CHAPTER 3 METHODOLOGY

3.1 Observation Data

The Tropical Rainfall Measuring Mission (TRMM) is a joint mission between NASA and the Japan Aerospace Exploration Agency (JAXA) designed to monitor and study tropical rainfall (NASA, 2008). This study used TRMM 3 hourly observation data version 7. The TRMM 3 hourly observation data can measure the vertical structure of rain over ocean and land. The horizontal resolution is 0.25 degree $\times$ 0.25 degree and period of data is during 0000 UTC 1 January 1998 to 2100 UTC 31 December 2013. The spatial of TRMM 3 hourly observation cover area is between latitude 180$^{\circ}E$ to 180 $^{\circ}W$ and longitude 50$^{\circ}N$ to 50$^{\circ}S$ as shown in Figure 3.1.

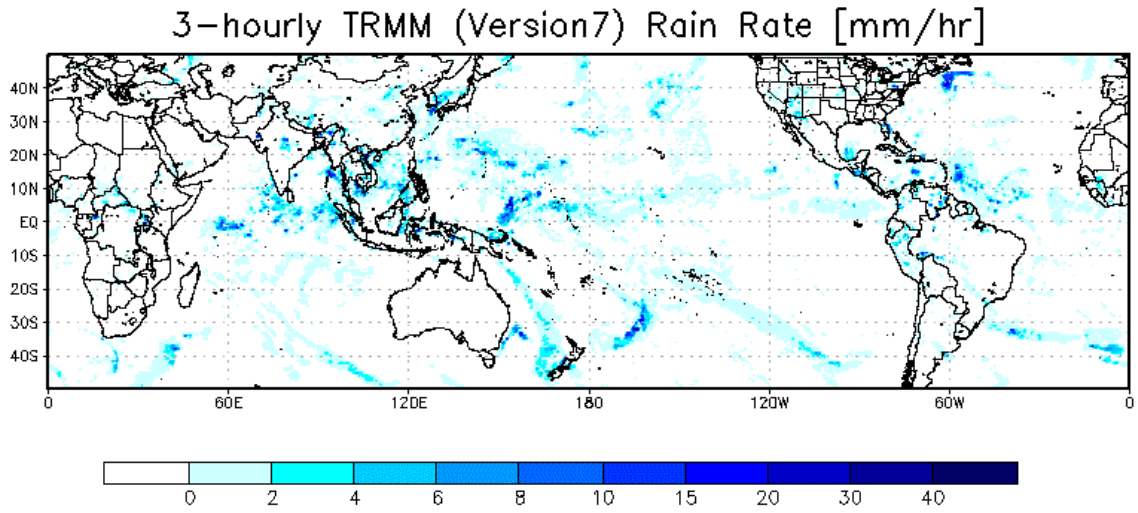


Figure 3.1 The rainfalls distribution pattern from TRMM 3 hourly observation data at 0000 UTC 10 September 2011

3.2 Model Configuration

The model configuration used the model is the Weather Research and Forecasting model (WRF) version 3.4. This study domain is the finest domain of three simulation domains and 26 vertical levels are 1000 mb, 975 mb, 950 mb, 925 mb, 900 mb, 850 mb, 800 mb, 750 mb, 700 mb, 650 mb, 600 mb, 550 mb, 500 mb, 450 mb, 400 mb, 350 mb, 300 mb, 250 mb, 200 mb, 150 mb, 100 mb, 70 mb, 50 mb, 30 mb, 20 mb, and 10 mb. The period experiment selected by TRMM observation data during 2000 to 2012. The

model configuration is sensitivity analysis with the microphysics parameterization and fixed another physics options used in this study.

3.3 Domain of Experiments for the Microphysics Parameterization WRF Model

The domain of experiments is the finest domain of three simulation domains. The resolutions of three nested domains were 36 × 36 km^2 (Domain1), 12 × 12 km^2 (Domain2), and 4 × 4 km^2 (Domain3) shown in Figure 3.2. The domain1 has 412 × 392 grids spacing covering at latitude -20.8265$^\circ N$ to 42.5789$^\circ N$ and longitude 66.9183 $^\circ E$ to 133.567$^\circ E$, the domain2 has 703 × 728 grid spacing covering at latitude -8.40932$^\circ N$ to 30.888$^\circ N$ and longitude 82.5465$^\circ E$ to 120.492 $^\circ E$, and the doamain3 has 667 × 971 grids spacing covering at latitude 4.4198$^\circ N$ to 21.8973$^\circ N$ and longitude 95.5056$^\circ E$ to 107.506$^\circ E$, respectively (set the ratio of 1:3). In this study focused on Thailand at latitude 5$^\circ N$ to 21$^\circ N$ and longitude 97$^\circ E$ to 106$^\circ E$. We focused study domain over Thailand on Domain 3, shown in Figure 3.6.

