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# Correlation Analysis of Sea Level Temperature in Indonesian Waters Against Seasonal Rainfall in D. I. Yogyakarta

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## Article Info

## ABSTRACT

*Indonesia is a maritime continent country whose territory is surrounded by sea. Sea Surface Temperature (SST) affects the climatic conditions of a region. The effect of SST is not the same for every place and every seasons. D. I. Yogyakarta is a region that bordering the Indian Ocean, so a study is needed to determine the effect of SST for rainfall in the region for each seasons. The result of study is very important for considerations in making rainfall forecasts. Correlation analysis was used to determine the effect of SST on rainfall in the D. I. Yogyakarta. The correlation coefisien in DJF, MAM are negative-positive and JJA, SON are positive, the highest correlation coefisien is in SON. There are three water areas in Indonesia that have a strong influence on seasonal rainfall in D. I. Yogyakarta. Three water areas in Indonesia are the southern of Java Island, southwest Sumatra and around the Maluku Islands. The highest percentage of correlation coefficient of 25 rain gauges for all seasons is SST in the Maluku Islands waters that the percentages are 60% (DJF), 56% (MAM), 56% (JJA) and 96% (SON). SST in Maluku Islands waters can be used as an indicator to predict JJA, SON rainfaal in D. I. Yogyakarta.*

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## 1. INTRODUCTION

Indonesia is the largest archipelagic country in the world whose territory includes waters so that Indonesia's atmospheric conditions generally tend to be humid. The territory of Indonesia is geographically located between two continents, namely the Asian continent and Australia, which is one of the drivers of monsoon winds. In addition, Indonesia is also flanked by two large oceans, namely the Indian Ocean to the west and the Pacific Ocean to the east, which are the waters driving the global phenomenon IOD and ENSO. The interaction between the atmosphere and the sea has an important role in influencing weather and climate variability in Indonesia [1, 2].

The sea is a source of water vapor, the amount of water vapor released into the atmosphere is influenced by *sea surface temperature* (SST). SST plays a very important role in the evaporation process so that it affects the formation of clouds and precipitation [3]. SST plays an important role in influencing the thickness variability of convective clouds in tropical waters. The threshold for SST that can trigger convective clouds is 27.5°C [4]. In the *maritime continent* the influence of SST on rainfall on land is higher than in the sea [5].

The dynamics of SST in Indonesian waters are influenced by global phenomena such as *El Nino Southern Oscillation* (ENSO) and *Indian Ocean Dipole* (IOD). From 2007-2016 SST in Indonesian waters ranged from 27.91 - 30.46°C. The coldest SST occurred in August 2007, 2012, 2015 and the warmest in April 2010 and 2016. There is a high correlation between SST in western Indonesian waters with IOD and Indonesian SST with ENSO [6]. The global phenomenon of IOD and ENSO not only affects the variability of SST in Indonesian waters but also affects rainfall in Indonesian territory. The negative (positive) influence of IOD on the increase (decrease) of rainfall in Indonesia is significant in the dry season period (JJA-SON) while in the rainy season period (DJF-MAM) the influence of IOD decreases [7]. Similarly, the influence of ENSO, El Nino (La Nina) has an effect on the reduction (increase) of rainfall in the Indonesian region during the dry season period (JJA-SON) [8].

The SST anomaly in the *maritime continent* is a parameter that can affect climate conditions in Indonesia. Some of the climatic parameters affected by the SST anomaly are air temperature, wind speed, solar radiation and air humidity and rainfall [9]. Many studies have been conducted to determine the association between SST variability and rainfall [2, 10, 11]. There is a positive (negative) correlation between SST in Bali waters and rainfall in the Bali region during the dry season (rain) period [10]. Warming of the SST in the Tropical Indian Ocean can have an impact on increased rainfall in the tropics, but at the time of El Nino the decrease in precipitation occurs at the same time as the warming of the SST [2]. The influence of SST on rainfall in an area is also influenced by monsoon activity. The cooling (warming) of the SST in the waters west of the Philippines can trigger an increase (reduction) of rainfall when simultaneously with the strengthening (weakening) of the Western Monsoon [11].

