Thermal Front in the North of Java Sea, Indonesia

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Abstract: Indian Ocean Dipole (IOD) is a phenomenon in the Indian Ocean caused by differences in the anomaly of Sea Surface Temperature (SST) between the West Coast of Sumatra and the East Coast of Africa. The phase difference of the formation of positive IOD (+) and negative IOD (-). The IOD phase can be known by using the Dipole Mode Index (DMI). This research aims to identify the effect of IOD phase on SST and distribution thermal front. Identification of distribution using the Pearson method, and analysis of the distribution thermal front using the Single Image Detection (SIED) method. Area research in North Java Seas during wet season 2013-2015. IOD phase with normal condition more often occure than IOD phase with weakly condition. Strong correlation occurred with negative direction, and moderate correlation occured with positive direction. Meanwhile, correlation IOD with rainfall not significant or uncorrelation. During five years the heat temperature was concentrated in the coastal area. IOD with normal condition has a larger thermal front area 1976 km², while IOD with weakly condition has a 624 km² thermal front area. Thermal front distribusion more often occure on north area of Central Java with a longwise and widing distribusion.

1 INTRODUCTION

Indonesia, which is in the tropics, receives the most amount of solar radiation and is influenced by various atmospheric phenomena, making this region vulnerable to variability and climate change. The climate in Indonesia will not always run normally every year, there is a time when there is a decrease in rainfall but at another time there is high rainfall. In general, the cause of rainfall in Indonesia is influenced by several phenomena including ENSO or commonly called El Nino and Indian Ocean Dipole (IOD). The phenomenon of IOD (Indian Ocean Dipole) can occur where there is a difference in sea surface temperature between the western tropical Indian Ocean or the east African coast and the eastern tropical Indian Ocean or the West Coast of Sumatra (Yamagata et al, 2000 in Fadholi, 2013). Sea surface temperature (SST) is one of the oceanographic parameters that characterize the mass of water in the ocean and is related to the state of the seawater layer below, so that it can be used in analyzing phenomena that occur at sea such as currents, upwelling and fronts (confluence of two water masses different). Thermal front is one of the oceanographic phenomena that can be identified by looking at the pattern of SST distribution (Inayah, 2015).

The potential of fish in the Java Sea is very large, but the potential utilization of fish in the Java Sea has already exceeded the limit or has reached 95 percent of the total available marine resources, it is one of the factors causing overfishing. Based on the description above, the understanding of the thermal front that is suspected to be an area that is liked by fish is important to be investigated. Thermal front as a local phenomenon cannot be separated from the influence of the adjacent regional oceanographic phenomena, in this case the IOD phenomenon that takes place in the Indian Ocean on the axis of East Africa and West Sumatra which is close to the research location, namely the Java Sea.

The research conducted focuses on the distribution of thermal fronts on IOD using SST parameters and rainfall in the east monsoon. SST and sea rainfall data used were obtained from imagery, and rainfall data was taken from representative samples in each region. Factors such as wind, surface currents, exposure time are ignored in this study.

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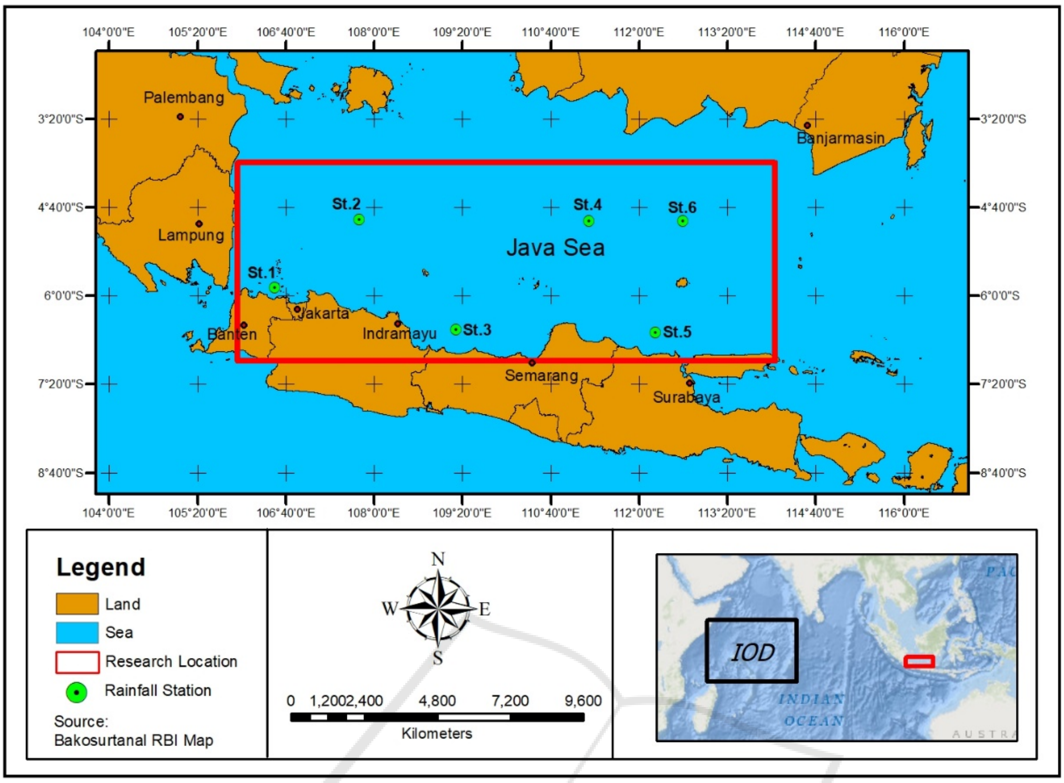