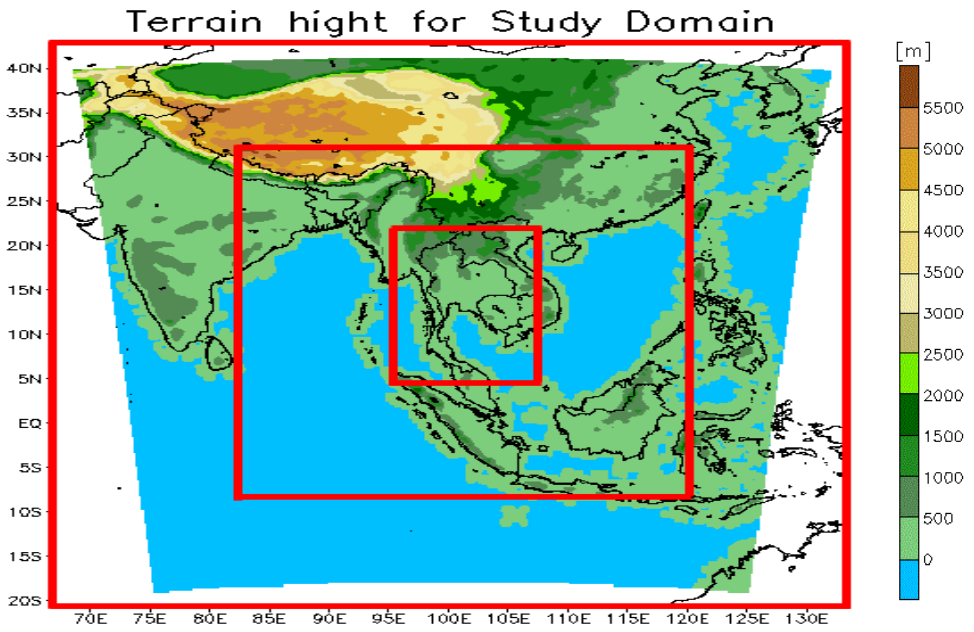


Figure 3.2 WRF model three nested domain with terrain height

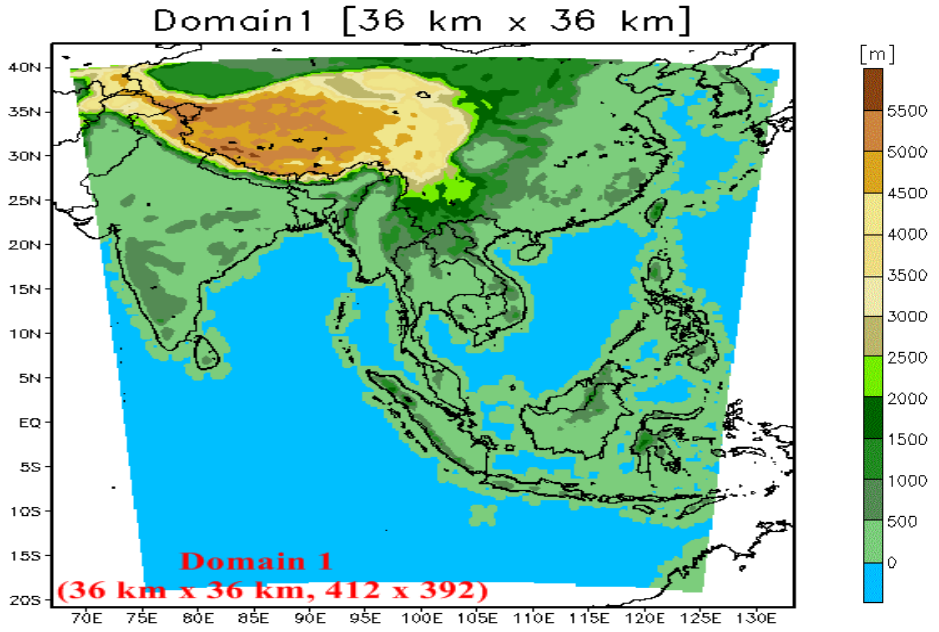


Figure 3.3 The resolutions of domain1 were 36 × 36 km^2 and has 412 × 392 grids spacing covering at latitude -20.8265$^\circ N$ to 42.5789$^\circ N$ and longitude 66.9183$^\circ E$ to 133.567$^\circ E$

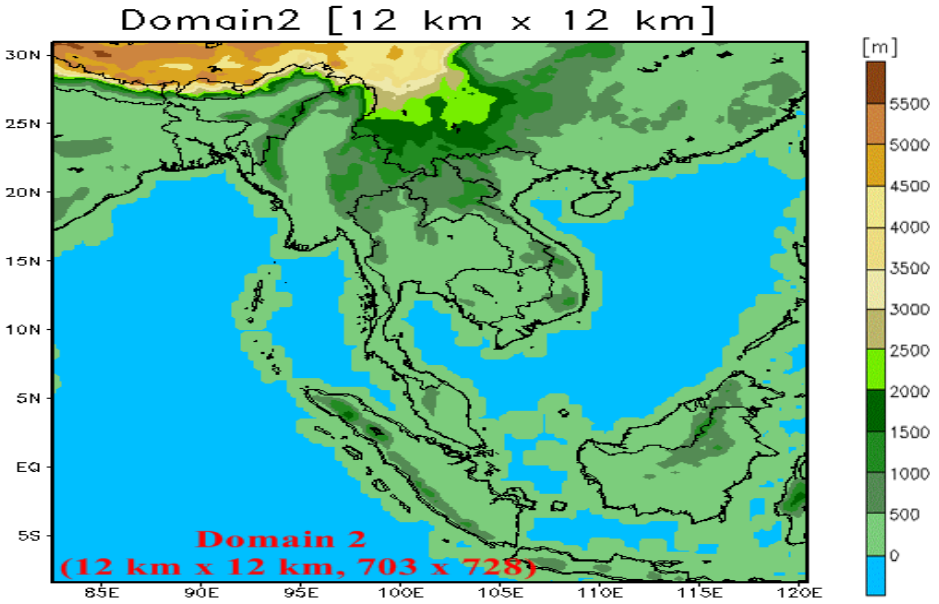


Figure 3.4 The resolutions of domain2 were 12 × 12 km^2 and has 703 × 728 grid spacing covering at latitude -8.40932$^\circ N$ to 30.888$^\circ N$ and longitude 82.5465$^\circ E$ to 120.492 $^\circ E$

