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Preparation of Climate Change Scenarios for Climate Change Impact Assessment in Thailand

Southeast Asia START Regional Center

15 January 2010

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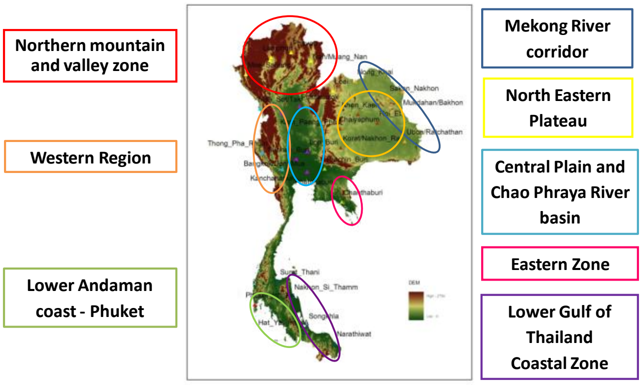
Executive summary

Climate change is an irreversible consequence of the global warming phenomenon. Global warming, or the greenhouse effect, has been brought about by an increase in greenhouse gases (GHG) in the atmosphere. Climate change will impact on bio-physical systems and ultimately will have consequences to human wellbeing. Understanding climate change is fundamental to prepare and to cope with future risk. Climate change impact on systems and sectors in Thailand is not well understood and better grounding is required. However, climate change is not uniform over space and time and its impact on bio-physical system varies from place to place. Therefore, it is necessary to understand climate change at the local scale and aim to get site-specific information. Global circulation models (GCMs) have been developed and are used to simulate future climate condition at global scale. The simulation results available today are coarse in scale due to limitations in the technology at the time they were generated. Various techniques were also developed to interpret long term future climate projection or climate change scenario at global scale to indicate future climate pattern at local scale in order to serve requirement in climate change impact assessment. This report provides summary of plausible future climate change in Thailand based on various tools and techniques. The information presented here can be used to initiate further climate change impact study.

Predicting future climate change carries a lot of uncertainty. Climate change scenarios, which are based on mathematical model simulations, may differ from model to model depending on the algorithm and assumptions used on how greenhouse gases may affect the atmospheric system. In addition, because the main driver for future climate change is the concentration of atmospheric greenhouse gases, the magnitude and pattern of climate change projections can differ from one another depending on what assumptions are made about future socio-economic conditions, which may differ from different development pathways. Since the simulation result cannot be fully proven for its precision, therefore, reviewing of multiple climate projections to summarize into a plausible climate scenario would help cover the uncertainty from different simulation to a certain extent. This report provides climate change scenarios for Thailand based on summary from projection of 8 climate models under moderate projection of greenhouse gas, SRES A1B scenario, which is extracted from Climate Change Explorer tool – the tools that developed by Stockholm Environmental Institute and Climate System Analysis Group (CSAG), University of Cape Town. In addition, this report also includes climate scenario with details spatial distribution of future climate change under upper and lower projections of greenhouse gas scenario, SRES A2 and B2 scenarios, which is based on simulation by PRECIS (Providing REgional Climates for Impacts Studies) regional climate model and used Global Circulation Model (GCM) ECHAM4 dataset as initial data for calculation.

Global warming is slow process and it would need rather long-term future climate projection to be able to clearly detect the change in future climate pattern. Global warming is a slow process and so in order to clearly detect the change in future climate patterns, long-term climate projections are needed. This report provide summary on how climate will change during the period of the years 2045-2065 (summarized in this section), and also details spatial distribution of the future climate throughout the 21st century (more details in Chapter 3).

Summary of climate change in Thailand is summarized by zone as follows:



Geographic zones used in summarizing trend of climate change in Thailand

The climate change scenario for Thailand is based on results from NCEP/NCAR reanalysis, which is used to represent the current climate condition, and the future climate projection is summarized from 8 Global Circulation Models as follows:

NCEP/NCAR Reanalysis	The National Centers for Environmental Prediction (NCEP) and National Center for Atmospheric Research (NCAR) Reanalysis Project
CCMA CGCM3.1	Canadian Centre for Climate Modeling and Analysis, the third generation coupled global climate model (CGCM3.1 Model, T47).
MPI _ECHAM5	Max Planck Institute for Meteorology, Germany, ECHAM5 / MPI OM
GISS	NASA Goddard Institute for Space Studies, ModelE20/Russell.
CNRM_CM3	Meteo-France, Centre National de Recherches Meteorologiques, the third version of the ocean-atmosphere model (CM3 Model)
CSIRO_MK3.0	CSIRO Atmospheric Research, Australia, MK3.0 Model
CSIRO_MK3.5	CSIRO Atmospheric Research, Australia, MK3.5 Model
IPSL_CM4	IPSL/LMD/LSCE, France, CM4V1 Model
GFDL_CM2.0	NOAA Geophysical Fluid Dynamics Laboratory, CM2.0 coupled climate model

The climate change scenario for Thailand is summarized in 3 variables; maximum temperature, minimum temperature and annual precipitation, and shown in range of plausible change: upper range, lower range and median as per table below:

Climate change scenario – annual average maximum temperature:

Region	Current climate	Future climate (average during 2045-2065)		
		Upper range	Lower range	Median
Northern mountain and valley	**32.41°C**	37.76°C	34.91°C	**35.82°C**
Central plain and Chao Phraya River basin	**33.49°C**	38.22°C	36.41°C	**36.90°C**
Western region	**33.25°C**	37.81°C	35.51°C	**36.39°C**
Mekong River corridor	**32.09°C**	37.35°C	34.81°C	**35.57°C**
Northeastern plateau	**32.66°C**	37.84°C	35.36°C	**36.11°C**
Eastern region	**32.90°C**	37.22°C	35.58°C	**36.42°C**
Lower gulf of Thailand coast	**31.96°C**	35.70°C	34.15°C	**34.81°C**
Lower Andaman coast - Phuket	**32.38°C**	36.20°C	34.99°C	**35.57°C**

Climate change scenario – annual average minimum temperature:

Region	Current climate	Future climate (average during 2045-2065)		
		Upper range	Lower range	Median
Northern mountain and valley	**20.43°C**	26.46°C	23.80°C	**24.82°C**
Central plain and Chao Phraya River basin	**23.74°C**	28.46°C	26.74°C	**27.67°C**
Western region	**21.72°C**	26.40°C	24.66°C	**25.56°C**
Mekong River corridor	**21.98°C**	27.12°C	24.94°C	**25.82°C**
Northeastern plateau	**22.55°C**	27.59°C	25.44°C	**26.50°C**
Eastern region	**23.84°C**	28.43°C	26.49°C	**27.53°C**
Lower gulf of Thailand coast	**23.79°C**	28.02°C	26.53°C	**27.22°C**
Lower Andaman coast - Phuket	**23.93°C**	27.92°C	26.50°C	**27.33°C**

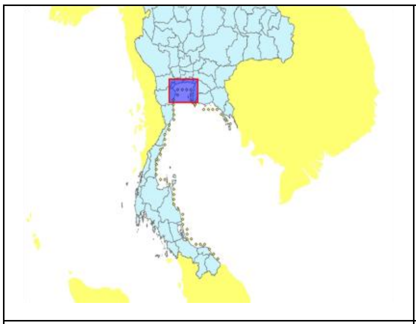
Climate change scenario – annual average precipitation:

Region	Current climate	Future climate (average during 2045-2065)		
		Upper range	Lower range	Median
Northern mountain and valley	**1,055 mm.**	1,499 mm.	720 mm.	**1,119 mm.**
Central plain and Chao Phraya River basin	**1,095 mm.**	1,627 mm.	839 mm.	**1,210 mm.**
Western region	**1,311 mm.**	1,863 mm.	825 mm.	**1,213 mm.**
Mekong River corridor	**1,567 mm.**	2,225 mm.	1,043 mm.	**1,494 mm.**
Northeastern plateau	**1,089 mm.**	1,564 mm.	779 mm.	**1,096 mm.**
Eastern region	**2,224 mm.**	3,285 mm.	1,775 mm.	**2,541 mm.**

Region	Current climate	Future climate (average during 2045-2065)		
		Upper range	Lower range	Median
Lower gulf of Thailand coast	**1,857 mm.**	3,805 mm.	1,336 mm.	**2,603 mm.**
Lower Andaman coast - Phuket	**2,360 mm.**	3,417 mm.	1,846 mm.	**2,555 mm.**

From this summary, most of the climate projections show a clear trend of temperatures warming throughout the country, both maximum and minimum temperature. However, various climate models show wide range of plausible annual precipitation in the future.

