Article

Characteristics of Diurnal Rainfall Cycle Over Java as seen by the TRMM Precipitation Radar

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Abstract

Precipitation is one element of climate that mostly studied in Indonesia because it has a very high diversity both temporal (time) as well as spatial (place). The diurnal cycle is one of the important factors in the occurrence of rain in the islands of Indonesia that have an impact on regional rainfall patterns in Indonesia. The diurnal cycle of precipitation is an essential component of the tropical climate and one of the predominant components of atmospheric variations. The aims of this research were to determine and analyze the spatial patterns and the characteristics of rainfall diurnal cycle in Java Island and the surrounding areas (Java Island, Java Sea and Indian Ocean) using remote sensing data. In this study, data from Tropical Rainfall Measuring Mission satellite (TRMM) Precipitation Radar level 2A25 and wind data from National Centers for Environmental Prediction (NCEP) for 5 years period from 2007 to 2011 are used. The results of this research are the spatial patterns of daily rainfall in Java Island and the surrounding areas are different between land and sea. In the land, rain generally occur in the afternoon (12.00 to 18.00 LT), whereas in the ocean (the Java Sea and Indian Ocean) generally occur at midnight and noon (00.00 to 12.00 LT). The characteristics of rainfall diurnal cycle in Java Island and the surrounding areas are effected by land-sea physical properties, day-night cycle and by land-sea location.

Keywords: *rainfall; wind speed; diurnal cycle; TRMM; precipitation radar*

1. Introduction

Precipitation is one element of climate that most often studied in Indonesia because it has a very high degree of diversity both temporal (time) as well as spatial (place). In addition, the state of Indonesia which has many large and small islands with diverse topography can also lead to higher rainfall variability in Indonesia (As-syakur and Prasetia., 2010).

One of the important factor in the occurrence of rain in the islands of Indonesia which have an impact in regional rainfall patterns in Indonesia are diurnal cycle. The diurnal cycle of precipitation is an essential component of the tropical climate and one of the predominant components of atmospheric variations. Like the seasonal cycle, it is a

manifestation of the atmosphere–ocean–land–cryosphere system's response to solar radiation. Such processes include intense surface heating, the advance of a sea breeze front, the convergence of sea–land breezes, mountain and valley winds, interactions of local circulations with synoptic flows, and perhaps nighttime cooling of cloud tops to promote atmospheric instability (Sorooshian et al., 2002).

Java island is one of the important islands in Indonesia because the capital city of Indonesia (Jakarta) is located in the island of Java. Knowledge of the characteristics of daily rainfall in land and sea is very important to study, because both land and sea have different characteristics and impact on daily rainfall variations in a region either in temporal and spatial. The role of wind in the daily rainfall cycles should also be investigated as a complement to determine the interactions and relations between daily rainfall cycles in land and sea with local and seasonal wind.

The aims of this research are to determine the spatial patterns of daily rainfall and to analysis the characteristics of rainfall diurnal cycle in the Java Island and surrounding areas (Java Island, Java Sea and Indian Ocean) using rainfall data (TRMM / PR level 2A25) and wind data (NCEP) for 5 years from 2007-2011.

2. Data and Analysis

This research use two primary data for rainfall and wind data. TRMM/PR level 2A25 for 5 years from 2007 to 2011 are used for the rainfall data and NCEP wind data are used as wind data. The scheme of this research is shown in Figure 1.

