Seasonal-Temporal Variability of Sea Surface Temperature Derived from Satellite and In Situ Data: Case Study of Indian Ocean Western Part of Sumatera Island

A Wahyudi[1], **S B Susilo**[1] and **J P Panjaitan**[1]

[1] Department of Marine Science and Technology, Faculty of Fisheries and Marine Sciences, Bogor Agricultural University, Kampus IPB Dramaga, Bogor 16680, Indonesia

Email : yudipro_91@yahoo.co.id

Abstract. It has been widely knowing that one of the important parameters to study about processes and phenomena in oceans is sea surface temperature (SST). This study is about the use of satellite and in situ data to find the seasonal and temporal SST value in Indian Ocean western part of Sumatera Island during 2010 to 2016. This result focuses on changes of SST and the accuracy of SST value derived from MODIS Satellite and ARGO Float. We divide the data into the dry and wet season based on a seasonal condition in Indonesia. The result shows the same pattern of SST value both from satellite and in situ data. The changes trend of SST value (Celsius) is increasing from 2010 to 2016 both in situ and satellite data. SST value increases 0.093 for in situ data and SST value increases 0.132 measured by MODIS satellite. The accuracy assessment (RMSE) value is 0,555. The coefficient of determination r^2 value shows a positive correlation between MODIS and ARGO data especially in dry season, while in the wet season the R^2 is smaller than in dry season.

1. Introduction

Dynamics and processes of biology, physic, and chemistry happen in oceans usually make a big influence on the living organism in it. We have to already know that oceans contain a high level of biodiversity. The coral reef is one of the ecosystems in oceans that have the complex ecosystem and high biodiversity. The other ecosystem like sea grass also have the same function as coral reef, many marine organisms use that for spawning ground, nursery ground and feeding ground and also protect from predators. Beside that coral reefs also protect coastal area from the high and big wave [1]. Parameters that exist in the oceans like physics, chemistry, and biology are an important parameter that must be studied to determine the biophysical condition of oceans. More deeply, finding out the mechanism and variability of marine ecosystem is required accurate and consistent measurement of the ocean condition and supporting data such as biological parameters in appropriate scale [2]. Classify the physical condition of oceans could help for explaining the patterns of the structure of the ocean. This classifies also have to provide and explain logically from different in situ measurement so in the result could be interpreted appropriately [3].

Oceanographic parameters such as seas surface temperature (SST), salinity, chlorophyll a concentration are forming a spatial pattern that is difficult to understand. Understanding these patterns is so important for understanding more process and dynamics of oceans. That processes and dynamics usually occur due to interactions among physical parameters in seawater. To understand the patterns of

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SST value will help to see seawater process such as upwelling, front, mixing and also the other process that happen between air and seawater interaction. Then the result of that is valued to understand pattern and spatial structure in terms of time scaling to responses of changing in oceans process are important to be learned [4].

Sea surface temperature is one of the parameters that contributed to equivalence with dynamics and processes in oceans. Sea surface temperature has been widely used in many differences research to acquire an understanding of the ocean's dynamic especially to determine the physical and biogeochemical processes in ocean surface [5]. The changes of SST value could affect for instance the level stress on coral reefs. SST data could assist the management of coral reefs ecosystems to face the climate change phenomenon [6]. The availability of this SST data could really provide valuable information on coral bleaching events [7].

Remote sensing is a technique that being developed at this time to solve the problems both spatially and temporally. Remote sensing is expected to provide the information about oceans conditions. Many satellite data like Landsat, National Oceanic and Atmospheric Administration (NOAA), Moderate Resolution Imaging Spectro radiometer (MODIS) could help for manage marine ecosystem combine with in situ data to get a more accurate result [8]. Remote sensing is one of a method that could help the researcher to study and manage widely oceans ecosystems. Remote sensing data to monitor water quality in coastal region has many advantages compared with in situ or conventional measurement in the field [9]. One of the oceans parameters that could measure using satellite is sea surface temperature. The satellite which has a high resolution could generate SST data then detect the SST variability that occurs in that area [10]. The problem with using this kind of satellite imaginary that SST data is prevented infrared radiometer caused by the presence of clouds [11].

In the last few decade, it is has been knowing that Indian Oceans has a major influence on climate change that previously, though. Changes of environmental conditions on the Indian Ocean believed that would affect the distribution and the survival of organisms therein. It is known that the Indian Ocean is one of the fishing ground for tuna, around 20,4% [12]. The aims of this study are to look at the trend of increase the value of sea surface temperature and the impact to the surrounding area.