Global warming also drives change in sea level because the warmer temperature causes water expansion. Moreover, climate change may have an effect on the wind speed and wind direction. Because Thailand is in the monsoon region, winds can also influence sea level from season to season. The analysis of sea level change in the Gulf of Thailand is based on the estimation of global mean sea level change, using Dynamic Interactive Vulnerability Assessment (DIVA) tool, and effect of future monsoon on the sea level, using Princeton Ocean Circulation Model (POM). Future sea level change is summarized in 2 time slices, 2010-2029, for 3 zones of the Gulf of Thailand as shown in the illustration below:

		
Inner Gulf of Thailand	Southern east coast	Eastern coast

Sea level change from baseline period (1980-2000):

Unit: cm

Zone	Near term change (average during 2010-2029)			Long term change (average during 2030-2049)		
	Upper range	Lower range	Average	Upper range	Lower range	Average
Inner Gulf of Thailand	16.97	-1.07	**9.41**	28.91	8.19	**20.02**
Southern east coast	12.45	-3.04	**5.98**	21.22	2.30	**13.26**
Eastern coast	10.76	-4.09	**5.03**	17.74	0.86	**10.89**

From this summary, the Inner Gulf of Thailand tends to face more severe sea level rise than the other zone, where the shoreline faces the open sea and also has a different influence from the monsoon effect. More detail, see Chapter 4.

In addition to the climate scenarios and sea level rise scenarios, this report also provides background of other climate change scenario developments in Thailand, all of which are supported by Thailand Research Fund and for which the work is still in progress, as follows.

- Future climate scenario developed by Dr.Jiamjai Kreasuwan et al, Department of Physics, Faculty of Sciences, Chiang Mai University.
- Future climate scenario developed by Dr.Sirintornthep Towprayoon et al, The Joint Graduate School of Energy and Environment (JGSEE).
- Future climate scenario developed by by Dr.Kansri Boonprakob et al, Faculty of Sciences, Ramkhamhaeng University.

This report also includes review of key climate change studies covering the impact, risk, vulnerability and adaptation assessment activities which have been conducted in Thailand. The review aims to provide background on the state of knowledge on climate change and highlight gaps, so it could be used as guideline for planning future climate change study in Thailand. The review primarily focuses on those climate change studies which are based on scenarios from future climate projection.

Finally, in order to facilitate the research community to continue studying climate change in the future, a Climate Change Data Distribution System has been developed and is now open for the use of technical users, who might need future climate data for their research purposes. Using this resource, it is possible to extract data and download future climate projection data via Internet. The system can be accessed at the following URL: http:cc.start.or.th

Chapter 1: Introduction

Section 1.1: Developing climate change scenarios

Climate change, which is induced by global warming, has become a global concern because it has the potential to impact many systems and sectors which would threaten human wellbeing (IPCC, 2001). Sound understanding of climate change is an essential pillar in planning, preparing and adapting to future risks. Global warming is a slow process and so in order to clearly detect the change in future climate patterns, long-term climate projections are needed (IPCC, 2007). For this reason, when assessing climate change impacts at local scale, projections of future climate scenarios is required. Scenarios are images of the future, or alternative futures. They are neither predictions nor forecasts. Rather, each scenario is one alternative image of how the future might unfold. As such they enhance our understanding of how systems behave, evolve and interact. They are useful tools for scientific assessments, for learning about complex systems behavior and for policymaking. They can assist in climate change analysis, including climate modeling and the assessment of impacts, adaptation and mitigation. A climate scenario is a plausible, self-consistent outcome of the future climate that has been constructed for the purpose of investigating the potential consequences of anthropogenic climate change. The characteristics of the future scenario can be based on various sources, such as simulations using climate models. Climate model projections from simulations are primarily determined by the changes in Green House Gas (GHG) emissions assumed in the model. These in turn are based on assumptions concerning a variety of variables such as socioeconomic and technological developments. Therefore, climate projections based on simulations carry substantial uncertainty and so we need to generate a number of climate scenarios to cover the plausible range of future emissions.

Section 1.2: Greenhouse gas emission scenarios

The recent IPCC Special Report on Emissions Scenarios (SRES) (Nakicenovic et al., 2000) has provided a series of scenarios for future greenhouse gas emission. The so called “SRES scenarios” are used as the basis of climate scenarios development in this study. Emission scenarios are particularly designed to portray future emissions of substances that are radiatively active (i.e. greenhouse gases) or which can affect constituents which are radiatively active (e.g. sulphur dioxide which forms sulphate aerosols). The scenarios are based on a coherent and internally consistent set of assumptions about the forces driving emissions (such as demographics, socio-economic development or technological change) and the relationships between them.

By 2100 the world will have changed in ways that are hard to imagine - as hard as it would have been at the end of the 19th century to imagine the changes of the 100 years since. Each storyline in the SERS assumes a distinctly different direction for future developments, such that the four storylines differ in increasingly irreversible ways. Together they describe divergent futures that encompass a significant portion of the underlying uncertainties in the main driving forces. They cover a wide range of key "future" characteristics such as population growth, economic development, and technological change. For this reason, their plausibility or feasibility should not be considered solely on the basis of an extrapolation of current economic, technological, and social trends.

The SRES scenario set comprises four scenario families or storylines for the 21st century: A1, A2, B1 and B2. Amongst one another, they differ in how global regions interrelate, how new technologies diffuse, how regional economic activities evolve, how protection of local and regional environments is implemented, and how demographic structure changes. Although the scenarios do not include additional climate initiatives, none of them are policy free. All four families describe future worlds that are generally more affluent compared to the current situation. Each storyline assumes a distinctly different direction for future developments, such that the four storylines differ in increasingly irreversible ways. Together they describe divergent futures that encompass a significant portion of the underlying uncertainties in the main driving forces. They cover a wide range of key "future" characteristics such as population growth, economic development, and technological change. For this reason, their plausibility or feasibility should not be considered solely on the basis of an extrapolation of current economic, technological, and social trends.

Within each family, the individual scenarios follow a broadly similar picture of world development. The A1 family includes three groups reflecting a variation of the storyline (A1T, A1FI and A1B). Hence, the

SRES emissions scenarios set consist of six distinct scenario groups (A1T, A1FI, A1B, A2, B1 and B2) all of which are plausible.

- A1 scenarios. The A1 storyline and scenario family describes a future world of very rapid economic growth, low population growth, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building, and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into four groups that describe alternative directions of technological change in the energy system.

  The A1 scenarios are of a more integrated world. The A1 family of scenarios is characterized by:
    - Rapid economic growth.
    - A global population that reaches 9 billion in 2050 and then gradually declines.
    - The quick spread of new and efficient technologies.
    - A convergent world - income and way of life converge between regions. Extensive social and cultural interactions worldwide.

  In addition, there are also subsets to the A1 family based on their technological emphasis:
    - A1FI - An emphasis on fossil-fuels.
    - A1B - A balanced emphasis on all energy sources.
    - A1T - Emphasis on non-fossil energy sources.

- A2 Scenario. The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in high population growth. Economic development is primarily regionally oriented and per capita economic growth and technological changes are more fragmented and slower than in other storylines.

  The A2 scenarios are of a more divided world. The A2 family of scenarios is characterized by:
    - A world of independently operating, self-reliant nations.
    - Continuously increasing population.
    - Regionally oriented economic development.
    - Slower and more fragmented technological changes and improvements to per capita income.

- B1 Scenario. The B1 storyline and scenario family describes a convergent world with the same low population growth as in the A1 storyline, but with rapid changes in economic structures toward a service and information economy, with reductions in material intensity, and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social, and environmental sustainability, including improved equity, but without additional climate initiatives.

  The B1 scenarios are of a world more integrated, and more ecologically friendly. The B1 scenarios are characterized by:
    - Rapid economic growth as in A1, but with rapid changes towards a service and information economy.
    - Population rising to 9 billion in 2050 and then declining as in A1.
    - Reductions in material intensity and the introduction of clean and resource efficient technologies.
    - An emphasis on global solutions to economic, social and environmental stability.

- The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social, and environmental sustainability. It is a world with moderate population growth, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented toward environmental protection and social equity, it focuses on local and regional levels.

The B2 scenarios are of a world more divided, but more ecologically friendly. The B2 scenarios are characterized by:

- Continuously increasing population, but at a slower rate than in A2.
- Emphasis on local rather than global solutions to economic, social and environmental stability.
- Intermediate levels of economic development.
- Less rapid and more fragmented technological change than in A1 and B1.

