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# *Modeling of monthly rainfall analysis in Aceh Besar District with Indonesia's Sea-Surface Temperatures as the primary component*

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**Abstract.** There are various fields that crucially require information about rainfall, including agriculture. A major drop or rise in rainfall may significantly impact the agriculture in Indonesia. For this reason, research regarding on variables that effected rainfall are still being improved by applying variety of models in order to provide accurate and closely related to the original data on rainfall forecast. Precise and accurate rainfall forecast is essential to help extension workers and farmers to determine when to start planting their crops and to decide what kind of crops are suitable for a particular region. Data applied in this research are data on monthly Sea-Surface Temperature (SST) data which are limited by 10°N – 15°S and 90°E – 145°E with a 1° x 1° grid, as well as data on monthly rainfall in Aceh Besar district which were obtained by averaging the data from 10 rain post points in collaboration with the BMKG of Aceh Besar District between 2010 – 2019. Correlation analysis between Sea-Surface Temperature (SST) and rainfall resulted in correlation value that fulfill the requirement of "sufficient" to "high" in a number of regions for each month. The highest correlation value was recorded by 0.87 for the positive correlation in October, and it was recorded by -0.87 for the highest negative value of correlation in December. Under those circumstances, by utilizing the Principal Component Regression (PCR) method, a forecasting model is created for each of the region with the highest correlation which allows for the identification of the area that most impacted rainfall in district of Aceh Besar. Model validation obtained error value of 37.1 or roughly around 19.5%. The highest value difference was occurred in October 2014, measuring by the value difference of 96 mm. The results of monthly rainfall forecast in 2021 provide a pattern of rainfall that is similar with the observation data obtained in August to December. Research results indicate that sea-surface Temperature (SST) in regions of Indonesia can be utilized as the indicator in forecasting rainfall at a district level.

**Keywords:** *Sea-Surface Temperature (SST), Rainfall, Correlation, PCR*

## Introduction

Indonesia is a country located exactly above the equator, which causes it to receive intensive sunlight throughout the entire year. According to its geographical location, Indonesia is sandwiched between two continents and two oceans. As this is an advantageous location, regions in Indonesia experiences exceptionally high rainfall all year long. Rainfall in Indonesia is frequently being related to global and regional phenomenon such as *El Niño* and *Southern Oscillation* (ENSO) as well as *Dipole Mode* (DM). Hence, the effects of ENSO and DM are varying by each region in Indonesia. According to Pratiwi (2020), the ENSO is effecting more in the eastern region of Indonesia, while *Dipole Model* is effecting more in the western region of Indonesia which adjacent to the Indian Ocean. In addition, Pamulatsih (2017) also mentions that the ENSO had no significant impacts on the Aceh region, while the *Dipole Model* gave major impact significantly to the Meulaboh region. Therefore, further research is required in order to identify the factors that may influence rainfall in the Aceh region.

The amount of rainfall is one of the elements of climate that is very influential toward a variety of fields, including the agriculture. One of the important information required within the agricultural field is the rainfall forecast. It is the information regarding to the estimated rainfall and is predictive in determining the potential rainfall data by utilizing data of the previous events as the input. Precise and accurate rainfall forecast is crucially important in supporting extension workers and farmers to determine when to start planting their crops and to decide what kind of crops are suitable for a particular region. According to the above statement, it is essential to create the finest rainfall forecast model in order to achieve precise and accurate values as this will be used as guidance by stakeholder in the better utilization of climate data.

Multiple suitable predicators are required in the process of creating rainfall forecast in order to create a model with low error value. Barnstone states in Bazo (2013) that sea-surface temperature (SST) is a variable that can be utilized as a tool in forecasting rainfall. This is due to the facts that sea surface temperature plays an important role in the process of evaporation which in turn impacts cloud formation and ultimately impacts rainfall (Lestari et

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al, 2017). High sea inertia causes the possibility to utilize SST analysis in creating rainfall forecast in a number of different parts of the world. SST is the water temperature measured at sea surface. It is highly related to rainfall. As the SST rises, a lot of evaporation will occur which then form into clouds and produce rain, and vice versa. Therefore, further study will be conducted within this research on how much of the correlation is between the SST in Indonesian regions and rainfall in district of Aceh Besar since there have been numerous instances of crop failures in the rice fields of Aceh Besar due to drought and flooding. In this research, the writer is attempts to determine the impacts caused by sea surface temperature (SST) toward rainfall in the District of Aceh Besar as well as the specified regions that has the greatest impacts on rainfall in the District of Aceh Besar.

