CHAPTER 3

METHOD

3.1 Description of data

3.1.1 RCM data

The simulated daily rainfall and temperature at the resolution of 15 km from the fifth-generation Pennsylvania State University NCAR Mesoscale Model MM5 regional climate model (MM5-RCM) forced with National Center for Atmospheric Research (NCAR) Community Climate Model version 3 (CCSM3) on dynamical downscaling technique provided by Atmospheric Physics Research Unit, Faculty of Science, Chiang Mai University (Chidthaisong, 2010)[33] were used to calculate extreme rainfall and temperature indices.

In MM5-RCM simulations, initial and lateral meteorological boundary conditions were taken from 6-hourly CCSM3 at the resolution of 1.40625 degrees. Forcing CCSM3 according to the Special Report on Emissions Scenarios (SRES) A1B was employed. The MM5-RCM physics schemes are listed in Table 3.1.

Table 3.1 MM5-RCM Physics Schemes

Physics and dynamics	**Option**
Cumulus Parameterizations	Betts-Miller cumulus scheme
Planetary Boundary Layer	Medium Range Forecast(MRF)
Moist Vertical Diffusion	Moist vertical diffusion in cloud
Horizontal Diffusion	Sigma-diffusion using temperature
Microphysics(Explicit Moisture) Schemes	Mixed-Phase (Reiner 2)
Radiation Schemes	RRTM radiation
Surface Schemes(Multi-layers Soil temperature)	5-Layer Soil Model
Hydrostatical /Non -hydrostatical	Non-hydrostatical

All MM5-RCM simulations above had been performed for the future period, 2010-2039 and the control period, 1970-1999 at the Atmospheric Physics Research Unit (APRU), Faculty of Science, Chiang Mai University. In this study, the outputs from this simulation in the period 1990-1999 and 2020-2029 were selected to focus the changes in extreme temperature and rainfall indices in the upcoming decade, 2020-2029 relative to the reference period, 1990-1999.

In order to decide the optimal scheme (between the Betts-Miller cumulus scheme and Kain–Fritsch cumulus scheme), the simulated results of both schemes in the year 1995 were compared with the observed data. The comparisons were analyzed focusing in the terms of correlation coefficients which is the measure of how well the simulated values from the model fit with the observed data.

3.1.2 Observational data

In order to calibrate MM5-RCM outputs and evaluate the bias-corrected results, the daily temperature and rainfall data for the period 1980-1999 and 1990-1999 were used, respectively. The observed data were taken from 50 meteorological and agro-meteorological stations distributed across the country. These stations were selected based on length of record (20 years) and the completeness of the dataset. The temperature and rainfall data were kindly provided by Thai Meteorological Department. The stations used in this study are shown in Figure 3.1.

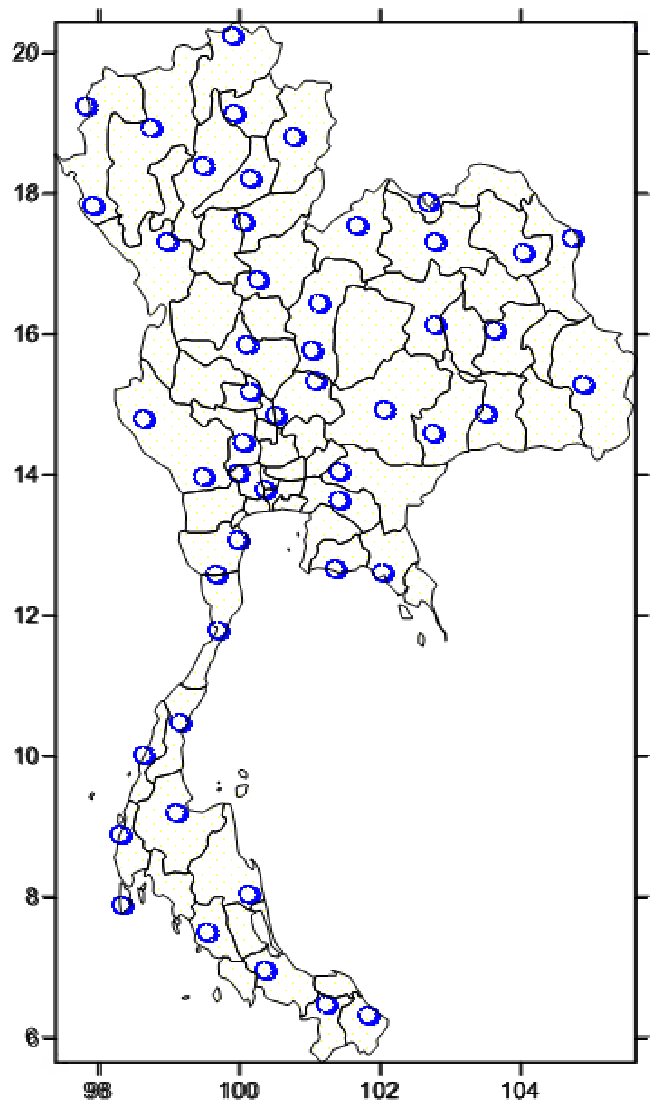

Figure 3.1 Location of the stations used in the study

Station names and coordinates are listed in the following Table.

