The Influence of ENSO to the Rainfall Variability in North Sumatra Province

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Abstract. The El Niño Southern Oscillation (ENSO) is a global phenomenon that affects the variability of rainfall in North Sumatra. The influence of ENSO will be different for each region. This review will analyse the influence of ENSO activity on seasonal and annual rainfall variability. In this research, North Sumatra Province will be divided into 4 (four) regions based on topographical conditions, such as: East Coast (EC), East Slope (ES), Mountains (MT), and West Coast (WC). The method used was statistical and descriptive analysis. Data used in this research were rainfall data from 15 stations / climate observation posts which spread in North Sumatera region and also anomaly data of Nino 3.4 region from period 1981-2016. The results showed that the active El Niño had an effect on the decreasing the rainfall during the period of DJF, JJA and SON in East Coast, East Slope, and Mountains with the decreasing of average percentage of annual rainfall up to 7%. On the contrary, the active La Niña had an effect on the addition of rainfall during the period DJF and JJA in the East Coast and Mountains with the increasing of average percentage of annual rainfall up to 6%.

1. Introduction
North Sumatera Province is located in the western part of Indonesia, located on 1° -4° N and 98° -100° E. The province is adjacent to the waters and land areas, which are: Aceh Province in the north, Malaysia State and the Malacca Strait in the, Riau and West Sumatra Province in the south, and Indian Ocean in the west. Based on geographical location, topography, and natural condition, North Sumatera Province is divided into 3 groups including West Coast (WC), Mountains (MT), and East Coast (EC)1.

Climate that occurs in a region will influence the other areas as well as El Niño-Southern Oscillation (ENSO) or well known as El Niño and La Niña. ENSO is a combined phenomenon of atmospheric and ocean interactions that causes annual climate variations worldwide 2, 3, 4. The maximum influence of ENSO occurs in almost all parts of Indonesia except the northern part of Sumatera and some parts of Kalimantan5. Several previous studies have stated that ENSO activity has impact on rainfall variability in Indonesian region 4, 6, 7, 8, 9. Furthermore, in another study there was a decrease in rainfall in North Sumatra region during El Niño event 10. This was the reason why we conducted the research of ENSO's influence on seasonal and annual rainfall in North Sumatra region during 1981-2016.

During El Niño event, sea surface temperature in the Eastern Equatorial Pacific becomes warmer than its normal conditions. Meanwhile, during La Niña event, sea surface temperature in the Eastern
Equatorial Pacific is colder than its normal condition (Figure 1). This both phenomena occur as a result of the wind circulation system, the movement of the atmosphere above the ocean, and the surface pressure over the ocean along the ocean in the equatorial zone. **El Niño** event make the rainy season come late and reduce the total rainfall. On the contrary, **La Niña** is one of the causes of increasing rainfall in Indonesia. The ENSO index was obtained by calculating the mean sea surface anomaly level in the Niño 3.4 region (190°-240° E and 5° S - 5° N) based on the **El Niño** definition. The results of ocean surface analysis of the Pacific Ocean region, especially in Nino 3.4 region, indicated a positive anomaly occurred during the **El Niño** years (1982, 1983, 1986, 1987, 1991, 1992, 1997 and 1998) with the highest anomalies occurred in 1983, 1977 and 2015 with sea level anomaly > 2° C (Figure 3), whereas during **La Niña** (1988, 1989, 1999, 2000, 2010, and 2011), the lowest negative anomalies occurred in 1988 and 1999 (Figure 4).
Figure 3. Sea surface temperature anomaly in Pacific Ocean and Indonesian waters during El Niño

Figure 4. Sea surface temperature anomaly in Pacific Ocean and Indonesian waters during La Niña
2. Data and Methods

2.1. Data
The data used were observation data of monthly and annual rainfall data from 15 stations / climate observation posts with period of data from 1981-2016. Meanwhile ENSO used in this research was sea surface temperature anomaly data in Nino region 3.4. North Sumatra Province has distinctive climatic characteristics, flanked by two waters which are Indian Ocean and the Malacca Strait, as well as the Bukit Barisan Mountains that stretch from North to South of the province. Therefore, we divided North Sumatra region into 4 (four) topographic areas: East Coast (EC), East Slope (ES), Mountains (MT), and West Coast (WC) (Figure 5 and Table 1).

