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Analysis of Heavy Rainfall Using Radar Image Data, Satellite Images, and Rain Gauges in the City of Padang

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ABSTRACT

Padang City, as the capital of West Sumatra Province, often experiences heavy rains that can cause flooding and landslides. This phenomenon of heavy rainfall is a matter of serious concern due to its impact on the lives of the community, infrastructure, and the regional economy. On March 7, 2024, heavy rainfall occurred in Padang City, triggering flooding and causing loss of life and property. The analysis was conducted using weather radar imagery, satellite imagery, and rainfall observation data from several rain gauges in Padang City. To obtain representative rainfall data with broad spatial coverage, the use of remote sensing data such as weather radar images and satellite images is vital, especially for areas with a limited number of rain gauges stations or difficult-to-reach topography. Therefore, this study aims to analyze the comparison of rainfall data based on radar imagery, satellite imagery, and rain gauge data to understand the advantages and limitations of each instrument. The combination of these three data sources is very important to improve the accuracy of rainfall monitoring. The research method used in this study is quantitative research using data from the BMKG. The results of the analysis obtained from the error and correlation, both from radar data and satellite imagery, generally show a tendency to underestimate the rainfall observed at rain gauges in Padang City, as indicated by the Mean Error (ME) value, which is predominantly negative at almost all rain gauges.

KEYWORDS : Radar Images, Satellite Images, Rain Gauges

INTRODUCTION

Indonesia is crossed by the equator, making it a country with surplus energy due to its higher exposure to sunlight. This makes Indonesia an area of intensive convective cloud formation with fairly high rainfall [1]. Convective clouds formed in Indonesia bring heavy rain, lightning, and thunder [2]. This results in Indonesia having a dynamic weather pattern that is influenced by meteorological scales, including global, regional, and local scales [3]. Padang is a city with high rainfall frequency and intensity. Rainfall data from seven observation stations was processed by Sudiar and Siregar [4].

The province of West Sumatra, especially the city of Padang, with its strategic geographical location on the west coast of Sumatra and varied topography, is very vulnerable to flooding [5]. The city of Padang, as the capital of West Sumatra Province, often experiences heavy rains that can cause flooding and landslides. This phenomenon of heavy rainfall is a matter of serious concern due to its impact on people's lives, infrastructure, and the regional economy (National Disaster Management Agency, 2018). History records that the city of Padang has repeatedly experienced flooding of varying intensity. According to Kodoatie and Sugiyanto (2002), the factors causing flooding can be classified into two categories, namely natural flooding and flooding caused by human actions [6].

One of the significant rainfall events in Padang City occurred on March 7, 2024, triggering flooding and causing loss of life and property. This event is used as a representative example within a broader analysis of rainfall characteristics over a one-year period (2023–2024).The analysis was conducted using weather radar imagery, satellite imagery, and rainfall observation data from several rain gauge stations in Padang City. Based on radar imagery data, rainfall occurred from morning until early morning, with peak rainfall observed at around 18:00 UTC (12:00 WIB), associated with convective and stratiform cloud systems. The rainfall intensity ranged from light to very heavy, with values between 20.0–43.1 mm/day from radar data and 50–105 mm/day from satellite data.

In Padang City, flooding has occurred since Thursday, March 7, 2024, at 16:00 WIB, affecting more than 8,000 residents, and is still ongoing until Friday, March 8, 2024. A total of eight subdistricts were submerged with water levels varying up to 1.5 meters, and an estimated 8,118 residents were affected, with 2,947 residents evacuated. The subdistricts that were submerged included Lubuk Begalung, Lubuk Kilangan, Pauh, Koto Tangah, Padang Utara, Kuranji, Naggalo, and Padang Selatan. In addition to the flooding, landslide debris is also blocking road access in Lubuk Paraku.

To obtain representative rainfall data with broad spatial coverage, the use of remote sensing data such as Weather Radar Images and Satellite Images is a vital solution, especially for areas with a limited number of rain gauges or difficult-to-reach topography. The use of data from Weather Radar has become a valuable tool in hydrological studies due to its ability to provide broad spatial and temporal coverage [7]. However, the main challenge in utilizing radar data is the issue of bias, especially in heavy rain conditions where underestimation often occurs [7].

