THE CHANGING EFFECT OF TWO TYPES OF ENSO IN THE SOUTH CHINA SEA

Lin, Chun-Yi[1], Lee, Yung-Hsiang[2], and Su, Feng-Chun[3]

[1]National Museum of Marine Science & Technology, Research & Collection Division, Keelung, Taiwan, R.O.C.
chunyi@mail.nmmst.gov.tw

[2] Department of Marketing & Distribution Management, Hsing Wu University, New Taipei City, Taiwan, R.O.C.
moles@ms24.hinet.net

[3]National Museum of Marine Science & Technology, Exhibition & Education Division, Keelung, Taiwan, R.O.C.
fengchunsu@mail.nmmst.gov.tw

KEY WORDS: South China Sea, EP ENSO, CP ENSO, WP

ABSTRACT: El Niño-Southern Oscillation (ENSO) events are one of the most principal impacts that affect the global climate, especially in the Tropical oceans. Previous studies have suggested the interannual variations on the conventional El Niño. However recent studies show the interannual variability connected with two type of El Niño, namely the Central-Pacific (CP) type of ENSO and Eastern-Pacific (EP) type of ENSO. During the CP type of ENSO, the maximum sea surface temperature anomalies are confined in the central equatorial Pacific, in contrast with the maximum sea surface temperature anomalies are found in the eastern equatorial Pacific during the EP type of ENSO. In order to focus on the influences on the ENSO events in the South China Sea (SCS) thermal variability, we should consider various influences of the CP and EP types of ENSO. In the study, air temperature, surface wind, precipitation, sea level press, sea surface temperature and multiple datasets has been used to analyze the interannual variations in the SCS. We estimate various thermal variability and indentify how well the two types of ENSO are influences on climate changes in the SCS. The composite for the EP ENSO events indicates a strong increase in the sea surface temperature anomaly over the SCS region. During the EP ENSO, the strength of the SST anomalies increases by as much as 0.5℃. However the decrease SST can be found in most part of the SCS during the CP ENSO. We also examine characteristics of atmosphere-ocean interaction between the SCS and western Pacific warm pool with the CP and EP types of ENSO.

1. INTRODUCTION

The western Pacific warm pool (WPWP) in the tropical Pacific Ocean has the highest sea surface temperature (SST) and the largest warm water of all the world’s ocean. The South China Sea (SCS) is the largest marginal sea influenced by the WPWP. Numerous studies have shown that the tropical Pacific Ocean is strong influenced by the ENSO-Southern Oscillation (ENSO) signals of surrounding areas such as the SCS (Lin et al, 2011; Yuan and

Yang 2012; Wang et al., 2013). There are previous studies that investigate the influences of the ENSO in the SCS, but their results are mostly based on one type of ENSO (e.g., Lau 1997; Qu et al., 2004; Wang et al., 2006; Wang et al, 2007; Lin et al, 2008). The different influences of the two types of ENSO have pointed increased study interest in the recent years (e.g., Ashok et al., 2007; Yeh et al., 2009; Kao and Yu, 2009; Yu and Kim, 2010; Yu et al., 2012). Since the ENSO is now classified into the Central-Pacific (CP) type of ENSO and Eastern-Pacific (EP) type of the ENSO. It is necessary to investigate various differences in the SCS under two types of ENSO.

The traditional ENSO referred to as the EP ENSO is characterized by warm SST anomalies in the Eastern Pacific. Nevertheless the maximum SST anomalies are confined in the central equatorial Pacific during the CP type of ENSO, in contrast with the EP type of ENSO. Investigations have indicated that different ENSO episodes, including the CP and EP types of ENSO, have different influences on weather and climate, at both regional and global scales (Larkin and Harrison, 2005; Ashok et al., 2007; Kug et al, 2009; Yeh et al., 2009; Yu et al., 2012; Liu et al 2014; Lin et al., 2014).

2. DATA AND METHOD

To understand the thermal fluctuations in the SCS thermal fluctuation, satellite-derived or in-situ-derived SST, and Sea level pressure from reanalysis dataset are estimated. In this study we use the dataset of the National Center for Atmospheric Research/ National Centers for Environmental Prediction (NCEP/NCAR) reanalysis project (Kalnay et al., 1996). The temporal resolution of NCEP reanalysis is one month and the spatial resolution is about 1.8°.