Figure 1: Research Location.

2 RESEARCH METHODS

This research was conducted in August 2018-June 2019 with the use of data for 5 years (2013-2017), with the area in the waters of the Java Sea located from 4° S to 7.1° S and from 106° E to 114° E. The research location is located on the east side of the IOD axis in East Sumatra (East Indian Ocean) with a distance of about 4000 km from the axis of the IOD (Figure 1).

The tools used in the processing and analysis of data in this study are a number of computer programs such as: ArcGIS, ODV, Microsoft Excel. The data used in this study can be seen in Table 1.

Table 1: Types and sources of data.

Data Types	Data Sources
SST	https://oceancolor.gsfc.nasa.gov/
Rainfall	https://apps.ecmwf.int
Dipole Mode Index	http://jamstec.go.jp/frcgc/ research/d1/IOD/DATA/DMI

Data processing methods are as follows: (1). IOD data that has been downloaded through the site is processed using Microsoft Excel and is classified seasonally and is classified based on DMI values, namely the positive and negative phases. As for the strength of the IOD phase consists of normal, moderate, and strong phases (Amri et al, 2010). (2) SST data downloaded is first processed using SeaDas software to cut images according to the location of the study, then processing SST variability and thermal front are processed using ArcGIS with the Single Image Detection method to identify the thermal front using a 0.5° thereshold value. (3) Rainfall data is processed using ODV to convert the nc format to txt and seasonal grouping and rainfall calculation are performed on Microsoft Excel.

The analysis in this study uses Pearson correlation analysis which is used to determine the degree of closeness of the relationship between the two variables. The analysis is done by calculating the monthly average of sea surface temperature (SST). Rainfall data and DMI values are not calculated. Correlation test using the DMI value aims to determine the level of relationship between the data parameters to the formation of IOD, namely the value of the X variable which is assumed to be the dependent variable (IOD) and the variable Y as the independent variable namely rainfall and SST.

3 RESULT AND DISCUSSION

3.1 Indian Ocean Dipole Dynamics

The monthly IOD conditions in 2013 occurred under normal conditions with both IOD (+) and IOD (-) phases, but IOD (+) phases were more common. IOD with a weak condition occurred two years during the 2013-2017 period, namely in 2015 and 2017. In 2013 during the east season, there was one negative IOD phase and three positive IOD phases with a condition where the DMI value was 0.08-0.29. In 2014 in the east season there were two negative IOD phases and a positive IOD under normal conditions. Early in the eastern season of 2015 there was a normal positive IOD phase with normal conditions, while the following three months (July-September) a positive IOD phase occurred with a low intensity at DMI 0.53-0.86. In 2016 the IOD phase that occurred was a negative IOD phase with normal intensity. In 2017 the IOD phase that occurred the same as in 2015 which occurred three times the positive IOD phase with weak strength and once with normal strength, but the weak strength IOD phase occurred at the beginning of the east season (June-August).

SST data has been processed by NASA has validated with the conditions in the waters. NASA sails to various waters including Indonesia for retrieve insitu SST data so that can validate derived SST data from MODIS imagery. Thermal front validation uses an algorithm developed by Cayula anda Cornillon. This algorithmm will search for different populations in each area. The population is the warm temperature area and the cold temperature area. The result accurate to detect thermal front in regional waters.

