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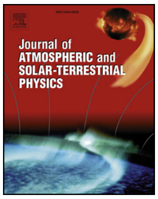

Circulation characteristics of EP and CP ENSO and their impacts on precipitation in South China

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ABSTRACT

EP and CP events have different effects on precipitation in South China (SC). In EP El Niño years, the winter precipitation increases and the summer precipitation is distributed in the form of a tri-pole; specifically, it increases in the northeastern and southwestern parts of SC and decreases in the central and northwestern parts. In EP La Niña years, the winter precipitation decreases in the most part of SC and the summer precipitation increases in the central part of SC and decreases in the eastern and southwestern parts. In CP El Niño years, the summer precipitation increases and the winter precipitation increases in the northeastern part of SC and decreases in the southwestern part. In CP La Niña years, the winter precipitation generally decreases and the summer precipitation decreases in the western and southeastern parts of SC but increases in the central and northeastern parts.

The results of both numerical simulations and diagnostic analyses show that in EP El Niño winters, there is a northerly wind on the lower troposphere of SC conducive to the southward movement of cold air to SC, converging in the south and diverging in the north, in agreement with the distribution of the precipitation anomalies. In the lower troposphere of SC in summer, an abnormal southwester is dominant, facilitating the movement of warm and moist air in the southwest toward SC, which is conducive to an increase in precipitation there. In EP La Niña winter, there is a southwester anomaly in the lower troposphere of SC, which is adverse to the southward movement of cold air from the north to SC, with the divergence field diverging in the south and converging in the north, in agreement with the distribution of precipitation anomalies in this region. In EP La Niña summer, there is a northeaster anomaly in SC that is in the water vapor convergence area, which is conducive to precipitation in SC. In CP El Niño summer. There are northerly winds over SC and an anomalous cyclone over the western Pacific and South China Sea, which was beneficial to precipitation.

1. Introduction

The El Niño–Southern Oscillation (ENSO) is a strong signal of the tropical air–sea interaction, which has a significant impact on global climate anomalies (Wang et al., 2000; Turner, 2004; Ferday et al., 2008; Zhang et al., 2012, 2014; 2015; Yuan et al., 2012; Feng et al., 2010, 2011; Weng et al., 2011; Tedeschi et al., 2013; Taschetto and England, 2009; Kug et al., 2010; Chen et al., 2014; Jin et al., 2016). In the past 20 years, it has been observed that a warming phenomenon that is different from the traditional El Niño occurs frequently in the tropical Pacific and its warming center is not in the equatorial eastern Pacific (EP event) but rather in the central equatorial Pacific. Ashok et al. (2007) named it the “ENSO Modoki” (CP event); Li et al. (2010) suggested an improved CP El Niño index; and Wang et al. (2012) evaluated the El Niño and CP El Niño variability based on a new ocean reanalysis.

Many studies have shown that the CP event also has a significant impact on global climate. For example, Ashok et al. (2009) simulated the CP El Niño event in 2004 and pointed out that the twin Walker circulation is an important cause of precipitation anomalies in tropical areas. Weng et al. (2011) compared the effects of three tropical systems, EP event, CP event, and the Indian Ocean Dipole (IOD), on summer climate in China. Among the three phenomena, CP El Niño has the strongest relationship with the western North Pacific summer monsoon. Feng et al. (2013) compared the differences between the influence of EP and CP events on precipitation in China during the decay stage. It is thought that the precipitation difference may be related to the variation in the anomalous anticyclone and the position difference in the northwestern Pacific, prompting further studies of the influence of CP event

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on Hadley circulation. Via an analysis of satellite observation data, Lee et al. (2010) found that the CP event anomalies had an increasing tendency. In addition, Wang et al. (2014) found that CP event affected the frequency of typhoons in the South China (SC) Sea.

Precipitation is abundant in SC; however, the interannual variation in the precipitation is obvious (Shen et al., 2014). In addition, sea surface temperature (SST) is an important factor affecting precipitation in SC (Chen et al., 2017). During the El Niño summer development phase, there is less precipitation in SC and North China but more precipitation in the Yangtze and Huaihe river basins (Huang et al., 1989). During EP El Niño winters, there are positive precipitation anomalies in southeastern China (Lu et al., 2017). In the El Niño late spring and early summer decaying phase, there is positive anomalous precipitation in SC (Zhang et al., 1999; Wang et al., 2000). Zhou et al. (2010) found that there is a significant correlation between the winter precipitation in SC and the SST in the equatorial regions of the central and eastern Pacific and the SC Sea. The summer precipitation in the Yangtze River Basin and SC shows significant asymmetry under the influence of the two types of ENSO (Karori et al., 2013). Hardiman et al. (2018) showed also that the Yangtze summer rainfall is not significant response following EP La Niña.

However, this relationship between ENSO and SC precipitation is variable (Li and Ma, 2012), with a stronger correlation or a weaker correlation at different times. Therefore, there is still a lot of uncertainty. In summary, EP and CP event have different effects on regional climate. Most related studies consider SC as a whole to analyze its response to SST anomalies; this study primarily analyzes the different circulation characteristics of EP and CP events and focuses on its impact on winter and summer precipitation in SC, while simultaneously taking regional differences into account.

