Greater Aceh, Indonesia Enters Climate Change: Climate on Extreme ENSO 2015-2016

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Abstract. The objective of the study is to analyse the rainfall variability and temperature over Greater Aceh and its correlation to ENSO event. Long-term rainfall observation data spanning from 1982-2018 was retrieved from meteorological station of Blang Bintang, Greater Aceh. The Pearson correlation was employed to find the relationship between rainfall and El Niño and Southern Oscillation (ENSO) occurrence. It is shown from frequency analysis that rainfall decreased in the 90s. After the tsunami as climate change become unequivocal the rainfall trend increase as a result of land use change and much worst as severe ENSO 2015 arrived over the region which statistically significant was found between those two corresponding events. During El Niño, rainfall is less while La Niña more rainfall than normal drop over the region. To cope with climate change issues where ENSO is very likely to occur in future time, an appropriate mitigation is required to conduct for instance: managing forest resources and land use by reducing deforestation and land conversion, the control of fossil fuel burning, and the most important thing is to establish a renewable energy as an effort to implement sustainable green energy in the future as well as climate risk reduction.

1. Introduction
Aceh Besar District (Greater Aceh-red) is one of the districts in Aceh Province, Indonesia. Greater Aceh is located at 05.37°N and 95.53°E in far northwest of Sumatera Island and geographically border the Indian Ocean and the Malacca Strait in the west and east, respectively. A unique topographic condition is found over Greater Aceh since it is surrounded by three highlands (lhee sagoe), i.e., hilly areas in the east, Mount Seulawah in the southeast, and Bukit Barisan Mountain in the west with lowland stretched in the center in the valley of these three highlands. Therefore, it contribute to the formation of specific meteorological characteristics over the region, especially rainfall variability. Since it is located at the edge of vast sea areas, Greater Aceh have a humid and warm tropical climate. According to Köppen climate classification, Greater Aceh similar to many regions in Indonesia is categorized into wet tropical climate (Am) where rainfall variability is the greatest [1, 2].
The weather and climate in the western and eastern parts of Greater Aceh are strongly influenced by local interactions between ocean and topographic condition of Bukit Barisan Mountain. Since it lies in windward region, climate conditions in the western of Greater Aceh is wetter than the eastern region. Sea breeze bringing air mass from the ocean become quickly saturated due to the orographic lift and contribute to moderate until heavy rainfall in the afternoon in the west. Different characteristics are found in the eastern part of Greater Aceh where located in the leeside of Bukit Barisan Mountain, air that have converted to adiabatic cooling in the western region descends and turn into adiabatic warming in the eastern region establishing a rain shadow area which create climate conditions along eastern region of Greater Aceh warmer and drier [3, 4].

Nevertheless, rain is still possible to occur since there exists a gap in the north that are connected to the Indian Ocean and Malacca Strait which allow the movement of water vapour carried by the sea breeze to the mountainous areas in the southwest. For instance: during daytime, the air that descends from Bukit Barisan is warmer and drier leading Greater Aceh to experience a hot and humid day while the sea breeze formed in the north in the afternoon carry water vapour towards hilly areas in the south and southwest. The air become saturated and turn into adiabatic cooling which cause clouds to form and rain is produced making the air temperature in the eastern region of Greater Aceh is cooler in the afternoon.

The worst ever recorded El Niño 2015 caused world’s weather to change than usual. In the following year during La Niña, the world once again went into a period of a changing climate. Following strong El Niño and La Niña (refer to ENSO-El Niño and Southern Oscillation), it is clear that climate change existed and threatening life on Earth. In Indonesia, ENSO episodes which are associated with cooling and warming of surface Pacific Ocean often linked to the drought and floods, respectively [5, 6, 7, 8]. Since Indonesia is dominated by three rainfall zones, ENSO occurrence over the region is very likely on typical monsoonal and local climatic zones which are mostly located in the central and eastern part of Indonesia [9, 10, 11]. In the west where Semi-Monsoonal type climatic zone is dominant, the influences of ENSO is about as likely as not [12, 13]. As ENSO signal is strengthening as a result of climate change, however, its impact is very likely to occur as what Greater Aceh suffer from strong ENSO 2015-2016 events. The purpose of the study is to analyze the characteristics of rainfall variability and temperature and its correlation to ENSO signal in Greater Aceh.