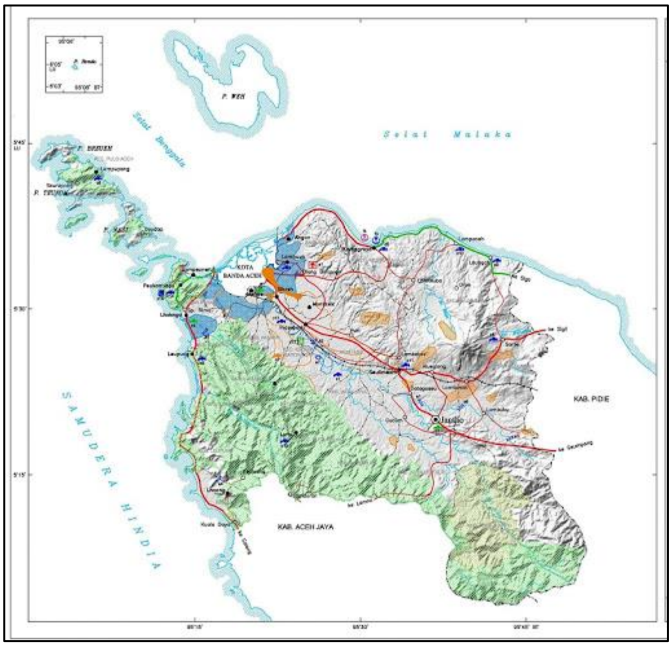

Figure 1 Aceh Besar District map (http://www.acehbesarkab.go.id/)

## Methodology

The research site is located in the District of Aceh Besar. Geographically, the District of Aceh Besar is located between the 5° 2′ – 5° 0.8′ North Latitude and 95° 80′ – 94° 88′ East Longitude (Figure 1).

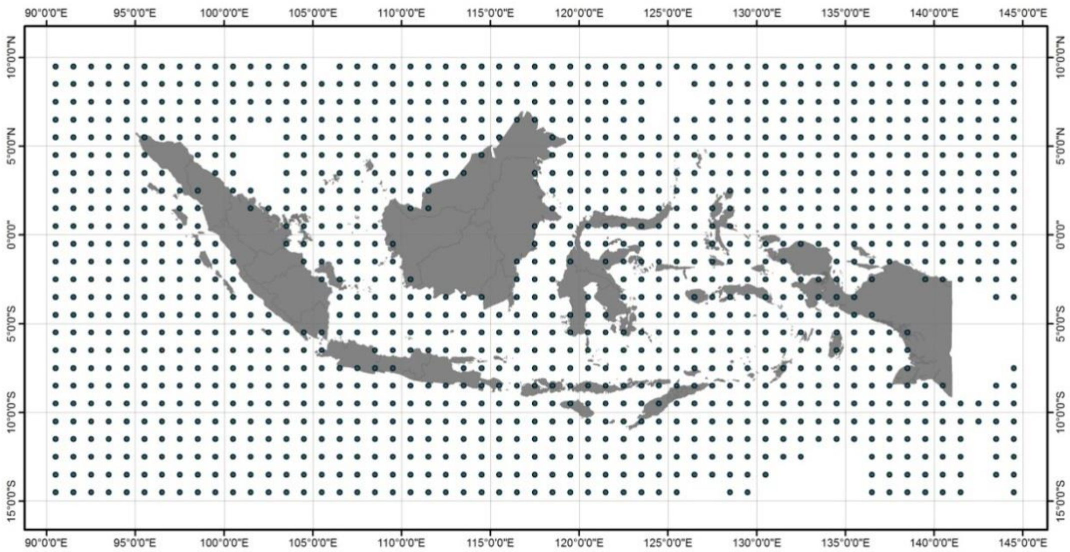


Figure 2 Location of Sea Surface Temperature (SST) sed

As shown in Figure 2, the data required for this research is anomaly data of monthly sea surface temperature (SST) of regions in Indonesia with a 1° x 1° grid located at 10°N – 15°S and 90°E – 110°E. For this research, the period of data used starts from 2010 through 2020. The SST data is utilized as the predicator which impacted rainfall in the district region of Aceh Besar. While the SST data are sourced from a website called *National Ocean and Atmospheric Administration* (NOAA) which can be accessed for free by downloading at http://iridl.ldeo.columbia.edu/ .

