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ANALYSIS OF RAINFALL CONDITIONS OVER NUSA TENGGARA BARAT DURING ENSO EVENTS BASED ON TRMM DATA *(ANALISIS KONDISI CURAH HUJAN DI NUSA TENGGARA BARAT SELAMA TERJADINYA ENSO BERDASARKAN DATA TRMM)*

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ABSTRACT

Nusa Tenggara Barat (NTB) is part of the Indonesian Maritime Continent region whose weather conditions are influenced by the dynamics of the Pacific Ocean and Indian Ocean. One of the dynamics that influenced the rainfall condition is the ENSO phenomenon (El Niño and La Niña). This study analyzed rainfall response in NTB to ENSO phenomenon. The research data was taken from TRMM 3B43 with a monthly temporal resolution and 0.25° spatial resolution. Based on the analysis, it was found that El Niño phenomenon characterized by the heating of Sea Surface Temperature (SST) in Niño 3.4 had an impact on decreasing rainfall in NTB. In contrast, the La Niña phenomenon characterized by the cooling of SST in Nino 3.4 tends to have an impact on increasing rainfall in NTB. Nevertheless, the value of the increase and decrease of Niño 3.4 SST anomaly and rainfall in NTB itself is not linear. This is due to the periodicity between rainfall and the Niño 3.4 index is not uniform. The rainfall in NTB follows a monsoonal pattern while the SST of Niño 3.4 tends to follow 2-7 years period. However, the correlation between rainfall and Niño 3.4 anomaly in the ENSO event showed a strong correlation with correlation value at 6 stations reaching smaller than -0.5. Spatially, almost all areas in NTB in El Niño month experience a decrease in rainfall. In contrast, almost all areas in NTB in the month of La Niña experience an increase in rainfall. Sumbawa Island has the smallest decrease or increase in rainfall during El Niño or La Niña. That means, the influence of the ENSO phenomenon in this region tends to be weak.

Keywords: *El Niño, La Niña, NTB rainfall, TRMM 3B43*

ABSTRAK

Nusa Tenggara Barat (NTB) adalah bagian dari wilayah Benua Maritim Indonesia yang kondisi cuacanya sangat dipengaruhi oleh dinamika Samudra Pasifik dan Samudra Hindia. Salah satu dinamika yang mempengaruhi kondisi curah hujan adalah fenomena ENSO (El Niño dan La Niña). Studi ini menganalisis respons curah hujan di NTB terhadap fenomena ENSO. Data penelitian diambil dari TRMM 3B43 dengan resolusi temporal bulanan dan resolusi spasial 0,25°. Hasil analisis menemukan bahwa fenomena El Niño yang ditandai dengan pemanasan temperatur permukaan laut (TPL) di wilayah Niño 3.4 berdampak pada penurunan curah hujan di NTB. Sebaliknya, fenomena La Niña yang ditandai dengan pendinginan TPL di wilayah Niño 3.4 cenderung berdampak pada peningkatan curah hujan di NTB. Namun demikian, nilai kenaikan dan penurunan anomali TPL Niño 3.4 dan curah hujan di NTB sendiri tidak linear. Hal ini disebabkan periodisitas antara kenaikan dan penurunan curah hujan dan indeks Niño 3.4 tidak seragam. Kenaikan dan penurunan curah hujan di NTB mengikuti pola monsunal, sedangkan TPL Niño 3.4 cenderung mengikuti periode 2-7 tahun. Namun demikian, pada kejadian ENSO korelasi antara curah hujan dan TPL Niño 3.4 menunjukan korelasi yang kuat dengan nilai korelasi di 6 stasiun mencapai lebih kecil dari -0,5. Secara spasial, hampir semua wilayah di NTB mengalami penurunan curah hujan pada saat El Niño. Sebaliknya, hampir semua wilayah di NTB mengalami peningkatan curah hujan pada saat La Niña. Penurunan atau peningkatan curah hujan terkecil selama El Niño atau La Niña terjadi di barat daya Pulau Sumbawa. Hal ini mengindikasikan bahwa pengaruh fenomena ENSO di wilayah tersebut cenderung lemah.

Kata kunci: *El Niño, La Niña, curah hujan NTB, TRMM 3B43*

1 INTRODUCTION

Indonesia's geographical location in the equator makes Indonesia strongly influenced by the movement of inter-tropical convergence zone position (ITCZ), so that the variability of Indonesian rainfall both monthly and seasonally is influenced by monsoonal system (western/wet and east/dry monsoon) (Ramage, 1971). Moreover, Indonesia is a maritime country that located between the Pacific Ocean and Indian Ocean. Changes in weather and climate conditions in both oceans can affect weather and climate conditions in Indonesia.

El Niño-Southern Oscillation (ENSO) is the interaction between the ocean and atmosphere in Pacific Ocean. Similar event occurring in the Indian Ocean Equator is known as the Indian Ocean Dipole (IOD). Both events can affect the humidity, wind and rainfall conditions in Indonesia. The impacts for each region vary depend on the topography and geography (Mulyana, 2002).

ENSO is a phenomenon of deviation of sea surface temperature that characterized by a shift of warm water columns between the Western Pacific and the Central Pacific. ENSO consists of El Niño and La Niña. El Niño occurs when sea surface temperature in the Niño 3.4 region (Pacific Region in 5°N-5°S, 120°W-170°W) is warmer than usual, whereas La Niña occurs when sea surface temperature in the Niño 3.4 region becomes cooler than usual. Interaction between ENSO and rainfall in Indonesia can be seen based on the value of Southern Oscillation Index (SOI). SOI is the difference between surface air pressure in East Pacific region measured in Tahiti (Hawaii) and the Western Pacific region measured in Darwin (Australia) (NCDC, 2019). According to Salmawati (2010), when SOI value less than -5 for 3 consecutive months in a year, then it is expressed as El Niño year. Whereas the value of SOI more than 5 for 3 consecutive months, then the year can be expressed as La Niña year.

