EVALUATION OF PDIR-NOW SATELLITE RAINFALL DATA ON OBSERVATIONAL RAINFALL DATA (Case Study: Taktakan District, Serang City, Banten)

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ABSTRACT

Rainfall data is one of the vital initial inputs in the hydrological analysis, but it is often incomplete due to various constraints such as damage to measuring instruments or uneven distribution of measurement stations. To overcome this problem, weather observation with satellites can be used. However, before using satellite rainfall data, it is necessary to test its suitability with field data to ensure its accuracy. This study aims to evaluate the PDIR-Now satellite rainfall data on observation rainfall data in Serang City to determine the feasibility of using satellite rainfall data and the influence of rain periods (daily (>50mm/day), 15 days, and monthly) on the reliability of satellite data. The analysis method in this study uses statistical analysis in the form of regression analysis at the calibration stage and RMSE, NSE, and Pearson (r) correlation coefficient at the validation stage. Based on the results of the study , it is known that the PDIR-Now satellite can estimate the best rainfall in the monthly period.

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1. INTRODUCTION

Rainfall data is one of the vital initial inputs in hydrological analysis [1-4]. The rainfall data has a very important role because it can be used in calculations for water infrastructure planning, watershed management, meeting raw water needs, hydropower plants, flood prevention, irrigation, and drought management [5]. However, what happens in the field, it is often found that rainfall data is not fully available due to various obstacles [3-4], such as due to broken measuring instruments, limitations of rainfall gauges, especially in remote areas, and uneven distribution of rainfall measurement stations [6-8].

Unavailability of data can have a significant impact on planning, as it can increase Error values leading to inaccurate estimates [9]. In order to overcome these problems, indirect weather observation or remote sensing weather observation with satellites can be used as an alternative to overcome the unavailability of data [4] [10-11]. There are several satellite rain data products that can be used, including PERSIANN [9][12-13], TRMM [2][9][14], GPM [2][12][15], Era-5 [10], and CMORPH [2]. One of Persiann's products, namely PDIR-Now, has the main advantage of providing global rainfall estimates with short latency (15-60 minutes) [16].

Satellite rainfall data is information about rainfall obtained through the application of remote sensing technology using infrared and microwave light [17]. Satellite rainfall data measures rainfall that occurs in the atmosphere, while observational rainfall data measures rainfall that occurs directly on the earth's surface, so it needs to be evaluated before the data can be used to determine whether satellite data can accurately represent rainfall patterns on Earth [2][1][10]. The use of satellite rainfall data depends on its suitability for conditions in the field. Therefore, the assessment of conformity between satellite rainfall data and data obtained from field measurements is very important in evaluating the accuracy of data obtained from satellites [12].

The evaluation of satellite rainfall data is carried out in two stages, namely calibration and validation [18]. A data is declared good if it has a low root-mean-square error (RMSE) value, a high Nash-Sutcliffe efficiency (NSE) value (close to 1), and a high r value (close to 1). If the data meets these criteria, then the data can be considered accurate and closer to the measurements that occur in the field [12] [18].

Previous research that examined the accuracy of satellite rainfall data and observational rainfall data included research on "Evaluation of ERA-5 Satellite Rainfall Data in Various Rainfall Data Periods in the Bodor Sub Watershed" by Sitepu et al (2023), research on "Evaluation of Trmm and Gpm Satellite Rainfall Data on Observational Rainfall Data in Central Kalimantan" by Dewi Kartika et al (2023), research on "Validation of TRMM (Tropical Rainfall Measuring Mission) Satellite Rainfall Data with Rainfall Measuring Post Data in the Grindulu Watershed, Pacitan Regency, East Java" by Jarwanti et al (2021), research on "Analysis of the Relationship between Persiann-Cdr & TRMM 3b42 Satellite Rainfall Data with Bmkg Rainfall Data at Rain Stations in the West Sumba Region" by Pattireja et al (2023), research on "Validity of Rainfall Data of IMERG Satellite Products on Measured Rainfall Data in the Bima and Dompu Regions" by Rostihanji & Humairo Saidah (2023), research on "Evaluation of Satellite Rainfall Data for Prediction of Observational Rainfall Data Using Cross Correlation" by Pratiwi et al (2017), and research on "Validation of Trmm Data on Actual Rainfall Data in Three Watersheds in Indonesia" by Syaifullah (2014). This study aims to evaluate the PDIR-Now satellite rainfall data on the observed rainfall data in Serang City to determine the feasibility of using satellite rainfall data and the influence of rain periods (daily (>50mm/day), 15 days, and monthly) on the reliability of satellite data.

