

ASSESSMENT OF THE WRF MODEL FOR SOUTHERN REGION OF VIET NAM IN DRY AND RAINY SEASONS

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Abstract: This article investigates the capability of the applicability of numerical WRF model to forecast weather at 48 hours for the Southern Region Viet Nam in the rainy and dry seasons in 2021 (12/2020 - 11/2021). The WRF model shows that predicted maximum temperature, minimum temperature and rainfall are lower than measured values. Temperature forecasts are more accurate than rainfall forecasts. Rainfall forecast in the rainy season has a higher error than the rainfall forecast in the dry season, on the contrary, the temperature forecast in the rainy season gives lower error than the temperature forecast in the dry season.

Keywords: WRF, temperature forecast, rainfall, Southern region.

1. Introduction

Nowadays, applying numerical models in weather forecasting and warning of different types of natural disasters is a prevailing method. The Weather Research and Forecasting (WRF) model [5] was developed in the US and is one of the models being applied for professional weather forecasting in many countries around the world including Viet Nam [2]. Moreover, the outputs of the model can also provide input data to hydrological, hydrographic, environmental models, etc. ... The WRF model was originally developed as a regional scale model. However, with the multi-layer mesh method, this model can be set up to simulate for the Southern region with detailed grid resolution of several kilometers.

The Southern region of Viet Nam is located in the tropical monsoon climate, with two distinct seasons in a year: The rainy season and the season. Rainy season usually lasts from May to November, accounting for 90 - 95% of the total annual rainfall. The change in topography can cause different weather patterns.

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Therefore, timely and accurate forecasting of the corresponding weather in the area is an important work. Air temperature and precipitation are meteorological factors that reflect the climatic characteristics of regions. In this study, the WRF model is applied to predict the changes and characteristics of the above factors between the rainy and dry seasons in the Southern region of Viet Nam.

2. Methods and data

2.1. Setting up the WRF model

The WRF model was developed by the National Center for Atmospheric Research (NCAR), and the National Center for Environmental Prediction (NCEP). The WRF model is designed to be flexible, highly customizable and capable of operating on mainframe systems and can be easily customized for both research and operational forecasting. WRF can simulate climate by dynamic downscaling (Dynamic downscaling climate simulations), air quality research and assessment, combined ocean-atmospheric models and ideal simulations (such as boundary layer vortices, convection, sub-pressure waves, etc.). Because of the above advantages, the WRF model is being used in atmospheric research and operational

forecasting in the United States as well as in many parts of the world. This article uses the latest version of WRFV4.0, which is much improved than before: Includes adding missing values to land fields (Soil temperature, soil moisture, etc.). The key equation of the WRF model is the Euler non-hydrostatic complete system of equations.

The vertical coordinate system is the pressure coordinate system. Horizontal coordinate system: Arakawa-C interlaced grid between quantities with wind direction (u,v) and scalar quantities (temperature, pressure).

The physical parameterization diagrams in the WRF model are divided into the following five

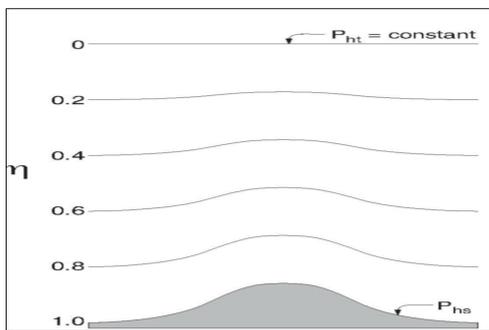


Figure 1. Vertical coordinate system and physical interactions in WRF

Initial conditions of WRF: WRFARW model can run with input from global models such as GME (General Department of Weather, Germany-DWD), GFS (US National Center for Environmental Forecasting-NCEP), GSM (Japan Meteorological Agency-JMA), NOGAPS (US Naval Meteorological Agency). In this article, the model is set to 6 h time step/metric for 04

categories: microphysical processes (describing the mixed physical processes of solid-liquid-gas phase to solve the model's cloud problem), convection parameterization schemes (shallow and deep convection parameterization), surface physical processes (due to the variety of surface coating properties from simple thermal models to fully vegetated and wet soil surfaces, including snow cover and sea ice), processes occurring in the boundary layer (for turbulent kinetic energy forecasting and diagrams) and radiative balance in the atmosphere (including long and short-wave effects with wide or short-wave only, cloud effects and surface fluxes).

sessions/day (00,06,12,18 UTC), the model resolution of domain 1 is 0.18° x 0.18° and domain 2 is 0.04° x 0.04° number of 32 ink levels, the data includes 21 surface variables (rain, t2m, q2m, um, v10m, cloud, OLR, Tsoil.....) and 5 variables on pressure level; Terrain altitude (H), wind (U, V), temperature (T), humidity (Q).