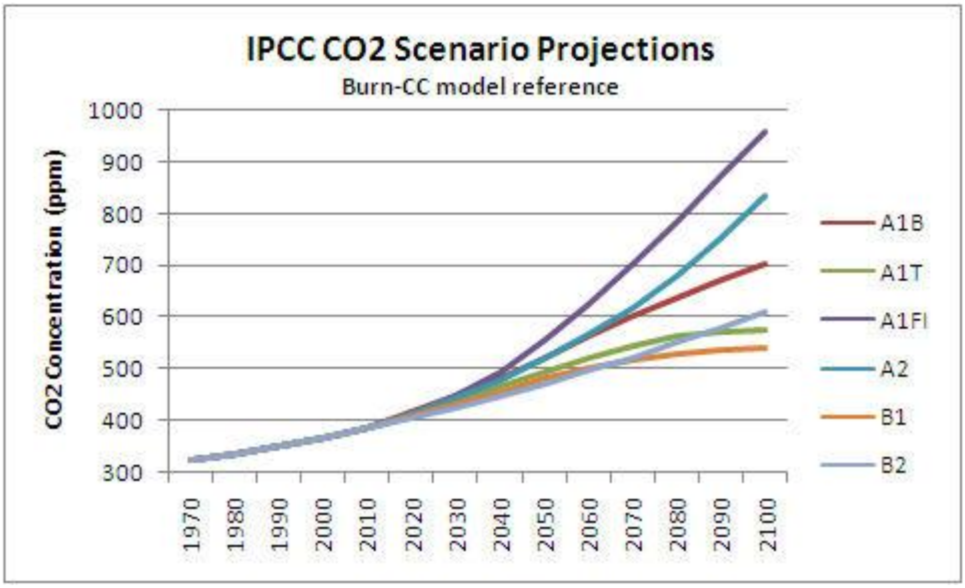


Figure 1: Projection of atmospheric greenhouse gas concentration under IPCC SRES

Section 1.3: Developing high resolution climate change scenarios for local scale impact assessment using downscaling

To estimate the effect that emissions have on the global climate, global climate models (GCMs) are employed. GCMs describe important physical elements and processes in the atmosphere, oceans and land surface that make up the climate system. One disadvantage of GCMs is that their scale is very coarse, typically a few hundred kilometers in resolution. In order to study the impacts of climate change, much finer scales of future climate projection is needed. Downscaling is used for this. Downscaling of global climate models refers to a process in which global information on climate response to changing atmospheric composition is translated it to a finer spatial scale. One that is more meaningful in the context of local and regional impacts. Two general approaches are used in downscaling:

- Statistical downscaling (also called empirical downscaling), where large scale climate features are statistically related to fine scale climate for the region.
- Dynamic downscaling (also called regional modeling), where a high resolution regional climate model (RCM) with a better representation of local terrain simulates climate processes over the region of interest.

The two approaches are not exclusive. They could be use in isolation or complement each other. The underlying concept of statistical downscaling is that local climate is conditioned both by large-scale climate and by local physiographical features (such as topography, distance to a coast, and vegetation). At a specific location, therefore, links should exist between large-scale and local climatic conditions. Statistical downscaling identifies empirical links between large-scale patterns of climate elements (predictors) and local climate (the predictand), and applies them to the output from global or regional models. Successful statistical downscaling thus depends on long reliable series of predictors and predictands (Giorgi et al. (2001) provide a survey of statistical downscaling studies with emphasis on studies published between 1995 and 2000). Statistical downscaling is a two-step process consisting of;

- Development of statistical relationships between local climate variables (e.g., surface air temperature and precipitation) and large-scale predictors.
- Application of such relationships to the output of GCM experiments to simulate local climate characteristics.

A range of statistical downscaling models has been developed (IPCC 1996, WG I), mostly for U.S., European, and Japanese locations where good quality data for model calibration is available. The main advancement in the last few years in this field has been the extension of many downscaling models from monthly and seasonal to daily time scales, which allows the production of data which is more suitable for a broader set of impact assessment models (e.g., agriculture or hydrologic models).

When optimally calibrated, statistical downscaling models have succeeded to some extent in reproducing various statistics about local surface climatology (IPCC 1996, WG I). Some examples where statistical downscaling was used to generate climate change scenarios have shown that in complex physiographic settings, local temperature and precipitation changes predicted through downscaling were significantly different from, and had a finer spatial scale structure than, those directly interpolated from the driving GCMs (IPCC 1996, WG I).

Compared to statistical downscaling, dynamic downscaling is far more computationally intensive. However, dynamic downscaling using a regional climate model (RCM) has the advantage that the regional model can simulate local fine-scale feedback processes not anticipated with statistical methods. Although it is more powerful, dynamic downscaling requires careful and cautious use, because ultimately the quality of the results are determined by the quality of the input data.

A technique, called one-way nested modeling, has been increasingly applied to climate change studies in recent years. This technique consists of using output from GCM simulations to provide initial and driving lateral meteorological boundary conditions for high-resolution Regional Climate Model (RCM) simulations. It is one way because the RCM does not feed back into the driving GCM. With the use of one-way nested modeling a regional increase in resolution can be attained to account for sub-GCM grid-scale forcing. The most relevant advance in the field of nested regional climate modeling activities has been to enable the production of continuous RCM multi-year climate simulations. Previous to this, regional climate change scenarios were mostly generated using samples of month-long simulations (IPCC 1996, WG I). The primary improvement represented by continuous long-term simulations consists of equilibration of model climate with surface hydrology and simulation of the full seasonal cycle. This allows impact studies to be able to assess a longer period. This ability to produce long-term runs facilitates the coupling of RCMs to other regional process models, such as lake models, dynamical sea ice models, and possibly regional ocean (or coastal) and ecosystem models.

Summary:

The high resolution climate scenario reviewed in this report as well as the trend of climate change in Thailand presented here are based on both statistical downscaling and dynamic downscaling techniques under different IPCC greenhouse gas scenarios. The summary also provides a snapshot situation of future climate conditions in Thailand as predicted by a variety of GCMs. By having multiple GCMs we ensure to capture the uncertainty of the climate models.

Chapter 2: Review studies on future climate projection for Thailand.

In 2007, the Thailand Research Fund (TRF) initiated a climate change research program and provided funding to support development of climate change scenarios in Thailand to use in a subsequent impact assessment. As of 2009, there were a number of long term climate projections done or under development to provide future climate scenario for Thailand as follows:

Section 2.1 Future climate scenario developed by Suppakorn Chinvanno et al, Southeast Asia START Regional Center (SEA START RC).

This future climate projection is the simulation of future climate in Thailand and surrounding countries at high resolution of grid size 20x20 km for the period of 2010 – 2099, using the period of 1960 – 1999 as a baseline. The simulation was based on the PRECIS (Providing REgional Climates for Impacts Studies) regional climate model and used the Global Circulation Model (GCM) ECHAM4 dataset as initial data for calculation. The simulation covers the Intergovernmental Panel on Climate Change (IPCC) emission scenarios A2 and B2. The simulation was carried out on multiple personal computers running in parallel and then assembled together. The results from this simulation operation provide a high resolution future climate projection for Thailand and its surrounding countries up to the end of the century. The result from PRECIS model was post-processed by rescaling technique in order to derive the final result that is more in-line with the observed weather data. The final result of future climate projection shows a trend of increasing temperature throughout Thailand, especially in the central plain of Chao Phraya river basin and the lower part of north-eastern region. The hot periods in a year will become longer in the future. Total annual precipitation may fluctuate in the early part of the century but the projection shows a clear trend of increasing precipitation from middle of the century onwards, especially in the area near Mekong River as well as the southern region, except the western border where future precipitation may remain almost unchanged. Change in wind speed and wind direction can be detected in the coastal zone, where south-west wind speed may increase by 3-5% in the future.

Status as of November 2009: Completed.

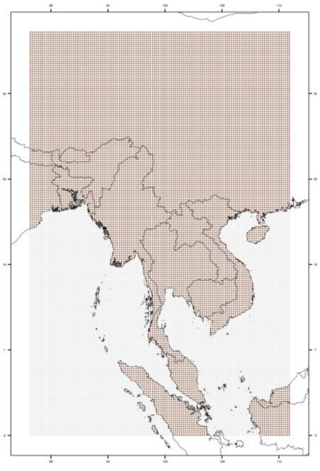


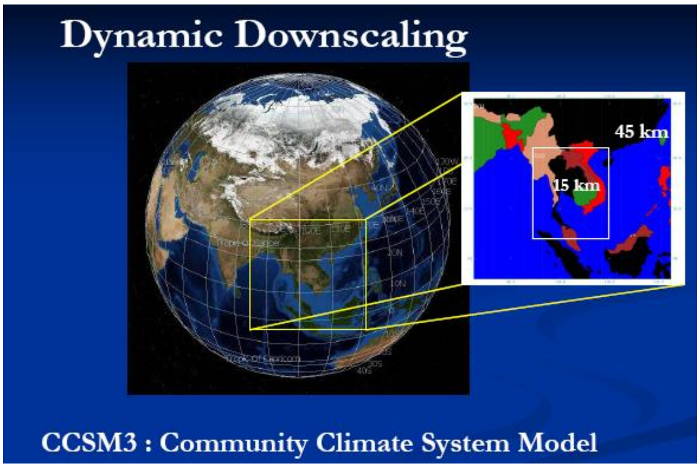
Figure 2: Domain coverage of climate scenario by Suppakorn Chinvanno et al, SEA START RC

Section 2.2 Future climate scenario developed by Dr.Jiamjai Kreasuwan et al, Department of Physics, Faculty of Sciences, Chiang Mai University.

This climate scenario is based on dynamic downscaling of Community Climate System Model version 3 (CCSM3), A2 and A1B scenarios, from The National Center for Atmospheric Research (NCAR) using the Fifth-Generation NCAR / Penn State Mesoscale Model (MM5) to simulate regional-scale atmospheric circulation. The downscaling process was set at resolution of 45km and 15km grid size. The climate scenario covers future climate projection for Thailand during period 2010-2039.

