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Evaluation Of The Infrared Single Channel Method On The Himawari-8 Satellite For Rainfall Estimation

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Abstract – The Himawari-8 weather satellite covers all parts of Indonesia in near real-time every 10 minutes. Therefore, satellite imagery is convenient for monitoring the weather in Indonesia's vast territory, and the weather formation is very complex. For this reason, in this study 4 rainfall estimation methods, namely Auto Estimator, IMSRA, Non-Linear Relation, and Non-Linear Inversion compared their performance. These are methods to calculate the rainfall rates using the Himawari-8 IR channel. The research area used for this study is the Indonesian archipelago. The metric used for this study is Root Mean Squared Error (RMSE) and Pearson Correlation. The data verifier used is GSMAP rain data per hour. To adjust the verifier data, the Himawari-8 image data used is also hourly data. This RMSE is used to determine the error value of general rain estimates and its response to light, moderate, and heavy rainfall events. Pearson correlation was used to see how well the correlation between estimated rainfall and GSMAP rainfall was. The experimental results show that IMSRA has the lowest RMSE value of 1.27 mm/hour and a correlation of 0.53. for general rainfall estimation. For the response to slight, moderate, and heavy rain IMSRA also has the lowest RMSE values, i.e., 1.72 mm/hour and 3.98 mm/hour, and 8.62 mm/hour and correlations 0.48, 0.14, 0.09. However, in the case of the response to extreme rains, the Non-Linear Inversion method has the lowest RMSE of 28.01 mm/hour and a correlation of 0.09. In general, IMSRA is the best method of estimating rainfall for most cases. All methods gradually increase in RMSE and weaken in correlation with the bigger intensity of GSMAP rainfall.

Keywords – Himawari-8, gsmap, rainfall estimation, RMSE, pearson correlation.

I. INTRODUCTION

Weather monitoring is essential for civil and military purposes. Knowing weather conditions such as rain is significant for military purposes when carrying out Search and Rescue (SAR) missions. The absence of weather information and the wrong strategy can be life-threatening for military and civilian personnel who will be evacuated. Civilians also interests need weather information for aviation and agricultural purposes.

Various remote sensing equipment is used to monitor weather conditions in near real-time and widely. There are two popular remote sensing equipment, radar and satellite. Radar is an active remote sensing equipment. The radar emits electromagnetic waves and is then reflected in the air by particles. From the reflected waves, the radar can detect the presence of precipitation particles in the air to estimate the area where rainfall occurs. Unlike radar, the satellite is passive remote sensing equipment. Satellites are placed in space and passively receive infrared and near-visible waves emitted by the Earth's surface. The waves received by satellites are then processed and estimate the presence of clouds, weather conditions, and the condition of the Earth's surface.

Satellites and radars have their advantages and disadvantages. Radar has better spatial resolution and can detect thin clouds but significant such as squall lines. Nevertheless, the radar coverage area is small compared to the satellite, where the coverage area is extensive. The geostationary satellite, Himawari-8, can monitor all areas of Indonesia and especially the maritime continent in Indonesia. For this advantage, the satellite can monitor the weather that cannot be covered by radar. For example, rescuing ships stranded on remote islands need satellite data to monitor weather conditions.

One of the Himawari-8 satellite products that BMKG often uses for monitoring weather conditions is the Himawari-8 Enhanced IR product. This product is a derivative of Himawari-8's cloud top temperature InfraRed channel. The lower the cloud top temperature value on the IR channel is often indicated, the higher the rainfall. Rainfall estimation methods using IR channels have been carried out in previous studies, such as Auto Estimator (AE), IMSRA, Non-Linear Relation (NLR), and Non-Linear Inversion (NLI).

This study compares four rainfall estimation methods: Auto Estimator, IMSRA, Non-Linear Relation, and Non-Linear Inversion, to calculate estimated rainfall in Indonesia. GSMAP rain data per hour and Himawari-8 image data were used for data verification. The accuracy of the error rainfall estimation method is indicated by the RMSE value and is associated with rainfall intensity, such as light, moderate, and heavy rain. Pearson correlation is used to determine the correlation between rainfall estimation and GSMAP rainfall. The methods are also compared in different rainfall intensities to look for the difference. GSMAP data is a satellite-estimated rainfall that has been calibrated using rain gauge data observation on the Earth's surface. Therefore, GSMAP data is used for verification data to calculate the accuracy of models for estimating rainfall.

II. Research Methods

This study's research area is Indonesia's territory and surroundings. GSMAP rain data per hour and Himawari-8 IR data were used for data verification, and the research period is January 2022. The flow data processing in this study can be seen in Figure 1.