Similar to ENSO, IOD is also characterized by shifting warm water columns. The difference from ENSO, IOD is shifting of warm water column that occur between the Western Indian Ocean (East African Coast) and Southeast (West Coast of Sumatra) Indian Ocean. IOD condition can be seen based on the magnitude of Dipole Mode Index (DMI) which is the gradient of West and Southeast Indian Ocean air pressure. Because IOD is a coupling of ocean-atmosphere interactions, the IOD condition can also be represented by other climatic parameters such as air pressure. A positive DMI score indicates a positive IOD event that can generally lead to a lack of rainfall in Indonesia, and vice versa.

ENSO and IOD occur independently, but the interaction of these two events can either reinforce or weaken of each event (Ashok et al., 2003). Positive ENSO events along with positive IOD will decrease the annual and seasonal rainfall in Indonesia (Tjasyono et al., 2008). Based on the NOAA Climate Prediction Center (CPC) data, 1997 and 2015 are indicated as years with strong positive El Niño phase. Both of these years caused a long and severe drought in most parts of Indonesia. However, according to the National Disaster Management Agency (BNPB), the dry season in 1997 caused more severe impacts than in 2015 because of a strong positive Niño 3.4 in 1997 along with strong positive IOD while in 2015 IOD condition is still relatively neutral.

Nusa Tenggara Barat (NTB) is part of Indonesia Maritime Continent (IMC) and is located in the southeast of the IMC area. Aldrian and Susanto (2003) classify this area into a monsoonal precipitation zone where the peak of monthly rainfall occurs in DJF season (December - January - February) and the lowest rainfall occurs in JJA season (June-July-August). This study aims to describe how the rainfall conditions in NTB temporally when El Niño (Niño 3.4 anomaly is positive) and La Niña (Niño 3.4 anomaly is negative) occured.

2 MATERIALS AND METHODOLOGY

2.1 Data

The following data were used in this research.

1. Monthly rainfall data throughout NTB was obtained from TRMM 3B43 with 0.25° spatial resolution. In accordance grid data with NTB's BMKG observation station points were used, namely in Batujai, Dompu, Gapit, Gunungsari, Ijobalit, Jurangsate, Kabul, Kadindi, Keru, Keruak, Kumbe, Kuripan, Lingkoklime and Loangmake. Data used for this research is TRMM 3B43 from 1998 to 2017. These points are illustrated on the map in Figure 2-1. TRMM 3B43 data is obtained from https://disc.gsfc.nasa.gov/SSW/#keywords=3B43.

   Tropical Rainfall Measuring Mission (TRMM) is a product of the orbiting satellite collaboration of National Aeronautics and Space Administration (NASA) and Japanese Aerospace Exploration Agency (JAXA) aimed at studying rainfall conditions in the tropics. The first TRMM satellite was launched in November 1997. With three sensors owned, satellites have been able to observe data such as rain structures, tropical and subtropical distribution and their role to find out the mechanisms of global climate change and monitoring of environmental variations. The three TRMM sensors are Precipitation Radar (PR), TRMM Microwave Imager (TMI), and Visible Infrared Scanner (VIRS). PR is the first space tool designed to provide a three-dimensional plot of storm structure. It has a horizontal resolution of about 5 km with 247 km swath width. PR can provide a vertical profile of rain and snow from the surface up to a height of 20 km and sensitive to light rainfall levels (0.5 $mm.hr^{-1}$ rain rate). TMI is a passive microwave sensor based on Special Sensor Microwave / Imager (SSM / I) and can measure radiation intensity at 10.7, 19.4, 21.3, 37 and 85.5 GHz. VIRS can capture radiation in visible and infrared wavelengths of 0.63, 1.6, 10.8 and 12 micrometers, and has a horizontal resolution of 2.4 km and a swath width of approximately 833 km.

TRMM satellite observation data is divided into 3 levels based on type and shape. Level 1 is raw data that has been radiometrically calibrated and geometric correction. Level 2 data is a picture of the geophysical parameters of rain. Level 3 data already has rain value, especially the monthly condition which is a combination of rain condition from level 2.

TRMM level 3, TRMM 3B43 version 7, was used in this study. TRMM 3B43 is a product of TRMM Multi-Satelite Precipitation Analysis (TMPA) in the form of rainfall value estimation, resulted from satellite rainfall prediction data (Sensor TRMM, IR, SSM / I and COMB) with observation data. It makes TMPA product has better accuracy than the original data (Mehta et al., 2008). TRMM 3B43 has a spatial resolution of 0.25°×0.25° with coverage from 50°N to 50°S and 180°W-180°E (NASA, 2012).

Validation of TRMM 3B43 data has been done in several studies as conducted by Fleming et al. in 2011. Their result shows that cross-correlation data value of TRMM 3B43 with measurement data is more than 0.90 for Australia region. Result from Principal Component Analysis show that the existence of spatial and temporal variation patterns is very similar between TRMM 3B43 data with measurement rainfall data results. The correlation of TRMM 3B43 with the measurement data shows the value higher than 0.60 for the territory of Indonesia (Mamenun et al., 2014). The suitability of TRMM 3B43 data and the measurement data is strongly influenced by Indonesia's topographical and ocean condition, and also the monsoonal pattern (As-syakur et al., 2013).

2. Sea surface temperature (SST) anomaly were calculated to get Niño 3.4 index. Niño 3.4 SST data were obtained from https://www.esrl.noaa.gov/psd/gcos_wgsp/Timeseries/Data/nino34.long.data. Figure 2-2 shows the SST Niño 3.4 anomaly.