Table 3.2 The stations and their locations used in this research

Name	Code	Latitude		Longitude		elevation
		degree	arc minute	degree	arc minute	
Chai Nat Agro met	402301	15	9	100	11	15
Suphan Buri	425201	14	28	100	8	7
Kamphaeng Sean Agro met	451301	14	1	99	58	7.5
Lop Buri	426201	14	48	100	37	10
Bankok Metropolis	455203	13	44	100	34	2
Bua Chum	426401	15	16	101	12	50
Prachin Buri	430201	14	3	101	22	5
Rayong	478201	12	38	101	21	3
Chacherngsao Agro met	423301	13	34	101	28	70
Chanthaburi	480201	12	37	102	7	3
Loei	353201	17	27	101	44	253
Chok Chai	431401	14	44	102	11	190
Nong Khai	352201	17	52	102	44	174
Udon Thani	354201	17	23	102	48	177
Khon Kaen	381201	16	26	102	50	165
Nang Rong	436401	14	37	102	43	179
Roi Et	405201	16	3	103	41	140

Surin	432201	14	53	103	30	146
Sakon Nakhon	356201	17	9	104	8	171
Nakhon Phanom	357201	17	25	104	47	140
Ubon Ratchasima	407501	15	15	104	52	123
Mae Sod	376202	16	40	98	33	196
Phitsanulok	378201	16	47	100	16	44
Nakhon Sawan	400201	15	48	100	10	34
Phetchabun	379201	16	26	101	9	114
Wichian Buri	379402	15	39	101	7	69
Mae Hong Son	300201	19	18	97	50	267
Mae Sariang	300202	18	10	97	56	212
Chiang Mai	327501	18	47	98	59	312
Lampang Agromet	328301	18	19	99	17	315
Chiang Rai	303201	19	55	99	50	395
Phayao	310201	19	8	99	54	377
Phrae	330201	18	10	100	10	161
Uttaradit	351201	17	37	100	6	63
Nan	331201	18	47	100	47	200
Chumphon	517201	10	29	99	11	3
Ranong	532201	9	59	98	37	7
Takua Pa	561201	8	51	98	16	3

Surat Thani (Airport)	551202	9	8	99	8	7
Phuket	564201	7	58	98	24	2
Nakornsi Thammarat Agro met	552301	8	20	100	5	2
Trang (Airport)	567201	7	31	99	32	14
Hat Yai (airport)	568502	6	55	100	36	34
Yala Agro met	581301	6	31	101	17	30
Narathiwat	583201	6	25	101	49	2
Thong Pha Phum	450401	14	45	98	38	97
Khanchanaburi	450201	14	1	99	32	28
Phetchaburi	465201	13	9	100	4	2
Nong Phlub Agro met	500301	12	35	99	44	
Prachuap Khiri Khan	500201	11	50	99	50	4

3.2 Extreme Climate Indices

There is a variety of ways to define climate extreme. This study focused on the use of international climate extremes indices. These indices are in the suite of extreme indices recommended by the joint Working Group on Climate Change Detection of the World Meteorological Organization - Commission for Climatology (WMO-CCL) and the research program on Climate Variability and Predictability (CLIVAR), and are featured prominently in the IPCC AR4 . The indices in this suite have been used widely in the assessment of extreme events in the future and present . Twelve selected indices including six indicators of extreme rainfall, and six indicators for extreme temperature were used as listed in table 3.3. [More details about theses indices can be found at http://cccma.seos.uvic.ca/ETCCDI.]

Table 3.3 The extreme rainfall and temperature indices used in this study (The full definitions can be seen in appendix I)

