Simulation of Rainfall Data by The GPM Satellite (Case Study at Sriwijaya University, Indralaya)

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Abstract. The problem in obtaining rainfall data information is that the measurement results of rainfall from the measuring station are not recorded and areas are difficult to reach to measure rainfall directly. Lack of data availability and continuity of rainfall data is one of the obstacles in obtaining climatological information in South Sumatra. GPM satellites (Global Precipitation Measurement) need to be researched in order to overcome obstacles in obtaining rainfall measurement data in an area. This study aims to validate rainfall data from the GPM satellite and daily rainfall data from the measurement results of the Hellmen type automatic rain gauge located in the Hydraulics Laboratory of Sriwijaya University. Validation of rainfall data was carried out to determine the accuracy of the measurement results. Validation was carried out by the Root Mean Square Error Method and the Nash-Sutcliffe Method. The results of the validation showed a high correlation value for the average daily rainfall. The correlation coefficient value is 0.77, the RMSE value is 11.42 and the NSE value is 0.996. The results of the validation of these methods show a strong correlation between the measurement rainfall data in the field and the GPM satellite.

1. Introduction
Rainfall data is widely used to predict climate or weather, research about flooding and plan the construction of water infrastructure [1-3]. Rainfall data includes hourly, daily, monthly and yearly rainfall data. Rainfall data is obtained by measuring at the location using manual, semi-automatic and automatic rainfall gauges, or it can be obtained through the BMKG (Meteorology, Climatology and Geophysics Agency) if the required data is in a long period of time [4-6]. However, the problem in obtaining rainfall data information is that the results of rainfall measurements are not recorded from measuring stations and areas that are difficult to reach in measuring rainfall directly. Insufficient amount of data and continuity of rainfall data were part of the team in producing information on rainfall data or climatological data in South Sumatra.

Currently, technological developments in the field of remote sensing such as satellite and radar have often been used to obtain climatological data, land use data, land contour data and others [7-9]. One of the georadar satellites that can be used to estimate bulk data is data from the GPM (Global Precipitation Measurement) satellite. The GPM satellite is one of the missions of NASA and JAXA and other international space agencies that are able to observe rain events in the next 2 to 3 hours [10]. This research was conducted by comparing the measurement of rainfall data using manual rain gauge stations and the results of measuring rainfall data using GPM satellite data to determine the correlation and comparison of the results of measuring rainfall data manually and the results from satellite georadar.
2. Methodology

2.1. Research Location
The location of the research was carried out in the hydraulic laboratory of the Civil Engineering Department, Sriwijaya University, Indralaya campus, South Sumatera, Indonesia. This research was carried out in several processes, namely, the background of the problem, literature study related to the problems being discussed, the stages of primary data collection, analysis of daily rainfall data and daily rainfall estimates using Georadar, the research flowchart as shown in Figure 1.

![Flow chart research](image)

**Figure 1.** Flow chart research

2.2. Measurement of rainfall data
Measurement of rainfall data in this study used an observatory-type manual rain gauge from a rainfall station located in a hydraulic laboratory, as seen in Figure 2. Measured rainfall data is daily rainfall data starting from 19 February 2020 to 21 April 2020. The instrument is set to start at 07.00 am and recorded on the next day after 24 hours, the rainwater collected on the instrument is measured using a measuring cup. The unit of measurement for rainfall is mm (millimeter).
2.3. GPM satellite (Global Precipitation Measurement).

GPM (Global Precipitation Measurement) is a meteorological satellite through high resolution precipitation data sets. GPM simply requires two instruments, the radar in GPM is the only dual frequency radar in space that is capable of creating 3D profiles and forecasts of rainfall intensity even up to snow and ice. GPM produces and has a variety of rainfall data. Data is provided at various levels of processing, from basic satellite measurements to best-estimate global rainfall maps using a combination of all constellation observations and other meteorological data. Rainfall data is available in various formats, spatial and temporal resolution, and processing rates which can be accessed on the Data Access Precipitation Measurement Mission web page [10]. Several data visualization and analysis tools are available to provide easy access to the science community and applications, including the Earth science data analysis tool Earth in Giovanni's browser, web API and 3D real-time global rainfall viewer. GPM Satellite rainfall data is obtained from the website disc.gsfc.nasa.gov. The duration and time of collecting rainfall data from the GPM satellite are equated with the duration and time when rainfall measurements are made using an observatory-type rain gauge [10,11]. Rainfall data capture images from GPM satellite can be seen in Figure 3.
2.4. Data validation