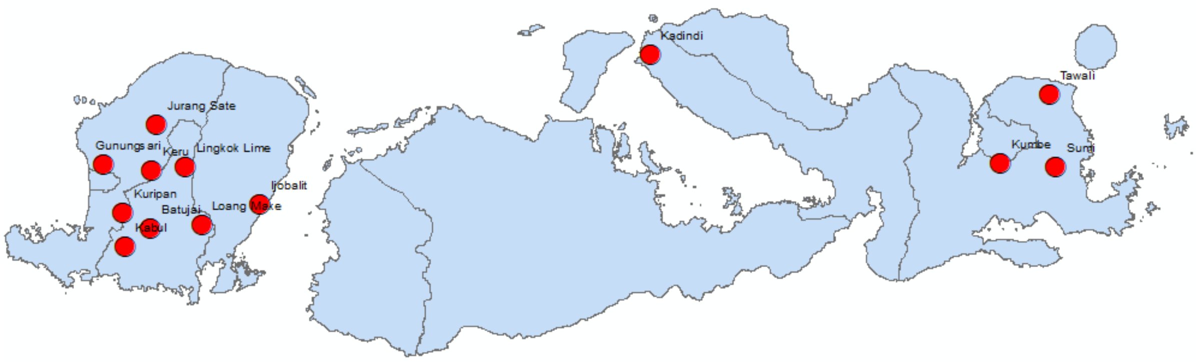

Figure 2-1. Location of BMKG observation station

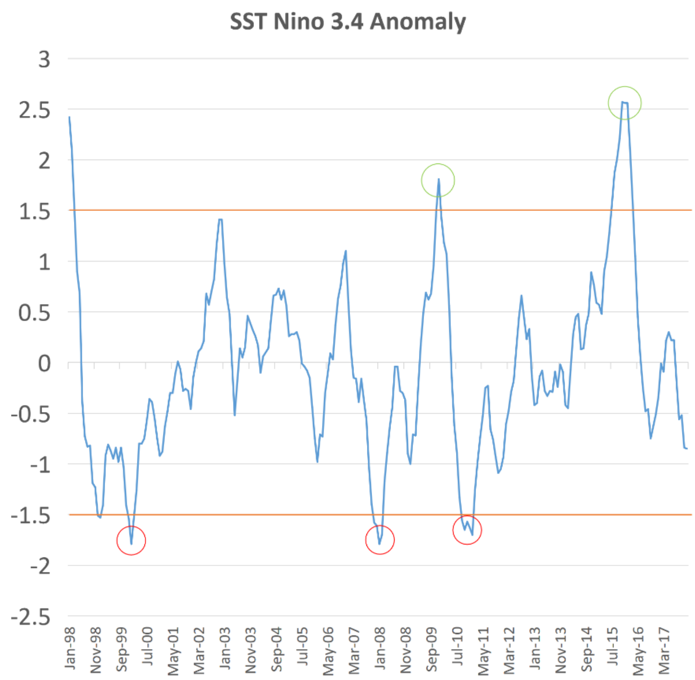

Figure 2-2. SST Niño 3.4 anomaly (red circle: La Niña, green circle: El Niño)

Niño 3.4 anomaly data are grouped into 5 classifications of ENSO conditions. Table 1 is a classification of Niño 3.4 anomalies.

TABLE 1. ANOMALY VALUE OF NIÑO 3.4 SST

Anomaly Value of Niño 3.4 SST	Meaning
Anomaly > 2.5	Strong El Niño
2.5> Anomaly >0.5	El Niño
0.5> Anomaly >-0.5	Neutral
-0.5> Anomaly >-2.5	La Niña
-2.5> Anomaly	Strong La-Niña

Based on Table1, we can classify when El Niño and La Niña occurred (Table 2).

TABLE 2. CLASSIFICATION OF EL NIÑO, LA NIÑA, AND NEUTRAL CONDITIONS BASED ON SST NIÑO 3.4 ANOMALY VALUE

Condition	Time (years)
El Niño	1998, 2002, 2004, 2006, 2009, 2015
Netral	2000, 2001, 2003, 2005, 2011, 2012, 2013, 2014, 2017
La Niña	1999, 2007, 2008, 2010, 2016

2.2 Methods

This research use Pearson correlation analysis and time series analysis. Figure 2-3 shows the flowchart of this research.

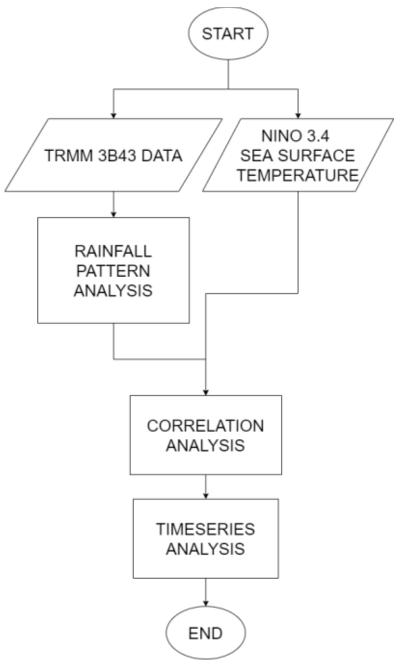

Figure 2-3. Flow chart of the research

The analysis of linear relationship between Niño 3.4 anomaly and rainfall is done by calculating Pearson correlation coefficient.

Pearson correlation is used to measure the strength of the relationship between the two variables. These variables are correlated if the changing of one variable are accompanied by changes in other variables. It should be remembered that even though the value of the correlation coefficient is small (not significant), it does not mean the two variables are not interconnected. It is possible that two variables have a strong relationship relationship, but the correlation coefficient value is near zero (for example, in the case of non-linear relationship). Thus, the correlation coefficient measures only the strength of the linear relationship. A strong linear relationship between two variables does not necessarily mean causality, cause and effect.