D. I. Yogyakarta is an area located in the southern hemisphere with a diverse topography and directly adjacent to the Indian Ocean. This condition allows the influence of SST Indonesia to affect the variability of rainfall in D. I. Yogyakarta. A study is needed to find out which water area SST has the greatest influence on seasonal rainfall in the D. I. Yogyakarta area. By knowing the water areas that have the greatest influence on rainfall for each season, it can be used as one of the considerations in making rainfall forecast information in the D. I. Yogyakarta area based on the conditions of SST variability that have been determined.

## 2. METHOD

In this study, the data used is monthly rainfall data for the period 1981-2019 which was measured in 25 rain posts spread across the D. I. Yogyakarta area. In addition, the data used are *CPC Merged Analysis of Precipitation* (CMAP) reanalysis data [12] and SST reanalysis data obtained from NOAA [13].

The method used in this study is the Pearson correlation coefficient method. A correlation coefficient that expresses the relationship between variable Y (rainfall) and variable X (sea surface temperature). The Pearson correlation coefficient is formulated as follows:

$$r_{xy} = \frac{N \sum XY - (\sum X)(\sum Y)}{\sqrt{[N \sum X^2 - (\sum X)^2][N \sum Y^2 - (\sum Y)^2]}}$$

with :

$r_{xy}$ = correlation coefficient between rainfall and SST
$X$   = rainfall variable
$Y$   = variable SST
$N$   = a lot of data

The correlation coefficient shows the degree of tightness of the relationship between 2 variables (rainfall and SST) with the range of correlation coefficients ranging from (-1) - 1. If the value of the correlation coefficient is close to a value of 1 or -1 then there is a strong relationship between SST and rainfall, while if it is closer to 0 then the relationship between SST and rainfall is weaker. If the correlation value is negative, then when the SST rises (falls), the rainfall falls (rises) and vice versa. The following is a classification table of the value of the pearson correlation coefficient:$r$

**Table 1**. Classification of the value  of *the r pearson  correlation coefficient* [14]

| Interval Koefisien | Tingkat Hubungan |
|---|---|
| 0,80 – 1,000 | Sangat Kuat |
| 0,60 – 0,799 | Kuat |
| 0,40 – 0,599 | Cukup Kuat |
| 0,20 – 0,399 | Rendah |
| 0,00 – 0,199 | Sangat Rendah |

## 3.  RESULTS AND DISCUSSION

To determine the highest influence of SST on seasonal rainfall conditions in the D. I. Yogyakarta region, a correlation analysis was conducted between the CMAP model and SST. To determine the level of conformity of the CMAP model with observation data, a correlation analysis of the average rainfall in the D. I. Yogyakarta area was carried out at 25 sample points or rain stations spread across the D. I. Yogyakarta area with the period 1981-2019 with the CMAP model with the same time period. Based on the correlation between rainfall, observations of the CMAP model show a positive correlation value for all seasons as shown by Figure 1.
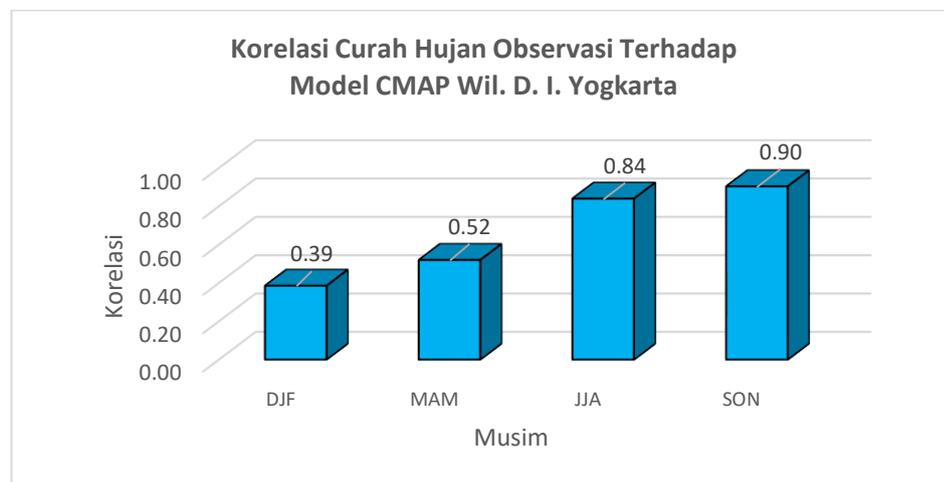


