

DEVELOPMENT SIMULATION OF AN UNSEASONAL HEAVY RAINFALL EVENT OVER SOUTHERN THAILAND BY WRFROMS COUPLING MODEL

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ABSTRACT: A coupled regional climate among atmosphere-ocean coupled model systems is developed using the regional model Weather Research and Forecasting (WRF) and Regional Ocean Modelling System (ROMS). In process of atmospheric, the parameters are used to force the ocean model that included the wind data (Uwind, Vwind), atmospheric pressure data (Patm), relative humidity data (RH), atmosphere surface temperature data (Tair), cloud fraction data (Cloud), precipitation data (Rain), short wave data (SW), long wave data (LW). On the other hand, in process of oceanic, the only parameter of process the oceanic model is used to force the atmosphere model that is Sea Surface Temperature (SST). In this study, to investigate the seasonal prediction and short-term rainfall prediction using WRF and coupled WRFROMS model. The resolution of term rainfall prediction resolution was 36 km× 36 km (domain 1), 12 km × 12 km (domain 2), and 4 km × 4 km (domain 3). The two different microphysics schemes in both cases were Lin scheme and WSM6 scheme. In conclusion, short term rainfall prediction, WRFROMS with WSM6 scheme simulated lower values (*RMSE*, *MAE*) and highest value (*CORR*) than the other experiment. However, the results of the WRFROMS with microphysics improved trend rainfall and SST better than simulation by only WRF model. So, this study found microphysics scheme and SST result from ROMS model that have affected to change results of rainfall prediction. Furthermore, the result of WRFROMS with WSM6 scheme was able to simulate rainfall more accurately when compared with the other experiments by consideration from statistical and quantitative results.

Keywords: Atmosphere-Ocean Coupled Model, Rainfall, ROMS, SST, Thailand, WRF, WRFROMS, WSM6

1. INTRODUCTION

In every year, rainfall is the one factor characteristic effecting of weather and climate in southern Thailand. This area has much rainfall almost all seasons, especially in winter season and rainy season was followed by Thai Meteorological Department [1] information. In winter season, the northeast monsoon is influenced wind during middle October to middle February in every year. This period occurs annually heavy rainfall over southern Thailand. A cold surge occurs in the northeast monsoon. It has crossed the South China Sea and flows to the cyclonic circulation over east southern Thailand and northern Malay Peninsula, this reason might be a main factor occurrence heavy rainfall in this area [2-4]

Sometime, several extreme event or heavy rainfall event was occurred suddenly over southern Thailand [2-4]. For example, an extreme rainfall event occurred on March 23-30, 2011 caused severe big flooding over east of southern Thailand.

The accumulated rainfall rage from 200 mm to 1,200 mm across the east of southern Thailand with the Malaysia Peninsula. Surat Thani province in the east of southern Thailand was recorded the most rainfall immediately by NASA, as represented in Fig.1. The flooding in this event was affected by 842,324 people, 8 provinces and killing 13 people [2, 5]. The rainfall behavior can be change possibly due to climate change. So, the extreme event has increasingly important in analyzing the rainfall.

From Table 1, the rainfall in winter and rainy seasons more than summer season. But in 2011 was different. Since 2011 in Thailand was the wettest year during 1951-2011 (61-years). From Thai Meteorological Department [1] information mainly from widespread rainfall in Thailand, especially during summer season (36.9% above normal rainfall in Mar 2011). The annual rainfall was about 24% above normal rainfall and 19% higher than previous year.

The monthly and annual rainfall anomalies (%) and annual mean temperature anomalies (Degree Celsius) for the year 2011 is shown in Fig. 1. The monthly and annual mean temperature anomalies (Degree Celsius) for the year 2011 is shown in Fig.2

Table 1. Seasonal rainfall (mm) and temperature (Degree Celsius) of west southern Thailand from TMD (Based on 1981-2010) [1,2].

	1981-2010					
	East Coast			Wesrt Coast		
	Winter	Summer	Rainy	Winter	Summer	Rainy
Rainfall	827.9	229.0	680.0	464.6	411.3	1,841.0
Temperature	26.3	28.2	27.8	27.0	28.4	27.5
Max Temperature	30.4	33.0	32.7	32.0	34.1	31.6
Min Temperature	22.8	24.1	24.4	23.2	24.0	24.3

