CHAPTER 1

INTRODUCTION

1.1 Background

Global warming is one of the most controversial science issues of the 21st century. The Intergovernmental Panel on Climate Change (IPCC) concluded that increasing greenhouse gases (GHG), such as carbon dioxide (CO_2) caused most of observed temperature increase since the middle of the 20th century. It is probable that there has been significant anthropogenic warming over each continent (except Antarctica) for the past 50 years [1]. According to the Special report on Emission Scenarios (SRES) in IPCC AR4, by the year of 2100, the minimum atmospheric concentration of carbon dioxide is projected to reach about 600 part per million. This implies that global warming or climate change, which had already started to impact in many regions around the world, will become more evident in the future.

This global warming causes many effects in social, economic, and environments. The effects include more extreme weather events, rising sea levels, droughts, flooding, extinction of species, and impacts on agriculture and human health. Therefore, impact assessments of climate change are drawing attention rapidly in recent decades.

A changing climate also leads to changes in the frequency, intensity, duration, and timing of extreme weather and climate events, and can result in unprecedented extreme weather and climate events [2]. Many evidences have found a significant increase in extreme temperature and precipitation indices in many parts of the world [3, 4]. An increase in extreme events can lead to more natural disasters e.g. floods, droughts, heat waves, and cool waves. An increase in the number and/or intensity of these disasters would have a negative impact that will cause very serious problems to environments, society, and human life.

The Intergovernmental Panel on Climate Change (IPCC) developed a special Report on Emission Scenarios (SRES). These scenarios have been widely used in the analysis of climate change and its possible impacts. SRES present four narrative storylines, labeled A1, A2, B1, and B2 describing the relationships between the driving greenhouse gases and aerosol emissions and their evolution [5].

Global climate models (GCMs) are the well-known tools and are commonly used in predicting and evaluating future climate change under various emission scenarios. There were numbers of studies that have analyzed extreme climate events from GCMs projections of future climate change in many regions under various emissions scenarios [5].

The impacts of global warming may differently affect regions around the world. Therefore the study of the impacts of global warming in a regional scale is very essential.

However, a resolution of GCMs is too coarse (normally of the order of hundreds of kilometers) to provide an information needed for the impact assessment at the regional scales. They are unable to resolve significant local sub grid scale. [6, 7] To overcome this limitation of GCMs, the application of downscaling technique is therefore necessary. There are various downscaling techniques to convert GCMs outputs to local scale. The two main approaches are dynamical and statistical downscaling. Dynamical downscaling combines the benefits of a high resolution weather model and global climate simulation capacity by embedding the weather model within the global model over regions of interest [8]. Dynamical downscaling has the potential to capture meso-scale nonlinear effects and provide coherent information among multiple climate variables. These models are formulated using physical principles and they can effectively reproduce a broad range of climate around the world, which increases confidence in their ability to realistically downscale future climates. Statistical downscaling methods start by use the relationships that have been derived from observed data at the desired scale and long time period, and apply these to climate model data [1,9]. In this study, the data were taken from the results of the dynamical downscaling of the 5^{th} generation Mesoscale Model (MM5) forced with the NCAR Community Climate System Model [10].

However, climate models (GCMs/RCMs) outputs usually deviate from the observed data. These biases limit the direct utilization of model simulated results in climate change impact studies. Extreme events such as heavy rainfall or the number of heavy rainfall days are either not well captured or their magnitude is unrealistically low. The bias correction is therefore essential in order to provide better input data for climate change impact assessments. The bias-correction of GCMs outputs leads to satisfactory results in many studies. [11, 12] The bias correction not only is important for GCMs outputs but it can be applied to RCMs output also [13-14]. The bias-corrected data are useful in the studies of climate change impacts to the extreme events and can be used as an input to other climate impact studies such as water resource, agriculture and environments

1.2 Thailand

Thailand is located in the tropical region between latitudes 5° 37'N to 20° 27' N, and longitudes 97° 22' E to 105°37' E. The country lies within complex terrain, land use, and coastlines. The climate of Thailand is under the influence of the southwest monsoon and the northeast monsoon. The southwest monsoon occurs during May - October, originating in the Indian Ocean [15]. This monsoon brings a moist air mass from the Indian Ocean toward the country causing rainfall, especially on the coastlines and windward side of the mountains. The northeast monsoon takes place October - February, originating in the anticyclone in China and Mongolia. This monsoon brings a cold and dry air mass toward Thailand causing cold and dry weather in the north and northeast as well as abundant rainfall in the southern Thailand.