The preliminary finding on MM5-RCM simulations of future projection during 2010 to 2019 states that mean temperature changes on both IPCC scenarios A2 and A1B are in good agreement. It indicates that during the warm season (March - May) the average temperature in upper Thailand will drop about 0.5ºC while the temperature in the southern Thailand will increase approximately 0.1ºC-0.6ºC relative to the average temperature during the past 30 years. For the cool season (November till February), mean temperature throughout Thailand with the exception of the southern region, will decrease slightly by 0.1ºC-0.4ºC. In contrast, the southern region will be at least 0.2ºC warmer. Additional warming of roughly 0.6ºC-1ºC will be anticipated for the whole country in the rainy season (June – October). During the period of 2020-2029, it will be approximately warmer by 0.6ºC-1ºC all over Thailand in the rainy season (June – October). Both scenarios A2 and A1B agree that it will be nearly 1ºC warmer throughout the country in rainy season, however, the southern part of Thailand will be warmer throughout the year. Simulated temperatures from both scenarios are somewhat different between the warm and cool season. In the warm season, the A1B scenarios shows a trend of warmer temperature by 1ºC all over Thailand, but the A2 scenario suggests a slightly less warmer trend in the western, central and northeastern region of Thailand, where the warming temperature could be approximately 0.6ºC. During the cool season, the temperature will increase in the range of 0.1ºC – 0.4ºC throughput the country, especially in the northern and southern region of Thailand under A2 scenario, however it tends to be slightly cooler in the northern part of Thailand under A1B scenario. During the period of 2030-2039, projection of future temperature shows a trend of warming temperature by 0.2ºC and 0.8ºC during the warm season according to A1B and A2 scenarios respectively. Both scenarios show a trend of increasing temperature by approximately 1ºC for the whole country during the rainy season and the same magnitude of change all year round in the southern region of Thailand. As to the cool season, there will be just only slight change toward cooler temperature in the northern region of Thailand under A1B scenario, however, contrary to the A1B scenario, the A2 scenario shows trend of slightly warmer. For the rainfall simulation, the MM5-RCM well captures the trend of rainy season in Thailand but considerably underestimates rainfall amount when compared to the station observations. The future rainfall projection during 2010-2039 will be relatively less in most part of the country, except the southern region and mountainous area throughout the country.

Status as of November 2009: Final conclusion in progress.


Dynamic Downscaling

CCSM3 : Community Climate System Model

Figure 3: Domain coverage of climate scenario by Dr.Jiamjai Kreasuwan et al, Chiang Mai University

Section 2.3 Future climate scenario developed by Dr.Sirintornthep Towprayoon et al, The Joint Graduate School of Energy and Environment (JGSEE).

This climate scenario is base on dynamic downscaling of ECHAM5 GCM, A2 and B2 scenarios, from Max Planck Institute for Meteorology, Germany, using The ICTP Regional Climate Model (RegCM) version 3 from the Abdus Salam International Centre for Theoretical Physics (ICTP). The downscaling process was set at resolution of 60km and 20km grid size. The climate scenario covers future climate projection for Thailand during period 2030-2070.

Status as of November 2009: Work in progress.

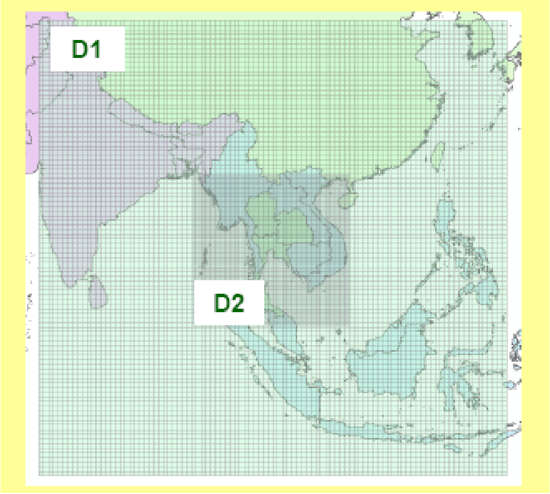


Figure 4: Domain coverage of climate scenario by Dr.Sirintornthep Towprayoon et al, JGSEE

Section 2.4 Future climate scenario developed by by Dr.Kansri Boonprakob et al, Faculty of Sciences, Ramkhamhaeng University.

This climate scenario is based on statistical downscaling technique using GDFL-R30 GCM, A2 and B2 scenarios, from Geophysical Fluid Dynamic Laboratory, National Oceanic Atmospheric Association (NOAA), USA. The downscaling process was set at resolution of 50km grid size. The climate scenario covers future climate projection for Thailand during period 2010-2029 and 2040 - 2059.

Preliminary result shows that in the near future (during 2010 – 2029) the average temperature in Thailand will increase slightly, according to both A2 and B2 scenarios,and this trend will continue further in the future (during 2040 – 2059). A more detailed analysis shows that the maximum temperature will increase under both scenarios on both near and distant future. The minimum temperature under A2 scenario tends to be slightly warmer than under the B2 scenario, but the B2 scenario nevertheless shows trend of increasing minimum temperature in the near future. So in the long-term, minimum temperature tends to increase under both A2 and B2 scenarios. Annual precipitation during the near and distant future may be less than the baseline period under the A2 scenario, but the B2 scenario indicates trend of increasing annual precipitation. The number of hot-day tends to increase throughout the country under both A2 and B2 scenarios, except some areas in the northeast, part of the lower central region and the lower southern region. On the contrary, number of cool-day tends to decrease throughout the country.

Status as of November 2009: Final conclusion in progress.

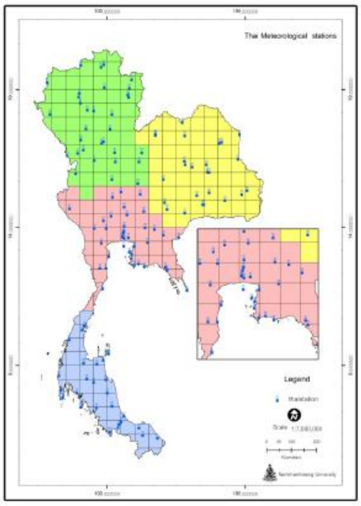


Figure 5: Domain coverage of climate scenario development by Dr.Kansri Boonprakob et al, Ramkhamhaeng University

Chapter 3: Summarized trend of climate change in Thailand

Climate change needs to be assessed on a scale of several decades in order to clearly detect a change in the climatic pattern. However, projections this long inevitably carry uncertainty from two sources: the uncertainty generated from the assumptions that were made and the uncertainty inherent to the simulation technologies. The most common approach to compensate for uncertainty in the climate models is to use multiple climate scenarios which are simulated by multiple models, thereby creating a spectrum of possibilities.

This chapter summarizes an analysis of selected high resolution climate scenarios data, which were derived from statistical and dynamical downscaling techniques. The summary covers analysis at various locations, which was aggregated to explain the trend of climate change in each region in Thailand. Moreover, the summary also includes spatial analysis on change in future climate pattern in Thailand, and provide a narrative report on key climate change characteristic in Thailand.

Summary of climate change trend in Thailand is based on 2 data sources as follows:

1. Data from Climate Change Explorer (CCE)[1], which is a tool developed by Stockholm Environmental Institute (SEI) and Climate System Analysis Group (CSAG), University of Cape Town that aims to facilitate the gathering of climatological information and its application to adaptation strategies and actions. The CCE is designed to simplify the tasks associated with the extraction, query and analysis of climate information, thereby enabling users to address issues of uncertainty when devising policies and strategies, and also when implementing actions. Point location information downscaled from 8 Global Circulation Models (GCM) under A1B SRES greenhouse gas scenario provide the local (station-scale) response to the large scale forcing as shown on the GCM. The analysis result shows range of change in future temperature and precipitation in Thailand by middle of the 21st century, which is shown as monthly average data over the period of 2045-2065 and compare to present period using NCEP/NCAR reanalysis data[2] over the period of 1961-2000.

   The 8 Global Circulation Models (GCM) consist of the following models:

NCEP/NCAR Reanalysis	The National Centers for Environmental Prediction (NCEP) and National Center for Atmospheric Research (NCAR) Reanalysis Project
CCMA CGCM3.1	Canadian Centre for Climate Modeling and Analysis, the third generation couple d global climate model (CGCM3.1 Model, T47).
MPI _ECHAM5	Max Planck Institute for Meteorology, Germany, ECHAM5 / MPI OM
GISS	NASA Goddard Institude for Space Studies, ModelE20/Russell.
CNRM_CM3	Meteo-France, Centre National de Recherches Meteorologiques, the third version of the ocean-atmosphere model (CM3 Model)
CSIRO_MK3.0	CSIRO Atmospheric Research, Australia, MK3.0 Model
CSIRO_MK3.5	CSIRO Atmospheric Research, Australia, MK3.5 Model
IPSL_CM4	IPSL/LMD/LSCE, France, CM4V1 Model
GFDL_CM2.0	NOAA Geophysical Fluid Dynamics Laboratory, CM2.0 coupled climate model

   The dataset from the 8 GCMs were downscaled to 33 point locations in Thailand as shown in the following figure:

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[1] Climate Change Explorer tool can be accessed at http://wikiadapt.org/index.php?title=The_Climate_Change_Explorer_Tool

[2] The NCEP/NCAR Reanalysis Project is a joint project between the National Centers for Environmental Prediction (NCEP, formerly "NMC") and the National Center for Atmospheric Research (NCAR). The goal of this joint effort is to produce new atmospheric analyses using historical data (1948 onwards) and as well to produce analyses of the current atmospheric state (Climate Data Assimilation System, CDAS).

