The Influence of Indian Ocean Dipole (IOD) on The Variability of Sea Surface Temperature and Precipitation in Sumatera Island

Muhammad Hafidz Ibnu Khaldun[1], Anindya Wirasatriya[1,2*], Agus Anugroho Dwi Suryo[1] and Kunarso[1]

[1]Oceanography Departement, Faculty of Fisheries and Marine Science, Diponegoro University. Prof. H. Sudarto, SH Street, Semarang. 50275 INA
[2]Center for Coastal Disaster Mitigation and Rehabilitation Studies, Diponegoro University, Semarang. Prof. H. Sudarto, SH Street, Semarang. 50275 INA

aninosi@yahoo.com

Abstract. Sumatera Island is located adjacent to the ocean and directly influenced by the dynamic of Indian Ocean. Indian Ocean Dipole (IOD) as one of the global climate factor has a big impact towards this dynamic. As it aims to get the influence of IOD towards Sumatera water area, high-resolution remote sensing data is needed. Those are Sea Surface Temperature (SST), precipitation, and Dipole Mode Index (DMI). DMI is calculated by the differentiation of SST anomaly. IOD condition is emphasized by using precipitation data. Area observed is divided into three areas which are in series West Sumatera water, East Sumatera water, and Bukit Barisan highland. During IOD negative, the precipitation values were estimated 5,43; 4,63; 4,5 mm/hr sequentially. Meanwhile, during IOD positive, those values were 2,74; 3,47; 3,11 mm/hr sequentially. It is shown that IOD has the impact of the precipitation values in Sumatera waters. By showing the higher value of IOD negative and the lower value on IOD positive. West Sumatera water is observed as the most influencing area by the dynamic of IOD. Topography is also influencing towards the precipitation and it is shown by its values weather on IOD negative or positive.

Keywords: SST, Precipitation, IOD, Sumatra Waters

1. Introduction

Indonesia is geographically located between two Continents and two Oceans and traversed by the equator which causes Indonesia to be affected by global climate change. Its strategic location makes Indonesia one of the centers of the world's climate control system so that the phenomenon of climate change occurring in Indonesia and globally will be interconnected [1]. One of the global climate variability that influences Indonesia is Indian Ocean Dipole (IOD) [2,3,4].

A more detailed assessment of global climate variability on the effect of sea surface temperature and precipitation is important. Based on the results of various studies that have been done show that there is a fairly clear connection between the phenomenon of sea surface temperature with the incidence of rain in an area [5,6]. This explains that the variability of precipitation is strongly influenced by changes in sea surface temperature and this is associated with changes in sea surface temperature anomalies either spatially or temporally [e.g., 7,8].

Anomalous sea surface temperature in the Indian Ocean Dipole Mode (IOD) greatly affects the intensity of precipitation in Indonesia. At the time of dipole fashion in the Indian Ocean, generally, precipitation in Indonesia has decreased. This is due to the positive anomalies of the southeast wind as the dipole mode progresses so that the southeast wind that blows in the area gets stronger. The strength of the southeastern winds that contain only a small amount of water causes more difficult precipitation to rain [9]. When IOD positive precipitation intensity will decrease and when IOD negative precipitation intensity will increase [e.g., 3,10,11]. Therefore, there is a need for further study on the study of the variability of sea surface temperature and precipitation and correlation with IOD climate variability in Sumatera Island. An understanding of the effect of Indian Ocean Dipole climate variability on SPL variability and precipitation and its physical processes on the Island and Waters of Sumatra can help to determine the mitigation measures of the disaster caused by the increase and decrease in precipitation.

2. Data and method

Precipitation and sea surface temperature data are obtained from daily data of Tropical Precipitation Measuring Mission (TRMM) satellite and daily data of Administration-Advanced Very High-Resolution Radiometer (AVHRR) and Advanced Microwave Scanning Radiometer on the Earth Observing System (AMSR-E) resolution $0.25^o \times 0.25^o$ with observation period from 1998 to 2016. These data are developed and distributed by the National Oceanic and Atmospheric Administration (NOAA). Data of precipitation and sea surface temperature were analyzed by compiling the data into monthly data until becoming monthly climatology data by using equation as follows [12]:

$$\overline{X}\,(x,y) = \frac{1}{n}\sum_{i=1}^{n} xi(x,y,t) \qquad (1)$$

Where, $\overline{X}\,(x,y)$ is monthly or monthly climatology mean value at position (x,y), $xi(x,y,t)$ its the value of the data at (x,y) position and time t. Furthermore, n is the number of data in 1 month and the number of monthly data in 1 period of climatology (i.e., from 1998 to 2016 = 18 data) for monthly calculation and monthly climatology calculation, respectively. If xi is a hollow pixel, that pixel is excluded in the calculation.

