Pattern Analysis of El Nino and La Nina Phenomenon Based on Sea Surface Temperature (SST) and Rainfall Intensity using Oceanic Nino Index (ONI) in West Java Area

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Abstract. Climate change occurs in 1998-2016 brings significant alteration in the earth surface. It is affects an extremely anomaly temperature such as El Nino and La Nina or mostly known as ENSO (El Nino Southern Oscillation). West Java is one of the regions in Indonesia that encounters the impact of this phenomenon. Climate change due to ENSO also affects food production and other commodities. In this research, processing data method is conducted using programming language to process SST data and rainfall data from 1998 to 2016. The data are sea surface temperature from NOAA satellite, SST Reynolds (Sea Surface Temperature) and daily rainfall temperature from TRMM satellite. Data examination is done using analysis of rainfall spatial pattern and sea surface temperature (SST) where is affected by El Nino and La Nina phenomenon. This research results distribution map of SST and rainfall for each season to find out the impacts of El Nino and La Nina around West Java. El Nino and La Nina in Java Sea are occurring every August to February. During El Nino, sea surface temperature is between 27°C - 28°C with average temperature on 27.71°C. Rainfall intensity is 1.0 mm/day – 2.0 mm/day and the average are 1.63 mm/day. During La Nina, sea surface temperature is between 29°C - 30°C with average temperature on 29.06°C. Rainfall intensity is 9.0 mm/day - 10 mm/day, and the average is 9.74 mm/day. The correlation between rainfall and SST is 0,413 which is expresses a fairly strong correlation between parameters. The conclusion is, during La Nina SST and rainfall increase. While during El Nino SST and rainfall decrease. Hopefully this research could be a guideline to plan disaster mitigation in West Java region that is related extreme climate change.

Keywords: Rainfall, El Nino, La Nina, ONI Index and SST Reynold.

1. Introduction
1.1. Problem Background
Rainfall is one of the most important climatic elements, but its existence is spatially and temporally still difficult to predict. In addition to its dynamic nature, the physical processes involved are also very complex. The uncertainty of rainfall pattern is complicated by anomalous climatic phenomenon like El Nino and La Nina. According to [3], various disastrous events in Indonesia show that most of the

disasters are related to the El Nino Southern Oscilation (ENSO) phenomenon. ENSO is a recurrent pattern of climate variability in the eastern Pacific Ocean that is characterized by sea surface temperature anomalies (sea level warming describes the El Nino incident whereas sea-level cooling illustrates the incidence of La Nina) anomalies [1].

ENSO values can be demonstrated by the Oceanic Nino Index (ONI) as well as changes in sea surface temperature that have an impact on rainfall intensity. So the incidence of El Nino and La Nina causes a decrease and increase in rainfall in Indonesia.Extreme El Nino phenomenon occurred in 2015, causing some areas in Indonesia experiencing drought. According to BMKG Meteorology Deputy, Yunus Subagyo Swarinoto, the results of monitoring the development of El Nino until the beginning of June 2015, show moderate condition of El Nino phenomenon. This condition is expected to last until November 2015 and has higher probability to increase [11].

Extreme La Nina phenomenon occured in 2016 which causes the rainy season becomes longer than the dry season. That conditions resulted in disastrous flood in some areas in Indonesia. According to BNPB Head of Information and Public Relations Data, Sutopo Purwo Nugroho, the rainfall is expected to rise 200 percent. Besides Sumatra and Java, eastern part of Sulawesi, central Papua and Kalimantan are also affected by this phenomenon [3]. Indonesia has lies in the hemisphere with a tropical monsoon climate which is very sensitive to ENSO climate anomaly. In addition to causing the occurrence of El Nino phenomenon, ENSO also increase occurrence of La Nina phenomenon. The phenomenon of El Nino and La Nina also affect the territory of Indonesia, one of which is West Java Province, affected by dry La Nina during the 2016. Further consequences are the occurrence of increasingly long dry season and rainy season. La Nina is characterized by high rainfall intensity in a region that is entering the rainy season, considering the potential for rain is quite larger at that time.