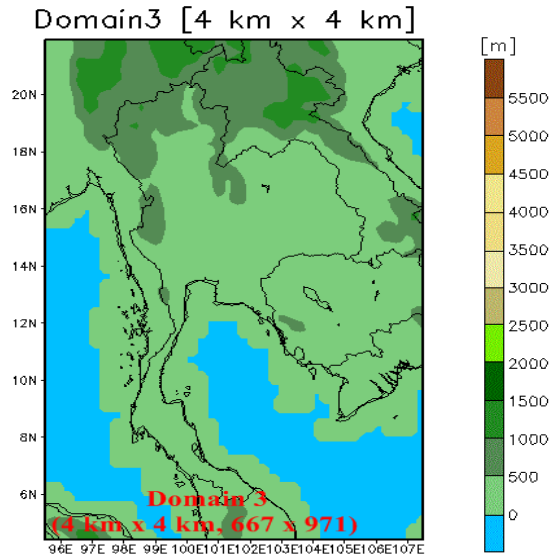


Figure 3.5 The resolutions of domain3 were 4×4 km^2 and has 667×971 grids spacing covering at latitude $4.4198^{\circ}N$ to $21.8973^{\circ}N$ and longitude $95.5056^{\circ}E$ to $107.506^{\circ}E$

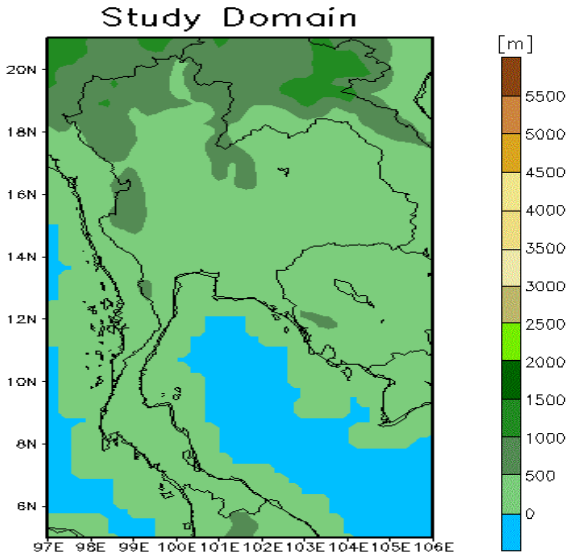


Figure 3.6 Study Domain with contour terrain height cover at latitude $5^{\circ}N$ to $21^{\circ}N$ and longitude $97^{\circ}E$ to $106^{\circ}E$

3.4 Period of Experiments for the Microphysics Parameterizations WRF Model

The selected year of TRMM observation data was chosen by maximum area average accumulate rainfall value during 2000 to 2012. In this study, and the highest maximum area average accumulate rainfall value is 2,293.72 mm/year in 2011 as shown in Figure 3.7. The rainfall pattern of TRMM observation data of 2011 is shown in Figure 3.8.

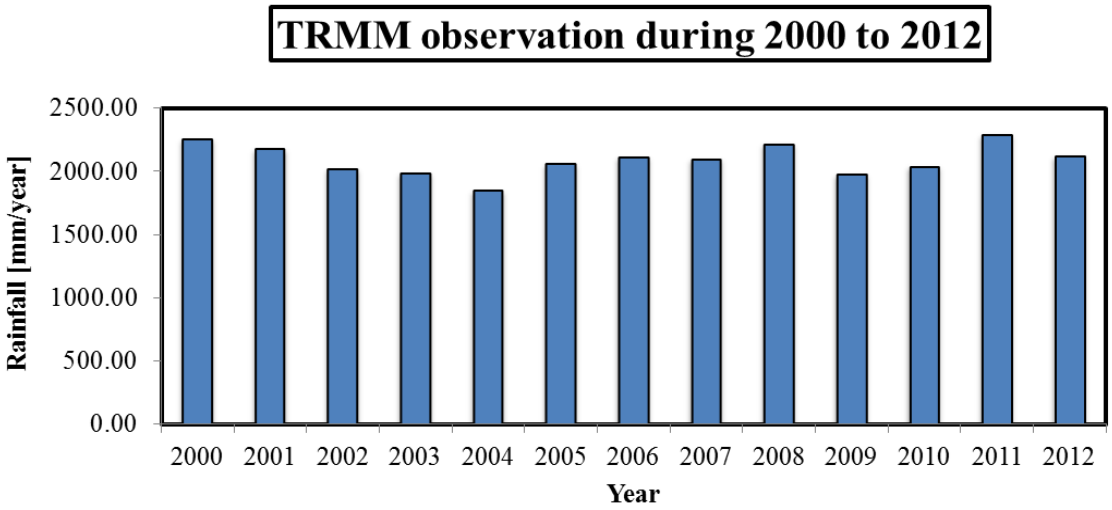


Figure 3.7 Area average accumulate rainfall value of TRMM observation data from 2000 to 2012 and 2011 showed the highest values