The applied data on rainfall constitutes the post rainfall data from approximately every sub-district in District of Aceh Besar. The period of data used starts from 2010 through 2019 with further specifics provided in Table 1 and Figure 3.

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Table 1 Rain Post coordinates

| Rain Post | Longitude | Latitude |
|---|---|---|
| Darussalam | 95.39730 | 5.58840 |
| Kota Jantho | 95.60126 | 5.29846 |
| Kuta Baro | 95.37683 | 5.536650 |
| Lhoknga | 95.242453 | 5.472636 |
| Montasik | 95.420874 | 5.457489 |
| Saree | 95.270 | 5.450 |
| Seulimeum | 95.569766 | 5.366247 |
| Stasiun Geofisika Mata Ie | 95.2960 | 5.49590 |
| Stasiun KlimatologiAceh Besar | 95.464787 | 5.403678 |
| Stasiun MeteorologiSultan Iskandar Muda | 95.417023 | 5.522438 |

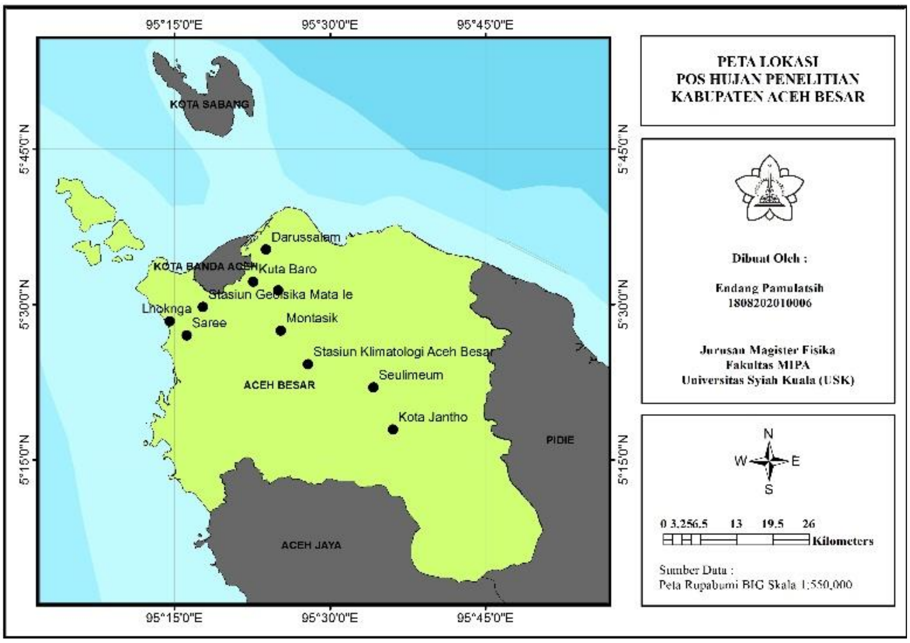


Figure 3 Location of the Rain Post used

The method applied in this research is descriptive analysis. Data of sea surface temperature were collected and arranged to support the analysis of the impacts of sea surface temperature toward rainfall in district of Aceh Besar. While the data of rainfall were obtained from the average results of 10 locations or rain posts points throughout Aceh Besar.

*Correlation Analysis*

Correlation analysis is the method analysis applied to measure the correlation between two or more variables which are stated as the level of relation (the degree of proximity) between variables (Kurniawan, 2016). Value of correlation typically lies between -1 up to 1. The higher the value of correlation, the closer the relation is between the variables. While negative correlation value indicates the existence of inverse relation between the two variables.