**Figure 1.** Correlation of observational rainfall to the CMAP model of the D. I. Yogyakarta region

Based on Figure 1, it shows that the correlation value between the observation bulk data and the CMAP model shows a positive value, meaning that every time the increase in rain from the observation data is also followed by an increase in the CMAP model rain data. The successive correlation values in the DJF, MAM, JJA, SON season are 0.39, 0.52, 0.84, 0.9 where in the DJF-MAM season period the correlation value is in the low-sufficient category and the JJA-SON period is in the very high category. The correlation value shown in Figure 1 indicates that CMAP data can represent seasonal rainfall conditions in the D. I. Yogyakarta area, especially in the JJA-SON period.
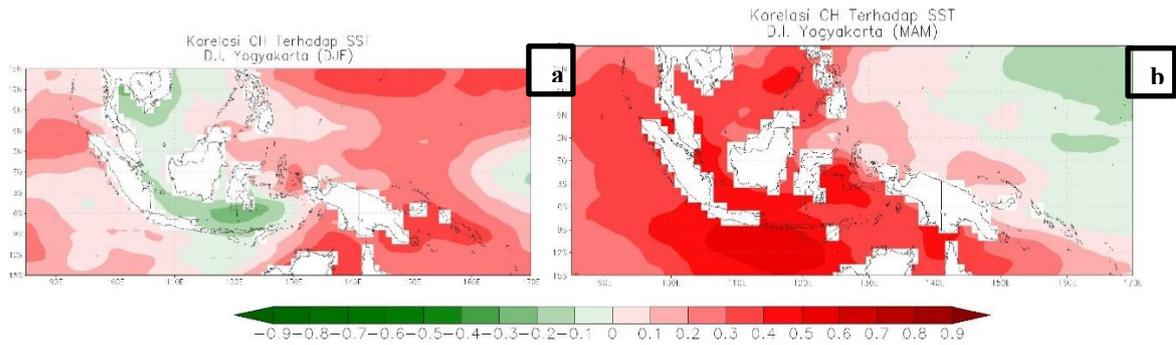
**Figure 2**. Correlation of SST to rainfall model CMAP D. I. Yogyakarta (a) DJF, (b) MAM

The correlation value of the SST of Indonesian waters to rainfall (CMAP) D. I. Yogyakarta in the month period of DJF generally shows a very low category - low $-0.3<r<0.3$, as shown in Figure 2a. This explains that the variability of sea surface temperature in Indonesian waters only contributes ±0.09% to the rainfall of D. I. Yogyakarta. This condition indicates that the rainfall during the DJF period is not much influenced by the dynamic conditions of the SST in Indonesian waters.