The results of rainfall measurements from the rain gauge station and the GPM satellite are validated to prove that a process / method can provide consistent results in accordance with predetermined specifications. Validation of measurement data was carried out using 3 methods: correlation coefficient (r), Root Mean Square Error (RMSE), and The Nash-Sutcliffe (NSE).

2.4.1. Correlation Coefficient (r) measures the closeness of the relationship between two ordinal variables [10,11]. This correlation coefficient is called the rank correlation coefficient or the Spearman correlation coefficient, which is denoted by r. For a data set (Xi, Yi) of size n, the correlation coefficient can be calculated using the formula:

\[ r = \frac{n \sum X_i Y_i - (\sum X_i)(\sum Y_i)}{\sqrt{[n(\sum X_i^2) - (\sum X_i)^2][n(\sum Y_i^2) - (\sum Y_i)^2]}} \]  

(1)

2.4.2. Root Mean Square Error (RMSE) method measure is most often used to compare the accuracy between 2 or more models in spatial analysis. The smaller the RMSE value of a model [10,11], the more accurate the model is. The RMSE calculation is carried out according to the formula:

\[ RMSE = \sqrt{\frac{\sum (H_{ti} - H_{ai})^2}{n}} \times 100 \]

(2)

Where:
RMSE = Root Mean Square Error
Hti = GPM Satellite Data Simulation
Hai = Field Data Measurement
n = Number of observations

2.4.3. The Nash-Sutcliffe (NSE) method is a statistical model that shows the magnitude of the effect of the relationship between simulation data and observation data [11]. The NSE value ranges between 0 and 1, where a value assessing 1 indicates that the performance of a model is good. The NSE statistical model is the most widely used to show the performance of a model because it can provide accurate information about a given value.

\[ NSE = 1 - \frac{\sum_{i=1}^{n} (Y_{i}^{obs} - Y_{i}^{sim})^2}{\sum_{i=1}^{n} (Y_{i}^{obs} - \bar{Y}^{mean})^2} \]  

(3)

Where:
Y_{i}^{obs} = Field Measurement data
Y_{i}^{sim} = GPS Satellite simulation data
Mean = average measurement data

3. Result and Discussion

3.1. Analysis of rainfall data from measurements in the field

Observatory type rain gauge is a collector type rain gauge that uses a cylinder glass to measure rainwater. This rain gauge is a rain gauge that is most often used in Indonesia. The observatory rain gauge has advantages in the form of: easy to install, easy to operate because it is measured directly on
the measuring cup and its maintenance is also relatively easy because there are no additional parts to the tool. However, the drawback is that the data obtained is only data on the amount of rainfall during a 24-hour period. The results of measuring rainfall data using an observatory in the hydraulic laboratory of the Civil Engineering Department, Sriwijaya University, Indralaya can be seen in Table 2 and Figure 4.

Table 2. Daily rainfall measurement results using the observatory rain gauge from 13 February 2020 to 21 April 2020

