Eight scenarios rapid update cycle effect on weather radar data assimilation WRF toward rainfall prediction in Palembang (cases study of flood events on November 12th, 2018)

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Abstract. Weather Research and Forecasting (WRF) is an open source numerical weather prediction model that can be used for high resolution rainfall predictions. Besides these advantages, WRF output accuracy can be affected by the initial condition. The accuracy of WRF model can be improved by data assimilation. Data assimilation is combining observation data with model data to improve the initial state of atmospheric flow. This study aims to investigate the effect of assimilation weather radar in models using WRF for predictions rainfall events in Palembang region on November 12th, 2018. This study uses radar radial velocity data as input data for assimilation. The assimilation technique uses the 3DVAR with rapid update cycle (RUC) procedure 1 hour, 3 hours, 6 hours with spin up 12 and 6 hours. The output of the model verified using Global Satellite Mapping of Precipitation (GSMaP) data and using rain gauge data for point verification. The results of this study indicate that the output of the assimilation model, especially in the spin-up 12 hours scenario implementation of the 1-hour RUC is better than the model without assimilation. From the eight scenario models implemented, it can be concluded that the 12 hours spin up is better than the 6 hours spin up.

1. Introduction

Numerical Weather Prediction (NWP) is one of the scientific weather modeling systems needed to predict weather through physics calculations in simulating a complex atmosphere [1]. The function of numerical weather prediction system assists weather forecasters generate weather prediction information promptly [2].

The weather prediction results from the WRF in territories tropical seas, tend to have a higher value than the observed data, while for the Indonesian region the results are inversely related. Research and development on an approach that uses original data from observations as the initial state, this approach is called data assimilation (DA) [3]. The data assimilation technique in the WRF numerical weather model uses a special program called WRF Data Assimilation (WRFDA). WRFDA is divided into several assimilation techniques, namely the Ensamble Kalman Filter (EnKF), The Three Dimensional...
Varitional (3DVAR), and The Four Dimensional Variational (4DVar) [2]. EnKF and 4DVAR in their application require high computational costs but 3DVAR is considered to have the best performance of all types of methods in analyzing hydrometeorological elements even with limited computational efficiency [4]. During its development, the data that can be assimilated in WRFDA is in the configuration of surface observation data, aerial observation, satellite and radar. The advantage of weather radar is having sufficient data (Z, V, and W) to represent the weather conditions in an area, since one point observation can generate data up to 200 km in diameter with high resolution.

[5] states that in general, the predictions generated after the assimilation of the Z and V PPI combination data produce rainfall which tends to be greater than observations (overcast). However, the positive impact of assimilating radar radial velocity data using the 3DVAR technique only lasts three to six hours after the initial prediction time. This shows that the wind field changes rapidly as the cloud system evolves, to increase the effectiveness of data assimilation with the 3DVAR technique the rapid update cycle (RUC) procedure should be involved in the prediction system. The application of RUC is able to produce rainfall estimates with smaller differences in quantity and phase with observational data.

The incident case was selected when there was a big flood on November 12th, 2018 in the Palembang area. The Doppler radar at the Meteorological Station of SMB II Palembang, may potentially a source of meso-scale weather analysis data and its predictions which play a role in producing data coverage that cannot be provided by in-situ instruments. Palembang is a lowland swamp city with an average elevation of 8 m above sea level [6]. Considering the condition of Palembang which has extremely typical conditions, therefore it requires accurate weather predictions. In order to improve the accuracy, hence radar data assimilation in weather prediction is carried out.

2. Materials and Methods
2.1. Location and Research Methods
The location of the research was conducted in the Palembang area, astronomically located at 2.96° S and 104.76° E, by referring case study on November 12th, 2018. This research was conducted with experimental and comparative models. The comparative research model was carried out by comparing the WRF model without assimilation with the assimilated WRF model in addition to radial velocity radar data by applying the rapid update cycle forecast (updates per 1 hour, 3 hours, and 6 hours) to improve the initial conditions of the model. In each experiment that was conducted, a spin-up of 12 and a spin-up of 6 hours was used to observe the comparison.