![Figure 5. Research Location in North Sumatera Region](image)

Table 1. Stations / Climate Observation Post as the research locations

| No | Station       | Latitude | Longitude | Period of time | Region  | Information |
|----|---------------|----------|-----------|----------------|---------|-------------|
| 1  | Pardamean     | 3.75° N  | 98.44° E  | 1983-2016      | East Coast | EC          |
| 2  | Sampali       | 3.62° N  | 98.78° E  | 1981-2016      | East Coast | EC          |
| 3  | Rambutan      | 3.38° N  | 99.16° E  | 1981-2016      | East Coast | EC          |
| 4  | Negeri Lama   | 2.32° N  | 100.0° E  | 1985-2016      | East Coast | EC          |
| 5  | Bahorok       | 3.50° N  | 98.13° E  | 1982-2016      | East Slope | ES          |
| 6  | Marihat       | 2.91° N  | 99.08° E  | 1981-2016      | East Slope | ES          |
| 7  | Bandar Pulau  | 2.65° N  | 99.50° E  | 1981-2016      | East Slope | ES          |
| 8  | Ujung Bandar  | 2.06° N  | 99.85° E  | 1981-2016      | East Slope | ES          |
| 9  | Sidikalang    | 2.73° N  | 98.33° E  | 1984-2016      | Mountains  | MT          |
| 10 | Kuta Gadung   | 3.15° N  | 98.50° E  | 1981-2016      | Mountains  | MT          |
| 11 | Gabehtutaraja | 2.11° N  | 98.95° E  | 1981-2016      | Mountains  | MT          |
| 12 | Arse          | 1.70° N  | 99.32° E  | 1985-2016      | Mountains  | MT          |
| 13 | Mompong       | 0.91° N  | 99.53° E  | 1981-2016      | Mountains  | MT          |
| 14 | Pinangsori    | 1.55° N  | 98.88° E  | 1981-2016      | West Coast | WC          |
| 15 | Gunung Sitoli | 1.27° N  | 97.58° E  | 1982-2016      | West Coast | WC          |
2.2. Methods
The method used in this research was statistical and descriptive analysis. Initial stage of the research was collecting rainfall data from climate stations / posts that exist in North Sumatra region. The rainfall data for each study area will be analyzed and linked to data of ENSO incident years, both El Niño (1982, 1983, 1986, 1987, 1991, 1992, 1997 and 1998) and La Niña (1988, 1989, 1999, 2000, 2010, and 2011).
This was conducted to determine the impact and influence of ENSO in North Sumatra region. The normal data used for comparison was during 1981 - 2010. ENSO conditions will be linked with the season forward or backward as well as its impact on annual and seasonal rainfall during: December-January-February (DJF), March-April-May (MAM), June-July-August (JJA), and September-October-November (SON) which were averaged by year of ENSO events and then spatially described.

3. Results and Discussion
3.1. The Influences of ENSO on Season in North Sumatera
Rainfall analysis in North Sumatra showed that the West Coast region (yellow line) and East Slope region (brown line) had a wet characteristic season along the year. This was characterized by rainfall per decade reached more than 50 mm, meanwhile the East Coast region (dark blue line) and Mountains region (light green line) had a distinct seasonal characteristics between the Dry Season (DS) and Rainy Season (RS) with 2 (two) Dry Season periods and 2 (two) Rainy Season periods (Figure 6).

![Figure 6. Normal Rainfall in North Sumatera Region](imageURL)

Rainfall data during El Nino and La Niña events was compared with the normal rainfall data of 1981 - 2010. Based on the analysis (Table 2), it showed that ENSO had no significant effect in the East Slope and West Coast region. This was due to the area of East Slope and West Coast in North Sumatra throughout the year has a rainy season criteria which was indicated by the absence of rainfall less than 50 mm throughout the year.15
During El Niño, the East Coast region experienced a long Dry Season (DS) up to 23 decades, during Jan 1-Aug 2, and the Rainy Season II (RS II) retreated for 3 decades. During La Niña, the period of DS I was shorter 6 decades, DS II was earlier 2 decades and shorter 1 decade, RS I was
earlier 6 decades and longer 2 decades, and RS II was advanced 3 decades. During *El Niño* condition, Mountain region (MT) experienced DS I earlier 3 decades, DS II was longer 5 decades (until Oct 1), RS I was retreated 1 decade, and RS II was retreated 5 decades. Meanwhile *La Niña* had no significant effect on RS and DS in Mountain region.

