Identification of Rainfall Variability Using TRMM Data Analysis

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Abstract. Indonesian climate is characterized with abundant rainfall throughout the year. Differences the amount of rainfall are seen significantly in areas with monsoonal patterns in the event of extreme climates, both El-Nino and La-Nina. Rainfall pattern dynamic that occurs in Indonesia, even worldwide, is reflected by meteorological extrem events in several regions, i.e. extreme rainfall, season change, sea level rise, drought, and flood. Lombok Island is one small island in Indonesia with high levels of vulnerability to climate change. Regarding to the meteorological events occurred in Lombok, this research aims to identify spatiotemporal distribution of rainfall pattern changes in Lombok island during 1999-2014. TRMM (Tropical Rainfall Measurement Mission) data precipitation was used as the main data due to limitation of available precipitation data. Results show annual rainfall trend was decreased and most of monthly rainfall were increased. There was an anomaly during 2009-2010 when consecutive El Nino and La Nina hit Lombok. El Nino and La Nina strongly effected on rainfall amount in Lombok Island. Western part of Lombok island is wetter than the eastern part because the monsoon starts earlier in the west. The northern part has more intense rainfall due to the orographic factor.

Keywords: Rainfall Variability, TRMM, Lombok Island

1. Introduction
Geographically, Indonesia lies on strategic position in context of trading and political interstates relation, on the other hand the geographical position causes Indonesia has unique natural condition. As an archipelagic country with more than 17.000 islands, which located between Indian Ocean and Pacific Ocean, Indonesia has tropical climate with three types of climate pattern, namely monsoon, equatorial, and local [1]. Due to the position, Indonesia is also susceptible to climate anomalies of ENSO (El Nino Southern Oscillation) [2].

In the last decades, climate change became worldwide issue. Scientists and experts have been doing researches and actions about climate change and global warming because it causes adverse impacts on the earth, i.e drought, flood, rainfall pattern change, and temperature change. At the balanced earth-atmosphere energy, the amount of energy received from the sun is equal with energy lost from the earth back into space. The condition makes stable climate on the earth [3]. Atmosphere takes the most important role in the climate stability. The obstructed of atmosphere system might cause energy released
from the earth is trapped at the atmosphere as surplus energy in form of heat, kinetic, and potential energy. The energy transformation changes climate parameters, which leads to warming process on the earth [1].

One of elements that forming climate is rainfall, hence the climate change affects rainfall, not only the pattern but also the intensity. Monsoon, Inter-Tropical Convergence Zone (ITCZ), ENSO, and regional circulation on the Pacific and Indian Ocean form rainfall pattern in Indonesia [1]. The wet season is in December – February, coincides with the Southern Hemisphere summer monsoon and the ITCZ. The dry season happens in May – September when dry south-easterly wind blows in from Australia. April and October are transition months between the wet and dry phases [4]. Pattern and amount of rainfall are diverse between seasons and years. Differences the amount of rainfall are seen significantly in areas with monsoonal patterns in the event of extreme climates, both El-Nino and La-Nina.

Rainfall pattern dynamic that occurs in Indonesia, even worldwide, is reflected by meteorological extrem events in several regions, i.e. extreme rainfall, season change, sea level rise, drought, and flood. Impacts from rainfall dynamic causes “wet get wetter, dry get drier”. Due to warming temperature on the earth triggers heat-trapping gases in atmosphere shifting existing precipitation patterns. Warmer air traps more water vapor then falls in already wet area (flood), oppositely due to balanced energy, evaporation is expected increase in some regions then causes drought.

Lombok Island is a small island with high levels of vulnerability to climate change rather than larger islands. Lombok island has a mountainous terrain and complicated coastline. Spatially, Lombok island has a very steep climate gradient. Rainfall pattern in Lombok Island is affected by Asia-Australia monsoon circulation. Due to the meteorological events occurred in Lombok, this research aims to identify spatiotemporal distribution of rainfall pattern changes in Lombok island.