The formula of correlation that is commonly used in order to determine the relation between two or more variables is the Pearson Correlation, as the formula is shown below :

$$r\,(x,y) = \frac{n\sum x\,y - (\sum x)(\sum y)}{\sqrt{\{n\sum x^2 - (\sum x)^2\}\{n\sum y^2 - (\sum y)^2\}}}$$

The value 'r' refers to the value of coefficient correlation. While the value 'x' refers as the Variable X (in the case of this research it refers to the value of rainfall). The value 'y' refers to Variable Y (in the case of this research it refers to the value of sea surface temperature). Additionally, 'n' refers to the amount of data.

*Principle Component Regression*

Principle Component Regression is an analytical technique which combines Regression Analysis and Principal

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Component Regression. Regression Analysis is used to determine the existence of relation between the response and predictors variables, while PCA is generally aimed to simplify observed variables by lowering (reducing) their dimensions. Principle component regression analysis is a type of regression analysis that examines the response variables toward uncorrelated primary components, the principle component regression can be expressed as follow:

$$Y = w_0 + w_1 K_1 + w_2 K_2 + \cdots + w_m K_m + \varepsilon$$

The value 'Y' refers to the Response Variable, 'K' refers to the value of principle components, and 'w' refers to the parameter of principle component regression. In determining the value of the principle component, components that are selected are those with Eigen value of >1 or those which are able to adequately explain high diversity (80% - 90%).

*Root Mean Square Error (RMSE)*
Root Mean Square Error (RMSE) is a method applied to determine the scale of error level in the results of forecast or within the forecast. The lower the value of RMSE (approximated to 0), the closer it is in achieving accurate result of forecast. The value of RMSE is obtained by finding the average square from the value of forecast with the value of observation on a certain set of data as shown in the formula below (Yaxin Qin et al in Abdurahman, 2016):

$$RMSE = \frac{\sum_{i=1}^{n}(X - Y)^2}{n}$$

Value 'X' refers to the value of the forecast. While the value 'Y' refers to the value of observation and 'n' refers to the amount of data.

## Result

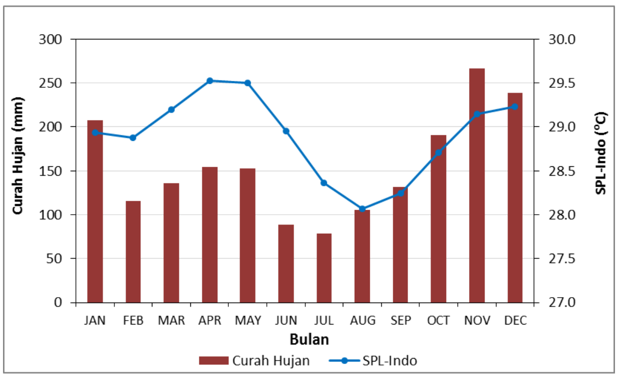


Figure 4 Aceh Besar's average rainfall and Indonesian SST (period 2010 – 2019).

Figure 4 displays data on the average of monthly rainfall in district of Aceh Besar and data on the average SST in Indonesia. Data on the average of monthly rainfall in district of Aceh Besar was obtained by averaging the rainfall data from 10 observation points of post rain. According to the average of monthly rainfall from 2010 - 2019, rainfall in regions of Aceh Besar are classified as monsoonal rain with 1 (one) peak during the rainy season and 1 (one) peak during the dry season. The peak in the rainy season comes in November with rainfall of 267 mm, while the peak in the dry season comes in July with rainfall of 78 mm. Additionally, the value of SST in the regions of Indonesia varies, with the highest SST that comes around April or May with the value of 29,5°C and its lowest SST comes in August with the value roughly 28,1°C.

*The Correlation between the Rainfall of Aceh Besar with the Indonesian SST*
The findings of correlation analysis between the rainfall in District of Aceh Besar with the Indonesian SST shows that the value varies in each month with the distribution of strongly correlated regions which locations are quite differs in each months. The response obtained is in the form of positive and negative correlation, where positive correlation indicates rainfall will increase when there is an increase in the SST. Meanwhile, negative correlation indicates the inverse result, meaning that rainfall will decrease when there is an increase in the SST.