2. Materials and Methods

2.1. Study Site

The study took place in Indian Ocean western part of Sumatera Island. Located in $90^{O}00'00''$ – $106^{O}00'00''$ BT and $8^{O}00'00''$ LS – $6^{O}00'00''$ LU (Figure 1). Indian Ocean is a unique ocean that not only has a high mean value of SST but also the variability of SST value is plenty tremendous [13]. This fact has led many researchers to do the investigation in the Indian Ocean to determine the dynamics and processes that occur in Indian Ocean water body.

2.2. Satellite Data

The SST data mainly derived from MODIS on board Aqua satellites from 2010 to 2016. Level 3 of MODIS mapped data on night-time data with 4 km resolution is used in this study. The long wave SST algorithm of MODIS bands at 11μ is also used in this study.

2.3. In Situ Data

In situ data in this study derived from Array for Real-Time Geostrophic Oceanography (ARGO Float) deployed spread around the world within the period from 2002 till present. ARGO Float is globally coordinated project proposed with identify pressure, temperature and salinity structure of the mid and upper ocean through the distribution of autonomous profiling floats [14]. The objective of ARGO program is to perform and control a set of 3000 floats distributed in all oceans [15]. Within this study, we focused on sea surface temperature of ARGO Float data in the Indian Ocean within duration from 2010 to 2016. Sea surface temperature data derived from ARGO Float usually measure in < 5 m depth from the surface.

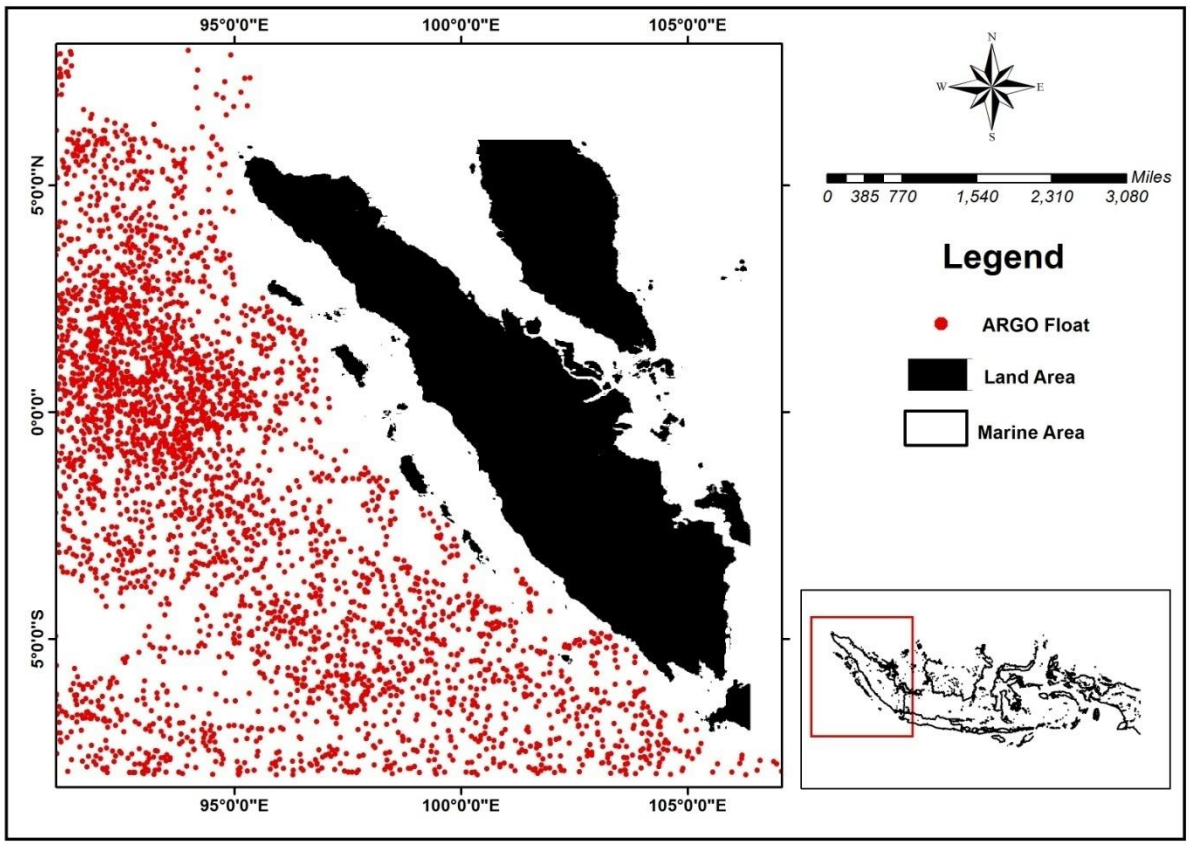


Figure 1. Study Site and ARGO Float Distribution (2005 – 2016)

