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Java Sea Surface Temperature Variability during ENSO 1997 – 1998 and 2014 – 2015

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ABSTRACT

Sea Surface Temperature (SST) is one of the important parameter to describe seawater characteristic. There is a strong linkage between SST and El Nino Southern Oscillation (ENSO). The purpose of this research is to investigate SST of Java Sea during in period 1997—1998 and 2014–2015. We use datasets from Hycom archieves, INDESO, and SOI. The result shows El Nino is started in March 1997 until April 1998 (peak in March 1998), then La Nina is started in June to December 1998 (peak in July 1998). Maximum Sea Surface Temperature Anomaly (SSTA) is occurred in August – September 1998 (0.8 °C – 0.9 °C). During 2014–2015, a propagation of El Nino is founded. El Nino is started in August until November 2014 (-7.6 < SOI < -11.4, peak in August), and is followed in May to October 2015 (-12 < SOI < -20.2, peak in October). During 2014–2015, a maximum Sea Surface Temperature Anomaly (SSTA) is founded in May 2014 (0.5 °C).

Keywords: *Java Sea, sea surface temperature, ENSO, 1997-1998, 2014-2015, Indonesia*

1. Introduction

Indonesia maritime continent is located between two continents (Asia and Australia) and also between two oceans (Pacifik and Indian). Those are influences the regional climate variability particularly by Monsoon system and El Nino Southern Oscillation (ENSO). The seawater mass circulation and its variabilty, in Indonesian seas, influenced by those interactions of both systems (Trenberth et al., 1997; Susanto et al., 2001; Sitompul et al., 2012). Climatic characteristics in different throughout the year has been identified different according to three distinct seasons based on predictions of climate characteristic (Yulianti et al., 2016). The first pioneering study and documented the ENSO on global scale i.e. Ropelewski & Halpert in 1987, Walker in 1923 – 1928, and Walker and Bliss in 1930 – 1937, were motivated by the effort to comprehend and predicted the variety of rainfall in Indian monsoon and then expanded for study of rainfall in around the world (Ropelewski & Halpert, 1987). ENSO reflects the anomaly process and fluctuation of sea surface sea surface temperature (SST). SST, in this article, is assump depending to an intensity from Pacific event (Pranowo et al., 2016). While in general, ENSO influences also Indonesian Throughflow, salinity, and chlorophyll concentration in Indonesia (Abigail et al., 2015; Siregar et al., 2017). ENSO phenomenon has period from 2 – 7 years (Quinn et al., 1978).

The important interoceanic exchange regions in the global ocean is The Indonesian Throughflow (ITF). The variations of SST in the ITF region are generally not much as compared to that in the Tropical Pacific Ocean due to the lack of strong equatorial upwelling (Muripto, 2016). Pacific seawater mass by Indonesian Throughflow (ITF) entering to Indonesian seas through North of Halmahera Island, Molluca Sea, and Lifamatola passage, Buru Sea, South Banda Sea direction to Flores Sea, and Java Sea (Gordon et al., 2010; Pranowo, 2012; Sagala et al., 2014). The seawater mass is characterized by a sea surface temperature and a typical salinity, both in horizontally and vertically (Wardani et al., 2014; Purba & Pranowo, 2015).

Java Sea has a high productivity, which indicating by the existence of seagrass, mangrove and coral reef ecosystems, including demersal and small pelagic fishes (Rosalina et al., 2013; Rustam et al., 2013). ENSO in Java Sea has been studied by several researchers (Susanto et al., 2001; Gordon et al., 2008; Wicaksana et al., 2015; Abigail et al., 2015). However, this research article more concerning to the sea surface temperature system during ENSO incident, in the period of 1997 – 1998 and 2014 – 2015, which never examined previously according to us as authors. The purpose of this research article is to investigating the sea surface temperature system of Java Sea during those periods of ENSO, adopted from several datasets (Hycom, 2016; INDESO-KKP, 2016; BOM, 2016).

2. Materials and Methods

Data Sets

Java Sea as the study area has bounding coordinates 3 °S – 8 °S and 105.5 °E – 115 °E (Fig. 1). Main datasets are used i.e: the sea surface temperature data (1/12° spatial resolution, daily average) from Hybrid Coordinate Ocean Model (Hycom) archives (1997 – 1998), and also from Infrastructure Development of Space Oceanography (INDESO) archives (2014 – 2015) http://indeso.web.id. and Southern Oscillation Index (SOI). El Nino and La Nina event during ENSO are identified by using Southern Oscillation Index (SOI, monthly average), which is picked up from Bureau of Meterology (BOM) http://www.bom.gov.au.

Methods

A quantitative statistical (monthly) spatial and temporal averages is applied to this investigation and follows by descriptive analysis [30]. Monthly spatial distributions has visualized in order to describes the sea surface temperature propagation during El Nino and La Nina during 1997 – 1998 and 2014 – 2015 (see Fig. 3 & 4). A spatial monthly average of sea surface temperature anomaly (SSTA) is computed and overlayed with monthly SOI data due to further trend analysis (see Fig. 2). The SSTA is also examined during period of monsoonal system i.e.: West Monsoon (December, January, February), East Monsoon (June, July, August), and the Transitional Monsoon (March – May and September – November) according to Putri (2005).