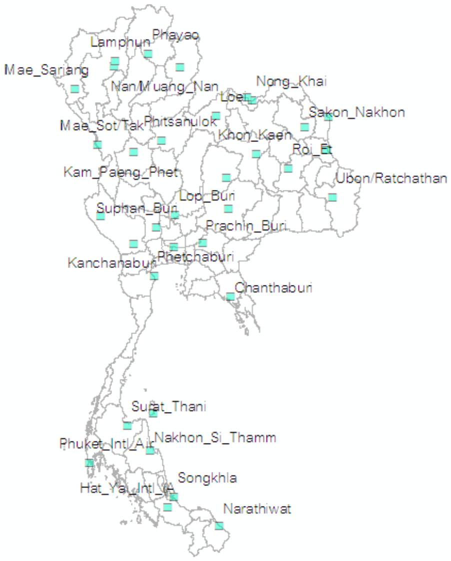

Figure 6: Point locations in Thailand for statistical downscale of 8 GCMs

Trend of climate change in Thailand was summarized based on geographical zones, which is represented by number of observation stations in each zone as follows:

- Northern mountain and valley zone. Analysis is based on the average of data from these point locations: Phayao, Loei, Chiang Mai, Nan, Mae Sariang, Lampoon.
- Central Plain and Chao Phraya River Basin. Analysis is based on the average of data from these point locations: Lopburi, Bangkok, Pisanulok, Kampangpetch, Suphanburi.
- Western Region. Analysis is based on the average of data from these point locations: Mae sot, Thongphaphum, Kanchanaburi
- Mekong river corridor zone. Analysis is based on the average of data from these point locations: Ubonratchathani, Nongkai, Sakonnakorn, Mukdahan, Nakonpanom.
- Northeastern Plateau. Analysis is based on the average of data from these point locations: Khonkaen, Roi-et, Chaiyaphum, Nakonratchasima
- Eastern Zone. Analysis is based on the average of data from these point locations: Chantaburi, Prachinburi
- Lower Gulf of Thailand Coastal zone. Analysis is based on the average of data from these point locations: Narathiwat, Suratthani, Nakornsrithammarat, Koh Samui, Songkhla, Hat yai
- Lower Andaman Coast – Phuket. Analysis is based on data from this point location: Phuket

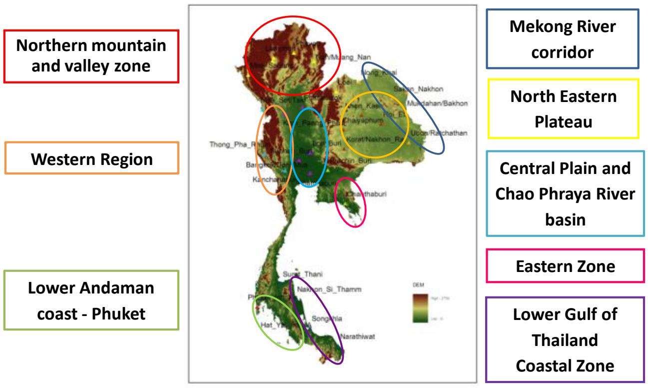

Figure 7: Geographic zones used in summarizing trend of climate change in Thailand

2. Data from simulation result of PRECIS regional climate model[3], which was developed by Hadley Centre for Climate Prediction and Research. PRECIS model was used as downscaling tool that adds fine scale (high resolution) information to the large-scale projections of a global general circulation model (GCM). ECHAM4 GCM dataset, which is based on SRES A2 and B2 GHG scenario (Nakicenovic et al., 2000), was used as initial dataset for the downscaling process. The downscaling process was set to resolution of .22º and output was rescaled to 20x20km resolution. Domain coverage is lat. 0-35ºN and lon. 90º-112ºE. Period of simulation covers baseline condition during 1970-1999 and future projection during 2010-2100.

   Summary of future change in maximum temperature and precipitation shows spatial pattern of distribution of temperature and precipitation over Thailand during the beginning, middle and the end of the 21st century in decadal average of 2010s, 2050s and 2090s.

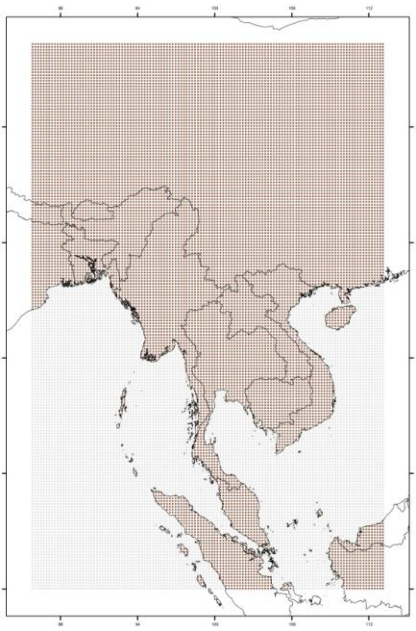

Figure 8: Geographical domain coverage used in PRECIS downscaling process

Section 3.1 Trend of temperature change in Thailand

Change in maximum temperature (also see Appendix 1)

By the middle of the 21st century (2045-2065), most of the 8 GCMs show that average monthly maximum temperature in Thailand is expected to increase by 3ºC-4ºC throughout the country.

For the northern mountainous and valley zone, annual average maximum temperature (or in other words, the daytime temperature) is expected to rise from 32.41ºC to 35.82ºC, when compared to the median value among the results from 8 GCM models. There is wide range of results during summertime, particularly during the month of March – April – May, which show the possibility that the maximum temperature during those months could be much warmer than the median value.

The central plain and Chao Phraya River basin and western region will undergo change in annual average maximum temperature in the same range, which is expected to rise from 33.49ºC to 36.90ºC and 33.25ºC to 36.39ºC respectively, when compared to the median value among the results from 8 GCM models. The maximum temperature during the summertime for the months of March – April – May could also highly deviate from the median value.

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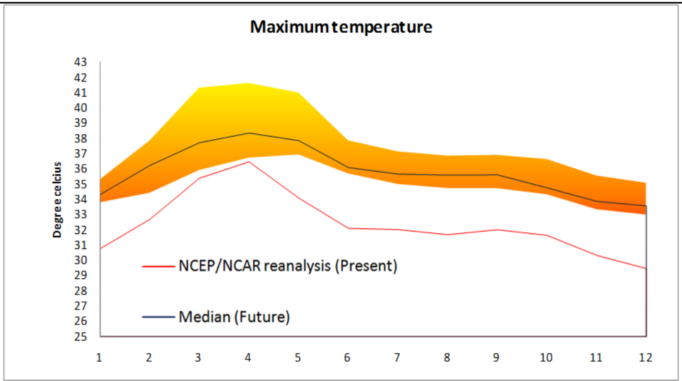
[3] Result from research project "Simulation of future climate scenario for Thailand and surrounding countries" (Chinvanno et al, 20009)

The northeastern plateau and eastern region will tend to get warmer than other regions, with average maximum temperature rising from 32.66ºC to 36.11ºC and 32.90ºC to 36.42ºC respectively. Results from 8 GCM models show high deviation during the summertime in the northeastern region, but most models predict closer range of change on the eastern region.

For the southern region of Thailand in lower Gulf of Thailand coastal zone and lower Andaman coast – Phuket, annual average maximum temperature is expected to rise from 31.96ºC to 34.81ºC and 32.38ºC to 35.57ºC respectively, when compare to the median value among the results from 8 GCM models. Results from 8 GCM models show high deviation during the beginning of the year over January to March and April period.

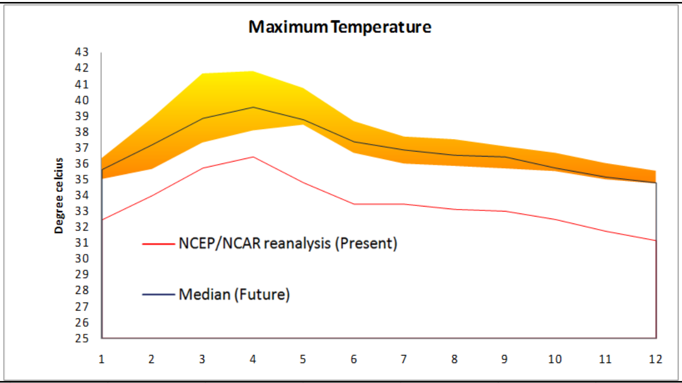
Results from 8 GCM models are summarized in graphs and charts as follows: *(note: NCEP/NCAR reanalysis is used to represent climate of present condition)*