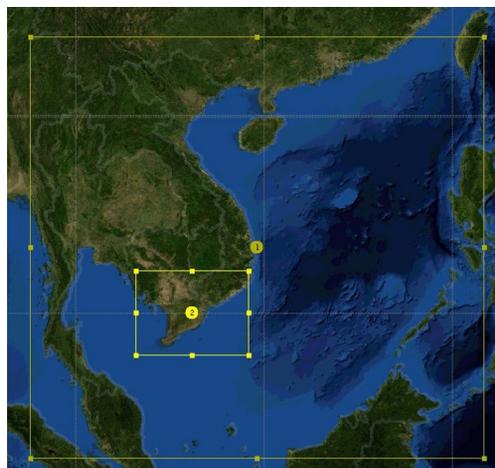


Figure 2. Simulation domain of the WRF model

Domain and grid of the model

Domain D01: Includes 130 x 120 grid points, grid size 20 km

Domain D02: Includes 161 x 121 grid points, grid size 4 km.

This paper evaluates the possibility of using the WRF model to forecast 48 hour weather for 19 stations in the South in 2021. The data time step is 6 hours (4 step: 00,06,12,18 UTC), the forecast time is 00 z UTC (or GMT+7).

Table 1. Parameterization diagram of the sign used in the simulation [1], [4]

Convection	Kain-Fritsch
Longwave radiation	RRTM
Shortwave radiation	Dudhia
Planetary boundary layer	Mellor-Yamada-Janjic
Soil	FAO 8km
Surface	Monin-Obukhov
Cloud microphysics	WSM 6-class

2.2. Data used and method of error assessment

GFS 0.5° input data is taken from the global model at website address: <http://para.nomads.ncep.noaa.gov/pub/data/nccf/com/gfs/para/gfs.yyyymmddhh>.

The observed temperature and rainfall data are taken from 19 meteorological stations in the South: Tan Son Nhat (Ho Chi Minh City), Tri An (Binh Duong), Bien Hoa (Dong Nai), Tay Ninh, Dong Phu (Binh Phuoc), Con Dao and Vung Tau (Ba Ria - Vung Tau), Moc Hoa (Long An), My Tho (Tien Giang), Cao Lanh (Dong Thap), Ba Tri (Ben Tre), Cang Long (Tra Vinh), Can Tho, Soc Trang, Bac Lieu, Chau Doc (An Giang), Rach Gia and Phu Quoc (Kien Giang), Ca Mau.

• Error assessment method:

Export the 48 hour forecast value for 19 station points, then calculate the average forecast value of temperature and rainfall in the Southern region. Actual temperature and rainfall data collected at 19 stations are also averaged for the Southern region.

Next, the study calculates the 48-hour forecast error in the months of the rainy season and in the months of the dry season according to the following error formulas:

F : Forecast; O : Monitoring; N : Total number of cases

▪ *Mean Error (ME)*: Indicates the trend of mean deviation of the predicted value from the observed value

$$ME = \frac{1}{N} \sum_{i=1}^N (F_i - O_i) \quad (1)$$

▪ *Mean absolute error (MAE)*: Represents the mean amplitude of the model error

$$MAE = \frac{1}{N} \sum_{i=1}^N |F_i - O_i| \quad (2)$$

▪ *Root-mean-square error (RMSE)*: Represents the average size of the error. The closer the RMSE is to the MAE, the more stable the model error, and the model product correction can be performed

$$RMSE = \sqrt{\frac{1}{N} \sum_{i=1}^N (F_i - O_i)^2} \quad (3)$$

3. Research results

Application of point weather forecast model for the South from December 2020 to November 2021. The factors studied and evaluated include temperature and precipitation. The forecast values of the above two factors are evaluated according to 02 seasons: Rainy season (from May to November), dry season (from

December 2020 to April).

The average 48-hour forecast results from 19 stations in the southern region are compared with the average monitoring data at 19 stations, then averaged monthly and divided into two seasons, through statistical indicators. to evaluate the predictive power of the model.

3.1. Meteorological forecast 48 hours in dry season

Example of a dry season meteorological forecast: 48 hour temperature forecast results (forecast time - 00 z on February 8, 2021) for the Southern region are shown in Figure 3 and rainfall forecast results 48 hours is shown in Figure 4.