3.2 SST Variability

The average SST for five years has a value of around 30˚-28˚C can be shown in Figure 2. In 2013 showed a phase change from IOD (-) with the normal nature to IOD (+) in the next three months. This causes the east season SST in that year continues to decrease every month. SST in 2014 was colder than in 2015, namely the beginning of the eastern season SST conditions around 29˚C and decreased in the next two months while at the end of the east season SST experienced a slight increase due to the change from IOD (-) to IOD phase (+). In 2015 SST experienced an increase from 2014 and was hotter than in 2013, a decrease in the value of DMI from the weak phase caused SST conditions in September to increase from August. The 2016 IOD conditions underwent a phase change at the end of the eastern season, ie from the IOD (-) phase to the IOD (+) which caused the average SST conditions in September to be higher than other years which nearly reached 31˚C. In 2017, it is indicated that the beginning of the east season has an IOD (-) phase and the end of the season has an IOD (+) phase, causing an increase in temperature from the previous month.

The relationship between the IOD phase and SST values over the past five years is shown in Table 2. The correlation value of IOD with SST in the Java Sea tends to have a strong interpretation relationship with the direction of the negative relationship, this can be seen in three years, namely in 2013, 2015 and 2017. high correlation value. Correlation value that has a relationship of interpretation is having a direction of a positive relationship that occurred in 2014 and 2016. The direction of a negative relationship can be stated that the increase in the value of DMI is followed by a decrease in the value of SST.

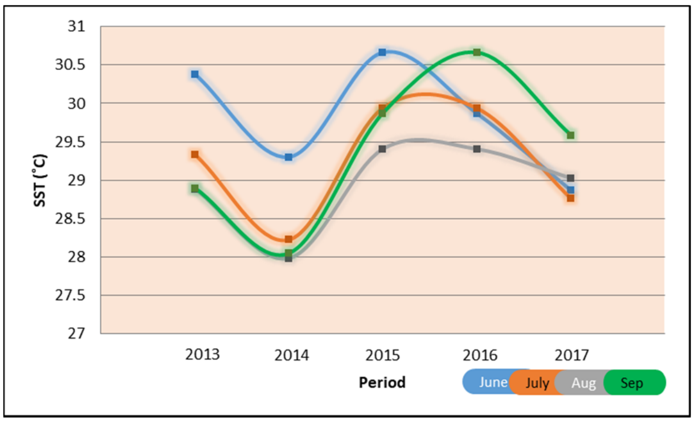

Figure 2: Average SST pattern for five years.

Table 2: Correlations between IOD and SST.

Period	DMI	SST	Correlation
2013			
June	-0.29	30.38	-0.93
July	0.12	29.34	
August	0.10	28.89	
September	0.08	28.90	
2014			
June	0.18	29.3	0.40
July	-0.05	28.23	
August	-0.08	27.98	
September	0.24	28.05	
2015			
June	0.50	30.66	-0.86
July	0.53	29.94	
August	0.86	29.41	
September	0.67	29.87	
2016			
June	-0.23	29.87	0.33
July	-0.43	29.94	
August	-0.15	29.41	
September	-0.05	30.66	
2017			
June	0.63	28.87	-0.93
July	0.83	28.77	
August	0.64	29.03	
September	0.42	29.59	

3.3 Front Thermal Distribution

The extent of the thermal front to IOD is very fluctuating as seen in Figure 3. The highest peak of the thermal front was experienced in 2016 with a normal IOD phase. The number of events of the IOD phase under normal conditions occurred more during 5 years, while the IOD phase with a weak condition only occurred 3 months for 2 years, namely 2015 and 2017. The IOD phase not only affects the SST but also affects the distribution of the thermal front. IOD phases with normal conditions are more common with larger fronts, whereas IOD phases with weak conditions tend to have smaller front areas.

The number of thermal front events is calculated from the number of pixels formed in the processed sea surface temperature image. The image used is an image with a resolution of 4km, so the area of the formed pixel front is 4 km². Seen from table 3 the number of thermal front events over a period of 5 years in the north waters of Java, then in 2016 experienced the most thermal front events of 823 points, while the lowest thermal front events occurred in 2015 with 347 points. In 2016 the waters condition was experiencing a normal positive IOD phase, whereas in 2015 the water conditions tended to experience a weak positive IOD phase. This condition is thought to affect the distribution of thermal fronts.

3.4 Rainfall Dynamics

Rainfall that occurs in the Java region has a monsoonal rainfall pattern which is indicated by longer drought conditions with one peak drought condition between August and September (Hamada et al, 2009). The monsoonal rainfall pattern was evidenced in 2013-2017 rainfall at all stations in September decreased or did not experience a rainfall