2.2. Research Data
The data used in this research are as following:
1. GSMaP rainfall data
GSMaP rainfall data is a high-resolution global rainfall data obtained from the site ftp://hokusai.eorc.jaxa.jp/realtime/. The GSMaP data in this study were used as spatial verification. GSMaP data has high precision estimated from satellite data.
2. Global Forecast System (GFS) Data
GFS data is the data used for the experiment of the non-assimilated WRF-ARW model and the radar data assimilation, having global coverage with a resolution of up to 28 km. GFS data was obtained from the site https://rda.ucar.edu/datasets/ds084.1/ with a resolution of 0.25° x 0.25° up to the first 12 hours of the previous day as spin up time.
3. Graphical Radar Data
BMKG Palembang C-Band Doppler Radar (CDR) data on November 11th and 12th, 2018 were used as observational data for the initial numerical prediction, obtained from the Class II Sultan Mahmud Badaruddin Meteorological Station Palembang.

2.3. Running model
Running assimilated WRF model uses GFS background data (Wrfinput_d0 * and WRFdy), and ASCII format radar. This study conducted four WRF assimilation scenarios, as follows:
Scenario 1: WRF Spin up 12 hours without assimilation
Scenario 2: WRF Spin up 6 hours without assimilation
Scenario 3: WRF Spin up 12 hours assimilation data radial velocity with implementation update cycle per 1 hour
Scenario 4: WRF Spin up 6 hours assimilation data radial velocity with implementation update cycle per 1 hour
Scenario 5: WRF Spin up 12 hours assimilation data radial velocity with implementation update cycle per 3 hours
Scenario 6: WRF Spin up 6 hours assimilation data radial velocity with implementation update cycle per 3 hours
Scenario 7: WRF Spin up 12 hours assimilation data radial velocity with implementation update cycle per 6 hours
Scenario 8: WRF Spin up 6 hours assimilation data radial velocity with implementation update cycle per 6 hours

Assimilation was carried out using the 3DVAR technique and applied a rapid update cycle (updates per 1 hour, 3 hours, and 6 hours). This process produced the output of radar data assimilation WRF model for each WRF assimilation scenario.

2.4. Analysis and conclusions
Rain prediction uses the output data of the WRF model without assimilation scenario and the WRF assimilation model with ruc implementation (updates per 1 hour, 3 hours, and 6 hours). There are some analysis and verification in predicting rain, namely:

a. Analysis the effect of assimilation on the initial conditions of WRF as input data.
b. Spatial analysis and verification by mapping the 24-hour rainfall data from the WRF and GSMaP models.
c. Analysis and verification at the observation point using model output data with rain observation data obtained from several AWS / ARGs in the Palembang area.

Verification to determine the performance of the WRF model without assimilation and WRF assimilation by searching PC, POD, FAR prediction skills using contingency tables on the dichotomy of rainy events, yes or no and searching the percentage of hits, underestimates, and overestimates based on case studies.

3. Results and Discussion
3.1. Analysis of Simulation of Rain Event without Assimilation
On November 12th, 2018 there had been rain in most parts of Palembang, causing flooding at several points. According to observational data, daily rainfall for 24 hours was recorded as 125 mm. One of the model scenarios that was carried out is the non-assimilation scenario, in which no observational input data was carried out on the initial data. The initial data variation used consisted of 6 hours spin up and 12 hours spin up.

3.2. Spin up without Assimilation
Based on Figure 1. The spatial distribution pattern of daily rain in the case of November 12th, 2018 with spin up without assimilation (a) shows that the highest rainfall distribution reaches 125 mm while in (b) the spatial distribution of rain is detected significantly with a value of 25 mm - 75 mm.
3.3. Analysis the Effect of Radar Data Assimilation on the Model Initial Data

In this study, data assimilation was conducted by applying the rapid update cycle (RUC) every 1 hour, 3 hours, and 6 hours as the time window. In the application of RUC, the observational data were entered into the initial data every 1 hour, 3 hours, and 6 hours according to the research time window. The observational data used in this research was weather radar data, because it is considered to have high resolution and the availability of spatially dense data. The weather radar data used in this research was radial velocity data, because the implementation of the rapid update cycle using radial velocity data is considered to be able to improve the reliability of the model compared to without assimilation [5]. Initial data used for assimilation are 6 hours spin up data and 12 hours spin up data, which has purpose to determine the initial conditions of the atmosphere.

