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Citation: **1801**, 060003 (2017); doi: 10.1063/1.4973107
View online: http://dx.doi.org/10.1063/1.4973107
View Table of Contents: http://aip.scitation.org/toc/apc/1801/1
Published by the American Institute of Physics

Spatio-Temporal Variations of Sea Surface Temperature in The Banda Sea During The Period of 2002 - 2008

Iskhaq Iskandar[1,2,3,a)], Wijaya Mardiansyah[1,2], Dedi Setiabudidaya[1], Muhammad Irfan[1] and Pradanto Poerwono[1]

[1]Jurusan Fisika, Fakultas MIPA, Universitas Sriwijaya, Jl. Raya Prabumulih, Km. 32, Inderalaya, OI, Sumatra Selatan, 30662 Indonesia
[2]Pusat Studi Geo-hazard dan Perubahan Iklim, Universitas Sriwijaya, Jl. Raya Prabumulih, Km. 32, Inderalaya, OI, Sumatra Selatan, 30662 Indonesia
[3]Pusat Penelitian Lingkungan Hidup (PPLH), Universitas Sriwijaya, Palembang, Sumatra Selatan, 30139 Indonesia

[a)]Corresponding author: iskhaq@mipa.unsri.ac.id

Abstract. Spatial and temporal variations of sea surface (SST) in the Banda Sea are studied for the period of June 2002 – May 2008. An empirical orthogonal function (EOF) analysis has been applied to an optimum interpolation SST (OISST) having spatial resolution of 0.25° and temporal resolution of 1 day. The results revealed that the four EOF modes account for 53.1% of the total SST variance. The first EOF mode, which accounts for 33.2% of the total variance, revealed the east-west SST pattern in the Banda Sea. This indicates 180° out of phase temporal variability between the eastern and the western parts of the Banda Sea. The second and the fourth modes explain 9.6% and 4.6% of the total variance respectively. Both two modes show the southeast-northwest spatial pattern. Meanwhile, the third mode accounting for 5.4% of the total variance indicates that the high SST variation is concentrated in the central Banda Sea. In addition, the corresponding principal component time series of the first mode revealed robust seasonal variability. The southeast monsoon (June – September) season is characterized by very low SST (26°C) occupied the Banda Sea region. Meanwhile, during the northwest monsoon (November – February) season, high SST (30°C) was observed in the Banda Sea region. The principal component time series of the second and the third modes, on the other hand, showed intraseasonal variation, which may relate to the local air-sea interaction in the Banda Sea. Meanwhile, the principal component time series of the fourth mode shows inter-annual variations. It is hypothesized that the Indian Ocean Dipole influence the SST in the Banda Sea on the inter-annual timescale.

INTRODUCTION

The Banda Sea is located in the eastern Indonesian region north of the Nusa Tenggara Islands Chain (Figure 1). Intermittent CTD (conductivity, temperature, depth) measurements performed within the Indonesian seas region between the years 1929 and 1981 were analyzed by earlier study [1]. They suggested that strong tidal mixing in the Banda Sea enhances the mixing of deep and surface waters leading to the modification of sea surface temperature (SST) in the Indonesian region. Moreover, recent study has demonstrated that SST in the Banda Sea undergoes a dramatic seasonal variation [2,3,4]. During the southeast monsoon, the SST decreases to about 26.5°C in August, while it increases to about 29.5°C during the northwest monsoon in December and May. They claimed that the local Ekman upwelling driven by the monsoonal winds plays a dominant role in generating the SST variations.

Variability of the SST in the Indonesian region, including the Banda Sea, has been shown to affect rainfall over the Maritime Continent [5] and Australia [6]. Recent study has shown a robust correlation between SST and precipitation over the Maritime Continent [7]. High precipitation rates over the Maritime Continent are associated with high SST. They also suggested that the strength of the Walker Circulation is related to the precipitation rates

The 6th International Conference on Theoretical and Applied Physics (The 6th ICTAP)
AIP Conf. Proc. 1801, 060003-1–060003-5; doi: 10.1063/1.4973107
Published by AIP Publishing. 978-0-7354-1469-3/$30.00

over the Maritime Continent. When the precipitation increases, the surface easterlies over the tropical Pacific Ocean are strengthened leading to a strong Walker Circulation.