2. Materials and Methods
Temperature and rainfall data from 1982 to 2018 were extracted from National Weather, Climate, and Geophysics Services (BMKG) under Data Online Website. The data originated from first class weather station of Blang Bintang, Greater Aceh. The ENSO signal was retrieved from KNMI Climate Explorer under Monthly Climate Indices representing by NINO3.4 where normal condition range between -0.5 and 0.5°C, El Niño and La Niña are recorded if they are above and below the normal ranges, respectively. The signal came from average anomalies of monthly HadISST sea-surface temperature. The Pearson correlation is employed to find the relationship between rainfall and ENSO.

| Climate indices (°C) | ENSO event       | Rainfall variability |
|----------------------|------------------|----------------------|
| -0.5 < Nino3.4 < 0.5 | Normal           | Normal               |
| 0.5 < Nino3.4 < 1.0  | Weak El Niño     | Normal               |
| 1.0 < Nino3.4 < 2.0  | Moderate El Niño | Below normal         |
| 2.0 < Nino3.4 < 3.0  | Strong El Niño   | Far below normal     |
| -1.0 < Nino3.4 < -0.5| Weak La Niña     | Normal               |
| -2.0 < Nino3.4 < -1.0| Moderate La Niña | Above normal         |
| -3.0 < Nino3.4 < -2.0| Strong La Niña   | Far above normal     |

BMKG classify the climate condition into several terms, i.e., below normal, normal, and above normal. Climate is considered normal if it ranges between the averages. Normal climate ranges
between 85% and 115% from the averages. Climate is considered below and above normal if they are lower and higher than 85% and 115% from the averages, respectively (BMKG, unpublished data).

3. Results and Discussion
The mean annual air temperature in Greater Aceh is 27.07°C. It is shown that no significant difference is found in the mean monthly air temperature. The mean maximum air temperature of 27.86°C reach its peak on June and mean minimum air temperature of 25.97°C is recorded on December (Figure 1). Because Greater Aceh is situated in the intertropical convergence zone, this area experiences intense solar radiation in nearly vertical direction, thus, little variability of temperature between the warmest and coldest months often describe changes in cloud cover instead of sun position. For instance, it is shown that the highest temperature is recorded in the month where rainfall is less in this case on June (Figure 1 and 2). Because the variability in mean air temperature is small, although June is the highest air temperature, it is, however, not the month of the lowest rainfall. The lowest rainfall is actually recorded at the peak of dry season on August with an average of 36 mm (Figure 2).

![Figure 1. Mean Monthly temperature (°C) over Greater Aceh.](image1)

![Figure 2. Mean Monthly Rainfall (mm) over Greater Aceh.](image2)
Greater Aceh has two main seasons, the dry season from June to August and the rainy season lasting from December to February, interrupted by two transition periods (March - May and September - November). However, it is noted that two peaks of rainy season fall over Greater Aceh, those are on May and November. A typical semi-monsoonal climatic pattern is observed over Greater Aceh where the region does not have a very distinct wet and dry season. Wet characteristics of climate occurred almost throughout year. The peak of the rainy season fall on November with an average monthly rainfall of 250 mm while in the dry season, a monthly average of 60 mm is observed on July. By understanding a dominant type climatic zone and its pattern accompanied by total amount of monthly rainfall and temperature over Greater Aceh based on their climatological variability (at least 30 years of data), a normal condition of climate is well-identified which might possibly be set up as baseline to determine the anomaly condition of the climate over Greater Aceh.

![Figure 3.](image1)

**Figure 3.** Rainfall anomaly (mm) during 1982-2018 over Greater Aceh. Blue and brown circle indicate flood and drought events due to La Niña and El Niño, respectively.