3.3.1. 6 Hours Spin up With Rapid Update Cycle Per 1 Hour

![Figure 2. Rapid Update Cycle per 1 hour (a) Spin Up 6 hours (b) Spin Up 12 hours](image-url)
Based on Figure 2. The spatial distribution pattern of daily rain in the case of November 12th, 2018 using the Rapid Update Cycle per 1 hour in (a) shows a significant overall rain distribution with a value of 10 mm - 125 mm. The distribution of spatial rainfall with the highest value is in the eastern region of Palembang up to 125 mm and in (b) describes the overall distribution of rain significantly with an intensity of 40 mm - 125 mm. The highest intensity with a value of 125 mm is around the east to northeast region of Palembang.

3.3.2. 6 Hours Spin up With Rapid Update Cycle Per 3 Hours

Based on Figure 3. The spatial distribution pattern of daily rain in the case of November 12th, 2018 using the Rapid Update Cycle per 3 hours in (a) describes a significant overall rain distribution with an intensity of 30 mm - 75 mm. The highest intensity with a value of 77 mm is located around the east to northeast of the Palembang region and in (b) the overall distribution of rainfall is significant with an intensity of 30 mm - 50 mm in the Palembang region.

3.3.3. 6 Hours Spin up with Rapid Update Cycle per 6 Hours

Based on Figure 4. The spatial distribution pattern of daily rain in the case of November 12th, 2018 using the Rapid Update Cycle per 6 hours in (a) shows a significant overall rain distribution with an intensity of 10 mm - 125 mm. The highest intensity with a value of 125 mm is around the east to northeast region of Palembang.
Based on Figure 4. The spatial distribution pattern of daily rain in the case of November 12th, 2018 using the Rapid Update Cycle per 6 hours in (a) describes the overall distribution of rain significantly, the rainfall intensity of 10 mm - 75 mm. The spatial rainfall distribution with the highest value in Figure 4.7b is in the southeastern region of Palembang up to 80 mm and in (b) the overall rainfall distribution is significant with an intensity of 30 mm - 50 mm.

3.4. Comparisons of Model Scenario
The results of the WRF model that was conducted on the spatial distribution of rain during the rainy events on November 12th, 2018 produced results that tended to be the same pattern, both without assimilation and rapid update cycle scenarios of 1 hour, 3 hours, and 6 hours. Figure 5. shows that the intensity of rainfall produced by the 6-hour spin up without assimilation or ruc assimilation for the Palembang region tends to be low with an intensity value of 10 mm - 40 mm. The 12-hour spin-up model without assimilation or ruc assimilation also generally had higher values than the 6-hour spin-up model. It is clearly observed in the 12 hours spin up model with 1 hour ruc in Figure 5(d), which obviously illustrates the rainfall intensity value distributed evenly in the Palembang area reaching a value of 40 mm, with the highest value of 125 mm in the eastern region of Palembang.
Figure 5. Comparisons of model scenario on November 12th, 2018 (a) spin up 6 hours without assimilation (b) spin up 12 hours without assimilation, (c) spin up 6 hours with ruc 1 hour, (d) spin up 12 hours with ruc 1 hour, (e) spin up 6 hours with ruc 3 hours, (f) spin up 12 hours with ruc 3 hour, (g) spin up 6 hours with ruc 6 hours, (h) spin up 12 hours with ruc 6 hours
3.5. Verification
Verification was carried out in two ways, namely spatially and dichotomically.

3.5.1. Spatial Verification
Spatial verification used GSMAP data as verification data, then overlaid GSMaP data with the earlier WRF model results, in order to show the spatial bias value. Previously, the GSMAP output data which had the same resolution as the WRF model, namely 0.25°, would be regrided or grid equalization with the model output data using the Climate Data Operation (CDO) application. Furthermore, the two data were searched for the bias value by overlaying using the Grads application.

