

ENSO Impact on the Sea Surface Properties of the East China Sea

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Abstract – A series of satellite-derived sea surface wind (SSW) and sea surface temperature (SST) images in the East China Sea (ECS) during the period from 1997 to 2001 are used to determine their interannual variability, especially the impact of the El Niño-Southern Oscillation (ENSO) events. The first Empirical Orthogonal Function (EOF) mode of the SSW anomaly data indicates that the 1997-1998 El Niño event may weaken the SSW in the ECS compared with the 1998-1999 La Niña year and even the following weaker La Niña years 1999-2000 and 2000-2001. The EOF mode 1 of the SST anomaly data emphasizes that the continuous positive SST anomaly occurred from November 1997 to February 1999, and a following negative SST anomaly extended to August 2000. Through the comparison to the Southern Oscillation Index (SOI), it is suggested that ENSO could affect the SST field in the ECS with a 9-month delay.

Keywords: East China Sea, Sea surface wind, Sea surface temperature, Empirical Orthogonal Function, El Niño-Southern Oscillation.

1. INTRODUCTION

The East China Sea (ECS) is a marginal sea of the northwest Pacific Ocean; it is located off the east China coast and separated from the western Pacific in the east by the Ryukyu Islands, also it extends from the southern end of the Yellow Sea in the north to the northern water of Taiwan in the south, and connects the South China Sea through the Taiwan Strait (Figure 1). The meteorological condition in the ECS is mainly dominated by the East Asia monsoon, it is a strong northerly monsoon in winter and a much weaker southerly monsoon in summer (Ning et al., 1998).

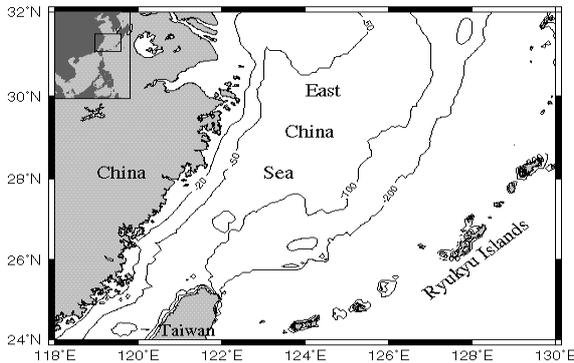


Figure 1. Map of the East China Sea with the 20, 50, 100, 200m isobaths.

In this study, the satellite-derived sea surface wind (SSW) and sea surface temperature (SST) data in the ECS during the period from 1997 to 2001 are analyzed to look for their temporal and spatial variability. Within this period, the 1997-1998 El Niño period was one of the strongest El Niño-Southern Oscillation (ENSO) events in the twentieth century (McPhaden, 1999), which had influences in the northwestern Pacific areas (e.g., Ho et al., 2000; Hong et al., 2001; Pan et al., 2002; Kuo et al., 2004; Kuo and Ho, 2004). How the ENSO events affect the SSW and SST in the ECS will be discussed in this paper.

2. DATA AND METHODS

2.1 Satellite Data

The satellite SSW data in this study includes the ERS-2 satellite scatterometer data from 1997 to 2000 and the QuikSCAT satellite SeaWinds scatterometer data in 2001. The ERS-2 scatterometer data are the monthly means with a spatial resolution of 1° latitude by 1° longitude, while the QuikSCAT SeaWinds data are also monthly with the spatial resolution of 0.5° latitude by 0.5° longitude. These two SSW data will be re-processed with a consistent spatial resolution of 1° in latitude and longitude. The SST data during 1997-2001 are from NOAA satellite AVHRR LAC (local area coverage) data; they have spatial resolution of 1.1 km and were processed as the monthly composite images. In this study, the monthly anomaly data of SSW and SST are considered. The monthly anomaly data are the residuals after removal of the individual climatologically monthly mean data in order. From anomaly SSW and SST variation, we can see their interannual variability more precisely, especially the ENSO impact on them.

2.2 Method

The Empirical Orthogonal Function (EOF) analysis is a popular technique to compress the spatial and temporal variability of a time series of a large amount of satellite images down to a finite number of dominant modes; these finite modes usually can explain most of the variance of the original data set (e.g., Lagerloef and Bernstein, 1988; Eslinger et al., 1989; Paden et al., 1991; Hernandez-Guerra and Nykjaer, 1997; Armstrong, 2000; Thomas et al., 2003; Ho et al 2004; Kuo et al., 2004; Kuo and Ho, 2004).