The 24 hour forecast, February 8, 2021, the Southeast region's temperature is 31 - 33°C, night temperature is 22 - 24°C. Bien Hoa, Tay Ninh, Dong Phu experience heavy rains, while moderate rain is occurred in Tan Son Nhat and no rain at the remaining stations. The average humidity is about 73 - 75%. In the Southwest region, the day temperature is 29 - 31°C, the night temperature is 22 - 25°C, the stations with the highest day temperature are Ba Tri, Cang Long, Soc Trang, Can Tho, Bac Lieu, Phu

Quoc and Rach Gia. Stations with the lowest night temperature are Ca Mau, Chau Doc, and Can Tho. Day and night without rain. The average humidity is about 73 - 76.5%.

Forecast for the next 48 hours, on February 9, 2021, the Southeast region's day temperature is 31 - 33°C, night temperature is 22 - 24°C. Heavy rain in Bien Hoa, Dong Phu, moderate rain in Tan Son Nhat, Tay Ninh and no rain at the remaining stations. Average humidity is around 73 - 75%. In the Southwest region, the day temperature is 29 - 31°C, the night temperature is 22 - 25°C, the stations with the highest day temperature are Ba Tri, Cang Long, Soc Trang, Can Tho, Bac Lieu, Phu Quoc and Rach Gia. The stations with the lowest night temperature are Ca Mau, Chau Doc and Can Tho. Day and night without rain. The average humidity is about 73 - 76.5%.

Evaluation of meteorological forecast results in the dry season (December 2020 - April 2021):

Figure 5 shows a negative ME error for the maximum temperature forecast for the dry season months, indicating the forecast value is lower than the actual measurement. The average MAE error value is 1.07°C. And the average RMSE error value is 1.2°C. January has the lowest RMSE error and April has the highest RMSE error.