The bias results for the rainy events on November 12th, 2018 are shown in Figure 6. The overlay results for the 6 hours spin up model in Figures 6a, 6c, 6e, and 6f illustrate that in general the model values tend to be underestimated to the value of -80 distributed evenly in the Palembang area. Whereas for the 12-hours spin up model shown in Figure 6b, 6d, 6f, and 6g, and the results are quite varied with the best bias value and closer to the GSMAP data is the 1 hour ruc scenario model. The 6-hours spin-up model shows that some areas of Palembang tend to be overestimated.

Figure 6. Bias Scenario Model on November 12th, 2018 (a) spin up 6 hours without assimilation (b) spin up 12 hours without assimilation, (c) spin up 6 hours with ruc 1 hour, (d) spin up 12 hours with ruc 1 hour, (e) spin up 6 hours with ruc 3 hours, (f) spin up 12 hours with ruc 3 hour, (g) spin up 6 hours with ruc 6 hours, (h) spin up 12 hours with ruc 6 hours
3.5.2. Dichotomy Verification
This verification showed the value skills of PC, POD, and FAR on rain prediction by means of a rain dichotomy yes/no that was calculated and measured based on the AWS and ARG point area which is used as verification data.

3.5.2.1. Percent Correct (PC)
Figures 7 and 8. show the graph of the verification value for the rain event on November 12th, 2018. Figure 7. in particular shows the verification value using the 12 hours spin up model scenario, generally showing improved reliability in the model, especially the 1 hour RUC scenario. Firstly, the Gandus area shows that the highest PC verification value is the 1 hour RUC scenario with a value of 80%, while the lowest value is the non-assimilation scenario with a value of only 32%. Secondly, the Jakabaring area has a fairly diverse value with the highest value in the 1 hour RUC scenario of 76% while the lowest value is setantr without assimilation with a value of only 40%. Thirdly, the Muara Padang area also has quite a variety of values with the best scenario being the model without assimilation of 77%, while the lowest value is the 6-hour RUC scenario of 48%.

![Figure 7](image.png)

**Figure 7.** PC on November 12th, 2018 *spin up 12 hours*

Furthermore, the P. Lampan area has quite a variety of values with the highest value in the 1 hour RUC scenario of 76% and the lowest value in the non-assimilation scenario of 44%. The Palembang Climatology Station area has various values with the best value in the 1 hour RUC scenario of 83%, while the lowest value is shown in the 6 hours RUC scenario with a value of 41%. The Palembang Meteorological Station area has various values with the best value in the 1 hour RUC scenario of 80%, and the lowest value is shown in the non-assimilation scenario with a value of only 31%.

![Figure 8](image.png)

**Figure 8.** PC on November 12th, 2018 *spin up 6 Hours*
Figure 7. shows the verification values using the 6 hours spin up model scenario, generally showing the verification values that tend to be the same. First, the Gandus area shows that the highest PC verification value is the 1 hour RUC scenario and without assimilation with a value of 76%, while the lowest value is the 3 hour RUC scenario with a value of only 48%. Second, the Jakabaring area has a fairly diverse value with the highest value in the 1 hour RUC scenario of 84% while the lowest value is 6 hours RUC scenario with a value of 68%. Third, the Muara Padang area has a low value which is the same as the best scenario is the 1 hour RUC model of 84%.

Furthermore, in the P. Lampan area, the value is quite diverse with the highest value in the 1 hour RUC scenario of 84% and the lowest value in the non-assimilation scenario of 44%. The Palembang Climatology Station area has various values with the best value in the 3-hour RUC scenario of 79%, while the lowest value is shown in the non-assimilation scenario with a value of 64%. The Palembang Meteorological Station area has various values with the best value in the 3-hour RUC scenario of 72%, and the lowest value is shown in the 6-hour RUC scenario with a value of 64%.