2. METHODS

This research was conducted at the Serang Maritime Meteorological Station, which is administratively located in Drangong Village, Taktakan District, Serang City, Banten. Geographically, the Serang Maritime Meteorological Station is located between -6.11185 LS and 106.11000 E. In this study, secondary data was used in the form of rain station post coordinates, daily rainfall data from station observations and daily rainfall data from the PDIR-Now satellite with a data length of 10 years (2014-2023). Observation rain data from the Serang Maritime Meteorological Station was obtained from the BMKG website, while PDIR-Now satellite rain data was obtained from the University of California, Irvine (UCI) (http://chrsdata.eng.uci.edu/) website whose coordinate points were adjusted to the location of the Serang Maritime Meteorological Station. This research was conducted by dividing 3 data periods, namely daily rainfall data (≤ 50mm/day), 15 daily, and monthly.

The evaluation of satellite rainfall data is carried out in two stages, namely calibration and validation. Validation is carried out in two stages, namely, the first validation (Uncorrected Validation) is carried out on the PDIR-Now satellite data obtained directly from the website, while the second validation (Corrected Validation) is carried out on the PDIR-Now satellite rainfall data that has been corrected at the calibration stage. The evaluation was used with daily rainfall data periods (≥50mm/day), 15 days, and months. In this study, the ratio of calibration and validation years was used, which is 9:1, so that 90% of the data, namely in 2014-2022, is used for the calibration process, and the other 10%, namely 2023, is used for the corrected validation process. The data range used for uncorrected validation is 9 years (2014-2022) and 1 year (2023).

2.1 Consistency Test

Before a data is used, it is necessary to conduct a data quality test, one of which is a consistency test. Consistency tests are carried out to ensure that the data in the field does not experience errors at the time of measurement, the data must accurately describe hydrological phenomena, such as the actual conditions in the field [4]. The RAPS method is one of the methods to test the consistency of rainfall data by calculating the cumulative value of its deviation against the average value [11].

This study uses the RAPS (Rescaled Adjusted Partial Sums) method to test the consistency of observed rain data and satellite rain data. The RAPS method is because only one rain station was used in this study.

$$S_k{}^* = (Y_i - \bar{Y}) \text{ (For the first year)} \quad (1)$$

$$S_k{}^* = (Y_i - \bar{Y})_t + (Y_i - \bar{Y})_{t+1} \quad (2)$$

$$Dy^2 = \sum_{i+1}^{n} \frac{(Y_i - \bar{Y})^2}{n} \quad (3)$$

$$Dy = \sqrt{Dy^2} \quad (4)$$

$$S_k{}^{**} = \frac{Sk^*}{Dy} \quad (5)$$

$$Q_{calculation} = \frac{Q}{\sqrt{n}} \quad (6)$$

$$R_{calculation} = \frac{R}{\sqrt{n}} \quad (7)$$

Determining Q and R values
Q = max value of absolute | Sk∗∗ |
R = absolute max value | Sk∗∗ | - absolute min value | Sk∗∗ |

The data allegedly to be consistent when $Q_{calculation}$ and $R_{calculation}$ are smaller than Qcritical and Rcritical. The critical value of Q and R according to Sri Harto (2009) is shown in the following Table 1.

Table 1. Critique Values Q and R

N	Q/√n			R/√n		
	90%	95%	99%	90%	95%	99%
10	1.05	1.14	1.29	1.21	1.28	1.38
20	1.1	1.22	1.42	1.34	1.43	1.6
30	1.12	1.24	1.46	1.4	1.5	1.7
40	1.13	1.26	1.5	1.42	1.53	1.74
50	1.14	1.27	1.52	1.44	1.55	1.78
100	1.17	1.29	1.55	1.5	1.62	1.86
∞	1.22	1.36	1.63	1.62	1.75	2

2.2 Calibration

Calibration is the process of adjusting the value of a model's parameters to produce the most accurate estimate of the data used [11]. In this study, calibration was carried out using a regression equation formed by the relationship between satellite rainfall (variable x) and observed rainfall (variable y). There are 6 regression analyses used, namely Linear, Logarithmic, Polynomial (Order 2 and Order 3), Power, and Exponential. The selection of the regression model is based on the magnitude of the highest determination coefficient (R2) value obtained from each equation.