3. Results and Discussion

Sea surface temperature anomaly temporal variability

El Nino, is the climate divergence, that triggers the warming of sea surface temperature from the normal condition. El Nino can be marked by the SOI negative value (less than -7), which propagates in 3 months. La Nina is indicated with a positive value (more than +7) also during 3 months propagation. A strong event indicated by the Index more than +/-10. SSTA during ENSO incident in 1997 – 1998 and 2014 – 2015 are presented in Fig. 2.

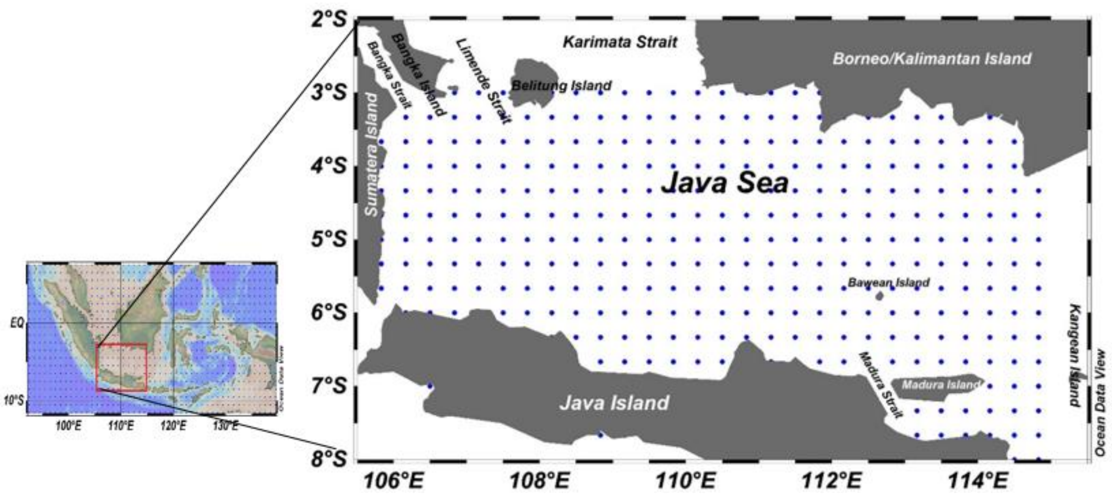

Fig. 1 Java Sea study area and its station map. There are 252 stations with 1/12° spatial resolution.

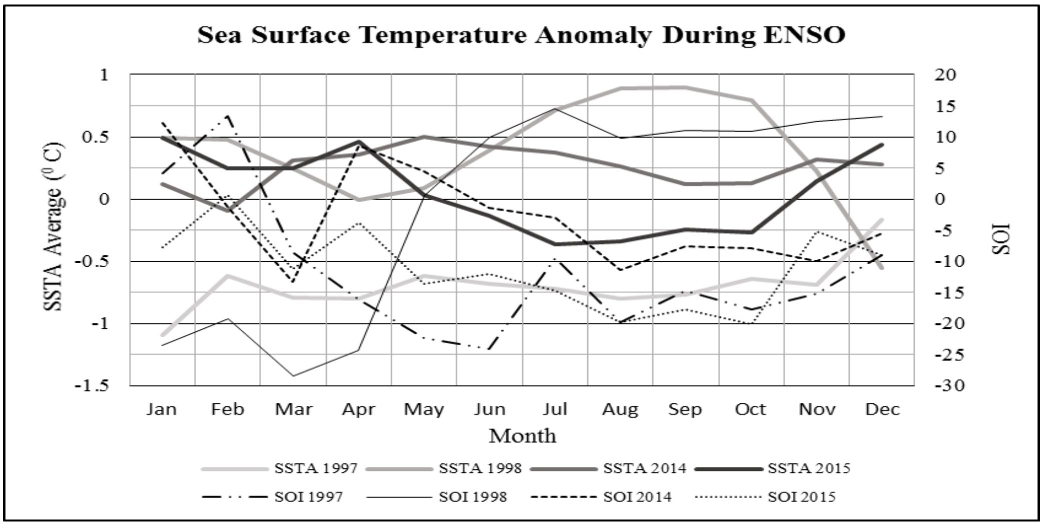

Fig. 2 Java Sea surface temperature monthly anomaly during ENSO 1997 – 1998 and 2014 – 2015

Monthly SOI values, in Fig. 2, shows El Nino and La Nina event is back to back propagated during 1997 – 1998 and 2014 – 2015. In 1997, El Nino is occurred during almost the year. It occurs on March until December, where the peak of strong El Nino event is occurred in June (SOI = -24.1). In 1998, a strong El Nino event (-22 < SOI < -28.5) is occurred during January – April (peak in March), follows by strong La Nina (+10 < SOI < +15), which is occurred June – December (peak in July). During 2014 – 2015, there is a long El Nino propagation. El Nino event is begin to occur in August until November 2014 (-7.6 < SOI < -11.4, peak in August), and follows in May until October 2015 (-12 < SOI < -20.2, peak in October). Fig. 2 shows an interesting pattern in Java Sea, that the ENSO intensity fluctation is occurring before/after the propagation of SSTA. El Nino is started in March 1997, and reached a peak in June 1998 (Supangat et al., 2004).

