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Correlation of the Rainfall Series Data From Indonesia Meteorological, Climatological, and Geophysical Agency and the Tropical Rainfall Measuring Mission in Banten Province

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Abstract

Daily and monthly rainfall data series are necessary data for planning purposes in Civil Engineering and other fields. Incomplete rainfall data often occurs, so that rainfall data must be estimated based on rainfall data from several other nearby locations. The addition of rainfall data can lead to inaccurate planning. Rainfall data used for planning in the civil engineering sector is usually taken from the Indonesia Meteorological, Climatological, and Geophysical Agency (BMKG) station. This data is taken from the rainfall station above the ground. Beside that, the data also produce rainfall data from the Tropical Rainfall Measuring Mission (TRMM) in Banten province. The rainfall data from TRMM at all locations according to a coordinate of location and denotes an average rainfall taken from the satellite approximately 250 meters above the ground surface. An equation will be obtained by comparing the daily and monthly rainfall data from the two different data sources. Based on TRMM rainfall, we can use the equation to estimate BMKG rainfall in any location. In this study, daily rainfall, monthly rainfall, the spectrum of daily and monthly rainfall data from BMKG are compared with rainfall and the spectrum of daily and monthly rainfall from TRMM. The analysis results show that the monthly rainfall from TRMM can be used to estimate BMKG monthly rainfall better than daily rainfall.

Keywords: *climatology, daily and monthly rainfall, spectrum, BMKG, TRMM*

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I. INTRODUCTION

Rainfall is a natural phenomenon that is difficult to measure accurately because rainfall in nature is a natural process in periodic and stochastic [1]. The factors that cause this rainfall event are very complex. Factors causing this rainfall include climatological factors, air temperature, wind direction, humidity and so on.

In planning activities in civil engineering, daily and monthly rainfall data, that was needed to carry out civil building planning activities, including road planning, dam planning, irrigation planning, and many other activities, as presented elsewhere [2,3].

Usually, the rainfall data needed and used for the planning is in the form of secondary rainfall data or rainfall data that already exists or is already available from the results of previous recordings. With the availability of rainfall data, a civil planner only uses available data or secondary data [4].

Some agencies provide rainfall data: government agencies, both from within the country and abroad, and private parties provide some. Examples of rainfall data service providers from Indonesia include the Meteorology, Climatology and Geophysics Agency (BMKG) and the Mesuji Sekampung River Basin Center (BBWS-MS). Meanwhile, internationally, we can get daily rainfall data for free, for example, from the Tropical Rainfall Measuring Mission (TRMM).

This rainfall data is the production of collaboration between NASA and the Japan Aerospace Exploration Agency (JAXA)

Rainfall data from previous researches [4,5] have advantages and disadvantages. The advantage of the BMKG rainfall data is that the rainfall data is data measured directly from above the earth's surface, so this data is more realistic. The lack of data from BMKG is that we can only get rainfall data from fixed locations or coordinates determined according to the location or coordinates of the rainfall station. So that, not every location we can get the data because not every place on earth has a rainfall station installed.

The advantage of rainfall data from TRMM is that we can take this data anywhere on earth as long as there are coordinates. So that even at sea, we can get the rainfall data. The disadvantage of the TRMM rainfall data is that this data is the average rainfall data taken for an average area of 0.25 degrees earth or approximately for an area of 100 sq km. This data is also not data taken on the earth's surface but from a height at least 250 meters above the earth's surface so that this data cannot be used directly for the planning of civil buildings that are above the surface [5].

In addition to the shortcomings above, the BMKG rainfall data also has a deficiency that does not occur in the TRMM rainfall data. Another lack of the BMKG rainfall data is that it is often incomplete or empty from a few days to several months. That is likely to happen because, at that time, no recording was carried out. It could be due to the damage to the measuring instrument. Furthermore, from some of the rainfall data obtained, sometimes the results of recording rainfall data are unrealistic or provide a rainfall height value that far exceeds the standard average rainfall height limit. It is also what may be one of the reasons why the planning carried out becomes invalid. For example, rainfall events in West Java, Jakarta, and Banten cause repeated flooding almost every year.

With the lack of quantity and quality of rainfall data from BMKG and with the excess of rainfall data obtained from TRMM. Suppose we get an equation of the relationship between rainfall from BMKG and rainfall from TRMM. We can get rainfall data in any location we want with better quality.

