Improvement of numerical weather prediction of heavy rain event using radar data assimilation using rapid update cycle method in Jabodetabek Region

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Abstract. Predictions of accurate heavy rain are needed in building a flood early warning system. One of the most commonly used weather parameter modeling models is the Weather Research Forecasting, but the results of the WRF model prediction have deficiencies in accuracy so that data assimilation needs to be done to improve accuracy. This research aims to determine the effect of radar data assimilation by applying RUC using WRF 3DVAR to improve the predictions of heavy rain events in the Jabodetabek area with cases representing each of the four seasons, on February 20, 2017, April 3, 2017, June 13, 2017, and November 09, 2017. The data used for this research are synoptic observation data, GSMaP, GFS, Radar data, in the form of Z CAPPI products. In general, WRF radar data assimilation with RUC shows better spatial and point values. This can be seen in the spatial rainfall distribution on February 20th, 2017, June 13th, 2017, and November 09th, 2017 analysis on Climatology Station of PondokBetung, as well as the analysis of rain dichotomy, shows WRF assimilation using RUC with a TS value increased by 9%, PC value increased by 10%, and FAR value fixed by 18%.

Keywords: Altitude Plan Position Indicator, data radar Z Constant, Rapid Update Cycle, Weather Research Forecasting.

1. Introduction
Accurate heavy rain predictions are needed in building flood early warning systems, according to Hastuti (2018), in understanding a complete weather system can be done objectively by using modeling, one of which is WRF (Weather Research Forecasting) [1]. However, WRF has flaws in accuracy and certainty, so this WRF model must be studied further to improve its accuracy [2-4].

One solution to overcome problems related to the accuracy and certainty of these predictions is to assimilate the data. Data assimilation (DA) is a technique used to improve the accuracy of prediction models by taking into account observational data in the prerequisite processing and combining all atmospheric information available at a given time to produce an estimate of its condition in a

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predetermined time analysis [5-7]. Data that can be assimilated are observation data (synop, metar, rason, etc.), satellite radiation observation data, and radar data (reflectivity and radial velocity data) [4,8-9].

The assimilation data which are used in this study was radar data. Radar data has the advantage of having high resolution and broad coverage using Z CAPPI radar products and Jabodetabek was chosen as a research region based on previous research conducted by Hastuti (2018) [1]. This study also used a new approach using radar reflectivity data to initialize a Rapid Update Cycle (RUC) model that has been developed and is being tested in real-time in NOAA / ESRL/ GSD [10]. Gustari (2014) conducted a radar data assimilation study using the RUC scheme and concluded that the results of RUC trials with three-hour intervals increased the probability of detection (PoD), and threat scores [2]. In other studies, RUC has produced accurate 36-hour predictions, especially at distances of 10 km [11]. In hourly RUC 3DVAR analysis, various observations were combined with RUC forecasts 1 hour earlier to renew mass, speed, and humidity [12-13]. Based on this, research needs to be carried out on the effect of radar data assimilation by applying RUC using WRF 3DVAR to improve the prediction of heavy rainfall in Jabodetabek.

2. Research Methodology

2.1. Research Focus

This study aims to determine the effect of radar data assimilation by applying RUC using WRF 3DVAR to improve the prediction of heavy rain events in the Jabodetabek area with cases that each represent four seasons, namely the rainy season on February 20, 2017, the transition from rain to dry season on the 3rd April 2017, the dry season on June 13, 2017, and the transition from dry to rainy season on November 9, 2017. This study uses an experimental method, a method that is carried out by doing manipulation of a research object and the existence of controls [14] and qualitative methods that contains a whole expression through data collection is descriptive and uses analysis [15].

2.2. Data Processing and Analysis Techniques

2.2.1. Pre data processing. Processing observation data, GSMaP data to verify vertically and spatially, then processing GFS data with WRF-ARW software with a 12 - hour spin up. Details about horizontal grid resolution, parameterization schemes, and temporal resolution can be seen in table 1.

| Configuration                | Description                      |
|------------------------------|----------------------------------|
| Horizontal grid Resolution   | Domain 1 = 27 km                 |
|                              | Domain 2 = 9 km                  |
|                              | Domain 3 = 3 km                  |
| Temporal Resolution          | 180 minutes                      |
| Physical Suite               | Tropical                         |
| Cumulus Scheme               | Domain 1 = New Tiedke (6)        |
|                              | Domain 2 = New Tiedke (6)        |
|                              | Domain 3 = 0                     |
| Microphysics Scheme          | Domain 1 = WRF Single Moment 6 class (16) |
|                              | Domain 2 = WRF Single Moment 6 class (16) |
|                              | Domain 3 = WRF Single Moment 6 class (16) |
| Radiation Scheme             | Domain 1 = RRTMG (4)             |
|                              | Domain 2 = RRTMG (4)             |
|                              | Domain 3 = RRTMG (4)             |
| Border Layer Scheme          | Domain 1 = YSU (1)               |
### Configuration

| Domain 2 | Description |
|----------|-------------|
| = YSU (1) |
| Domain 3 | = YSU (1) |