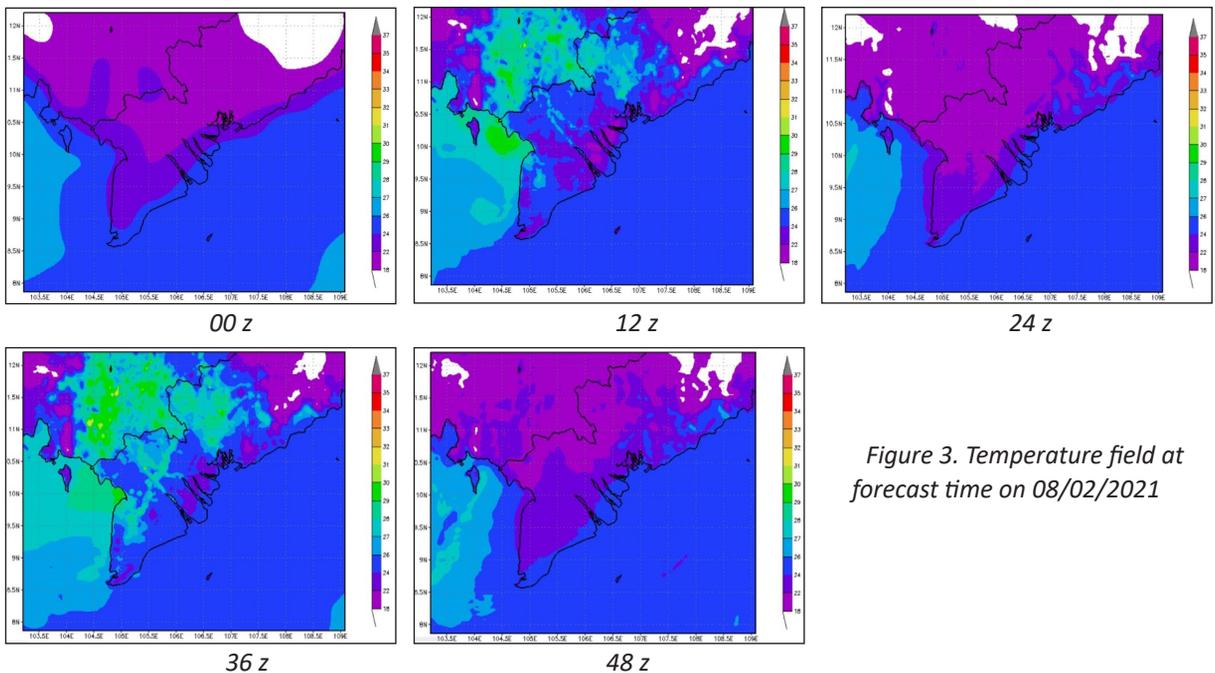


Figure 3. Temperature field at forecast time on 08/02/2021

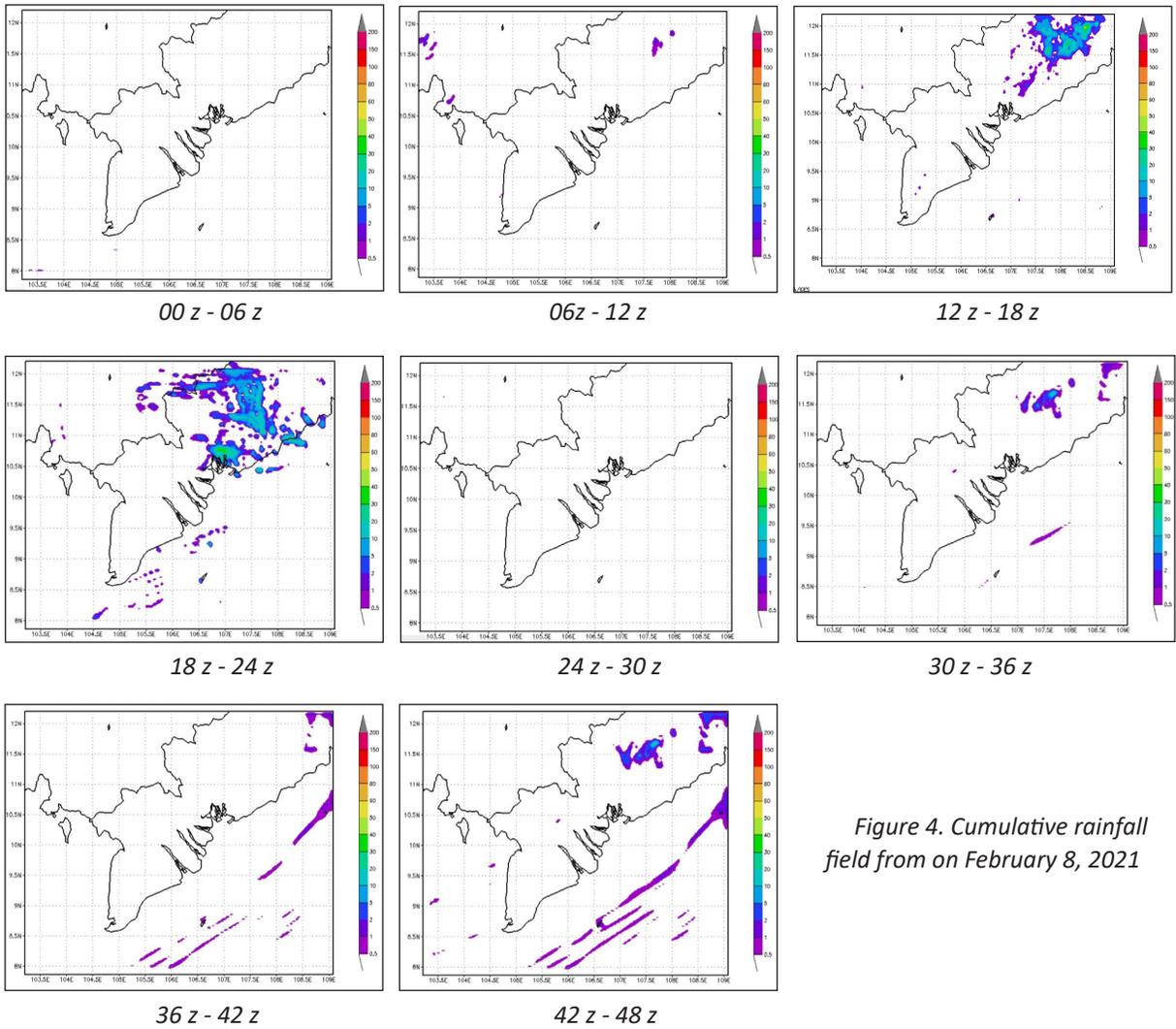


Figure 4. Cumulative rainfall field from on February 8, 2021

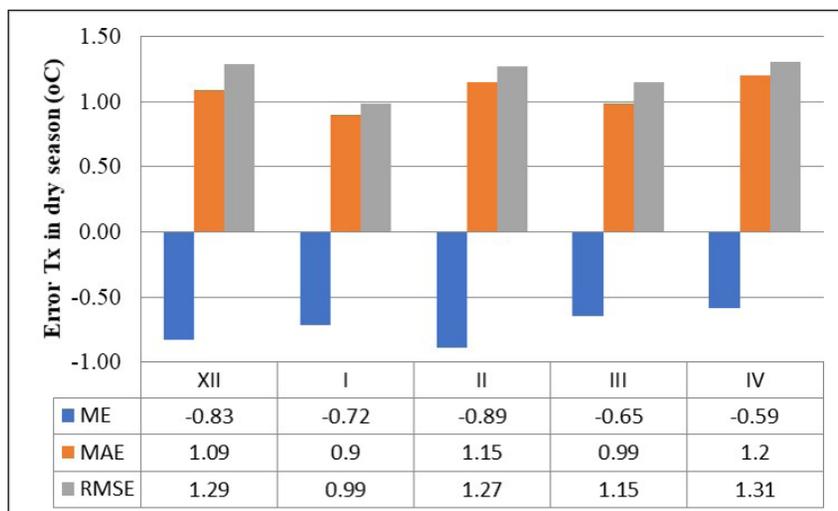


Figure 5. Average maximum temperature error in dry season (°C)

Figure 6 presents the forecast of the minimum temperature in the dry season months. ME error is negative, which means that the forecast is lower than the actual