This research step is the best way and is highly expected for planners in civil engineering to obtain more accurate rainfall data. By using accurate data, it is expected that planning will reduce the incidence of flood events.

Comparing the BMKG rainfall data series with the TRMM series is necessary to get more complete results. The data being compared is in time series rainfall data, both from daily and monthly cumulative rainfall data. In addition, the rainfall spectrum was calculated using Fast Fourier Transform (FFT) from the BMKG will also be compared with the TRMM rainfall data, as also suggested previously [4-6]. By conducting a more comprehensive compare-son, it is hoped to formulate the correlation between BMKG rainfall data and TRMM well.

II. MATERIALS AND METHODS

In general, it can decompose the time series data into an equation with a deterministic component. It can be formulated into values in the form of exact solutions and stochastic components, where this value is always represented as a function consisting of several data functions. Time series. Time series data X(t) is presented as a model consisting of the following functions [6,7]:

$$X_{(t)}=T_{(t)}+P_{(t)}+S_{(t)} \quad (1)$$

where:

$T_{(t)}$ = trend component, t = 1, 2, 3, ..., N
$P_{(t)}$ = periodic component
$S_{(t)}$ = stochastic component

The trend component describes the change in the increase in the data value concerning the length of the long rainfall data recording during the rainfall data recording and by ignoring the short duration fluctuation component. In this study, for the rainfall data used, it is assumed that there is no trend. Thus, this equation can be represented as follows,

$$X_{(t)}=P_{(t)}+S_{(t)} \quad (2)$$

Equation (2) is the approximate equation for the rainfall data used. It shows that the rainfall data used consists of periodic (P) and stochastic (S) components.

A. Spectral Method

This spectral method aims to transform rainfall data from the time domain or time series into rainfall data in the frequency domain. This method is presented as a Fourier Transform as follows [8]:

$$P(f_m) = \frac{\Delta t}{2\sqrt{\pi}} \sum_{n=\frac{-N}{2}}^{n=\frac{+N}{2}} p(t_n).e^{\frac{-2.\pi.i}{M}.m.n} \quad (3)$$

From the equation (3), it can be explained that $p(t_n)$ is rainfall data in time series (time-domain) and $P(f_m)$ is rainfall data in frequency series (frequency domain). tn

is a time series that shows the amount or length of data up to N. f_m is rainfall data in a frequency series (frequency domain).

The early development of this method was not very attractive because the transformation required a long time, so this method was deemed less effective. After several years of research, this spectral (Fourier Transform) method has developed towards the efficiency of transformation calculations to obtain a faster transformation calculation method. The use of the Fourier Transform became more widespread after the discovery of a faster transformation calculation method, called FFT (Fast Fourier Transform), as developed by other [3]. The program that has been used for this analysis based on this method.

Based on the above theory, a frequency analysis calculation method was developed, named FTRANS, developed by previous research [9]. The frequency obtained from FTRANS can be used to determine the frequency of the periodic rainfall model.

B. Regression and Correlation Equations

After obtaining the daily and monthly rainfall series, one can search the daily and monthly rainfall series spectrum from the BMKG and TRMM rainfall data, the correlations and similarities between the two different data sources. If the TRMM data is the x-axis and the BMKG data is the y-axis, we can find a relationship between the x and y variables. This relationship will produce a regression equation with a correlation value between 0 to 1. The correlation value (r) [2,6] is closer to 1, the better the equation is, for the linear regression equation and its correlation coefficient, it is presented as the following equation,

$$f(x) = y = ax + b \tag{4}$$

$$r = \frac{n\sum xy - \sum x \sum y}{\sqrt{n\sum x^2 - (\sum x)^2}.\sqrt{n\sum y^2 - (y)^2}} \tag{5}$$

where: a and b are constants of the linear regression equation to be searched.

C. Methodology

C.1 Daily Rainfall

The research steps used in this study are as follows: First, data collection is carried out by downloading daily rainfall data, both from BMKG and TRMM, for the coordinates of rainfall stations located in the Banten region. Because the available daily rainfall data from TRMM is from January 1, 1998, to December 31, 2020, the data to be downloaded from BMKG is also on the same date and year and for the exact location or coordinates.