| No | Date    | OBS | No | Date    | OBS | No | Date    | OBS | No | Date    | OBS |
|----|---------|-----|----|---------|-----|----|---------|-----|----|---------|-----|
| 1  | 19-Feb  | 2.4 | 18 | 07-Mar  | 0   | 35 | 24-Mar  | 0.4 | 52 | 10-Apr  | 3.6 |
| 2  | 20-Feb  | 1.2 | 19 | 08-Mar  | 1.4 | 36 | 25-Mar  | 0.2 | 53 | 11-Apr  | 0   |
| 3  | 21-Feb  | 4.6 | 20 | 09-Mar  | 0   | 37 | 26-Mar  | 6.0 | 54 | 12-Apr  | 1.0 |
| 4  | 22-Feb  | 1.1 | 21 | 10-Mar  | 0   | 38 | 27-Mar  | 8.7 | 55 | 13-Apr  | 2.4 |
| 5  | 23-Feb  | 0   | 22 | 11-Mar  | 6.4 | 39 | 28-Mar  | 0   | 56 | 14-Apr  | 0   |
| 6  | 24-Feb  | 3.5 | 23 | 12-Mar  | 5.0 | 40 | 29-Mar  | 2.2 | 57 | 15-Apr  | 0   |
| 7  | 25-Feb  | 8.2 | 24 | 13-Mar  | 0   | 41 | 30-Mar  | 7.1 | 58 | 16-Apr  | 0   |
| 8  | 26-Feb  | 0   | 25 | 14-Mar  | 0   | 42 | 31-Mar  | 17.4| 59 | 17-Apr  | 0   |
| 9  | 27-Feb  | 0   | 26 | 15-Mar  | 0   | 43 | 01-Apr  | 34.8| 60 | 18-Apr  | 1.1 |
| 10 | 28-Feb  | 0   | 27 | 16-Mar  | 13.2| 44 | 02-Apr  | 2.2 | 61 | 19-Apr  | 0   |
| 11 | 29-Feb  | 0   | 28 | 17-Mar  | 0   | 45 | 03-Apr  | 0   | 62 | 20-Apr  | 0   |
| 12 | 01-Mar  | 0   | 29 | 18-Mar  | 33.6| 46 | 04-Apr  | 0   | 63 | 21-Apr  | 0   |
| 13 | 02-Mar  | 0   | 30 | 19-Mar  | 29.2| 47 | 05-Apr  | 20.9|   |          |     |
| 14 | 03-Mar  | 0   | 31 | 20-Mar  | 1.3 | 48 | 06-Apr  | 0   |   |          |     |
| 15 | 04-Mar  | 36.2| 32 | 21-Mar  | 0   | 49 | 07-Apr  | 3.1 |   |          |     |
| 16 | 05-Mar  | 0   | 33 | 22-Mar  | 0.3 | 50 | 08-Apr  | 39  |   |          |     |
| 17 | 06-Mar  | 11.1| 34 | 23-Mar  | 0   | 51 | 09-Apr  | 0   |   |          |     |

Figure 4. The relationship between time and depth of rainfall measurement results of manual rainfall gauge OBS observatory

3.2. Rainfall data analysis from GPM Satellite
The steps to get rainfall data from satellite GPM start on the website disc.gsfc.nasa.gov. The next step is to arrange daily rainfall data, set the date, month, time and location point of the data to be taken, then the website will issue the data needed to be analyzed. The data below are the results of
measurement of rainfall data from satellite GPM in Table 3 and a graph of the relationship between time and rainfall depth from satellite GPM in Figure 5.

Table 3. Results of daily rainfall measurement from GPM satellite February 13, 2020 to April 21, 2020