In 1997, minimum SSTA (-1.1 °C) is occur in January, before period of strong El Nino is started in March. Maximum SSTA (-0.1 °C) is occur in December. In 1998, maximum SSTA (0.49 °C), during the periods of strong El Nino (January – April), is occurring in January. The maximum SSTA, during the year of 1998 (0.8 – 0.9 °C), is occuring during August – September after the peak of strong La Nina (in July). During 2014 – 2015, the maximum SSTA (0.5 °C) is founded in May. While in 2015, the minimum SSTA (-0.36 °C) is founded in July, which 2 months after the period of strong El Nino is started (in May). Anomalies longest and highest values is founded in 1997 – 1998 (2.9 °C), which is dominantly influences by El Nino (Widisantosa et al., 2016).

In 1997, SSTA average, during West Monsoon (December, January, February), is in the range between -1.1 °C and -0.6 °C. In 1998, SSTA average, during West Monsoon, is in the range between -0.4 °C and 0.5 °C, where before the period of El Nino is started (March 1997). In 2014, SSTA average, during West Monsoon, is in the range between -0.5 °C and 0.1 °C. In 2015, SSTA average, during West Monsoon, is in the range of 0.24 – 0.49 °C. In 1997, SSTA average, during East Monsoon (June, July, August), is in the range between -0.8 °C and -0.6 °C, where the peak of strong El Nino event is occurred in June. In 1998, SSTA average, during East Monsoon, is in the range of 0.4 – 0.9 °C, where the peak of strong La Nina event is occurred in July. In 2014, SSTA average, during East Monsoon, is in the range of 0.2 – 0.4 °C. In 2015, SSTA average, during East Monsoon, is in the range between -0.4 °C and -0.1 °C, where El Nino is started in May until October.

Sea surface temperature monthly spatial distribution

The sea surface temperature (SST) is important physical parameter, which influences to other parameter such as biological (Rochman et al., 2016). The sea surface temperature, in Java Sea, during 1997 – 1998 and 2014 – 2015, shows a unique spatial distribution and also a unique monthly propagation. The annual average Java SST, based on 1997 – 1998 and 2014 – 2105 monthly data, is ~28 °C. In 1997 – 1998, along the southern coasts of Java and Sumatra during easterly winds induced strong upwelling, the El Niño is coinciding with the IOD positive phase (Muripto, 2016). The seawater mass, in Java Sea, is coming from South China Sea, which crosses over Karimata Strait during West Monsoon. While during East Monsoon, seawater mass is coming from Makassar Strait and Flores Sea (Sadhotomo, 2006). The spatial distribution of monthly Java SST for 1997, 1998, 2014, and 2015 is respectively presented in Fig. 3, 4, and 5.