There are different methods to decompose the CP and EP ENSO from traditional ENSO, such as (1) the Niño method (Yeh et al., 2009), (2) the ENSO Modoki index (EMI) method (Ashok et al., 2007), (3) the EP/CP-index method (Kao and Yu, 2009), (4) the consensus method (Yu et al., 2012). In this study, we apply monthly SST anomalies to identify the EP and CP types of ENSO from the significant EP/CP-index method combined with consensus method calculated by a regression-empirical orthogonal function (EOF) analysis (Kao and Yu, 2009; Yu and Kim, 2010; Yu et al., 2012). To obtain the SST anomaly pattern of the CP type and EP type of ENSO, monthly anomalies from the model simulations and the observations are calculated by removing the respective monthly mean climatology and trend. With this method, we first removed the tropical Pacific SST anomalies that are regressed with the Niño 1+2 SST index and then applied the EOF analysis to the remaining SST anomalies to obtain the SST anomaly pattern for the CP ENSO (Kao and Yu, 2009; Yu and Kim, 2010). Similarly, we subtracted the SST anomalies regressed with the Niño4 SST index from the original SST anomalies before the EOF analysis was applied to identify the leading structure of the EP ENSO.

3. RESULT

The SST anomalies of the CP ENSO are confined to the area surrounding the International Date Line, whereas those of the EP ENSO are located off the South American Coast (Figure 1). We analyze only strong EP (CP) ENSO events defined as those whose EP and CP index has a magnitude larger than one standard deviation (Kao and Yu, 2009; Yu and Kim, 2010). Based on this selection criterion and the consensus method (Yu et al., 2012), SST observations collected during 1982-2014 in the tropical Pacific are used to contrast the 5 EP type of ENSO events (1982-1983, 1986-1987, 1997-1998, 2006-2007and 2011-2012) and 7 CP type of ENSO events (1987-1988, 1991-1992, 1994-1995, 2002-2003, 2004-2005, and 2009-2010) (Table 1).

The patterns of EP ENSO and its climate changes are distinguish from those of the CP ENSO. There are previous studies that investigate the influences of the ENSO on the SCS SST, but their results are mostly based on one type of ENSO. Since the Niño is now classified into the CP type of ENSO and EP type of ENSO. In order to focus on the impacts on the ENSO in the SCS thermal variability, we should analyze various influences of the CP and EP types of ENSO.

To understand the thermal variability influenced by the ENSO in the SCS, we plotted SST anomalies and WP size anomalies from 1982 to 2014 as shown in Fig. 2. The WP is usually defined as an area where SST is at least 28°C. The SCS has warm water which is higher than 28°C during most of year as a part of WPWP. In this study, to reveal the interannual signals, we removed the mean seasonal cycle from the SST and the warm pool area in the SCS and then applied a low-pass filter to remove anomalies shorter than 12 months. Time series of SST anomaly shows a strong interannual cycle and relative maximum values are evident in 1982, 1987, and 1997. The warm pool area in the SCS (hereafter SCSWP) is defined in the same way as the WPWP but for the box from 105^{o}E to 120^{o}E and from the 5^{o}N to 20^{o}N (Lin et al., 2011).

The SCSWP fluctuates in sync with the SST changes in the SCS, with broader SCSWP being accompanied by higher SST with a correlation coefficient of 0.87. The time series of SCSWP anomalies are shown in Fig. 2b, evidencing a strong interannual cycle. But the relative maximum SCSWP can be found in 1982, 1988, 1997, and