Instrumental limitations and the potential for estimation errors influenced by environmental factors necessitate data evaluation and integration studies. Dzwonkowski et al. (2025) emphasize that comparing radar data with Rain Gauge observation data is essential for measuring bias and accuracy, as well as understanding instrument limitations in various geographical conditions [8][9]In addition, rainfall measurement data (temporal and spatial) is scarce or non-existent for some countries in the world, especially in developing countries [10].

Therefore, to analyze the comparison of rainfall data based on radar imagery, satellite imagery, and rain gauge data in order to understand the advantages and limitations of each instrument, a combination of these three data sources is very important to improve the accuracy of rainfall monitoring. In this study, an analysis of heavy rainfall events in the city of Padang will be conducted using data from radar imagery, satellite imagery, and rain gauges. This analysis will be conducted in four seasonal periods, namely December-January-February (DJF), March-April-May (MAM), June-July-August (JJA), and September-October-November (SON).

Based on several previous studies, analyses of heavy rainfall generally still focus on a single specific event and use limited data, such as radar, satellite, or a simple combination with field observation data. In a study conducted by Purba et al. in 2019, radar, satellite, and rain gauge data were combined, but only for a single flood case in Padang Pariaman [11]. Another study conducted by Tri Anggun Lestari, Afif Rowina Khairi, Bachrudin Kafhi, and Imma Redha Nugraheni in 2022 in Jakarta placed greater emphasis on the use of radar data alone [12]. Furthermore, studies conducted by Vinca Amalia Rizkiafama, Tesla Kadar Dzikiro, and Agus Safril in 2018 in Padang and by Maria O.R. Hutagalung, Iqbal Gusranda, Daffa Adhitiansyah, and Aditya Mulya in 2021 in Manado relied more heavily on satellite data to assess atmospheric conditions without fully integrating it with other data [13],[14]. Therefore, this study has the advantage of examining heavy rainfall in the city of Padang in a more comprehensive manner, namely by using three types of data simultaneously: radar, satellite, and rain gauge data. Additionally, this study does not focus on a single event but aims to understand the patterns of heavy rainfall more generally. This study also compares the results from each data source to determine their levels of accuracy and limitations. With this approach, it is hoped that the research findings will provide a clearer picture of the characteristics of heavy rainfall in the city of Padang and assist in disaster mitigation efforts.

METHODS

This study will focus on the city of Padang, West Sumatra Province, with coordinates between 0°44'00'' – 0°08'35'' S and 100°05'05'' – 100°34'09'' E. This area was selected based on the frequent occurrence of hydrometeorological disasters, especially flooding caused by heavy rainfall. Some of these areas include Teluk Bayur, Marapalam/Parak Karakah, Tambang Semen Padang, Bandar Buat, Water Plant Semen Padang, Nanggalo, and Lubuk Minturun.

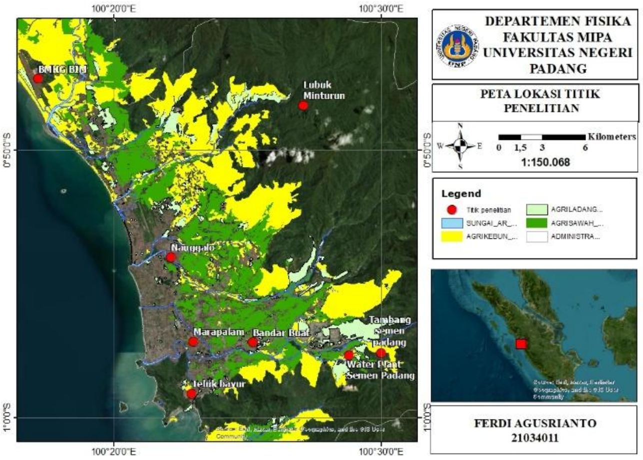

Figure 1. Research Area

This study is a quantitative study using radar imagery, satellite imagery, and rainfall data from BMKG rain gauges. The data used covers a one-year period, from 2023 to 2024. The data was divided into four seasonal periods: December–January–February (DJF), March–April–May (MAM), June–July–August (JJA), and September–October–November (SON). This one-year dataset is used to analyze rainfall characteristics and evaluate the performance of radar and satellite data across different seasonal conditions in Padang City.