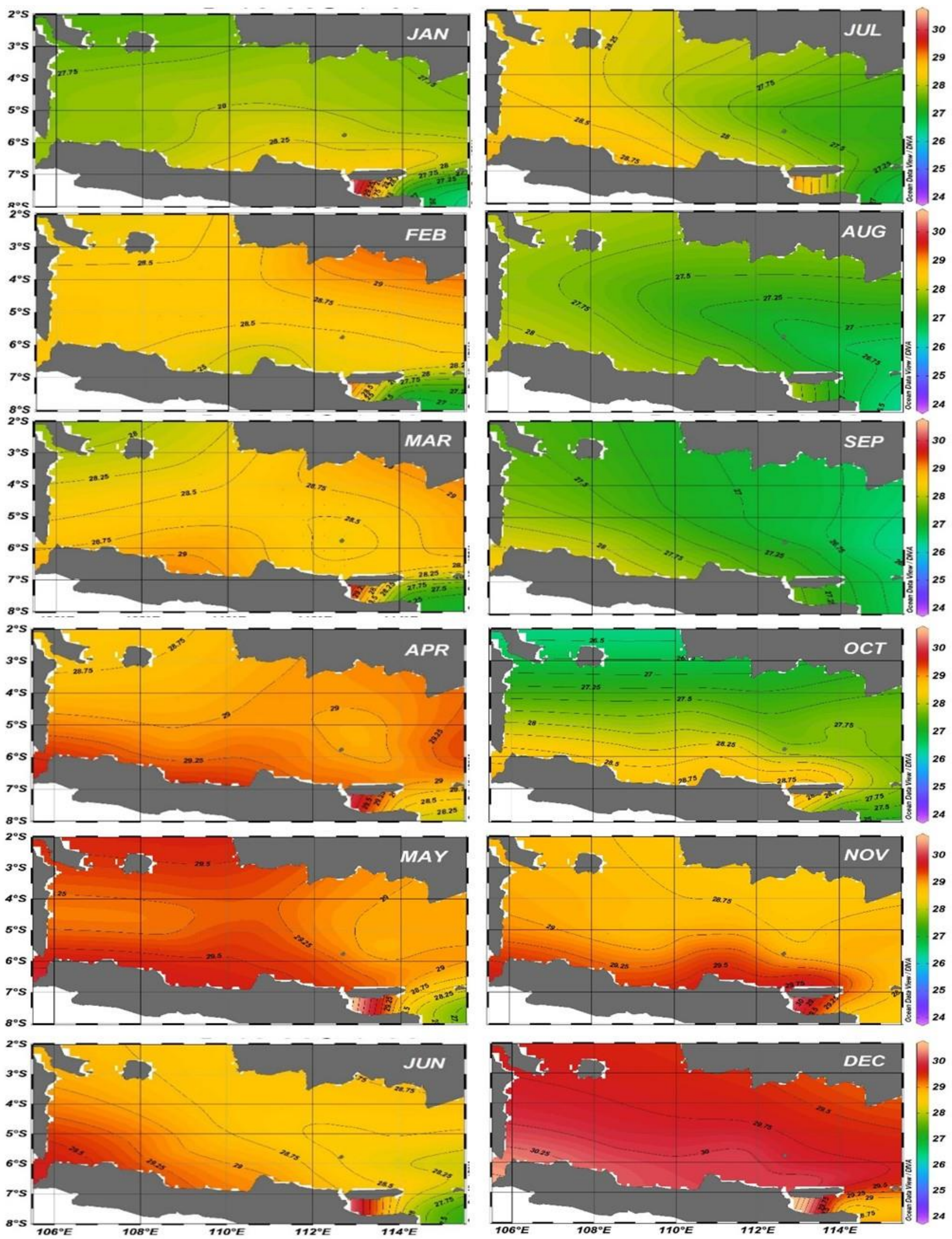

Fig. 3 The Java sea surface temperature monthly propagation in 1997

The monthly propagation of Java sea surface temperature in 1997 is provided as Fig. 3. SST, in January 1997, is showing a slightly cooler in the western part of Java sea, meanwhile warmer in the eastern part especially in the Madura Strait. Its cooler sea surface temperature is most probably because of during the West Monsoon tending to rainy season. During the West Monsoon, wind is blowing from west to east brings more humid air. SST in the western part of Java Sea, during West Monsoon, is cooler than the East Monsoon, as well as parts of eastern part. Sea surface temperature (SST) during West Monsoon generally is relatively warmer than the East Monsoon.

Furthermore, in February and June, sea surface temperature in the Java Sea region warmer and then returned cooling in July. In February, sea surface temperature is slightly warmer, in the northeastern region, than in other regions. In March, it's compared to the South China Sea, Java SST is warmer. In April, almost the entire area of Java Sea has a warm SST. Java SST generally in May is warmer than SST in April. Most probably, Java SST is increasingly warming due to the transitional period from rainy season to the dry season (Siregar et al., 2017).

Furthermore, in June, Java SST in the western region is warmer than in the eastern region. Most probably, it is influence by seawater mass of Makassar Strait, which is start to entering Java Sea in June. In July to September, the Java SST is cooler than the previous months. The cooling is happening during the East Monsoon, where the air is going to drought. In October, SST is warmer in the north coasts of Java and Madura Strait. The cooler SST in the northern region of Java Sea, most probably is coming from the propagation of cooler seawater mass of the South China Sea through Karimata Strait. In November, generally the Java SST is continuing tend to further warm, especially in the north coasts of Java and Madura Strait. In December, the temperature in the Java Sea is the warmest SST. This month, the warmest temperature is in the area of Java and Madura Strait.

In 1997, the strong El Nino influences Indonesia seas in generally, including impacts to Java seawater mass (Siregar et al., 2017). Indonesian sea is one of main connection low latitude in the world ocean (Mustikasari et al., 2015; Xue et al., 2016). This connection is enabling a transfer of a huge seawater mass of Pacific into Indian Ocean, with ITF. Consequently, ITF plays the important role in climate system above Java Sea (Gordon et al., 2010). Therefore, the signal annually during an ITF formed, somehow is coincides with the ENSO variability in Java Sea (Potemra & Schneider, 2007). Java Sea is influences by ITF which passing to Makassar Strait nearby. During El Nino event, ITF carries out cool water in Makassar Strait. It makes a shallow thermocline and increase an upwelling signal (Susanto et al., 2001). During La Nina event, ITF carries out warmer in Makassar Strait, decreasing an upwelling signal. Longest duration of sea surface temperature anomaly is founded during 1997 – 1998, around 2.9 °C during El Nino occurs in Java Sea (Widisantosa et al., 2016).