ID	Indicator name	Definition	Unit
SDII	Simple daily rainfall intensity index (an indicator of the rainfall intensity)	The ratio of annual or seasonal total rainfall to the number of days during the year or season with rainfall greater than or equal to 1 mm. (SDII=$\frac{\text{rainfall amount of wet days}}{\text{number of wet days of the period}}$)	mm/day
Rnn*	The number of heavy rainfall days	The annual or seasonal total number of days with rainfall amount greater than the 95^{th} percentile of rainfall amount in the base period	days
Rx1day	Maximum 1-day rainfall amount	The monthly maximum 1-day rainfall amount	mm
Rx5day	Maximum 5-day	The monthly maximum consecutive 5-day	mm

	rainfall amount	rainfall amount	
CWD	The maximum wet spell	The longest annual or seasonal period of consecutive days with at least 1 mm of rainfall	days
CDD	The maximum dry spell	The longest annual or seasonal period of consecutive days with no or less than 1 mm of rainfall	days
SUnn*	Hot summer days	Annual or seasonal number of days when daily maximum temperature is greater than the 95th percentile of maximum temperature in the base period	Days
TxX	Maximum daytime temperature	Monthly maximum value of daily maximum temperature	°C
TnX	Maximum nighttime temperature	Monthly maximum value of daily minimum temperature	°C
Tx90P	Frequency of hot days	Percentage of days with daily maximum temperature greater than the 90th percentile of daily maximum temperature of a 5-day window centered on each calendar day of the base period	%

Tn90P	Frequency of warm nights	Percentage of days with daily minimum temperature greater than the 90th percentile of daily minimum temperature of a 5-day window centered on each calendar day of the base period	%
DTR	Diurnal temperature range	Monthly mean difference between maximum and minimum temperature	°C

Note that the nn* in the Rnn index denoted the 95th percentile of rainfall amount in the base period, which was which was calculated for each station [34]. The extreme rainfall indices were calculated based on annual and seasonal bases, namely the wet (May - October) and dry (November - April) seasons.

For extreme temperature indices the nn* in the SUnn index denoted the 95th percentile of maximum temperature in the base period, which was calculated for each station. The extreme temperature indices above were chosen to investigate hotter condition in the future. They were calculated based the cool (November - February), warm (March - May), and rainy (June - October) seasons. To investigate the significance of change, the Student t-test was used to detect the significant change by a level of 95 percent confidence.

The calculation of rainfall indices were performed using RClimDex software; developed and maintained on behalf of the Expert Team on Climate Change Detection and Indices (ETCCDI) by the Climate Research Branch of the Meteorological Service of Canada. (This is also available on the above website). The indices are calculated for the present period (1990 - 1999) and for the future period (2020 - 2029) on annual and seasonal bases. For rainfall analysis, the climatic cycle was divided into two seasons: wet-season (May - September) and dry-season (October - December to January - April). For temperature analysis, the climatic cycle was divided into three seasons: the cool (November - February), warm (March - May), and rainy (June - October) seasons.

3.3 Bias-correction Method

Simulation outputs are not always in a good accordance with observation. There may be some biases associated with models. These biases limit the direct utilization of model simulated results in climate change impact studies. Sometimes, heavy rainfall, number of heavy rain days as well as their magnitude are not well reproduced by RCMs. The bias correction is therefore necessary.

The bias correction approach is employed in this study to reduce the model biases. The bias correction algorithms are developed based on the comparison of observed data and the model output for the same time period.

3.3.1 Rainfall

For rainfall correction, the direct method (DM, sometimes referred to as delta method) was applied [35 - 37]. The direct method scales the simulated rainfall by multiplying it with the parameter which is the ratio of observed and RCM-simulated rainfall. Let

P_{MM5}= raw MM5-RCM rainfall

$P_{adj-MM5}$= adjusted MM5-RCM rainfall

$\bar{P}_{obs}$= mean observed rainfall

$\overline{P_{MM5}}$ = mean raw MM5-RCM rainfall

The equation that is used to adjust the P_{MM5} to the $P_{adj-MM5}$ is

$$P_{adj-MM5} = P_{MM5} \times \frac{\overline{P_{obs}}}{\overline{P_{MM5}}} \qquad (12)$$

Note that the parameters $\bar{P}_{obs}/\bar{P}_{MM5}$ were calculated for each month in each station using data from the periods 1980-1999.

3.3.2 Temperatures

In this study, the bias-correction method which is a variant of quantile-mapping was applied to reduce temperature biases from MM5-RCM [38 - 41]. The graphical representation of bias-correction method is illustrated in figure 3. The bias-correction uses both cumulative distribution functions (CDFs) of the observed and simulated temperatures to remove bias by replacing the simulated value with the observed value that have the same probability. [Figure 3.2]