Regresi Linear

$$\hat{Y} = a + bX \tag{5}$$

Exponential Regression

$$\hat{Y} = be^{ax} \tag{6}$$

Regression Power

$$\hat{Y} = bX^{a} \tag{7}$$

Regressi Logarithm

$$\hat{Y} = b + a\log X \tag{8}$$

Polynomial Regression

$$\hat{Y} = b_0 + b_1X + b_2X^2 + b_3X^3 + \ldots + b_mX^m \tag{9}$$

2.3 Validation

The validation method used for rainfall that occurs in the field and satellite rainfall uses statistical evaluation methods in the form of root mean square error (RMSE), Nash-Sutcliffe Efficiency (NSE), and Pearson correlation coefficient (r)[8][11][14][15]. The methods used in this validation stage are Root Mean Squared Error (RMSE), Nash-Sutcliffe Efficiency (NSE), Pearson Correlation Coefficient (r).

a. RMSE

The RMSE parameter indicates the error rate or error [8]. The closer to zero the RMSE value, the better and more accurate the simulation results [8][19].

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(Y_i - X_i)^2}{n}} \tag{10}$$

b. NSE

The NSE parameter describes the level of accuracy resulting from the correlation relationship between observation/observation data and estimated data [8][19]. The NSE value ranges from – not to 1, the higher the NSE value means the better the model simulation results [10]. The categories and classes of NSE parameters according to Sitepu et al (2023) are shown by Table 2.

$$NSE = 1 - \frac{\sum_{i=1}^{n}(Y_i - X)^2}{\sum_{i=1}^{n}(Y_i - \bar{Y}_i)^2} \tag{2}$$

Table 2. NSE class categories

Class	NSE
Excellent	0.75-1
Good	0.65-0.75
Compliant	0.50-0.65
Not Compliant	≤0.50

c. Pearson Correlation Coefficient

The r parameter shows the strong relationship between an estimation model and the actual data [10][8]. The correlation is said to be strong if the coefficient value is close to +1 or -1 and is said to be weak if the coefficient value is close to 0 [19]. The category of Pearson's correlation coefficient according to Sitepu et al (2023) is shown by Table 3.

$$r = \frac{n\sum_{i=1}^{n} Y_1X_1 - \sum_{i=1}^{n} Y_1 - \sum_{i=1}^{n} X_1}{\sqrt{n\sum_{i=1}^{n} Y_i^2 - \left(\sum_{i=1}^{n} Y_1\right)^2}\sqrt{n\sum_{i=1}^{n} X_i^2 - \left(\sum_{i=1}^{n} X_1\right)^2}} \quad (3)$$

Tabel 3. Categories of Pearson correlation coefficient

Class	r
Very low	0-0,19
Low	0,20-0,39
Moderate	0,40-0,59
Strong	0,60-0,79
Very strong	0,81-1

3. RESULTS AND DISCUSSION

3.1 Consistency Test

The data tested at the consistency test stage using the Rescaled Adjusted Partial Sums (RAPS) method are annual rainfall data from the PDIR-Now satellite and observed rainfall data for 10 years (2014-2023). A Q value of 2,602 was obtained so that a $Q_{calculation}$ of 0.823 was obtained and an R value of 2,570 was obtained so that an $R_{calculation}$ of 0.813 was obtained.

Table 4. Data Consistency Test Results (RAPS)

Data	Period	$R/\sqrt{n}_{calculation}$	$R/\sqrt{n}_{calculation}$	$Q_{critical}$	$R_{critical}$	Description
BMKG	Yearly	0.823	0.813	1.14	1.28	CONSISTENT
PDIR-Now	Yearly	1.005	0.971	1.14	1.28	CONSISTENT

Based on Table 4. It is known that the $Q_{calculation}$ and $R_{calculation}$ values of the precipitation data and the PDIR-Now satellite rainfall data are smaller than the Qkritik and Rkritik values of the confidence degree of 5% so that the two rainfall data are declared consistent and can be used for further analysis.

3.2 Uncorrected Validation

Uncorrected validation is carried out on the downloaded PDIR-Now satellite data without a calibration process. The length of the data used in the uncorrected validation analysis was 9 years and 1 year. The data used in the analysis only includes data that has a rain value (rain data with a value of 'zero' is not used).

Refers to Table 5. It is known that the results of the validation of satellite rainfall data and the rainfall of station observations whose accuracy is still very low in each period and data range. This indicates that the PDIR-Now satellite rainfall data is still not able to represent the rainfall that occurs in the field, so it is necessary to make satellite data corrections at the calibration stage to optimize the value of the PDIR-Now satellite rainfall data so that it is closer to the value of the observed rainfall data.