#### Number of Vertical Level

32 Layers

The second step was processing. Then do the c-band Doppler EEC radar data processing for assimilation that is radar data that has been obtained has a volumetric format (.vol) which then the format was changed to two, namely polar coordinate netCDF and CSV using EDGE applications. Then, the polar coordinate netCDF format radar data were being processed with wradlib-python application to convert the format to cartesian coordinate netCDF while processing the data into Z CAPPI data in the netCDF format. The results of this process will produce radar data in ASCII format or the WRFDA application input format.

#### 2.2.2. Running model

The model with the assimilation of radar data without applying RUC on running uses GFS background data that has been obtained in the previous process in the form of wrfinput_d0* and wrfdy, and ASCII format radar. The assimilation model applies RUC on running using GFS background data in the form of wrfinput_d0* and wrfdy and ASCII format radar. In this process using the Rapid Update Cycle (RUC) assimilation scenario (table 2)

#### Table 2. RUC assimilation scenario with 12-hour spin-ups

| Date             | Scheme            | Description                                |
|------------------|-------------------|--------------------------------------------|
| February 19th    | Cycle 1           | GFS + Radar Data at 12 UTC                 |
| February 19th    | Cycle 2           | Radar Data at 18 UTC + wrfout cycle 1      |
| February 19th    | Cycle 3           | Radar Data at 00 UTC + wrfout cycle 2      |

This RUC assimilation scenario was carried out in all cases. The results of this process were wrfvar_output (for each domain) and wrfbdy_d01. Furthermore, the output was being processed modeling with WRF-ARW and produce a file in form wrfout_d0*. The results obtained from the model that has been running namely wrfout_d0* then processed on ARWPost to convert the data to the format .datand .ctl on each model.

#### 2.3. Analysis and verification

The verification carried out in this study was spatial verification and dichotomy, in example prediction, is said to be a dichotomy if the prediction reads "yes, the event will occur" or "no, the event will not occur" [15]. The dichotomy verification used a contingency table that would get Hits values, for example, Predicted events that actually occur, False Alarms, in example events that were predicted to occur, do not occur (or namely “Misses”), in example events that were predicted not to occur but being occurred, Correct Negatives, in example events that were predicted not to occur, true not occur and Total Marginal is the total amount on the right and bottom of the table called the marginal distribution.

Furthermore, contingency tables are used to calculate predictive skills that aim to test the reliability or level of fitness of predictions with observations [2-3].

#### Table 3. Configuration Table

| Observation | Yes | No  |
|-------------|-----|-----|
| Yes         | Hits| False Alarms |
| No          | Misses| Correct Negatives |
Contingency tables in table 3 can be analyzed using values such as Percent Correct (PC), Treat Score (TS), Probability of Detection (POD) and False Alarm Ratio (FAR).

\[
PC = \frac{\text{hits} + \text{correctnegatives}}{\text{total}}
\]

\[
FAR = \frac{\text{falsealarms}}{\text{hits} + \text{falsealarms}}
\]

\[
POD = \frac{\text{hits}}{\text{hits} + \text{misses}}
\]

\[
TS = \frac{\text{hits}}{\text{falsealarms} + \text{hits} + \text{misses}}
\]

PC values range from 0 to 1, as a perfect value of 1. The range of FAR values is between 0 and 1, where the model is considered perfect if FAR = 0, which means there are no false alarms and the worst value if FAR = 1. POD values range from 0 to 1, as a perfect value of 1. The range of TS values from 0 to infinity where the value 1 is a perfect score.

3. Discussion
This research began by comparing the results of the assimilation of radar data before and after a rapid update cycle with GSMaP data as a verifier. GSMaP showed the distribution of rainfall in the Jabodetabek area dominated by light to heavy rain with an intensity of 5-60 mm. Assimilation without RUC shows the distribution of rain in the Jabodetabek area is dominated by moderate to heavy rain with an intensity of 15-120 mm. Assimilation using RUC shows the distribution of rain in the Jabodetabek area was dominated by light to heavy rain with an intensity of 5-110 mm (figure 1).

