EVALUATION OF DAILY SATELLITE AND REANALYSIS OF RAINFALL DATA OVER SOUTH SUMATRA REGION

(Evaluasi Data Curah Hujan Satelit Harian dan Analisis Ulang Data Curah Hujan di Wilayah Sumatra Selatan)

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ABSTRACT

The limitations of good rainfall data due to constraints on direct measurements can be overcome by using satellite data or reanalysis data. The use of this data must, of course, go through a validation process first. This research aims to evaluate daily data from the Tropical Rainfall Measurement Mission (TRMM) version 3B42RT (TRMM_3B42RT) and European Center for Medium-Range Weather Forecasts (ECMWF) Reanalysis 5 (ERA5) data against data collected from 17 rain gauges in the Sumatra region South. Evaluation is carried out based on the Correlation Coefficient (CC), Root Mean Square Error (RMSE), Mean Absolute Error (MAE), and Mean Bias Error (MBE) values between the data. In addition, the estimation capabilities of TRMM_3B42RT and ERA5 were evaluated based on the Probability of Detection (POD), False Alarm Ratio (FAR), and Critical Success Index (CSI) values. The results show a very high correlation between TRMM_3B42RT and ERA5 with rain gauge data, especially in terms of monthly data. These values (monthly data) for TRMM_3B42RT and ERA5 data are 0.3-0.9 and 0.2-0.9, respectively. The RMSE values of TRMM_3B42RT and ERA5 data in monthly analysis are 75-250mm/month and 100-180mm/month, respectively. The forecasting performance of TRMM_3B42RT and ERA5 shows good results, especially for moderate rainfall in daily data and heavy rainfall in monthly data. The results of this analysis show that the monthly data TRMM_3B42RT is more in line with the station data and can be used in further research.

Keywords: automatic rain gauge, automatic weather station, ERA5, TRMM_3B42RT

ABSTRAK

Keterbatasan data curah hujan yang baik akibat kendala pada pengukuran langsung dapat diatasi dengan menggunakan data satelit atau data analisis ulang. Penggunaan data tersebut tentunya harus melalui proses validasi terlebih dahulu. Penelitian ini bertujuan untuk mengevaluasi data harian Misi Pengukuran Curah Hujan Tropis (TRMM) versi 3B42RT (TRMM_3B42RT) dan data European Center for Medium-Range Weather Forecasts *(ECMWF)* Reanalisis 5 *(ERA5) terhadap data yang dikumpulkan dari 17 alat pengukur hujan di wilayah Sumatra Selatan. Evaluasi dilakukan berdasarkan nilai* Correlation Coefisien *(CC),* Root Mean Square Error *(RMSE),* Mean Absolute Error *(MAE), dan* Mean Bias Error *(MBE) antara data tersebut. Selain itu, Kemampuan estimasi TRMM_3B42RT dan ERA5 dievaluasi berdasarkan nilai* Probability of Detection *(POD),* False Alarm Ratio *(FAR), dan* Critical Success Index *(CSI). Hasilnya menunjukkan adanya korelasi yang sangat tinggi antara TRMM_3B42RT dan ERA5 terhadap data alat pengukur hujan, terutama dalam hal data bulanan. Nilai-nilai ini (data bulanan) untuk data TRMM_3B42RT dan ERA5 masing-masing adalah 0,3-0,9 dan 0,2-0,9. Nilai RMSE data TRMM_3B42RT dan ERA5 pada analisis bulanan masing-masing adalah 75-250mm/bulan dan 100-180mm/bulan. Kinerja peramalan TRMM_3B42RT dan ERA5 menunjukkan hasil yang baik, terutama untuk curah hujan sedang pada data harian dan curah hujan lebat pada data bulanan. Hasil analisis ini menunjukkan bahwa data bulanan TRMM_3B42RT lebih sesuai dengan data stasiun dan dapat digunakan pada penelitian selanjutnya.*

***Kata Kunci**: pengukur hujan otomatis, stasiun cuaca otomatis, ERA5, TRMM_3B42RT*

INTRODUCTION

Monitoring climate variability has an essential role in determining policies for regulating water resources, the environment and society, and even the economy, especially when there is a drought or flood (Salio, Hobouchian, García Skabar, & Vila, 2015; Tan & Duan, 2017). Spatio-temporal and historical knowledge of precipitation are important aspects of monitoring climate variability

(Zambrano, Wardlow, Tadesse, Lillo-Saavedra, & Lagos, 2017). The right policy certainly supports the quality of the precipitation data used (Sun et al., 2018).

As a maritime nation, most of Indonesia's territory, including the South Sumatra Region, receives abundant annual rainfall. The average annual rainfall in Sumatra is more than 2400mm (Nur et al., 2018). In Indonesia, rainfall generally follows a seasonal pattern. Although each region has local characteristics, seasonal variations dominate rainfall patterns in Indonesia. There are three rainfall patterns in Indonesia, namely the equatorial pattern, the monsoonal pattern, and the local pattern. The equatorial pattern has two peak rainy seasons: October to November (ON) and March to May (MAM). The monsoonal pattern has one peak rainy season from November to March.

In contrast, the local pattern has a peak rainy season from June to August (Aldrian & Susanto, 2003). By taking into account the area coverage and characteristics of each region, spread over thousands of islands from the lowlands to the mountains, monitoring rainfall at the Indonesian earth station has not been able to provide data with the speed and accuracy required for accurate analysis of rainfall patterns, mainly as spatial variability. Therefore, it would be helpful if satellite-based sensors could produce accurate rainfall information, which is available with minimal delays and has sufficient accuracy.