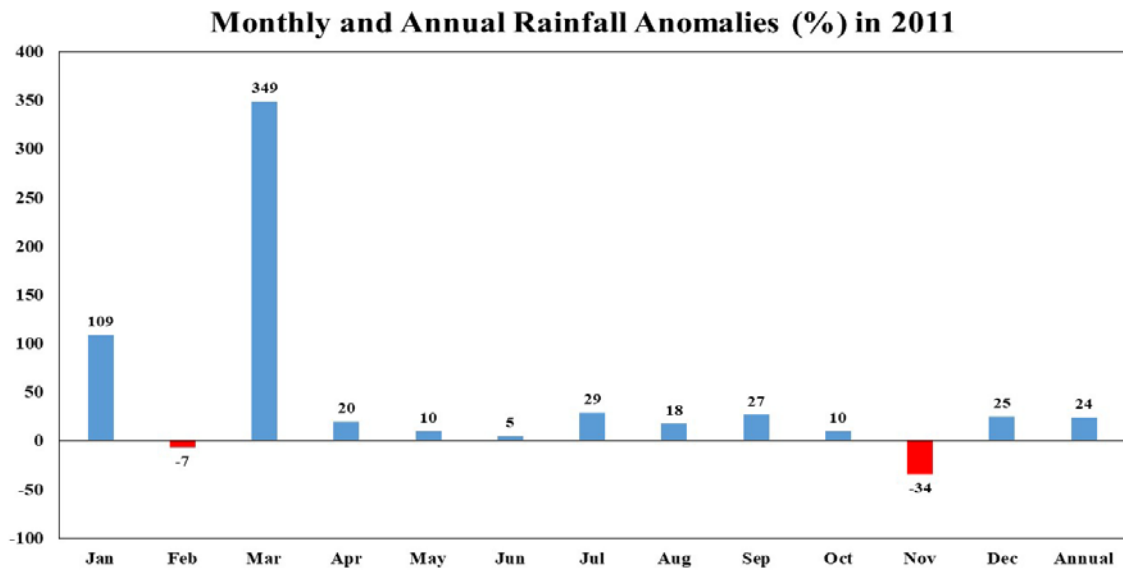


Fig. 1. The Monthly and annual rainfall anomalies (%) in 2011 [1, 2].

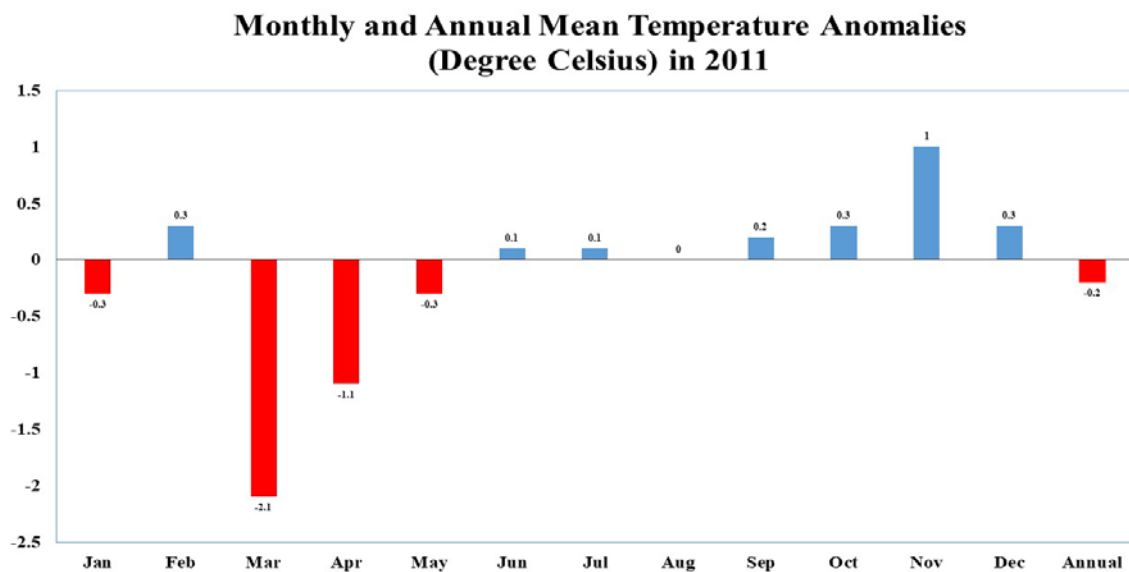


Fig. 2. The monthly and mean temperature anomalies (Degree Celsius) in 2011 [1, 2].

Improving rainfall prediction is be the main factor in helping to manage water. It will help researcher to minimize damage by warning in advance effect from rainfall. Good estimations of rainfall are crucial to help the risk management of natural disasters, in addition to improving water management. It is well recognized that one of the best options to improve the accuracy of rainfall simulation and to enhance and improve Numerical Weather Prediction (NWP) models. Rainfall prediction with high spatial resolution is a major challenge due to the influence of multiple factors such as the topography of subcontinent, atmosphere and effect from ocean. High resolution numerical modelling is needed to better predict rainfall simulation [6, 7].

Therefore, this study used physics parameterization and coupled model to help improve the rainfall simulation. In physic parameterization scheme, one of the necessary physics parameterizations were impact rainfall simulation over high resolution that is microphysics parameterization scheme. The sensitivity test two microphysics parameterization scheme that was Lin scheme and WSM6 scheme. Since both microphysics parameterization scheme included five parameters process in clouds (water vapor, cloud water, cloud ice, snow, grauple, and rain). Therefore, the objective of this study is simulated heavy rainfall event in both case of standalone regional atmospheric model (WRF) and regional coupled model system (WRFROMS) model over southern Thailand on March 23-31, 2011.