In this research, ONI indicator (Oceanic Nino Index) has been used in observing ENSO phenomena in the form of El Nino and La Nina associated with rainfall in West Java. ONI is one of the most commonly used parameters to state the events of El Nino and La Nina. The Nino Ocean Index represents monthly average value of the SST (Sea Surface Temperature) the month after and before from normal condition, which is then compared with the normal SST of current month. If the value is less than -0.5, then that area is experiencing strong La Nina, -0.5 up to 0.5 experiencing neutral conditions and value of more than 0.5 indicating strong El Nino.

In the end, this research aims to establish SST distribution map and seasonal rainfall. The map will be used to determine the effect of El Nino and La Nina phenomenon in West Java. The final result of this research is the analysis of correlation between the impact of El Nino and La Nina on rainfall and correlation between rainfall data with online BMKG rainfall data.

1.2. Research Hypothesis
a. How to identify the influence of El Nino and La Nina against 1998-2016 rainfall using ONI indicator?
b. What is the analysis of El Nino and La Nina spatial patterns from 1998-2016 based on the ONI indicator?

1.3. El Nino and La Nina Phenomenon
1.3.1. El Nino Phenomenon
El Nino is defined as a phenomenon of a marked difference between observed sea level temperatures compared to normal conditions in the equatorial Pacific Ocean region. El Nino is a global-scale atmospheric oceanic phenomenon [9]. Such conditions occur repeatedly every 3-8 years period and are usually associated with negative value of the negative oscillation index.

1.3.2. La Nina Phenomenon
La Nina cannot be seen by the Pacific, even the period is not fixed. In average, La Nina occurs in 3 years to 7 years. It can last 12 months to 36 months; La Nina doesn't have a fixed period so all is expected to happen at 6 months to 9 months beforehand. At the time of La Nina phenomenon, sea surface temperature in the Eastern Equatorial Pacific was lower than its normal condition. While the

sea surface temperature in Indonesia becomes warmer. So that there are many convection and resulted in air mass gathered in the territory of Indonesia, including air mass from the Eastern Equatorial Pacific. It supports the formation of clouds and rain. So, La Nina phenomenon often result in rainfall far above normal that could cause flooding and landslide, or even followed by strong wind [2].

1.4. The Oceanic Nino Index (ONI Index)

The Oceanic Index is an index showing the division of regions and measures the value of SST (Sea Surface Temperature) in these areas in the Pacific sea [6]. ONI is a new index, which actually is one of El Nino indexes. The ONI is calculated based on the calculation principle for monitoring, assessment and prediction of the ENSO cycle. The ONI also measures the change in the SST value of the regional average of Nino 3.4. The average of three-month is taken and the value of SST change similar to the historical SST analysis is observed [10].

2. Materials and Methods

2.1. Research Area

The study area of this study is the territory of Indonesia, especially in the province of West Java lies in the position 104°48'00" E - 108°48'00" E and 5°50'00" S - 7°50'00"S. Research area can be seen in Figure 1.

2.2. Data Research

Data researches needed in this research are:

a. NOAA image of Reynolds SST data from 1998-2016.

b. TRMM image in the form of daily data of rainfall year 1998-2016.

c. BMKG Daily Rainfall Record Years 1998-2016.

Figure 1. Research Area

2.3. Research Methodology

For processing using IDL software divided by several stages can be seen in Figure 5. The final result of this data processing step with IDL is SST and precipitation that has been compiled into monthly climatology in the form (.txt) and (.png), the ONI index of SST is three-month average, and graph of the relationship between SST and rainfall parameters. For data processing flowchart in this research can be seen in Figure 2.

3. Results and Discussion

3.1. El Nino and La Nina phenomenon identification based on ONI algorithm

The results of data processing of sea surface temperature and rainfall on a monthly basis are classified into three classes namely El Nino, La Nina and normal which is show in Table 1. The classification is

based on the ONI index that are average of moving obtained from previous month's SST, current SST and SST one month later.