C.2 Monthly Rainfall

Based on daily rainfall data, will make a monthly cumulative rainfall series. The rainfall spectrum from this rainfall series will also be calculated using the FFT method from 2 data sources, namely BMKG and TRMM. Furthermore, based on the results that have been obtained, a correlation analysis was carried out.

III. RESULTS AND DISCUSSIONS

A. BMKG Coordinates

In this study, the daily rainfall series data used is the rainfall series data from the ground station or data from BMKG and TRMM. This data comes from the Banten Region. From the Banten area there are 3 stations, namely Curug Budiarto station, Maritim Serang station, and Pondok Betung station. Each data series used has the same data length, 22 years, starting from January 1, 1998, to December 31, 2020. The coordinates of the locations of these stations can be seen in Table 1 below.

Tabel 1. BMKG Station Coordinates for Banten Region

Station Name	Latitude(°)	Longitude(°)
Curug Budiarto	-6.28670	106.56389
Maritim Serang	-6.11185	106.11000
Pondok Betung	-6.26151	106.75084

B. TRMM Coordinates

Daily rainfall series data taken from BMKG and TRMM based on BMKG station coordinates as presented in Table 1. Rainfall series data from BMKG is point rainfall series data. In contrast, TRMM rainfall series data is regional average rainfall series data with an area of 0.25° degrees × 0.25° earth assuming the earth's circumference is 360°.

The BMKG rainfall series data is data from the ground station, or data taken from above the ground, approximately 1 m above the ground. The TRMM data is taken from the satellite to the earth's surface, altitude of 250 from the ground. The following regional coordinates for TRMM data can be seen in Table 2.

Table 2. TRMM Coordinates

BMKG station	Bounding Box
Curug Budiarto	106.625, -6.375, 106.625, -6.375
Maritim Serang	106.125, -6.125, 106.125, -6.125
Pondok Betung	106.875, -6.375, 106.875, -6.375

From Table 2, it is known that the Curug Budiarto station area and Maritim Serang station and Pondok Betung station are not in the same bounding box. It means that the station locations are not close to each other.

C. BMKG and TRMM daily rainfall

The daily rainfall series data used in this study are presented in the following figures.

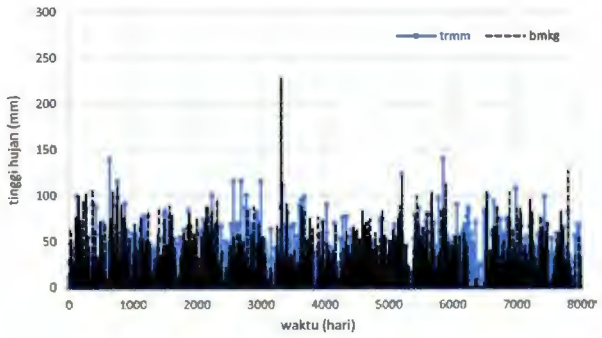

Figure 1. Daily rainfall from Curug Budiarto.

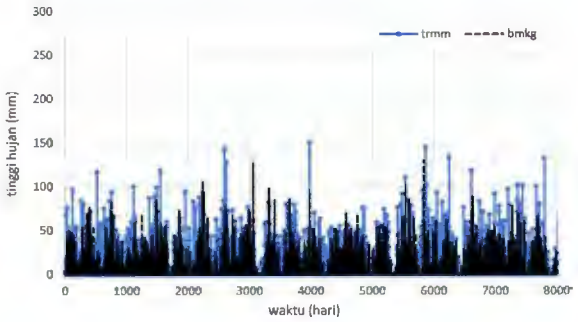

Figure 2. Daily rainfall from Maritim Serang.

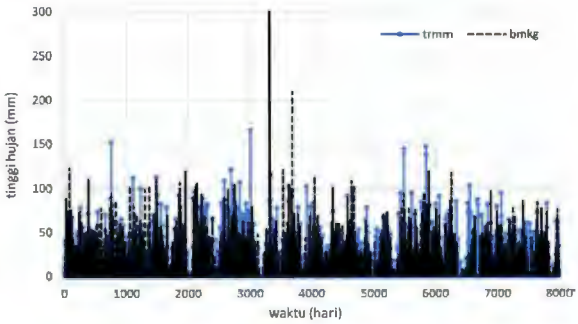

Figure 3. Daily rainfall from Pondok Betung.