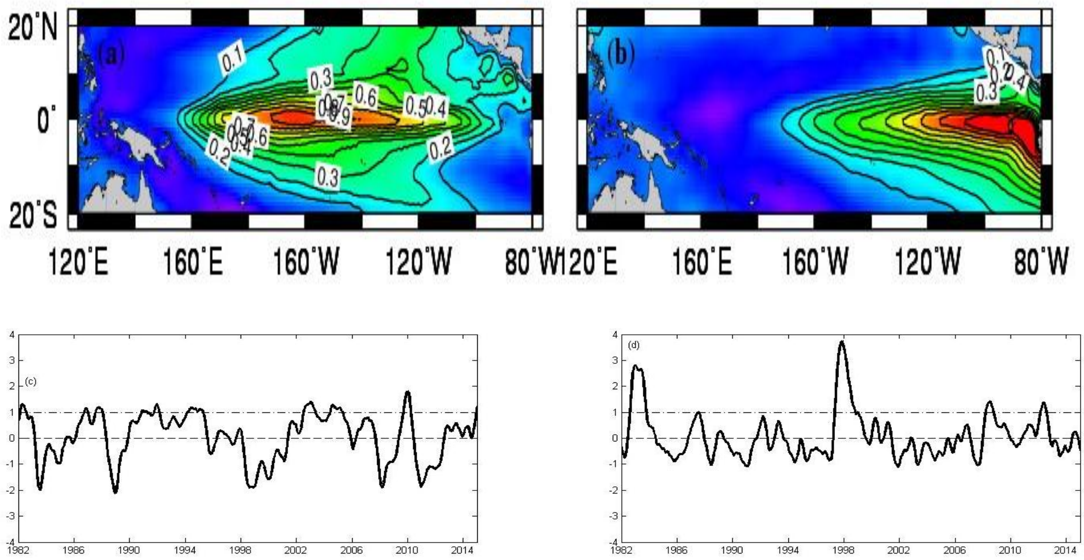

Figure 1. Spatial patterns and corresponding time functions of the first mode of the EOF obtained by a EOF-regression analysis method for the CP ENSO (a, b) and EP ENSO (c, d) calculated from NCEP Reanalysis.

Table 1. The EP ENSO and CP ENSO years using NCEP reanalysis dataset from 1982-2014.

EP ENSO years	CP ENSO years
1982-1983, 1986-1987, 1997-1998, 2006-2007, 2011-2012	1987-1988, 1991-1992, 1994-1995, 2002-2003, 2004-2005, 2009-2010

2002 ENSO events (Fig. 2b).

The SCSWP fluctuates in sync with the SST changes in the SCS, with broader SCSWP being accompanied by higher SST with a correlation coefficient of 0.87. The time series of SCSWP anomalies are shown in Fig. 2b, evidencing a strong interannual cycle. But the relative maximum SCSWP can be found in 1982, 1988, 1997, and 2002 ENSO events (Fig. 2b). It is noted that most of relative maximum periods are associated with the EP type of ENSO. The warming patterns during the EP ENSO is more significant than that during the CP ENSO. However the monsoon forcing is a dominant factor controlling the SCS climate (Lau 1997; Yuan and Yang et al., 2012; Liu et al., 2014), some common air-sea interaction features and differences are discussed in next section in more detail.

Fig. 3a shows the climatological values (1982-2014) of the monthly SST in the SCS. The high SST area is particularly prominent in the southeastern areas of the SCS and its magnitude decreases toward the north. The composite for the EP ENSO (Fig. 1b) events indicates a increase in the SST anomaly over the SCS region. The increase is particularly large over the center portion of the SCS basin. During the EP ENSO, the strength of the SST anomalies increase by as much as 0.43°C, which is about 3% of the climatological value.

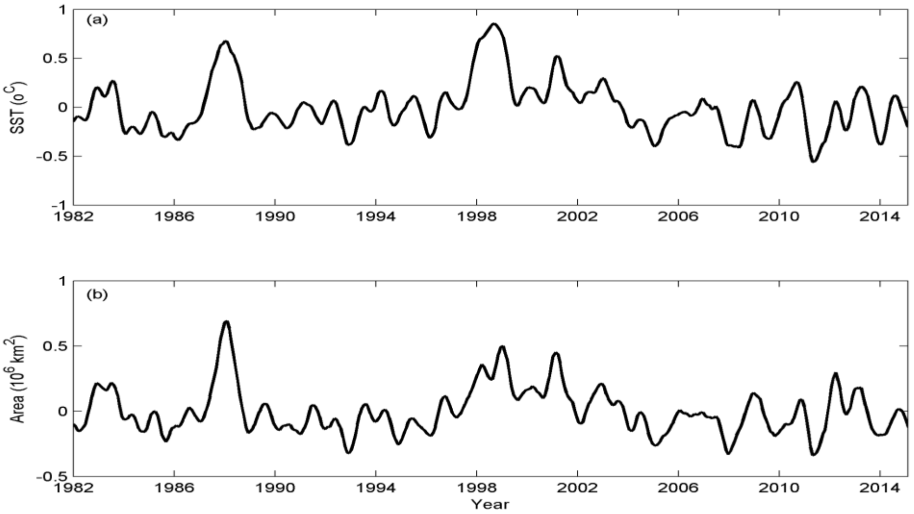

Figure 2. Time series of the SST anomalies and areas of WP anomalies from 1982 to 2014 in the SCS.

