1. Title

The interannual variation of coastal upwelling along the west coast of East China Sea

2. Members' names and affiliations

MAO Xinyan	Ocean University of China
SHI Jie	Ocean University of China
YANG Shugang	Ocean University of China
LENG Qian	Ocean University of China

3. Aim

(1)Analyze the interannual variation of coastal upwelling along the west coast of East China Sea.

(2) Determine the influencing factors of interannual variation of upwelling.

(3) Promote the exchanges and cooperation between Coastal Dynamics Group in Ocean University of China and the Center for Marine Environmental Studies (CEMS) in Ehime University.

4. Procedure

Based on JCOPE2 datasets, the interannual variation of coastal upwelling in summer offshore of Zhejiang province is analyzed. Temperature gradient threshold method is used to extract the upwelling region. The formula is as follows: dST > dTc, where dST is the horizontal gradient of water temperature at 10m layer; dTc is the temperature gradient threshold, set as 0.05 ° C/mile. The area where dST greater than 0.05 °C / mile is selected as the upwelling area. Fig. 1 shows the water temperature gradient distribution of the 10m layer in August. The blue region represents the non-upwelling region with a gradient of less than 0.05 °C/mile and other areas are the upwelling region. In this study, the larger upwelling area in the range of 27°N-31°N between July and August is set as the characteristic value of upwelling area (S); the larger gradient of upwelling center intensity between July and August is set as the upwelling center intensity (UI).

A new dimensionless upwelling index, NUI, is proposed in this study with a range of 0-1. It combined upwelling area S and upwelling center intensity UI, which were usually applied to estimate upwelling intensity in previous studies. The specific formula is as follows:

$$\mathrm{NUI}(i) = \left(\frac{S(i)-\min(S)}{\max(s)}\right) \times \left(\frac{UI(i)-\min(UI)}{\max(UI)}\right), \quad i=1993, \ldots, 2016$$

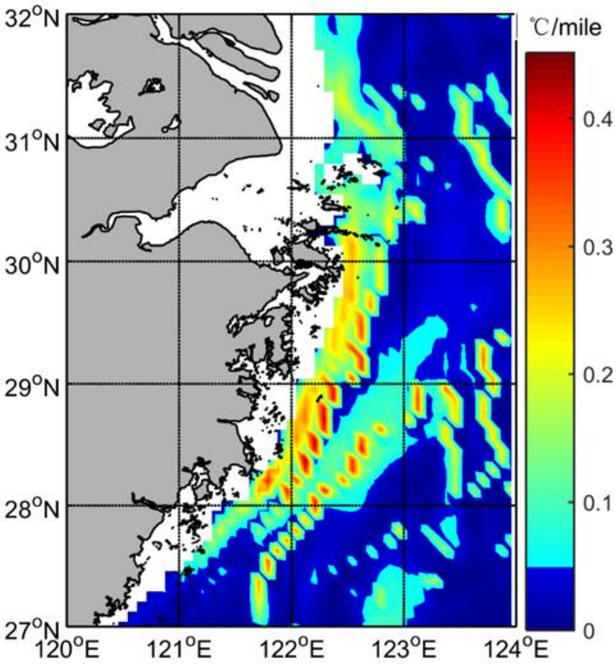

Fig. 1 Temperature Gradient Distribution on 10m Layer in August

5. Results

The results and discussions are all based on NUI time-series from 1993 to 2016. It can be inferred from Fig. 2 that the average value of NUI is 0.06, the periodic signal is variable and the overall trend weakens during the 24 years. With NUI exceeding 0.10, the upwelling intensity is stronger in 1995, 2002, 2006, 2010, and 2013; the upwelling intensity is weaker in 1997, 2004, 2011, 2012, 2014, and 2015 with NUI lower than 0.02.

By applying empirical mode decomposition (EMD) method to further explore the pattern of upwelling variation, three modes of NUI (blue lines in Fig. 3) were obtained. The variation period of the first two modes is 4 years and 8 years, respectively and the amplitude contribution of the first mode is twice of the second one. Therefore, the main period of upwelling index variation along the coast of Zhejiang is four-year. The correlation coefficient between NUI and ENSO index is significant (-0.42) and the test P value is 0.03 with 95% confidence interval in the range of -0.70 to -0.16. These statistical parameters indicate that the change of upwelling intensity is closely related to the ENSO phenomenon.

