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Evaluation of GSMaP Data for Extreme Rain Events and Causing Floods in East Kotawaringin

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Abstract

On 12 May 2021, 12 August 2021, 6 September 2021 and 27 June 2022, extreme rain occured with an intensity of 58.85 mm/day, 101.3 mm/day, 124.4 mm/day and 176.8 mm/day respectively in East Kotawaringin. These phenomena occurred during the dry season and caused flooding, which is a rare condition during the dry season in East Kotawaringin. This study aims to evaluate extreme rainfall using GSMaP (Global Satellite Mapping of Precipitation) data, where analysis using GSMaP has never been done before in East Kotawaringin. These GSMaP data were processed and compared with the observation data from the Meteorological Station of H. Asan, East Kotawaringin. After that, the GSMaP rainfall results are verified using statistical methods, namely RMSE, correlation coefficient and bias. The verification results show that the bias gives underestimate results for all dates. In addition, the RMSE values on 12 May 2021, 12 August 2021, 6 September 2021 and 27 June 2022 are 10.83, 17.32, 12.41 and 34.03, respectively. These high RMSE values indicate that the GSMaP rainfall value is quite far from the observed rainfall value. The correlation value between GSMaP rainfall and observations has a high correlation with values of 0.84, 0.90, 0.96 and 0.98 for each date. These results show that the GSMaP data has a good correlation value and can be used for extreme rainfall analysis at the Meteorological Station of H. Asan, East Kotawaringin.

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INTRODUCTION

On May 12 2021, August 12 2021, September 6 2021 and June 27 2022, very heavy rains occurred in Kotawaringin Timur Regency and resulted in flooding in several areas, including at the Meteorological Station of H. Asan, East Kotawaringin. Based on observational data from at the Meteorological Station of H. Asan, East Kotawaringin, the rainfall measured on 12 May 2021 has an intensity of 113 mm/day, 101.3 mm/day for 12 August 2021, 124.4 mm/day for 6 September 2021 and 176.8 mm/day for June 27, 2022. This extreme phenomenon is a rare event because it occurs in the dry season. Therefore, it is important to evaluate and monitor extreme rains, because they can trigger floods and other natural disasters (Tashima, et al., 2020). One of the data that can be used for extreme rainfall evaluation and monitoring is the Global Satellite Mapping of Precipitation (GSMaP) data. GSMaP is a type of satellite precipitation products (SPPs) developed by the Japan Aerospace Exploration Agency (JAXA) (Pratama, et al., 2022).

GSMaP data can be used to analyze rain events (Rahman & Indra, 2020) because it has high spatial and temporal resolution (Sofiati & Avia, 2018). Research on the evaluation of GSMaP data has been carried out by Thi, et al., (2021) in Vietnam, Rahman & Indra, (2020) in Jabodetabek, Pratama et al., (2022) in South Lampung, Tashima et al., (2020) in East Asia and the West Pacific, Natadiredja et al., (2018) in Bali and Nusa Tenggara, Kurniawan (2020) at the Yogyakarta Mlati Climatology Station, Chen et al., (2016) in China and Sofiati & Avia (2018) in Yogyakarta.

The results of the research above show that the GSMaP data provides a fairly good result of evaluating rainfall in these study areas. Therefore, this study will evaluate GSMaP data for extreme rainfall in East Kotawaringin. Research using GSMaP data has never been done before in East Kotawaringin, therefore an evaluation is needed to improve extreme weather monitoring results.

METHOD

The research location is located at the Meteorological Station of H. Asan, East Kotawaringin. Located in Baamang District with coordinates -2.505150272 South Latitude and 112.9754699 East Longitude.

The data used in this study are: Observational rainfall data from the Meteorological Station of H. Asan, East Kotawaringin on May 12 2021, August 12 2021, September 6 2021 and June 27 2022; GSMaP daily rainfall data downloaded from ftp://hokusai.eorc.jaxa.jp.realtime/, with a spatial resolution of 0.250 (11.06 x 11.06 km). Then, GSMaP data is extracted using *The Grid Analysis and Display System* (GrADS); *High Resolution Cloud Analysis Information* (HCAI) data which is used as supporting data and obtained from ftp://202.90.199.64.