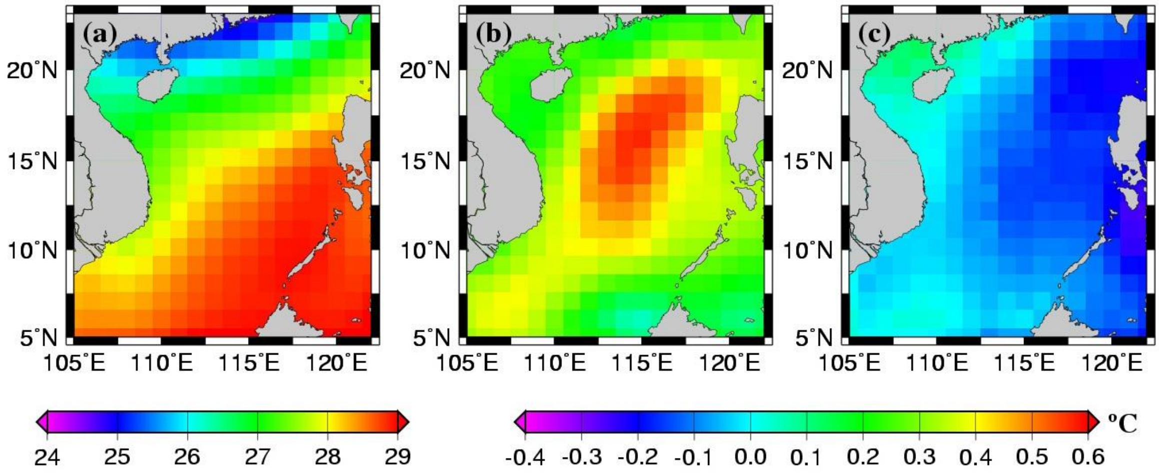

Figure 3. Composite patterns of SST anomalies for (a) climatological mean (b) the EP ENSO events and (c) the CP ENSO events in the SCS (1982-2014).

In contrast, Fig. 3c indicates that the SST anomaly during the EP ENSO. The decrease SSTs can be found over the SCS basin, except for surrounding areas near Hainan Island. The strength of cooling patterns weakens by about -0.23°C in the eastern portion of the SCS. A opposite and distinct effect is influenced between the EP type of ENSO and CP type of ENSO. The evolution of the SCS SST changes during CP and EP ENSO is basically consistent with the results of Wang et al. (2006).

In order to comprehend why the two types of ENSO produces opposite impacts on the strength of thermal variability, we discuss the atmosphere-ocean interaction features in the SCS. The climatological sea level pressure and sea level pressure anomalies during the EP ENSO events and the CP ENSO events are shown in Fig. 4. The climatological mean sea level pressure is about 996 hPa, with maximum values in the northern portion of the SCS and minimum values in the eastern areas of Vietnam. Associated with the EP ENSO (Fig. 4b), significant positive sea level pressure anomalies are found over the SCS basin. A total opposite sea level pressure anomalies is found in the composite for the CP ENSO.

Wang et al. (2000) and Yuan and Yang (2012) illustrated that the central Pacific and East Asia can be linked by anomalous Philippine Sea anticyclone during the strong phases of ENSO cycles, which can induce warming in the East Asia and weaken the winter monsoon. The negative sea level pressure anomalous over the SCS during CP ENSO seem to result from the anomalous low-level anticyclone over the SCS, which is located more westward than the Philippine Sea anticyclone during EP ENSO (Yuan and Yang, 2012; Liu et al., 2014). The effect of anomalous westward shift of the low-level anticyclone during CP ENSO, it is important to study the surface wind and precipitation variations interacted between the two types of ENSO.

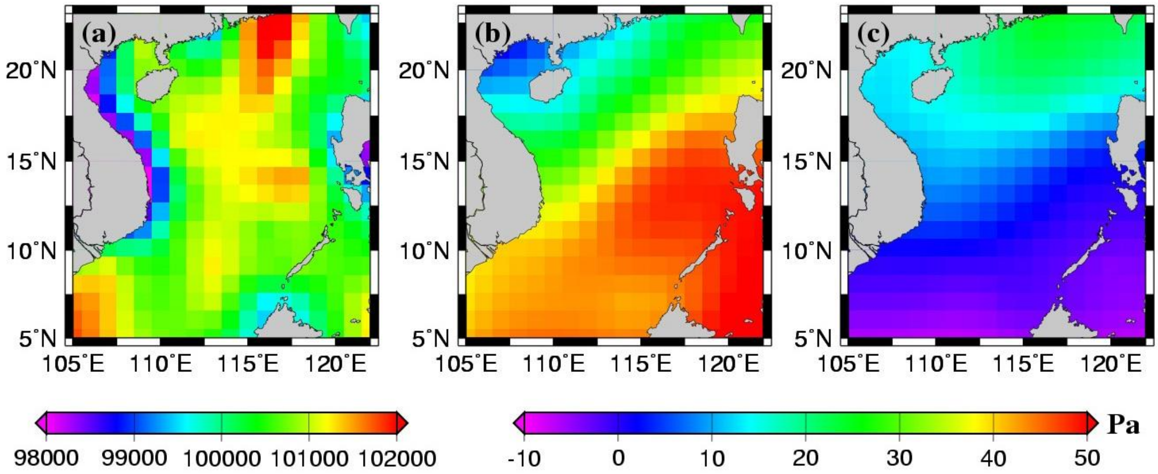

Figure 4. As in Fig. 3, but for sea level pressure anomalous.