The correlation value of the SST of Indonesian waters to rainfall (CMAP) D. I. Yogyakarta in the MAM month period of the highest value occurred in the southern waters of Java Island of 0.5-0.6, which is in the category of quite strong, shown in Figure 2b. This indicates that the warming (cooling) of SST in the southern waters of Java Island will affect the increase (reduction) of rainfall in the D. I. Yogyakarta area. SST in the southern waters of Java Island contributes 0.25%-0.36% to rainfall in the D. I. Yogyakarta area.
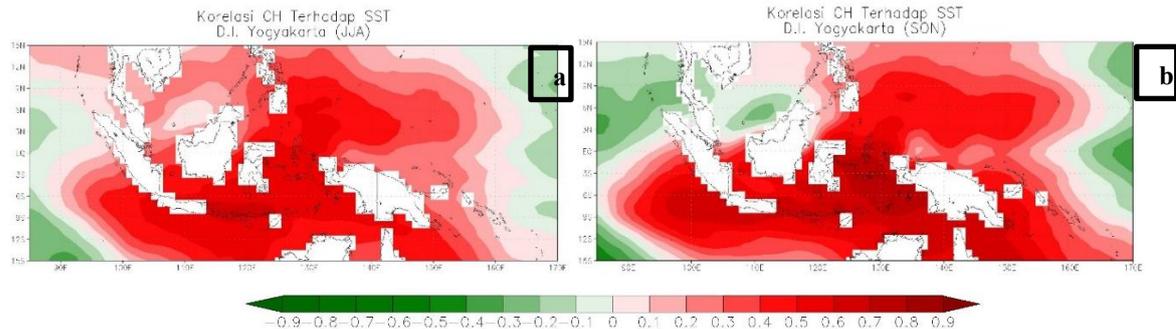


**Figure 3.** Correlation of CMAP model rainfall to SST D. I. Yogyakarta (a) JJA, (b) SON

In the JJA period, the correlation value shows that the highest value is found in the waters south of Java and the waters of the Maluku Islands, which is 0.5 - 0.6 in the category of quite strong, as shown in Figure 3a. The variability of sea surface temperature in the waters south of Java and the waters of the Maluku Islands contributed to an increase or decrease in rainfall by 0.25% - 0.36%.

The correlation value in the SON period showed the highest correlation value compared to other periods, namely in the waters southwest of Sumatra and the waters south of Java valued at 0.6-0.7 (strong category) and the waters of the Maluku Islands of 0.7 - 0.8 (strong category) as shown in Figure 3b. Rainfall variability in the SON D. I. Yogyakarta period is closely related to changes in SST valuesin the waters southwest of Sumatra, southern Java, the Maluku Islands is 0.36% - 0.64%.

Based on the correlation value of the CMAP model of the D. I. Yogyakarta region to SST during the DJF, MAM, JJA, SON period, it shows that the highest correlation value is generally found in the region, namely the waters of the Maluku Islands, the waters south of Java and the waters southwest of Sumatra. Furthermore, an analysis of the correlation of observed rainfall in 25 rain posts spread across the D. I. Yogyakarta region was carried out on several locations in Indonesian waters, namely the southern waters of Java Island (108°E - 114°E; 9°LS - 11°LS), the waters of the Maluku Islands (126°E - 132°E; 6°LS - 0°LS) and the waters southwest of Sumatra (100°E - 105°E; 8°LS - 5°LS).
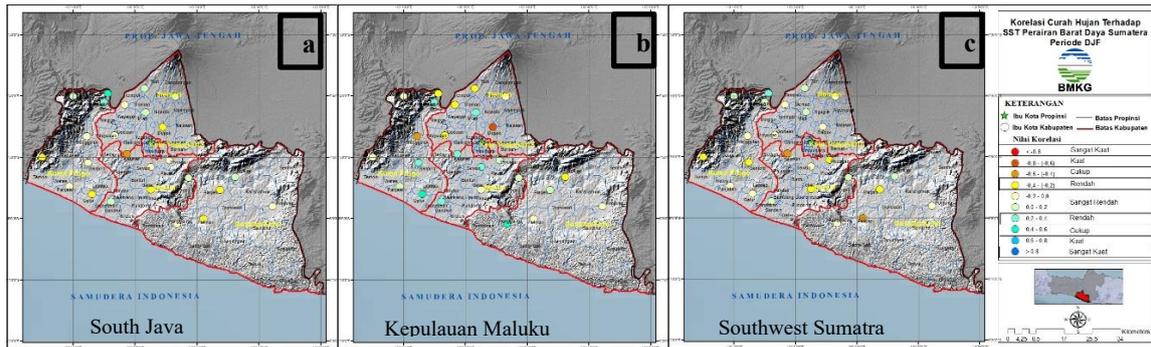
**Figure 4.** Correlation of observed rainfall to SST in the waters south of Java, Maluku Islands, southwest of Sumatra during the DJF period