The method used in evaluating GSMaP rainfall data is using the statistical verification method, which is as follows: Root Mean Square Error (RMSE). The equation for calculating RMSE according to Wilks (2019) is as follows:

$$\mathrm{RMSE} = \sqrt{\frac{\sum_{n=1}^{N}(xi-yi)^2}{N}}$$

where N is the amount of data, *xi* is the rainfall from the GSMaP data and *yi* is the rainfall from the observation data (mm).

Pearson Correlation Coefficient. According to Wilks (2019), the formula used to calculate the correlation coefficient is:

$$r_{xy} = \frac{\Sigma(xi-\overline{x})(yi-\overline{y})}{\sqrt{\Sigma(xi-\overline{x}\,)^2}\sqrt{\Sigma(yi-\overline{y}\,)^2}}$$

where *xi* is the rainfall from the GSMaP data and *yi* is the rainfall from the observation data (mm).

Table 1. Correlation Coefficient Value

Coefficient Intervals	Relationship level
0,00-0,199	Very low
0,20-0,399	Low
0,40-0,599	Moderate
0,60-0,799	Strong
0,80-1,000	Very strong

Source: Dasar-dasar Statistika, 2016

Bias is the comparison between the average forecast and the average observation. Bias is used to determine whether the value of the data is *underestimate/underforecast* or *overestimate/overforecasting* (Wilks, 2019). The bias equation based on Santos et al., (2011):

$$\text{Bias} = \frac{1}{N}\sum_{i=1}^{n}(xi - yi)$$

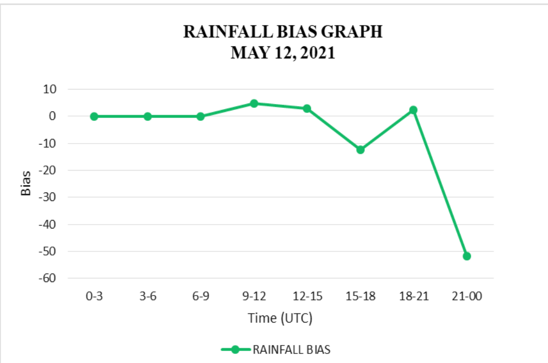
where *xi* is the rainfall from the GSMaP data and *yi* is the rainfall from the observation data (mm).

RESULT AND DISCUSSION

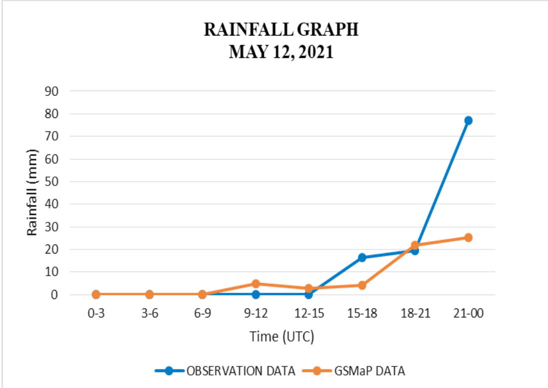
May 12, 2021

Based on the rainfall data extracted from GSMaP, it records a rainfall of 58.85 mm/day. The results of statistical calculations show that GSMaP produces an *underestimate* bias, which is -2,166 mm/day. The *underestimated value* was caused by a remarkable decrease in GSMaP rainfall between 21.00-00.00 UTC, which was -51.65 mm (Figure 1). In addition, there was a quite drastic decrease in rainfall between 15.00-18.00 UTC, namely -12.39 mm. This affects the results of daily rainfall bias at the Meteorological Station of H. Asan, East Kotawaringin. The statistical verification results also show a very strong correlation between the observation data and GSMaP data, namely 0.84.

Other verification results show that the RMSE gives a value of 10.83, which is the lowest RMSE value compared to the other three dates. This shows that the GSMaP data on May 12 2021 was not responsive enough to capture extreme rain events which caused flood in East Kotawaringin.



Source: Analysis, 2022
Figure 1. Rainfall Bias Graph on May 12 2021



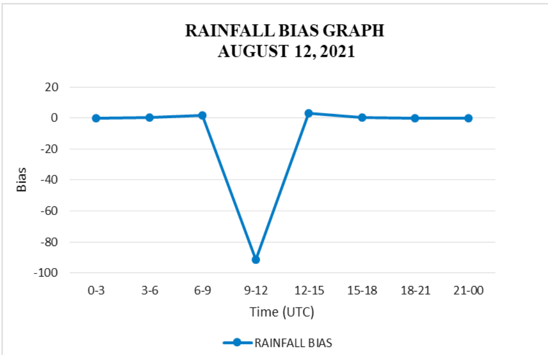
Source: Analysis, 2022
Figure 2. Comparison of Observational and GSMaP Rainfall Data Graph for May 12, 2021