Given the importance of SST within the Maritime Continent, this paper further exploits high temporal-resolution of the satellite-retrieved SST data using a powerful technique for spatial and temporal analysis namely the Empirical Orthogonal Function (EOF) analysis. The aim of this paper is to describe the spatio-temporal variations of the Banda Sea surface temperature.

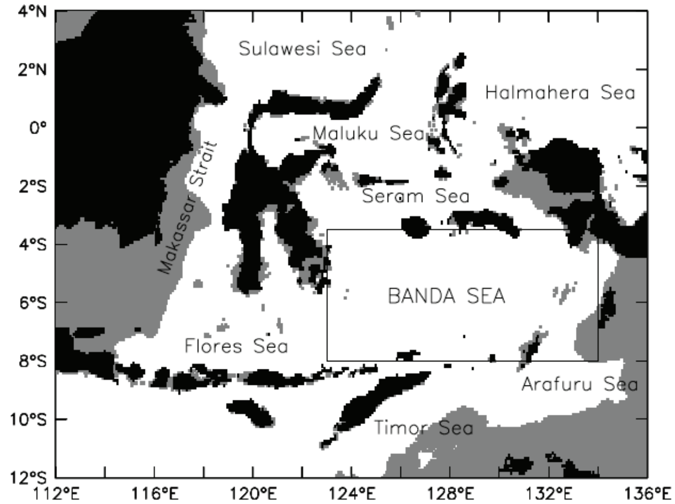

FIGURE 1. The Banda Sea area is indicated by a rectangular box.

DATA AND METHOD

The new daily optimum interpolation SST (OISST) data with a horizontal resolution of 0.25° for the period from 1 June 2002 to 31 May 2008 were obtained from the NOAA/National Climatic Data Center [8]. The optimum interpolation combined the Advanced Very High Resolution Radiometer (AVHRR) SST data and the Advanced Microwave Scanning Radiometer (AMSR) SST data. The AVHRR data is mainly use in the region near the land as the AMSR data is not available there. On the other hand, both data are used in the cloud-free region.

The EOF analysis is useful for identifying a spatial pattern and temporal characteristic of variability and providing the importance of each spatial pattern [9]. Typically, the first mode explains the most important variance. The decomposition of the original SST data into a few dominant modes of variability using the EOF analysis can be expressed as:

$$X(t) = \sum_{i=1}^{N} [a_i(t)\alpha_i] \quad (1)$$

where $X(t)$ is the original time series of the SST, a_i is the time variability of the mod-i (principal component), and α_i is the spatial pattern of the mode-i (spatial eigenfunction).

RESULTS AND DISCUSSION

Time mean SST from 1 June 2002 through 31 May 2008 shows a clear east-west SST gradient, with maximum value in the western Banda Sea, decreasing eastward (Figure 2-*left*). The coldest SST values occur close to the western coast of Papua, while warm water is found in the southwestern Banda Sea near the Flores Sea. On the other hand, the standard deviation field (Figure 2-*right*) indicates that the greatest SST variations are found in the eastern Banda Sea, consistent with that described by in earlier study [2,3].