D. BMKG dan TRMM Monthly Rainfall

The monthly rainfall series data used in this study are presented in the following figures 4-6.

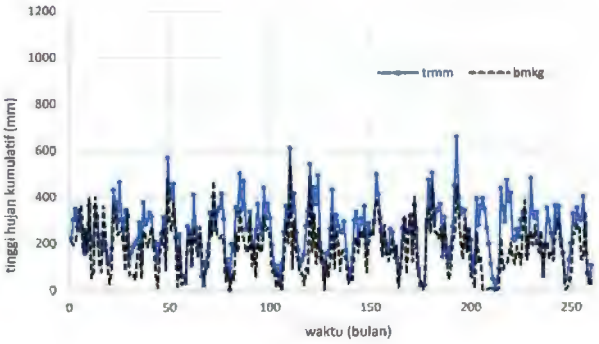

Figure 4. Monthly rainfall from Curug Budiarto.

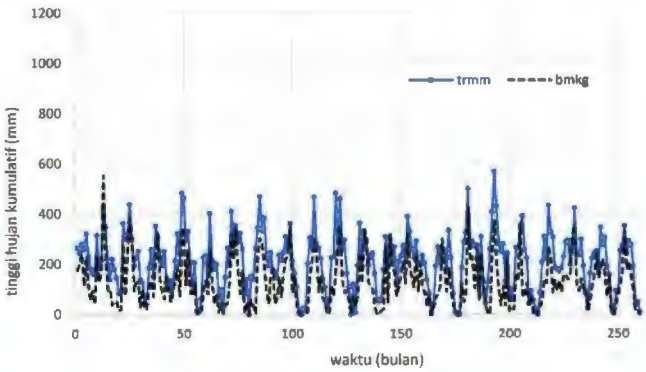

Figure 5. Monthly rainfall from Maritim Serang

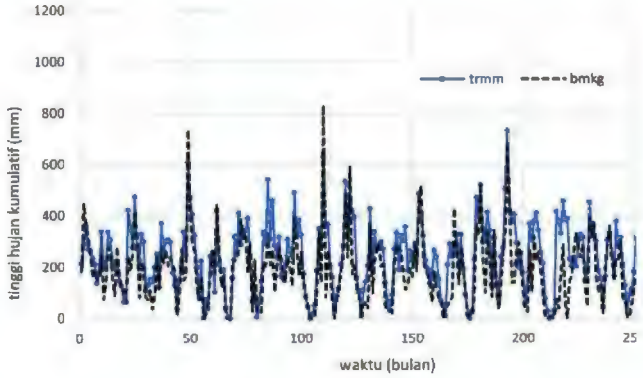

Figure 6. Monthly rainfall from Pondok Betung.

E. Correlation of daily rainfall

Correlation of daily rainfall are presented as follows,

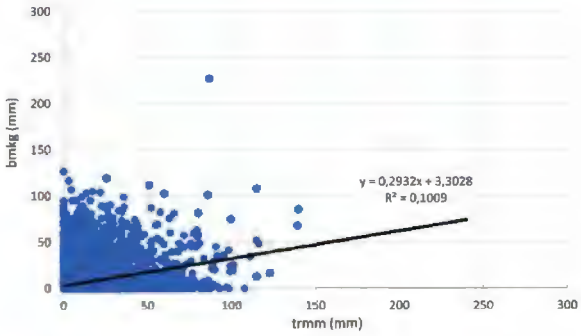

Figure 7. Correlation of dailly rainfall C. Budiarto

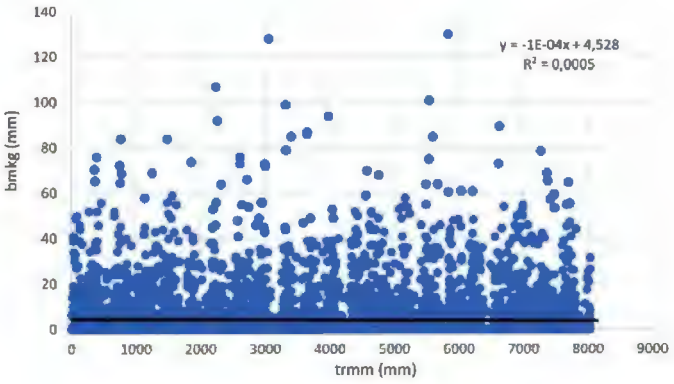

Figure 8. Correlation of daily rainfall M. Serang.