2. MODEL CONFIGURATION

The Coupled Ocean Atmosphere Wave Sediment Transport (COAWST) model system, this model system is an agglomeration of open source modeling components that has been improved to investigate coastal environment [7]. The coupler is the Model Coupling Toolkit (MCT) that allow the transmission and transformation of various distributed data between component models using parallel coupled approach. The MCT is a program written in Fortran90 and work with the MPI communication protocol [7]. In previous work, to use a coupled atmospheric and oceanic model to simulate rainfall over Thailand on June-July-August on 2014. In the processes of atmospheric model was forced u wind, v wind, atmospheric pressure, humidity, temperature, cloud, rain and radiation to oceanic model. On the other hand, the oceanic model was forced sea surface temperature to atmospheric model [8]. In this study, to improve the oceanic model from ideal case study to real case study. Furthermore, to change the domain simulation of atmospheric model from only one domain to three nested

domains for simulating heavy rainfall event over southern Thailand.

2.1 The Atmospheric Model

The Weather Research and Forecasting (WRF) model, the model system is a nonhydrostatic, terrain following sigma coordinate for vertical coordinate, Arakawa C-grid for horizontal grid, initial conditions, boundary condition, coupled model and a full set of physics parameterization options. The more detailed description of WRF in [8].

The selected microphysics parameterization schemes were Lin scheme and WSM6-class scheme. It contained prognostic equations for cloud water, rain, water, ice, snow, and graupel and hail mixing ratios. On the other hand, the different microphysics parameterization schemes, the same model configuration was fixed. The other physics options that were used in this study; Kain-Fritsch (KF) cumulus parameterization, New Rapid Radiative Transfer Model (RRTMG) shortwave radiation, New Rapid Radiative Transfer Model (RRTMG) long-wave radiation, the Shin-Hong scheme planetary boundary layer scheme, and the unified Noah land-surface model.

2.2 The Oceanic Model

The Regional Ocean Modeling System (ROMS) model, the model system is a general class free-surface, a terrain following a numerical model that solve the three-dimensional Reynold-averaged Navier-Stokes equation, the hydrostatic and Boussinesq approximations and base on primitive equation oceanic model. In part of grid spacing, to use finite-difference approximation on Arakawa-C staggering for horizontal grid and on a vertical stretched terrain following coordinate [8].

In previous work, the study was followed on ideal case study by fixing the initial condition values of oceanic model that was u wind (0 m/s), v wind (0 m/s), temperature (35 degree Celsius), and salinity (18 ppt) [8]. But in this study, to use the initial condition from the reanalysis data for simulating via atmospheric model in coupled atmospheric and oceanic model. The initial condition of oceanic model was more detail in chapter 3. Furthermore, the vertical mixing layer of oceanic model was General Large Scale (GLS) to use in this study.

3. DOMAIN AND EXPERIMENT DESIGN

The domain of atmospheric part of coupled model in the short-term heavy rainfall prediction. The multiple three nested domain configuration included 36-km resolution outer domain, sub domain resolution was 12-km and 4-km resolution inner domain (the ratio of 1:3), with 128×104 , 114×90 and 183×198 grid points, respectively

(Figure 6.10). The inner domain was covering the southern Thailand and gulf of Thailand location between longitudes 97.139° East and 103.761° East and latitudes 5.028° North to 12.111° North. The 26 levels direction with a maximum of 50 hPa are used for all domains. The oceanic model domain is the same as the biggest domain of atmospheric model. The horizontal grid spacing is 36-km. But the vertical level of oceanic model is 41 levels. The model domain is shown in Fig. 3.

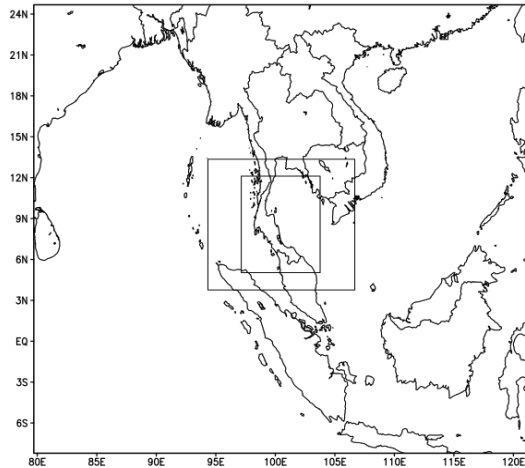


Fig. 3. The domain configurations used an outer domain grid resolution of 36-km, sub domain grid resolution of 12-km and inner domain grid resolution 4-km for short term heavy rainfall prediction rainfall.