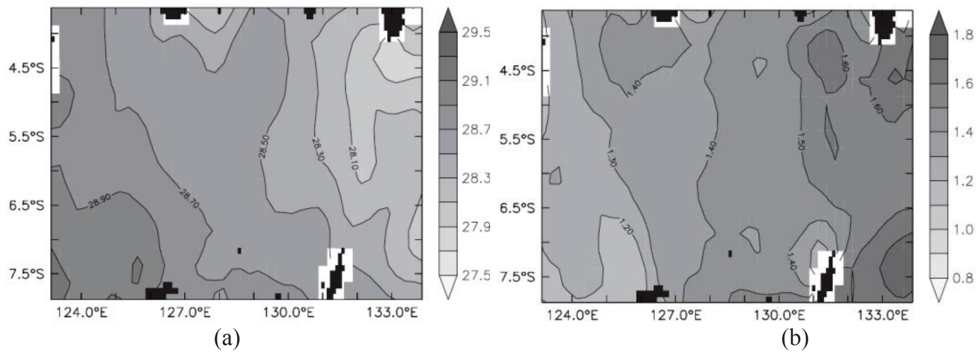

FIGURE 2. Time mean (a) and standard deviation (b) of SST from 1 June 2002 – 31 May 2008.

The five-year (January 2003 – December 2007) monthly SST climatology depicts strong annual variations (Figure 3). In the eastern Banda Sea, the highest SST of about 30°C is observed during December (southeast monsoon season), while it is decreases to about 26°C in August (northwest monsoon). On the other hand, similar annual cycle is also present in the western part. The SST increases to about 29°C in December, while it is decrease as low as about 25.5°C in August. Previous study has attributed this seasonal SST variation to the local Ekman pumping generated by local wind forcing [2,3]. The southeasterly (northwesterly) winds during southeast (northeast) monsoon generate Ekman upwelling (downwelling) leading to low (high) SST there.