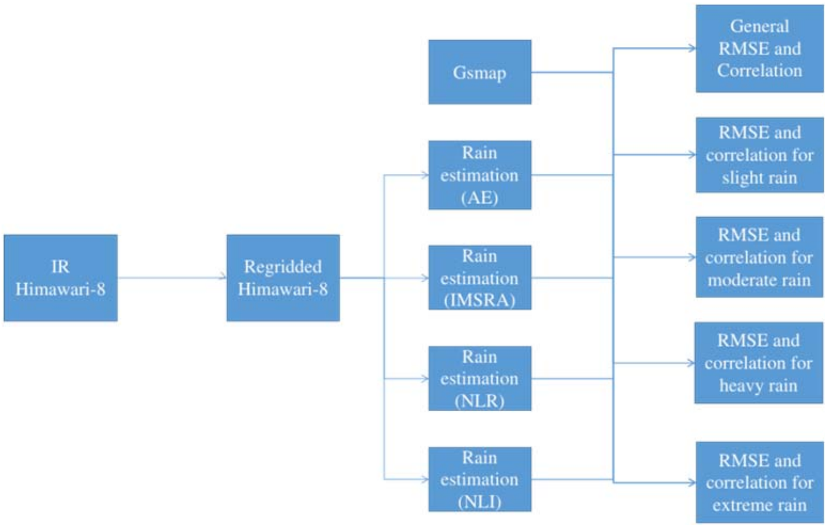


Figure 1. Flowchart of the experiment

Before estimating rainfall, the Himawari-8 data are gridded to match the resolution with GSMAP. Then, the regridded data is transformed into four rainfall equations from four rainfall estimation methods. It (1-4) can be seen from the equation for transforming IR data into rainfall using the AE, IMSRA, NLR, and NLI methods. In this equation, Rf is rainfall, and IR is the value from the Himawari-8 IR channel data [1].

$$Rfp = 1.1183 \cdot 10^{11} e^{-3.6382 \cdot 10^{-2} \cdot IR^{1.2}} \quad (1)$$

$$Rfp = 8.613098 \cdot e^{\frac{-(IR-197.97)}{15.7061}} \quad (2)$$

$$Rfp = 2 \cdot 10^{25} IR^{-10.256} \quad (3)$$

$$Rfp = 1.380462 \cdot 10^{-7} \cdot e^{\frac{3789.518}{IR}} \quad (4)$$

After obtaining the value of estimated rainfall, the performance of this method is measured using RMSE (RMSE) (5) and Pearson correlation (cor) (6). The RMSE was measured for the entire estimation. The estimated rainfall calculation compares the method rfp with GSMAP data (rft). Then, the RMSE measured the model's response to rainfall intensity, such as light, moderate, and heavy rain events.

$$RMSE = \sqrt{\frac{\sum_{x=1}^{n}(rfp_x - rft_x)}{n}} \tag{5}$$

$$cor = \frac{n(\sum_{x=1}^{n} rfp_x \cdot rft_x) - (\sum_{x=1}^{n} rfp_x)(\sum_{x=1}^{n} rft_x)}{\sqrt{\left(n\sum_{x=1}^{n} rfp_x^2 - (\sum_{x=1}^{n} rfp)^2\right) \cdot \left(n\sum_{x=1}^{n} rft_x^2 - (\sum_{x=1}^{n} rft)^2\right)}} \tag{6}$$

III. Result And Discussion

The RMSE value and general correlation obtained from the experiment can be seen in Table 1. It can be seen that IMSRA has the lowest error value compared to other methods. The correlation of IMSRA predictions is also the highest with NLR. Meanwhile, the AE error value is the highest. The correlation of predictions from AE is also the lowest compared to other methods.

Table 1. RMSE and general correlation of precipitation estimation methods

Method	RMSE	Correlation
AE	11.63	0.46
IMSRA	1.27	0.53
NLR	7.56	0.53
NLI	2.80	0.51

The performance of the rainfall estimation method compared to rainfall intensities can be seen in Table 2. The result four rainfall estimation methods are better at estimating light-intensity rainfall. The higher the rainfall intensity estimation, the higher the error. The correlation between estimated rainfall and GSMAP also decreases with increasing rain intensity. The correlation of estimated rainfall has its lowest point when estimating heavy and extreme rainfall, which is 0.09. In this case, all rainfall estimation methods have the same correlation value.

IMSRA has the lowest RMSE errors for all rainfall intensities for light, moderate, and heavy rain intensities. Meanwhile, the NLR has the lowest RMSE error value for cases of extreme rain. The IMSRA method significantly increases the error value in estimating heavy rainfall towards the extreme. It can be seen that the RMSE IMSRA increased by 24.96. This increase in error values is higher even if all IMSRA errors at the light, moderate, and heavy rain intensities are combined.