In Fig. 4. the processes were shown step of the sensitivity simulation in rainfall seasonal prediction case. The first step was created the domain configuration. The grid points of domain 1, domain 2 and domain 3 have 128×104 , 114×90 and 183×198 grid points, respectively. Second step, to prepare the initial data for simulation. The initial condition was used the National Climate for Environment Prediction Final Operational Global Analysis data or (NCEP-FNL) for Atmospheric model and used National Centers for Environmental Prediction (NCEP) Climate Forecast System Version 2 (CFSV2) for oceanic model. The NCEP-FNL atmospheric initial condition is developed by Global Data Assimilation System (GDAS). The resolution of grid spacing data was 1 degree \times 1 degree and covered at longitude 180 degrees east to 180 degrees west and latitude 90 degrees south to 90 degree north. The CFSV2 oceanic initial condition is developed by the National Centers for Environmental Prediction (NCEP). The resolution of grid spacing data was 2.5 degrees \times 2.5 degrees and covered at longitude 180 degrees east to 180 degrees west and latitude 90 degrees south to 90 degrees north. Third step, to select the physics parameterization scheme. But in this study was

focused on the high resolution unseasonal heavy rainfall case. The Lin and WSM6 scheme use of simulation in sensitivity simulation in this study. Fourth step was the run model process by standalone atmospheric model and coupled atmospheric and oceanic model. The simulation of two cases were complete. The results from two cases simulation were compared with the TRMM gridded and TMD station observations data. Three statistics method was used in this study. That is CORR, RMSE and MAE respectively, that was shown in fifth steps. The last step was post processing. This step was summary and discuss the results for high resolution on short term heavy rainfall prediction.

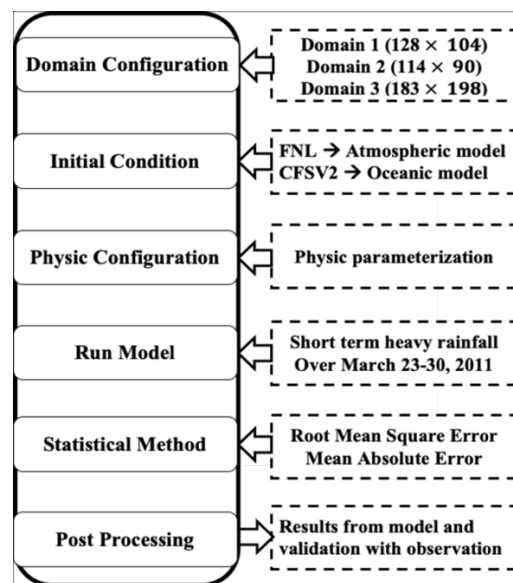


Fig. 4. The flow chart of the rainfall simulation in this study

4. RESULTS AND DISSCUSIONS

Consider on Fig. 5, the result shown the SST simulation in domain 3 by WRF Lin scheme model (a) and WRFROMS Lin scheme (b). The WRFROMS Lin scheme was shown the smooth SST simulation than WRF Lin scheme especially over Gulf of Thailand and Andaman sea. In the same way, consider on Fig. 6, the result shown the SST simulation in domain 3 by WRF WSM6 scheme model (a) and WRFROMS WSM6 scheme (b). The WRFROMS WSM6 scheme was shown the smooth SST simulation than WRF WSM6 scheme especially over Gulf of Thailand and Andaman sea similarly with Lin scheme case. From the both Figures (Fig. 5 and Fig. 6), that mean the coupled model was updated SST simulation from initial condition and made SST smoother than simulation by only atmospheric model. However, the microphysics scheme was shown effect with SST results. For example, the SST results from WRFROMS WSM6 scheme was

shown spread SST than WRFROMS Lin scheme over Gulf of Thailand around heavy rainfall area. On the other hand, the SST results from WRFROMS Lin scheme was shown spread SST than WRFROMS WSM6 scheme over Andaman sea nearly Malaysia peninsular. Furthermore, the SST from WRFROMS Lin scheme and WRFROMS WSM6 scheme captured the trend of

SST over heavy rainfall area (Samui Island). That corresponds to the meaning, that if the area has a higher Sea Surface Temperature there will be occur rainfall. Because its increased evaporation over that area. Therefore, in this study can confirm the SST that is one important parameter when predict rainfall or heavy rainfall event.