Each month, correlation analysis is conducted and yields a distinct set of results. In January, the highest positive correlation was obtained by 0.85 which was located in the northern Kalimantan or around the South China Sea. In February, the highest positive correlation was obtained by 0.81 which was located in the southeast of Natuna. In March, the highest positive correlation was obtained by 0.76 which was located in the northern part of Papua New Guinea, along with the highest negative correlation which was obtained by -0.75 in the Indian Ocean, southern part of Java Island. In April, the highest positive correlation was obtained by 0.81 located in the northern part of Papua New Guinea. In May, the highest positive correlation was obtained by 0,81 located in the Pacific Ocean northern part of Papua. In addition, in June, the highest positive correlation was obtained by 0,85 which was located in the northern part of Japen Island, Papua (Figure 5a).

In July, the highest positive correlation was obtained by 0.73 which was located in the northern part of Sulawesi. In August, the highest positive correlation was obtained by 0.75 located in the Indian Ocean of southern Java Island. In September, the highest positive correlation was obtained by 0.72 located in the west of the City of Banda Aceh. In October, the highest positive correlation was obtained by 0.87 located in the South China Sea. In November, the highest positive correlation was obtained by 0.83 located in the South China Sea, as well as the highest negative correlation which was obtained by -0.71 located in the Indian Ocean western part of Aceh. In December, the highest positive correlation was obtained by 0.81 which

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was located in the north Kalimantan, as well as the highest negative correlation which was obtained by -0.87 located in the Celebes Sea (Figure 5b).

Based on the findings of correlation between rainfall in Aceh Besar and Indonesian SST in January – December, the highest positive correlation value was obtained ranging from 0.72 – 0.85. On the other hand, the highest negative correlation value was obtained ranging from -0.32 to -0.87 with a variety of zones. The highest positive correlation (0.85) occurred in January and July, while the highest negative correlation (-0.87) was occurred in December.