In the DJF period, in general, the correlation value of rainfall with SST in the very low to low range has a percentage of 92% (waters south of Java), 84% (waters of the Maluku islands) and 96% (waters southwest of Sumatra). This indicates that SST does not have a very small contribution to the variability of rainfall in the D. I. Yogyakarta area during the rainy season period (DJF).
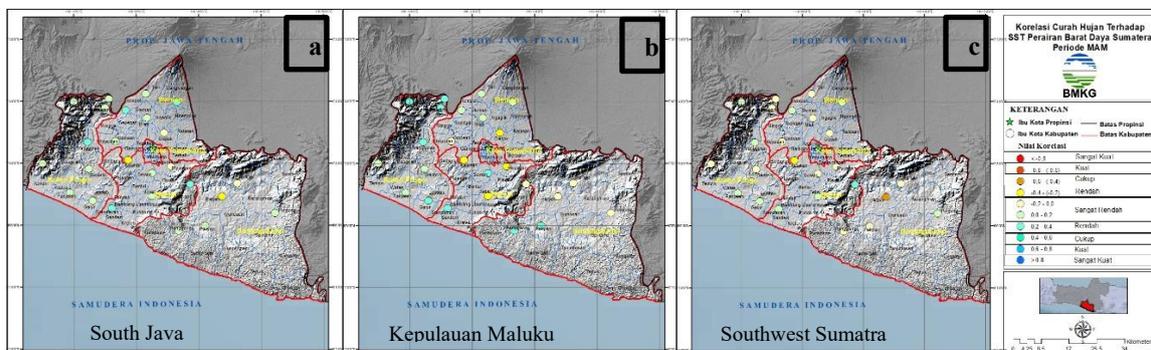


**Figure 5**. Correlation of observed rainfall to SST in the southern waters of Java, Maluku Islands, southwest of Sumatra MAM period

In the MAM period, in general, the correlation value of rainfall with SST is in the very low to low range with a percentage level of 100% both in the southern waters of Java and the waters of the Maluku archipelago, while in the waters southwest of Sumatra it is 96%. This indicates that SST does not contribute to rainfall in the D. I. Yogyakarta area during the pancaroba season period from rainy season to dry season (MAM).
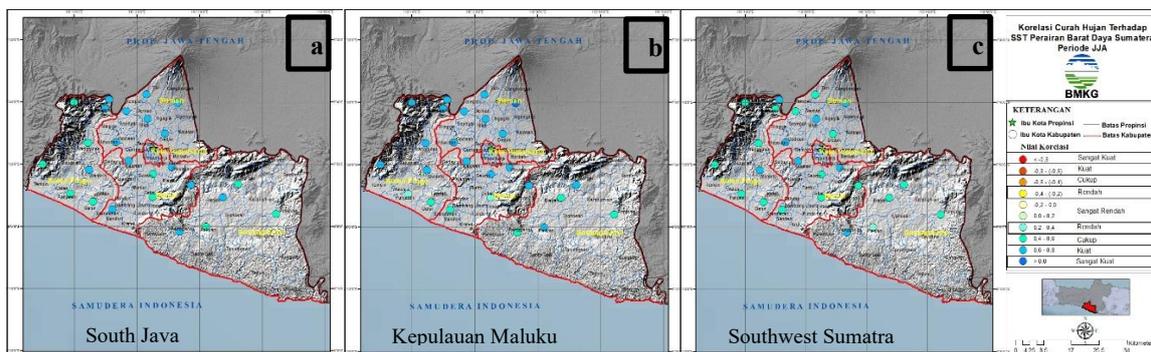


**Figure 6**. Correlation of observed rainfall to SST in the waters south of Java, Maluku Islands, southwest of Sumatra during the JJA period