Time series of rainfall anomaly for three decades showed the increase of rainfall in the last 15 years. It is shown that the signal of flood event appeared frequently. Rainfall above normal was known to have been accompanied by La Niña occurrence particularly during moderate La Niña 2010-2011 and 2016. The increase of rainfall over tropics was reported in the IPCC AR5 where based on their ensemble model results, the tropical region is projected to receive a lot of rainfall in the future [14]. This condition is triggered by high sea-surface temperature as well as strong surface convection. Such factors then develop cumulonimbus clouds that may reach the stratosphere. The deep dark clouds might cover a whole tropics leading such hydrometeorological hazards as floods/inundation, wind and hailstorm, lightning to be very likely and intense in frequency to happen both nowadays and future time. In the 80s and 90s, the El Niño signal was repeatedly detected as rainfall decrease below normal over the periods (Figure 3).

The trends of rainfall variability were shown to decrease in the 80s and 90s and raise in middle 2000s up to present time which is confirmed by regular emergences of El Niño and La Niña events, respectively. It is also shown that ENSO play a major role in influencing the rainfall variability in Greater Aceh despite time-series correlation is weak. The statistical performance showed that a p-value of 0.6470 which is less than 0.95 revealed that the significant correlation exists between Nino3.4 and the onset that fall on October-December. Since ENSO is a global climate anomaly, its teleconnection might alter throughout the globe which was confirmed by field statistical test among Nino3.4, Greater Aceh rainfall, and global air temperature where a statistically significant connection (p-value < 5.0%) was found in the map of the present study (Figure 4).
Figure 4. Time series correlation between rainfall variability and ENSO Signal (Nino3.4) over Greater Aceh

Figure 5. Characteristics of monthly rainfall (mm) and ENSO signal (°C) in Banda Aceh during 2013-2017.

In 2015, the El Niño signal started appearing above normal on April, raise severely in the following months, and establish on November-January. The intensification was accompanied by the decrease of the monthly rainfall (Figure 5). At the peak of rainy season on December, the total amount of rainfall was far below normal which resulted in the retreat of the onset in Banda Aceh. During dry season, El Niño affected to the drought due to the lack of water resources as rain drop below normal. It is also noted that the emergence of El Niño signal lead the first peak of the rainy season in Banda Aceh that occurred on May to fall far below normal. In addition, a lot of rain was received on April prior to the growth of intense El Niño. It is interesting to notice that more and less rainfall at the opening of El Niño period could be an indicator of typical severe El Niño years in Banda Aceh. In 2016, the development of La Niña on October lead the onset of the rainy season to advance. Following extreme
La Niña years, the worst condition due to high rainfall terrify the Greater Aceh. When annual rainfall arise, flooding are haunting as the climate change arrive over the region. The disaster risk reduction by minimizing the climate risk by means of performing proper adaptation and mitigation is urgently implemented. Anthropogenic effect derived from the excessive utilization of fossil fuel, exploiting forest values, land cover change, forest fire have polluted the environment. The release of greenhouse gas emission have been uncontrolled since industrial revolution which have reached an alarming level leading global climate processes to disturb. In consequence, climate anomaly of ENSO become more frequent which further threatening the terrestrial life. The monitoring of weather and climate condition, climate field school, dissemination of the research output as well as building public awareness associated with extreme weather and its climate change impact in many sectors, e.g., health, agriculture, tourism, fisheries etc are sort of adaptation action that could be executed to address the climate change issues. The awareness as well as the preservation of the environment and the development of green energy foremost are such mitigation that could be introduced to cope with an inconvenient truth of global warming.

4. Concluding remarks
Climate variability is very likely to occur in Banda Aceh. In addition to retreat the onset, strong El Niño cause annual rainfall to drop leading to drought. On the contrary, La Niña period bring surplus water that is potential to water reserves to cope with water scarcity during dry season in the region. It is however, La Niña is well-known for the years of flooding due to the excessive rainfall, urban built-up, lack of catchment areas, and mismanagement foremost.

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