Table 5. Recapitulation of Uncorrected Validation Analysis Results

Data	Period	RMSE	NSE		R	
			NSE	Interpretation	R	Interpretation
9 Tahun	Daily	69.474	-6.270	Not Compliant	-0.202	Low
1 Tahun	Daily	61.189	-31.362	Not Compliant	-0.14	Very Low
9 Tahun	15 Days	73.336	-0.745	Not Compliant	0.575	Moderate
1 Tahun	15 Days	63.904	0.115	Not Compliant	0.631	Strong
9 Tahun	Monthly	108.742	-0.391	Not Compliant	0.690	Strong
1 Tahun	Monthly	78.779	0.215	Not Compliant	0.899	Very Strong

3.3 Calibration

Because the validation results have low accuracy, to get more optimal results, it is necessary to correct the satellite data at the calibration stage. Regression analysis is carried out with the help of scatterplots, the regression model is selected based on the highest determination coefficient (R^2) value.

Table 6. Recapitulation of Calibration of Rainfall Data for the Daily Period

Regression	R^2	Equation
Linear	0.0409	72.698-0.2445x
Logarithmic	0.1654	84.99-9.509ln(x)
Polynomial (Ordo 2)	0.0916	$0.012x^2-1.3674x+78.117$
Polynomial (Ordo 3)	0.1668	$(-0.0005x^3)+0.0801x^2-3.5432x+86.076$
Power	0.1823	$80.754x^{-0.12}$
Eksponensial	0.0441	$69.063^{e-0.003x}$

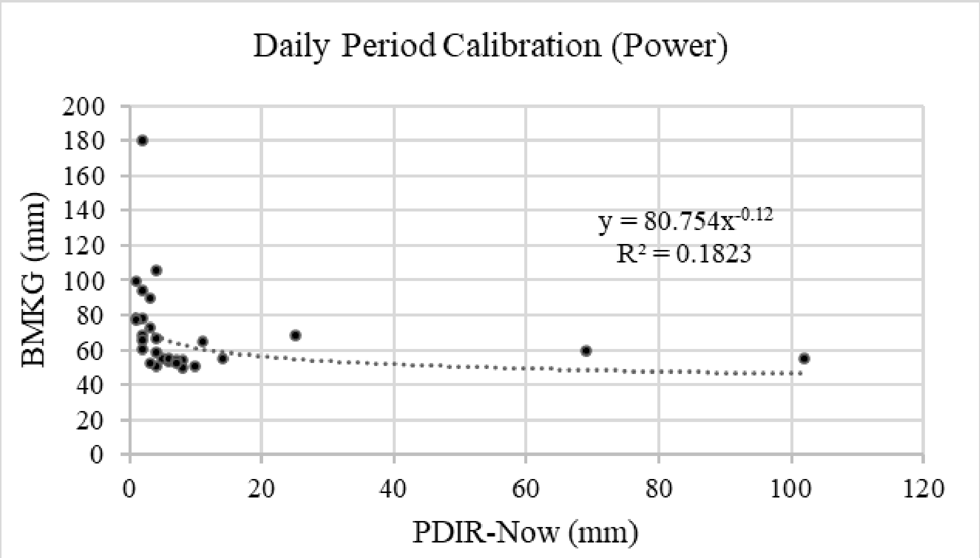

Figure 1. Calibration of Selected Daily Period

According to the Table 6. It is known that the Power regression model obtained the highest determination coefficient value with a value of R^2 = 0.1823 or 18.23%. This means that 18.23% of the factors that affect rainfall at the Serang Maritime Meteorological Station can be explained by variable X, namely PDIR-Now satellite rainfall, while the remaining 81.77% is explained by other factors that are not studied in this study. So the regression model chosen is the power regression for the daily period.

Data correction is carried out using 10% of the data, namely 2023 data using the selected regression equation, namely power regression. The example of the calculation used is on January 28, 2023.