**Table 2. Normal condition and the influence of ENSO in North Sumatra Region**

| No | Region | Condition | DS I       | DS II      | WS I       | WS II      |
|----|--------|-----------|------------|------------|------------|------------|
| 1  | EC     | Normal    | Jan 1 - Apr 3 | Jun 2-Jul 2 | May 1-Jun 1 | Jul 3-Dec 3 |
|    |        | *El Niño* | Jan 1-Aug 2  | -          | -          | Aug 3-Dec 3 |
|    |        | *La Niña* | Jan 3- Feb 3 | May 3-Jun 2 | Mar 1- Apr 3 | Jun 3-Desc 3 |
| 2  | ES     | Normal    | -          | -          | -          | -          |
|    |        | *El Niño* | Jan 2 - Mar 1 | -          | -          | -          |
|    |        | *La Niña* | -          | -          | -          | -          |
| 3  | MT     | Normal    | Feb 1-Feb 3 | May 2-Aug 2 | Mar 1-May 1 | Aug 3-Dec 3 |
|    |        | *El Niño* | Jan 1-Mar 1 | May 3-Oct 1 | Mar 2-May 2 | Oct 2- Dec 3 |
|    |        | *La Niña* | Feb 1-Feb 3 | May 1-Aug 2 | Mar 1-Apr 3 | Aug 3-Dec 3 |
| 4  | WC     | Normal    | -          | -          | -          | -          |
|    |        | *El Niño* | -          | -          | -          | -          |
|    |        | *La Niña* | -          | -          | -          | -          |

3.2. The Influences of *El Niño* on the Rainfall in North Sumatera Region

The influence of *El Niño* on rainfall in North Sumatera during the DJF period (Figure 7.a) showed that in general, *El Niño* affected on rainfall reduction between 51-100 mm in some parts of the Central and Southern part of Mountain region, the Northern part of East Slope, and the southern part of East Coast. During MAM period (Figure 7.b), *El Niño* affected on rainfall reduction ranged from 51-100 mm in the East Coast and rainfall reduction ranged from 200-300 mm in the Northern part of East Slope. On the contrary, in the Center and Southern part of Mountain region and the West Coast, rainfall increasing ranged from 100-200 mm. This condition was due to the increasing of sea surface temperature around the Indian Ocean in the western part of Sumatera.

During JJA period (Figure 7.c), in general, *El Niño* gave impact on rainfall reduction ranged from 51-100 mm in the Central part of Mountain region, the Northern part of East Slope, the Northern part of East Coast, and some parts of West Coast. During SON period (Figure 7.d), *El Niño* had an effect on the reduction of rainfall ranged from 51-100 mm in all regions of North Sumatera except the Northern part of East Coast and also the Northern and Southern part of Mountain region.

Based on the results of *El Niño* events analysis that occurred in 1982/1983, 1986/1987, 1991/1992, 1997/1998 and 2015/2016 comparing with annual rainfall data in the same year, there was a decrease in rainfall with average decrease up to 7%. The East Coast region had a decreasing rainfall ranged from 3-13% with an average decrease up to 8%. The East Slope region had a decreasing rainfall ranged from 4-21% with an average decrease up to 11%. The Mountain region had a decreasing rainfall ranged from 3-9% with an average decrease up to 5%. The West Coast region had a decreasing rainfall ranged from 1-2% with an average decrease up to 1.5% (Figure 8).
3.3. The Influences of La Niña on the Rainfall in the North Sumatera Region

The influence of La Niña on rainfall in North Sumatra during the DJF period (Figure 9.a) showed that La Niña generally affected the addition of rainfall ranged from 51-100 mm in the Northern and Southern part of Mountain region and the Northern part of the East Coast region. The insignificant
reduction of rainfall occurred in the Central part of East Slope region. During MAM period (Figure 9.b), La Niña only influenced the addition of rainfall ranged from 101-200 mm in the Northern part of East Slope and the Northern part of East Coast region, whereas in the Northern and Southern part of Mountain region and the Central part of East Slope region had a decreasing rainfall ranged from 51-100 mm.