3.5.2.2. False Alarm Ratio (FAR)

Figures 9 and 10. show the graph of the FAR verification value for the rain event on November 12th, 2018, in general, the values tend to be the same. The FAR value which indicates the reliability of the best model is close to 0, the smaller the FAR value, the better the reliability of the model. Figure 9. shows the verification values using the 12-hour spin up model scenario and shows the various values.

First, the Gandus area generally shows a variety of FAR verification values with the best value in the 1 hour RUC scenario of 35%. Second, the Jakabaring area shows a value of 40%. Third, the Muara Padang area has a value of 33%. Furthermore, in the P. Lampan area it has a value of 40%. The Palembang Climatology Station area has a value of 30%. The Palembang Meteorological Station area has a value of 30%. Figure 10. shows the verification values using the 6 hours spin up model scenario, generally showing various values. First, the Gandus area generally shows various FAR verification values with the best value in the 1 hour RUC scenario of 38%. Second, the Jakabaring area has 27%. Third, the Muara Padang area has a value of 23%. Furthermore, in the P. Lampan area has a value of 30%. The Palembang Climatology Station area has a value of 38%. The Palembang Meteorological Station area has a value of 36%.
3.5.2.3. Probability of Detection (POD)

The perfect score for the POD method dichotomy verification is one. If the value almost near to and even reaching one, then the model will categorize as has good reliability.

Figures 11 and 12 show a graph of the POD verification value for the rain event on November 12th, 2018, in general, the values tend to be the same. Figure 11 shows the verification values using the 12-hours spin up model scenario, generally showing various values. First, the Gandus area generally shows a variety of POD verification values with the best value in the 1 hour RUC scenario of 100% and the lowest value in the 6 hour RUC scenario of 55%. Second, the Jakabaring area has a fairly diverse value with the best value in the 1 hour RUC scenario of 100% and the lowest value in the 3 hour RUC scenario of 66%. Third, the Muara Padang area has quite diverse values with the best scenario is the 1 hour RUC model of 91% and the lowest value in the 3 hour RUC scenario of 63%. Furthermore, the P. Lampan area has the same value between all scenarios with a perfect score of 100%. The Palembang Climatology Station area has a value that tends to be the same as the value of 100%, but there is an anomaly in the value of the 6 hour RUC to the lowest POD value of 55%. The Palembang Meteorological Station area has various values with the best value in the 1 hour RUC scenario of 90%.
Figure 12. POD on November 12th, 2018 spin up 6 Hours

Figure 12, shows the verification values using the 6-hour spin up model scenario, generally showing fairly the same values. First, the Gandus area generally shows a variety of POD verification values with the best value in the scenario without assimilation of 100% and the lowest value in the 6 hours RUC scenario of 66%. Second, the Jakabaring area has a fairly diverse value with the best value in the scenario without assimilation of 100% and the lowest value in the 6-hours RUC scenario of 77%.

Third, the Muara Padang area has a value that tends to be the same as the value of 90%. Furthermore, the P. Lampan area has the same value between all scenarios with a perfect score of 100% with anomaly in the scenario without assimilation as the lowest scenario with a value of 88%. The Palembang Climatology Station area has a value that tends to be the same as the value of 100%, but there is an anomaly in the value of the 1 hour RUC to the lowest POD value of 89%. The Palembang Meteorological Station area has various values with the best value in the 1 hour RUC scenario of 80%.

Based on the analysis of daily rainfall patterns with spatial distribution between 6 hours spin up, 12 hours spin up, and the implementation of the rapid update cycle, does not show a very significant difference. The rain event on November 12th, 2018 also showed the same results, the 12 hours spin up model produced a more significant daily rain distribution than the 6 hours spin up model which tended to have a low value. This research used spatial daily rain verification to observe the rain pattern spatially by comparing it with the GSMAP rain map as a verificator. In the rain case on November 12th, 2018, the rain pattern produced by the 6 hours spin up model without assimilation, 6 hours spin up with 1 hour ruc, 6 hour spin up with 3 hour ruc, and 6 hour spin up with 6 hours ruc closely match the map GSMAP rain though tends to be underestimated. While the model run on a 12 hours spin up without assimilation, a 12 hours spin up with a 1 hour cycle, a 12 hours spin up with a 3 hours roll, a 6 hours spin up also produces the same pattern results as the GSMAP rain map but tends to be overestimated. In the 12 hours spin up model with 1 hour ruc, it can be said to be the best scenario because it has the lowest bias value and the pattern results tend to be the same as the GSMAP rain map.