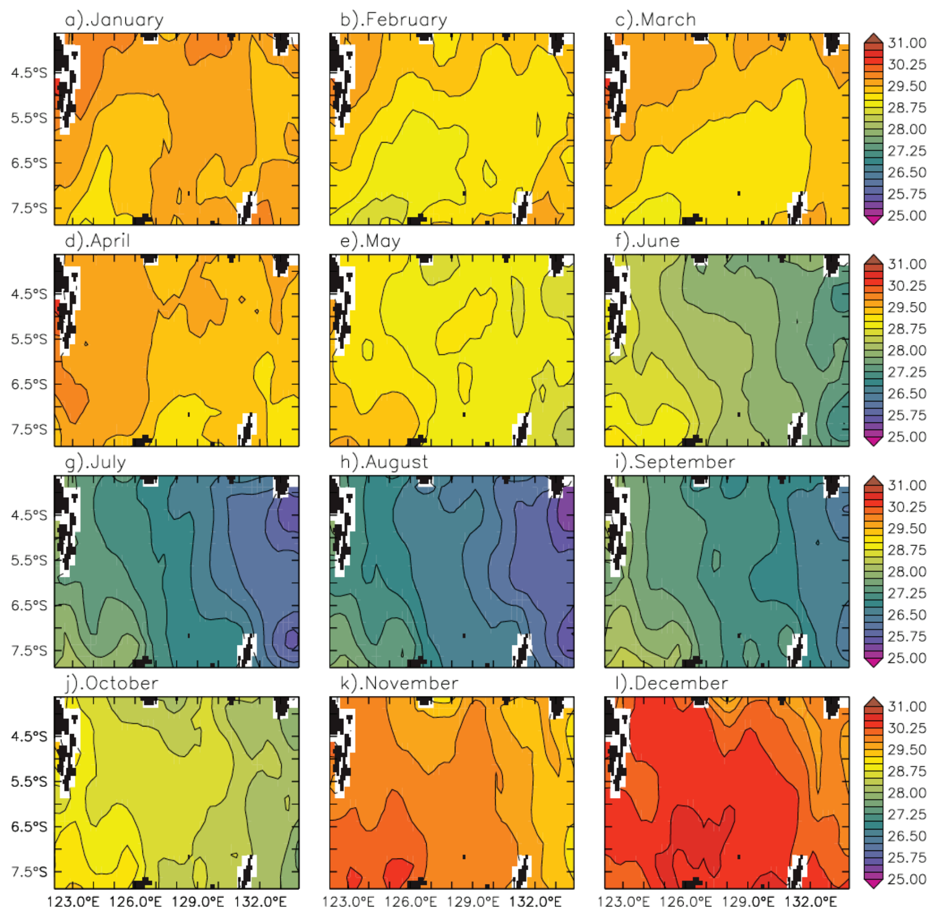

FIGURE 3. Monthly climatology of the SST in the Banda Sea

In order to evaluate the spatio-temporal of SST in the Banda Sea, an EOF analysis was performed on the SST anomalies. Note that the anomaly was calculated by subtracting the long-term mean at each grid point. The spatial functions of the first-four leading EOF mode, which describe spatial variability of the SST fields are presented in Figure 4. The SST pattern of the first EOF mode, which account for 33.2% of the total variance, reveals the presence of high variability in the western and eastern sides of the Banda Sea (Figure 4a). The pattern also reveals 180° out of phase temporal variability between the eastern and the western parts of the Banda Sea. The second EOF mode explaining 9.6% of the total variance shows high variability in the region confined the southeastern boundary of the Banda Sea (Figure 4b). The third EOF mode is accounting 5.4% of the total variance and its spatial pattern reveals maximum variability in the center of the Banda Sea (Figure 4c). On the other hand, the fourth EOF mode, which explains up to 4.9% of the total variance, depicts high variability in the northwestern and southwestern boundaries of the Banda Sea (Figure 4d).

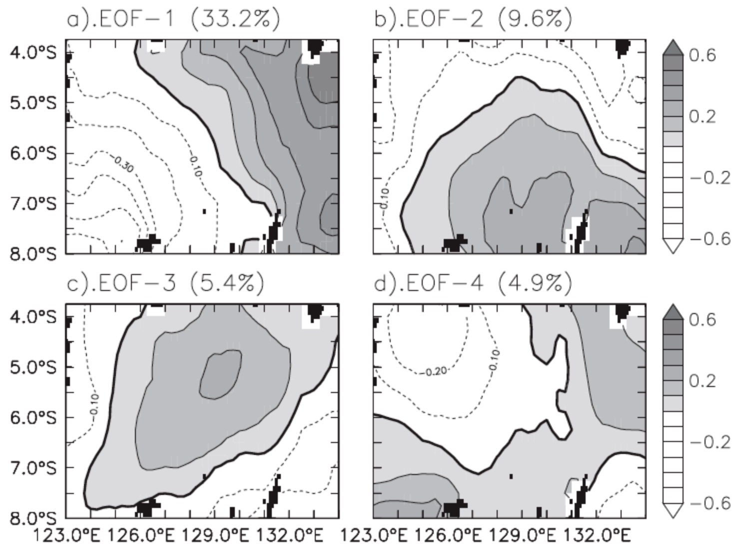

FIGURE 4. Spatial eigenfunctions of the first EOF mode of the SST in the Banda Sea

The time series of the principal component of the first four EOF modes, which represent the temporal variability of the the SST in the Banda Sea are presented in Figure 5. It is not surprising that the most apparent feature of the first EOF time series is a seasonal cycle, which is associated with the seasonal change in the monsoon winds. The Ekman pumping generated by the local wind is suggested to be the main driving force for this seasonal cycle [2,3]. The time series of the second and the third EOF modes reveal short-term variability. Note that the second EOF mode indicates an opposite variability during 2006 – 2007. On the other hand, the fourth EOF mode reveals an interannual variability. It shows high variability during 2006 – 2007. Previous studies have shown that during 2006 – 2007 the Indian Ocean Dipole (IOD) events took place in the tropical Indian Ocean [10]. This result may suggest that the strengthening of the third EOF mode is associated with the IOD event.