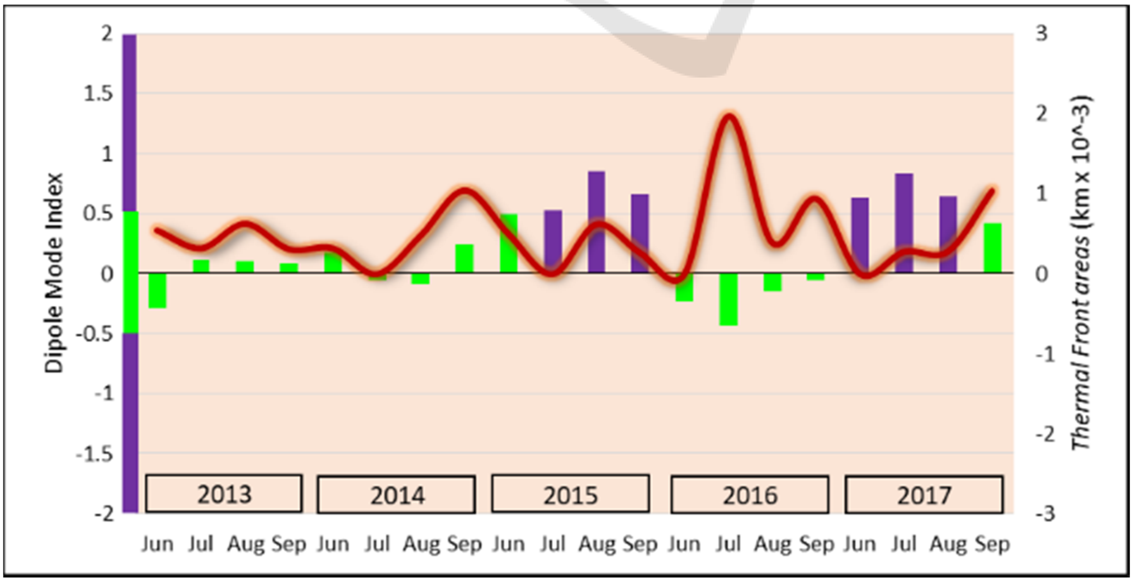

Figure 3: Relationship between IOD and thermal front area for five years.

Table 3: Number of thermal front events over a period of 5 years.

Period		DMI	*Thermal Front Area*	
			pixel	km²
2013	June	-0.29	137	548
	July	0.12	81	324
	August	0.10	158	632
	September	0.08	78	312
2014	June	0.18	81	324
	July	-0.05	0	0
	August	-0.08	121	484
	September	0.24	262	1048
2015	June	0.50	125	500
	July	0.53	0	0
	August	0.86	156	624
	September	0.67	66	264
2016	June	-0.23	0	0
	July	-0.43	494	1976
	August	-0.15	98	392
	September	-0.05	236	944
2017	June	0.63	0	0
	July	0.83	70	280
	August	0.64	71	284
	September	0.42	260	1040

supplement for the month (Figure 4). In 2013 the degree of correlation was 0.38 with the direction of a positive relationship, which means that when the DMI value decreased the rainfall also decreased. In contrast to 2013, 2014 had a degree of correlation of -0.73 which means it showed a good correlation between IOD and rainfall with the direction of the negative relationship. So the correlation relationship can be stated when the DMI value rises, the rainfall will decrease. Correlations with the direction of the negative relationship also occurred in 2015. 2016, and 2017 with the degree of correlation respectively

Table 4: Correlation results between IOD and rainfall for 5 years.

Period	DMI	Rainfall (mm)						Correlation
		1	2	3	4	5	6	
June	-0.29	355	768	519	515	768	467	0.38
July	0.12	717	1022	601	700	538	638	
August	0.10	355	472	519	515	666	467	
September	0.08	340	294	189	94	55	88	
2014								
Period	DMI	Rainfall (mm)						Correlation
		1	2	3	4	5	6	
June	0.18	559	661	479	524	308	445	-0.73
July	-0.05	618	804	574	397	251	302	
August	-0.08	558	351	238	124	88	148	
September	0.24	282	69	62	13	0	8	
2015								
Period	DMI	Rainfall (mm)						Correlation
		1	2	3	4	5	6	
June	0.50	352	399	239	355	223	313	-0.13
July	0.53	259	134	44	70	22	47	
August	0.86	307	76	52	16	23	0	
September	0.67	208	39	22	0	50	0	
2016								
Period	DMI	Rainfall (mm)						Correlation
		1	2	3	4	5	6	
June	-0.23	388	769	312	647	428	443	0.34
July	-0.43	405	601	374	54	442	388	
August	-0.15	354	467	232	212	189	144	
September	-0.05	474	476	435	368	298	262	
2017								
Period	DMI	Rainfall (mm)						Correlation
		1	2	3	4	5	6	
June	0.63	483	653	436	503	406	443	0.40
July	0.83	426	629	295	503	261	439	
August	0.64	221	322	68	147	25	123	
September	0.42	304	308	255	195	164	146	

-0.13, 0.34 and 0.40 expressed by IOD and rainfall have poor relationship interpretation.