![Figure 1](image_url)

Figure 1. Heavy rain on February 20th, 2017, (a) GSMaP data, (b) Assimilation without RUC, (c) RUC
In figure 2, GSMaP showed the distribution of rain in the Jabodetabek area dominated by mild to moderate rain with an intensity of 5-35 mm. Assimilation without RUC shows the distribution of rain in the Jabodetabek area dominated by moderate to heavy rain with an intensity of 30-100 mm. Assimilation using RUC shows the distribution of rain in the Jabodetabek area dominated by moderate to heavy rain with an intensity of 10-70 mm.

In figure 3, GSMaP showed the distribution of rain in the Jabodetabek area dominated by mild to moderate rain with an intensity of 5-35 mm. Assimilation without RUC shows the distribution of rain in the Jabodetabek area dominated by moderate to heavy rain with an intensity of 30-100 mm. Assimilation using RUC shows the distribution of rain in the Jabodetabek area dominated by moderate to heavy rain with an intensity of 10-70 mm.
In figure 3, GSMaP showed the distribution of rain in the Jabodetabek area dominated by mild to moderate rain with an intensity of 5-30 mm. Assimilation without RUC shows the distribution of rain in the Jabodetabek area dominated by light to heavy rain with an intensity of 5-100 mm. Assimilation using RUC shows the distribution of rain in the Jabodetabek area dominated by light to heavy rain with an intensity of 5-90 mm.

GSMaP showed the distribution of rain in the Jabodetabek area dominated by light to heavy rain with an intensity of 5-60 mm. Assimilation without RUC shows the distribution of rain in the Jabodetabek area dominated by light to heavy rain with an intensity of 5-100 mm. Assimilation using RUC shows the distribution of rain in the Jabodetabek area dominated by light to heavy rain with an intensity of 5-100 mm (Fig. 4).

Verification of time series prediction of rain accumulation per three hours was carried out at five points of the rain observation station namely Soekarno Hatta Cengkareng Meteorology Station, Pondok Betung Climatology Station, Kemayoran Meteorological Station, Tanjung Priok Meteorological Station, and Citeko Meteorological Station (Table 4). Time series rain verification showed that assimilation using RUC was superior, especially at Pondok Betung Climatology Station. The dichotomous rain prediction verification (yes/no) was done by looking at forecast skills in each rainy case. The following is the combined value of forecast skill between assimilation using RUC and assimilation without RUC.

The difference value of TS between assimilation without RUC and assimilation using RUC was 0.09, where the assimilation value without RUC was 0.29 and assimilation using RUC 0.38 which the value was close to 1 (perfect score). The PC value between assimilation without RUC and assimilation using RUC has a different value of 0.1, where the assimilation value without RUC was 0.71 and the assimilation value using RUC was 0.81. Assimilation without RUC and assimilation using RUC for POD values have the same value that was 0.54. This shows that around 54% of the predicted "yes" events actually happened. The FAR value indicates a difference in the value of 0.18. (Fig. 5)
Table 4. Verification of the time series prediction for rain accumulation per three hours

| Region          | Date       | WRF Model |          |          |
|-----------------|------------|-----------|----------|----------|
|                 |            | Without RUC | RUC      |          |
| Cengkareng      | February 20th | +         | +        |          |
|                 | April 3rd   | +         | +        |          |
|                 | June 13th   | -         | -        |          |
|                 | November 9th | -         | -        |          |
| Pondok Betung   | February 20th | -         | +        |          |
|                 | April 3rd   | -         | +        |          |
|                 | June 13th   | -         | +        |          |
|                 | November 9th | -         | +        |          |
| Kemayoran       | February 20th | +         | -        |          |
|                 | April 3rd   | -         | +        |          |
|                 | June 13th   | -         | -        |          |
|                 | November 9th | +         | +        |          |
| Tanjung Priok   | February 20th | -         | +        |          |
|                 | April 3rd   | +         | -        |          |
|                 | June 13th   | -         | -        |          |
|                 | November 9th | +         | -        |          |
| Citeko          | February 20th | +         | +        |          |
|                 | April 3rd   | -         | -        |          |
|                 | June 13th   | -         | -        |          |
|                 | November 9th | -         | -        |          |

Figure 5. Combined forecast skill score

4. Conclusion
In general, the results of radar data assimilation using RUC show better values spatially and point compared to assimilation without RUC. The spatial verification proved that assimilation using RUC has good results especially on February 20th, 2017, June 13th, 2017, and November 09th, 2017. The time series analysis and dichotomous rain analysis (yes/no) proves that assimilation using RUC has good results based on the results of the analysis especially on Pondok Betung Staklim, and the results of the
dichotomy rain analysis show a superior value on all skills with a TS value increased by 9%, PC values increased by 10% and improved FAR values by 18%.

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