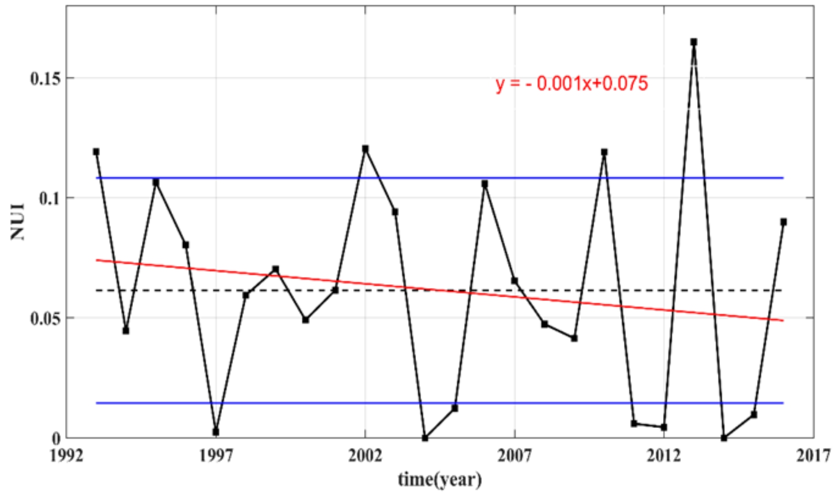

Fig. 2 Time series of NUI

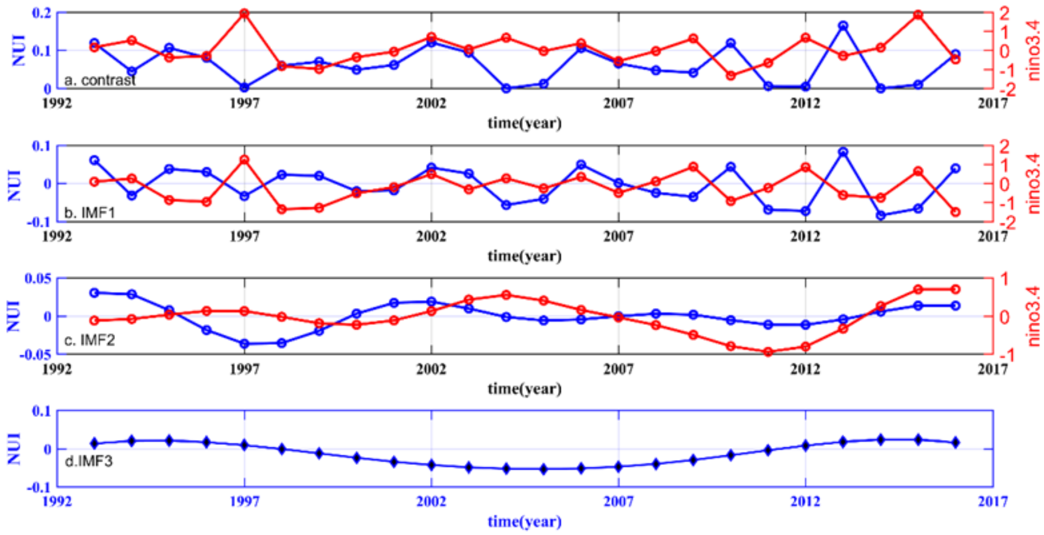

Fig. 3 NUI and Nino 3.4 Time Series

Besides, the wind vector is decomposed into two components: along the tangential and normal directions of the coastline. It is found that the southerly winds and offshore winds make contributions to the upwelling flow (Fig. 4b and 4c). NUI is positively correlated with wind speed but negatively with wind deviation angel (Fig. 4a and 4d). It can be considered that the weakening of the upwelling intensity along the coast of Zhejiang is mainly caused by the increase of wind deviation angel.

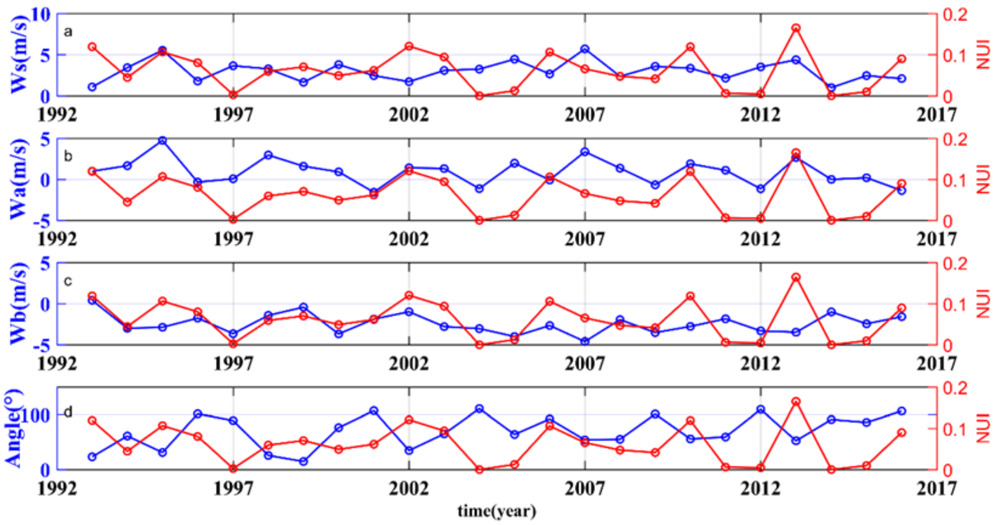

Fig. 4 Comparison of Wind Field and NUI

By further analysis, it is found that in the El Niño years (1997, 2009, 2014, etc.), the wind deviation angel is greater than 100° and the coastal wind speed is small. At this time, the upper seawater is transported to the shore, which is not conducive to the development of the upwelling flow, so the upwelling in that year is weak. While in the La Niña Year (1999, 2010, 2016, etc.), the wind deviation angel is within 50° and the coastal wind speed is large. At this time, the upper seawater is transported offshore and the bottom seawater moves to the shore and uplifts; the upwelling is strong. In addition, under the same wind speed, the smaller the wind deviation angel, the stronger the offshore surface transport, and the upwelling flow formed by the upward replenishment of seawater is stronger. However, the wind in 2005 shows a larger wind speed and smaller wind deviation angel when compared with 2006, but the upwelling intensity in 2005 is weaker than that in 2006, indicating that in addition to the wind field, there are other factors that modulate the upwelling. This issue will be continued to study in the future.

6. Publication/Conference presentation

Conference presentation

Title: The interannual variation of coastal upwelling along the west coast of East China Sea

Speaker: LENG Qian

Date: 11 December 2018.

Location: Ehime University.

7. Perspectives in Future

(1) Explore other factors influencing the interannual variation of coastal upwelling along the west coast of East China.

(2) Discriminate the relative importance between human activity shown by nutrients from Yangtze River discharge and climate change shown by upwelling variation.

(3) Enhance the cooperation and student and teacher exchange program between Ocean University of China and CEMS of Ehime University.