In the JJA period, in general, the correlation value of rainfall with SST in the criteria is quite strong to strong. The correlation of rainfall with SST in the waters south of Java is generally in the strong category with a percentage of 60%, in the waters of Maluku it is generally in the strong category with a percentage level of 72% and in the waters southwest of Sumatra in general it is in the medium category with a percentage of 68%. From Figure 6. shows that SST in the southern waters of Java Island, the waters around the Maluku islands and

the southwestern waters of Sumatra have contributed to influencing rainfall in most areas of D. I. Yogyakarta during the dry season period (JJA).
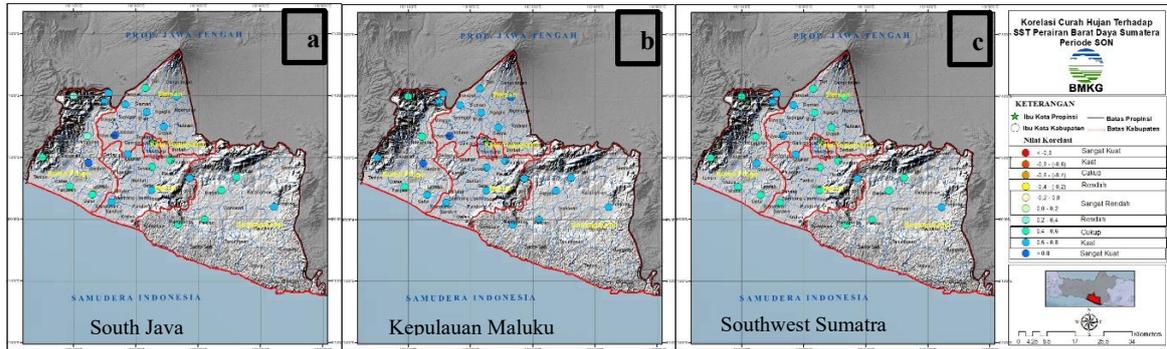


**Figure 7**. Correlation of observed rainfall to SST in the southern waters of Java, Maluku Islands, southwest of Sumatra during the SON period

In the SON period, the correlation of rainfall with SST in the southern waters of Java was generally in the category of quite strong to strong with a percentage of 40% and 52%, in the waters of Maluku in general the strong to very strong category with a percentage level of 72% and 16%, in the waters southwest of Sumatra in general the category was quite strong to strong with percentages of 68% and 32%, respectively. Based on Figure 7. shows that SST in the southern waters of Java Island, the waters around the Maluku Islands and the southwestern waters of Sumatra have contributed to influencing rainfall in most areas of D. I. Yogyakarta during the pancaroba season period from dry season to rainy season (SON).