Pearson correlation is calculated by the following formula (Eq. 1):

$$r = \frac{n(\sum xy)-(\sum x)(\sum y)}{\sqrt{[n\sum x^2-(\sum x)^2][n\sum y^2-(\sum y^2)]}} \qquad (1)$$

where x is the SST anomaly data and y is rainfall data.

Table 3 shows the meaning of Pearson correlation value.

TABLE 3. CORRELATION VALUE MEANING

r > 0.5	strong positive correlation
0<r<0.5	weak positive correlation
r = 0	not correlated
-0.5<r<0	weak negative correlation
-1<r<-0.5	strong negative correlation

3 RESULTS AND DISCUSSION

The result of rainfall composite data of TRMM 3B43 in 1998 - 2017 indicates that the peak rainfall in most of NTB occurred in December, January and February while the minimum rainfall occurred in June, July, August and September (Figure 3-1). This rainfall pattern follows the monsoon precipitation pattern where rainfall is heavily influenced by monsoon phenomena (Ramage, 1971). Weather conditions in NTB are heavily influenced by Australian monsoon dynamics that blowing from the southeast of NTB and the Asian monsoon that blowing from the Pacific (Kirono et al., 2014).

In addition to the monsoon phenomenon, the weather dynamics in NTB may be influenced by other inter seasonal dynamics such as ENSO or IOD. Correlation analysis between the sea surface temperature anomaly in Niño 3.4 and rainfall anomaly in NTB based on TRMM 3B43 satellite monitoring was calculated for knowing how far the influence of inter-seasonal phenomenon dynamics to rainfall.

The strong El Niño and La Niña phenomena (1.5 to 1.9 SST anomaly) have occurred several times. In 1998, El Niño occurred in January - March and La Niña occurred in November - December. Very strong El Niño also recorded occurred in 2015 in June to December. Generally, almost all regions in Indonesia are experiencing lack of rainfall during strong El Niño, and vice versa (Hamada et al., 2002; Hendon, 2003). In this study, the relationship between SST and rainfall conditions in NTB is expressed in terms of Pearson correlation coefficient.

In almost all seasons throughout the site, the correlation between the Niño 3.4 SST and rainfall anomalies tend to be negative (Figure 3-2.). This result indicates that if the Niño 3.4 anomaly is positive, then there is a tendency of rainfall in the fourteen observation points to have a negative anomaly. The negative correlation in this case also indicates if the Niño 3.4 have positive anomaly (El-Niño), then rainfall in NTB tends to decrease. Similarly, if the Niño 3.4 SST anomaly is negative or in other words Niño 3.4 SST cooler than usual (La Niña), then there is an indication of rainfall in NTB will increase.However, in terms of correlation coefficient value, this correlation value is still relatively weak according to Gulliford classification (Storch and Zwiers, 1999). The strongest correlation is only shown in the JJA season where the value reaches -0.4 (Figure 3-2). While in other seasons, especially DJF, the correlation value between the two variables averages below -0.2. This is probably due to the DJF season's predictability of rainfall in the IMC region is quite low when compared to the JJA season (Haylock and McBride, 2001).