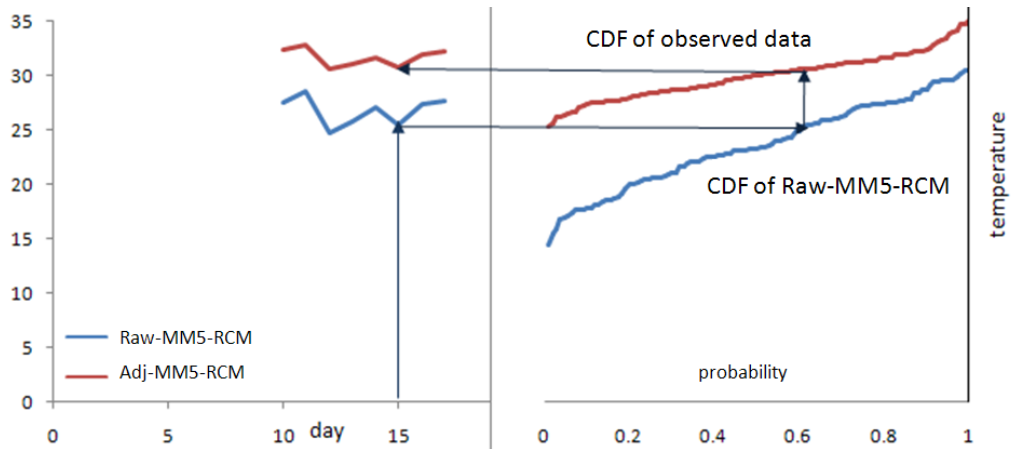

Figure 3.2 Graphical representation of bias-correction method

Let$F(T)$,T_{ctl}, and $T_{adj-ctl}$ denote the cumulative distribution function of temperature, raw MM5-RCM temperature in reference period and the bias-corrected temperature in the same period, respectively. The transformation that is used to adjust the T_{ctl} to the $T_{adj-ctl}$ is

$$T_{adj-ctl} = F_{obs}^{-1}(F_{ctl}(T_{ctl})) \tag{13}$$

Where F_{ctl} and F_{obs}^{-1} is a CDF of raw MM5-RCM temperature and the inverse CDF of observed temperature in the reference period. The bias-correction also applies to the projected temperatures by the assumption that the bias of the temperature is equal for the same probability. [39]

The bias-corrected MM5-RCM output (adj-MM5-RCM) can also be used as an input data to other climate impact studies such as water resource, agriculture and environments for further studies.

3.4 Cumulus Parameterization

Parameterization is the method in atmospheric models by which the subgrid-scale processes are determined from variables at model grid points by relating subgrid-scale effects to large-scale properties. One of the most processes that is commonly parameterized is cumulus convection. Cumulus convection operates on scales that are smaller than the grid element and cannot be directly resolved by the models. This process need to be represented by parameterization. In order to determine the optimal parameterization schemes for prediction of extreme events, two convective cumulus parameterizations were selected. The Betts-Miller Janjic (BMJ) scheme is the most popular for tropical systems. The Kain-Fritsch scheme (KF) has not been run extensively in the tropics but it has been configured as the standard configuration in many models. The simulations of rainfall and temperature using the both cumulus schemes for the base-year 1995 have been carried out by the Weather Research and Forecasting (WRF) modeling system. The WRF configurations are shown in Table 3.4.

Table 3.4 WRF configurations

Year	1995
Forcing	The Community Climate System Model version 3 (CCSM3)
Planetary Boundary Layer	Mellor-Yamada-Janjic (Eta) TKE scheme
Microphysics Schemes	WSM 6-class graupel scheme
Longwave radiation option	RRTM scheme
Shortwave radiation option	Goddard short wave

The study domain is shown in Figure 3.3.

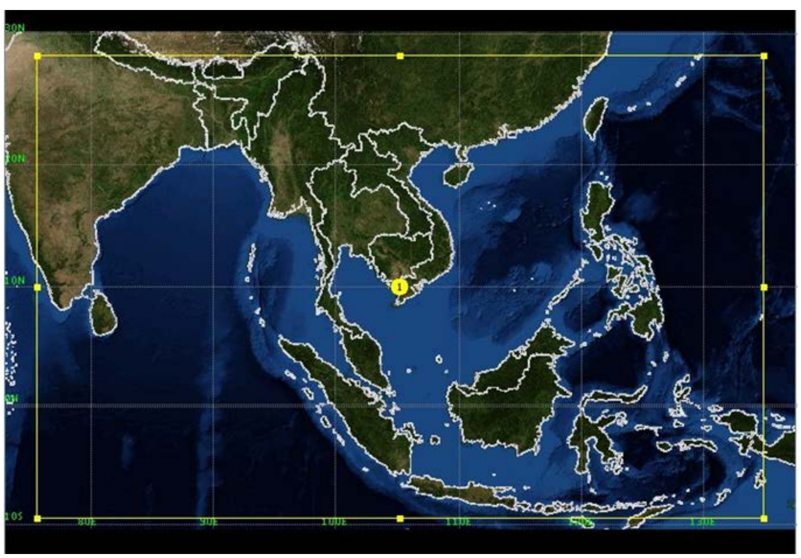

Figure 3.3 The study domain that is use in cumulus parameterization