Rainfall and SST data are processed using IDL software resulting monthly data of climatology as the outcome. So, the analysis of the relationship between SST and rainfall on El Nino, normal and La Nina can be established. During El Nino phenomenon, SST tends to be cooler while the intensity of rainfall decreases. Meanwhile, during La Nina phenomenon, SST tends to be warmer and rainfall intensity becomes greater as compared to El Nino. The impact of El Nino and La Nina on Rainfall are shown in Figure 3 and Figure 4.
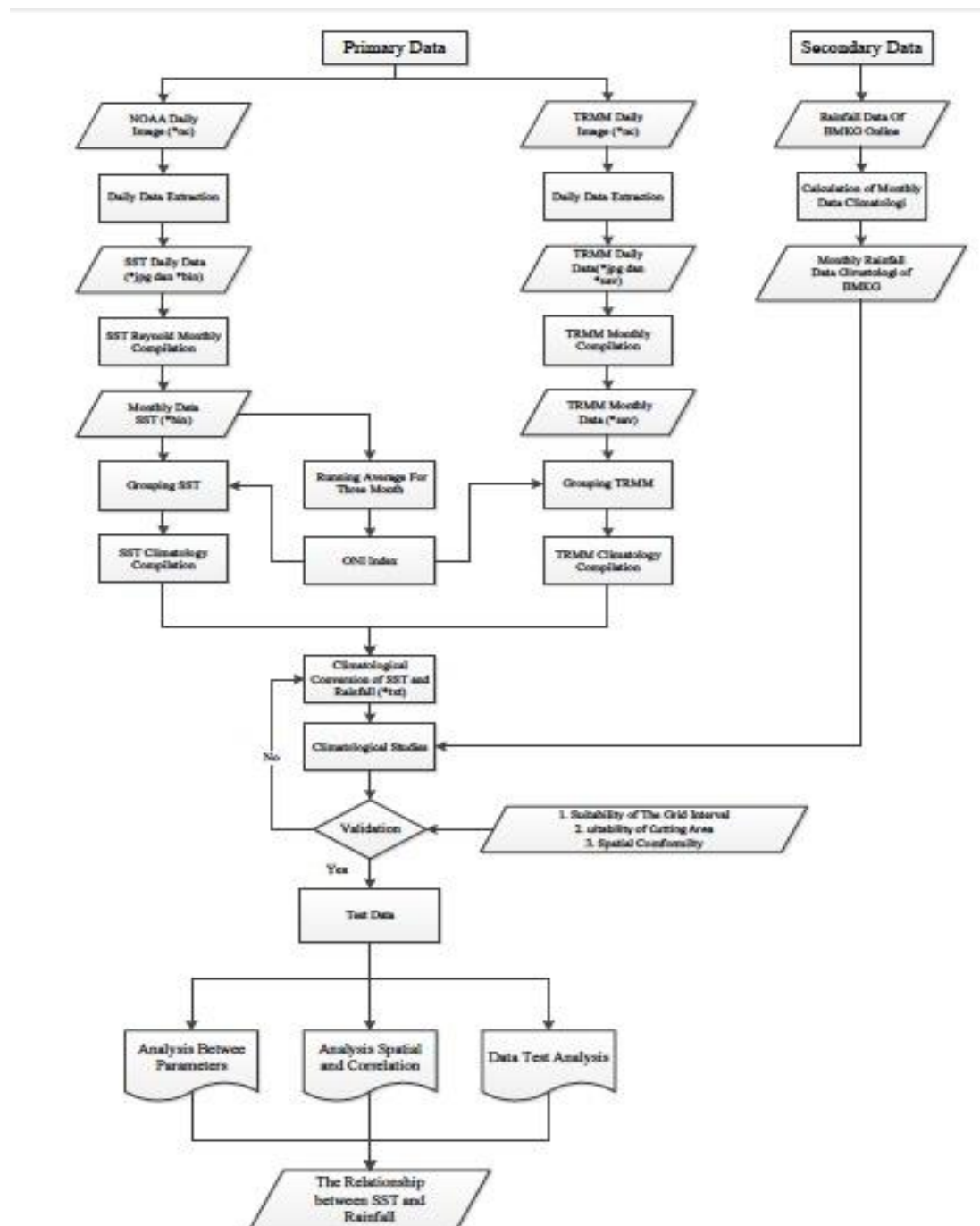