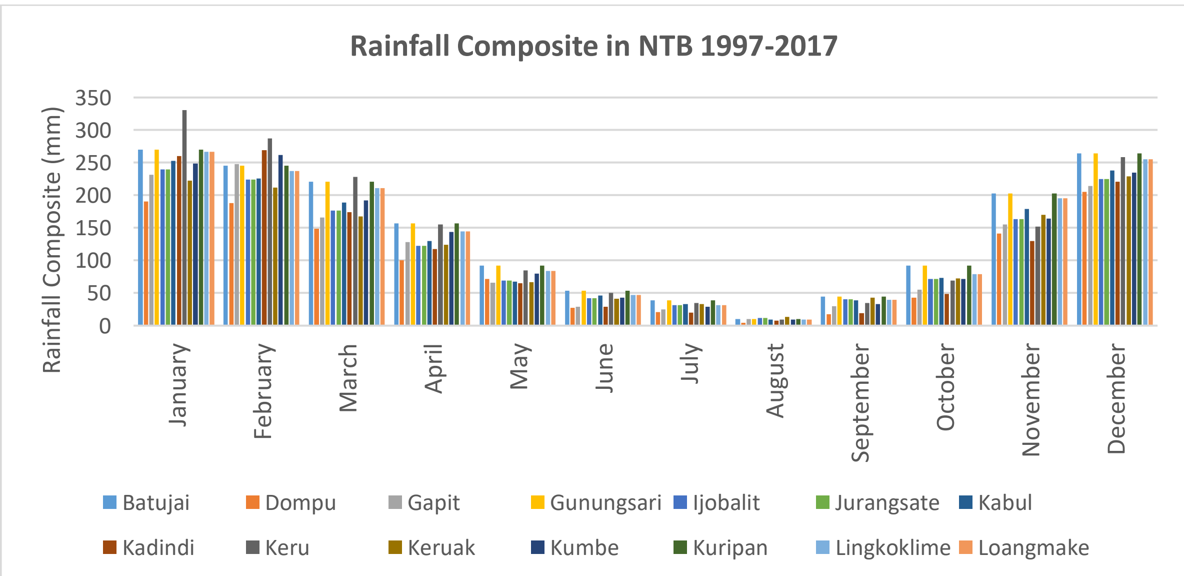

Figure 3-1. Rainfall composite in Nusa Tenggara Barat 1998-2017

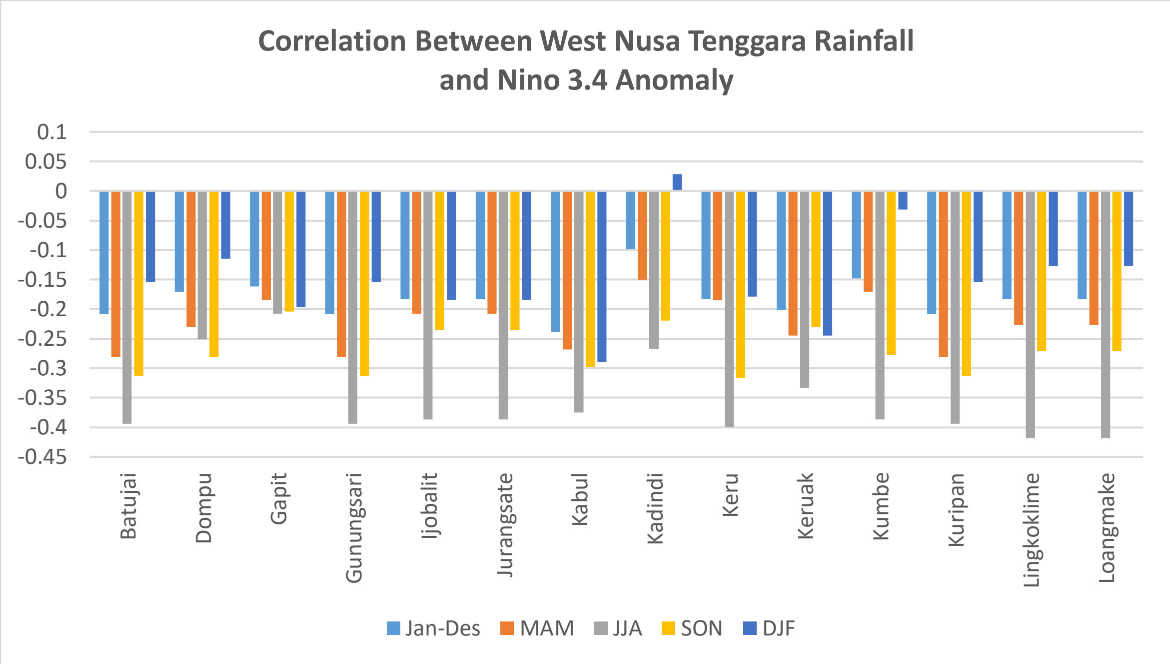

Figure 3-2. Coefficient correlation between NTB rainfall and Niño 3.4 anomaly

A time series analysis of rainfall anomalies at the fourteen points in NTB and Niño 3.4 SST anomaly was used to know the further relationship between ENSO phenomena and rainfall conditions in NTB. Generally, when the Niño 3.4 SST anomaly tends to be positive, the value of rainfall anomalies in the all regions tends to be negative (Figure 3-3). Otherwise, when the Niño 3.4 SST anomaly is negative, the rainfall anomaly in all regions tends to be positive (Figure 3.3). It re-emphasizes that if the Niño 3.4 SST tends to warmer than the average, then the rainfall anomaly in NTB tends to be less than its mean. Conversely, if the Niño 3.4 SST cooler than usual, there is a trend of rainfall in NTB will increase. However, the relationship between Niño 3.4 SST and rainfall in NTB does not always go in same direction. In January 1998, it was seen that the Niño 3.4 SST anomaly tended to be positive, but the rainfall anomaly was not negative (rainfall anomaly ~1)(Figure 3-3). This is likely due to lag time or lead time between ENSO phenomena and rainfall conditions in NTB (Barnston, 2012).

The correlation value between the Niño 3.4 index and the rainfall throughout the year and seasonally reaches the strongest value of -0.4. Negative values indicate that the relationship between the Niño 3.4 anomaly value and rainfall at the fourteen stations in NTB tends to be the opposite. This means that if Niño 3.4 heats up (positive anomaly), the rainfall in the fourteen stations in NTB tends to decrease, and vice versa. However, the value -0.4 is still relatively weak according to Guilford's classification. This is likely due to the decrease and increase periodicity in Niño 3.4 SST which tends to be different from rainfall in NTB. The increase of rainfall in NTB tends to rise and fall following the pattern of monsoonal rainfall where each year the rainfall tends to be low in the June - July - August (JJA) season and becomes high in the December-January-February (DJF) season. Different things happen to SST of Niño 3.4 where the value of the increase in Niño 3.4 occurs over a period of 2-7 years. Therefore, the inverse relationship tends to be seen between the Niño 3.4 SST anomaly and rainfall in NTB because the periodicity of the increase and decrease between the two variables is different.

To be able to emphasize the relationship between Niño 3.4 SST and rainfall in NTB, a Pearson correlation was calculated when ENSO occurred. The criteria for the occurrence of ENSO is when the anomaly value of Niño 3.4 SST is more than 1. If the Niño 3.4 SST anomaly is less than -1, then there will be a cooling SST in Niño 3.4 region which means La Niña.

There were 28 El Niño and La Niña occurrences during the 1997 - 2018 calculated from the Niño 3.4 SST anomaly value. After calculating the correlation value, it is seen that the correlation between NTB rainfall and Niño 3.4 SST anomaly tends to strengthen negatively. It can be seen in Figure 3-4 that in most of observation stations the value tends to be below -0.48. There are 6 stations showing a strong negative correlation value because the correlation tends to be smaller than -0.5