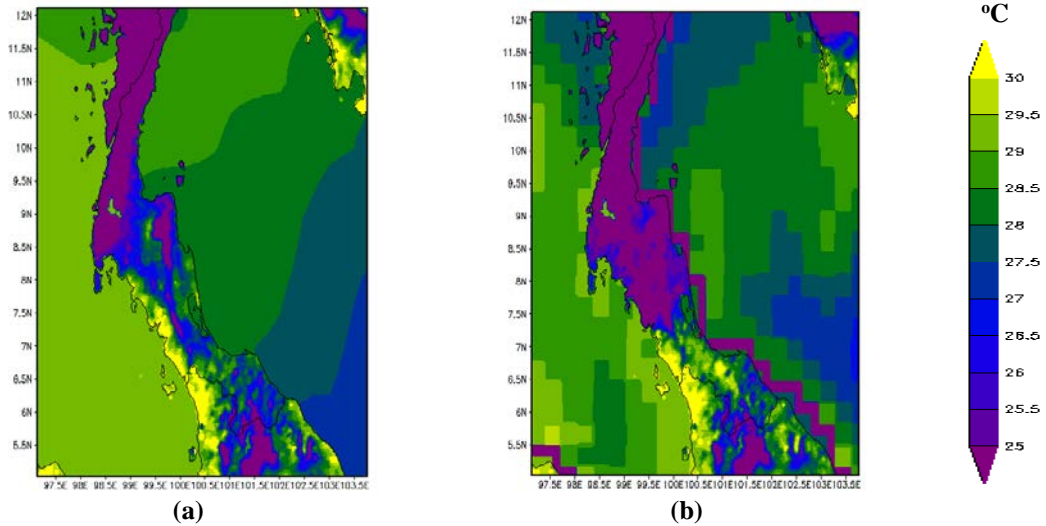


Fig. 5. The SST prediction by microphysics schemes from domain 3 on March 23-31, 2011: (a) WRF Lin scheme, and (b) WRFROMS Lin scheme.

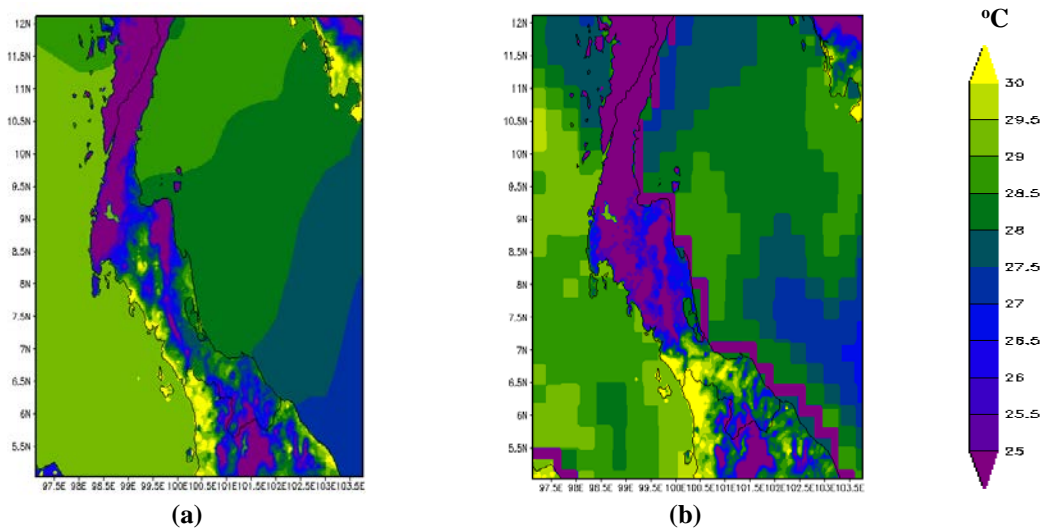


Fig. 6. The SST prediction by microphysics schemes from domain 3 on March 23-31, 2011: (a) WRF WSM6 scheme, and (b) WRFROMS WSM6 scheme

The accumulate rainfall prediction from domain 3 on March 23-31, 2011 as shown in Fig. 7 (a) TRMM observation data, (b) WRF Lin scheme, (c) WRF WSM6 scheme, (d) WRFROMS Lin scheme, and (e) WRFROMS WSM6 scheme. The TRMM observation data was recorded heavy rainfall (~more than 950 mm) over east southern

Thailand. In case of WRF Lin scheme and WRF WRM6 scheme were captured heavy rainfall (~more than 950 mm) over east southern Thailand similarly TRMM observation data. In case of WRFROMS Lin scheme and WRFROMS WRM6 scheme were captured heavy rainfall (~more than 950 mm) over east southern Thailand similarly

TRMM observation data. However, in case coupled mode (WRFROMS Lin scheme and WRFROMS WSM6 scheme) were shown spread trend of heavy rainfall same TRMM observation than simulation only WRF model (WRF Lin scheme and WRF WSM6 scheme). In Fig. 8. To show the mass variable over heavy rainfall area from domain 3 on March 23-31, 2011: (a) WRF Lin scheme, (b) WRF WSM6 scheme, (c) WRFROMS Lin scheme and (d) WRF WSM6 scheme. In case of WRF Lin scheme and WRF WRM6 scheme were shown similarly trend of mass variable. But, the WRF WSM6 scheme was shown qs and qg more than WRF Lin scheme between 10 km to 26 km in vertical level. In case

of WRFROMS Lin scheme and WRFROMS WRM6 scheme were shown similarly trend of mass variable. However, the mass variable from coupled model were shown the results more than the mass variable from simulating only WRF model. That mean, the WRFROMS coupled model were corresponded with heavy rainfall event that shown good and increase trend of spatial heavy rainfall event and mass variable (qc, qg, qi, qr, and qs) than standalone WRF model. It was confirmed the coupled model that was improved the rainfall simulation and shown a good trend than standalone model simulation