Figure 2. Data Processing Flowchart

Table 1. Monthly SST Reynolds Classification

Month	Monthly Temperature																		
	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1	0.00	-1.87	-2.03	-1.16	-0.58	0.71	-0.07	0.16	-1.17	0.32	-1.85	-1.13	1.19	-1.68	-1.09	-0.86	-0.89	0.26	2.01
2	1.54	-1.37	-1.65	-0.73	-0.22	0.64	-0.03	0.25	-0.90	0.10	-1.55	-0.84	1.20	-1.33	-0.70	-0.56	-0.75	0.40	1.95
3	1.43	-0.75	-0.93	-0.24	0.27	0.69	0.31	0.53	-0.23	0.24	-0.86	-0.18	1.30	-0.64	-0.24	0.07	-0.09	0.93	1.90
4	1.38	-0.29	-0.35	0.19	0.71	0.62	0.67	0.92	0.38	0.44	-0.17	0.48	1.22	0.03	0.27	0.52	0.75	1.35	1.66
5	0.86	-0.20	-0.04	0.42	1.12	0.48	0.90	1.07	0.81	0.59	0.10	1.00	0.79	0.38	0.67	0.63	1.19	1.72	1.28
6	0.11	-0.39	-0.16	0.40	1.15	0.37	0.89	0.86	0.72	0.30	0.12	1.07	0.07	0.39	0.76	0.33	0.93	1.69	0.50
7	-0.81	-0.82	-0.34	0.19	0.99	0.25	0.74	0.45	0.52	-0.10	-0.01	0.89	-0.65	0.03	0.72	-0.06	0.43	1.64	-0.13
8	-1.21	-1.12	-0.60	-0.15	0.76	0.10	0.62	0.00	0.33	-0.70	-0.21	0.65	-1.24	-0.45	0.46	-0.26	0.05	1.58	-0.65
9	-1.44	-1.36	-0.78	-0.38	0.73	0.05	0.48	-0.23	0.36	-1.17	-0.39	0.58	-1.57	-0.82	0.30	-0.40	0.03	1.72	-0.87
10	-1.50	-1.52	-0.95	-0.54	0.90	0.07	0.43	-0.46	0.51	-1.49	-0.51	0.82	-1.68	-1.04	0.21	-0.30	0.27	2.06	-1.03
11	-1.77	-1.77	-1.17	-0.69	1.02	0.09	0.38	-0.75	0.66	-1.63	-0.76	1.12	-1.67	-1.17	-0.14	-0.41	0.34	2.23	-1.05
12	-1.92	-2.04	-1.26	-0.73	0.92	-0.03	0.30	-1.11	0.61	-1.81	-1.03	1.29	-1.75	-1.21	-0.50	-0.60	0.29	2.24	0.00

La Nina	Normal	El Nino
>-0,5	-0,5<0<0,5	>0,5
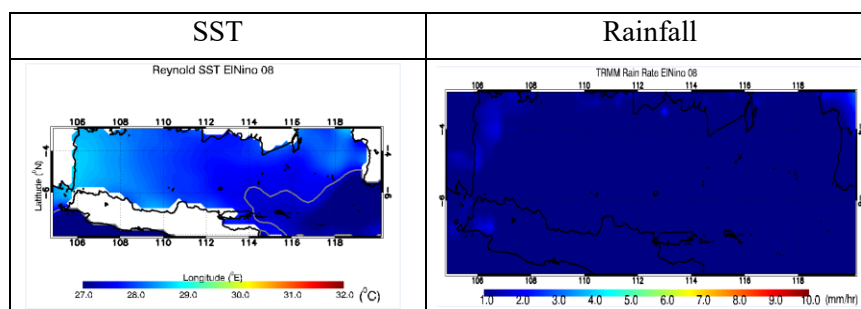
SST	Rainfall