The data obtained was analyzed using the following data processing techniques: 1) Electromagnetic wave formula in radar: Weather radar utilizes electromagnetic waves to detect water particles in clouds. Radar reflectivity (Z) measured in dBz can be correlated with rainfall intensity (R) using the formula $Z = aR^b$. To calculate rainfall intensity from radar reflectivity, the formula is changed to $R = (\frac{z}{a})^{(1/b)}$. 2) Electromagnetic wave formula on satellites: Weather satellites, such as Himawari-8, use infrared and microwave sensors to measure cloud top temperatures. The relationship between cloud top temperature (Tc) and rainfall (R) can be expressed as R = k.(T_{max}- T_c); 3) Bias Correction: Bias Correction is used to improve the precision and accuracy of processed data (radar and satellite) compared to observation data from rain gauges stations as reference data[15], with the formula $S_{Kor1} = S_i \times \frac{\Sigma G_i}{\Sigma S_i}$. 4) Mean Absolute Error (MAE): MAE is used to measure the average absolute error between radar/satellite data and observation data from rain gauge stations[16][17][18], with $MAE = \frac{1}{n}\sum_{i=1}^{n}|P_{pred,i} - P_{obs,i}|$. 5) Mean Error: ME is used to determine the bias between radar/satellite data and observation data[17], with $ME = \frac{1}{n}\sum_{i=1}^{n}(P_{pred,i} - P_{obs,i})$. With the provision that if ME > 0, it means that the model tends to overestimate rainfall compared to observation data. If ME < 0, it means that the model tends to underestimate rainfall compared to observation data. If ME ≈ 0, it means that the model has no significant bias.

From the results of data processing, data interpretation techniques were carried out by understanding the relationship between the results of radar image processing, satellite images, and rainfall data on the characteristics of heavy rainfall in Padang City. The interpretation process was carried out comprehensively by considering spatial, temporal, and atmospheric dynamics aspects.

In addition to statistical analysis, physical meteorological analysis was conducted to interpret rainfall formation processes. Radar reflectivity data were used to identify rainfall intensity patterns, while satellite cloud-top temperature data were used to analyze cloud characteristics. Convective clouds, indicated by high reflectivity and low cloud-top temperatures, are generally associated with intense and localized rainfall, whereas stratiform clouds produce more widespread but lower intensity rainfall. This approach allows a more comprehensive understanding of rainfall characteristics and helps explain differences between radar, satellite, and rain gauge observations in Padang City.

RESULTS AND DISCUSSION

From the results of the research conducted, it was found that the rainfall estimates obtained from weather radar and satellite images compared to rainfall observation data in the Padang City area were as follows:

1. Correction of Radar and Satellite Data

In this study, before conducting a comparative analysis between data sources, rainfall data from radar and satellites first underwent a correction process based on rain gauges observation data as *ground truth*. The correction process was carried out to minimize systematic biases that commonly occur in remote sensing data, such as the tendency to *underestimate* heavy rainfall due to spatial resolution limitations, radar signal *attenuation*, and cloud top temperature-based estimation approaches on satellites. With this correction, the estimated values obtained are more representative of the actual rainfall conditions in Padang City, as shown in Table 2.

Table 1. Correction values for each rain gauges

No.	Rain Stations Gauges	Satellite(mm)	Radar(mm)
1	Bayur Bay	43.821 + 0.406 s*	56.614 + 0.126 r*
2.	Lubuk Minturun	52.634 + 0.264 s*	52.179 + 0.287 r*
3.	Marapalam	46.789 + 0.457 s*	57.934 + 0.365 r*
4.	Padang Cement Mine	51.421 + 0.473 s*	57.475 + 0.376 r*
5.	Nanggalo	46.880 + 0.514 s*	55.461 + 0.381 r*
6.	Bandar Buat	46.694 + 0.483 s*	42.808 + 0.786 r*
7.	Semen Padang Water Plant	61.018 + 0.285 s*	61.192 + 0.258 r*

s* = Satellite rainfall value

r* = Radar rainfall value

Based on the correction results table, each rain gauges shows different constant values and correction coefficients for satellite and radar data. This indicates that the characteristics of the relationship between estimated data and observed data are location-specific. The differences in these values show that the amount of adjustment required at each rain gauges is not uniform. Stations with larger coefficients show a greater need for adjustment to the observed data.

When linked to topographical conditions, it can be seen that rain gauges with relatively similar elevations tend to show correction coefficient values that are not significantly different. This indicates that elevation is a factor that influences the pattern of radar and satellite rainfall estimation. Regions with similar elevation characteristics have relatively similar precipitation responses to area-based sensor observations. Thus, the correction values obtained at a rain gauges can potentially be used as an approximation for other regions with similar elevation and topographical characteristics, especially in areas without rain gauges. However, this application still depends on the similarity of the geographical and spatial conditions of the region.