4. Conclusion
Rain verification is also carried out dichotomically to test the reliability of the model in predicting whether or not rain will occur using the PC index which describes the accuracy value of the model, the POD index which describes the ability to predict rain and FAR which shows the tendency of overforecasting. According to the summary of the verification rain prediction skill results on
November 12th, 2018, dichotomically yes/no in table 1, the best skills of PC, POD, and FAR occurred in the 12-hour WRF spin-up with 1 hour ruc. The summary of the verification rain prediction skill results on November 12th, 2018 is dichotomically yes/no shown in table 1, the best PC, POD, and FAR skills occur in the same model as above, namely the 12 hours spin up model with 1 hour ruc. However, the model with daily spatial rainfall distribution patterns that are closest to and tend to be the same as GSMAP rainfall data is a 12-hour spin-up model with 1 hour ruc implementation.

From the summary table 1, generally for models with 12 hours spin up show better reliability than models with 6 hours spin up according to the statement [5]. In general, the effect of assimilation with the best implementation of ruc is 1 hour ruc with 12 hours of spin up, but for other ruc scenarios it does not show a significant pattern of improvement in WRF model without assimilation. In accordance with the statement [7] modeling with the implementation of ruc requires a model configuration that is in accordance with the area such as parameterization, background error, and local conditions of the research area. RUC implementation is also effective in short-term forecasts of up to 6 hours ahead [5].

Based on this research, it can be concluded that the best spatial and dichotomous verification results are shown by the 12-hours spin-up model implementing rapid update cycles per 1 hour. The best model mean values for the PC, FAR, and POD values in the related model were 73%, 39%, 62%, respectively. The prediction results are classified as underestimated due to many factors, one of which is that the scheme parameterization test has not been carried out for the Palembang area. The results will be even better when using the tested and parameterized scheme for the Palembang region. Improving the prediction results by assimilating radar data with the implementation of the rapid update cycle can be conducting by using radar reflectivity data or combination of reflectivity with radial velocity.

### Table 1. Summary Model on November 12th, 2018

| skill  | Wilayah     | WRF Model |
|--------|-------------|-----------|
| FAR    | Gandus      | B2 B1 B3 A3 A1 A4 B4 A2 |
|        | Jakabaring  | B2 A2 A1 A3 A4 B3 B4 B1 |
|        | Muara Padang| B2 A2 A1 A3 A4 B1 B3 B4 |
|        | P. lampan   | B2 A2 A3 A4 B4 A1 B3 B1 |
|        | Staklim     | B2 A3 A2 A4 A1 B1 B3 B4 |
| POD    | Gandus      | B2 A2 A1 A4 B3 A3 B4 B1 |
|        | Jakabaring  | A2 A3 A1 B2 A4 B4 B3 B1 |
|        | Muara Padang| A2 A1 A3 A4 B2 B1 B3 B4 |
|        | P. lampan   | B2 A2 A3 A4 B4 A1 B3 B1 |
|        | Staklim     | B2 A3 A2 A4 A1 B1 B3 B4 |
|        | Stamat      | B2 A3 A1 A2 A4 B3 B4 B1 |

Improving the prediction results by assimilating radar data with the implementation of the rapid update cycle can be conducting by using radar reflectivity data or combination of reflectivity with radial velocity.
Information:
A1 = Without spin up assimilation for 6 hours
A2 = RUC 1 hour \textit{spin up} 6 hours
A3 = RUC 3 hours \textit{spin up} 6 hours
A4 = RUC 6 hours \textit{spin up} 6 hours
B1 = Without spin up assimilation for 12 hours
B2 = RUC 1 hour \textit{spin up} 12 hours
B3 = RUC 3 hours \textit{spin up} 12 hours
B4 = RUC 6 hours \textit{spin up} 12 hours

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