The Indian Ocean Dipole climate variability data was obtained using Dipole Mode Index (DMI). DMI is a value derived from differences in sea surface temperature anomalies in the West Indian Ocean Hindia (10^oN-10^oS and 50^oE-70^oE) and East Indian Ocean (10^oS-0^oU and 90^oE-110^oE) [13]. The value of DMI is obtained by the weight equation:

$$DMI = West - East \qquad (2)$$

Where DMI is IOD Index, $West$ is the mean sea surface temperature value in the western area of the Indian Ocean (10^oN-10^oS and 50^oE-70^oE). Furthermore, $East$ is the mean sea surface temperature value in the southeastern area of the Indian Ocean (10 ^{o}S-0^oN and 90^oE -110^oE). DMI data used has a range of time range from 1998 to 2016. Anomaly values obtained are used to classify Dipole Mode Index (DMI) data in 2 (two) phenomena namely Negative DMI and DMI Positive with threshold value ± 0.4.

The phenomenon of Indian Ocean dipole always happens every year as shown in Figure 1. Data processing of sea surface temperature from January 1 1998, to December 31 2016, obtained results that show the strongest positive IOD phenomenon occurred in October 2006 with an anomaly index value of 1.211. The strongest negative IOD phenomenon occurred in July 2016 with an anomaly index value of -1.043.

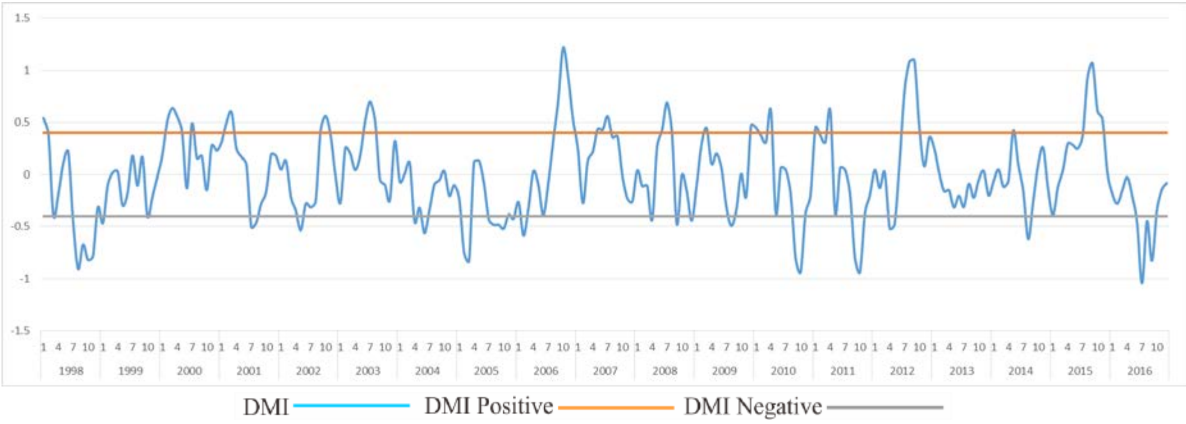

Figure 1. Anomalous Index of Sea Surface Temperature (DMI)

3. Result and Discussion

The distribution of sea surface temperature distribution pattern and monthly climatology precipitation in Figures 2 and 3 shows the difference of sea surface temperature and precipitation value in Sumatera waters when influenced by climate variability. Figures 2 and 3 show lower sea-surface temperature values when IOD positive and increases when IOD negative which indicates that IOD phenomena affect the variability of sea surface temperature and precipitation in Sumatera island. Sea surface temperature values in area 2 and area 3 are obtained from sea surface temperature values close to the area. The value can be interpreted as the value of sea-surface temperature that has an effect on area 2 and area 3.

The distribution of sea surface temperature distribution and monthly climatology precipitation in Figure 3 shows an interesting pattern of distribution on the value of the pattern of precipitation distribution in December whose territory is located in South East Sumatra waters which tend to be higher than the East of Sumatera Island. Therefore, the authors divide the study concentration area into 3 areas. The determination of this area is based on the value of precipitation contour in December climatology which has the highest precipitation value compared to other months which can be seen in Fig. 4.