2. MAE and ME Analysis at Each Rain Gauges

After the radar and satellite data were corrected using the specified correction formula, adjusted estimate values were obtained. The corrected data were then used to calculate the Mean Absolute Error (MAE) and Mean Error (ME) to measure the level of accuracy and bias tendency of the observation data. MAE shows the average absolute error, while ME shows the direction of deviation (overestimate or underestimate). The MAE and ME values obtained are then classified into error level categories as presented in Table 2.

Table 2. Categories of MAE and ME values

ME Category	Description
ME > 0	Overestimate
ME < 0	Underestimate
ME≈ 0	Significant

Based on the analysis results at each rain gauges, the MAE and ME values for each region can be seen in Table 3.

Table 3. MAE and ME Analysis

No	ME(mm)		MAE(mm)	
	satellite	radar	satellite	radar
Bayur Bay	-18.41	-25.80	18.43	27.82
Marapalam	-23.36	-43.10	24.70	43.10
Padang cement mine	-33.74	-41.17	33.74	41.42
Bandar Buat	-26.90	-36.74	26.98	36.74
Water plant in Padang	-38.18	-35.71	38.85	36.63
Nanggalo	-27.16	-35.50	27.28	36.16
Lubuk Minturun	-22.35	-26.31	23.58	26.31

Based on descriptive statistics from several observation locations, both satellite and radar data show negative ME values, indicating a tendency to *underestimate* observed rainfall. In the Teluk Bayur area, satellite ME values of −18.41 and radar ME values of −25.80 were obtained, with MAE values of 18.43 and 27.83, respectively. In Bandar Buat, the satellite ME value was −26.91 and the radar ME value was −36.74, with MAE values of 26.99 and 36.74, respectively, while in

Lubuk Minturun, the satellite ME value was −22.36 and the radar ME value was −26.31, with MAE values of 23.58 and 26.31, respectively. In the Marapalam area, the ME values were −23.37 for satellite and −43.11 for radar, with MAEs of 24.71 and 43.11, while in Nanggalo, the ME values were −27.16 for satellite and −35.51 for radar, with MAEs of 27.29 and 36.16. Furthermore, at the Padang Cement Mine, the ME values were −33.74 for satellite and −41.18 for radar, with MAEs of 33.74 , and 41.42. Furthermore, at the Padang Cement Water Plant, the ME values were −38.18 for satellite and −35.71 for radar, with MAEs of 38.85 and 36.63.

In general, the larger radar ME value indicates that radar tends to produce lower rainfall estimates than satellite and observation data, and this is also supported by the smaller satellite MAE value, which shows that satellite accuracy is relatively better in most research locations. However, in the Water Plant Semen Padang area, different results were obtained, namely a satellite ME value of −38.18 and a radar ME value of −35.72 with a satellite MAE of 38.86 and a radar MAE of 36.64, indicating that at this location, radar estimates are slightly more accurate than satellite estimates, although the difference is not very significant. Overall, the results of the study show that satellite-based rainfall estimates tend to have a better level of accuracy than radar in representing observed rainfall in most of the study areas.

3. Rainfall Comparison Graph for 1 Year at 7 Rain Gauges

The rainfall comparison graph presented in this section is compiled based on corrected data that has been calculated and then visualized in graph form to facilitate analysis of fluctuation patterns and comparisons between radar, satellite, and rain gauge data in Figure 2.