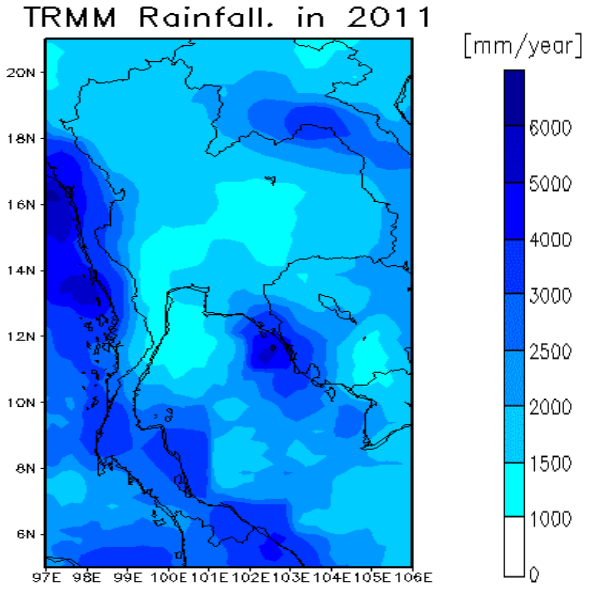


Figure 3.8 The rainfall pattern of TRMM observation data in 2011

The selected month of seasonal simulation of TRMM observation data was choose by maximum area average accumulate rainfall value of TRMM observation data from January to December of 2011, as shown in Figure 3.9.

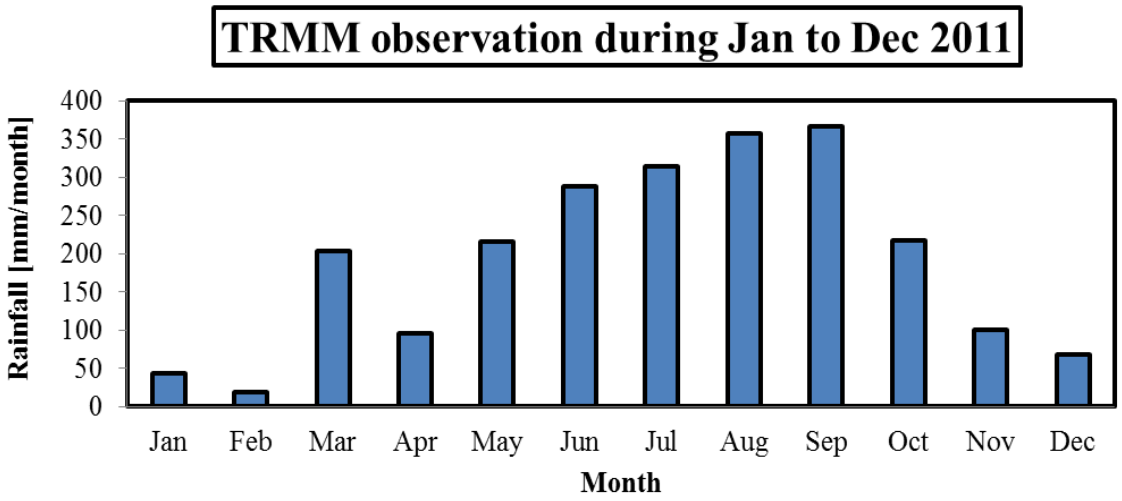
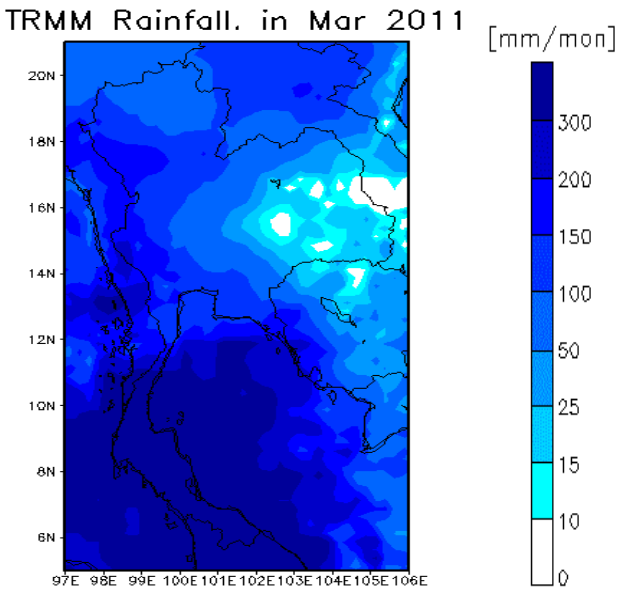


Figure 3.9 Area average accumulate rainfall value of TRMM observation data from January to December 2011

The selected month of summer season simulation from TRMM observation data is March 2011. Because it has the highest maximum area average accumulate rainfall value in summer season 2011 and the maximum area average accumulate rainfall value is 203.45 mm/month (Figure 3.9) and the rainfall pattern of TRMM observation data March 2011 is shown in Figure 3.10. The selected month of rainy season simulation from TRMM observation data is September 2011. It has the highest maximum Area average accumulate rainfall value in rainy season 2011 and it is 367.08 mm/month. (Figure 3.9) and the rainfall pattern of TRMM observation data of September 2011 is show in Figure 3.11. The selected month of winter season of simulation from TRMM observation data is November 2011. Because it has the highest maximum Area average accumulate rainfall value in winter season of 2011 and its value is 100.77 mm/month (Figure 3.9) and the rainfall pattern of TRMM observation data of November 2011 is shown in Figure 3.12.