| No | Date   | GPM  | No | Date    | GPM  | No | Date    | GPM  |
|----|--------|------|----|---------|------|----|---------|------|
| 1  | 19-Feb | 8.60 | 18 | 07-Mar  | 0.6  | 35 | 24-Mar  | 4.33 |
| 2  | 20-Feb | 7.37 | 19 | 08-Mar  | 8.65 | 36 | 25-Mar  | 0.83 |
| 3  | 21-Feb | 2.17 | 20 | 09-Mar  | 0.82 | 37 | 26-Mar  | 12.14|
| 4  | 22-Feb | 25   | 21 | 10-Mar  | 3.11 | 38 | 27-Mar  | 10.81|
| 5  | 23-Feb | 0.09 | 22 | 11-Mar  | 18.05| 39 | 28-Mar  | 0.05 |
| 6  | 24-Feb | 4.57 | 23 | 12-Mar  | 0.14 | 40 | 29-Mar  | 1.00 |
| 7  | 25-Feb | 13.66| 24 | 13-Mar  | 0.00 | 41 | 30-Mar  | 35.34|
| 8  | 26-Feb | 0.05 | 25 | 14-Mar  | 0.13 | 42 | 31-Mar  | 26.31|
| 9  | 27-Feb | 0.00 | 26 | 15-Mar  | 0.14 | 43 | 01-Apr  | 47.02|
| 10 | 28-Feb | 0.09 | 27 | 16-Mar  | 45.34| 44 | 02-Apr  | 10.79|
| 11 | 29-Feb | 0.43 | 28 | 17-Mar  | 1.86 | 45 | 03-Apr  | 0.07 |
| 12 | 01-Mar | 0.00 | 29 | 18-Mar  | 21.17| 46 | 04-Apr  | 0.09 |
| 13 | 02-Mar | 0.00 | 30 | 19-Mar  | 54.14| 47 | 05-Apr  | 33.03|
| 14 | 03-Mar | 2.95 | 31 | 20-Mar  | 14.91| 48 | 06-Apr  | 3.18 |
| 15 | 04-Mar | 75.51| 32 | 21-Mar  | 0.04 | 49 | 07-Apr  | 34.08|
| 16 | 05-Mar | 3.17 | 33 | 22-Mar  | 0.07 | 50 | 08-Apr  | 16.80|
| 17 | 06-Mar | 38.4 | 34 | 23-Mar  | 0.95 | 51 | 09-Apr  | 5.37|

![Figure 5. Graph of relationship between time and depth of rainfall results of satellite GPM measurement](image)

3.3. Data validation

The data validation aims to determine the correlation between the measured rainfall data and the GPM satellite results. In this study, the data validation was carried out statistically with the correlation coefficient method, the Root Mean Square Error and the Nash-Sutcliffe Efficiency Method. The results of data validation can be seen in table 4. Data validation using the correlation coefficient method is 0.77 which indicates that there is a strong positive correlation between GPM satellite data and rainfall data measured in the field. The RMSE method validation value is 11.41 and NSE is 0.996 which indicates that there is a very close relationship between measurement data and GPM satellite simulation because the data is said to be a strong correlation if 0.75 < NSE < 1.00. It can be concluded
that the GPM rainfall data has a strong enough correlation so that the GPM satellite simulation data can be used as a substitute data for measurement results in the field.

| No | Validation Method          | Result   | Conclusion       |
|----|----------------------------|----------|------------------|
| 1  | Correlation Coefisien      | 0.77     | Strong Correlation |
| 2  | Root Mean Square Error      | 11.41    | Strong Correlation |
| 3  | Nash Sutcliffe Efficiency   | 0.996    | Strong Correlation |

3.4. Rainfall Mapping Based on GPM Satellite Data

Furthermore, the GPM satellite data is carried out by the process of extracting the determined grid data with a grid size of 0.1 x 0.1. By using Arc Gis 10.3 software. Rainfall data from GPM satellite is carried out by spatial analysis to create a daily rainfall classification map for the Indralaya Ogan Ilir area. Making a rainfall classification map based on GPM satellite data is expected to provide better information spatially compared to surface data which is unevenly distributed. In Figure 6 is one of the rainfall classification maps based on the amount of rainfall intensity, it can be seen that the highest rainfall value in the Ogan Ilir area is 67.63 mm which is marked in orange and the lowest rainfall is 2.202 mm which is marked in dark blue.

![Figure 6. Map of Ogan Ilir Rainfall Classification.](image-url)

4. Conclusion

Measurement of daily rainfall data in the field using an observatory-type manual rain gauge and rainfall measurements from the GPM satellite. Results of validation of measurement data in the field and GPM satellite with the correlation coefficient method is 0.77, the RMSE method is 11.42 and the NSE method is 0.77. The results of the validation of these methods show a strong correlation between the measurement data in the field and the GPM satellite. From this study, GPM satellite data allows it to be used as a substitute for measurement data in the field. From the results of the spatial map analysis of rainfall data based on GPM satellite data using Arc GIS 10.3 software, it can be seen that the classification of rainfall is based on the height of rainfall which is classified using color on each grid input on the map.
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