Northern mountain and valley zone



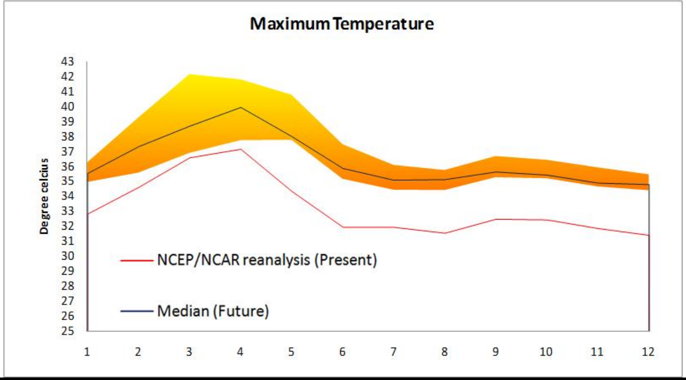
month	NCEP/NCAR reanalysis	cccma_cgcm3_1	cnrm_cm3	csiro_mk3_0	gfdl_cm2_0	giss_model_e_r	ipsl_cm4	mpi_echam5	Max	Min	Median
1	30.78	34.27	34.04	33.82	34.91	35.29	34.56	34.33	35.29	33.82	34.33
2	32.72	36.25	36.45	34.44	35.98	36.00	36.35	37.85	37.85	34.44	36.25
3	35.43	39.25	39.79	35.94	36.98	36.49	37.74	41.32	41.32	35.94	37.74
4	36.51	40.04	40.83	36.98	37.25	36.75	38.38	41.63	41.63	36.75	38.38
5	34.12	37.88	41.01	37.68	37.27	36.97	38.34	37.88	41.01	36.97	37.88
6	32.13	35.74	37.35	36.11	36.10	36.44	37.86	35.72	37.86	35.72	36.11
7	32.05	35.54	35.42	35.02	35.94	36.69	37.14	35.68	37.14	35.02	35.68
8	31.71	35.22	35.34	34.75	35.72	36.31	36.86	35.61	36.86	34.75	35.61
9	32.03	35.29	35.63	34.74	35.36	36.08	36.91	35.79	36.91	34.74	35.63
10	31.67	34.69	34.77	34.35	34.57	35.65	36.63	35.01	36.63	34.35	34.77
11	30.35	33.74	33.36	33.89	34.18	34.93	35.55	33.54	35.55	33.36	33.89
12	29.48	33.29	33.59	33.38	34.22	34.43	35.08	33.01	35.08	33.01	33.59
Ave.	32.41								37.76	34.91	35.82

Central plain and Chao Phraya River basin



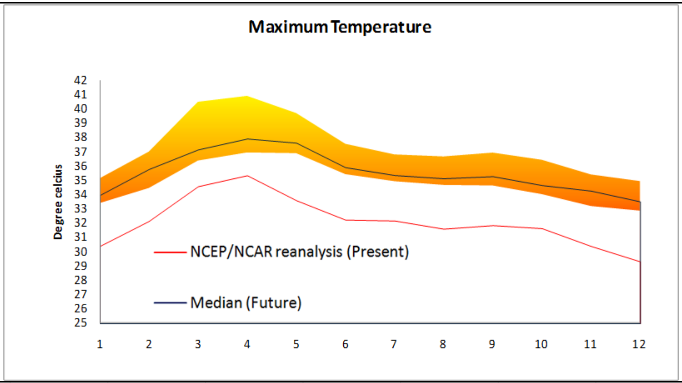
month	NCEP/NCAR reanalysis	cccma_cgcm3_1	cnrm_cm3	csiro_mk3_0	gfdl_cm2_0	giss_model_e_r	ipsl_cm4	mpi_echam5	Max	Min	Median
1	32.47	35.60	35.66	35.15	36.34	35.63	35.00	36.06	36.34	35.00	35.63
2	34.00	37.20	37.52	35.63	37.50	36.52	36.55	38.87	38.87	35.63	37.20
3	35.72	39.29	39.91	37.38	38.85	37.29	38.30	41.67	41.67	37.29	38.85
4	36.43	40.03	40.89	39.26	39.23	38.05	39.55	41.82	41.82	38.05	39.55
5	34.80	38.66	40.75	40.14	38.42	38.46	39.23	38.76	40.75	38.42	38.76
6	33.46	37.14	37.89	37.56	36.65	37.38	38.67	37.01	38.67	36.65	37.38
7	33.45	37.05	36.55	35.97	36.57	36.86	37.69	36.92	37.69	35.97	36.86
8	33.12	36.69	36.53	35.82	36.44	36.42	37.52	36.75	37.52	35.82	36.53
9	33.01	36.42	36.47	35.66	35.96	36.28	37.08	36.55	37.08	35.66	36.42
10	32.49	35.57	35.96	35.49	35.53	35.72	36.67	35.86	36.67	35.49	35.72
11	31.75	34.98	35.11	35.27	35.29	35.16	36.02	34.98	36.02	34.98	35.16
12	31.16	34.79	35.23	34.72	35.50	34.72	35.54	34.75	35.54	34.72	34.79
Ave.	33.49								38.22	36.14	36.90

Western region



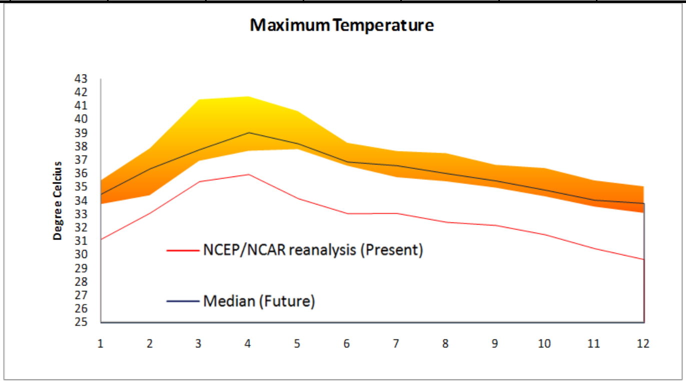
month	NCEP/NCAR reanalysis	cccma_cgcm3_1	cnrm_cm3	csiro_mk3_0	gfdl_cm2_0	giss_model_e_r	ipsl_cm4	mpi_echam5	max	min	Median
1	32.82	35.56	35.59	35.09	36.25	35.24	34.92	36.18	36.25	34.92	35.56
2	34.59	37.35	37.56	35.55	37.46	36.05	36.41	39.23	39.23	35.55	37.35
3	36.56	39.79	40.29	37.65	38.73	36.86	38.16	42.12	42.12	36.86	38.73
4	37.14	40.18	41.15	39.98	38.81	37.71	39.45	41.77	41.77	37.71	39.98
5	34.33	38.03	40.75	40.34	37.77	37.73	38.99	37.88	40.75	37.73	38.03
6	31.94	35.75	36.74	36.65	35.35	35.90	37.45	35.14	37.45	35.14	35.90
7	31.93	35.29	34.69	34.41	35.11	36.06	35.78	34.85	36.06	34.41	35.11
8	31.54	35.00	34.93	34.39	35.19	35.66	35.73	35.15	35.73	34.39	35.15
9	32.47	35.52	35.89	35.24	35.61	35.66	36.66	35.96	36.66	35.24	35.66
10	32.42	35.17	35.60	35.45	35.26	35.34	36.41	35.53	36.41	35.17	35.45
11	31.85	34.62	34.91	35.18	35.05	34.80	35.90	34.81	35.90	34.62	34.91
12	31.40	34.64	35.22	34.62	35.28	34.37	35.44	34.81	35.44	34.37	34.81
Ave.	33.25								37.81	35.51	36.39

Mekong river corridor zone



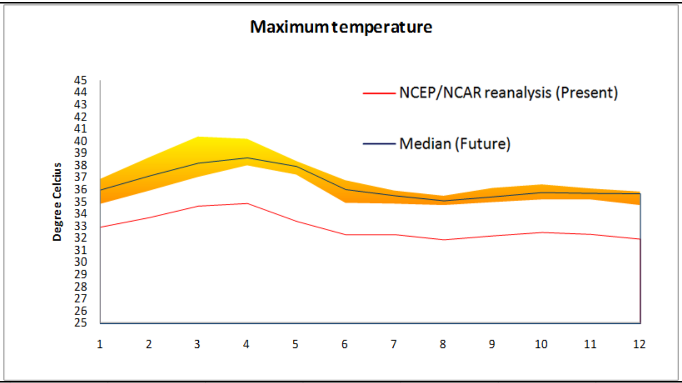
month	NCEP/NCAR reanalysis	cccma_cgcm3_1	cnrm_cm3	csiro_mk3_0	gfdl_cm2_0	giss_model_e_r	ipsl_cm4	mpi_echam5	Max	min	Median
1	30.38	33.39	33.66	33.96	35.16	35.06	34.38	33.98	35.16	33.39	33.98
2	32.12	35.41	35.80	34.45	35.97	35.91	35.80	37.02	37.02	34.45	35.80
3	34.55	38.01	38.64	36.36	37.17	36.68	37.16	40.51	40.51	36.36	37.17
4	35.31	38.70	40.04	37.81	37.42	36.93	37.94	40.93	40.93	36.93	37.94
5	33.57	37.13	39.72	38.16	37.08	36.88	37.92	37.65	39.72	36.88	37.65
6	32.22	35.41	36.42	35.93	35.88	36.37	37.57	35.74	37.57	35.41	35.93
7	32.15	35.34	35.25	34.92	35.84	36.75	36.83	35.38	36.83	34.92	35.38
8	31.58	34.66	34.90	34.68	35.46	36.49	36.68	35.15	36.68	34.66	35.15
9	31.83	34.62	34.99	34.91	35.43	36.04	36.95	35.30	36.95	34.62	35.30
10	31.62	34.02	34.48	34.67	35.13	35.40	36.45	34.66	36.45	34.02	34.67
11	30.38	33.42	33.19	34.28	34.68	34.80	35.42	33.71	35.42	33.19	34.28
12	29.31	32.86	33.24	33.53	34.60	34.31	34.95	32.96	34.95	32.86	33.53
Ave.	32.09								37.35	34.81	35.57