. **Figure 3.10** The rainfall pattern of TRMM observation data in March 2011

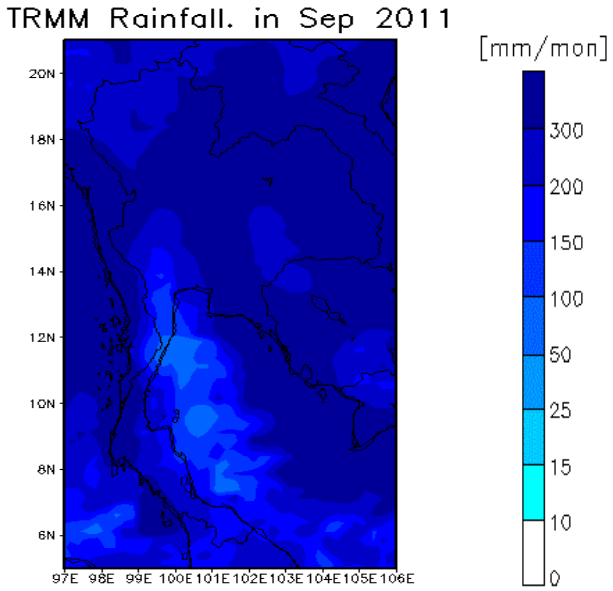


Figure 3.11 The rainfall pattern of TRMM observation data in September 2011

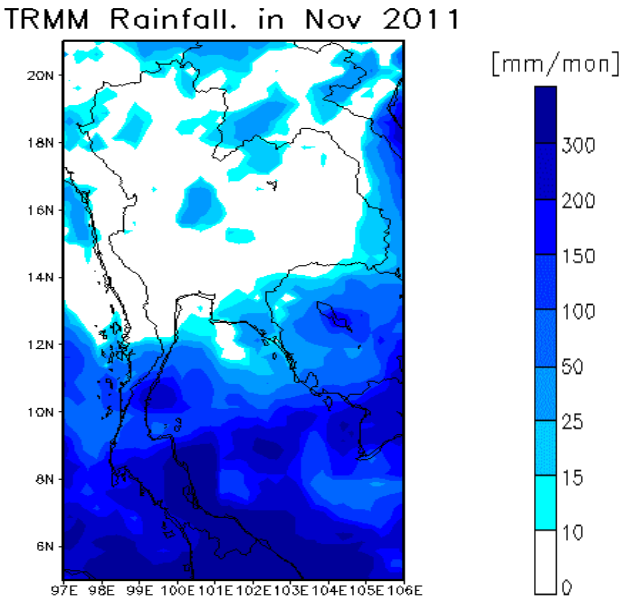


Figure 3.12 The rainfall pattern of TRMM observation data in November 2011

The date of summer season simulation from TRMM observation data and selected date simulation by chosen maximum area average accumulate rainfall value of TRMM observation data in summer season, as shown in Figure 3.13.

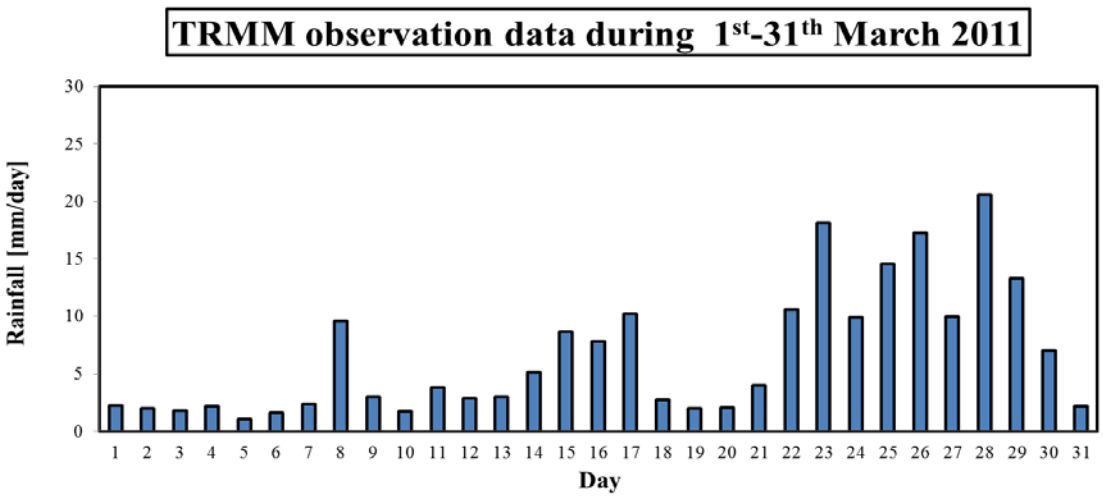


Figure 3.13 Area average accumulate rainfall value of TRMM observation data during 1st-31th March 2011

The date of summer season of simulation from TRMM observation data is 28 March 2011. Because it has the highest maximum area average values rainfall in summer season of 2011 and the maximum area average value is 20.60 mm/day from the Figure

3.13 and the spatial pattern of TRMM observation data is 28 March 2011 shown in Figure 3.14.

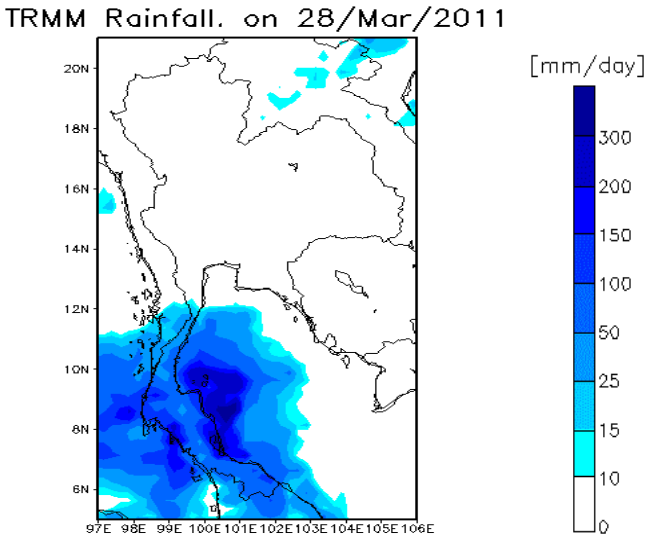


Figure 3.14 The rainfall pattern of TRMM observation data on 28th March 2011

The date of rainy season simulation from TRMM observation data and selected date simulation by chosen maximum area average accumulate rainfall value of TRMM observation data in rainy season, as shown in Figure 3.15.