X = 29 mm

Model Regresi Power

Y = $80.754x^{-0.12}$

Y = $80.754(29)^{-0.12}$

Y = 53.911 mm

Table 7. Recapitulation of Rainfall Data Calibration for the 15-Day Period

Regression	R^2	Equation
Linear	0.3302	33.946+0.3844x
Logarithmic	0.3083	28.298ln(x)-46
Polynomial (Ordo 2)	0.3515	$(-0.0006x^2)+0.5826x+23.847$
Polynomial (Ordo 3)	0.3527	$0.0000008x^3-0.0011x^2+0.6773x+20.962$
Power	0.3522	$2.6711x^{0.6831}$
Eksponensial	0.0984	$21.993e^{0.0075x}$

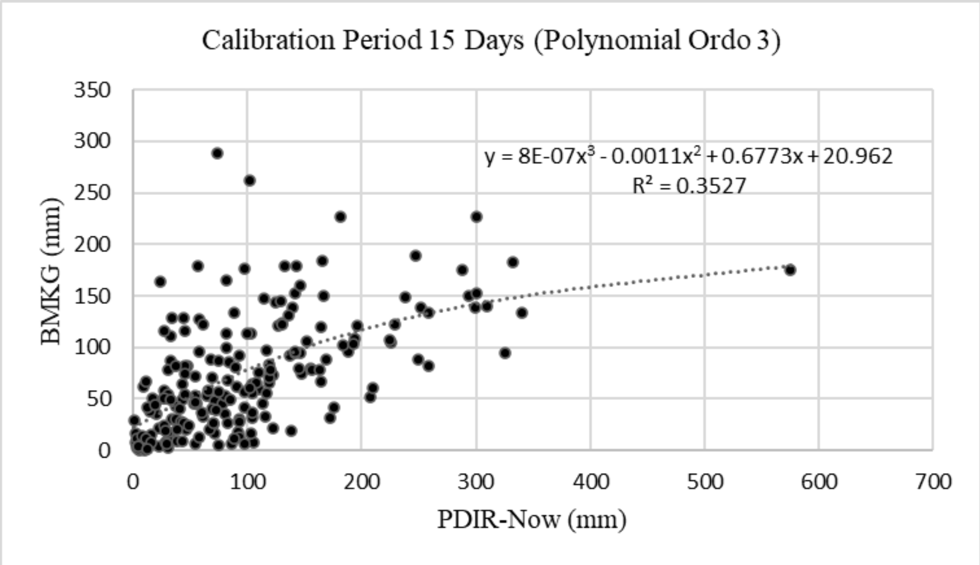

Figure 2. Calibration of the Selected 15 Daily Period

According to the Table 7. It is known that the Polynomial regression model (Order 3) obtains the highest determination coefficient value with a value of R^2 = 0.3527 or 35.27%. This means that 35.27% of the factors affecting rainfall at the Serang Maritime Meteorological Station can be explained by variable X, namely PDIR-Now satellite rainfall, while the remaining 64.73% is explained by other factors that are not studied in this study. So the regression model chosen is Polynomial regression (order 3) for a period of 15 days. Data correction was carried out using 10% of the data, namely the 2023 data using the selected regression equation, namely order 3 polynomial regression. The example of the calculation used is in January 2023.

X = 82 mm

Order 3 Polynomial Regression Model

Y = $0.0000008x^3-0.0011x^2+0.6773x+20.962$

Y = $0.0000008(82)^3-0.0011(82)^2+0.6773(82)+20.962$

Y = 69.545 mm

Table 8. Recapitulation of Rainfall Data Calibration for the Monthly Period

Regression	R^2	Equation
Linear	0.4755	46.678+0.4795x
Logarithmic	0.4403	58.457ln(x)-148.34
Polynomial (Ordo 2)	0.5138	$(-0.0006x^2)+0.7811x+19.604$
Polynomial (Ordo 3)	0.514	$0.0000002x^3-0.0007x^2+0.8228x+17.401$
Power	0.4836	$0.9356x^{0.938}$
Eksponensial	0.1223	$31.493e^{0.0056x}$