measurement. The average MAE error value is 1.23°C and the average RMSE error value is 1.43°C. December has the lowest RMSE error and March has the highest RMSE error.

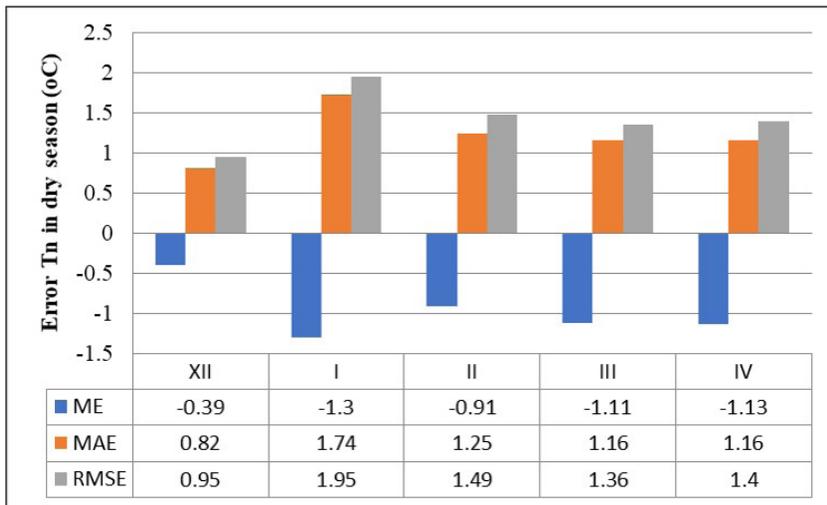


Figure 6. Chart of average minimum temperature error in dry season (°C)

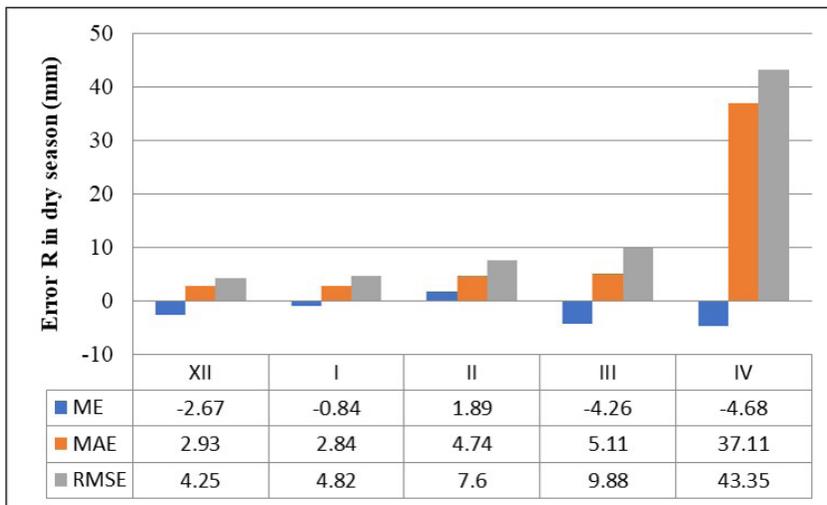
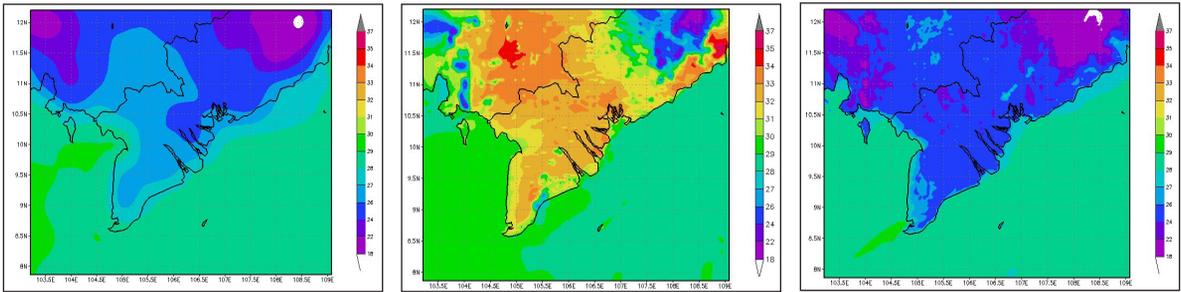