The Meteorology, Climatology, and Geophysics Agency (BMKG) is an Indonesian government agency responsible for bringing together climate change, one of which is precipitation. This study of precipitation is carried out by placing sensors at several observation points (rain gauges). These sensors include Automatic Weather Station (AWS), Automatic Agroclimate Weather Station (AAWS), and Automatic Rain Gauge (ARG). In general, the number of rain gauges is minimal, especially in developing countries. Therefore, the data collected could be more extensive, and this is called data loss (Mashingia, Mtalo, & Bruen, 2014). Besides that, the available data are old (Michot et al., 2018). The difference in spatial and geographical conditions between the two sensors is also another factor that limits data availability. To compensate for this lack of data, satellite data is needed (Kuswanto & Naufal, 2019), even though it is necessary to validate the data before use (Yang, Yong, Hong, Chen, & Zhang, 2016).

South Sumatra is a province located on the island of Sumatra. It is located at an altitude of 8 above sea level to 280 above sea level. South Sumatra experiences the monsoon rain pattern. The peak of the rainy season occurs in January and December, while the dry season occurs in the middle of the year, with peak droughts in August and September (Kuswanto & Naufal, 2019)

The TRMM Multi-Satellite Precipitation Analysis (TMPA) is a satellite that produces a lot of secondary data, including TRMM_3B42RT_Daily. The results concluded from data obtained from this satellite have been the subject of various studies. For example, (Caparoci Nogueira, Moreira, & Lordelo Volpato, 2018) compared to other satellite data (Sharifi, Steinacker, & Saghafian, 2016), data from TRMM_3B42RT often underestimates observed precipitation in peak rainy season, and TRMM_3B42RT robust performance to predict precipitation at high elevation (Sekaranom, Nurjani, Hadi, & Marfai, 2018).

The ERA5 is one of the ECMWF reanalysis products. ECMWF has been reanalyzing data since 1950 (Hersbach et al., 2020). ECMWF generates a reanalysis of both atmospheric and ocean data. ERA5 has two main precipitation datasheets called the 1950 to 1978 time series (preliminary version) and the 1979 to present time series. Both datasheets contain hourly and monthly data, and they are also ~25KM in spatial resolution. Various studies compare ECMWF products to other datasheets, like Ran et al. (2018), Moses and Ramotonto (2018), Diro, Tompkins, and Bi (2012), Bock et al. (2005), and Gleixner, Demissie, and Diro (2020). The studies that used ECMWF in Indonesia are Baihaqi, Kusnarta, and Yasin (2020), Mandailing et al. (2020), and Bai et al. (2021).

Despite the research that has been done on TRMM and ERA5 data, particularly in the South Sumatra Region, research on the suitability of TRMM and ERA5 data to rain gauge data has yet to be carried out. There are some method to compare the precipitaion data i.e Auto Estimator, IMSRA, Non-Linear Relation, Non-Linear Inversion (Ayasha, 2020). In this study, we are focuses on the correlation between satellite precipitation data and rainfall data provided by the rain gauge. This method is simple and have used in various study (Ayoub, Tangang, Juneng, Tan, & Chung, 2020; J. Liu, Duan, Jiang, & Zhu, 2015; Nur et al., 2018; Tan & Duan, 2017; Tan, Ibrahim, Duan, Cracknell, & Chaplot, 2015). This correlation is measured as the CC value. The discrepancy of satellite data is also measured from the values of RMSE and Mean MAE. Further, deviations of the station data are evaluated based on the value of Bias, and the satellite's ability to predict precipitation is evaluated with the POD, FAR, and CSI values. In addition to using statistical analysis, this research also compares the monthly and daily analysis data.

METHODS

The data used in this study are satellite data and rain gauge data. The satellite data used is TRMM_3B42RT daily. TRMM_3B42RT daily is data from the TRMM satellite with 25KM spatial resolution (Huffman & Bolvin, 2018). This data is a real-time, daily data. TRMM combines micro and infrared wave data and then adjusts it to the Global Precipitation Climate Project (GPCP) data (Duan et al., 2016; Huffman et al., 2007; Salio et al., 2015). The other data used in this study is ERA5 from January 2017 to December 2019. ERA5 is also 25 km in spatial resolution. Although time series reanalysis data from January 2017 to December 2019, the data is selected to adjust to data availability in the rain gauge, as shown in **Table 1**.

The spatial range for this study is 5ºLS toward 1.5ºLS and 102ºE toward 107ºE. . The data from 17 rain gauges in South Sumatra were used to compare secondary data from satellites. The coordinates and numbers of BMKG rain gauges, scattered in the South Sumatra region, are shown in the following **Table 1**.

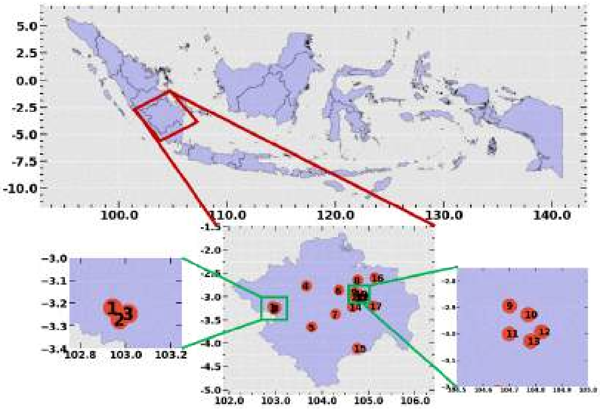

Figure 1. Rain gauges in the South Sumatra Region.