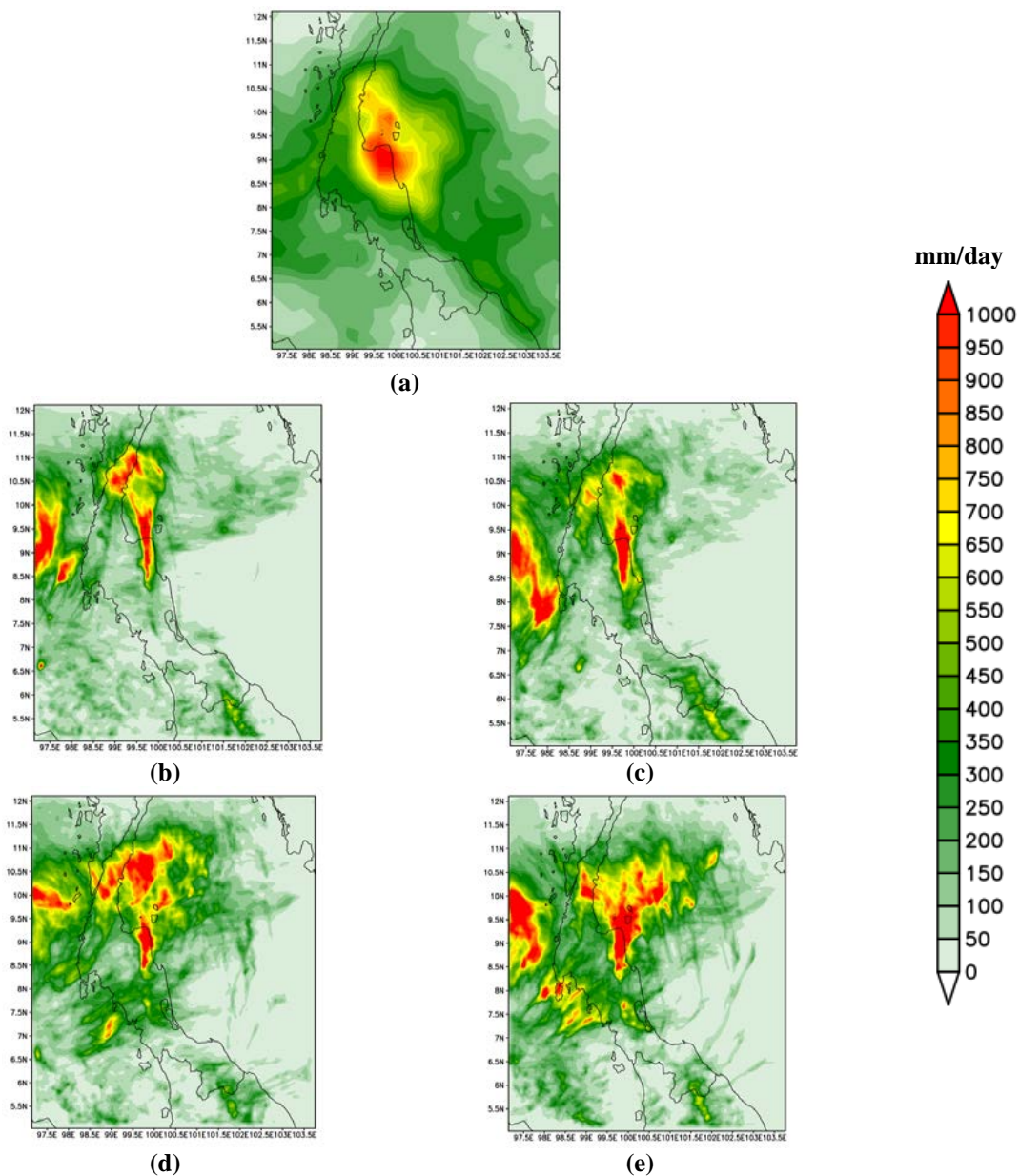


Fig. 7. The accumulate rainfall prediction from domain 3 on March 23-31, 2011: (a) TRMM observation data, (b) WRF Lin scheme, (c) WRF WSM6 scheme, (d) WRFROMS Lin scheme, and (e) WRFROMS WSM6 scheme.