2.4. Methodology

The extraction of MODIS level 3 data are using SEADAS 7.3.2 version to get SST value and distributions of SST in Indian Oceans. We calculated the average, maximum and minimum value of temperature seasonally (since of Indonesia season divided into the two seasons, wet and dry season, in order that we used November, January, and March for the wet season while May, July, and September for the dry season. This categorization also used in ARGO Float data). Reducing effect from the cloud on a sunny day, so in this research, we used MODIS satellite data acquisition in night data.

For the extraction of ARGO Float data, we used Ocean Data View 4.7.8 version and MS excel to get the SST data value. Although the ARGO Float data provide the vertical distribution sea surface data, but we only use SST data for this study.

2.5. Data Analysis

Data analysis in this research is focused on finding out SST trend using trend analysis models with linear type. The equation for calculate trend of SST values is:

$$Yt = \beta_o + (\beta_1 x\, t) + e_t \qquad (1)$$

While β_1 represents the average change of SST value in one period to next period.

In this research also calculate the Root Mean Square Error (RMSE). RMSE is a frequently used measure of the difference valued between MODIS satellite and the values obtained by ARGO Float, the environment that is being modeled. RSME used for predict the error value between SST value from MODIS satellite and ARGO Float. The equation for calculating the error value is:

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(xi - \hat{x}i)} \quad (2)$$

The RMSE value gives the deviation between SST in the field and SST value by MODIS satellite. High RMSE can be interpreted that SST of MODIS satellite is highly predicted or unpredicted from the actual SST value by ARGO Float.

This research also calculated the relationship between in situ and satellite data by used the coefficient of determination (r^2). r^2 value ranged between 0 – 1 which means that if the r^2 value is greater than 0,9 or approach 1 means that *X* has similarities to *Y*.

3. Result and Discussion

The result indicated that SST value is increasing during 2010 to 2016 both on satellite and in situ data (Figure 2). The graph shows the same pattern but SST value derived from ARGO Float has higher SST value then SST from MODIS satellite. It can explain that ARGO Float measures the SST in 5m depth or less but MODIS satellite only measure in the skin layer of surface water.

SST derived from ARGO data increases 0.093^{O}C and SST data from MODIS satellite increases 0.132 ^{O}C. The SST data in 2011 show decreases from the year before both in situ dan satellite data, it can be explained because in 2011 there are La Nina phenomena occurred in that year. La Nina is phenomena that held in oceans with characteristic sea surface temperature value decreases from mean SST value in normal condition. This phenomenon also explains in 2011 that there are La Nina phenomena held in Pacific Oceans [16].

The average seasonal composite of SST value is calculated to see the variability of SST based on the different season in Indonesia (Tabel 1). The average SST in study site shows that dry season has higher SST value than wet season.

The determination coefficient (R^2) is also computed to see the accuracy of MODIS SST data in comparison to SST data from ARGO Float (Table 2). The R^2 value shows a positive correlation between MODIS and ARGO data especially in dry season, while in the wet season the R^2 is smaller than in dry season. Perhaps in the wet season, there is a lot of clouds spread around study site so produce noise contribute to some error in SST value. However, MODIS satellite categorized as passive satellite which makes MODIS satellite very sensitive to cloud cover and contribution another factor likes rainfall possibly make data error of SST.