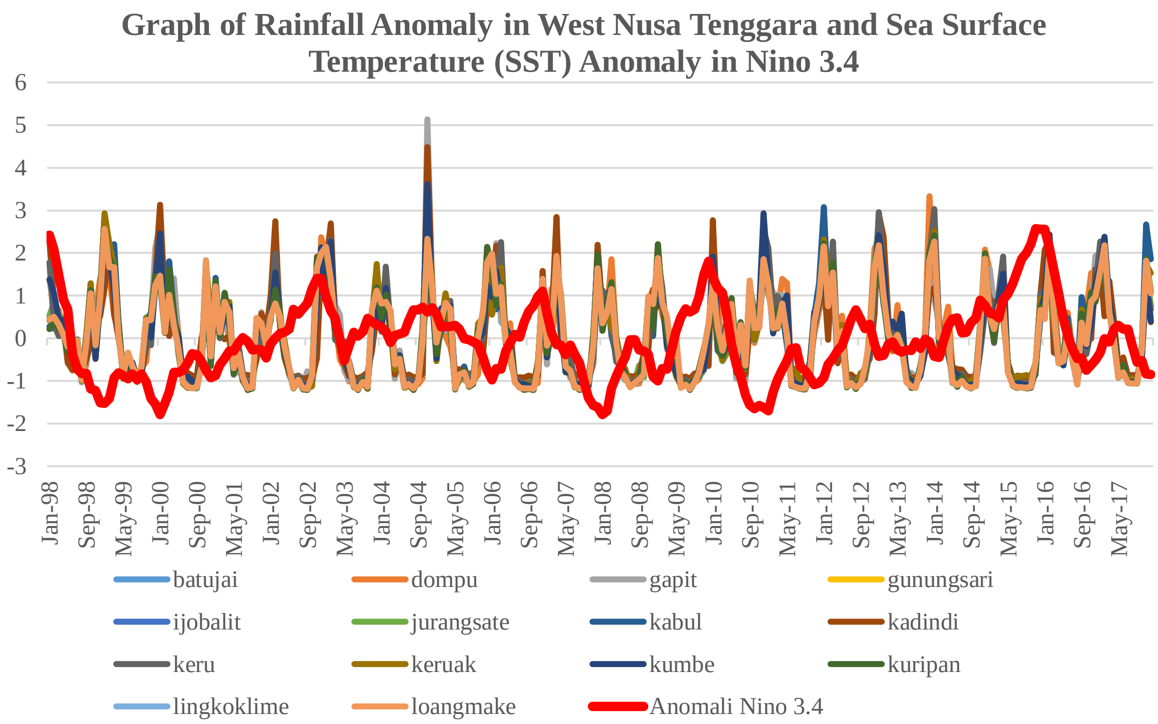

Figure 3-3. Graph of rainfall anomaly in NTB and SST anomaly in Niño 3.4

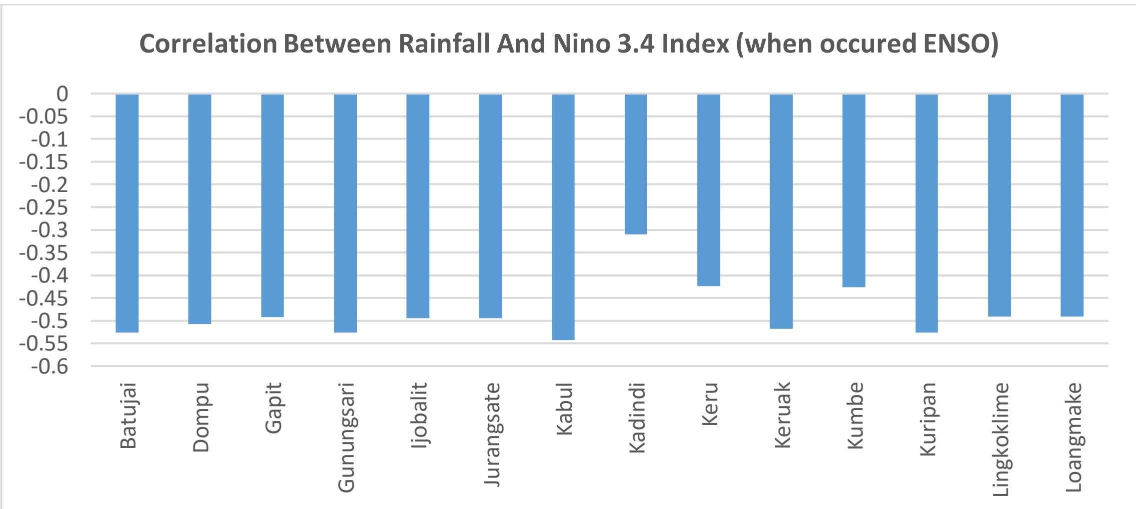

Figure 3-4. Correlation between rainfall and Niño 3.4 SST anomaly (when ENSO ccurred)

Spatial analysis of deviation values or changes in rainfall across the entire NTB region was calculated to see the response of spatial rainfall to the ENSO phenomenon. This analysis is done by reducing monthly rainfall in El Niño or La Niña months with an average rainfall of 20 years from 1998-2017. El Niño in November 2015 was chosen with index value 2.57. The month of La Niña was chosen in January 2008 with an anomaly value -1.79.

Spatially, in El Niño month, the rainfall in almost all NTB areas decreased compared to the average. This is evidenced by the spatial plot of rainfall anomaly in NTB in October 2015 which state that in the month of El Niño almost the entire region experiences a water shortage (negative anomaly) when compared with the average (Figure 3-5). The biggest shortfall occurs in the area of the Bali Sea, whereas the smallest changes occur in the southwest region of Sumbawa Island where the anomaly is only about 40 mm (Figure 3-5).

Spatially, in the month of La Niña almost all areas in Sumbawa Island experienced an increase in rainfall (Figure 3-6). However, if in El Niño the deviation or decrease of rainfall is in ranges up to 40 mm, then in the month of La Niña the deviation reach 80 mm (Figure 3-6). Interestingly, the smallest deviations or smallest rainfall changes in both El Niño and La Niña occur on the Northwest Sumbawa Island. In El Niño conditions, rainfall reduction only occurs about 160 mm (Figure 3-5) while at the time of La Niña the change reaches 80 mm (Figure 3-6).