August 12, 2021

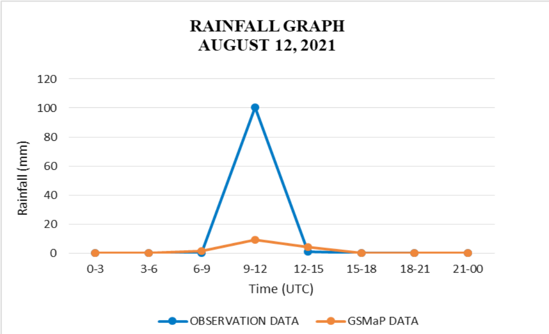
The GSMaP data extracted on August 12 2021 recorded rainfall of 14.65 mm/day. The RMSE statistic verification result is 17.32 with a correlation coefficient of 0.90, where this value indicates a very strong correlation between observed rainfall data and GSMaP rainfall. However, the daily rainfall bias is *underestimate*, which is -3.46. There is a considerable decrease in rainfall in GSMaP rainfall, namely at 09.00-12.00 UTC, which is -91.51 (Figure 3).

This was caused by an increase in rainfall between 09.00-12.00 UTC, which reach 100.5 mm, so that GSMaP was less able to capture the spikes in rain that occurred during that time.

Decreasing value of the rainfall bias occurs because of the *time lag* on a satellite which is marked by a delay in heavy rain falling to the earth's surface and is marked by a drastic decrease in the rainfall bias value (Ayasha, 2020).



Source: Analysis, 2022
Figure 3. Rainfall Bias Graph on August 12 2021

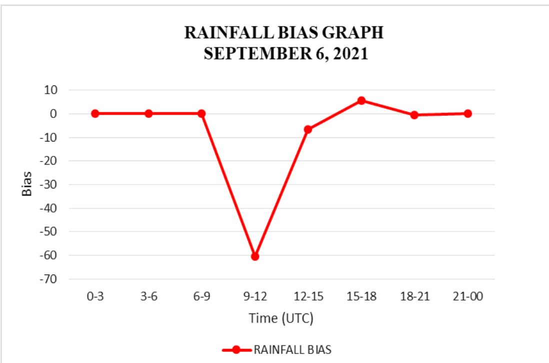


Source: Analysis, 2022

Figure 4. Comparison of Observational and GSMaP Rainfall Data Graph for August 12, 2021

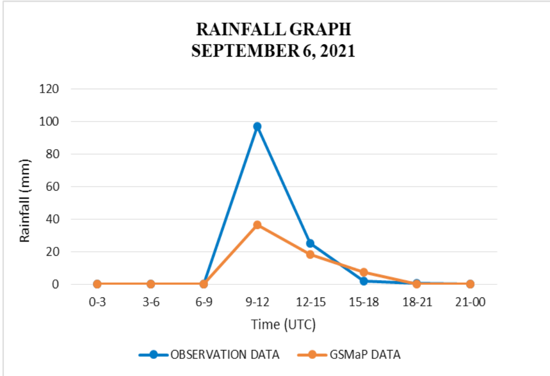
September 6, 2021

Rainfall data on September 6 extracted using GSMaP data gives the value of 62.33 mm/day, which is the highest rainfall value extracted from GSMaP data among the three other dates. RMSE statistic verification results, correlation coefficient and bias are 12.41, 0.96, and -2.48. These results indicate that there is a very strong relationship between rainfall observation and GSMaP rainfall which is indicated by a correlation value close to 1. However, there is a significant bias value, which has an *underestimate* result. This is happen due to a rainfall decrease at 09.00 – 12.00 UTC, which reaches -60.58 mm (Figure 5). The large rainfall bias at that hour affects the evaluation of the overall daily rainfall bias on 6 September 2021. This shows that the GSMaP data on 6 September 2021 at 09.00 -12.00 UTC is not sufficiently responsive to extreme rain events that cause flooding in East Kotawaringin.