Based on the coordinates in **Table 1**, the locations of the BMKG rain gauges are marked with a red circle, for the given serial number, as shown in **Figure 1**. Each rain gauge point, as shown in **Figure 1**, is not precisely at the intersection of the given latitude and longitude. Therefore, to obtain satellite data with coordinates close to the rain gauge, the Inverse Distance Weight (IDW) method is used, that presented in **Equation 1.** w_i in **Equation 1** is detailed in **Equation 2**.

$$u(x) = \frac{\sum_{i=1}^{n} w_i(x) u_i}{\sum_{i=1}^{n} w_i(x)} \quad (1)$$

$$w_i(x) = \frac{1}{\sqrt{(x-x_i)^2+(y-y_i)^2}} \quad (2)$$

u_i is precipitation in $i-th$ longitude (x_i) and latitude (y_i). x and y are the longitude and latitude of the rain gauge. u and w_i are rainfall and weight at the i-th coordinate, respectively. A comparison of the satellite to rain gauge data is evaluated based on the values of *CC*, *RMSE*, *MAE*, and *MBE*, which are presented in **Equation 3**, **Equation 4**, **Equation 5** and **Equation 6**.

$$CC = \frac{\sum_{i=1}^{n}(O_i-\bar{O})(S_i-\bar{S})}{\sqrt{\sum_{i=1}^{n}(O_i-\bar{O})^2}\sqrt{\sum_{i=1}^{n}(S_i-\bar{S})^2}} \quad (3)$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(S_i - O_i)^2} \quad (4)$$

$$MAE = \frac{1}{n}\sum_{i=1}^{n}|S_i - O_i| \quad (5)$$

$$MBE = \frac{1}{n}\sum_{i=1}^{n}(S_i - O_i) \quad (6)$$

S_i and O_i are $i-th$ satellite and rain gauge data respectively, while $\bar{S}$ and $\bar{O}$ are the average of satellite and rain gauge data respectively. *CC* describes the relationship between satellite data and rain gauge data. This value is in the range of -1 to 1. Positive values of *CC* indicate the suitability and comparability of the data.

The best value of *CC* is 1 (Ayoub et al., 2020; C.-Y. Liu, Aryastana, Liu, & Huang, 2020) . *RMSE is* used to calculate the sensitivity of error measurement of precipitation by satellites against that of the rain gauge. *MAE* is a value that represents the absolute error (difference) between satellite data and rain gauge data. *MBE* is the average difference between satellite data and rain gauge data. Negative *MBE represents* underestimated satellite data, and positive MBE represents overestimated data (Nur et al., 2018).

Table 1. Rain gauge coordinates and continuity data.

No	Rain Gauge	Latitude	Longitude	Data Continuity
1	AWS Tugu Mulyo	-3.219922	102.9419	11-2017 to 10-2019
2	ARG Lubuk Linggau	-3.270924	102.9733	04-2018 to 10-2019
3	ARG Muara Beliti	-3.245865	103.011818	11-2017 to 11-2018
4	ARG Babat Toman	-2.765371	103.664652	04-2017 to 10-2019
5	AAWS Muara Enim	-3.653785	103.7763	03-2019 to 10-2019
6	ARG Suak Tape	-2.859353	104.3568	03-2018 to 10-2019
7	ARG Prabumulih	-3.372838	104.285316	11-2017 to 10-2019
8	ARG KTM Tanjung Lago	-2.645684	104.760298	04-2017 to 11-2018
9	AWS Digi Stamet Palembang	-2.894545	104.7011	04-2017 to 10-2019
10	AWS Staklim Palembang	-2.927103	104.77187	04-2017 to 10-2019
11	ARG Gandus	-3.0	104.7	03-2018 to 10-2019
12	ARG Plaju	-2.992007	104.8217	03-2018 to 10-2019
13	ARG JakaBaring	-3.027666	104.781354	04-2017 to 10-2019
14	AWS SMPK Ogan Ilir	-3.22258	104.6538	03-2018 to 05-2019
15	AAWS Belitang	-4.106389	104.7581	04-2018 to 05-2019
16	AWS Muara Padang	-2.597376	105.132643	11-2017 to 02-2019
17	ARG Pangkalan Lampan	-3.202146	105.098844	04-2017 to 10-2019

The statistical magnitudes (*CC*, *RMSE*, *MAE,* and *MBE*) previously mentioned are very much influenced by the satellite's ability to estimate the intensity of the precipitation that occurs. The capabilities of these satellites are indicated by the POD (**Equation 7**), FAR (**Equation 8**), and CSI (**Equation 9**) values.

$$POD = \frac{H_{so}}{H_{so}+M_o} \quad (7)$$

$$FAR = \frac{F_s}{F_s+H_{so}} \quad (8)$$

$$CSI = \frac{H_{so}}{H_{so}+F_s+M_o} \quad (9)$$

H_{so} is the amount of precipitation detected correctly by satellites and rain gauges (Ayoub et al., 2020). H_{so} is marked as one of the satellites, and rain gauges give the same data; else is 0. For example, suppose we count the 1mm of precipitation; H_{so} is marked as one of the satellites, and rain gauge precipitation is 1mm. F_s is the amount of precipitation detected by the satellite but not by the rain gauge. Like H_{so}, F_s is marked as one if the precipitation of satellite data is 1mm and the precipitation of rain gauge data is not 1mm. M_o is the precipitation detected by the rain gauge but not by the satellite (Duan, Liu, Tuo, Chiogna, & Disse, 2016; Tan & Duan, 2017). M_o is vise versa of F_s. The simple picture of H_{so}, F_s, and M_o is shown in **Table 2**, known as the Contingency matrix.