4. SUMMARY

In the study, the thermal variability during two different types of ENSO and possible mechanisms are discussed. We have also examined the variations of anomalous SST, and sea level pressure from reanalysis dataset. we analyze the different impacts of CP El Niño and EP El Niño defined by regression-empirical orthogonal function on SCS thermal variability. It is noted that SST observations collected during 1982-2014 in the tropical Pacific are used to contrast the 5 EP type of El Niño events (1982-1983, 1986-1987, 1997-1998, 2006-2007and 2011-2012) and 7 CP type of El Niño events (1987-1988, 1991-1992, 1994-1995, 2002-2003, 2004-2005, and 2009-2010). For the air-sea interaction in the SCS, the SST changes play important role on influencing the climate variability. While the EP Niño events induce high SST anomalies and positive sea level pressure anomalies over the SCS to drive anomalous westerly wind and the precipitation strengthening. On the other hand the negative sea surface wind anomalies and low-level sea level pressure anomalies are associated with anomalous easterly wind and dry conditions over the SCS during the EP ENSO. Compared with multiple variables, the impact of the EP ENSO on the thermal variability is more significant than the influence of the CP ENSO.

REFERENCES

Ashok, K., S. K. Behera, S. A. Rao, H. Weng and T. Yamagata 2007. El Niño Modoki and its possible teleconnection. Journal of Geophysical Research 112, C11007, doi:10.1029/2006JC003798.

Kalnay, E. and Coauthors 1996. The NCEP/NCAR 40-year reanalysis project. Bull. Amer. Meteor. Soc., 77, pp. 437-470.

Kao, H.-Y. and J.-Y. Yu 2009. Contrasting eastern Pacific and central Pacific types of ENSO. Journal of Climate, 22, pp. 615-632.

Kug, J.-S., F.-F. Jin and S.-I. An 2009. Two types of El Niño events: Cold tongue El Niño and warm pool El Niño.

Journal of Climate 22, pp. 1499-1515.

Larkin N. K. and D. E. Harrison 2005. On the definition of El Niño and associated seasonal average U.S. weather anomalies. Geophysical Research Letters, 32, L13705.

Lau K. M. 1997. South China Sea Monsoon Experiment (SCSMEX) observed from satellite. EOS Transactions American Geophysical Union, 78, pp. 599-603.

Lin, C.-Y., C.-R. Ho, Z.-W. Zheng and N.-J. Kuo 2008. Validation and variation of upper layer thickness in South China Sea from satellite altimeter data. Sensors, 8, pp. 3802-3818.

Lin, C.-Y, C,-R. Ho, Q. Zheng, S.-J. Huang and N.-J. Kuo 2011. Variability of sea surface temperature and warm pool area in the South China Sea and relationship to the western Pacific warm pool. Journal of Oceanography, 67, pp. 719-724.

Lin, C.-Y., J.-Y. Yu and H.-H. Hsu 2014. CMIP5 model simulations of the Pacific meridional mode and its connection to the two types of ENSO. International Journal of Climatology, doi: 10.1002/joc.4130.

Liu, Q.-Y., D. Wang, X. Wang, Y. Shu, Q. Xie and J. Chen 2014. Thermal variations in the South China Sea associated with the eastern and central Pacific El Nino events and their mechanisms. Journal of Geophysical Research Oceans, 119, pp. 8955-8972.

Wang, C., W. Wang, D. Wang and Q. Wang 2006. Interannual variability of the South China Sea associated with El Niño. Journal of Geophysical Research 111, C03023, doi:10.1029/2005JC003333.

Wang, C. and X. Wang 2013. Classifying El Niño Modoki I and II by different impacts on rainfall in southern China and typhoon tracks. Journal of Climate 26, pp. 1322-1338.

Wang, C., C. Li, M. Mu and W. Duan 2013. Seasonal modulations of different impacts of two types of ENSO events on tropical cyclone activity in the western North Pacific. Climate Dynamics, 40, pp. 2887-2902.

Wang, G., J. Su, Y. Ding and D. Chen 2007. Tropical cyclones genesis over the South China Sea. Journal of Marine Systems, 68, pp. 318-326.