The relationship between IOD and rainfall has an insignificant correlation shown in table 4. This can be said because of the five years the correlation values obtained tend to be very low, which means IOD and rainfall have no relationship at all. The low correlation between IOD and rainfall is caused by many factors, such as irradiation time, wind direction, and the time needed from evaporation to the formation of rain.

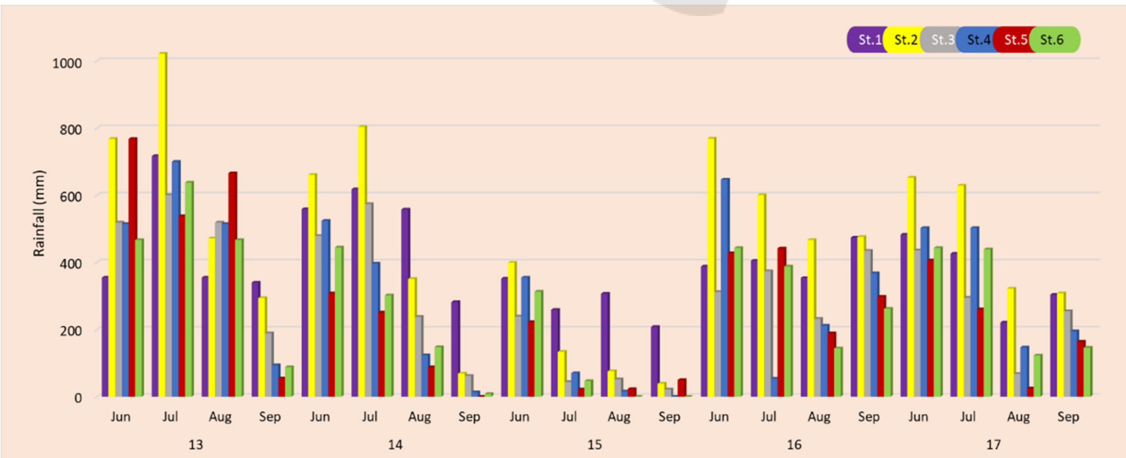

Figure 4: Fluctuations in rainfall for 5 years in the north waters of Java.