Figure 7. Error chart of average rainfall in dry season months (mm)

The precipitation forecast for the dry season months (Figure 7) gives a negative ME error (except for February), which means that the forecast model is mostly lower than the actual measurement. The average MAE error value is 10.55 mm and the average RMSE error value is 13.98 mm. January has the lowest RMSE error and April has the highest RMSE error up to 43.35 mm.

3.2. Meteorological forecast 48 hours in rainy season

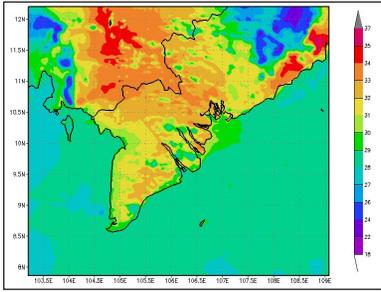
Example of meteorological forecast for the rainy season: 48 hour temperature forecast results (forecast time - 00 z on July 14, 2021) for the Southern region are shown in Figure 8 and rainfall forecast results 48 hours is shown in Figure 9.



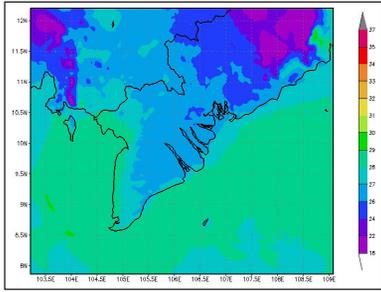
00 z

12 z

24 z

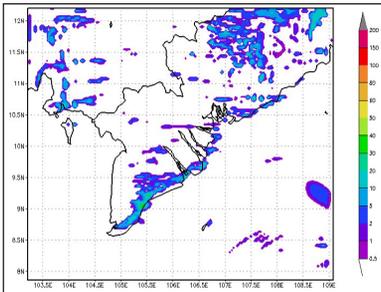


36 z

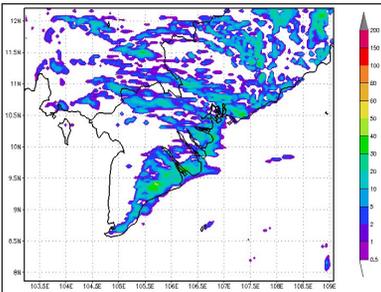


48 z

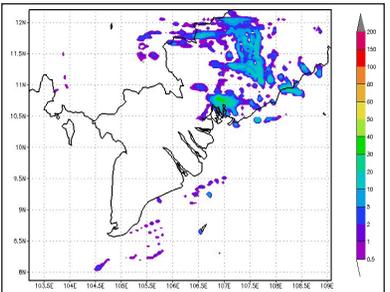
Figure 8. Temperature field at the forecast time on 14/7/2021