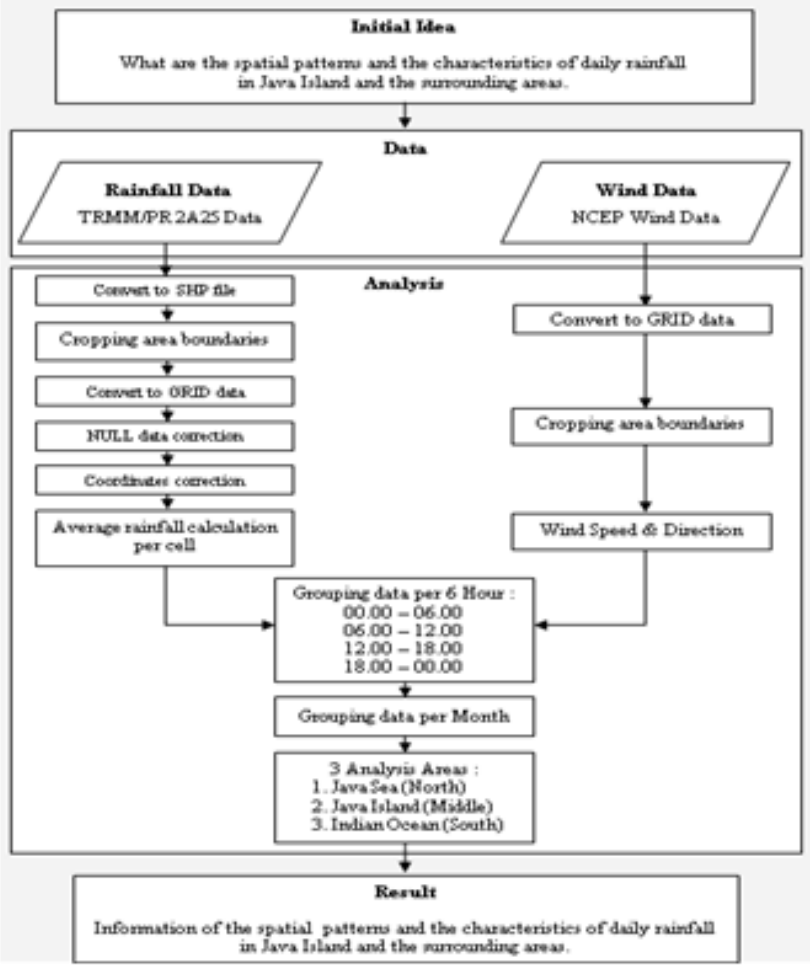

Figure 1. Research Scheme

The research location was focused in 3 area. The first area was in Java Sea at north part of Java Island, second place was in Java Island, and the third place was in Indian

Ocean south of Java Island. The region of the research range between 105° E ~ 117° E and 4° S ~ 12° S is shown in Figure 2.

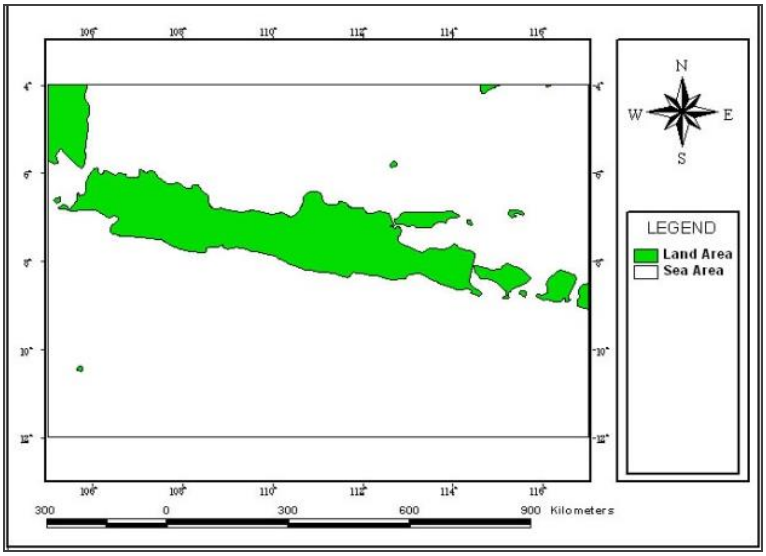

Figure 2. Research Areas

Tropical Rainfall Measuring Mission (TRMM) Precipitation Radar (PR) level 2A25 for 5 years from 2007 to 2011 are used. The rainfall data provide data per 90 minutes or every half an hour with spatial resolution 0.05º x 0.05º (~5 Km). National Centers for Environmental Prediction (NCEP) are used as wind data provided data every 6 hour and has 2.5º x 2.5º resolution data.

Further rainfall data grouped into each 6 hours, the data at 00.00 ~ 06.00, 06.00 ~ 12.00, 12.00 ~ 18.00 and 18.00 ~ 00.00. Then, grouped data analyzed in monthly and combined with 6-hourly wind data. Wind data used as a data complement to rainfall analysis which can provide information about wind direction that affect the direction of clouds and rain pattern. By obtaining the spatial patterns of diurnal cycle, the characteristics of daily rainfall in Java Island and the surrounding areas can be derived.