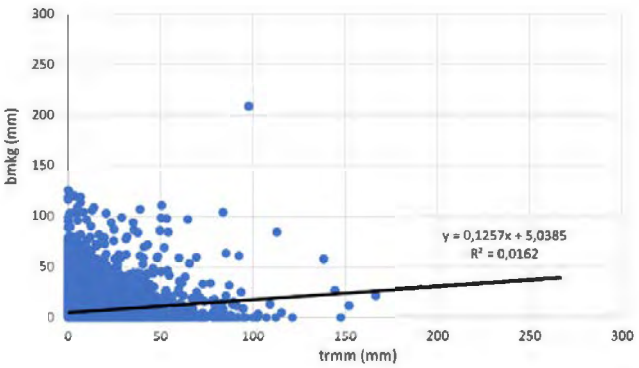

Figure 9. Correlation of daily rainfall P. Betung.

F. Correlation of monthly rainfall

Correlation of monthly rainfall are presented as follows,

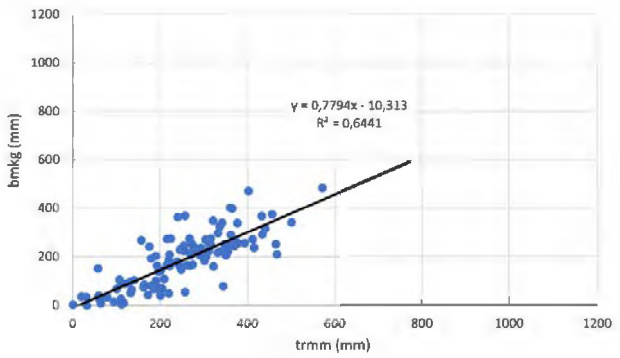

Figure 10. Correlation of monthly rainfall C. Budiarto

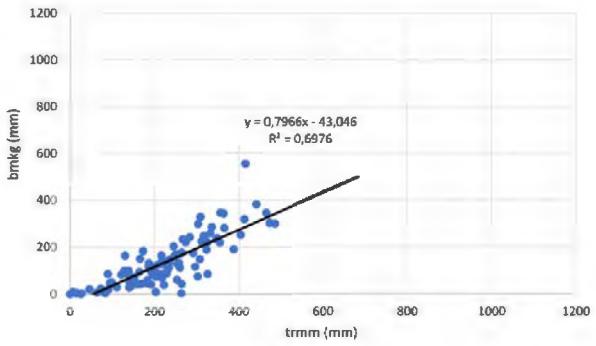

Figure 11. Correlation of monthly rainfall M. Serang.

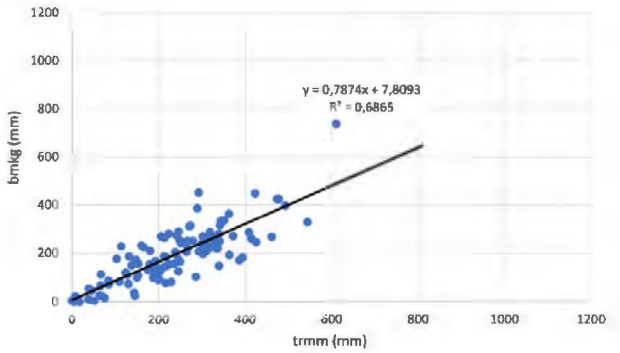

Figure 12. Correlation of monthly rainfall P. Betung.

G. Equation for daily and monthly rainfall

Based on Figure 1 to Figure 3, Figures 7 to 9 are obtained, namely the daily rainfall data correlation between TRMM and BMKG. Based on the figure, the equations and correlation coefficients between TRMM daily rainfall and daily rainfall from BMKG are obtained as presented in Table 3.

Table 3. Equation and correlation of daily data

Station name	Equation	R^2
Curug Budiarto	y = 0.2932x + 3.3028	0.1009
Maritim Serang	y = -1E-04x + 4.5280	0.0005
Pondok Betung	y = 0.1257x + 5.0385	0.0162

From Table 3, it is known that the slightest correlation between TRMM and BMKG for daily rainfall series data is 0.0005, and the most significant correlation is 0.1009. Based on Figure 4 to 6, Figure 10 to 12 is obtained, namely the correlation of monthly rainfall data between TRMM and BMKG.