For a space-time data set $\{ T(x_i, y_j, t_k) \}$, through EOF decomposition $T(x_i, y_j, t_k)$ can be expressed as:

$$T(x_i, y_j, t_k) = \sum_p a_p(t_k) F_p(x_i, y_j). \quad (1)$$

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The contribution of a given EOF mode for a certain time can be calculated by multiplying the spatial function, $F_p(x_i, y_j)$, by its corresponding temporal value, $a_p(t_k)$. Usually, the first few modes of the decomposed functions with high percentage variance may generally have physical significance, while the other functions with small percentage of variance are difficult to interpret due to the orthogonality constraint and are usually disregarded. In this study, the EOF analysis is applied to the monthly anomaly data set of the satellite-derived SST and SSW data in the ECS during the period from 1997 to 2001. Meanwhile, only the mode 1 results are chosen to emphasize major parts of their interannual variation.

3. RESULTS AND DISCUSSION

In order to see the ENSO impact, we divide the whole duration of 1997-2001 into four periods according to the Southern Oscillation Index (SOI) listed in Table 1. They are the mature El Niño year 1997-1998 (May 1997-April 1998) with negative and high SOI value, the mature La Niña year 1998-1999 (May 1998-April 1999) with positive and high SOI value, and the following weaker La Niña years 1999-2000 (May 1999-April 2000) and 2000-2001 (May 2000-April 2001).

Table 1: SOI index during the period from 1997 to 2001 (from: <ftp://ftp.ncep.noaa.gov/pub/cpc/wd52dg/data/indices/soi>)

Year	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Average
1997-1998	-3.0	-3.2	-1.7	-3.4	-2.6	-3.1	-2.3	-2.1	-5.4	-4.4	-5.7	-3.2	-3.34
1998-1999	0.1	1.2	2.0	1.6	2.0	1.6	1.7	2.3	3.2	1.2	1.4	2.2	1.71
1999-2000	0.1	-0.1	0.8	0.1	-0.1	1.5	1.8	2.5	1.1	2.6	1.6	1.9	1.15
2000-2001	0.3	-1.0	-0.7	0.6	1.7	1.6	3.3	1.1	1.8	2.4	0.8	-0.1	0.98

3.1 SSW EOF results

Figure 2 shows the first EOF result of the SSW anomaly during the period from 1997 to 2001. It contains 49.2% of the total variance. From Figure 2a one can see the major wind anomaly in the ECS is in the direction parallel to the China coastline, either southwesterly or northeasterly depending on the sign of the temporal amplitude in Figure 2b. Combining Figure 2a and 2b, one can see northeasterly wind anomaly in summer and southwesterly wind anomaly in winter during 1997-1998 El Niño year, the reversed situation happened in 1998-1999 La Niña year and even the proceeding weaker La Niña years in 1999-2000 and 2000-2001. Because the SSWs in the ECS are mainly southwesterly in summer and northeasterly in winter, Figure 2 implies that the 1997-1998 El Niño event may have caused the weakened sea surface winds compared with the 1998-1999 La Niña year and the following weaker La Niña years.

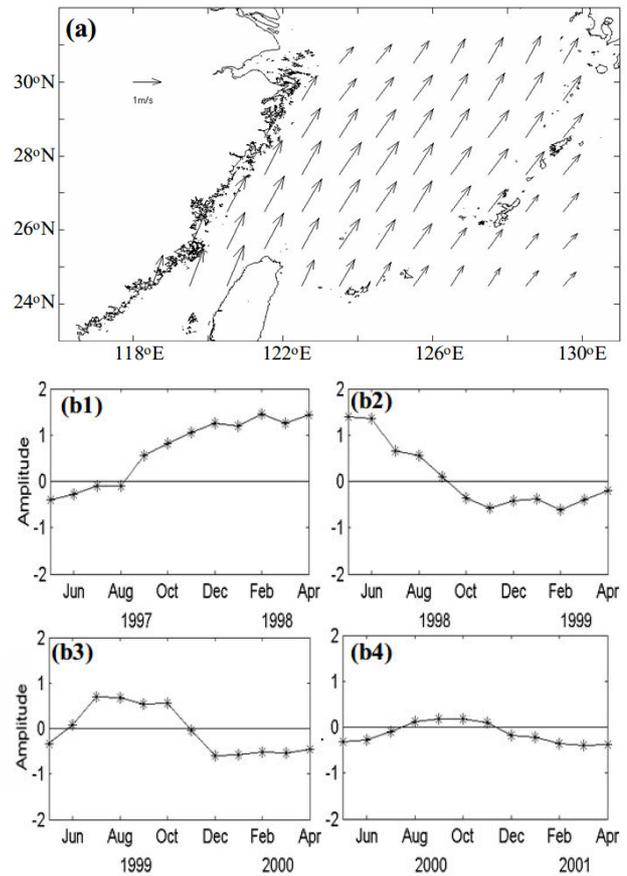


Figure 2. EOF mode 1 spatial distribution (a) and its time-varying amplitude (b) for SSW anomaly in the ECS during 4 separated periods from 1997 to 2001.