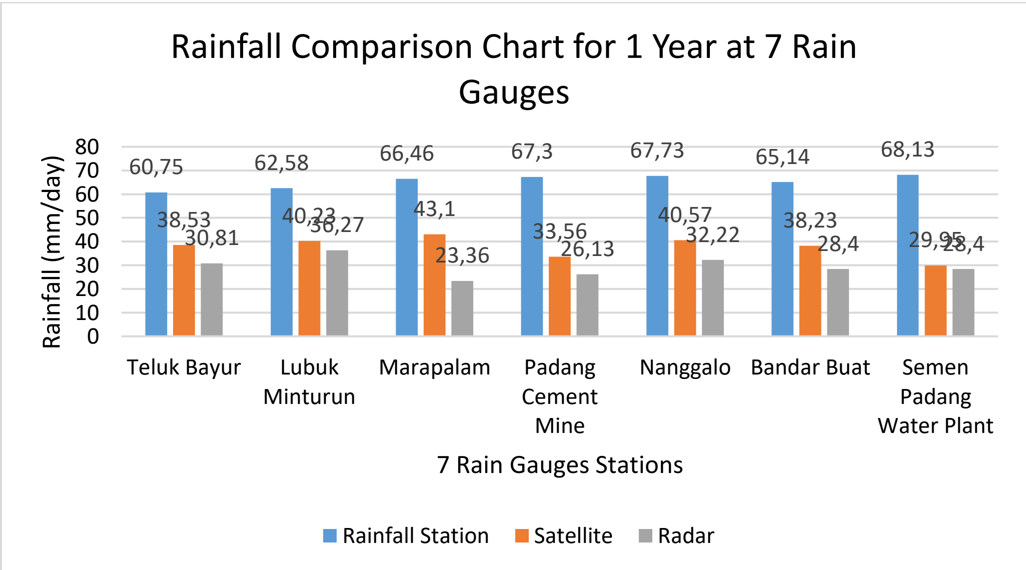

Figure 2. Rainfall Graph at 7 Rain Gauges

Based on the rainfall comparison graph at Teluk Bayur Station during 2024, it can be seen that rainfall data from rain gauges stations, satellites, and radar show relatively similar fluctuation patterns throughout the observation period. Overall, the three data sources show consistent seasonal patterns, with an increase in rainfall in the middle to late year and a decrease in certain periods in the middle of the year. This indicates that despite differences in absolute values, both satellites and radar are able to capture rainfall temporal trends in Teluk Bayur quite well, but still require validation against rain gauge data as the main reference.

Based on the rainfall comparison graph in Lubuk Minturun, it can be seen that rain gauge data generally shows higher and relatively stable values compared to satellite and radar data. Overall, this graph shows that the temporal pattern of rainfall is relatively consistent, but there are differences in magnitude, with satellites and radars tending to underestimate rain gauge observations in Lubuk Minturun.

Based on the graph, it can be seen that rainfall in Marapalam fluctuated throughout 2024 with relatively similar patterns across the three data sources, although the magnitude differed. Rain gauges data generally shows the highest rainfall values compared to satellite and radar data, indicating that direct measurements in the field tend to capture greater rainfall intensity. In general, this graph shows a similarity in temporal patterns between the three data sources, although there are differences in rainfall magnitude. This is reasonable due to differences in measurement methods, where rain gauges are point-based, while satellites and radar represent a wider area.

Based on the rainfall comparison graph at the Semen Padang Mine Station during the 2024 observation period, it can be seen that the three data sources, namely rain gauges, satellites, and radar, show quite varied fluctuation patterns throughout the year. Rain gauge data consistently recorded higher values than satellite and radar data. This variation is likely influenced by cloud reflectivity, the topography around the mine site, and potential radar signal attenuation. Overall, the three data sources show relatively consistent rainfall change patterns despite differences in absolute values. Rain gauges remain the main reference as direct observation data, while satellite and radar data serve as representative supporting data in describing the temporal trends of rainfall in the Padang Cement Mine area.

Based on the rainfall comparison graph at Nanggalo Station during the observation period, it can be seen that the three data sources, namely rain gauges, satellites, and radar, show quite dynamic fluctuation patterns throughout the year. Overall, the three measurement methods show consistency in rainfall change patterns, despite differences in absolute values. Rain gauges remain the main reference because they provide direct measurements in the field, while satellite and radar data can be used as supporting data capable of describing temporal trends in rainfall in the Nanggalo region.

Based on the rainfall comparison graph at the Bandar Buat Station during the 2024 observation period, it can be seen that the three data sources, namely rain gauges, satellites, and radar, show relatively similar fluctuation patterns despite clear differences in values. Rain gauge data consistently shows higher rainfall values than satellite and radar data. Overall, the three measurement methods show consistency in the temporal pattern of rainfall, with a significant increase in April and fluctuations in the middle to the end of the period. Despite the differences in absolute values, satellite and radar data are still able to illustrate the trend of rainfall changes in Bandar Buat, but validation of rain gauge data is still needed as the main reference for field measurements.