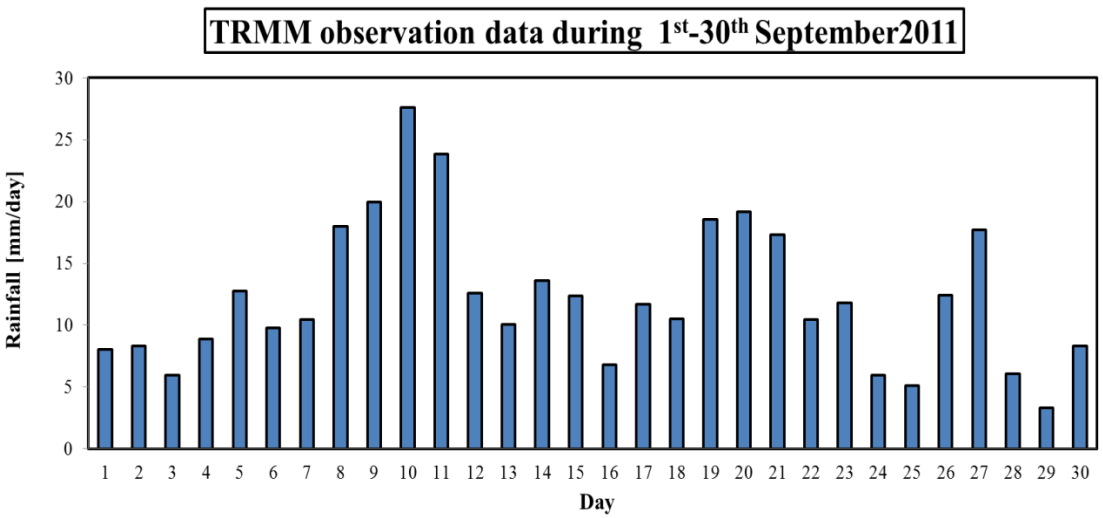


Figure 3.15 Area average accumulate rainfall value TRMM observation data during 1st-30th September 2011

The date of rainy season of simulation from TRMM observation data is 10 September 2011. Because it has the highest maximum area average accumulate rainfall value in rainy season of 2011 and the maximum area average accumulate rainfall value is 27.59 mm/day from the Figure 3.15 and the rainfall pattern of TRMM observation data is 10 September 2011 shown in Figure 3.16.

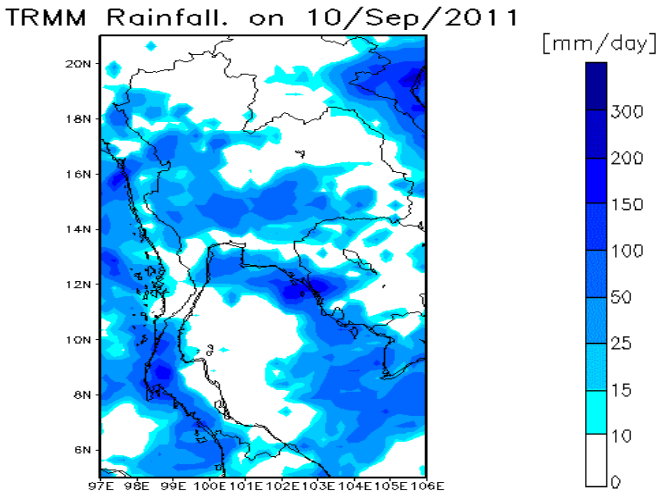


Figure 3.16 The rainfall pattern of TRMM observation data on 10th September 2011

The date of winter season simulation from TRMM observation data and selected date simulation by chosen maximum area average accumulate rainfall value of TRMM observation data in winter season, as shown in Figure 3.17.

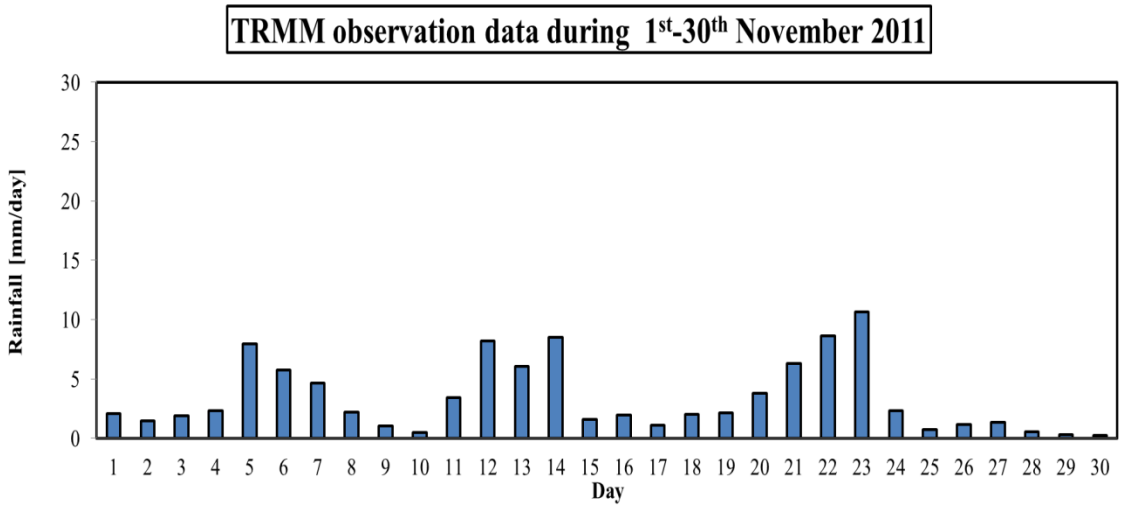


Figure 3.17 Area average accumulate rainfall TRMM observation data during 1st-30th September 2011

The date of winter season of simulation from TRMM observation data is 23 November 2011. Because it has the highest maximum area average accumulate rainfall value in winter season of 2011 and maximum area average accumulate rainfall value is 10.62 mm/day from the Figure 3.17 and the spatial pattern of TRMM observation data is 23 November 2011 shown in Figure 3.18.