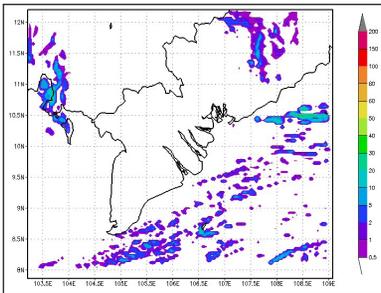
00 z - 06 z



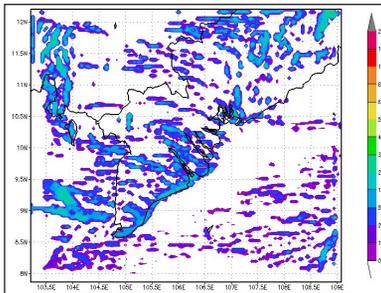
06 z - 12 z



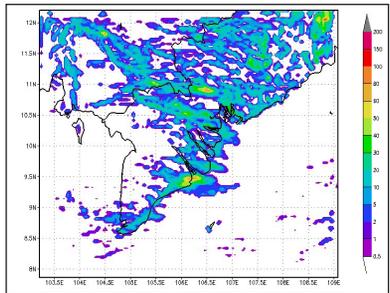
12 z - 18 z



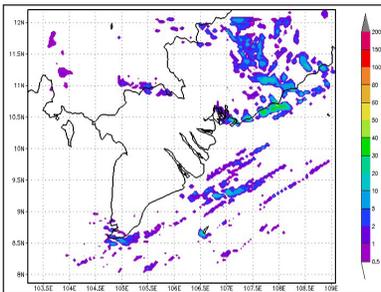
18 z - 24 z



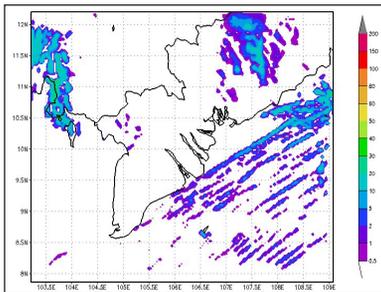
24 z - 30 z



30 z - 36 z



36 z - 42 z



42 z - 48 z

Figure 9. Accumulated rainfall field on 14/7/2021

The 24-hour forecast on July 14, 2021, in the Southeast region, the day temperature is 29.1 - 34.7°C, the night temperature is 22.3 - 27.1°C. The station with the highest day temperature is Tan Son Nhat, the station with the lowest night temperature is Dong Phu. There is rain in many places. The average humidity is about 72.7 - 82.05%. In the Southwest region, the day temperature is 29.5 - 33.9°C, the night temperature is 22.7 - 27.9°C. The station with the highest day temperature is Moc Hoa, the station with the lowest night temperature is Cao Lanh. Heavy rain in Bac Lieu, Chau Doc, Soc Trang and Moc Hoa have moderate rainfall, My Tho, Cang Long experience insignificant rainfall, while no rain at the remaining stations. The average humidity is around 75.25 - 78.1%.

Forecast for the next 48 hours, on July 15, 2021, the Southeast region's daily temperature

is 28.7 - 34.9°C, night temperature is 23.5 - 26.8°C. The station with the highest day temperature is Tan Son Nhat, the station with the lowest night temperature is Dong Phu. Heavy rainfall in Dong Phu and Tay Ninh, no rain in Vung Tau and Con Dao, while the remaining stations has moderate rainfall. The average humidity is around 72.8-85.25%. In the Southwest region, the daily temperature is 29.3 - 34.2°C. The night temperature is 23.5 - 27.2°C. The station with the highest day temperature is Chau Doc, the station with the lowest night temperature is Can Tho. Heavy rainfall in Bac Lieu and Can Tho, no rain in Ca Mau and Soc Trang, while the remaining stations has moderate rainfall. The average humidity is about 69 - 81%.

Evaluation of meteorological forecast results in the rainy season (5/2021 - 11/2021):

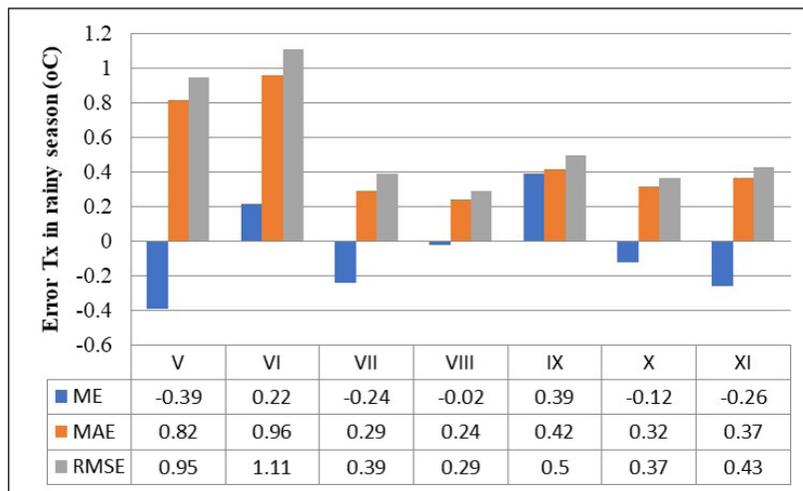


Figure 10. Average maximum temperature error in rainy season (°C)

The maximum temperature forecast in the rainy season (Figure 10) gives a negative ME error (except for June and September), which means that the forecast model is almost lower than the actual measurement. The average MAE error value is 0.49°C and the average RMSE error value is 0.58°C. August has the lowest RMSE error and June has the highest RMSE error.

Figure 11 indicates the forecast of the minimum temperature in the rainy season gives a negative ME error (except for July and September), which means that the forecast model is almost lower than the actual

measurement. The average MAE error value is 0.62°C and the mean RMSE error value is 0.74°C. July has the lowest RMSE error and June has the highest RMSE error.