Based on the rainfall comparison graph at the Semen Padang Water Plant Station during the 2024 observation period, it can be seen that rain gauges, satellite, and radar data show quite dynamic fluctuation patterns over time. Rain gauges data generally has higher values than the other two data sources. Overall, the three data sources show a relatively consistent pattern of rainfall change, despite differences in absolute values. Rain gauges remain the main reference because they provide direct measurements in the field, while satellite and radar data can be used as representative supporting data in describing temporal rainfall trends in the Semen Padang Water Plant area.

4. Correlation Analysis

Table 4. Correlation analysis of rain gauges, satellite, and radar at 7 rain gauges

Rain Gauges	Radar		Satellite	
	Correlation	Significant	Correlation	Significant
Bayur Bay	0.217	0.419	0.593	0.015

Marapalam	0.539	0.047	0.553	0.040
Padang cement mine	0.511	0.013	0.619	0.002
Bandar Buat	0.725	0.001	0.635	0.005
Water plant cement padang	0.580	0.007	0.450	0.019
Nanggalo	0.662	0.000	0.706	0.000
Lubuk Minturun	0.633	0.027	0.688	0.013

Based on Table 4, the correlation between rainfall observations at rain gauges and radar and satellite data at seven locations shows variations in correlation values and levels of significance. In general, most rain gauges show a significant correlation ($p < 0.05$) with both radar and satellite data, indicating that both sensors are still capable of representing rainfall variability in the Padang City area. However, the varying strength of the correlation at each rain gauge reflects the influence of local factors such as geographical conditions, topography, distance from the radar, and the characteristics of rainfall at each location.

At the Teluk Bayur rain gauge station, the radar correlation is relatively low and insignificant, while the satellite shows a fairly strong and significant correlation. This condition is thought to be related to the characteristics of coastal areas that are prone to sea *clutter* interference and small-scale convective rainfall that is difficult for radar to capture consistently. In contrast, satellites are better able to represent large-scale cloud systems developing in coastal areas. In Marapalam and Tambang Semen Padang, both radar and satellite show significant correlations with relatively balanced values, indicating that rainfall in these areas is fairly homogeneous and organized, so that it can be well represented by both sensors despite the influence of topography and local activity.

The Bandar Buat rain gauge station showed a very strong and significant radar correlation, indicating that this location is within optimal radar coverage with relatively little topographical influence on the radar beam. This allows the radar to capture variations in rainfall intensity more accurately. Meanwhile, at the Semen Padang Water Plant, the radar correlation is higher than the satellite correlation, indicating the dominance of local rainfall with medium to high intensity that is more sensitive to radar reflectivity, while satellites tend to be less optimal in representing surface rainfall in areas with complex topography.

In Nanggalo and Lubuk Minturun, both sensors showed strong and significant correlations, with satellite correlation values slightly higher. These conditions indicate that rainfall in both areas is relatively stable and influenced by medium to large-scale rainfall systems, making the relationship between satellite, radar, and surface rainfall parameters more consistent. Overall, the differences in correlation values between rain gauges confirm that the performance of radar and satellites is greatly influenced by local conditions, making the complementary use of both sensors important for obtaining more accurate rainfall estimates in the Padang City area.