The climate of Thailand may be divided into three seasons: the rainy season (mid-May to mid-October), the cool season (mid-October to mid-February), and the summer (mid-February to mid-May). The southwest monsoon prevails in Thailand during the rainy season causing rainfall throughout the country. In the cool season, the country is influenced by the northeast monsoon; it is cool in upper-Thailand while there is still a great amount of rainfall in the south. In summer, which is the pre-monsoon season, the weather is warmer throughout the country: the temperature reaches maximum in this season.

Thailand has also experienced a gradual warming associated with the significant warming trend from observed record [16]. The aim of this study is to estimate the change in extreme temperature and rainfall indices in Thailand for the future decade, 2020-2029, relative to the reference decade, 1990-1999, under the IPCC SRES A1B emission scenarios. In this study, the simulated daily temperature and rainfall data of the MM5 RCM forced with CCSM3 at the resolution of 20 km were used to calculate the climate indices. Before the calculations of extreme temperature and rainfall indices were made, the raw MM5-RCM outputs were adjusted in bias-correction process. Using the bias corrected MM5-RCM (Adj-MM5-RCM) results; the relative changes in extreme indices in Thailand on annual and seasonal bases for the period 2020–2029 relative to 1980–1999 were analyzed.

1.3 Literature Reviews

A fine resolution regional climate change experiment over China was performed [17] using the regional climate change model PRECIS. The PRECIS was employed to simulate the baseline (1961 - 1990) climate and the future climate change responses in 2071 - 2100 (2080s) under SRES B2. Initial and boundary conditions were provided by the Hadley Centre HadAM3P global climate model. The model configurations are as following:-

- 0.44°×0.44° horizontal resolution.
- 19 vertical layers.
- MOSES land surface scheme

PRECIS can simulate the local distribution characteristics of surface air temperature over China quite well. The simulated precipitation values were lower than observations over southeast coastal areas. There would be an overall increase of the simulated precipitation in 2080s under SRES B2 scenario over most areas of China, while there would be significant precipitation decreases in South China in winter; there would be obvious precipitation decreases in Northeast China and North China in summer with higher surface air temperature.

One of the most worldwide regional climate change model is MM5 Regional Climate Model (MM5 RCM). Tadross, A. and his staff performed MM5 simulation to find the most suitable set of schemes.[18] Two cumulus convection and two planetary boundary layer (PBL) schemes were used to investigate the climate of southern Africa using the MM5 RCM with the forcing European Centre for Medium-range Weather Forecasting Reanalysis(ERA-15) at the horizontal resolution of 50 km. This study focused on the combination of two different PBL and two different cumulus convection schemes. The two PBLs are

1. Mellor-Yamada scheme
2. Hong-Pan scheme (medium range forecast model)

And the convection schemes utilized in the experiment are

1. Betts-Miller scheme
2. Kain-Fritsch scheme.

The Betts-Miller convection scheme in MM5 simulated the peak rainfall later in the day and less rain days than observed, whereas the Kain-Fritsch convection scheme simulated the peak rainfall earlier in the day and more rain days than observed. Precipitation during the wet 1988/89 season was reasonably captured by most simulations. It is clear that the medium range forecast model is appropriate for simulations over the region but there is no clear choice for the appropriate convection scheme.

The changes of extreme climate indices have been studied in many regions of the world. For example, the future potential changes in duration of extreme dry and wet spells and rainfall intensity in Eastern Mediterranean have been estimated [19]. Daily precipitation amounts, deriving from the regional climate model of UK Hadley Centre HadRM3P had been used for the present (1960-1990) and the future period 2070-2100 based on IPCC SRES B2 emission scenario. For the identification of precipitation extremes three climatic indices were employed: a) CWD (Maximum number of consecutive wet days), b) CDD (Maximum number of consecutive dry days) and c) SDII (quotient of precipitation amount of wet days and the number of wet days of the period). They were calculated for the present and future period, on a seasonal and annual basis. In the future, it is expected to be drier in Eastern Mediterranean, with reduced rainfall intensity. Longer dry spells are expected in all seasons, except autumn, with the largest increase in the southern part of the area. Extreme wet spells will likely shorten everywhere during all seasons, except autumn. Precipitation intensity is expected to reduce for all seasons and mostly in summer for South Aegean Sea.