In El Niño month, not all values of rainfall anomaly in NTB are negative (in the other words rainfall is reduced). In March 2016, the value of the Niño 3.4 index ranged at 1.6. However, the rainfall anomaly in almost all areas of NTB is positive (Figure 3-7). Thus, it can be concluded that generally, the response of rainfall in almost all areas of NTB to the phenomenon of El Niño is the reduction of rainfall value or the tendency of drought. While, the response of rainfall in NTB to La Niña phenomenon is the increase of rainfall value.

However, this response is not always consistent with the magnitude of the anomalies SST Niño 3.4. That is, the increase and decrease of Niño 3.4 SST is not always in line with the decrease or increase in rainfall in NTB. This is what causes the relationship between Niño 3.4 anomaly and rainfall in NTB is not linear so the value of correlation coefficient is small. In other words, El Niño strongly influence the reduction of rainfall in NTB, and La Niña strongly influence the increase of rainfall in NTB, but how far its influence can not be determined because rainfall in NTB itself is much influenced by other phenomena.

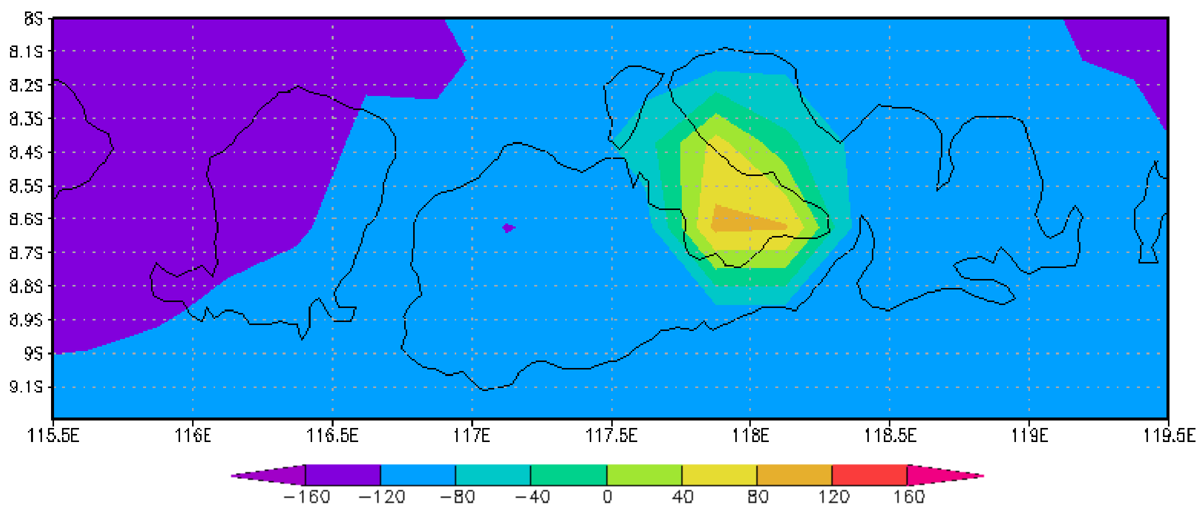

Figure 3.5. Rainfall anomaly in NTB October 2015 (month of El Niño)

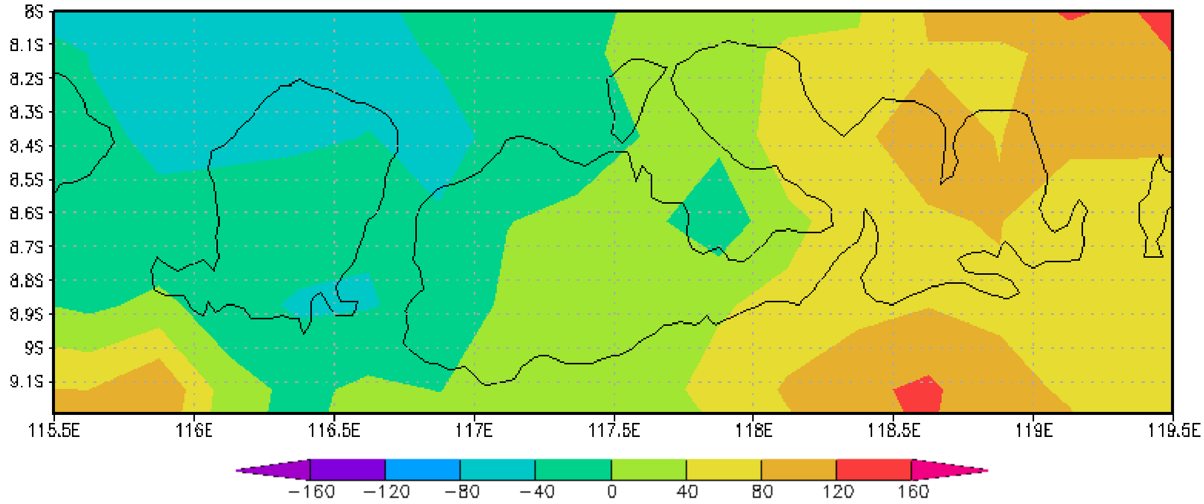

Figure 3-6. Rainfall anomaly in NTB in November 1998 (month of La Niña)