5. **Analysis of heavy rain clouds on November 17, 2024**

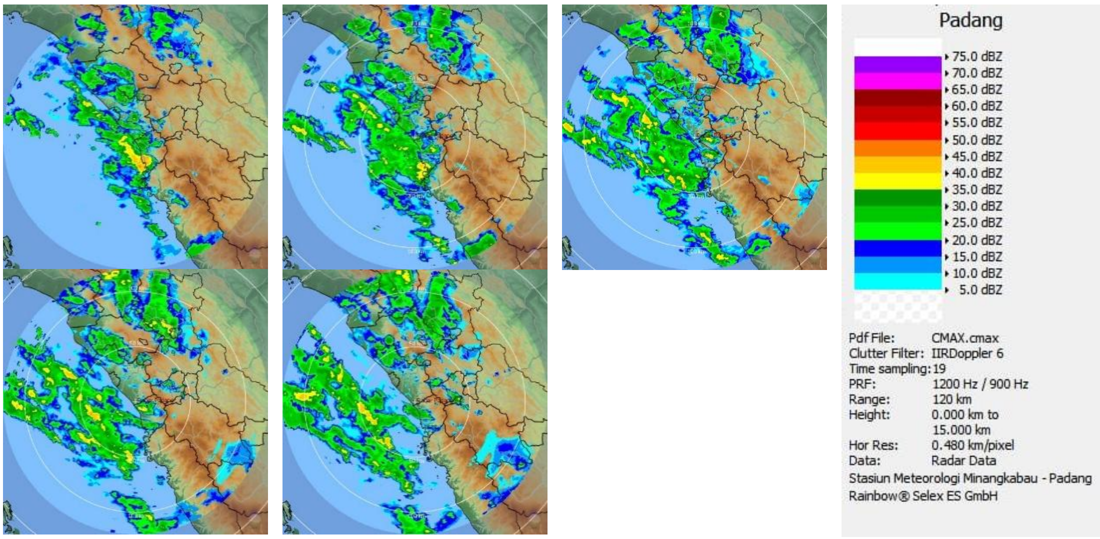

Figure 3. Heavy Rain Cloud Growth at 10:38 a.m. - 2:08 p.m.

CMAX analysis from the Minangkabau Meteorological Station shows that the city of Padang experienced a strong convective cycle from noon to late afternoon. The period between 10:38 AM and 11:38 AM WIB was the development and initial peak phase, where convective cells reached high reflectivity (35 to 55 dBZ) and were concentrated in the coastal and central areas, causing heavy rain in Nanggalo, Teluk Bayur, and Bandar Buat as a result of strong daytime surface heating. At 12:08 WIB, a significant shift occurred, with a strong convective core (40 dBZ) beginning to develop in the eastern hills, directly affecting the Padang Cement Mine and the Padang Cement Water Plant.

This phenomenon indicates the dominance of orographic mechanisms that maintain heavy rainfall intensity in the upstream area. After reaching its peak in the afternoon, this activity entered a phase of decay and dispersion from 13:08 WIB to 14:08 WIB. The highest reflectivity disappeared, and the rain generally dissipated into a stratiform type (moderate to light rain, 35 dBZ) that spread widely, covering the entire city of Padang, including Lubuk Minturun, with a longer duration of rain.