Figure 12 shows that the rainfall forecast in the rainy season gives a negative ME error (except for May and June), which means the forecast model is almost lower than the actual measurement. The average MAE error value is 18.71 mm and the average RMSE error value is 22.23 mm. November has the lowest RMSE error and May has the highest RMSE error up to 31.21 mm.

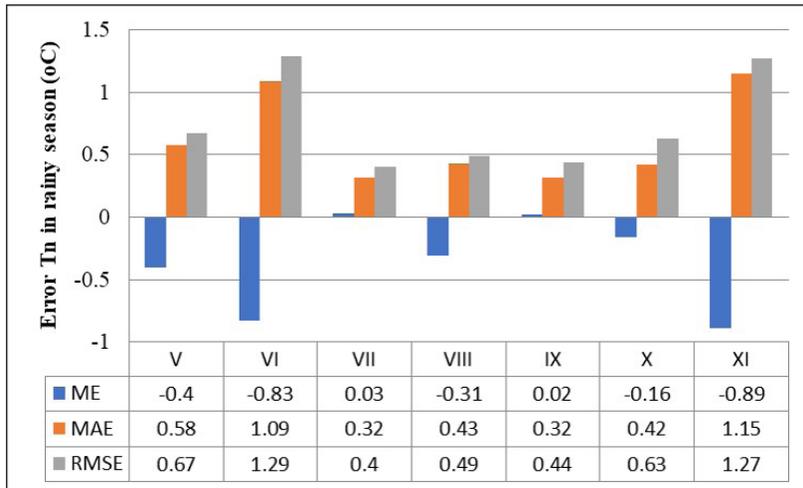


Figure 11. Chart of average minimum temperature error in rainy season ($^{\circ}\text{C}$)

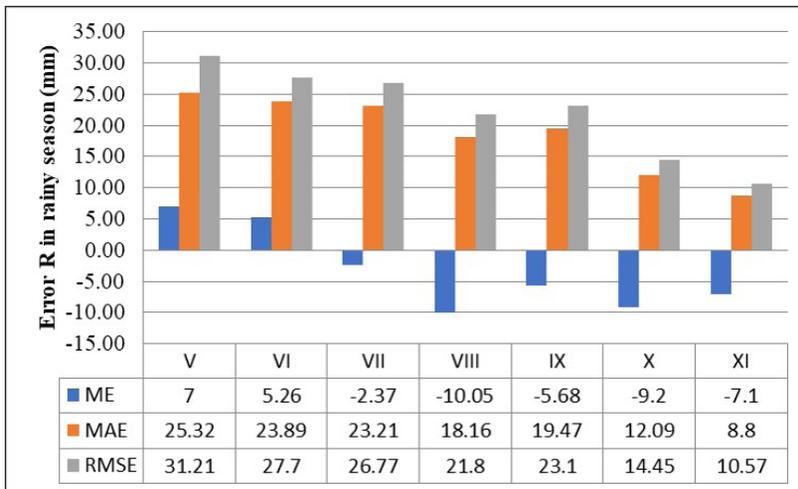


Figure 12. Error chart of average rainfall in rainy season months (mm)

4. Conclusion

In the dry season: WRF model predicts maximum and minimum temperatures that are lower than actual measurements. In the forecast of the maximum temperature, the error value MAE is 1.07°C and RMSE is 1.2°C . For the forecast of the minimum temperature, the MAE error value is 1.23°C and the RMSE error value is 1.43°C . Rainfall forecast in the dry season months is mostly lower than the actual measurement. The MAE error value is 10.55 mm and the RMSE error value is 13.98 mm . April has an RMSE error of up to 43.35 mm .

In the rainy season: WRF model predicts the maximum temperature, the forecast value is mostly lower than the actual measured. In

the forecast of the maximum temperature, the error value MAE is 0.49°C and RMSE is 0.58°C . For the forecast of the lowest temperature, the MAE error value is 0.62°C and the RMSE error value is 0.74°C . Rainfall forecast in the dry season months is mostly lower than the actual measurement. The MAE error value is 18.71 mm and the RMSE error value is 22.23 mm . May has an RMSE error of up to 31.21 mm .

Thus, the WRF model for predicting the temperature is more reliable than the rain and the temperature prediction error is lower than the rain forecast. Rainy season rainfall forecast gives higher error than dry season rainfall forecast, conversely, rainy season temperature forecast gives lower error than dry season temperature forecast.

Acknowledgment: *This study was completed within the framework of regular functional tasks in 2022. Task 9: "Assess the trend of change of climate factors and review solutions to respond to climate change, forecast waves, tides, saltwater intrusion in the Southern region".*

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