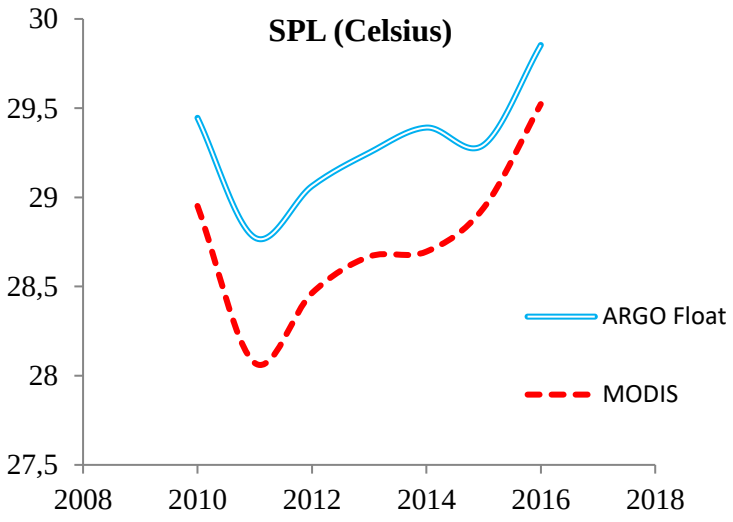


Figure 2. Sea surface temperature trends changes

Table 1. The average seasonal composite of SST value from 2010 to 2016

Data Base	Average Seasonal Composite													
	2010		2011		2012		2013		2014		2015		2016	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
ARGO	29.61	29.33	28.91	28.61	29.12	28.94	29.27	30.58	29.46	29.29	29.41	29.16	29.93	29.79
MODIS	28.88	28.99	28.20	27.81	28.49	28.33	28.60	28.59	28.80	28.35	29.16	28.65	29.65	29.44

Table 2. R^2 value for each season from 2010 to 2016

Year	Season	Match-up Numbers	R^2 Value
2010	Dry	121	0.391
	Wet	104	0.257
2011	Dry	150	0.555
	Wet	115	0.153
2012	Dry	180	0.625
	Wet	169	0.233
2013	Dry	139	0.372
	Wet	181	0.439
2014	Dry	142	0.301
	Wet	106	0.135
2015	Dry	157	0.833
	Wet	195	0.3
2016	Dry	149	0.517
	Wet	152	0.645

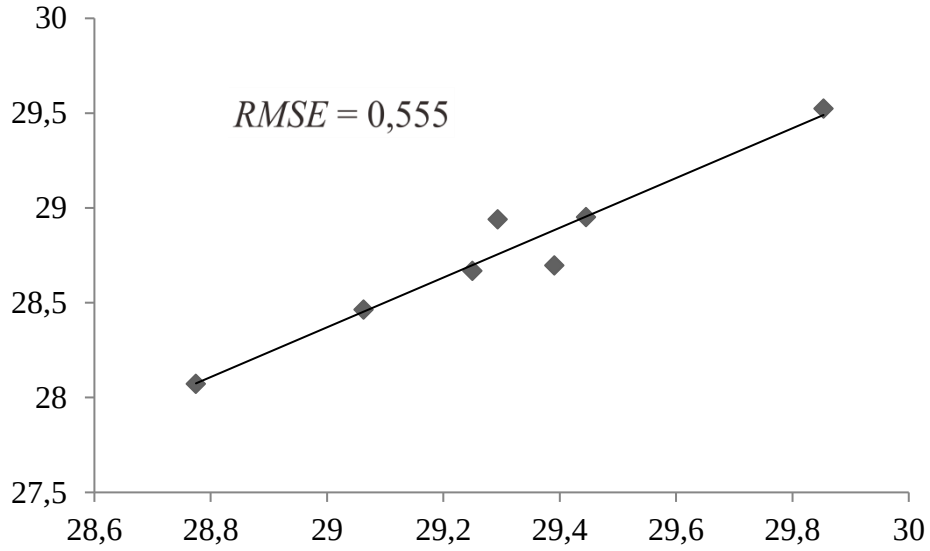


Figure 3. Comparisons SST value between *in situ* measured and MODIS satellite

The accuracy assessment of SST value from MODIS satellite have the same pattern as SST assessment derived from ARGO Float measurement. The value of RMSE is 0,555. RMSE value shows the accuracy of the data. While RMSE value is lower it means more accurate the data value measured by satellite to SST value measured by ARGO Float.

Indian Oceans western part of Sumatra possess complex dynamics and process on its seawater system. By using SST value could help the researcher to investigate another process in the areas namely upwelling, front, mass transport and other phenomena. The mapping that phenomena like upwelling are helpful because upwelling usually brings a lot of nutrient up. By knowing the upwelling event, it could assist the fishermen for catching fish by utilized the upwelling mapping phenomena site as their fishing ground.

4. Conclusion

Indian Ocean western part of Sumatera Island has trend changes of SST value from 2010 to 2016. Both measured by MODIS satellite and ARGO Float show the same pattern increasing of SST value. SST value measured by ARGO Float has increased 0,093^{O}Celsius and MODIS satellite has increased 0,132^{O}Celsius. RMSE value to predict how accurate SST value derived from MODIS satellite to ARGO Float is 0,555. The coefficient of determination r^2 value shows a positive correlation between MODIS and ARGO data especially in dry season, while in the wet season the R^2 is smaller than in dry season.

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