Based on Figures 10 to 12, the equations and correlation coefficients between the TRMM monthly rainfall and the BMKG monthly rainfall are obtained as presented in Table 4 below.

Table 4. Equation and correlation of monthly data.

Station name	Equation	R^2
Curug Budiarto	y = 0.7794x – 10.313	0.6441
Maritim Serang	y = 0.7966x – 43.046	0.6976
Pondok Betung	y = 0.7874x + 7.8093	0.6865

From Table 4, it is known that the slightest correlation between TRMM and BMKG for monthly rainfall series data is 0.6441, and the most significant correlation is 0.6976.

This comparison shows that the correlation of monthly data from TRMM - BMKG for Banten area stations can be much better than that of daily data.

H. Correlation of FFT daily and monthly rainfall

It is not only a direct comparison of rainfall data. The spectra of the daily and monthly rainfall data of TRMM and BMKG were also compared. The spectrum of the FFT method is used to obtain the daily and monthly rainfall spectrum from TRMM and BMKG. From the comparison of the spectrum obtained as presented in the following figures.

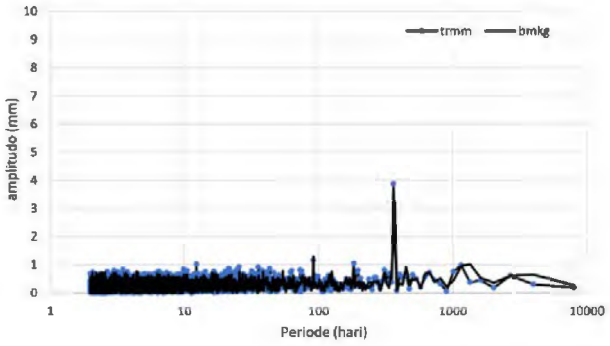

Figure 13. Spectrum daily rainfall from C. Budiarto

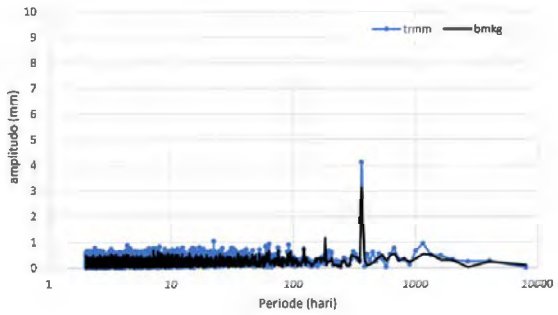

Figure 14. Spectrum of daily rainfall M. Serang.

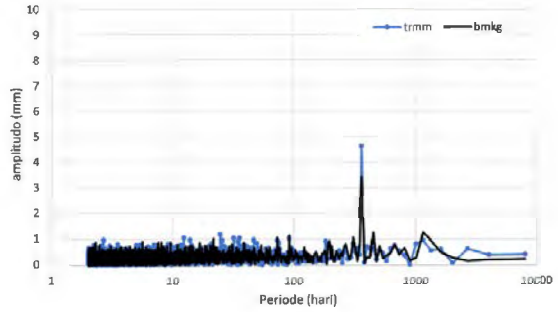

Figure 15. Spectrum daily rainfall from P. Betung.

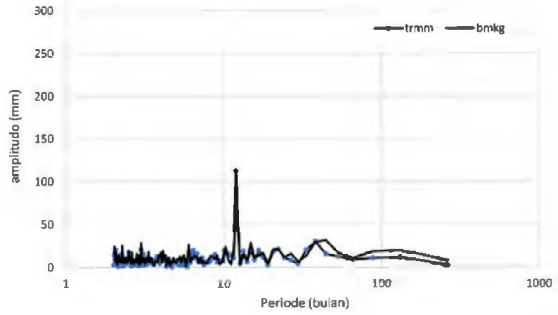

Figure 16. Spectrum of monthly rainfall C. Budiarto.