CONCLUSION

The SST variability in the Banda Sea is strongly influenced by the seasonal variability of the monsoonal winds. This seasonal wind generates Ekman pumping that forces seasonal SST variability in the Banda Sea. The EOF analysis reveals interesting features. The spatial pattern of the first EOF mode, which account for 33.2% of the total variance, has an the east-west SST pattern in the Banda Sea, indicating a 180° out of phase temporal variability between the eastern and the western parts of the Banda Sea. The second and the fourth modes explain 9.6% and 4.6% of the total variance respectively. Both two modes show the southeast-northwest spatial pattern. Meanwhile, the third mode accounting for 5.4% of the total variance indicates that the high SST variation is concentrated in the central Banda Sea. In addition, the corresponding principal component time series of the first mode revealed robust seasonal variability. The principal component time series of the second and the third modes, on the other hand, showed intraseasonal variation, which may relate to the local air-sea interaction in the Banda Sea. Meanwhile, the principal component time series of the fourth mode shows inter-annual variations. It is hypothesized that the Indian Ocean Dipole influences the SST in the Banda Sea on the inter-annual timescale.

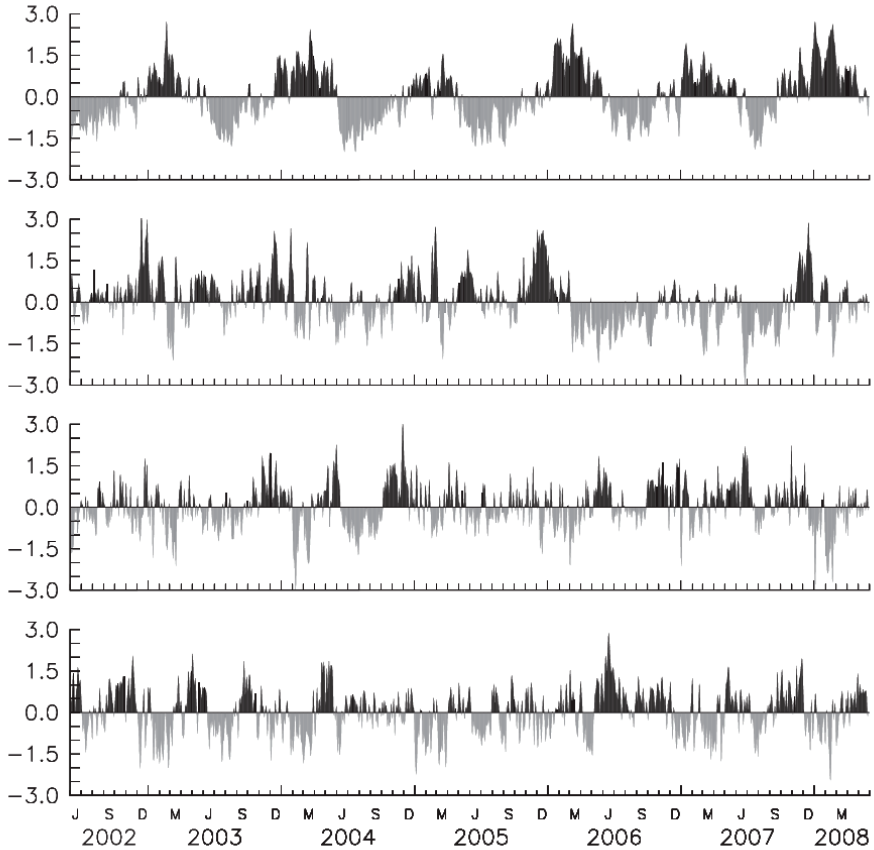

FIGURE 5. Time series of the principal component of the first four EOF mode of the SST in the Banda Sea.

ACKNOWLEDGMENTS

This study is supported by the University of Sriwijaya through "*Hibah Kolaborasi Internasional*" and by the Ministry of Research, Technology and Higher Education through "*Hibah Kompetensi*" (No. 023/Sp2H/LT/DPRM/II/2016). Ferret software has been used for analysis and creating the figures.

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