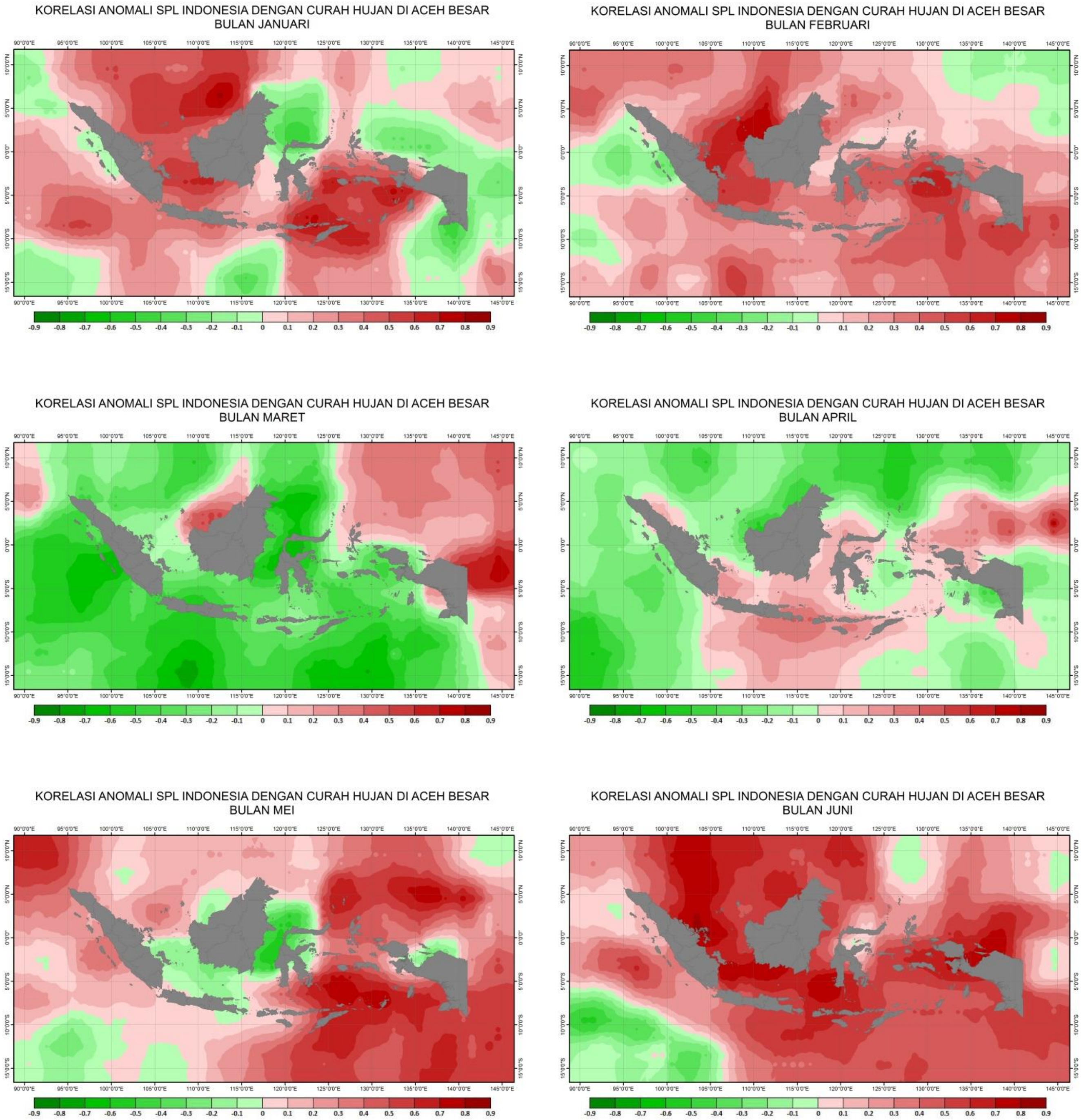


Figure 5a. Correlation of Indonesian SST anomaly with rainfall in Aceh Besar (January – June).

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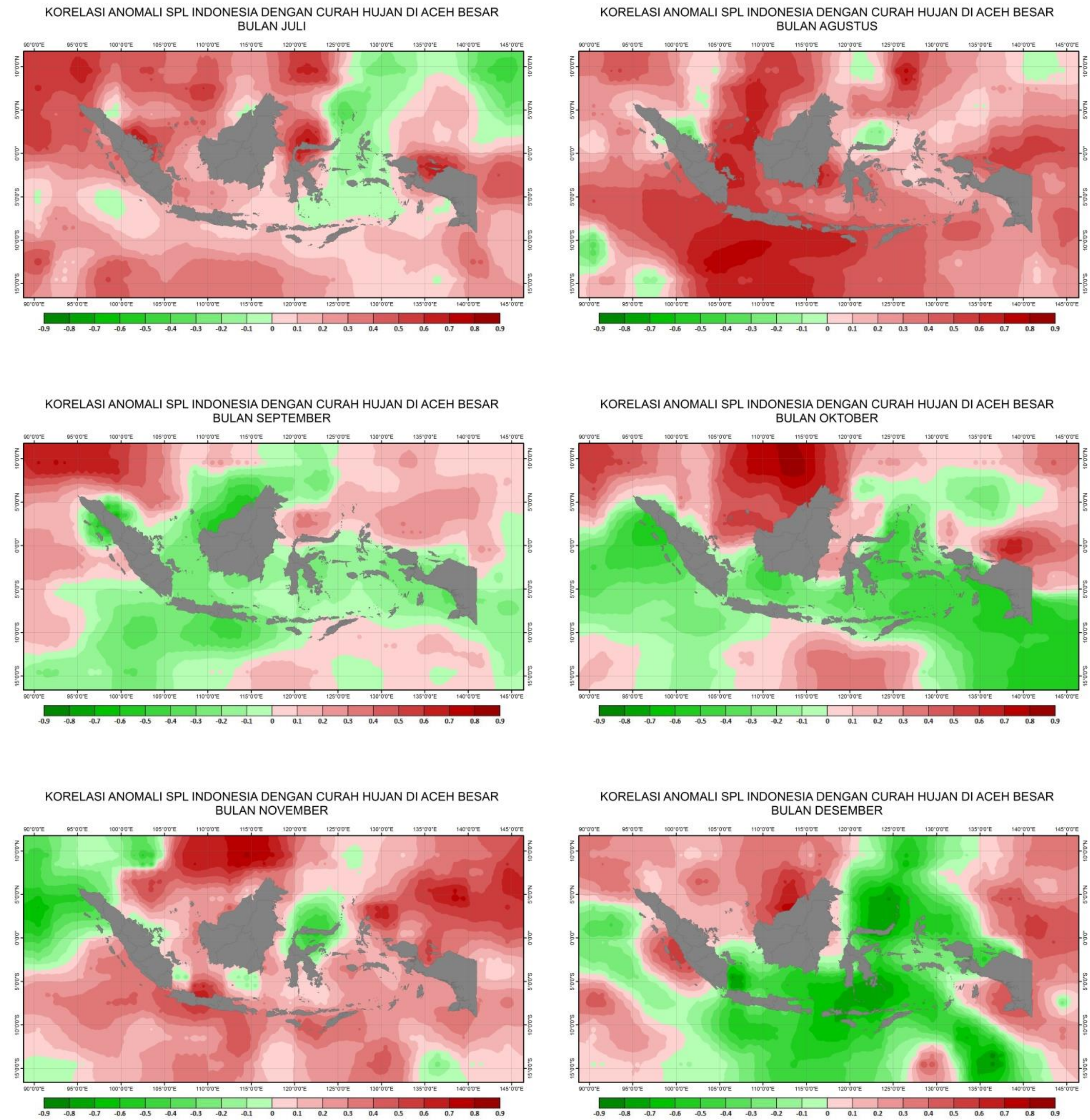


