Application of advanced research WRF model using tropical (New Tiedtke) scheme and Kain-Fritsch scheme in predicting short-term weather in Palembang and its surrounding areas

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Abstract. The New Tiedtke and Kain-Fritsch schemes in WRF-ARW had been applied separately for the case of short-term weather predictions in Palembang and its surroundings from 1 to 7 December 2017. The WRF-ARW predictions compared to observation data at SMB II station showed that the Kain-Fritsch scheme gave better results than the New Tiedtke scheme either for temperature (MAE = 1.24 °C to 1.31 °C, RMSE = 1.49 °C to 1.60 °C, and MAPE = 4.46 to 4.67) or for relative humidity (MAE = 6.24% to 6.54%, RMSE = 7.61% of 8.28%, and MAPE = 8.16% for 8.61%). However, for precipitation predictions even from dichotomous test the FBI value obtained by the Kain-Fritsch scheme (FBI=2.6) is better than that by the New Tiedtke scheme (FBI=3) with a FBI value of 3, both schemes could not predict precipitation well (ACC = 0.67 to 0.64, TS = 0 to 0, POD = 0 to 0, FAR = 1 to 1).

1. Introduction

Weather is the condition of the atmosphere especially in the lowest part of planetary boundary layer which directly contacts to the surface of the earth. It gives biggest impacts to human life. Therefore man tries to learn weather behavior and characteristics. The effort to predict weather has been attempted from 19th century beginning with calculation of changing of barometric pressure, and current weather parameters. Now days, weather prediction is developed using numerical models calculated by computer. One of the models is named Weather Research Forecasting (WRF) which was originally developed by some atmospheric agencies such as the National Center for Atmospheric Research (NCAR), the National Centers for Environmental Prediction (NCEP), Forecast Systems Laboratory (FSL), etc. and then later also supported by some researchers from educational institutions (universities atmospheric research groups). There are two variants of WRF i.e.: WRF-ARW (Advance Research WRF) and WRF-NMM (Non-hydrostatic Meso-scale Model).

Some physics parameters have been taken into account in WRF processing such as, cumulus parameterization, wave radiation, microphysics, planetary turbulence, etc [2]. Some schemes are offered based on the choice of atmospheric parameters involved into calculations. One of them is the New Tiedtke scheme which based on analyzing tropical cyclone prediction over western pacific in the year of 2015 and 2016 [3, 4]. Another scheme is called Kain-Fritsch which was introduced by Fritsch and Chappell in 1980. The modified version of the scheme was developed in 1990 and 1993 by applying more atmospheric aspects i.e.: a simple cloud model, detrainment, entrainment and microphysics [2, 5, 6].
This study was designed to evaluate the performances of the Tropical with New Tiedtke scheme and the Kain-Fritsch scheme in predicting short-term weather over Palembang. The performances were obtained by comparing the prediction results to the observation data obtained from SMB II meteorology station Palembang, Indonesia.

2. Data
This study used WRF input data from Global Forecast System (GFS) with resolution of $0.5^\circ \times 0.5^\circ$ grid and observation data from SMB II Meteorology station Palembang, Indonesia in a period from 1 December 2017 to 7 December 2017.

3. Methodology
This research was conducted at Atmospheric Physics Laboratory, Faculty of Mathematic and Natural Sciences, Sriwijaya University, Indonesia. The predictions of temperature and relative humidity obtained by either the New Tiedtke scheme or the Kain-Fritsch scheme will be compared to observation data. Standard error analysis will be used to evaluate the performance of both schemes. While for evaluating the performance of WRF precipitation predictions, the dichotomous test will be used instead.

3.1. Standard Error Analysis

3.1.1. Mean Absolute Error. The Mean Absolute Error (MAE) is given by [7]:

$$ MAE = \frac{1}{n} \sum_{i=1}^{n} |y_i - f_i| $$

With $y_i$ is the measured value at time $i$, $f_i$ is the predicted value at time $i$, $n$ is amount of data.