Limitation of data availability, particularly rainfall data, in Indonesia is not rare case. Problem when recording data or managing the recorded data often inhibit to make meteorological and climatological assessment. The data limitation is now able to be completed by using TRRM (Tropical Rainfall Measuring Mission) data. TRRM provides information of precipitation and associated storms and climate progresses in the tropics [5]

2. Method

2.1. Data Acquisition

TRMM (Tropical Rainfall Measurement Mission) data precipitation was used as the main data in this research. TRMM satellite launched in cooperation with US and Japan to provide detailed spatiotemporal rainfall dataset over tropical and subtropical continents [6]. The TRMM data has been widely used for various application around the world such as meteorological, hydrological, agricultural and disaster management. There are three different levels produced by TRMM satellites. TRMM Multi-Satellite Precipitation Analysis (TMPA) product as known as 3B42 provides best rainfall estimation from multiple sensors onboard multiple satellites [6][7]. TRMM 3B42 provides 0,25° x 0,25° gridded daily rainfall data from 50°S to 40°N. This rainfall data is available online in several online data services managed by NASA.

Based on data availability, this research used daily rainfall data in range 1999 – 2014. TRMM satellite ended mission activities on 8 April 2015 so there were some missing data values after 2014. Area-averaged gridded daily rainfall was used in this research. The value is gridded area-averaged from all of grids values in this research area. Good correlation was shown between TRMM daily rainfall and rain gauge data with 0,6 – 0,8 level accuracy [8]. Area-averaged daily rainfall correlation is better than point-by-point daily rainfall correlation. Generally, 3B42 would be capable to replace rain gauge data in large covered areas [8][9].

Lombok Island generally has 10 TRMM data grids which covered 0,25° x 0,25° (Figure 1). Topographically Lombok is divided into mountainous and lowland area. Mountainous area is located in the northern part whereas lowland area is located in the southern part of Lombok Island. Monsoon and trade winds have a strong effect on climate condition in Lombok Island [10].
2.2. Data Analysis
Rainfall data analysis in this research was divided into three major analysis included annual, monthly and seasonal. Daily rainfall data was processed into monthly data to perform this analysis. In order to identify rainfall variability for two periods, monthly rainfall data was divided into two groups that are 1999-2006 and 2007-2014. Seasonal rainfall analysis is based on BMKG definition of wet and dry season in NTB. The normal dry season period in NTB is April-October and the normal wet season period is November-March [11].

Trend analysis was used in this research to identify annual, monthly and seasonal rainfall trends. Trend analysis for rainfall datasets was performed by Mann-Kendal test. The Mann-Kendal test is a non-parametric test, that does not involve normally distributed data [12]. This test was functioned to analyse statistical significance for all rainfall trends.

3. Rainfall Variability and Trends
Monsoon and trade winds influenced the climate condition in Lombok Island [10][13]. Due to the monsoon and trade winds, Lombok is distinctively separated by two seasons, dry season and wet season. The wet season onset in Lombok starts later than the western part of Indonesia. Wet season starts on August in the north-western part of Sumatra, while in Lombok wet season starts on November [14][15] [10]. Asian monsoon which has rich air moisture reached astern part of Indonesia on November but it has lost much of their moisture [10][16]. It resulted the climate condition in the eastern part of Indonesia include Lombok is drier than the western part [17][14].
3.1. Annual Rainfall

Times series of annual rainfall is presented in Figure 2. Based on Mann Kendall test, the Z value is -0.68 which means negative trend. The negative trend is not statistically significant because p value is larger than 0.1. Generally annual rainfall in Lombok Island was declining since 1999. The maximum value is 2158 mm and the minimum values is 1207 mm. The highest rainfall occurred in 2010 whereas the lowest rainfall occurred in 2009. There was a distinct difference in rainfall between 2009 and 2010 due to consecutive El Nino and La Nina [18,19]. El Nino started on May 2009 and caused decreasing rainfall over Indonesia includes Lombok Island [20]. Lombok experienced drought in 2007-2009 that caused severe paddy field damage [21]. Strong La Nina event occurred in 2010 triggered abundant rainfall. La Nina characterized by increasing sea surface temperature (SST) in Indonesia and decreasing sea surface temperature (SST) in eastern Pacific. It resulted intensive trace wind that cause increasing rainfall in Indonesia [13].