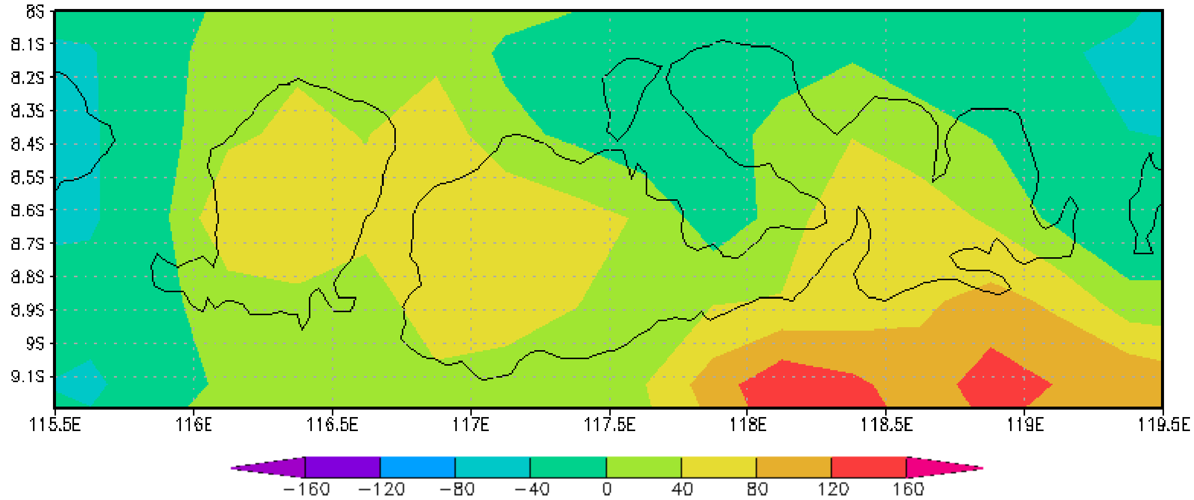

Figure 3-7. Rainfall anomaly in NTB in March 2016 (month of El Niño)

4 CONCLUSIONS

If El Niño (SST of Niño 3.4 warming/ positive anomaly) occurs, then rainfall in NTB tends to decrease (has a negative anomaly). Otherwise, if La Niña occurs (SST of Niño 3.4 cooling / negative anomaly), then rainfall in NTB tends to increase (has a positive anomaly).

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REFERENCES

Ashok, K., Z. Guan, T. Yamagata, 2003. *A Look at the Relationship between the ENSO and the Indian Ocean Dipole*, Journal of the Meteorological Society of Japan, 81(1), 41-56.

As-Syakur, A. R., T. Tanaka, T. Osawa, M. S. Mahendra, 2013. *Indonesian Rainfall Variability Observation using TRMM Multi-Satellite Data*, International Journal of Remote Sensing, 0(0), 1-16.

Barnston, A. G., M. K. Tippet, M. L. L'Heureux, S. Li, D. G. DeWitt, 2012. *Skill of Real-Time Seasonal ENSO Model Predictions during 2002–11: Is Our Capability Increasing?*, Bulletin of American Meteorological Society, 93, 631-651.

Fleming, K., J. L. Awange, M. Kuhn, W. E. Featherstone, 2011. *Evaluating the TRMM 3B43 Monthly Precipitation Product using Gridded Rain-Gauge Data over Australia*, Journal Australian Meteorological and Oceanographic, 61(1), 171-184.

Hamada, J., M. Yamanaka, J. Matsumoto, S. Fukao, P. Winarso, P. Sribimawati, 2002. *Spatial and Temporal Variations of the Rainy Season over Indonesia and Their Link to ENSO*, Journal of the Meteorological Society of Japan, 80(2), 285-310, https://doi.org/10.2151/jmsj.80.285.

Haylock, M., J. McBride, 2001. *Spatial Coherence and Predictability of Indonesian Wet Season Rainfall*. Journal of Climate, https://doi.org/10.1175/1520-0442(2001)014<3882:SCAPOI>2.0.CO;2

Hendon, H., 2003. *Indonesian Rainfall Variability: Impacts of ENSO and Local Air–Sea Interaction*, Journal of Climate, https://doi.org/10.1175/1520-0442(2003)016<1775:IRVIOE>2.0.CO;2

Mehta, A. V., S. Yang, 2008. *Precipitation Climatology over Mediterranean Basin from Ten Years of TRMM Measurements*, Advanced Geosciences, 17, 87–91.

Mamenun, M., H. Pawitan, A. Sopaheluwakan, 2014. Validasi dan Koreksi Data Satelit TRMM Pada Tiga Pola Curah Hujan di Indonesia, Jurnal Meteorologi dan Geofisika, 15(1).

Mulyana, E., 2002. *Pengaruh Dipole Mode terhadap Curah Hujan di Indonesia*, Jurnal Sains dan Teknologi Modifikasi Cuaca, 3(1), 39-43.

NASA, 2017. *Tropical Rainfall Measuring Mission TRMM: Data Products and Usage*, accessed https://arset.gsfc.nasa.gov/sites/default/files/water/national-weather-center/P3_TRMM_Overview_Oklahoma_2012.pdf, 27 September 2019.

NASA, Goddard Earth Sciences Data and Information Services Center, 2017. *Readme Document for the Tropical Rainfall Measurment Mission (TRMM) Version 7*, accessed https://disc2.gesdisc.eosdis.nasa.gov/data/TRMM_L3/TRMM_3B43/doc/README.TRMM_V7.pdf, 28 March 2018.

NOAA, 2019. *El Niño/Southern Oscillation (ENSO) Technical Discussion*, accessed https://www.ncdc.noaa.gov/teleconnections/enso/enso-tech.php, 19 August 2019.

Ramage, C., 1971. *Monsoon Meteorology*, International Geophysics Series, vol. 15, San Diego, CA: Academic Press.

Salmawati, 2010. *Studi Pengaruh Indeks Osilasi Selatan sebagai Indikator ElNino terhadap curah hujan di Sulawesi Utara*, Skripsi Sarjana FMIPA Unsrat.

Storch, H. and F. W. Zwiers, 1999. *Statistical Analysis in Climate Research*, Cambridge University Press, 484 p.

Tjasyono, B., A. Lubis, I. Juaeni, Ruminta, S. W. B. Harijono, 2008. *Dampak Variasi Temperatur Samudera Pasifik dan Hindia Ekuator terhadap Curah Hujan di Indonesia*, Jurnal Sains Dirgantara, 5(2), 83-95.