In order to calculate the average, the data has a positive value and zero value only (No data was not included in the calculation of averages). The equation to determine the percentage of rainfall anomalies as follow.

$$The\ percentage\ of\ rainfall\ anomaly = \left(\left(\frac{P}{\overline{P}} \times 100 \right) - 100 \right) \quad (1)$$

Where :

P: Rainfall in the m month

$\overline{P}$: Average rainfall in the m month during 5 years

3. Results

The rainfall patterns in Java Island and the surrounding areas has a variety in spatial patterns both land and in the oceans. From 5 years analysis (2007 to 2011) shows the patterns of rainfall in the land tend to occur in mid-afternoon until evening, meanwhile rainfall patterns in the ocean tend to occur at mid-night until morning. In the land, the highest rainfall average is on February and the lowest occurred on August. In ocean areas, in the Java Sea the highest rainfall average is on December, and the lowest occurred on September. As for the rainfall average in the Indian Ocean in the south island of Java, occurred in common with the land, where the highest rainfall average is on February, and the lowest occurred on August.

Wind data were observed for 5 years (2007 to 2011) at a pressure of 850 hPa shows the wind patterns every 6 hours in Java island and the surrounding areas. The wind patterns

leading to westward occured on April and October. While the wind patterns leading to eastward occured on November to March. In the overall wind patterns, the transition occurs both in terms of wind speed and direction towards the opposite direction. This transition occurred on March and April, which the east winds gradually turn toward to the west. The next transition occurs on November and December, where the winds are heading westward gradually turn toward the east.

Figure 3(a) below shows the overall rainfall patterns of the entire area of research, that is every 6 hours for the past 5 years of observation. And not much different from previous results, the overall rainfall patterns on the ground reached the highest peak at 12.00 to 18.00 LT and the lowest point at 00.00 to 06.00 LT. In the overall rainfall patterns in the Java Sea and the Indian Ocean south of Java Island showed the highest peak at 00.00 to 06.00 LT. As for the lowest point over the past 5 years, in the Java Sea occurred at 18.00 to 00.00 LT and the Indian Ocean south of Java Island occurred at 12.00 to 18.00 LT.

The patterns of rainfall average in Java Sea as shown in Figure 3(b) shows that in these area the rainfall peak average occur at midnight until morning between the hours of 00.00 to 06.00 LT. Whereas for the lowest rainfall average occurs in the afternoon until the evening between the hours of 18.00 to 00.00 LT. The highest rainfall for the past 5 years in the Java Sea took place on December which reached ~ 0.64 mm / hour. And the lowest rainfall occurs on September, which only reached ~ 0.017 mm / hour. Figure 3(c) shows the rainfall patterns in Java Island and the surrounding lands, the rainfall peak average occurred in the midday to evening between the hours of 12.00 to 18.00 LT. While the lowest rainfall average occur at midnight until morning between the hours of 00.00 to 06.00 LT. From the data obtained during the 5 years, the highest rainfall on Java Island and the surrounding lands occurred on February which reached ~ 0.98 mm / hour. And the lowest rainfall occur on August, which only reached ~ 0.03 mm / hour. And The rainfall average patterns in the Indian Ocean south of Java Island, as shown in Figure 3(d) shows that in these area the rainfall average peaks occur at midnight until noon between the hours of 00.00 to 12.00 LT. Whereas for lowest rainfall on average occurred at midday to evening between the hours of 12.00 to 18.00 LT. The highest rainfall for the past 5 years in the Java Sea occurred on February to reach ~0.37 mm / hour. And the lowest rainfall occur on August, which only reached ~0.007 mm / hour.