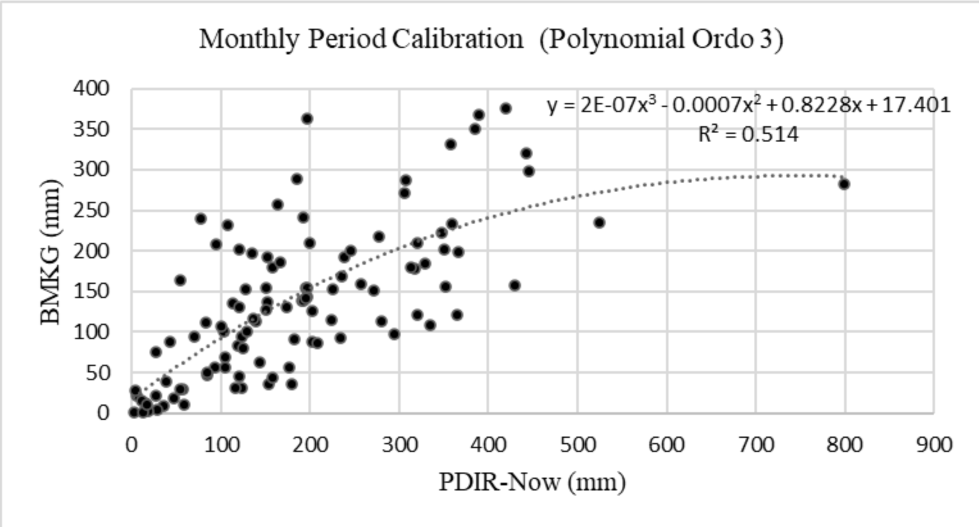

Figure 3. Calibration of Selected Monthly Period

Based on Table 8. It is known that the Polynomial regression model (Order 3) obtains the highest determination coefficient value with a value of R^2 = 0.514 or 51.40%. This means that 51.40% of the factors that affect rainfall at the Serang Maritime Meteorological Station can be explained by variable X, namely the rainfall of the PDIR-Now satellite, while the remaining 48.60% is explained by other factors that are not studied in this study. So the regression model chosen is a Polynomial regression (order 3) for the monthly period. Data correction was carried out using 10% of the data, namely 2023 data using the selected regression equation, namely Order 3 Polynomials. The example of the calculation used is in January 2023.

X = 287 mm

Order 3 Polynomial Regression Model

$Y = 0.0000002x^3-0.0007x^2+0.8228x+17.401$

$Y = 0.0000002(287)^3-0.0007(287)^2+0.8228(287)+17.401$

Y = 200.614 mm

Table 9. Recapitulation of Calibration Results

Period	Selective Regression Model		
	R^2	Regression	Equation
Daily	0.1823	Power	$80.754x^{-0.12}$
15 Days	0.3527	Polynomial (Ordo 3)	$0.0000008x^3-0.0011x^2+0.6773x+20.962$
Monthly	0.514	Polynomial (Ordo 3)	$0.0000002x^3-0.0007x^2+0.8228x+17.401$

Based on Table 9. It is known that the lowest coefficient of determination (R^2) value is obtained by daily period rainfall data with a power regression model, which is 0.1823 which means that the ability of PDIR-Now satellite rainfall data in explaining measured rainfall in the field is very limited. The highest value of the determination coefficient (R^2) was obtained from the monthly period rainfall data with a polynomial regression model (order 3) of 0.514 where according to Ghozali & Latan (2015) and Hair, et al (2019) the value can be categorized as a moderate model. Thus the monthly period is quite good in explaining the measured rainfall in the field, but it is not perfect.

3.4 Corrected Validation

Corrected data validation is validation that is carried out after the calibration stage using satellite data that has been corrected using a selected regression model. The validation process is carried out using 10% of the data, namely the 2023 data. The parameters used in corrected validation are the same as in uncorrected validation.

Table 10. Recapitulation of Corrected Validation Analysis Results

Period	RMSE	NSE		R	
		NSE	Interpretation	R	Interpretation
Daily	16.380	-1.319	Not Compliant	-0.187	Very Low
15 Days	53.502	0.379	Not Compliant	0.638	Strong
Monthly	39.204	0.806	Excellent	0.911	Very Strong

Based on Table 6, it is known that the PDIR-Now satellite estimates the most accurate rainfall data in the monthly period. This is in line with the results of previous research with the Era-5 Satellite in the Bodor Sub-Watershed (Sitepu et al., 2023), the TRMM Satellite in the Grindulu Watershed (Jarwanti et al., 2021), the PERSIANN-CDR and TRMM 3B42 Satellites in the West Sumba Region (Agustinus H. Pattiraja, James I. Tupamahu, 2023), and the IMERG Satellite in the Bima and Dompu regions (Rostihanji & Humairo Saidah, 2023). Based on this, the PDIR-Now satellite with a monthly rainfall data period can be used as an alternative to estimate rainfall data in Serang City, Banten in the event of a data gap.

4. CONCLUSION

Based on the results of the study with statistical methods (RMSE, NSE, and r), it is known that the monthly PDIR-Now satellite rainfall data has a reliable value and is close to the value of rainfall in the field so that the PDIR-Now satellite data with the monthly period can be used as an alternative to estimate rainfall data in Serang City, Banten if there is a data gap.

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