Figure 3. El Nino on August
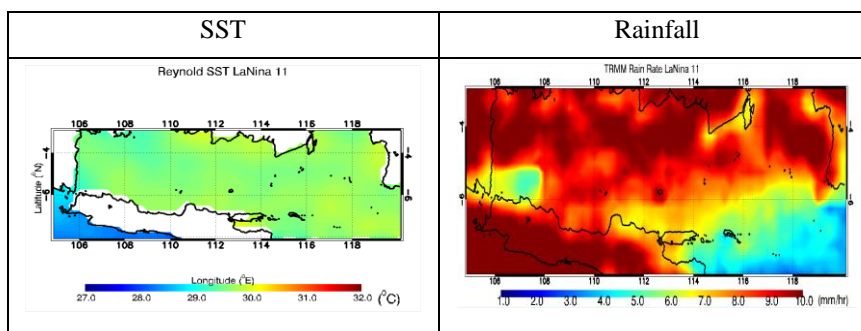
SST	Rainfall

Figure 4. La Nina on November

*3.2. Pattern Analysis of Sea Surface Temperature and Rainfall Variability*

This SST variability assessment aims to determine the spatial pattern of El Nino and La Nina during 1998 until 2016. The spatial distribution value of SST and monthly rainfall of climatology are shown in Table 2. It can be seen that the difference between SST and rainfall from January to December for almost 20 years. It shows a positive change when the sea surface temperature rises and rainfall rises. But in a few months, there is no interrelationship between sea level rise in temperature and rainfall.

Multi temporal graph between SST variable and rainfall in West Java region can be seen in Figure 5. The multi temporal graph shows the relationship between parameters in each month on a seasonal basis.

Table 2. SST Value and Rainfall Based on Monthly Climatology

Months	Sea Surface Temperature (Celsius)	Rainfall (mm/days)
January	28,63002	12,3085
February	28,64475	12,18645
March	28,94295	9,55454
April	29,42991	8,35645
May	29,55567	6,07406
June	29,05264	4,58059
July	28,29524	3,5924
August	27,70947	1,63389
September	27,75353	1,86311
October	28,42904	5,41364
November	29,05697	9,74061
December	29,05771	11,50177

Meanwhile in normal circumstances, the temperature is not remarkably high, but still at the value of 29°C-30°C. In the state of La Nina, SST looks cooler than normal. The temperature range at La Nina is 28°C-29°C. The spread of the temperature began to warm from the northern part of Java Sea so that the temperature spread from North to West. The average value of SST in the vicinity of West Java is 28.63°C.
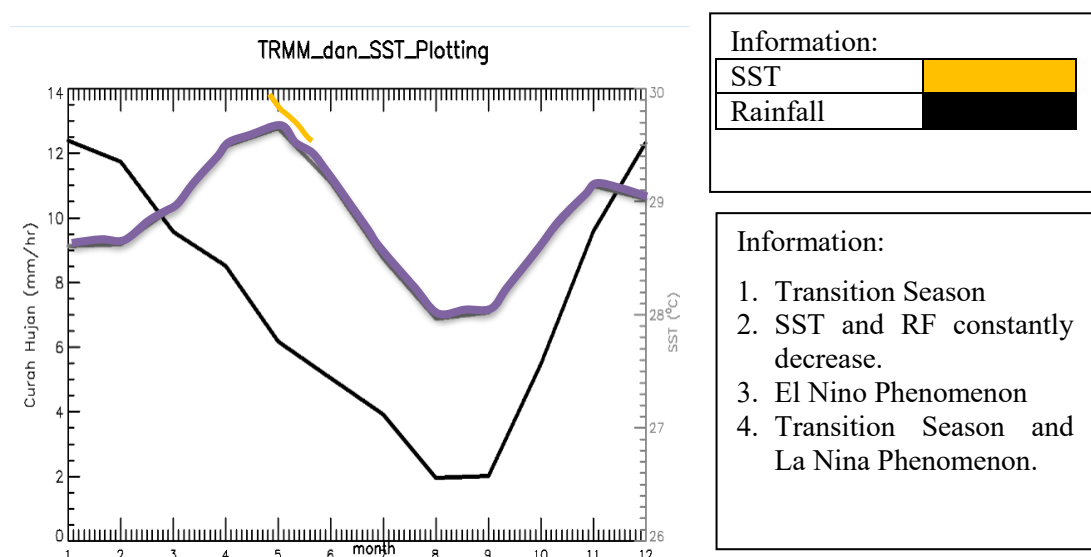
Figure 5. Rainfall Intensity in Multi Temporal Season