The monthly propagation of Java sea surface temperature in 1998 is provided as Fig. 4. Sea surface temperature, in January 1998, shows that a warm sea surface temperature is coming from South China Sea through the Karimata Strait. The warmer sea surface temperature is founded in the eastern part of the Java Sea, especially in Madura Strait and the trans-boundary area of Makassar Strait. In February, sea surface temperature slightly cooler in the South China Sea and Karimata Strait, while warmer sea surface temperature in the eastern region, especially in the Madura Strait and Makassar Strait. During northwest monsoon period (West Monsoon) seawater mass of the South China Sea coming to Java Sea, at the same time wind and the surface current moving eastwards (Sagala et al., 2014). In March and April, warmer SST is founded in the Madura (basin) Strait. Furthermore, Java SST in May and June, both are warmer than its happened in the previous months.

During July - August, the SST becomes cooling in the eastern region, particularly in the Madura Strait up to near Makassar Strait. Those are increased in October. In November, the western Java SST is a little bit cooler than the eastern region. Furthermore, in December, almost all region of Java sea is warm, but the warmest is founded in the Madura Strait.

In general, during April and also during October, the Java sea surface current direction is changes, with maximum speed 100 cm/ second (Wicaksana et al., 2015; Siregar et al., 2017). In 1997/1998, Java SST increases more than 1 °C, which may caused by the strong El Nino propagation (Gordon et al., 2008; Gordon et al., 2010).

In 1998, the maximum Java SST is founded in November, i.e. 29.937 °C, with the minimum of 28.87 °C. The Java SST is actually started increasing from November 1997 until July 1998 (~29 °C). Based on SOI, El Nino begins on March 1997 and achieve its peak on

June 1998 (Supangat et al., 2004). This phenomenon is impact to the changes of Java SST and also its salinity [24]. The Java SST will be increases when the salinity decreases. It is happened since the saline water usually coming from cool deeper waters. The Java SST monthly propagation in 2014 can be seen in Fig. 5.