During JJA period (Figure 9.c), it was showed that generally La Niña affected on the addition of rainfall ranged from 51-100 mm in the Central and Northern part of the East Coast region, the Southern part of Mountain region, and also the Northern and Southern part of East Slope region. During SON period (Figure 9.d), it was showed that generally La Niña influenced the addition of rainfall ranged from 51-100 mm in the Southern part of Mountain region and the East Coast region, meanwhile the Northern part of the East Slope and the Southern part of East Coast had a decreasing rainfall ranged from 51 -100 mm.

**Figure 9.** The influence of La Niña on the Rainfall

Based on the results of La Niña event analysis that occurred in 1988/1989, 1999/2000 and 2010/2011 comparing with annual rainfall data in the same year, there was an increase in rainfall with an average increase up to 6%. The East Coast region had an increasing rainfall ranged from 5-13% with an average increase up to 9%. The East Slope region had an increasing rainfall ranged from 0-4% with an average increase up to 2%. The Mountain region had an increasing rainfall ranged from 0-22%
with average increase up to 5%. The West Coast region had an increasing rainfall ranged from 5-6% with an average increase up to 5.5% (Figure 10).

![Figure 10. The percentage of rainfall decrease during La Niña years](image)

It was generally seen that *El Niño* and *La Niña* were not significantly affected the rainfall in North Sumatra region. This was because besides ENSO, there were several other factors that affect North Sumatra region. The interaction between the atmosphere and the Indian Ocean in the West Coast of Sumatera and East Africa causes Dipole Mode phenomenon or better known as IOD (Indian Ocean Dipole). Dipole Mode value is positive if the western coastal sea surface temperature is cooler and negative if it is warmer than the East Coast African sea surface temperature. Positive Dipole Mode causes reduced rainfall and negative value causes more rainfall in Indonesia. Variations of the IOD index have implications on climate change, especially in the western part to the southern part of Indonesia, from Sumatera, Java, to Nusa Tenggara.°

In addition, sea surface temperature can also affect rainfall in Indonesia, which one of them is in North Sumatra. Theoretically, when sea level temperatures warm up, it will have an impact on increasing the chance of rain due to an increase in convective clouds growth. Furthermore, if the IOD event is associated with ENSO events, it will further affect the *El Niño* and *La Niña* events. Another factor that can affect rainfall in North Sumatra is the tropical disturbance in the form of a cyclonic pattern around the South China Sea and also in the Indian Ocean. This cyclonic pattern can increase the rainfall in North Sumatera region by establishing a convergence region.

### 4. Conclusions

Based on the discussion above, it can be concluded several things as follows:

1. The East Coast (EC) and Mountain (MT) region were regions in North Sumatra with a clear difference of Dry Season (DS) and Rainy Season (RS), meanwhile the West Coast (WC) and the East Slope (ES) tended to be wetter with Rainy Season criteria throughout the year.

2. *El Niño* caused longer Dry Season (DS) and shorter Rainy Season (RS). This condition was significant in the East Coast (EC), East Slope (ES), and Mountain (MT). In general, there was a reduction of rainfall ranged from 51-200 mm during DJF, JJA and SON. On the contrary, during MAM in the West Coast (WC) and the Central-Southern part of the Mountain region (MT), there was an increase of rainfall ranged from 51-200 mm.

3. *La Niña* caused shorter Dry Season (DS) and longer Rainy Season (RS), which was significant in the East Coast and Mountain region. In general, there was additional rainfall ranged from 51-200 mm during DJF and JJA.
4. There was a decrease in annual rainfall during the active El Niño in North Sumatra with an average percentage decrease up to 7%. The significant percentage decrease occurred in the East Coast, East Slopes, and Mountain region with an average decrease up to 8%, 11% and 5%.

5. There was an increase in annual rainfall during the active La Niña in North Sumatra with an average percentage increase up to 6%. The significant percentage increase occurred in the East Coast and Mountain region with an average of increase up to 9% and 5%.

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