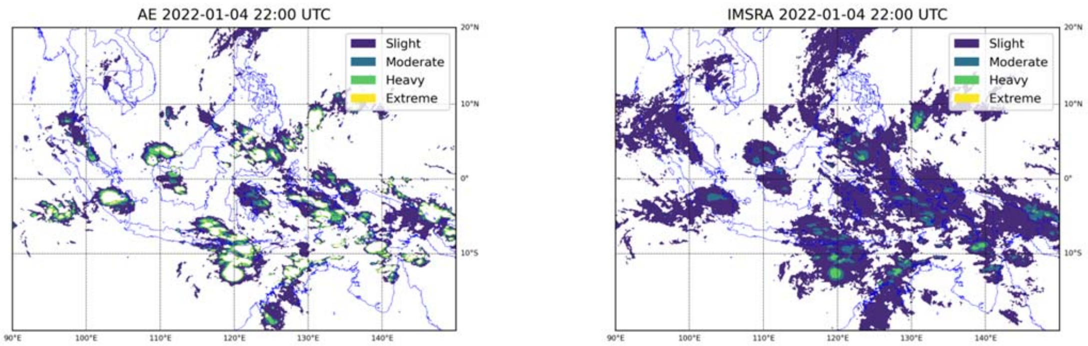
Table 2. RMSE and correlation to different rainfall intensity events

Rain intensity	Metric	AE	IMSRA	NLR	NLI
Slight	RMSE	23.81	1.72	16.09	5.83
	Correlation	0.32	0.48	0.51	0.41
Moderate	RMSE	59.37	3.98	28.70	12.12

	Correlation	0.12	0.14	0.14	0.13
Heavy	RMSE	79.96	8.62	30.34	14.50
	Correlation	0.09	0.09	0.09	0.09
Extreme	RMSE	94.41	33.58	29.03	28.01
	Correlation	0.09	0.09	0.09	0.09

In Figure 2, one can see one of the cases resulting from the mapping of estimated rainfall using AE, IMSRA, NLR, and NLI, as well as the cloud top temperature of the IR channel in Figure 3 on January 22, 2022, in 22.00 UTC. It can be seen that the pattern of rainfall occurrence in all rainfall estimation methods follows the cold cloud top temperature pattern of the IR channel. The lower the temperature, the higher the estimated rainfall will be. It happens because all the methods used calculate the rainfall based only on this IR channel variable. The visible variation of the different estimation methods is the sensitivity of these methods in detecting rainfall. The NLR method is the most sensitive among other methods. It can be seen from the mapping results, which show light rain in all mapped areas. It makes the NLR method tend to produce false alarm estimates. False alarm, in this case, is when the rain estimation method states that there is rainfall in an area when the area does not rain.

Figure 4 shows the rainfall that occurred on January 4, 2022, at 22.00 UTC based on the GSMAP. The spatial rainfall pattern from the GSMAP differs significantly from that produced by the rainfall estimation method. Even so, the AE and NLR methods can capture extreme rain events in the Java Sea, bordering Kalimantan and Sulawesi.