In January, as can be seen from Figure 6 that rainfall in Java undergoes shifting from La Nina to El Nino. This phenomenon is indicated by the color change from dark red to yellow with a value of 7.0mm/hr-10mm/hr. At time when La Nina tends to occur throughout West Java, these areas experience rainy season with a higher intensity than normal and El Nino. For January, the average value of rainfall in West Java is 12.30 mm/hr.
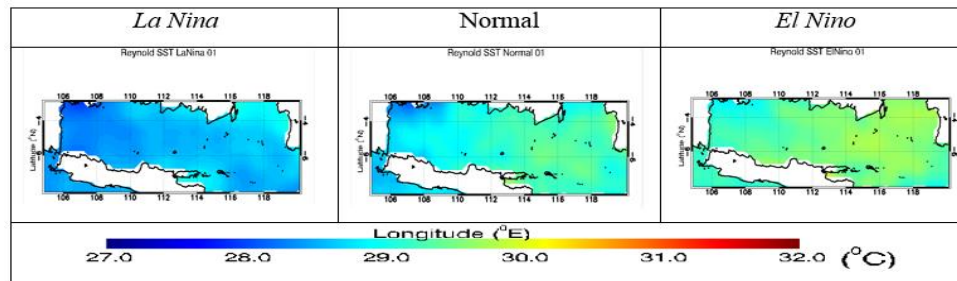
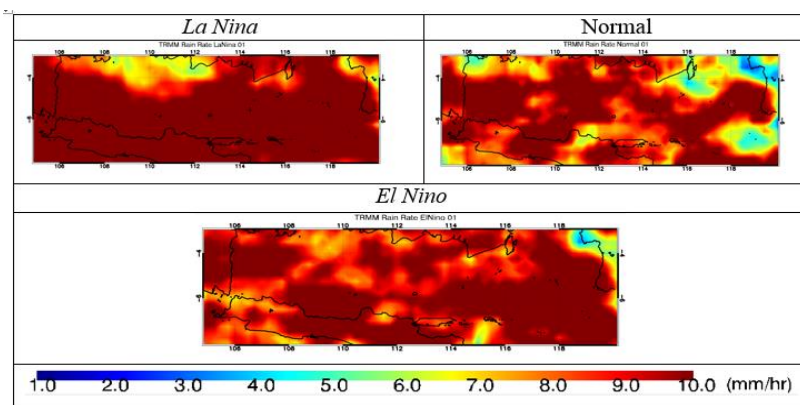**Figure 6.** SST distribution during January for 20 years Climatology

Figure 7. Rainfall distribution during January for 20 years Climatology

3.3. Pattern Analysis of Multi Temporal Graph of SST and Rainfall Variability

This analysis aims to see the relationship between rainfall intensity and SST during La Nina and El Nino phenomenon. It was also to see the influence of on the impact of SST changes in Java Sea to the rainfall intensity during El Nino, normal and La Nina from 1998 to 2016 in the three part regions.

A. Northern region

For the northern part of West Java, samples were taken in Bekasi and Karawang region. The objective is to analyze the impact of sea surface temperature change in Java Sea on the intensity of rainfall in that regions. Multi-temporal graph analysis in Bekasi and Karawang region is shown in Figure 8.

As can be seen on Figure 8, rainfall during La Nina from January to June is under climatological rainfall while from July to November is above climatological rainfall. During El Nino, the entire phenomenon is opposite to the state of La Nina. During La Nina from January to June, SST is under the climatological SST while in July to November the value is above the climatological SST. As for December, both values are opposite, as El Nino values rise, whereas at La Nina the value falls.

B. Central region

For the central part of West Java, samples were taken in Bandung. The objective is to analyzed the impact of sea surface temperature change in Java Sea on the intensity of rainfall in that regions. Multi-temporal graph analysis in Bandung region is shown in Figure 9.