Source: Analysis, 2022

Figure 5. Rainfall Bias Graph on September 6 2021



Source: Analysis, 2022

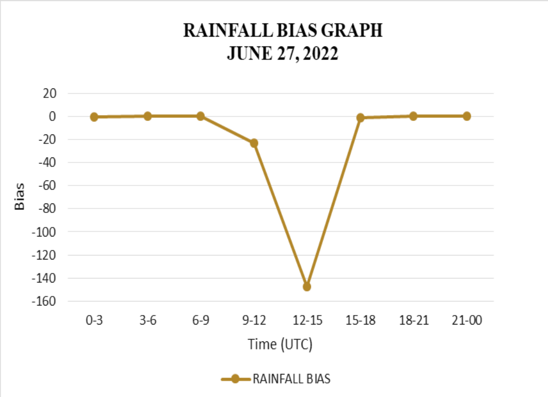
Figure 6. Comparison of Observational and GSMaP Rainfall Data Graph for September 6 2021

June 22, 2022

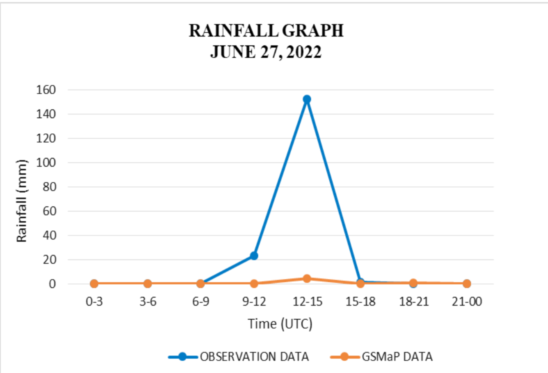
Rainfall data on June 27 2022 extracted from GSMaP data resulted in a rainfall of 6.65 mm/day. When compared with the rainfall observation values of the Meteorological Station of H. Asan East Kotawaringin, there is a huge gap in values between the GSMaP data and the observed rainfall data (176.8 mm/day). This is based on the results of statistical verification, namely the RMSE value of 34.03, a correlation coefficient of 0.98 and the largest bias compared to the other three dates, namely -6.81. This value indicates a strong correlation between the observational data and GSMaP, although the results of rainfall is *underestimate*.

The *underestimate* bias value can be caused by a remarkable decrease in the amount of rainfall at 12.00 - 15.00 UTC, which was -147.56 mm (Figure 7). This phenomenon can occur due to the influence of local conditions that affect the extreme rain, so there is a very large distinction between the GSMaP rainfall data and the observational data. This is proven by the *High Resolution Cloud Analysis Information* (HCAI) imagery, which shows that there is no Cumulonimbus clouds during extreme rain events on June 27, 2022 (Figure 9).

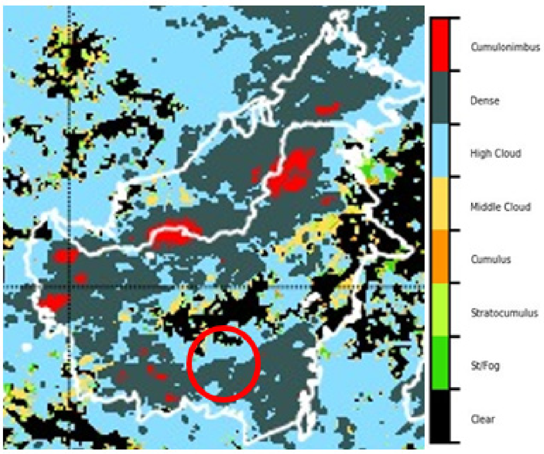
The influence of wind movements and fast cloud movements also gives the opportunity to affect the accuracy of falling rainfall (Ayasha, 2020) in East Kotawaringin.



Source: Analysis, 2022
Figure 7. Rainfall Bias Graph on June 22 2022



Source: Analysis, 2022
Figure 8. Comparison of Observational and GSMaP Rainfall Data Graph for June 22 2022



Source: Analysis, 2022
Figure 9. High resolution Cloud Analysis Information (HCAI) imagery

CONCLUSION

In the evaluation results of heavy and extreme rain events in East Kotawaringin on 12 May 2021, 12 August 2021, 6 September 2021 and 27 June 2022, GSMaP rainfall data has a strong correlation with the rainfall observation but less able to capture spikes in rainfall with very heavy intensity in a short time period. This is shown by the results of statistical verification which produces a positive RMSE value and a correlation close to 1 but with an underestimated rainfall bias value. In addition, there is the influence of local weather conditions that affect the process of forming this extreme rainfall, thus causing a huge gap in rainfall data between the observational data and the GSMaP data on several occurrence dates.

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