During IOD negative, the sea-surface temperature values were estimated 27,78; 27,96; 27.85^{o}C sequentially. Meanwhile, during IOD positive, those values were 27,63; 27,87; 27,71^{o}C sequentially. And during IOD negative, the precipitation values were estimated 5,43; 4,63; 4,5 mm/hr sequentially. Meanwhile, during IOD positive, those values were 2,74; 3,47; 3,11 mm/hr sequentially. The area I has a relatively higher precipitation value than the other two areas with the highest intensity of 5.43 mm/hr. This is caused by the increase of sea surface temperature which is more dominant than other areas reaching 27.78^{o}C so that the intake becomes more leverage. This is also due to the difference in pressure that occurs in the eastern Indian Ocean area is higher than the western Indian Ocean causing the mass of water to move towards Sumatera [e.g., 3,9,10,14,15,16].

Area III has the lowest precipitation value than in the other two areas, ie 4-6 mm/hr. At the highest precipitation area III has an intensity of 5.02 (mm/hr) and when the lowest intensity is only 0.68 (mm/hr). This is because the temperature of the sea surface in the eastern waters is lower when compared to the value of sea surface temperature watered west. In addition, the eastern part of the island of Sumatera has a low topography so that the condensation process is not running optimally. On a spatial scale, precipitation variability is strongly influenced by topography [e.g., 17,18,19,20].

Area II precipitation value is relatively higher than the area III that is 4.63 mm/hr. This is due to the difference in altitude along the western coast of Sumatra that there is a plateau of Barisan. This resulted in the condensation process resulting in an increase in the value of precipitation. Based on the results in Fig. 4 it can be seen that variability of sea surface temperature and precipitation is influenced by IOD phenomenon. At the time of negative IOD, precipitation intensity becomes higher than normal while in positive IOD precipitation intensity will be lower. When IOD positive precipitation intensity will decrease and when IOD negative precipitation intensity will increase [10].