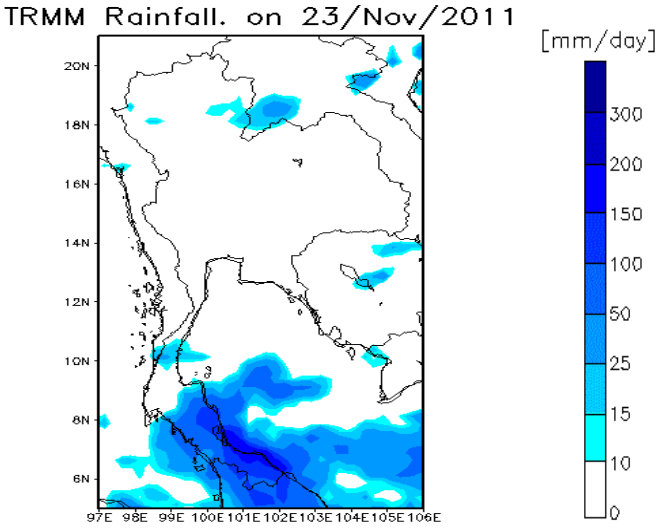


Figure 3.18 The spatial pattern of TRMM observation data on 23th November 2011

In this study, to selected three case of period experiment the first case is 3 hourly-rainfall during 0000 UTC 28 March 2011 to 0000 UTC 29 March 2011 (summer season), the second case is 3 hourly-rainfall during 0000 UTC 10 September 2011 to 0000 UTC 11 September 2011 (rainy season) and the last case is 3 hourly-rainfall during 0000 UTC 23 November 2011 to 0000 UTC 24 November 2011 (winter season) for the microphysics parameterizations of WRF model, as shown in Table 3.1.

Table 3.1 Experiments for the Microphysics Parameterizations WRF model

Case	Simulation period
Case 1 (Summer season)	3 hourly-rainfall during 0000 UTC 28 March 2011 to 0000 UTC 29 March 2011 (spin up 3 hour for 2100 UTC 27 March 2011)
Case 2 (Rainy season)	3 hourly-rainfall during 0000 UTC 10 September 2011 to 0000 UTC 11 September 2011 (spin up 3 hour for 2100 UTC 09 September 2011)
Case 3 (Winter season)	3 hourly-rainfall during 0000 UTC on 23 November 2011 to 0000 UTC 24 November 2011 (spin up 3 hour for 2100 UTC 22 November 2011)

3.5 Initial Boundary Data for the Microphysics Parameterizations of WRF Model

The NCEP FNL (Final) Operational Global Analysis data is product from the Global Data Assimilation System (GDAS). The resolution of data is 1 degree × 1 degree grid spacing and prepared operationally every six hours. The period of data preparing during 1800 UTC 30 July 1999 to present and analyses are available on the surfaced, at 26 mandatory (and other pressure) levels from 1000 millibars to 10 millibars. The spatial coverage from latitude is $180^{\circ}E$ to $180^{\circ}W$ and longitude is $90^{\circ}N$ to $90^{\circ}S$.

3.6 Experiments for the Microphysics Parameterizations of WRF Model

Experiment cases of the simulations were performed with fourteen distinct combinations of physical schemes. The fourteen distinct microphysics parameterization schemes were used with two options of other physical schemes. The first option of the microphysics parameterization schemes is the single-moment scheme and the second option of the microphysics parameterization schemes is the double-moment scheme. The mass mixing ratios (q_x) denoted hydrometeor species, where $x = c, r, i, s, g$, and h (cloud-water, rain, cloud-ice, snow, graupel, and hail, respectively) and the number concentration (N_x) for the water and ice species where $x = c, r, i, s, g$, and h (cloud-water, rain, cloud-ice, snow, graupel, and hail, respectively) are shown in Table 3.2.

Table 3.2 List of the microphysics scheme available in WRF model

Mp_physics	Scheme	Mass Mixing Ratios	Number Concentration	single-moment scheme	double-moment scheme
1	Kessler	q_c q_r	-	✓	×
2	Purdue Lin	q_c q_r q_i q_s q_g	-	✓	×
3	WSM3	q_c q_r	-	✓	×
4	WSM5	q_c q_r q_i q_s	-	✓	×
5	Eta	q_c q_r q_i q_s	-	✓	×
6	WSM6	q_c q_r q_i q_s q_g	-	✓	×
8	Thompson	q_c q_r q_i q_s q_g	N_i N_r	×	✓

Table 3.2 List of the microphysics scheme available in WRF model (Cont.)