As can be seen in Figure 9, the increase of SST does not impact the change of rainfall significantly during January to April. From May to September, rainfall and SST intensity show the same pattern in

which is the SST value decrease and the rainfall value also decreases. The dotted line indicating the El Nino state has the same pattern but the value differs from the pattern in Bekasi and Karawang area.
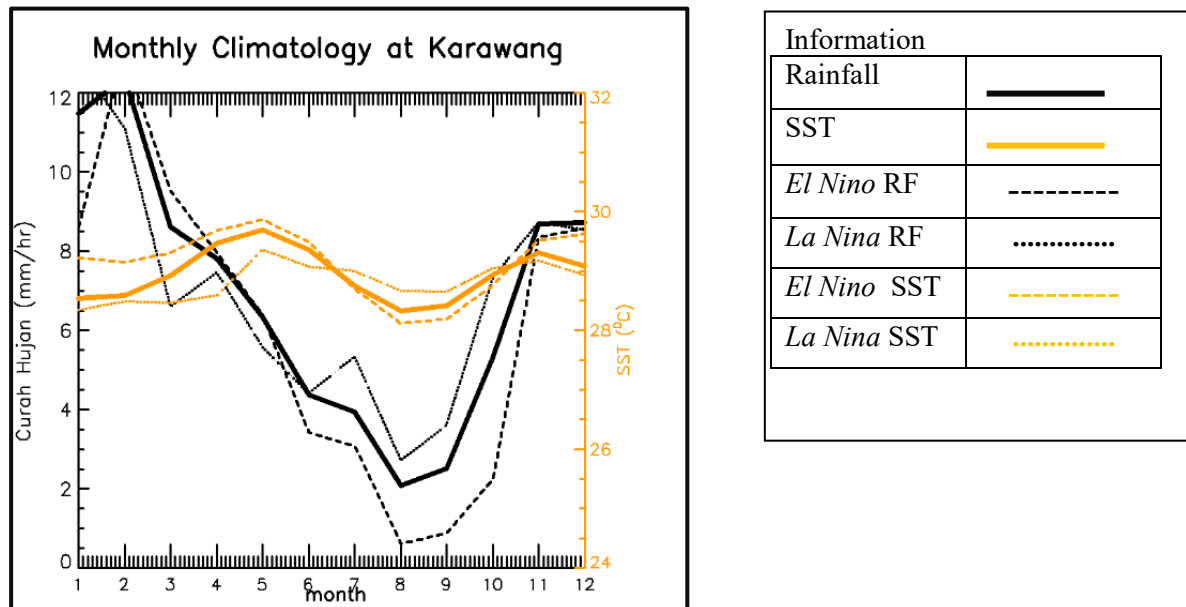

Information	
Rainfall	————
SST	————
El Nino RF	---------
La Nina RF	··············
El Nino SST	---------
La Nina SST	············

Figure 8. Multi Temporal Graph of Karawang Region

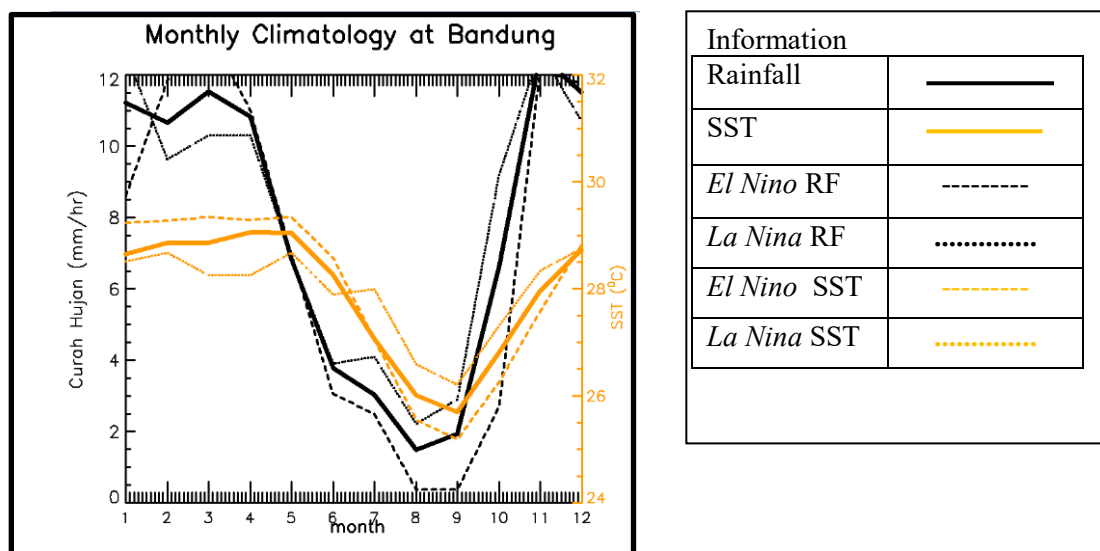| Information	
Rainfall	————
SST	————
El Nino RF	---------
La Nina RF	··············
El Nino SST	---------
La Nina SST	············