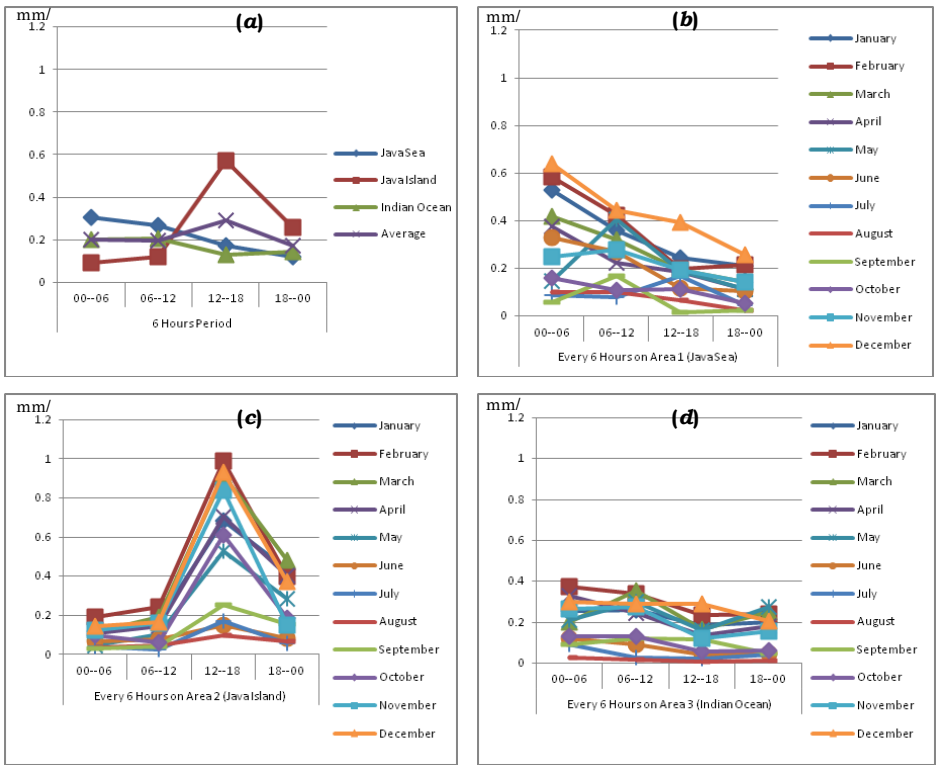

Figure 3. The rainfall average every 6-hours from 2007 to 2011 in all of the research areas (a); Java Sea (b); Java Island (c); Indian Ocean south of Java Island (d).

Compared with the oceans in the Java Sea area, the rainfall average in the Indian Ocean south of Java Island tend to be less. There was also a difference in the period of the lowest rainfall occurance. The lowest rainfall in the Java Sea occurred between the hours of 18.00 to 00.00 LT, while in the Indian Ocean south of Java Island occurred at 12.00 to 18.00 LT.

Figure 4 shows the average result of monthly rainfall in 2009 to 2011. The highest rainfall in each year tend to occur on about December-January-February with the highest reached ~0.47 mm / hour. While the lowest rainfall occurs in the months of July-August-September with the lowest rate approaching ~0.003 mm / hour. The form of rainfall patterns throughout the measurement period is generally shaped like the letter U, which has two highest point and one low point in every year.

Satellite image TRMM / PR level 2A25 used to generate spatial data distribution of rainfall in the area of Java Island and the surrounding areas. However, from the processing of wind data from NCEP, results obtained was only on the change of wind patterns every 6 months (moonsoon), no noticeable changes in the wind patterns was observed every 6 hours. So the result of wind data obtained can not support the explanation of the changes in rainfall diurnal patterns. In addition, the high differences in spatial resolution between the rainfall data (TRMM / PR 2A25) 0.05° x 0.05° with a spatial resolution of wind data (NCEP) 2.5° x 2.5° made a comparison not so obvious. Thus, other relevant literature was used in this study about the daily wind patterns (land-sea breeze) in general.

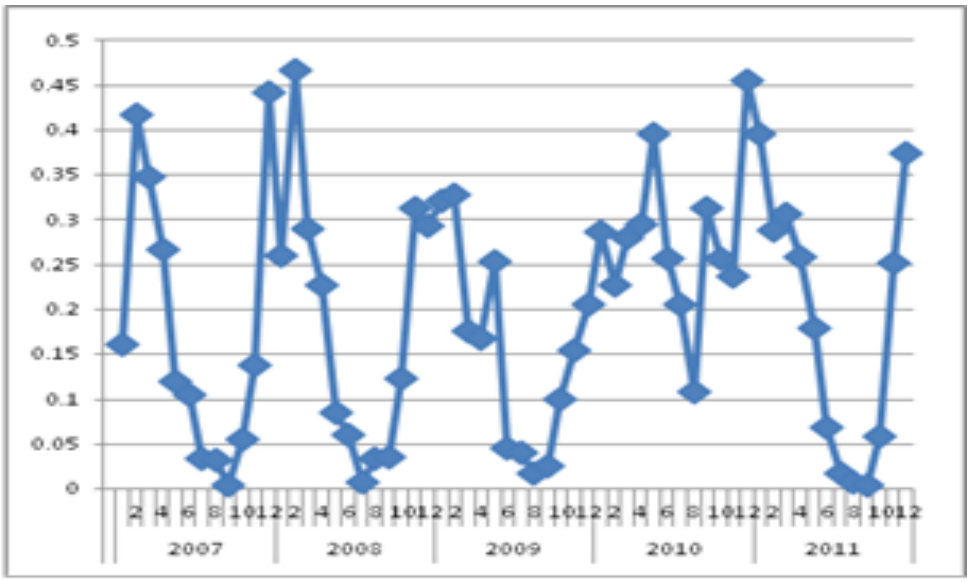

Figure 4. Monthly average rainfall in all of the research areas from 2007 to 2011.