Table 2. Contingency matrix.

		Rain Gauge	
		Yes	No
Satellite	Yes	H_{so}	F_s
	No	M_o	

POD compares the number of forecasting precipitation events and the number of precipitation events in a rain gauge. The POD value indicates the satellite's ability to predict the amount of precipitation correctly. FAR is the error of the number forecasting precipitation events that rain gauges do not record. FAR is also a miss between the satellite estimates and the rain gauge data. CSI is the sum of the ratio of forecasting precipitation events (Guo et al., 2015) against precipitation intensity. The threshold of this metric is 0 to 1. The worst value of POD and CSI is 0, while the worst value of FAR is 1.

To calculate H_{so}, F_s and M_o, we follow the intensity of precipitation classification (J. Liu et al., 2015; Tan & Duan, 2017; Xu et al., 2017), i.e., *0-5mm/day* or *0-5mm/month* as light precipitation events, 5*-50mm/day* or 5*-50mm/month* as moderate precipitation events and >50*mm/day* or >*50mm/month* as heavy precipitation events.

RESULTS AND DISCUSSION

Monthly and Daily Precipitation

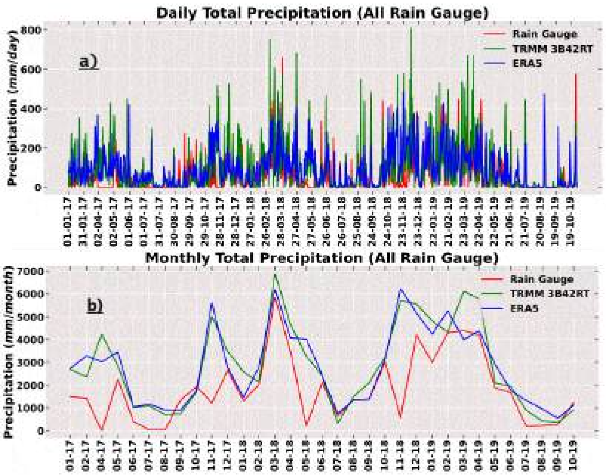

Figure 2. Comparison of Total Precipitation in daily (a) and monthly (b). This Figure is the total precipitation of 17 rain gauges for daily and monthly data. These data are collected from BMKG observation stations.

The monthly and daily precipitation from 17 rain gauges with TRMM_3B42RT and ERA5 data are shown in **Figure 2**. This precipitation was mainly from January 2017 to October 2019 and some from May 2017 to October 2019. The monthly precipitation (**Figure 2.b**) varied at 0-5829 mm/month for the rain gauge, 0-6881 mm/month for TRMM_3B42RT, and 0-6442 mm/month for ERA5. The daily precipitation (**Figure 2.a**) varied at 0-658 mm/day for the rain gauge, 0-806 mm/day for TRMM_3B42RT, and 0-486 mm/day for ERA5. These results show that the difference between TRMM_3B42RT and ERA5 for rain gauge is 1052 mm/month (overestimated) and 613 mm/month (underestimated), respectively, while for daily precipitation, these results are 148 mm/day (overestimated) and 172 mm/day (underestimated) for TRMM_3B42RT and ERA5, respectively. The monthly precipitation, as shown by both TRMM_3B42RT and ERA5, increased on 04-2017, 07-2017, 11-2017, 05-2018, and 11-2018, while the rain gauge decreased. In general, both the TRMM_3B42RT and ERA5 data were overestimated in the monthly precipitation forecasts (figure is not included).

Correlation and Error Analysis

TRMM_3B42RT Data

The TRMM_3B42RT CC values are shown in **Figure 3**. **Figure 3.a** shows the daily analysis data, while **Figure 3.b** shows the monthly data. The values for daily and monthly analysis range from 0.2 to 0.6 and 0.3 to 0.9. The CC value for the monthly analysis shows a low to very high correlation (0.7-0.9), while the daily analysis shows an unrelated to moderate condition. In both daily and monthly analyses, a high correlation occurs in the AAWS Muara Enim (5) and ARG Suak Tape (6), while a low correlation occurs in the ARG KTM Tanjung Lago (8).

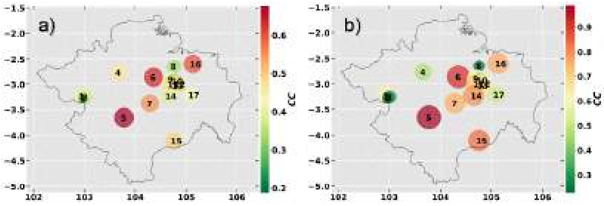

Figure 3. Coefficient correlation for daily (a) and monthly (b) of TRMM_3B42RT. The color gradient shows the correlation value. The green and red color are show of weak and strong correlation.