Figure 9. Multi Temporal Graph of Bandung Region

C. Southern Region

For the southern part of West Java, samples were taken from Sukabumi area. The objective is to analyze the impact of sea surface temperature change in Java Sea on the intensity of rainfall in that region. Multi-temporal graph analysis in the Sukabumi region is shown in Figure 10.
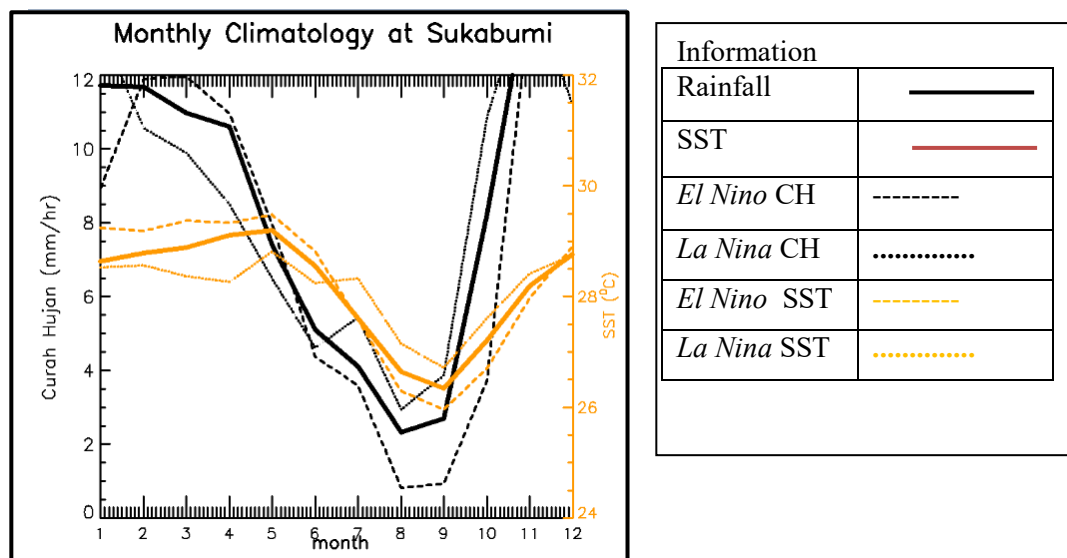
Figure 10. Multi Temporal Graph of Sukabumi Region

As can be seen on Figure 10, the increase of SST does not impact significantly on the change of rainfall during January to May. As for June to September, the pattern is similar so that during the decrease of SST, the value of rainfall also decreases. From October to December, the value between SST and rainfall are both increasing. Dashed lines and dots in the picture show the condition when El Nino and La Nina have the same pattern as Bandung area but have different values.

4. Conclusion
Based on this research, it can be concluded as follows:
1. This research has been identified the impact of El Nino and La Nina on rainfall during 1998-2016 using ONI indicator by classifying sea surface temperature (SST) data into several categories, namely El Nino, La Nina and Normal condition. Classification of sea surface temperature (SST) were also used to categorized rainfall data. Therefore, the impact of sea surface temperature which is relatively warm on the increase in rainfall intensity and vice versa can be observed.
2. The result of spatial analysis between SST and rainfall on El Nino and La Nina phenomenon in West Java and Java Sea region reveal that in August to September is the highest El Nino condition with average sea surface temperature 27.71ᵒC - 27.75ᵒC followed by decrease in average rainfall intensity of 1.63 mm/hr-1.86 mm/hr. While December to February is the highest La Nina condition with average sea surface temperature 29.06°C - 28.64°C followed by increase in rainfall intensity of 11.50 mm/hr - 12.15 mm/hr.

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