From 5 years of rain observation (2007-2011) it was obtained that the varying result of rainfall patterns occured between land and sea in the island of Java and the surrounding areas. The differences of rainfall patterns are influenced by many of natural factors. One of them is the physical nature of the land and sea are different. The land more easily absorb and release heat, while the ocean tend to be stable (not easily warm or cold). This makes the land to be warmer than the ocean during the day, and will be colder than the ocean at night. This condition affects the difference in the amount of evaporation and wind direction (land-sea breeze) that occur both in land and sea in the period of time of day and night. Increased evapotranspiration causes high cloud formation processes resulting in increased rainfall in nearby Indonesia (Saji and Yamagata, 2003). Sea breezes blow toward Java from early afternoon to late evening (13.00–22.00 LT). The daily wind anomalies reverse direction after midnight and become land breezes and mountain winds during the morning hours (01.00–10.00 LT), lasting until after sunrise (Qian, 2007).

From the observation of the spatial patterns of rainfall on the island of Java and the surrounding area for 5 years, the results showed the patterns of rainfall in these land showed the same patterns in all of the measurement period, both in rainy and dry

seasons. Figure 5 illustrates the migration schematic of diurnal rainfall in Java Island and the surrounding areas which influenced by land-sea breeze. The rainfall peak in the land has generally occurred in the afternoon between 12.00 - 18.00 LT. In the subsequent period, the chart patterns began to decline and the lowest rain intensity in the land occured after midnight between 00.00 LT - 06.00 LT. Daily wind patterns greatly affected rainfall patterns in the region this land. Sea breeze in the afternoon (13.00 - 22.00 LT) which blows from the sea towards the land carrying moisture material from convection results in the sea to the land, therefore in the land will experience rain in the afternoon. While at night, evaporation is minimal in the land and the effect of the land breeze which brings moisture from land to the ocean leads to low rainfall in the land.

Rainfall patterns in the ocean both north and south of Java island tend to be similar, the rain peak generally occurs after midnight until early morning between 00.00 LT - 06.00 LT and tend still going on until the next period at 06.00 LT - 12.00 LT. The physical properties of the ocean that tends to be stable (not easily warm or cold) makes evaporation and rain formation is still going on in the ocean at night. In addition, the influence of Land Breeze on the evening (01.00 LT - 10.00 LT) of the islands surrounding the Java Sea which blows from the land towards the sea making the sea water vapor from convection results remain concentrated in the ocean and make the rain with high intensity happened.

However for the lowest point, there is a difference of rainfall patterns between the sea in the northern and the southern Java Island. In the Java Sea, the minimum number of rainfall tends to occur in the afternoon until midnight between 18.00 LT - 00.00 LT. While in the Indian Ocean south of Java tend to occur during the day between 12.00 LT - 18.00 LT. Influence of Sea Wind, especially in the afternoon (13.00 LT - 22.00 LT) makes winds that bring moist air blowing from the sea to the mainland, impacted to the minimum number of rainfall in the oceans during this period.