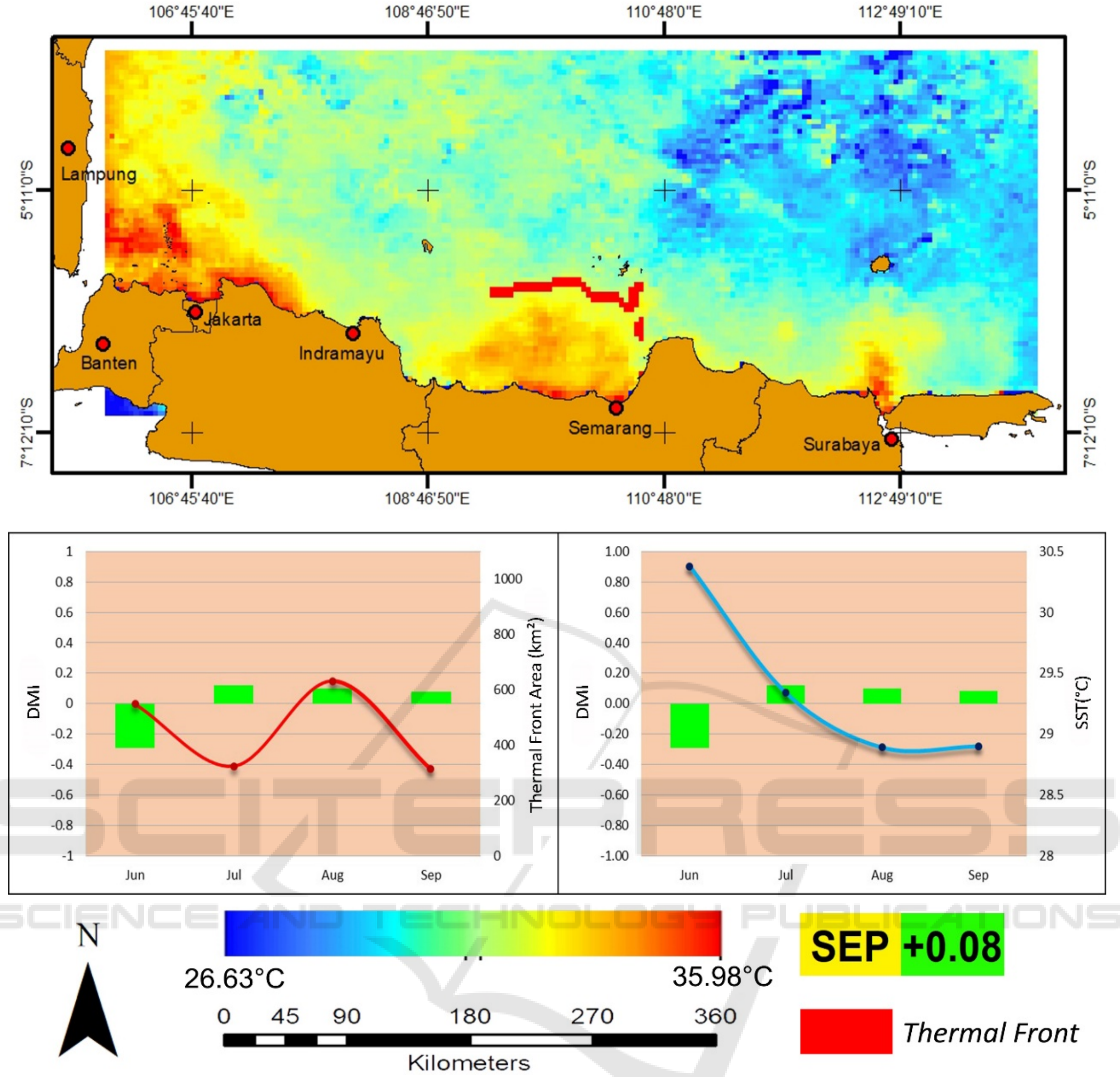

Figure 5: Variability and relationship between IOD and SST and thermal front when the positive IOD condition is normal in 2013.

3.5 Relationship among Parameters

In September 2013 the waters experienced a normal positive IOD phase with the lowest DMI value of 0.08, making the water temperatures colder. The distribution of hot temperatures concentrated near the coast with a maximum temperature of 34.42 °C and cold temperatures spread in the offshore area with a minimum temperature of 27.29 °C. Cold temperatures and warm temperatures spread in the offshore area evenly from west to east. The average temperature this month is 28.9 °C. The degree of correlation between IOD and SST is -0.93 which means it has a very good relationship with a negative relationship direction can be seen in Figure 5. The occurrence of thermal front in that month was 78 pixels or 236 km² scattered on the north coast of Semarang.

Whereas in September 2016 a normal negative IOD phase occurred with the lowest DMI value of -0.05 causing SST to warm up in the study area. The average SST in this month is 30.66 °C with a maximum and minimum temperature of 35.50 °C and 28.28 °C shown in Figure 6. The relationship between IOD and SST this month has a degree of correlation of 0.33 which is stated IOD has no effect on the rise or fall of SST. The distribution of thermal fronts is spread in coastal and offshore areas with a total occurrence of 236 pixels or an area of 944 km².