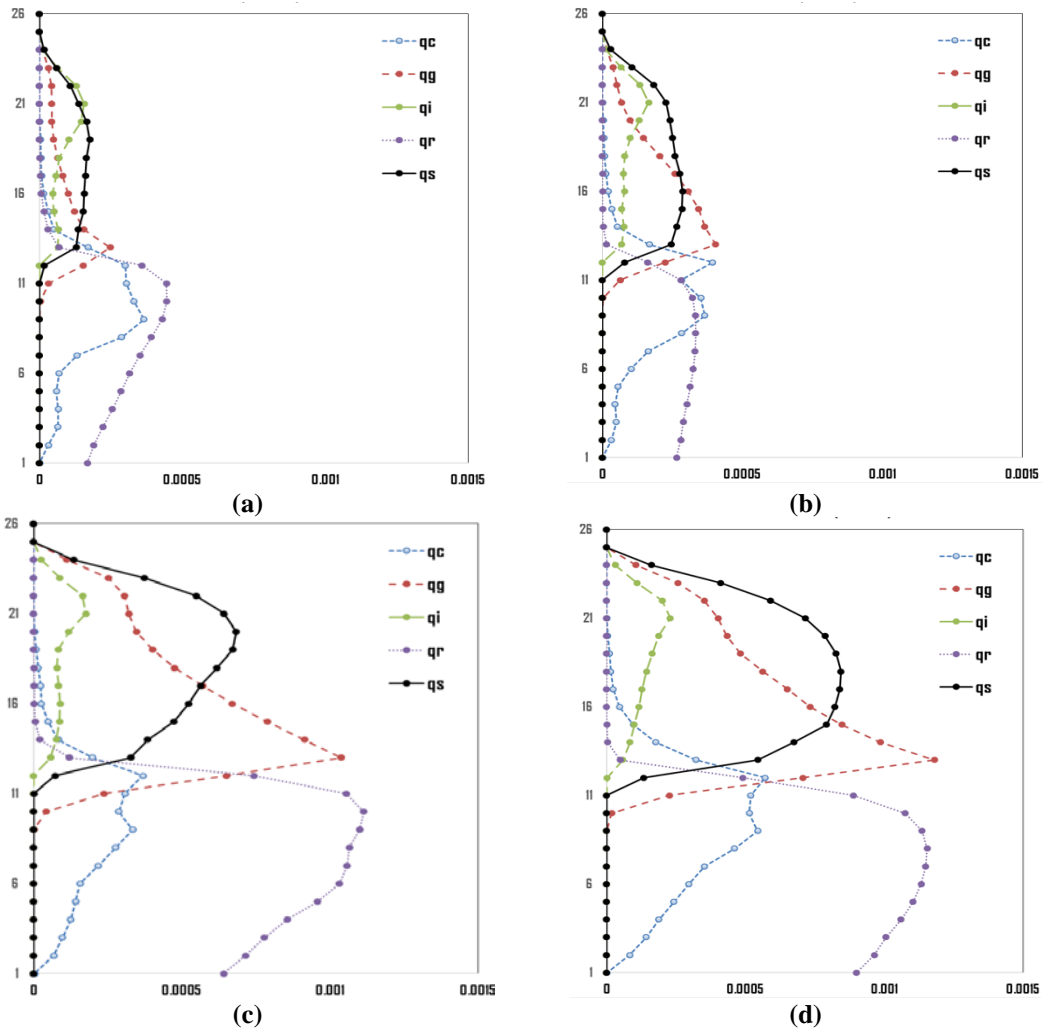


Fig. 8. The mass variable over heavy rainfall area from domain 3 on March 23-31, 2011: (a) WRF Lin scheme, (b) WRF WSM6 scheme, (c) WRFROMS Lin scheme and (d) WRF WSM6 scheme.

All model results over southern Thailand: heavy rainfall over Samui Island, average accumulated rainfall, Correlation Coefficient (*CORR*), Root Mean Square Error (*RMSE*) and Mean Absolute Error values are shown (*MAE*) in Table 5. In heavy rainfall case, the WRF Lin scheme and WRFROMS Lin scheme were shown overestimated heavy rainfall over Samui Island. But WRF WSM6 scheme and WRFROMS WSM6 were shown underestimated heavy rainfall over Samui Island. However, the WRF Lin scheme (42.464 cm/day), WRFROMS Lin scheme (42.576 cm/day) and WRFROMS WSM6 scheme (40.084 cm/day) were shown good performance closely the Samui Island station. In average accumulated rainfall case, the WRFROMS WSM6 scheme was shown closely value at 10.91 cm/day that was a better value than another value. The *RMSE* was compared with the TMD station data. The WRFROMS WSM6 supported the lowest *RMSE* value at 6.10, with the WRFROMS Lin scheme the next closest at 6.85. In case of *CORR*, the highest

value was shown by WRFROMS WSM6 scheme at 0.80. In Table 6, the SST mean results (Fig. 6.) the WRFROMS WSM6 scheme was shown closely value at 29.52 °C. The WRFROMS WSM6 supported the lowest *RMSE* value at 3.10, with the WRFROMS Lin scheme the next closest at 3.85. In case of *CORR*, the highest value was shown by WRFROMS WSM6 scheme at 0.88. The WRFROMS WSM6 scheme simulated lower values (*RMSE*, *MAE*) and highest value (*CORR*) than the other experiment in both heavy rainfall and SST values. However, the WRFROMS WSM6 scheme was based on WSM6 scheme, and coupled WRFROMS model. Following Fig. 7. the SST value effected by microphysics. Because SST over heavy rainfall from Lin and WSM6 scheme that gave different the SST value. So, SST parameter has effect heavy rainfall over Southern. However, the WRFROMS WSM6 scheme was able to simulate rainfall more accurately compared with the other cases used in this study.