The climate modeling community in the framework of IPCC-AR4 has provided valuable global data sets of climate evolution for the twentieth century as well as for a range of future scenarios in the twenty-first century. Zhihong Jiang [20] and his team used all the seven available models including the GFDL CM2.0, GFDL-CM2.1, INM-CM3.0, IPSL-CM4, MIROC3.2-MEDRES,CNRM-CM3, and NCAR-PCM1 to study climate extremes in China. The extreme indices used in the study were frost days (Fd), intra-annual extreme temperature range (ETR), growing season length (GSL), heat wave duration index (HWDI) ,warm night index (Tn90),simple daily intensity index (SDII), maximum number of consecutive dry days (CDD),number of days with precipitation greater than 10 mm (R10), maximum 5-day precipitation total (R5d), and fraction of annual total precipitation due to events exceeding the 95th percentile (R95T) defined from 1961–1990.Model results were compared to observations from 550 stations in China for the period 1961–1990 in order to evaluate the simulated present-day climate extremes. Results showed that all the seven models had certain abilities to simulate the basic characteristics of extreme climate indices, including both the spatial distribution and temporal trends in the observed period. Higher scores were obtained for frost days, heat wave duration and annual extreme temperature range for the temperature indices, and fraction of rainfall exceeding the 95th percentile and simple rainfall intensity for the precipitation indices. For temperature indices, the largest biases were found over the Tibetan Plateau. For precipitation indices, there was a reduction of spatial contrast over China. In a general manner, the models' simulation ability for extreme temperature indices is higher than for extreme precipitation indices. The multi-model ensemble constructed from all models by simple arithmetic average is in fact extremely good in reproducing most of the extremes. For the twenty-first century projection of extreme temperature indices, the trends and changes at the end of the twenty-first century go into the same direction. Decreasing trends are expected for both frost days and annual extreme temperature range, while increasing trends are expected in growing season length, heat wave duration and warmer night mainly in the Tibetan Plateau and Southwest China. For precipitation indices, the twenty-first century projection shows an increase in both the extreme precipitation frequency and intensity. This is particularly true in the middle and lower reaches of the Yangtze River, the Southeast coastal regions, the west part of Northwest China, and the Tibetan Plateau. In the meanwhile, accompanying the decrease in the consecutive dry days in Northeast and Northwest, the drought situation is expected to reduce.

Model errors are a limitation to the use of RCMs in the evaluation of possible changes in climate extremes. Model often tends to underestimate heavy rainfall, very cold or very hot temperature. A correction technique was proposed by Michel Déqué [21] in order to adjust the simulated values according to the observed ones. This process was applied to both reference and scenario simulation. Synthetic indices of extreme events were calculated with corrected simulations. Météo-France atmospheric model ARPEGE/Climate had been used to simulate present climate (1961–1990) and a possible future climate (2071–2100) under IPCC SRES A2 scenario through two ensembles of three 30-year numerical experiments. The model covers the whole globe, with a variable resolution reaching 50 to 60 km over France. The results showed that the extreme cold temperatures and summer heavy precipitations were underestimated. The number of heavy rain (> 10 mm) days increased by one quarter in winter. The maximum length of summer dry episodes increased by one half in summer. The number of heat wave days was multiplied by 10. The response in precipitation is less when only the change in the mean is considered. Such a corrected simulation is useful to feed impact models which are sensitive to threshold values.

The climate change impact assessment in the northeast U.S. have been studied using the bias corrected and downscaled dataset developed from GCM and RCM simulations for the IPCC SRES A2 emission scenario, three temperature-related and two precipitation-related extreme indicators were analyzed by Kazi and team [13]. For a subset of models and indices, results based on raw and bias corrected model outputs for the present-day climate were compared with observations, which demonstrated that bias correction is important not only for GCM outputs, but also for RCM outputs. For future climate, bias correction led to a higher level of agreements among the models in predicting the magnitude and capturing the spatial pattern of the extreme climate indices. They found that the incorporation of dynamical downscaling as an intermediate step did not lead to considerable differences in the results of statistical downscaling for the study domain.

1.4 Research Objectives

1.4.1 To investigate effects of global warming on regional climate changes over Thailand.

1.4.2 To determine the optimal physical parameterization schemes for prediction of extreme rainfall events and other extreme indices for the period 2020-2029.