Figure 5b Correlation of Indonesian SST anomaly with rainfall in Aceh Besar (July – December).

*Modeling Rainfall in Aceh Besar with Principal Component Regression (PCR) Method*

The highest value of correlation between rainfall in Aceh Besar with Indonesian SST is used as the guidance in determining regions that will be used in creating the Aceh Besar Rainfall model for each month. For instance, in January a region with the borders of 4° North – 9° North and 108° East – 115° East is selected, and the same process follows for the next months. The anomaly data of SST on the grid is utilized in the process of creating the rainfall forecast model by using the PCR method, which therefore results models for each of the months with the model details such as presented in Table 2.

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Table 2 Aceh Besar Rain Forecast Model

| Month | Forecast Model |
|---|---|
| Januari | CH = 208 – 11.2 PC1 – 10.0 PC2 |
| Februari | CH = 115 – 9.28 PC1 + 10.4 PC2 |
| Maret | CH = 136 + 8.10 PC1 – 0.29 PC2 + 7.7 PC3 – 7.3 PC4 |
| April | CH = 154 – 21.7 PC1 |
| Mei | CH = 153 – 9.07 PC1 + 0.38 PC2 – 11.1 PC3 |
| Juni | CH = 88.8 – 6.53 PC1 + 3.48 PC2 – 4.3 PC3 – 0.8 PC4 |
| Juli | CH = 78.1 – 13.6 PC1 |
| Agustus | CH = 105 – 6.17 PC1 |
| September | CH = 131 – 6.63 PC1 – 0.21 PC2 |
| Oktober | CH = 190 – 11.6 PC1 + 10.2 PC2 |
| November | CH = 267 – 15.3 PC1 – 3.84 PC2 |
| Desember | CH = 239 + 36.6 PC1 |

Before being applied in forecasting rainfall in 2020, the formula presented in Table 3 was also applied in order to find the value of rainfall in 2010 – 2019. Results of rainfall forecast in 2010 – 2019 and the rainfall value observations can be seen as it is presented in Figure 6.

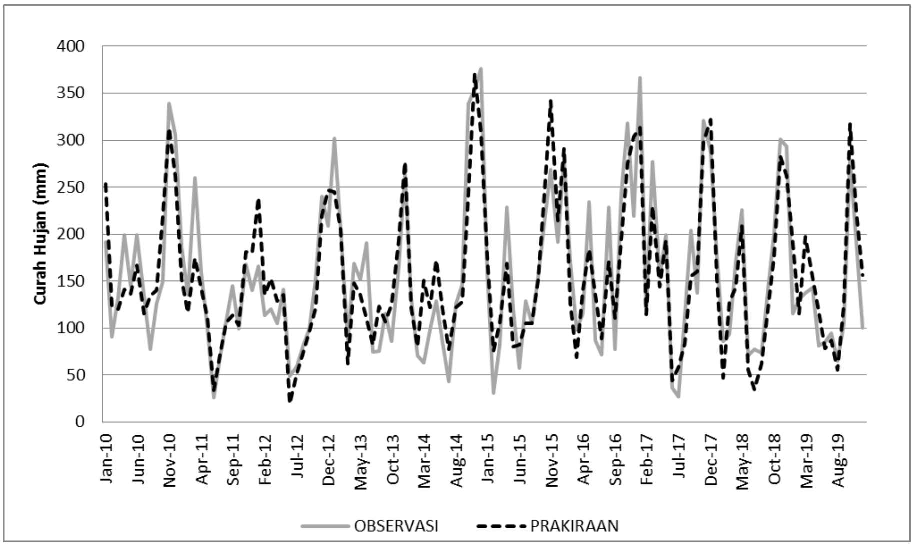


Figure 6 Comparative graph of observational rainfall in Aceh Besar and Forecast Model within 2010 - 2019