The RMSE values for daily and monthly analysis are shown in **Figure 4.a** and **Figure 4.b**, respectively. This value shows a more excellent daily RMSE value than the monthly value. This value is shown based on the number of stations (in daily data) with RMSE leading to the maximum RMSE more than monthly data. **Figure 4.a** shows that greater RMSE occurs in rain gauges AWS Tugu Mulyo (1), ARG Lubuk Linggau (2), ARG Muara Beliti (3), ARG Babat Toman (4), AWS SMPK Ogan Ilir (14), and AAWS Belitang (15). The greater RMSE for monthly analysis occurs in AWS Tugu Mulyo (1), ARG Lubuk Linggau (2), and ARG Muara Beliti (3). The number of rain gauges with greater RMSE indicates that the monthly precipitation data is better than the daily data. Apart from RMSE, a greater MAE occurs at the same rain gauge in the case of both daily (**Figure 5.a**) and monthly (**Figure 5.b**) analysis.

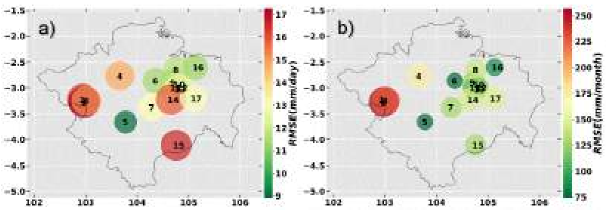

Figure 4. RMSE for daily (a) and monthly (b) of TRMM_3B42RT.

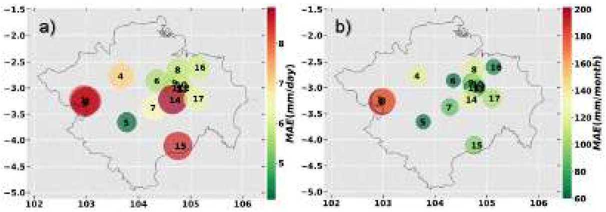

Figure 5. MAE daily (a) and monthly (b) of TRMM_3B42RT.

Figure 6.a and **Figure 6.b** shows the daily and monthly MBE values of TRMM_3B42RT to rain gauge data. From these Figure, we can see that the more significant skewness for TRMM_3B42RT to rain gauge data occurs in AWS Tugu Mulyo (1), ARG Lubuk Linggau (2), and ARG Muara Beliti (3) for both daily and monthly analysis.

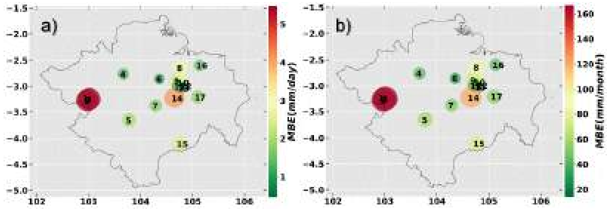

Figure 6. MBE for Daily (a) and Monthly (b) of TRMM_3B42RT.

ERA5 data

Figure 7.a and **Figure 7.b** show daily and monthly correlation analysis of ERA5 data to rain gauge. Correlation in the daily analysis is in the range of 0.1 to 0.4. This value indicates no low correlation in each rain gauge. The monthly analysis shows no high correlation in each rain gauge, with values of 0.2 to 0.9. The daily analysis data shows a low correlation occurs in rain gauges AWS Tugu Mulyo (1), ARG Lubuk Linggau (2), ARG Muara Beliti (3), AAWS Muara Enim (5), and ARG Prabumulih (7). The high correlation in the monthly analysis occurs at rain gauges AAWS Muara Enim (5), ARG Suak Tape (6), and AWS SMPK Ogan Ilir (14). In general, monthly analysis shows a better correlation than daily analysis.

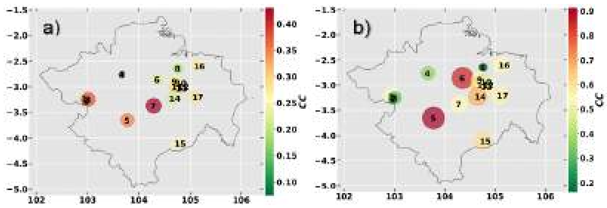

Figure 7. Coefficient Correlation Daily (a) and Monthly (b) of ERA5.

Daily analysis (**Figure 8.a**) shows that greater RMSE occurs in ARG Babat Toman (4) and AAWS Belitang (15). **Figure 8.b** shows RMSE in monthly analysis. Monthly analysis shows that greater RMSE occurs in rain gauge AWS Tugu Mulyo (1), ARG Lubuk Linggau (2), ARG Muara Beliti (3), ARG Babat Toman (4), and ARG KTM Tanjung Lago (8). The number of rain gauges with greater RMSE in monthly analysis is more than in daily analysis.

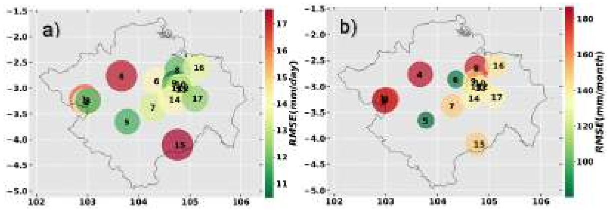

Figure 8. RMSE for Daily (a) and Monthly (b) of ERA5.

