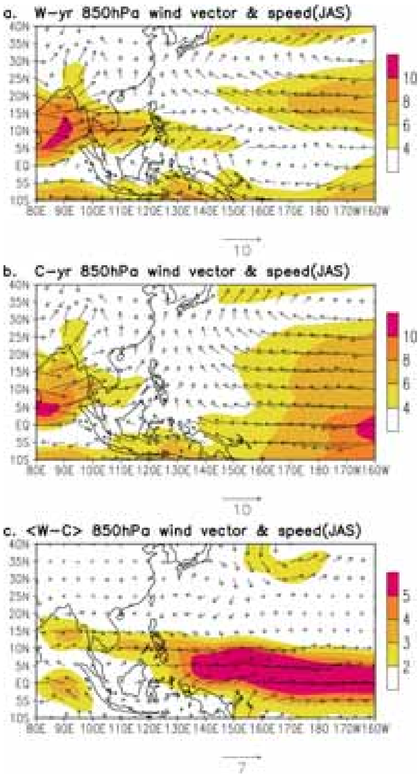

Fig 4

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