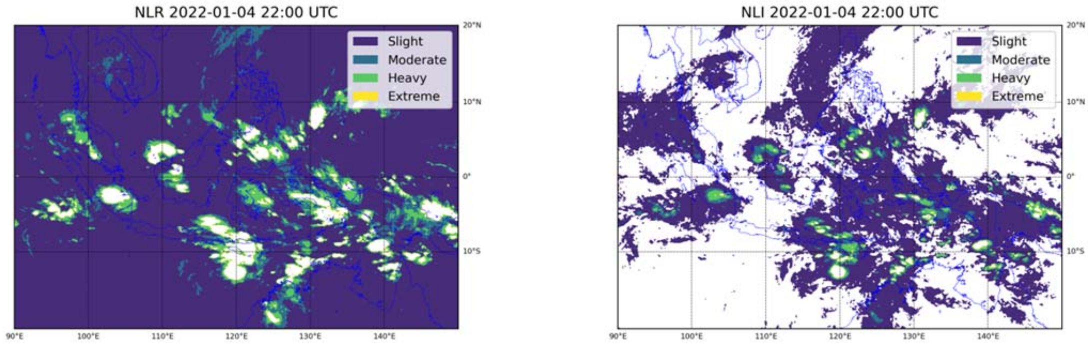


Figure 2. Estimated rainfall on January 4 at 22.00 UTC

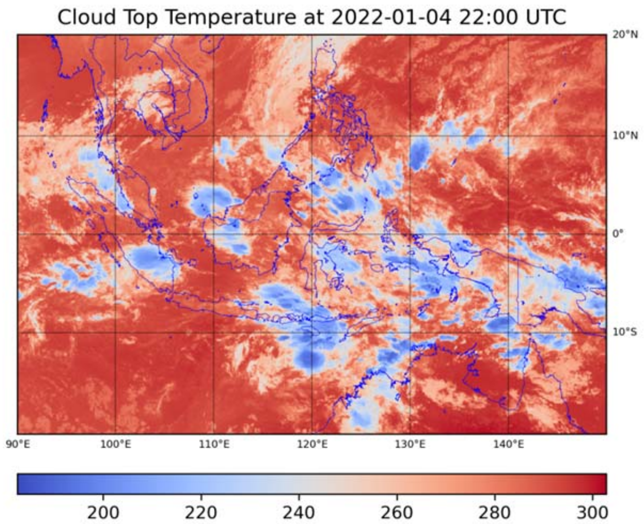


Figure 3. Cloud Top Temperature berdasarkan kanal IR Himari-8

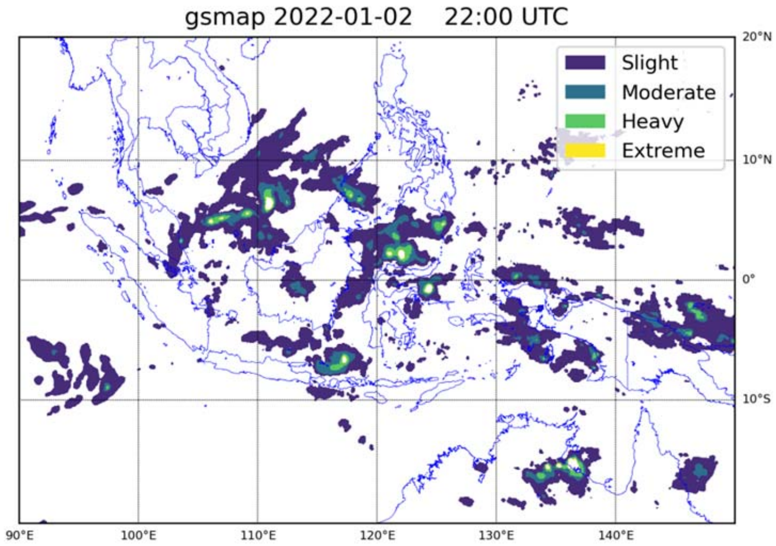


Figure 4. Cloud Top Temperature berdasarkan kanal IR Himari-8

In Figure 5, you can see a graph of the correlation between the cloud top temperature of the IR channel and GSMAP rainfall for January 2022 data. The correlation between these two factors is not very strong. Cloud top temperature and GSMAP rainfall are inversely correlated, namely -0.44. There are many cases where the cloud top temperature is low, but the rainfall is low or does not rain.

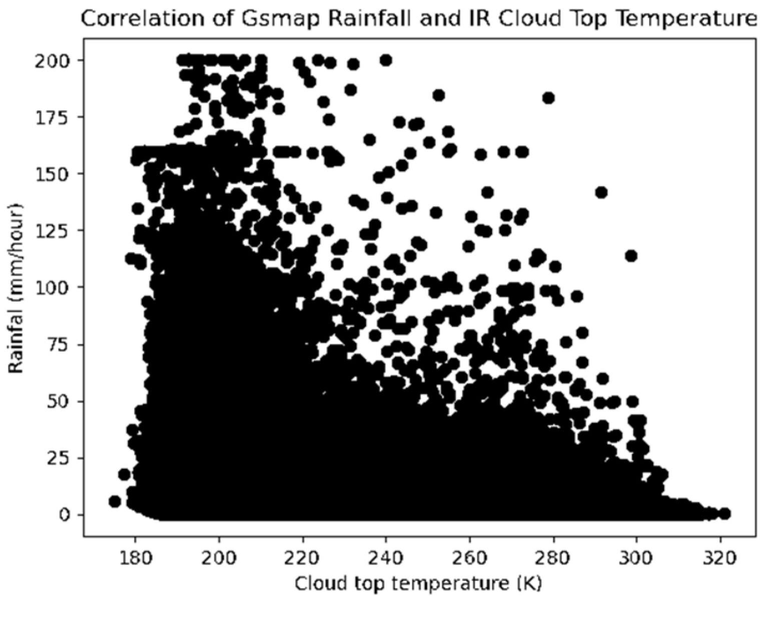


Figure 5. Correlation of Gsmap Rainfall and IR Cloud Top Temperature

IV. CONCLUSION

In this study, of the four rainfall estimation methods tested, IMSRA has the best performance, both for RMSE and correlation values. However, the overall performance of the method worsens the heavier the intensity of the rain. It happens because these four rainfall estimation methods only consider one variable. The estimated rain pattern from the four estimation methods tested has the same pattern as the low temperature on the IR channel. Meanwhile, the process of occurrence of rainfall is very complex. The occurrence of rain does not fully follow the low-temperature pattern of the cloud top temperature value of the IR channel. It is evidenced by the correlation value of the cloud top temperature of the IR channel and GSMAP rainfall which could be stronger.

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