The daily analysis (**Figure 9.a**) shows more of rain gauges with greater MAE than the monthly analysis (**Figure 9.b**). The rain gauges with greater MAE in the daily analysis are ARG Babat Toman (4), AWS SMPK Ogan Ilir (14), AAWS Belitang (15), and AWS Muara Padang (16). The monthly analysis shows greater MAE in AWS Tugu Mulyo (1) and ARG KTM Tanjung Lago (8). The greater MAE in the daily analysis is more than that in the monthly analysis.

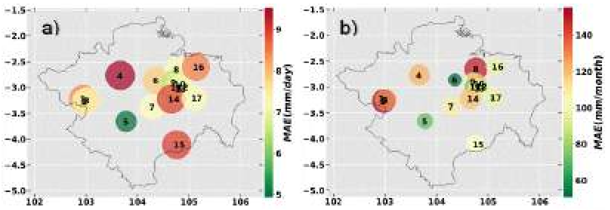

Figure 9. MAE for Daily (a) and Monthly (b) of ERA5.

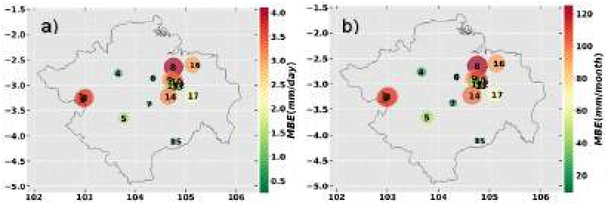

Figure 10. MBE for Daily (a) and Monthly (b) of ERA5.

Daily and monthly analysis of MBE for each rain gauge is shown in **Figure 10.a** and **Figure 10.b**, respectively. The number of rain gauges of greater MBE are the same in both daily and monthly analyses, and they are AWS Tugu Mulyo (1), ARG Lubuk Linggau (2), ARG Muara Beliti (3), ARG KTM Tanjung Lago (8), AWS Digi Stamet Palembang (9), AWS Staklim Palembang (10), AWS SMPK Ogan Ilir (14), and AWS Muara Padang (16).

Statistical Analysis (POD, FAR, and CSI)

TRMM_3B42RT data

Figure 11.a, **Figure 11.b**, and **Figure 11.c**, shows the daily POD analysis of light, moderate, and heavy precipitation, respectively. The better POD in this analysis is shown in **Figure 11.a** (light precipitation) and **Figure 11.b** (moderate precipitation), while a good value for heavy precipitation is shown by AAWS Muara Enim (5). The POD precipitation's monthly analysis value is shown **Figure 11.d**, **Figure 11.e**, and **Figure 11.f**, for light, moderate, and heavy precipitation, respectively. The TRMM_3B42RT forecasting is poor for light precipitation and very good for heavy precipitation. The TRMM_3B42RT forecasting is failing in the same rain gauge, i.e., AWS Tugu Mulyo (1), ARG Lubuk Linggau (2), ARG Muara Beliti (3), ARG Babat Toman (4), AWS SMPK Ogan Ilir (14), and ARG Pangkalan Lampan (17).

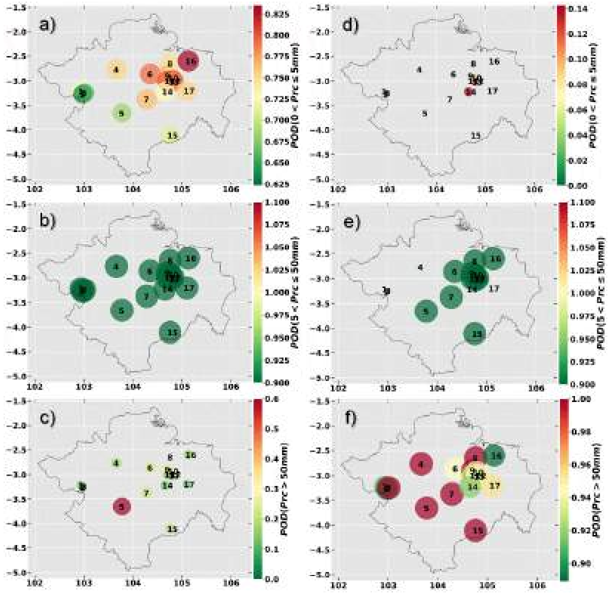

Figure 11. Daily (a-c) and monthly (d-f) POD of TRMM data for the amount of precipitation is 0mm-5mm, 5mm-50mm, and >50mm.

The FAR for daily analysis is shown in **Figure 12.a**, **Figure 12.b**, and **Figure 12.c**. This result shows a small value for light and moderate precipitation and a more excellent value for heavy precipitation. This result shows that the TRMM_3B42RT performance is suitable for light and moderate precipitation, but poor for heavy precipitation. The monthly analysis is shown in **Figure 12.d**, **Figure 12.e**, and **Figure 12.f**. A greater value of FAR in monthly analysis occurs for heavy precipitation (**Figure 12.f**), especially in AWS Tugu Mulyo (1), ARG Lubuk Linggau (2), ARG Muara Beliti (3), and AAWS Muara Enim (5). Although this value is small, it cannot indicate that TRMM_3B42RT's performance could be better because the POD value for this range of precipitation is not small, and vice versa. As shown in Figure 12.a, the FAR and the POD value for light precipitation is small. Therefore, it cannot indicate that TRMM_3B42RT has poor performance.