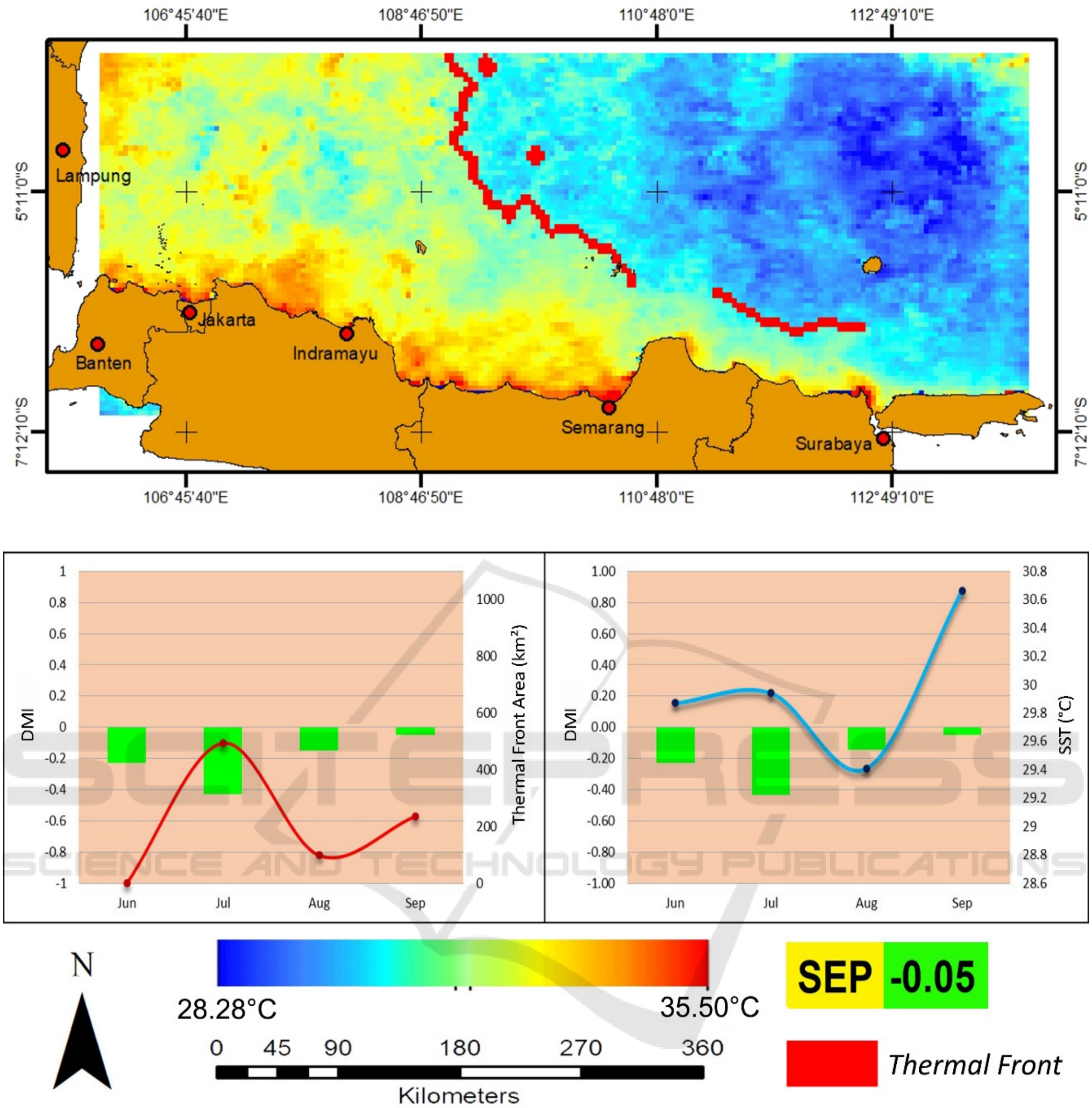

Figure 6: Variability and relationship between IOD and SST and thermal front when negative IOD is normal in 2016.

The weak phase IOD condition was experienced in August 2017 with the lowest DMI value of 0.64. These conditions make the average water temperature decreased to 29.03 ° C. hot temperatures remain concentrated in coastal areas with a maximum temperature of 34.39 ° C and a minimum temperature of 26.04 ° C. The relationship between IOD and SST has a degree of correlation of -0.93 which means it has a very good relationship with the direction of the negative relationship. It can be seen in Figure 7 that the lower the DMI value, the higher the SST value. In this condition also affects the distribution of thermal fronts. The number of thermal front events on weak IOD tends to be smaller. This month's thermal front is 71 pixels wide or 284 km².

The distribution of hot temperatures in 2013-2017 is concentrated in coastal areas with the highest distance of 200 km to the north and 125 km to the east. When the IOD (+) phase warm temperature distribution reaches the northern waters of East Java, while the IOD (-) phase the warm temperature is only concentrated to the northern waters of Central Java. The more eastward the distribution of heat has a smaller concentration.