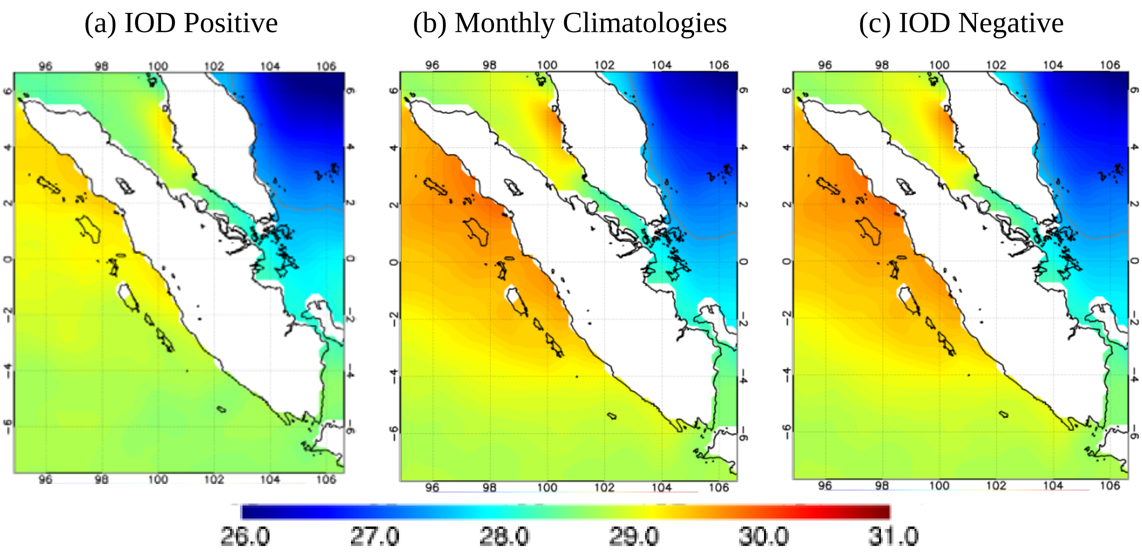

Figure 2. The pattern of distribution of sea surface temperature in December

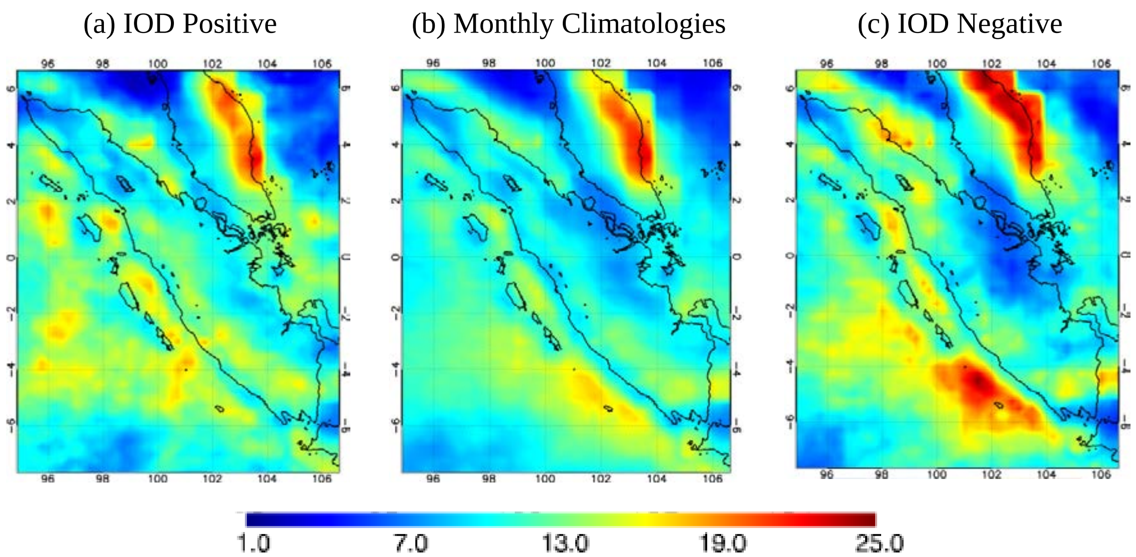

Figure 3. The Pattern of Distribution of Precipitation in December

During the IOD phenomenon, Negative sea surface temperature values and precipitation intensity will be higher when compared to when IOD is positive. This is due to the differences in the pressure of the East Indian Ocean and the West Indian Ocean resulting in the mass transfer of air containing moisture. At IOD Negative sea surface temperatures in the East Indian Ocean will be higher than in the West Indian Ocean, resulting in an increase in precipitation in the West waters of Sumatra. In contrast to positive IOD sea surface temperatures in the West Indian Ocean will be higher than the East Indian Ocean so that there is a decrease in precipitation in West waters of Sumatra [e.g., 3,9,10,14,15,16].