Mp_physics	Scheme	Mass Mixing Ratios	Number Concentration	single-moment scheme	double-moment scheme
9	Milbrandt	$q_c\ q_r\ q_i\ q_s\ q_g\ q_h$	$N_c\ N_r\ N_i\ N_s\ N_g\ N_h$	×	✓
10	Morrison	$q_c\ q_r\ q_i\ q_s\ q_g$	$N_r\ N_i\ N_s\ \ N_g$	×	✓
13	SBU-YLin	$q_c\ q_r\ q_i\ q_s$	-	✓	×
14	WDM5	$q_c\ q_r\ q_i\ q_s$	$Nn(CCNnumber)\ N_c\ N_r$	×	✓
16	WDM6	$q_c\ q_r\ q_i\ q_s\ q_g$	$Nn(CCNnumber)\ N_c\ N_r$	×	✓
17	NSSL	$q_c\ q_r\ q_i\ q_s\ q_g\ q_h$	$N_c\ N_r\ N_i\ N_s\ N_g\ N_h$	×	✓
18	NSSL+CCN	$q_c\ q_r\ q_i\ q_s\ q_g\ q_h$	$N_c\ N_r\ N_i\ N_s\ N_g\ N_h$	×	✓

The selected microphysics parameterization schemes were Kessler scheme, Lin scheme, WSM3-class scheme, WSM5-class scheme, Eta scheme, WSM6-class scheme, SBU-YLin 5-class scheme, Thompson double-moment scheme, Milbrandt-Yau double-moment scheme, Morrison double-moment scheme, WRF double moment 5-class scheme (WDM5), WRF double moment 6-class scheme (WDM6), NSSL double-moment (NSSL), and NSSL double-moment with CCN prediction scheme (NSSL+CCN). 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 others physics options that were used in this study; Betts-Miller-Janjic (BMJ) cumulus parameterization, Dudhia shortwave radiation, Rapid Radiative Transfer Model (RRTM) long-wave radiation, the Yonsei University planetary boundary layer (YSU) scheme, and the unified Noah land-surface model as shown in Table 3.3.

Table 3.3 Physical processes and options that used in this study

Physical Process and options	Selected Option
Cumulus parameterization (Cu)	Betts-Miller-Janjic (BMJ)
Short-wave radiation	Dudhia shortwave radiation
Long-wave radiation	Rapid Radiative Transfer Model (RRTM) long-wave radiation
Planetary Boundary Layer (PBL)	The Yonsei University planetary boundary layer (YSU) scheme
Initial Boundary	The NCEP FNL (final) Operational Global Analysis data resolution (FNL)

This study has fourteen experiment of microphysics parameterization scheme of WRF model for rainfall simulation over Thailand. In summer season, we simulated rainfall over Thailand during 0000 UTC 28 March 2011 to 0000 UTC 29 March 2011 with fourteen microphysics parameterization schemes. The fourteen experiment cases are during 0000 UTC 28 March 2011 to 0000 UTC 29 March 2011, shown in Table 3.4.

Table 3.4 Experiment cases for Microphysics Parameterizations on 28th March 2011

Experiment case	Mp	Period	Cu	Short-wave	Long-wave	PBL
EXP01	Kessler	3 hourly-rainfall during 0000 UTC 28 March 2011 to 0000 UTC 29 March 2011	BMJ	Dudhia	RRTM	Yonsei
EXP02	Lin					
EXP03	WSM3					
EXP04	WSM5					
EXP05	Eta					
EXP06	WSM6					
EXP07	Thompson					
EXP08	Milbrandt					
EXP09	Morrison					
EXP10	SBU-YLin					
EXP11	WDM5					
EXP12	WDM6					
EXP13	NSSL					
EXP14	NSSL+CCN					

In rainy season, we simulated rainfall over Thailand during 0000 UTC 10 September 2011 to 0000 UTC 11 September 2011 with fourteen microphysics parameterization schemes. The fourteen experiment case is during 0000 UTC 10 September 2011 to 0000 UTC 11 September 2011, shown in Table 3.5.

Table 3.5 Experiment cases for Microphysics Parameterizations on 10th September 2011

Experiment case	Mp	Period	Cu	Short-wave	Long-wave	PBL
EXP01	Kessler	3 hourly-rainfall during 0000 UTC 10 September 2011 to 0000 UTC 11 September 2011	BMJ	Dudhia	RRTM	Yonsei
EXP02	Lin					
EXP03	WSM3					
EXP04	WSM5					
EXP05	Eta					
EXP06	WSM6					
EXP07	Thompson					
EXP08	Milbrandt					
EXP09	Morrison					
EXP10	SBU-YLin					

Table 3.5 Experiment cases for Microphysics Parameterizations on 10th September 2011 (Cont.)

Experiment case	Mp	Period	Cu	Short-wave	Long-wave	PBL
EXP11	WDM5					
EXP12	WDM6					
EXP13	NSSL					
EXP14	NSSL+CCN					

In winter season, we simulated rainfall over Thailand during 0000 UTC 23 November 2011 to 0000 UTC 24 November 2011 with fourteen microphysics parameterization schemes. The fourteen experiment case is during 0000 UTC 23 November 2011 to 0000 UTC 24 November 2011, shown in the Table 3.6.

Table 3.6 Experiment cases for Microphysics Parameterizations on 23th November 2011

Experiment case	Mp	Period	Cu	Short-wave	Long-wave	PBL
EXP01	Kessler	3 hourly-rainfall during 0000 UTC 23 November 2011 to 0000 UTC 24 November 2011	BMJ	Dudhia	RRTM	Yonsei
EXP02	Lin					
EXP03	WSM3					
EXP04	WSM5					
EXP05	Eta					
EXP06	WSM6					
EXP07	Thompson					
EXP08	Milbrandt					
EXP09	Morrison					
EXP10	SBU-YLin					
EXP11	WDM5					
EXP12	WDM6					
EXP13	NSSL					
EXP14	NSSL+CCN					