3.1.2. Root Mean Square Error. The Root Mean Square Error (RMSE) is given by:

$$ RMSE = \sqrt{\frac{\sum_{i=1}^{n} (y_i - f_i)^2}{n}} $$

3.1.3. Mean Absolute Percentage Error. The Mean Absolute Percentage Error (MAPE) is given by:

$$ MAPE = \frac{1}{n} \sum_{i=1}^{n} \frac{|y_i - f_i|}{y_i} \times 100 $$

3.2. Dichotomous Test
While for precipitation, a statistical analysis namely the dichotomous test will be conducted as shown in Table 1 [8].

|                | Observed |                |
|----------------|----------|----------------|
|                | yes      | no             |
| Forecast yes   | Hits     | False Alarms   |
| Forecast no    | Misses   | Correct Negatives |
| total          | observed yes | observed no   |
|                | total    |                |

Frequency Bias Index (FBI) = $\frac{\text{Hits} + \text{False Alarms}}{\text{Hits} + \text{Misses}}$

Accuracy (ACC) = $\frac{\text{Hits} + \text{Correct Negatives}}{\text{Total}}$

Threat Score (TS) = $\frac{\text{Hits}}{\text{Hits} + \text{Misses} + \text{False Alarms}}$

Probability Of Detection (POD) = $\frac{\text{Hits}}{\text{Hits} + \text{Misses}}$
False Alarm Ratio (FAR) = \frac{False \text{ Alarm Hits}}{Hits + False \text{ Alarm}} \quad (8)

4. Result and Discussion
The New Tiedtke and Kain-Fritsch schemes in WRF-ARW had been applied separately for the case of short-term weather predictions in Palembang and its surroundings from 1 to 7 December 2017. An example of visualizations from WRF-ARW outputs is shown in figure 1.

![Figure 1. Visualization output WRF for precipitation](image)

The WRF-ARW temperature predictions compared to observation data at SMB II station can be seen in Figure 2 and their standard error analysis are shown in Table 2.

![Figure 2. Temperature comparisons between WRF Outputs and Observation Data](image)
Table 2. Standard Error Analysis of Temperature Predictions

| ERROR | Temperature (°C) | NEW TIEDTKE | Kain-Fritsch |
|-------|------------------|-------------|--------------|
| MAE   | 1.308854         | 1.245554    |
| RMSE  | 1.601993         | 1.497109    |
| MAPE  | 4.673645         | 4.468874    |

Based on standard error analysis, the WRF-ARW temperature predictions compared to observation data at SMB II station showed that the Kain-Fritsch scheme gave better results indicating by smaller errors than the New Tiedtke scheme.

The WRF-ARW relative humidity predictions compared to observation are shown in Figure 3 and their standard error analysis in Table 3.

![Figure 3](relative_humidity_comparisons.png)

**Figure 3.** Relative Humidity comparisons between WRF Outputs and Observation Data

Table 3. Standard Error Analysis of Relative Humidity Predictions

| ERROR | Relative Humidity (%) | New Tiedtke | Kain-Fritsch |
|-------|------------------------|-------------|--------------|
| MAE   | 6.539896               | 6.244582    |
| RMSE  | 8.286123               | 7.606649    |
| MAPE  | 8.606521               | 8.162834    |

Form Table 3, it can be seen that relative humidity predictions of the Kain-Fritsch scheme also gave better results than the New Tiedtke scheme.

The WRF-ARW precipitation predictions compared to observations are shown in Figure 4. The performance of predictions was evaluated using dichotomous test as shown in Table 4.

![Figure 4](precipitation_comparisons.png)

**Figure 4.** Precipitation comparisons between WRF Outputs and Observation Data
Table 4. Dichotomous Test

|               | SMB II |                      |
|---------------|--------|----------------------|
|               | New Tiedtke | Kain-Fritsch |
| Total data    | 56     | 56                   |
| HIT           | 0      | 0                    |
| False Alarm   | 15     | 13                   |
| Miss          | 5      | 5                    |
| Correct Negative | 36   | 38                  |
| Appropriate Test |     |                      |
| FBI           | 3      | 2.6                  |
| ACC           | 0.642857143 | 0.678571429 |
| TS            | 0      | 0                    |
| POD           | 0      | 0                    |
| FAR           | 1      | 1                    |

From dichotomous test, the Kain-Fritsch scheme gave a better prediction with a FBI value of 2.6 compared to the New Tiedtke scheme with a FBI value of 3. However, the both schemes had not been able to predict rainfall well which can be seen by poor values of FBI (which is far from 1), zero values of TS & POD and bad values of FAR.

5. Conclusions
The WRF-ARW models using New Tiedtke and Kain-Fritsch schemes can produce short term weather predictions over Palembang and its surroundings. For temperature and humidity predictions, the Kain-Fritsch scheme gave better results compared to those obtained from New Tiedtke scheme. Both schemes gave poor performances for precipitation predictions.

Future Works
More observation data will be used to see consistence of the WRF performance in weather predictions. Deep analysis will be performed to make a clear conclusion about the advantages and disadvantages between New Tiedtke and Kain-Fritsch schemes.

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