![Annual Rainfall](image)

**Figure 2.** Time series of annual rainfall in Lombok Island, the trend was negative but it is not statistically significant (p>0,1)

3.2. Monthly Rainfall

Average monthly rainfall variability shows in Figure 3. The graph indicates monsoonal behavior strongly influenced on rainfall pattern in Lombok Island. High rainfall amount occurred during November-April and low rainfall amount occurred during May-October. Peak of wet season occurred during December – January which have rainfall amount more than 200 mm. During the wet season Asian monsoon dominates stronger when Australian monsoon is weakening [22]. Hence during dry season Australian monsoon which contains low moisture air mass is stronger than Asian monsoon.
Figure 3. Monthly rainfall average during 1999-2014

Figure 4 shows comparison between monthly rainfall pattern during 1999-2006 and rainfall pattern during 2007-2014. There is a difference rainfall pattern in these two periods of time. Rainfall pattern during 2007-2014 has a steeper rainfall gradient between one month to another. For examples, the difference rainfall amount between January and February reached 105 mm. Generally monthly rainfall during 2007-2014 is higher than monthly rainfall during 1999-2006.

Figure 4. Monthly rainfall pattern during 1999-2006 compared to 2007-2014

Monthly rainfall trend during 1999-2014 is shown in Figure 5. Based on Mann-Kendall test, there are five months indicating negative trends, one month indicating no trend and six months indicating positive trends. Most of trends are not statistically significant due to the p values are more than 0.1 except the trend in July. The positive trend in July is significant at p<0.1 with 0.7 mm increased rainfall per year. Negative trends occurred in February, March, April, October and November. Negative trends mean that rainfall is tend to be decrease year by year but it is not statistically significant due to the p
values more than 0.1. Rainfall in June indicates no trend to decrease or increase. Generally monthly rainfall in Lombok Island tends to be increase year by year.

3.3. Seasonal Rainfall

Average rainfall during wet season in Lombok island is 1149 mm. As presented in Figure 6, the graphic of wet season rainfall shows Z value is 0.0. The value indicates there is no trend of the data series. It means there was not tendency to be downward nor upward trend of the wet season rainfall. Rainfall
value was distributed evenly during 1999 – 2014. Rainfall variability on wet season was influenced by pressure differences which drive trade winds movement [17].

![Figure 6. Trend of wet season rainfall during 1999-2014](image)

Based on Mann Kendall test, the Z value of dry season rainfall is -0.14. The value indicates downward trend however the trend is not significant because the significance level is greater than 0.1. During the time series, average dry season rainfall was calculated 387 mm. Based on the Figure 7, there is extreme rainfall data on 2010, that the value reaches 1026 mm. It turned out that there was anomaly in 2010, rainfall in dry season increased in some months. It was triggered by strong La Nina event in that year. La Nina effected on increasing rainfall in Lombok throughout the year.

![Figure 7. Trend of dry season rainfall during 1999-2014](image)

4. Rainfall Spatial distribution

Spatial distribution of monthly rainfall average during 1999-2014 is shown in Figure 8. Spatially, the western part of Lombok is wetter than the eastern part due to the monsoon starts earlier in the west [10][16]. Lombok also has distinct topographical features which are mountainous terrain and coastal area. It resulted the distinct climate condition regarding to the topographical features [13]. The northern
part is mountainous area whereas the southern part is coastal complex. Northern part of Lombok has more intense rainfall due to the orographic factor. Therefore, high varied rainfall occurred in Lombok. August was the peak of dry season when monthly rainfall was less than 50 mm throughout Lombok area. Then December was the peak of wet season when monthly rainfall was more than 300 mm.

Figure 8. Spatial distribution of monthly rainfall average during 1999-2014
5. Conclusions

Lombok Island has a monsoonal rainfall type that resulted in two distinct seasons, wet and dry season. Trend analysis was applied for annual, monthly and seasonal rainfall. Almost all of the trend results are not statistically significant except the trend of monthly rainfall on July. It was caused by the lack of long-term data availability. Generally, annual rainfall trend was decreased and most of monthly rainfall were increased. There was an anomaly during 2009-2010 when consecutive El Nino and La Nina hit Lombok Island. 2009 was the driest year during 1999-2014 whereas 2010 was the wettest year. El Nino and La Nina strongly affected on rainfall amount in Lombok Island. Spatially, Lombok Island has two distinct climate conditions due to the topographical features and trade winds movement. The western part is wetter than the eastern part because the monsoon starts earlier in the west. The northern part has more intense rainfall due to the orographic factor.

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