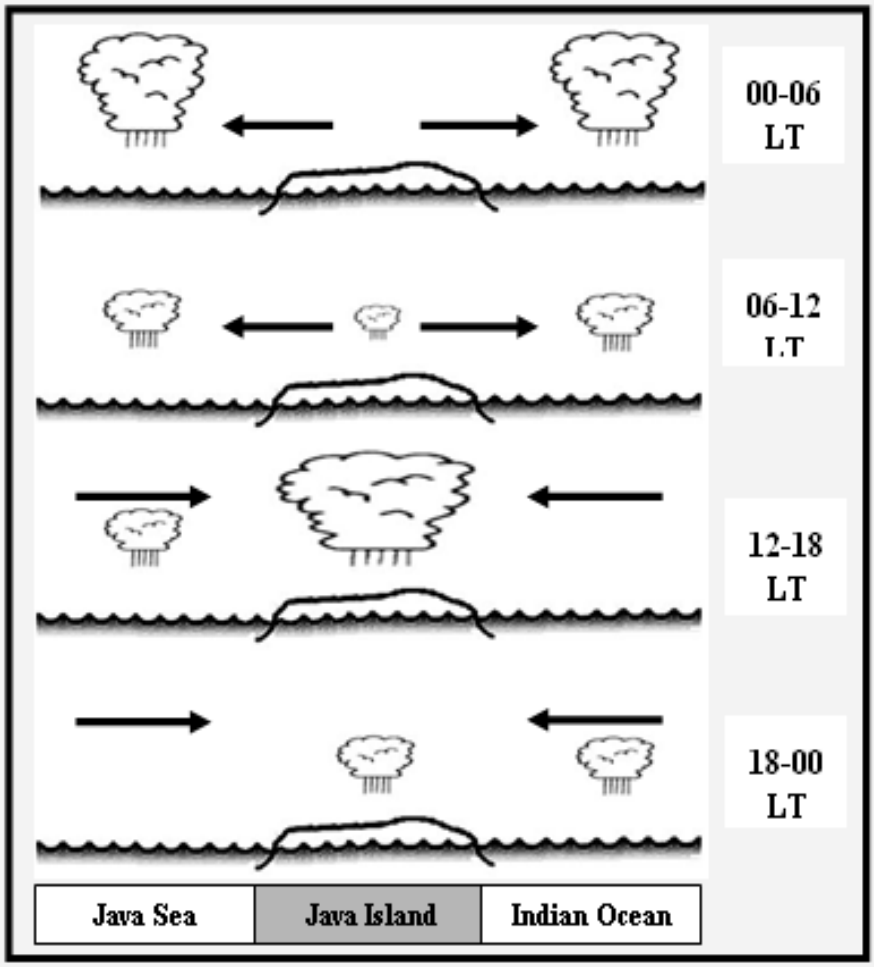

Figure 5. The schematic pictures of diurnal land–sea rainfall peak migration in Java Island and surrounding which influenced by land-sea breeze

4. Discussions

The spatial patterns in rainfall diurnal cycle in the Java Island and surrounding areas are diverse and different between sea and land. From these results could study the characteristics of the rainfall diurnal cycle in the region. There are several things that affect rainfall patterns in Java and in Indonesia in general, the existence of islands large and small which surrounded by sea, topographic diversity, SST, Monsoon and others (As-syakur and Osawa, 2011). Related to the effects of physical properties of sea and land, the daily cycle of day and night play an important role affecting the absorption and release of heat from the ocean and land. During the day, high temperatures easily absorbed by the land, and makes land warmer than the ocean. While at night low temperatures cause the land releases heat so the land temperatures cooler than the ocean.

The characteristics of rainfall diurnal cycle in Java Island and the surrounding areas are also affected by the location of the land and oceans. It can be seen from the spatial pattern of rain in Java Island and the surrounding areas are different between land and sea. On the land, both Java Island and other islands in the study area have the similar patterns of rain. While on the ocean north and south of Java Island, have the same pattern of the high intensity rainfall period, but there is a difference of the lowest rain period. Another difference between these two oceans is the amount of rainfall. The intensity of rain in the Java Sea were more a lot than the intensity of rainfall in the Indian Ocean south of Java. The influence of location and geographical position of the Java Sea that surrounded by many islands like Java, Sumatra, Kalimantan, Sulawesi, Bali and other islands in NTB, makes the Java Sea experienced more rainfall than in the Indian Ocean south of Java. This is because the land breeze of each islands will gather around the Java Sea, so the water vapor material which carried by the wind will concentrate in the Java Sea and causes high intensity rainfall occurs. Unlike the Java Sea, the condition of the vast Indian Ocean and the less number of islands that surrounding the Indian Ocean cause the rainfall in this area tend to be much less than in the Java Sea.

The rain in the oceans that surrounding Java Island is easily influenced by other phenomena caused by interaction of ocean and atmosphere. So that the results of this research, there are lots of differences in the pattern of rainfall in the sea between one month to other months. This is especially occur in the Indian Ocean south of Java Island. When referring to the TRMM satellite data / PR is used, the possibility of data errors can be taken into consideration. Because the orbit of non-sun-synchronous satellite TRMM PR, the satellite will re-record into the same point/location approximately every 3.6 days (As-syakur, 2011). So the possibility of when the rain of high intensity in one location occurs, the satellite does not record or otherwise.