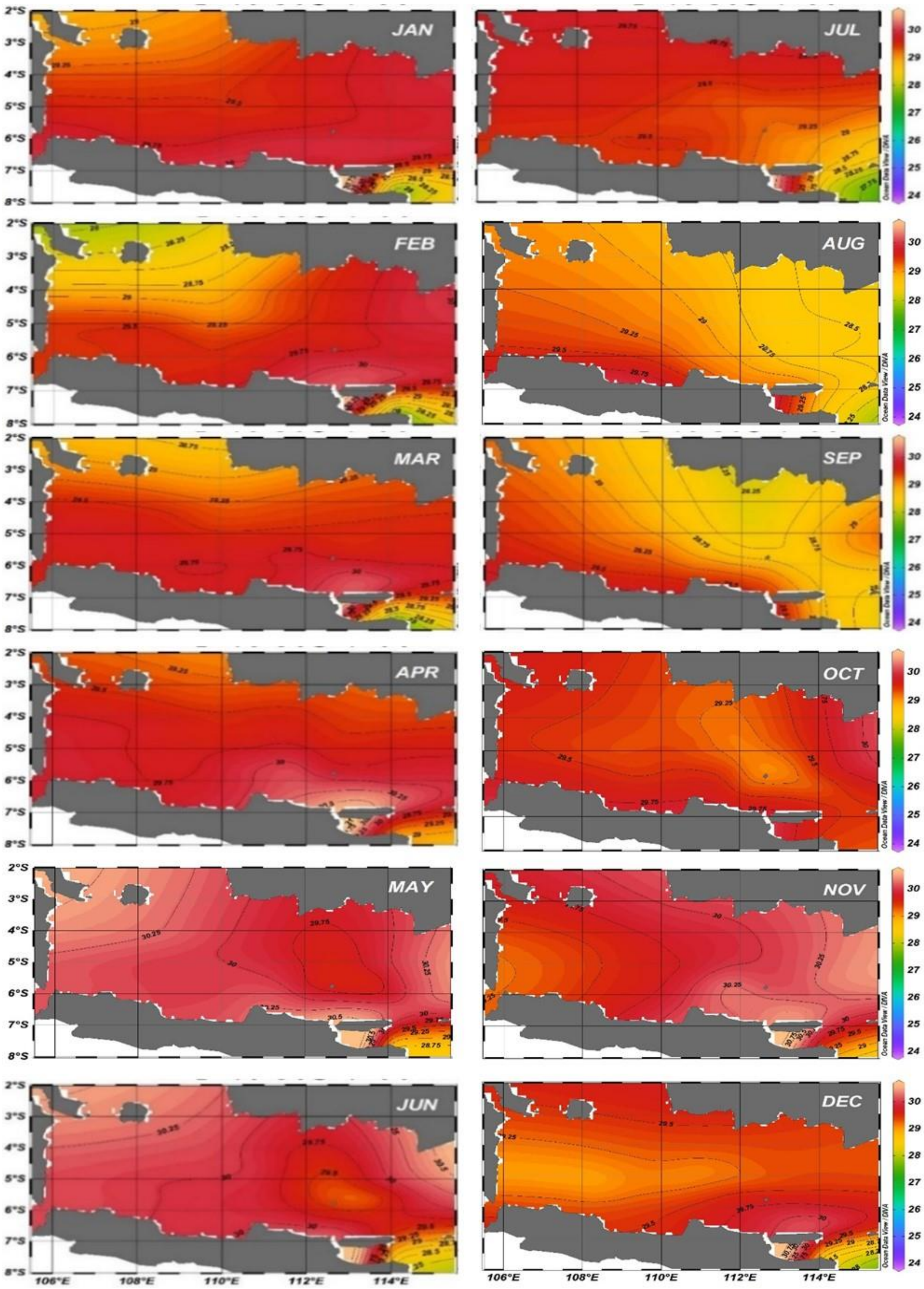

Fig. 4. The Java sea surface temperature monthly propagation in 1998

Sea surface temperature in Fig. 5, in January shows sea surface temperature was warmer in the territorial waters of the island of Java and in the eastern region. During West Monsoon, winds and currents moving from the west to the east, so the mass of water of the South China Sea to lower sea surface temperature to fill the Java Sea (Sagala et al., 2014; Siregar et al., 2017). In February, the sea surface temperature are warm in the Makassar Strait. While, the sea surface temperature is a slightly cooler is in the South China Sea and Karimata Strait. In March, the sea surface temperature warmer in almost all regions, especially in the waters the around of Java Island and in the east area, while the sea surface temperature is a slightly cooler in the South China Sea and Karimata Strait. In April and May, the sea surface temperature warmer in almost all regions, the sea surface temperature in the month reached 31 °C.