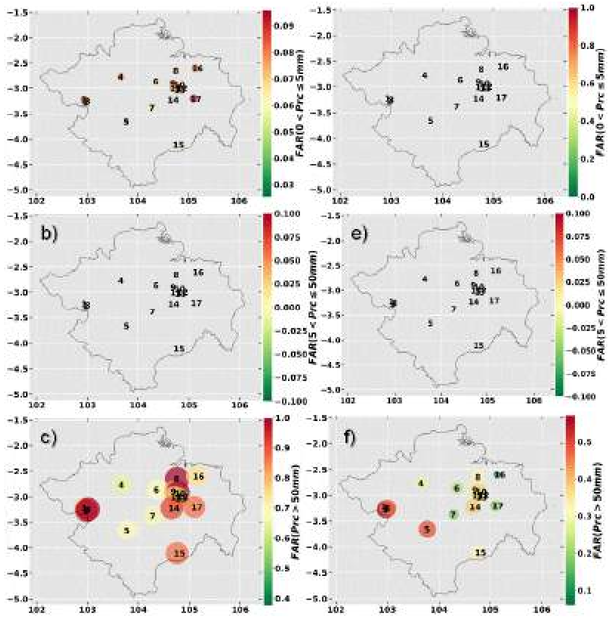

Figure 12. Daily (a-c) and monthly (d-f) FAR of TRMM data for the amount of precipitation is 0mm-5mm, 5mm-50mm, and >50mm.

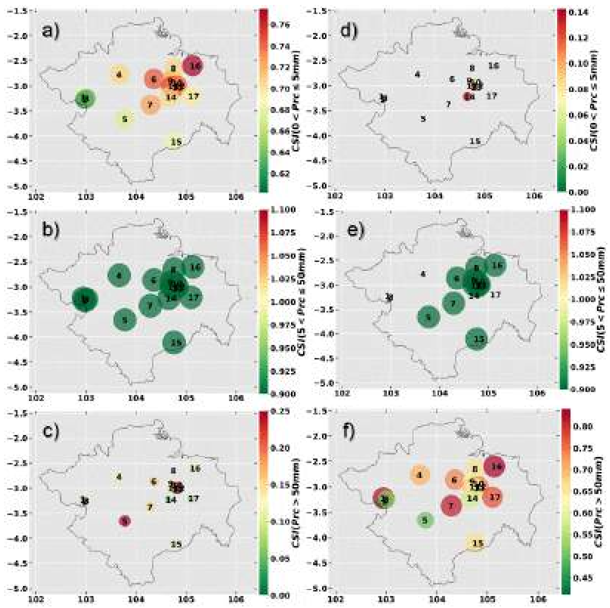

Figure 13. Daily (a-c) and monthly (d-f) CSI of TRMM data for the amount of precipitation is 0mm-5mm, 5mm-50mm, and >50mm.

The CSI values for daily and monthly analysis are shown in **Figure 13.a, Figure 13.b** and **Figure 13.c** shows data for light, moderate, and heavy precipitation in daily analysis. **Figure13.d**, **Figure 13.e**, and **Figure 13.f** for light, moderate, and heavy precipitation in monthly analysis. As illustrated in **Figure 13.a** and **Figure 13.b**, this value tends to be 1, especially in the case of moderate precipitation, as illustrated in the monthly analysis (**Figure 13.e**). For heavy precipitation (**Figure 13.c**) in the daily analysis and light precipitation in the monthly analysis (**Figure 13.a**) gives a small value. The daily and monthly analyses of the CSI values indicate that the yield of TRMM_3B42RT is good, even though it must be confirmed by another study, especially for heavy precipitation in monthly analysis.

ERA5 data

The POD value of daily analysis ERA5 data is shown in **Figure 14.a, Figure 14.b,** and **Figure 14.c** for light, moderate, and heavy precipitation. In contrast, the data for monthly analysis is shown in **Figure14.d**, **Figure 14.e**, and **Figure 14.f**. The daily analysis shows a good POD value for light and moderate precipitation (**Figure 14.a** and **Figure 14.b**). It indicates that the ERA5 performance forecast is the best for moderate precipitation, better for light precipitation, and bad for heavy precipitation. In monthly analysis data, ERA5 could not detect light precipitation. ERA5 could detect good heavy precipitation in monthly analysis, but it could not detect moderate and heavy precipitation. ERA5 could not detect some rain gauges i.e., AWS Tugu Mulyo (1), ARG Lubuk Linggau (2), ARG Muara Beliti (3), ARG Babat Toman (4), AAWS Muara Enim (5), ARG Suak Tape (6), ARG KTM Tanjung Lago (8), AWS SMPK Ogan Ilir (14), and AWS Muara Padang (15).

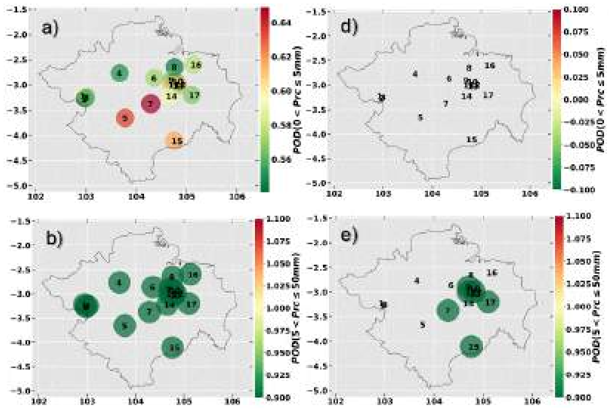

Figure 14. Daily (a-c) and monthly (d-f) POD of ERA5 data for the amount of precipitation is 0mm-5mm, 5mm-50mm, and >50mm.