Another reason of the diversity of rainfall patterns in the Indian Ocean south of Java Island is the extent of the Indian Ocean that make many phenomena of the ocean and the atmosphere can affect the characteristics of the rainfall in this region. One of the most widely studied is the influence of tropical cyclone rainfall in Indian Ocean south-west of Java island. Tropical cyclone that caused the high intensity of rain in a short time in an area is also one of the causes that influence the differences in rainfall patterns in the Indian Ocean (Dyahwathi et al, 2007). Most of tropical cyclones (65%) formed between 10°-20° LS of the equator and the effects of a tropical cyclone can affect weather conditions in many parts of Indonesia. This is indicated by the occurrence of tropical cyclones by 80 to 100 times per year (Suryantoro, 2008).

On a large scale, almost all parts of Indonesia experienced strong rainfall that influenced by the ITCZ and monsoon (Aldrian and Susanto, 2003). The existence of inter-tropical convergence zone (ITCZ) is meeting the air mass of the northern and southern hemisphere, (As-syakur and Osawa, 2011). ITCZ reaches the northern region in August and reached the southern region in February. ITCZ in the southern region in February this affects the rainfall intensity in the southern region of Indonesia, including Java and the Indian Ocean. While previously around December, lane ITCZ is around the Java Sea and the impact on the high intensity of rainfall in the Java Sea.

Another phenomenon of interaction between the atmosphere and the ocean around Indonesia that affects rainfall variability in Indonesia is such as El Niño-Southern Oscillation (ENSO) and Indian Ocean Dipole events (IOD) (Aldrian and Susanto, 2003; Nicholls, 1988; Ropelewski and Halpert, 1987; Saji et al., 1999; Saji and Yamagata, 2003).

The result of the relationship analysis between the monthly average rainfall for the past 5 years with the IOD and ENSO index showed the negative correlation average (-) between rainfall to IOD and ENSO. In general, it shows as IOD and ENSO index rose / maximum, the rainfall in the study area will be minimum. Whereas if the IOD and ENSO index down / minimum, there would be rainy with a high intencity in the area of research. Three ENSO events were recorded in the period 2007 to 2011, the La Nina in 2008 and 2010 as well as the El Nino in 2009. Based on the three months analysis, there are a variations in the correlation results between the rain with IOD and ENSO. In observations on DJF (December-January-February) months, correlation between rainfall average with IOD and ENSO has a strong correlation (r = -0.64). However, only the dominant occurred in the Java Sea and the Indian Ocean south of Java Island, while in Java Island both IOD and ENSO the correlation is not clear. On MAM (March-April-May), IOD influence is dominant in all areas of research, but the influence of ENSO is not so visible.

On JJA (June-July-August), despite having a strong average, the overall influence of ENSO appear larger than IOD. In this month the smallest IOD and ENSO index correlations occurs in the Indian Ocean south of Java Island. And on SON (September-October-November), the influence of ENSO appear more dominant throughout the study area. While the IOD influence is not obvious, except in Indian Ocean south of Java Island. The occurrence of El Nino and La Nina leads to a decrease and an increase in rainfall in Indonesia. El-Nino phenomenon causes a decrease in the amount of rainfall rainy season, dry season, the beginning of the dry season faster and the slower early rainy season (Irianto, 2003). The same phenomenon when the IOD occurs. IOD positive (negative) caused the decline (increase) of rainfall in Indonesia (Saji et al., 1999; Saji and Yamagata, 2003; Tjasyono et al., 2008; D'Arrigoa and Wilson, 2008). The increased of sea surface temperatures lead to the increased of evapotranspiration in the ocean waters around Indonesia. Increased evapotranspiration causes the high cloud formation processes resulting in increased rainfall in Indonesia and surrounding (Saji and Yamagata, 2003).

5. Conclusion

From the previous discussion, it could be concluded as follows :

1. The spatial patterns of daily rainfall in Java Island and the surrounding areas were different between land and sea. In the land, rain generally occured after noon (12.00 to 18.00 LT), whereas in the ocean (the Java Sea and Indian Ocean) generally occured at midnight and noon (00.00 to 12.00 LT).
2. The characteristics of rainfall diurnal cycle in Java Island and the surrounding areas were effected by land-sea physical properties, day-night cycle and by land-sea location.

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