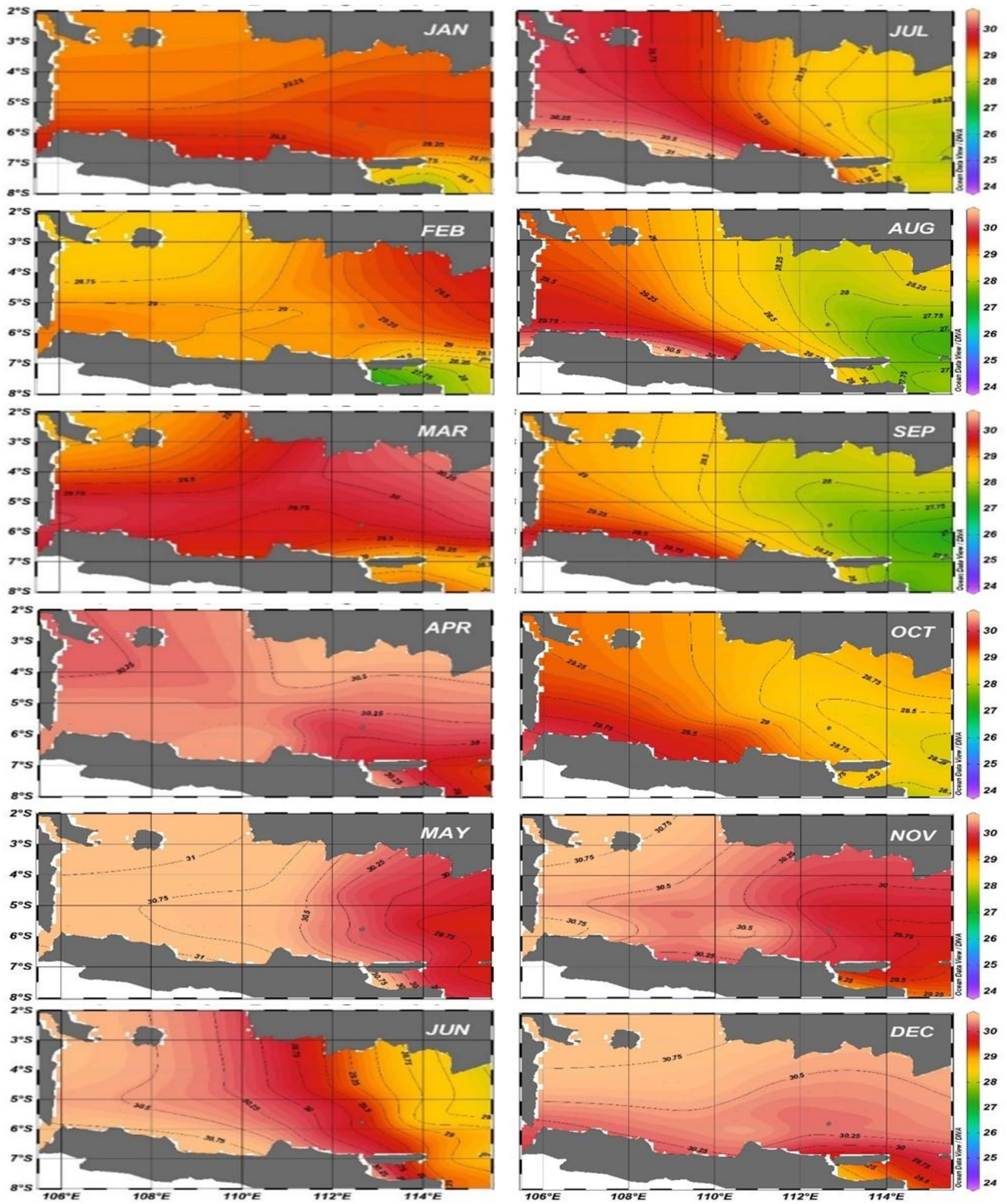

Fig. 5 The Java sea surface temperature monthly propagation in 2014

In June, sea surface temperature is slightly cooler in the eastern region and the sea surface temperature is getting warmer toward the western region. Warm sea surface temperature is the around of Java Island, the South China Sea and Karimata Strait. The East Monsoon period, winds move from east to west region so as to bring the mass of water is relatively lower sea surface temperature of the area east to west (Sagala et al., 2014; Siregar et al., 2017). In July to September, slightly cooler sea surface temperature in the eastern region which is the area around of Makassar Strait and warm sea surface temperature are in the western region. In October, the sea surface temperature in the eastern region a little warmer than the sea surface temperature in the previous month. Warm sea surface temperature this month occurred in the western region. In November, the sea surface temperature warmer than the sea surface temperature in the previous month.