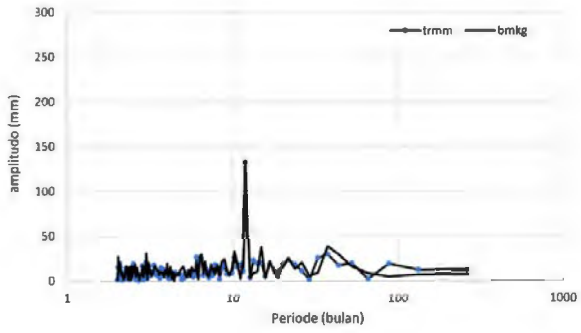

Figure 17. Spectrum monthly rainfall from M. Serang

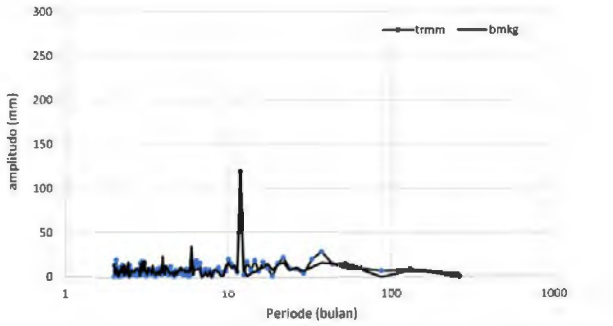

Figure 18. Spectrum monthly rainfall from P. Betung

I. Equation for FFT daily rainfall

Based on Figures 13 to 15, the equations and correlation coefficients are obtained between the FFT spectrum of the TRMM daily rainfall data series and the FFT spectrum of the BMKG daily rainfall data series. The equations and correlation coefficients can be seen in Table 5.

Table 5. Equation and correlation coefficient of FFT spectrum from daily rainfall data.

Station name	Equation	R^2
Curug Budiarto	y = 0.1838x + 0.2146	0.0416
Maritim Serang	y = 0.2242x + 0.1371	0.0967
Pondok Betung	y = 0.2685x + 0.2069	0.0796

From Table 5, it is known that the slightest correlation between TRMM and BMKG for daily rainfall series data is 0.0416, and the most significant correlation is 0.0967.

J. Equation for FFT monthly rainfall

Based on Figures 16 to 18, we get the equations and correlation coefficients between the FFT spectrum of the TRMM monthly rainfall data series and the FFT spectrum of the BMKG monthly rainfall data series. The equations and correlation coefficients can be seen in Table 6 as follow.

Table 6. Equation and correlation coefficient of FFT spectrum from monthly rainfall data.

Station name	Equation	R^2
Curug Budiarto	y = 0.6215x + 5.451	0.6431
Maritim Serang	y = 0.6949x + 2.435	0.7489
Pondok Betung	y = 0.7166x + 4.7944	0.6950

From Table 6, it is known that the slightest correlation between TRMM and BMKG for daily rainfall series data is 0.6431, and the most significant correlation is 0.7489.

This comparison shows that the correlation of the FFT spectrum from the monthly data of TRMM - BMKG stations in the Banten area can be 16 times better than the correlation of the FFT spectrum from the daily data.

In the other literature, it is known that the use of FFT

in processing monthly rainfall data has been widely carried out, has been done by [4], [6], and [7,8].

In his research, the FFT method has been used to analyze the normality of rainfall data in the West Sumatra region [6], while other used the FFT method to analyze the periodicity of the monthly rainfall cycle in the southern area of the Jatiluhur reservoir, Subang Regency, West Java [1]. Meanwhile, the FFT method to analyze rainfall patterns in the island of Kalimantan [7].

These several studies show that monthly rainfall data and FFT methods are widely used to analyze the characteristics of rainfall data rather than daily rainfall data. It is shows that FFT has been used to study many monthly rainfall data than daily rainfall data.

IV. CONCLUSIONS

In this study, the rainfall data from the TRMM is used to get the BMKG rainfall data in areas that do not have rainfall recording stations. From the correlation coefficients shows that the correlation of monthly rainfall data between TRMM and BMKG from stations in the Banten area is much better than daily data, both direct comparisons and comparisons of the FFT spectrum. This result of this study also shows good agreement with several studies. From this comparison, it shows that the correlation of monthly rainfall data between TRMM and BMKG from stations in the Banten area is much better than daily data, both direct comparisons and comparisons of the FFT spectrum.

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