Figure 6 demonstrates that rainfall forecast Aceh Besar with the observation data have quite similar patterns. However, the achieved forecast values are not entirely the same due to the differences existed with the observation values in several months. The highest difference value occurred in October 2014 by 96 mm of difference value. Forecast model produces error value (RMSE) of 37.1 or roughly 19.5%.

*Rainfall Forecast of Aceh Besar in 2020*

According to the model validation findings, monthly rainfall forecast are conducted for the period of January to December 2020 (Figure 7). Rainfall forecast findings present similar patterns as the observation data in August – December with a various difference value. The highest difference value occurred in May with a difference reaching 281 mm. while the lowest difference value occurred in February with a difference by 12 mm. As a comparison (Rohmah *et al*., 2019) conducted monthly rainfall forecast in Pondok Betung by utilizing the primary component predictor of sea surface temperature in Indonesian seas. The research provides a fairly fine forecast and follows the rain pattern, yet it has not proven successful in predicting exceptionally heavy rain. Finally, (Pratiwi *et al*., 2020) applied the SST data in order to predict rainfall in regions of West Lombok. In addition, the findings of validation presents that rainfall forecast in the regions of west Lombok have the closest pattern to the observed rainfall pattern with the RMSE value of 81.92. Meanwhile, according to the validation based on the type of rain using the contingency table, 42% of all the rainfall forecast attributes were accurate.

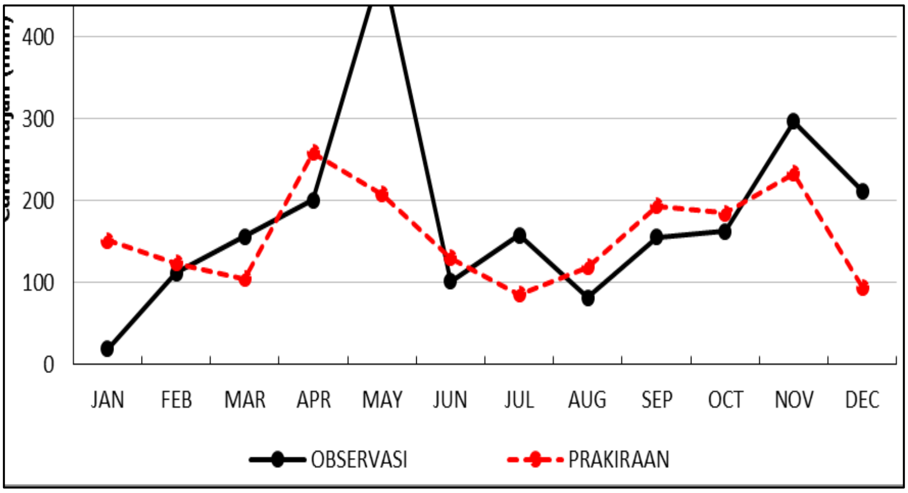


Figure 7 Graph of Comparison of Rainfall Forecasts and Observations in Aceh Besar in 2020

## Conclusions

The correlation between Rainfall in Aceh Besar and Indonesia's SST on the average from January to December shows that the highest positive correlation value is ranging from 0.72 to 0.85. While the highest negative correlation ranges from -0.32 to -0.87 with a variety of zones. The highest positive correlation (0.85) occurred in January and June, while the highest negative correlation (-0.87) occurred in December. Validation of rainfall model results as RMSE value of 37.1 or roughly 19.5% with the highest difference value occurred in October 2014 by 96 mm of difference value.

The rainfall forecasting model utilizing the SST in Indonesia regions can be further developed to forecast rainfall in other districts using other different forecasting method as what has been done in the previous research

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