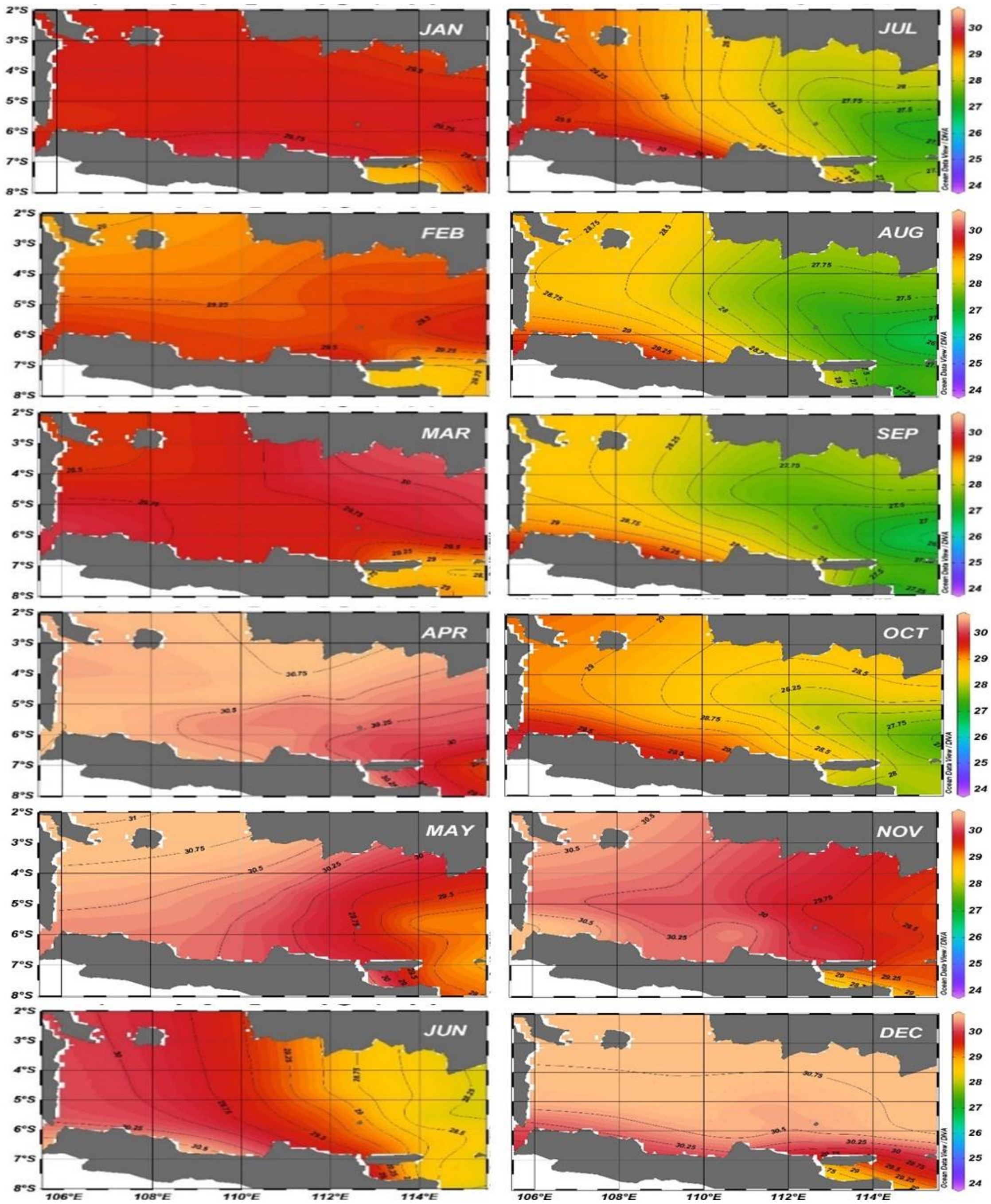

Fig. 6 The Java sea surface temperature monthly propagation in 2015

This month, the warmer sea surface temperature was in the western regions, especially in the South China Sea and Karimata Strait, while slightly cooler sea surface temperature in the eastern region as the Madura Strait and Makassar Strait. In December, the warm sea surface temperature are in all waters, but warmer sea surface temperature in the South China Sea and Karimata Strait. In December month, the warm sea surface temperature on all waters territories, but the warmer sea surface temperature at South China Sea territorial and Karimata Strait. ENSO phenomenon causes the air distraction circulation to east Indonesia primarily on turn transition time from rainy day to dry seasons or from dry seasons into rain seasons (MAM) according to Mulyana (2002). Climate change impacts to rise in sea levels, temperature rise, changes in rainfall patterns and increase in frequency, intensity of extreme weather events, and availability of water (Hidalgo, 2015; Yulianti et al., 2016).

Based on Fig. 5, the maximum sea surface temperature on May month with average sea surface temperature on this month is 30.316 °C. The minimum sea surface temperature on September month is 28.098 °C. Drastically sea surface temperature change occurs on October month to November month. Taking place change is the sea surface temperature increase until 1.287 °C. In year 2015 as El Nino incident peak after 1997, where in 2015, the waters sea surface temperature becomes warmer (Kosasih, 2015). In the ITF region, small variations in SST can significantly affect the atmosphere ocean interaction processes (Muripto, 2016). The Figure about waters sea surface temperature of Java Sea in 2015 can be seen on Fig. 6.

Sea surface temperature in Fig. 6, the sea surface temperature in almost all waters in January is warm and the sea surface temperature decreased in February. In February, slightly warmer sea surface temperature in the region around of Java Island and Makassar Strait, while, in the South China Sea, Karimata Strait, and Madura Strait lower sea surface temperature or slightly cooler. In March, sea surface temperature is warmer in the Makassar Strait and southwest of the Java Sea, while, sea surface temperature is lower in the region Karimata Strait and South China Sea. In April, the sea surface temperature warmer than in the previous month. This month, almost all the territorial waters of high sea surface temperature, but the sea surface temperature was slightly lower at Madura Strait region. In May and June, sea surface temperature is warmer in the South China Sea and Karimata Strait, while, slightly cooler sea surface temperature in the Madura Strait and Makassar Strait.

In July to September, the sea surface temperature is a slightly cooler in the Madura Strait and Makassar Strait, while, sea surface temperature is warmer in the southwestern region of the Java Sea, South China Sea and Karimata Strait. In October to December, the sea surface temperature increases and warmer in the territorial waters. In November, the sea surface temperature slightly cooler in the Makassar Strait and around of Madura Strait, while in other areas the sea surface temperature is warmer. In December, sea surface temperature in almost all warm temperate regions, while slightly cooler sea surface temperature in the Madura Strait. Monsoon wind movement causes the surface sea surface temperature variety of Java Sea, where Southeast Monsoon period (East Monsoon), the wind and flow of Java Sea move from east to west carries out the water mass relatively more cool lead to west direction [6]. Oceanic water with sea surface temperature lower in monsun period intensively (Mulyana, 2002; Sagala et al., 2014; Siregar et al., 2017).

Based on Fig. 6, the maximum sea surface temperature on December month with average sea surface temperature in this month is 30.417 °C. The minimum sea surface temperature on August month is 27.718 °C. Drastically sea surface temperature change occurs on October month to November month. The change of sea surface temperature increase experiences the change from 28.354 °C on October month becomes 29.862 °C on November. Drastically sea surface temperature change becomes 29.862 °C on November month. The change of sea surface temperature increase achieves 1.508 °C.

4. Conclusions

ENSO phenomenon influences the sea surface temperature pattern in Java Sea. According to southern oscillation index (SOI), in 1997 – 1998 as El Nino incident that followed by La Nina, while 2014 – 2015 as El Nino. The sea surface temperature pattern from 1997 – 1998 and 2014 – 2015 experienced the change. It is depending on ENSO intensity on such year. El Nino started in March 1997 to April 1998 (peak in March 1998). La nina occurred in 2014, in June and December (peak in July). During 2014 – 2015 there is a long El Nino propagation. El Nino event begin to occur in August until November 2014 (-7.6 < SOI < -

11.4, peak in August), and follows in May until October 2015 (-12 < SOI < -20.2, peak in October). The maximum SSTA during the year of 1997 – 1998 (0.8 – 0.9 °C) is occuring during August – September 1998 after the peak of strong La Nina (in July). During 2014 – 2015, the maximum SSTA (0.5 °C) is occur in May.

In East Monsoon, the cool sea surface temperature (SST) move from the eastern region (Makassar Strait) to the west of the Java Sea (Bangka Island, Belitung Island, and Karimata Strait), so that in the western part of the Java Sea experienced a warm SST. In West Monsoon, cool SST move from the west to east of Java Sea. On years of research, SST warm evenly cover the Java Sea in December 2015.

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