This paper is organized as follows. Section 2 contains a simple description of the data. Section 3 presents an empirical orthogonal function (EOF) analysis of the SST in the tropical Pacific. Section 4 presents the effects of SST anomalies on precipitation in SC. Section 5 focuses on the circulation and anomalies. Section 6 contains the simulation experiments, and the results are summarized in Section 7.

2. Data

Average monthly precipitation data was gathered from 160 stations by the National Climate Center. The global SST $1^\circ \times 1^\circ$ reanalysis data from 1951 to 2010 was acquired from the Hadley Centre (Rayner et al., 2003). We used the NCEP/NCAR monthly $2.5^\circ \times 2.5^\circ$ reanalysis data (Kalnay et al., 1996). The CP event index (EMI) was calculated based on the expression of the SST anomalies in three sea areas selected by Ashok (2007):

$$EMI = 1.0T_{a,A} - 0.5T_{a,B} - 0.5T_{a,C} \quad (1)$$

A (165° E − 140° W, 10° S–10° N), B (110° W–70° W, 15° S–5° N), and C (125° E − 145° E, 10° S–20° N). $T_{a,A}$ 、$T_{a,B}$ 、$T_{a,C}$ represent SST anomalies of three regions of A、B、C, respectively.

3. EOF analysis of SST in the tropical Pacific

A number of studies have shown that the SST had significant interdecadal variations in the late 1970s; therefore, to remove the influence of interdecadal variations, the SST time series were divided into two periods, 1951–1975 and 1979–2010, and the tropical Pacific SST anomalies were analyzed using EOF for the two periods separately. From 1951 to 1975, the variance contribution of the first mode is 40.9% (Fig. 1a) and belongs to the EP event. The variance contribution of the second mode is 9.5% (Fig. 1b), and the type of distribution is similar to CP event; however, the SST anomalies in the western Pacific are not obvious. From 1979 to 2010 (Fig. 1c and d), the variance contribution of the first mode is 45.3% and belongs to the EP event. The variance contribution of the second mode is 11.2% and shows a tri-pole distribution characteristic of CP event.

To distinguish the two different types of SST anomalies, the Niño3 index was defined to be ± 1 times its standard deviation in the EP event years and the EMI index was defined to be ± 0.9 times its standard deviation in the CP event years. The abnormal years from 1951 to 2010 are listed in Table 1.

4. Effects of EP and CP event on precipitation in SC

To investigate the relationship between SST and precipitation in SC and to distinguish the influence of EP and CP event on precipitation in SC, the Niño3 index and the EMI index were used to analyze the partial correlation regression of precipitation in SC and to calculate the partial correlation coefficient (Fig. 2).

The correlation between the Niño3 index and the precipitation in SC is good, and the entire area in winter has a positive correlation of more than 0.4 (Fig. 2a). There is a positive correlation in the eastern part of SC, a negative correlation in the middle and northwestern parts of SC, and a positive correlation in the southwestern part of SC during the summer (Fig. 2b); however, there are few areas with significant correlations. In winter, the EMI index is negatively correlated with the precipitation of South China over the southeast (Fig. 2c), and is positively correlated over the northwest. The significant region is in the north central; the summer EMI index is generally positively correlated with the precipitation of South China (Fig. 2d), and the significant region is in the southwest.

According to Table 1, the EP and CP event years can be distinguished. Fig. 2a showed a positive correlation between the Niño3 index and the in winter precipitation in SC, the significant region is most of the SC region. The EMI index was generally positively correlated with the summer precipitation in SC (Fig. 2d), and the significant region is in the southwest. Fig. 3 showed more clearly that the winter precipitation in EP events is more than in CP events (Fig. 3a and c), but the summer precipitation in CP events is more than in EP events (Fig. 3b and d). This feature is clearer in El Niño years (Fig. 3a and b).

5. Circulation and anomalies

5.1. 850 hPa wind field and divergence

In EP El Niño winters (Fig. 4a), there are southwesterly winds over SC and an anomalous anticyclone over the Philippines; SC is in the anomalous convergence zone, leading to additional precipitation anomalies. This teleconnection patterns agreed with Lu et al. (2017) too. In EP La Niña winters (Fig. 4c), there are northeasterly winds over SC, anomalous anticyclone circulation over the Yangtze River Basin, and weak anomalous cyclone circulation over the Philippines; most regions of SC are in the divergence zone, leading to less precipitation. In EP El Niño summers (Fig. 4b), there are weak southwesterly winds over SC, anomalous cyclone circulation over the northwest Pacific, and a strong wind shear over the eastern part of the Philippines; most regions of SC are in the divergence zone, leading to low precipitation. In EP La Niña summers (Fig. 4d), there are anomalous southwesterly winds over SC and weak cyclone circulation over the sea in the eastern part of the Philippines; the southwestern part of SC is in the divergence zone and the eastern part is in the convergence zone, which is consistent with the distribution of the precipitation anomalies. The comparison with Figs. 2 and 3 can be seen that the teleconnection patterns are more significant in winter.

As well as the differences of summer precipitation in the Yangtze River Basin and SC between the two ENSO types (Karori et al., 2013) there is also asymmetry in the difference between La Nina and El Nino (Hardiman et al., 2018), Our conclusion also agreed with Hardiman et al. (2018).

In CP El Niño winters (Fig. 5a), there are southwesterly winds over SC, an anomalous anticyclone over the Philippines, and anomalous