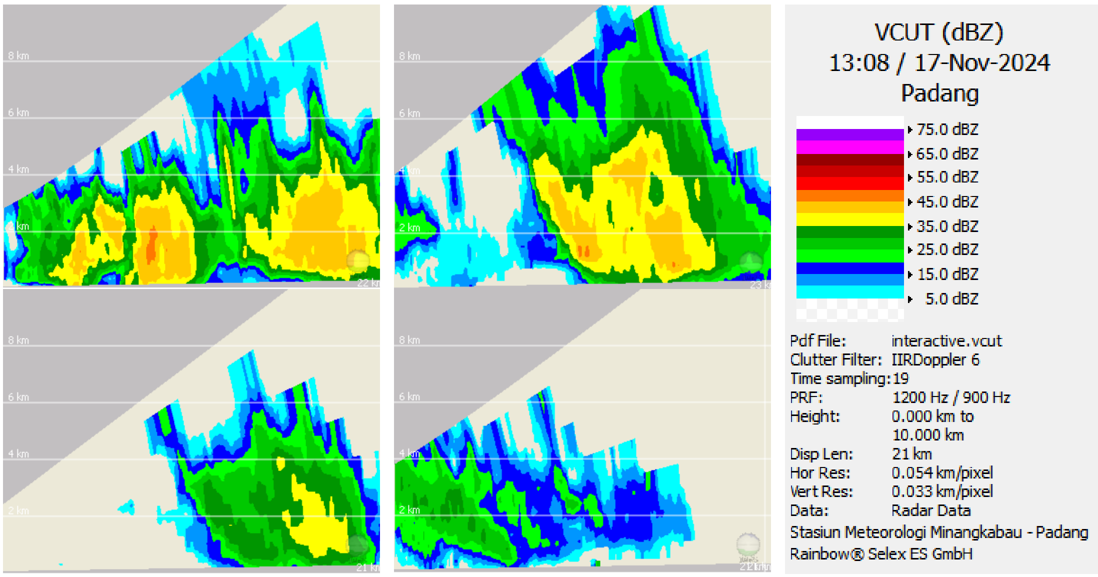

Figure 4. Height of Heavy Rain Clouds at 11:08-14:08

Vertical cross-section radar (VCUT) analysis from 11:08 AM to 2:08 PM on November 17, 2024, shows the classic evolution of a strong thunderstorm toward weaker and more evenly distributed rainfall. From 11:08 AM until it reached its peak intensity at 12:08 PM, the clouds were in a mature convective phase, characterized by very high echo peaks (reaching 6 to 8 km) and a strong reflectivity core (45 dBZ) extending vertically to medium altitudes, indicating the presence of large raindrops and intense *updrafts*. After 12:08 WIB, the clouds entered a *dissipating* phase. This was evident from the decrease in cloud echo height to around 5 km at 13:08 WIB, which then became even shallower at 14:08 WIB. At the last observation, the strong reflectivity had almost completely disappeared from the upper atmosphere, leaving only low rain echoes near the surface. Overall, VCUT visually recorded the collapse of the storm cloud's vertical structure and its transition to stratiform rain (light to moderate rain) dominated by horizontal processes.

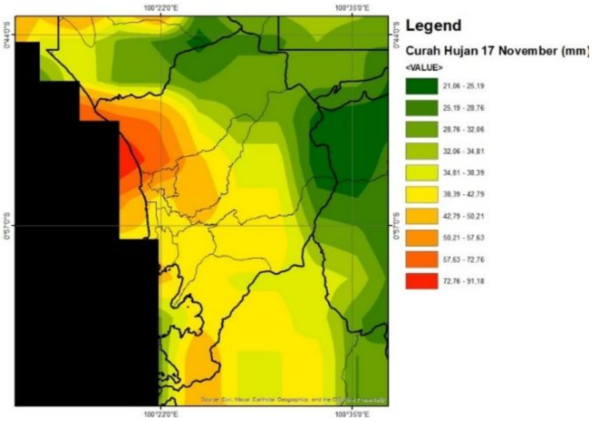

Figure 5. CHIRPS Satellite Image of Padang

Daily rainfall data from the CHIRPS satellite on November 17 clearly indicates that all rain gauges in Padang City were in a zone of very high to extreme rainfall accumulation. Coastal and lowland locations such as Teluk Bayur, Nanggalo, and Bandar Buat were located precisely in the highest rainfall path, which reached the Red category, with accumulations between 72.76 mm and 91.18 mm in one day.

Meanwhile, rain gauges located further upstream and in the hills, namely the Semen Padang Water Plant and the Semen Padang Quarry, were also in a zone of significant high rainfall, mostly in the *Orange* category (around 50.21 mm to 72.76 mm). This massive rainfall concentration confirms that all vital areas in Padang City, from the coast to the upstream catchment area, experienced extreme rainfall on that day, which is very consistent with the strong and prolonged convective activity recorded in the CMAX and VCUT radar analysis.

From the overall analysis results, it can be concluded that satellite imagery data generally shows a higher level of accuracy than radar imagery in representing measured rainfall in the field, as indicated by smaller MAE values at most rain gauge stations. However, this difference in accuracy is not uniform across all locations. In certain areas, radar data shows comparable or slightly better performance, indicating that the accuracy of each data source is influenced by local environmental conditions.This variation can be explained by the influence of topography and spatial rainfall characteristics in Padang City, where complex terrain such as coastal and mountainous areas affects the performance of remote sensing measurements. These findings are consistent with previous studies, which reported that radar data tends to underestimate rainfall due to signal attenuation and topographic interference, while satellite data provides more stable estimates but may smooth extreme rainfall values.

CONCLUSION

Based on the results of error and correlation analysis, both radar and satellite image data generally show a tendency to underestimate rainfall observations at rain gauges in Padang City , as indicated by the Mean Error (ME) value, which is predominantly negative at almost all rain gauges. However, satellite imagery showed relatively better performance than radar, as indicated by Mean Absolute Error (MAE) values that were generally smaller and a more consistent and significant correlation with rain gauge data. Significant correlations in radar data were found at most rain gauges stations, but showed a weakening in coastal areas such as Teluk Bayur, while satellite image data showed positive and significant correlations at all rain gauges stations with varying degrees of strength. This difference in performance is influenced by the local and spatially heterogeneous nature of rainfall in Padang City, as well as the complex influence of the Bukit Barisan topography on the precipitation process and the performance of remote sensing sensors. Thus, satellite image data is considered more reliable in representing spatial rainfall variations in Padang City, while radar data remains important as supporting data, particularly in real-time rainfall monitoring and analysis of high-intensity rainfall events.

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