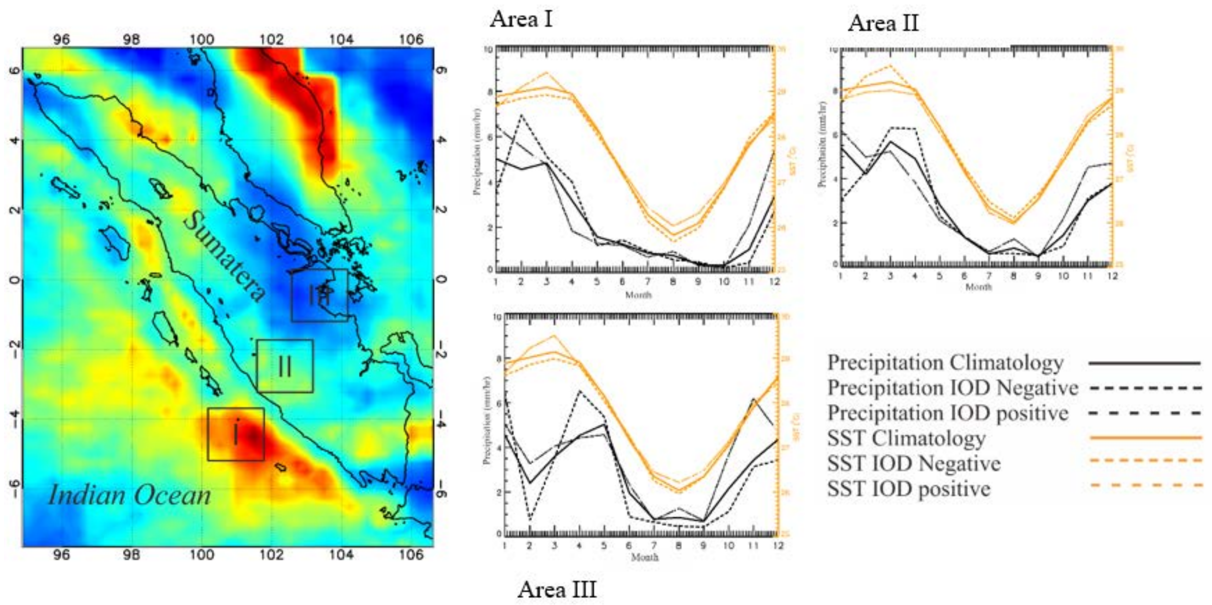

Figure 4. Precipitation distribution pattern in December and Graph of SPL and Precipitation relationship

4. Conclusion
IOD phenomenon affects the variability of sea surface temperature and precipitation that have been studied using remote sensing data of TRMM and AVHRR-AMSRE satellite with resolution $0.25^o \times 0.25^o$. During the phenomenon of IOD (IOD Negative) occurs, in general, an increase in sea surface temperature intensity of 0.05^oC and precipitation of 0.3 mm/hr. This is due to the differences in the pressure of the East Indian Ocean and the West Indian Ocean resulting in the mass transfer of air containing moisture. Increased precipitation also occurs in areas with relatively high topography caused by more optimum condensation.

References
[1] Robertson A, Moron V, Qian J, Chang C P, Tangang F, Aldrian E, Koh T Y and Juneng L 2011 *The Maritime Continent Monsoon, in The Global Monsoon System: Research and Forecast, 2nd Ed*. Eds. CP Chang, Y Ding, NC Lau, RH Johnson, B Wang and T Yasunari, (World Scientific Publication Company) Vol 5. 608 p
[2] Webster P J, A Moore, J Loschnigg and M Leban 1999 *Nature* **401** 356-360
[3] Saji N H, B N Goswami, P N Vina yachandran and T Yamagata 1999 *Nature* **401** 360-363
[4] Fadholi A 2013 *J. Ilmu Lingkungan* **2(1)** 43-50
[5] Estiningtyas, W Ramadhani F and Aldrian E 2007 *J. Agromet Indonesia* **21(2)** 46–60
[6] Lindzen R S and S Nigam 1987 *J.Atmos. Sci*. **44** 2418–2436
[7] Shailendra Rai and A C Pandey 2008 *Atmosphere-Ocean* **46 (3)** 361-376 doi:10.3137/ao.460305
[8] Arif Suryantoro and Bambang Siswanto 2008 *J.Sains Dirgantara* **6(1)** 1-21
[9] Mulyana E 2002 *J. Jurnal Sains & Teknologi Modifikasi Cuaca*. **3(1)** 39-43
[10] Kunarso, Hadi S, Ningsih N S and Baskoro M S 2012 *J. Ilmu Kelautan*. **17(2)** 87-89
[11] Karumuri Ashok, Zhaoyong Guan and Toshio Yamagata 2001 *Geophys. Res. Lett.* **28(23)** 4499- 4502
[12] Wirsatriya A, Setiawan R Y and Subardjo P 2017 *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens. (JSTARS)*, **10(12)** 5513 - 5518 doi: 10.1109/JSTARS.2017.2745207
[13] Han Soo Lee 2015 *Water* **7** 1751-1768 doi:10.3390/w7041751
[14] Aurelie P Harou, Robert F Lajoie, Dominic R Kniveton and Michael R Frogley 2006 *Int. J.*

Climatol, **26** 45–54 doi: 10.1002/joc.1239
[15] Clark C, Webster P and Cole J 2003 *J. Climate* **16** 548–554
[16] Richard Washington and Anthony Preston 2006 *J.Geophysical Research*, **111** 1 – 15 doi:10.1029/2005JD006724
[17] Tongkukut S 2011 *J. Ilmiah Sains*. **11(1)** 102-108
[18] Alison M Anders, Gerard H Roe, David R Montgomery and Bernard Hallet 2008 *Geology* **36(6)** 479 – 482 doi: 10.1130/G24821A.1
[19] Ntwali D, Ogwang B A and Ongoma V 2016 *Atmospheric and Climate Sciences* **6** 145-157 http://dx.doi.org/10.4236/acs.2016.62013
[20] Alan Basist, Gerard D Bell and Vernon Meentemeyer 1994 *J. Climate* **7** 1305 – 1315