3.2 SST EOF results

Figure 3 shows the EOF mode 1 results of the SST anomaly data in the ECS. This mode contains 37.2% of the total variance. Combining Figure 3a and 3b, one can see a colder summer and a warmer winter in 1997-1998 El Niño year compared with the 1998-1999 La Niña year. Meanwhile, the SST anomaly in 1999-2000 shows an opposite tendency compared with the 1998-1999 strong La Niña year. Furthermore, we compare the temporal amplitudes in Figure 3b with the 9-month ahead shifted SOI data in Figure 4. A correlation coefficient of -0.77 between them implies that the SST field in the ECS can be influenced by the ENSO events. It is suggested that the ENSO effect on the SST in the ECS may not be an instantaneous response, the El Niño will cause sea surface warming and the La Niña can cause cooling with the time lag of about 9 months. Park and Oh (2000) found that the SST anomaly in the East Asian Marginal Seas (EAMS) have a significant correlation with that in the Niño 3.4 region with a time lag of 5-9 months similar to our finding.

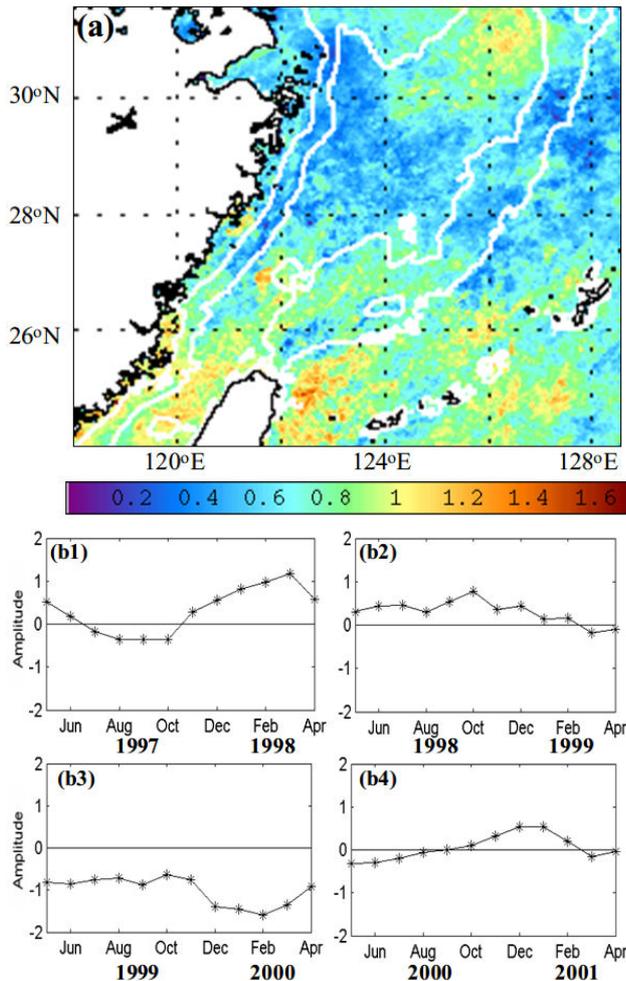


Figure 3. EOF mode 1 spatial distribution (a) and its time-varying amplitude (b) for SST anomaly in the ECS during 4 separated periods from 1997 to 2001.

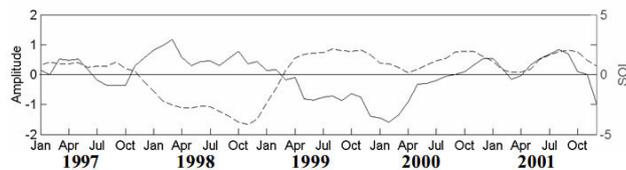


Figure 4. Comparison of EOF mode 1 temporal amplitude of the SST anomaly (solid line) to the 9-month ahead shifted SOI (dotted line).

4. CONCLUSIONS

In this study, the ERS-2 and QuikSCAT scatterometer SSW data and NOAA/AVHRR SST data in the ECS from 1997 to 2001 are used to detect their interannual variability, especially the influence of the ENSO events. Through EOF analysis some major findings are summarized as follows:

- 1). The 1997-1998 El Niño event may weaken SSW compared with the 1998-1999 La Niña year and the following weaker La Niña years.
- 2). The ENSO can affect the SST field in the ECS nearly with a 9-month delay.

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