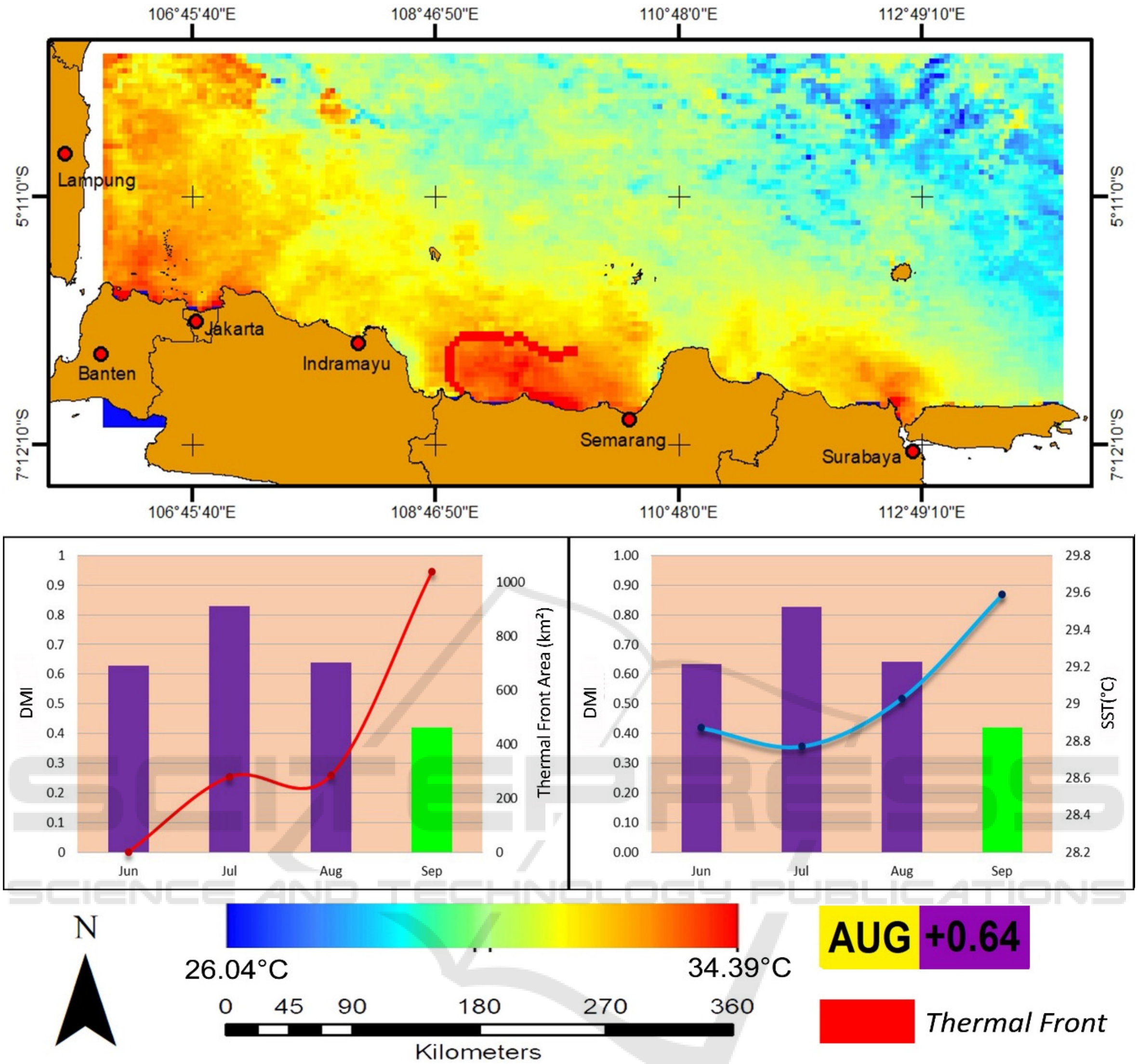

Figure 7: Variability and relationship between IOD and SST and thermal front when IOD is positively weak in 2017.

2013 and 2017 experienced an IOD (+) phase with differences in normal and weak conditions, while in 2016 experienced an IOD (-) normal. Based on the results of the third year SST image processing shows that sea surface temperatures tend to be hotter when a negative IOD phase occurs, and temperatures tend to be cooler when a positive IOD occurs. This can be reinforced by the statement of Yamagata et al., (2004) in Fadholi, (2013) the dipole mode structure characterized by SST anomalies warmer than usual in the west and colder than usual in the eastern Indian Ocean.

The distribution of thermal front tends to be more visible in normal IOD (+) or (-) phases with the highest area of 1976 km², whereas in weak IOD phases the thermal front tends to be less with a maximum area of 624 km². Thermal front events occur more frequently in the northern waters of Central Java with an elongated and winding shape that has a distribution to the offshore.

4 CONCLUSIONS AND RECOMENDATION

Based on this research, conclusions can be obtained as follows: (1) The phenomenon of IOD in the east season during the five-year phase of IOD with normal conditions occurs more frequently than IOD in weak conditions. The decrease in SST value is caused by the occurrence of the IOD (+) phase and the warmer SST occurs when the IOD (-) phase. (2) The correlation between IOD and SST in the Java Sea tends to have a negative relationship, which means an increase in the value of DMI is followed by a decrease in the value of SST (r = -0.9).

Meanwhile the correlation of IOD to rainfall is not significant which means it does not have a correlation. (3) The heat temperature is concentrated in the coastal area with the furthest distance of 200 km² to the north and is evenly distributed to the northern waters of East Java which tends to occur in the IOD (+) phase. Whereas the IOD (-) phase of the scattered heat only reaches the northern waters of Central Java. (4) Thermal front events are more common when IOD is in the normal phase with the largest area of 1976 km², whereas in the weak phase the thermal front tends to have a smaller area or number of events with a maximum area of 624 km². Several months were not found thermal front events due to temperature differences that did not reach 0.5 °C. The distribution of thermal fronts tends to form in the northern waters of Central Java with a form extending north and south.

Future studies can use data with a longer duration in order to find out the relationship between parameters and use several seasons for comparison. In addition it is necessary to add parameters such as currents, irradiation times, wind to determine the characteristics of the formation of thermal front and IOD.

The result of this study can be used as a reference for further research which is associated with high productivity waters. The location of the thermal front can be further investigated about fishing grounds, so as to avoid overfishing in waters.

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