The daily analysis of FAR is shown in **Figure 15.a**, **Figure 15.b**, and **Figure 15.c**. This value shows promising results for light, moderate, and heavy precipitation. POD values confirm this result in the daily analysis. The same result is also shown by monthly analysis. The good values of FAR are shown in **Figure15.d**, **Figure 15.e**, and **Figure 15.f**. ERA5 cannot detect light precipitation. The POD value confirms it for light precipitation. The same result was also shown for moderate and heavy precipitation. Although the value of FAR from some rain gauges cannot be detected, it is also confirmed by the POD value.

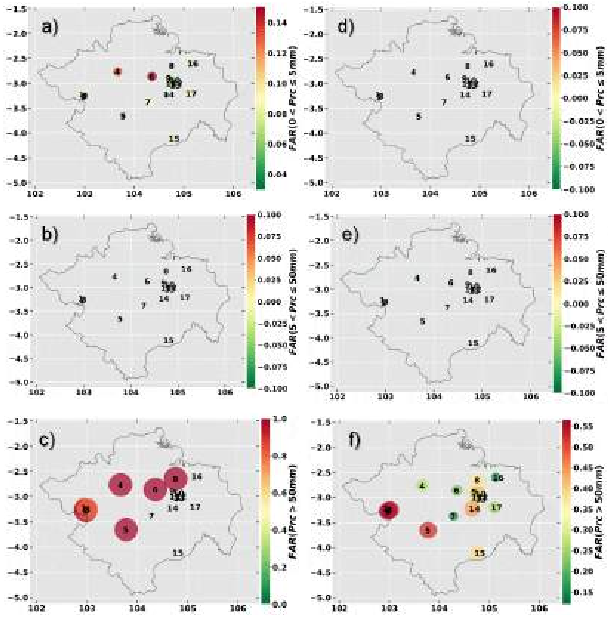

Figure 15. Daily (a-c) and monthly (d-f) FAR of ERA5 data for the amount of precipitation is 0mm-5mm, 5mm-50mm, and >50mm.

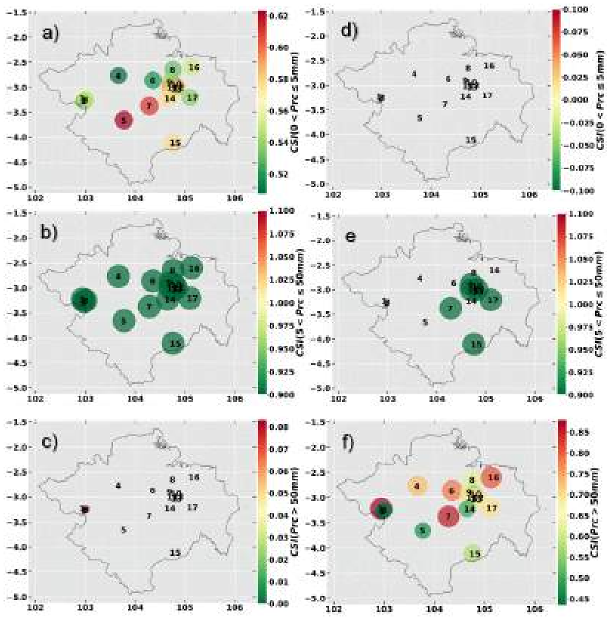

Figure 16. Daily (a-c) and monthly (d-f) CSI of ERA5 data for the amount of precipitation is 0mm-5mm, 5mm-50mm, and >50mm.

CSI values confirm ERA5 POD and FAR values for daily (**Figure 16.a**, **Figure 16.b** and **Figure 16.c**) and monthly (**Figure 16.d**, **Figure 16.e**, and **Figure 16.f**) analysis. Smaller values for CSI were obtained in light and heavy precipitation for daily and monthly analysis. Although these values were small, it is on track with small POD and great FAR values, especially for moderate precipitation. ERA5 cannot detect CSI values for light precipitation in monthly analysis (Zhou, Chen, Li, & Luo, 2023). However, this result is off the track with small PDO and FAR. Based on these results, ERA5 can be used to detect disasters due to moderate to heavy rainfall, for example floods (Lavers, Simmons, Vamborg, & Rodwell, 2022).

CONCLUSION

The daily and monthly analyses give different results for both TRMM_3B42RT and ERA5 data, and this is normal because it is caused by the use of different algorithms by TRMM_3B42RT and ERA5. The daily analysis shows that the precipitation of both TRMM_3B42RT and ERA5 data vary from rain gauge data. The monthly analysis shows that both TRMM_3B42RT and ERA5 are overestimated. However, the correlation value shows that the monthly TRMM_3B42RT and ERA5 data are better than the daily data. This is also supported by the results of the error test and suitability test of the two data. Based on these results, monthly TRMM_3B42RT and ERA5 data can be used to anticipate and manage disasters related to rainfall, for example droughts and floods.

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