From the correlation results between rainfall in 25 rain sample points spread across the D. I. Yogyakarta area to SST in several water areas (south of Java Island, around the Maluku islands and southwest of Sumatra) show quite different results, namely in the DJF and MAM periods in general, the correlation values in the category are very low-low with varying correlation values, namely positive and negative. This indicates that rainfall in D. I. Yogyakarta during the rainy season period is not much influenced by SST but is more influenced by the Asian monsoon winds [11]. The correlation values of the JJA and SON periods are generally in the medium to very strong category with positive correlation values.
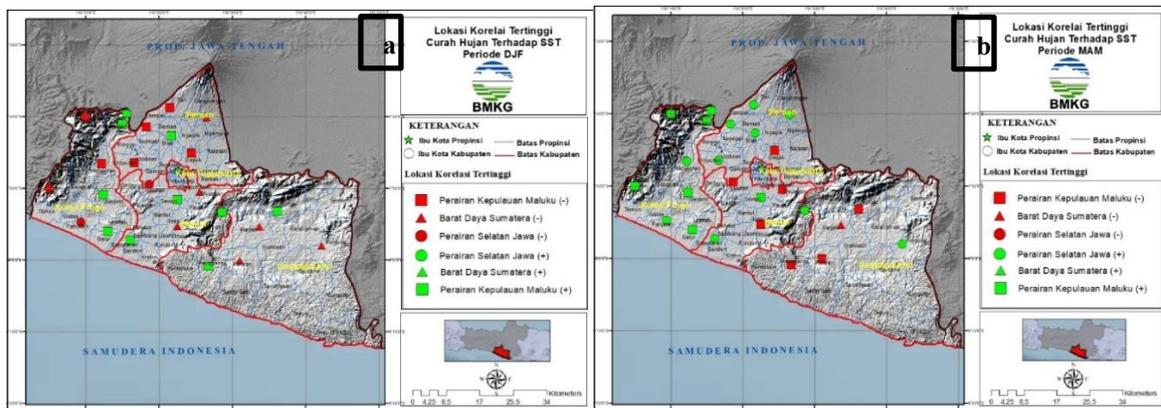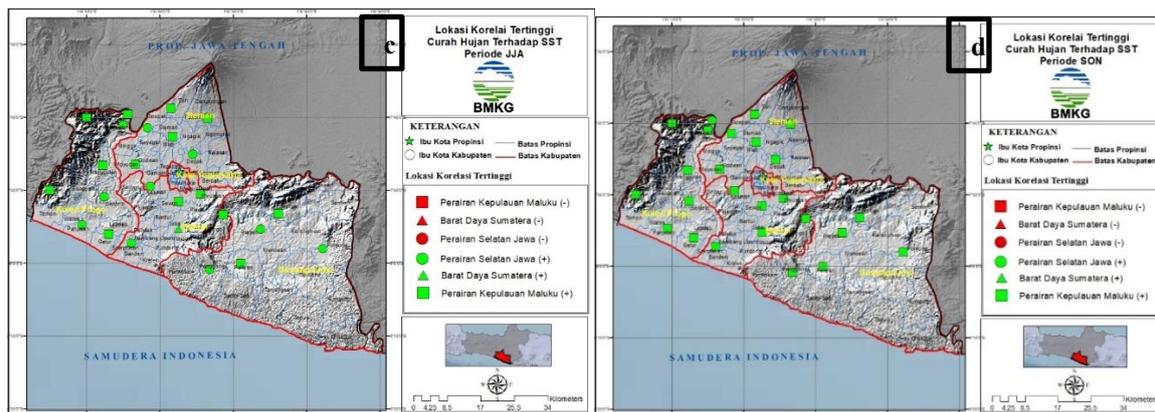
**Figure 8**. Rainfall stations with the highest correlation value (a) DJF, (b) MAM, (c) JJA, (d) SON

If calculated, the highest correlation value for each rainfall post shows that SST in the waters of the Maluku islands has the highest percentage level compared to SST in other waters, namely 60% (DJF), 56% (MAM), 56% (JJA) and 96% (SON) while SST in the southern waters of Java Island is 16% (DJF), 40% (MAM), 40% (JJA), 4% (SON) and SST in the waters southwest of Sumatra has a percentage of 24% (DJF), respectively. 4% (MAM), 4% (JJA), 0% (SON). This indicates that SST in the waters of the Maluku islands has the greatest influence on seasonal rainfall conditions in the D. I. Yogyakarta region compared to SST in the southern waters of Java Island and southwest Sumatra.

## 4. CONCLUSION

The correlation value of SST to rainfall in D. I. Yogyakarta varies, in the DJF - MAM period the correlation value is negative - positive while the JJA period, SON has a positive value and the highest correlation value occurs in the SON period. Waters in Indonesia that have a strong correlation (0.6 - 0.8) include the waters south of Java Island, southwest Sumatra and around the Maluku Islands. The highest correlation coefficient percentage for all seasons of the 25 rainfall stations was SST in the waters of the Maluku Islands where the percentages were 60% (DJF), 56% (MAM), 56% (JJA) and 96% (SON). SST in the waters of the Maluku Islands can be used as one of the considerations to make seasonal rainfall forecasts, especially in the JJA-SON period in D. I. Yogyakarta.

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