Table 5. Heavy rainfall, Average rainfall, RMSE, MAE and CORR in March 23-31, 2011

EXP	TMD (Heavy rainfall = 41.470 cm/day)	TMD (Average Rainfall=10.845 cm/day)			
	Samui Island station	Average	RMSE	MAE	CORR
WRFL	42.464	7.51	7.39	6.22	0.70
WRFW	37.872	11.25	7.59	6.21	0.72
WRFROMSL	42.576	8.81	6.85	5.73	0.75
WRFROMSW	40.084	10.91	6.10	4.89	0.80

Table 6. SST over heavy rainfall area, Average SST, RMSE, MAE and CORR in March 23-31, 2011

EXP	OISST (SST = 29.53 °C)	OISST (SST (whole domain) =25.34 °C)			
	Samui Island station	Average	RMSE	MAE	CORR
WRFL	28.23	24.34	5.89	4.26	0.79
WRFW	28.32	24.65	4.39	3.37	0.81
WRFROMSL	29.33	25.04	3.85	1.53	0.85
WRFROMSW	29.52	25.38	3.10	1.29	0.88

5. CONCLUSIONS

In heavy rainfall prediction was selected period over March 23-31, 2011. The resolution of prediction was 36 km × 36 km (domain 1), 12 km × 12 km (domain 2), and 4 km × 4 km (domain 3). The initial and boundary condition used in this case that was FNL initial condition for atmospheric model and in case oceanic model was used CFSV2 for initial and boundary condition. The physics parameter used in atmospheric model that includes Lin scheme and WSM6 scheme for microphysics scheme, KF scheme for cumulus scheme, RRTMG for long-wave radiation, RRTMG for short-wave radiation, Shin-Hong scheme for PBL scheme, and Noah Land-Surface Model for Land Surface scheme. In case oceanic model has an only one physics parameter that is General Large Scale (GLS). The observation was used comparison to find accuracy model that was TRMM observation for rainfall and OISST observation for Sea Surface Temperature.

On the spatial pattern the WRF model both Lin scheme and WSM6 scheme were shown overestimation rainfall than observation data. From TRMM observation data was shown the heavy rainfall over eastern southern Thailand. The WRF Lin scheme and the WRF WSM6 scheme were capture heavy rainfall over east southern Thailand similarly observation data.

In case the WRFROMS with Lin scheme and

the WRFROMS with WSM6 scheme were increased over heavy rainfall than only WRF model. The SST prediction by microphysics scheme from domain 3. The SST results from WRF Lin scheme and WRF with WSM6 scheme were similarly SST over The Gulf of Thailand. On the other hand, The SST results from WRFROMS with Lin scheme and WRFROMS with WSM6 scheme captured the high SST over heavy rainfall area (Samui Island). That corresponds to the meaning, that if the area has a higher Sea Surface Temperature there will be occur rainfall. Because its increased evaporation over that area.

The rainfall prediction by microphysics scheme from domain 3, in this case was analysis heavy rainfall. The mass variable between WRFROMS was shown more mass variable (qc, qg, qi, qr, and qs) than only WRF model. In the case the mass variable between WRFROMS Lin scheme that was shown more mass variable (qc, qg, qi, qr, and qs) than only WRF model similarly WRFROMS WSM6 scheme case. Furthermore, the results of WRFROMS WSM6 scheme simulated lower values (RMSE, MAE) and highest value (CORR) than the other experiment in both heavy rainfall and SST values.

However, the WRFROMS WSM6 scheme was based on WSM6 scheme, and coupled WRFROMS model. The SST value effected by microphysics. Because SST over heavy rainfall from Lin and WSM6 scheme that gave different the SST value. So, SST parameter has effect heavy rainfall over Southern

Thailand. However, the WRFROMS with WSM6 scheme was able to simulate rainfall more accurately compared with the other cases used in short term rainfall prediction. In this study was found the microphysics scheme were affected SST over heavy rainfall area. Furthermore, the WRFROMS coupled model can be capture heavy rainfall better than only WRF model. This study can conclude the WRFROMS coupled model can be useful rainfall prediction better than only WRF model for this study.

6. ACKNOWLEDGMENTS

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