Northeastern plateau



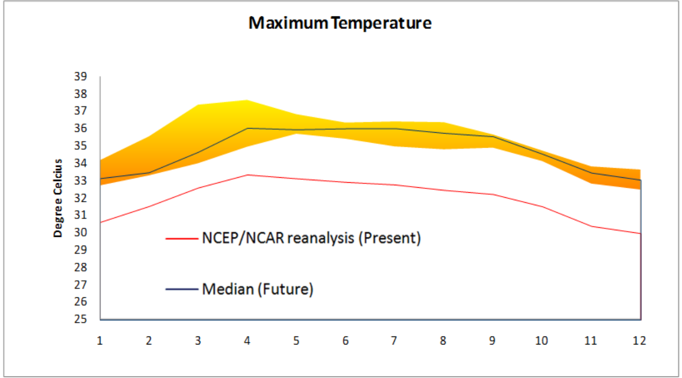
month	NCEP/NCAR reanalysis	cccma_cgcm3_1	cnrm_cm3	csiro_mk3_0	gfdl_cm2_0	giss_model_e_r	ipsl_cm4	mpi_echam5	Max	min	Median
1	31.13	34.12	34.47	33.74	35.47	35.35	34.61	34.46	35.47	33.74	34.47
2	33.08	36.20	36.80	34.40	36.53	36.36	36.18	37.86	37.86	34.40	36.36
3	35.40	38.94	39.69	36.95	37.76	37.18	37.51	41.48	41.48	36.95	37.76
4	35.92	39.58	40.86	39.02	38.18	37.69	38.37	41.70	41.70	37.69	39.02
5	34.15	38.14	40.61	39.81	37.81	38.16	38.38	38.20	40.61	37.81	38.20
6	33.04	36.67	37.38	36.86	36.67	37.36	38.27	36.59	38.27	36.59	36.86
7	33.06	36.81	36.13	35.74	36.59	36.98	37.66	36.42	37.66	35.74	36.59
8	32.41	36.01	35.76	35.43	36.19	36.38	37.50	35.91	37.50	35.43	36.01
9	32.17	35.40	35.48	34.97	35.39	35.47	36.64	35.57	36.64	34.97	35.47
10	31.49	34.33	34.79	34.51	34.87	35.07	36.40	34.61	36.40	34.33	34.79
11	30.47	33.56	33.67	34.04	34.47	34.57	35.49	33.64	35.49	33.56	34.04
12	29.66	33.26	33.81	33.13	34.64	34.24	35.05	33.10	35.05	33.10	33.81
Ave.	32.66								37.84	35.36	36.11

Eastern region



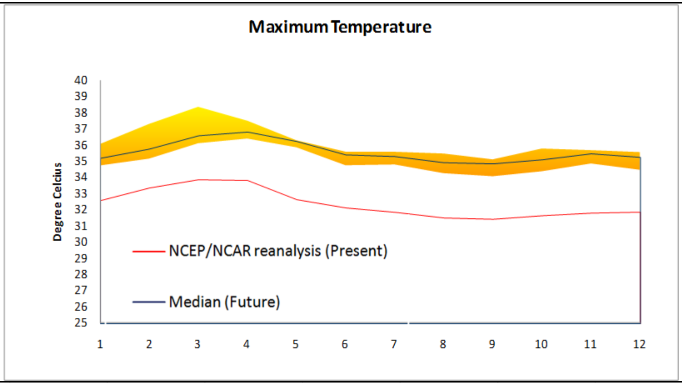
month	NCEP/NCAR reanalysis	cccma_cgcm3_1	cnrm_cm3	csiro_mk3_0	gfdl_cm2_0	giss_model_e_r	ipsl_cm4	mpi_echam5	Max	min	Median
1	32.90	36.39	35.98	35.42	36.41	35.54	34.77	36.83	36.83	34.77	35.98
2	33.68	37.52	37.14	35.86	37.58	36.44	36.06	38.61	38.61	35.86	37.14
3	34.63	38.52	38.20	36.99	38.92	37.22	37.60	40.33	40.33	36.99	38.20
4	34.84	38.52	38.63	37.94	38.74	37.96	38.84	40.14	40.14	37.94	38.63
5	33.38	37.46	38.32	38.13	37.18	37.93	38.15	37.74	38.32	37.18	37.93
6	32.29	36.05	36.03	35.74	34.87	36.38	36.74	35.82	36.74	34.87	36.03
7	32.29	35.82	35.18	34.80	34.88	35.89	35.59	35.52	35.89	34.80	35.52
8	31.87	35.43	35.10	34.68	34.75	35.02	35.46	35.46	35.46	34.68	35.10
9	32.19	35.52	35.43	34.92	35.17	34.98	35.71	36.11	36.11	34.92	35.43
10	32.47	35.76	35.86	35.78	35.65	35.14	35.97	36.40	36.40	35.14	35.78
11	32.31	35.91	35.60	35.71	35.58	35.14	35.82	36.06	36.06	35.14	35.71
12	31.92	35.80	35.69	35.12	35.68	34.68	35.45	35.81	35.81	34.68	35.68
Ave.	32.90								37.22	35.58	36.42

Lower Gulf of Thailand coastal zone



month	NCEP/NCAR reanalysis	cccma_cgcm3_1	cnrm_cm3	csiro_mk3_0	gfdl_cm2_0	giss_model_e_r	ipsl_cm4	mpi_echam5	Max	min	Median
1	30.61	33.75	32.81	33.14	33.55	32.70	32.93	34.16	34.16	32.70	33.14
2	31.53	34.66	33.27	33.37	34.48	33.40	33.49	35.53	35.53	33.27	33.49
3	32.60	35.85	34.09	34.45	35.86	33.97	34.66	37.36	37.36	33.97	34.66
4	33.35	36.02	35.06	36.05	36.18	34.92	36.12	37.63	37.63	34.92	36.05
5	33.13	36.24	35.89	36.66	35.80	35.67	35.96	36.81	36.81	35.67	35.96
6	32.92	36.02	36.13	35.73	35.38	35.47	36.33	36.25	36.33	35.38	36.02
7	32.77	36.03	36.22	35.72	35.43	34.94	36.40	36.14	36.40	34.94	36.03
8	32.46	35.76	35.78	35.43	35.16	34.77	36.35	35.84	36.35	34.77	35.76
9	32.22	35.56	35.57	35.05	34.97	34.87	35.64	35.59	35.64	34.87	35.56
10	31.52	34.60	34.56	34.10	34.26	34.51	34.69	34.72	34.72	34.10	34.56
11	30.39	33.76	32.80	33.47	33.40	33.56	33.42	33.81	33.81	32.80	33.47
12	29.97	33.49	32.46	33.04	33.06	32.52	33.23	33.63	33.63	32.46	33.06
Ave.	31.96								35.70	34.15	34.81

Lower Andaman Coast – Phuket



Month	NCEP/NCAR reanalysis	cccma_cgcm3_1	cnrm_cm3	csiro_mk3_0	gfdl_cm2_0	giss_model_e_r	ipsl_cm4	mpi_echam5	Max	Min	Median
1	32.58	35.60	34.74	35.19	35.72	35.11	35.12	36.07	36.07	34.74	35.19
2	33.36	36.40	35.16	35.35	36.60	35.76	35.65	37.31	37.31	35.16	35.76
3	33.87	37.03	36.11	36.24	37.39	36.26	36.58	38.37	38.37	36.11	36.58
4	33.82	36.54	36.62	37.06	36.81	36.40	37.23	37.51	37.51	36.40	36.81
5	32.64	35.86	36.30	36.25	35.99	36.11	36.23	36.25	36.30	35.86	36.23
6	32.13	35.47	35.40	34.85	34.75	35.31	35.60	35.46	35.60	34.75	35.40
7	31.86	35.59	35.30	34.80	34.83	34.94	35.53	35.31	35.59	34.80	35.30
8	31.51	35.17	34.96	34.31	34.52	34.26	35.48	34.92	35.48	34.26	34.92
9	31.43	34.85	34.91	34.07	34.48	34.28	35.12	35.11	35.12	34.07	34.85
10	31.65	35.09	35.13	34.93	35.10	34.38	35.22	35.79	35.79	34.38	35.10
11	31.81	35.51	34.86	35.53	35.14	34.99	35.47	35.69	35.69	34.86	35.47
12	31.87	35.44	34.47	35.07	35.25	34.81	35.46	35.57	35.57	34.47	35.25
Ave.	32.38								36.20	34.99	35.57

The following simulation result from a PRECIS regional climate model and subsequent rescaling shows a spatial representation of the average maximum temperature throughout the 21st century. The result shows a tendency for the average maximum temperature to increase through the century unevenly throughout the country. Under the most drastic result, which would occur if there was a rapid increase of atmospheric greenhouse gas under IPCC SRES A2 GHG scenario, the central plain and Chao Phraya River basin as well as some parts of southern Thailand become the warmest zones in Thailand with the average maximum temperature increasing from of 33ºC – 35ºC to 37ºC - 39ºC by the end of the 21st century. Under the least drastic result, which would occur if there was a rapid increase of atmospheric greenhouse gas under IPCC SRES B2 GHG scenario, there is also an increase in temperature but to a lesser extent, as shown in the figures below:

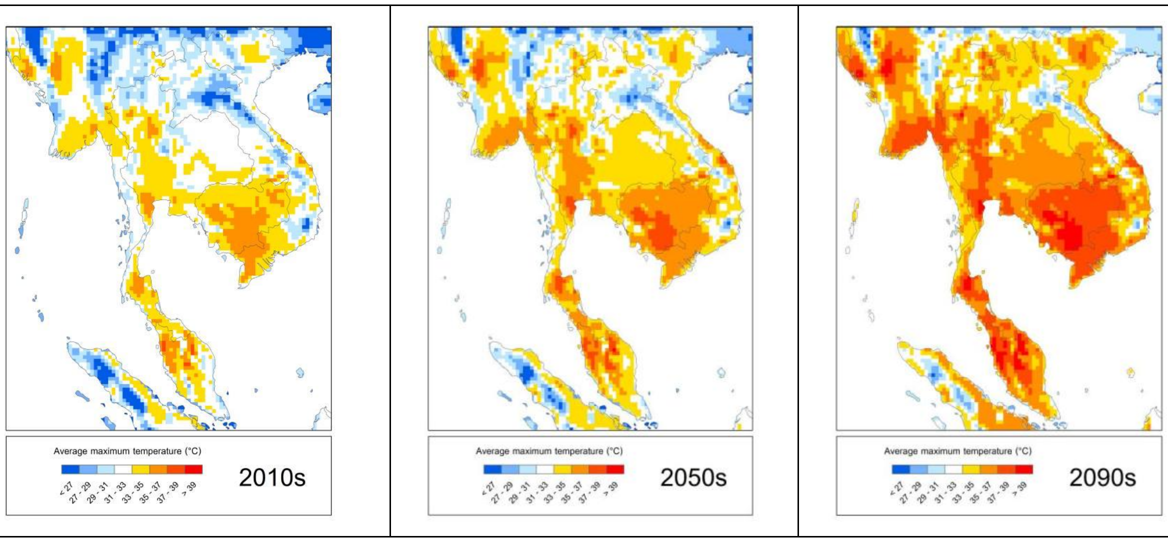


Figure 9: Decadal average daily maximum temperature at beginning, middle and end of 21st century under IPCC SRES A2 GHG scenario

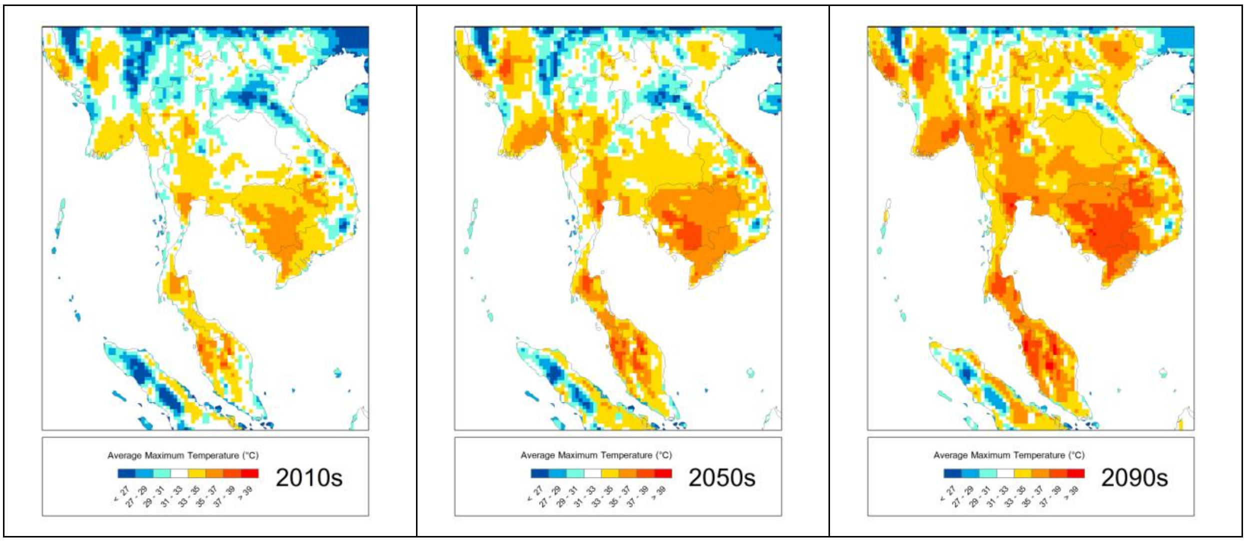


Figure 10: Decadal average daily maximum temperature at beginning, middle and end of 21st century under IPCC SRES B2 GHG scenario

Change in minimum temperature (also see Appendix 1)

By middle of the 21st century (2045-2065), all of the 8 GCMs show that average monthly minimum temperature in Thailand is expected to increase by over 4ºC throughout the country. This means that the nighttime temperature will get warmer than the daytime temperature.

For the northern mountainous and valley zone, annual average minimum temperature is expected to rise from 20.43ºC to 24.82ºC compared to the median value among the results from 8 GCM models. For the wintertime, particularly during the months of December – January – February there is a wide range of results which show the possibility that the minimum temperature could be warmer than the median value.

The average minimum temperature in the central plain and Chao Phraya River basin will increase from 23.74ºC to 27.76ºC and most models agree on the change in the minimum temperature, which is shown in narrow range of deviation of approximately +/- 1ºC throughout the year.

The western region and Mekong River corridor will suffer a change in annual average minimum temperature in the same range, which is expected to rise from 21.72ºC to 25.56ºC and 21.98ºC to 25.82ºC respectively, when compare to the median value among the results from 8 GCM models.

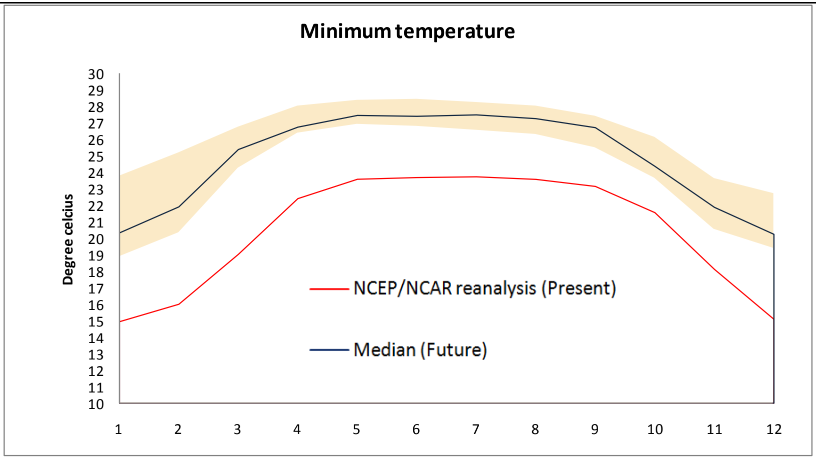
The northeastern plateau average minimum temperature will rise from 22.55ºC to 26.50ºC when compared to the median value among the results from 8 GCM models.

The eastern region average minimum temperature will rise from 23.84ºC to 27.53ºC when compared to the median value among the results from 8 GCM models.

In the southern region of Thailand, the coastal zone on the lower Gulf of Thailand and the lower Andaman coast - Phuket, there will be a change in annual average minmum temperature where the temperature will rise from 23.78ºC to 27.22ºC and 23.93ºC to 27.33ºC respectively, compared to the median value among the results from 8 GCM models.

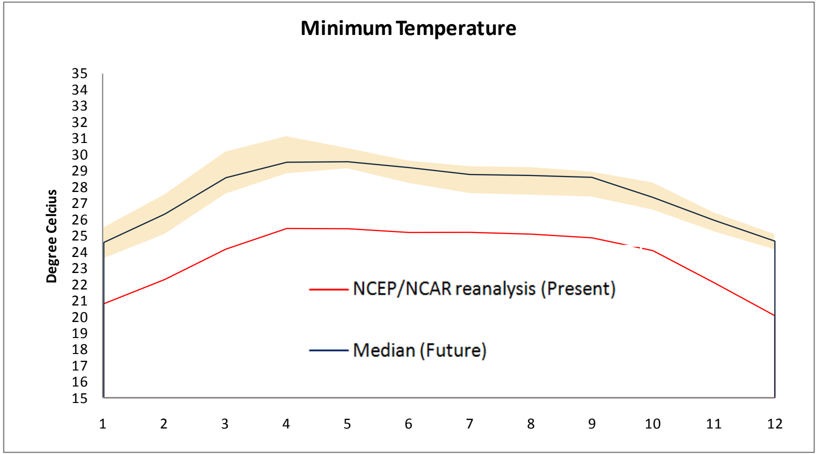
Results from 8 GCM models are summarized in graphs and charts as follows: *(note: NCEP/NCAR reanalysis is used to represent climate of present condition)*

Northern mountain and valley zone



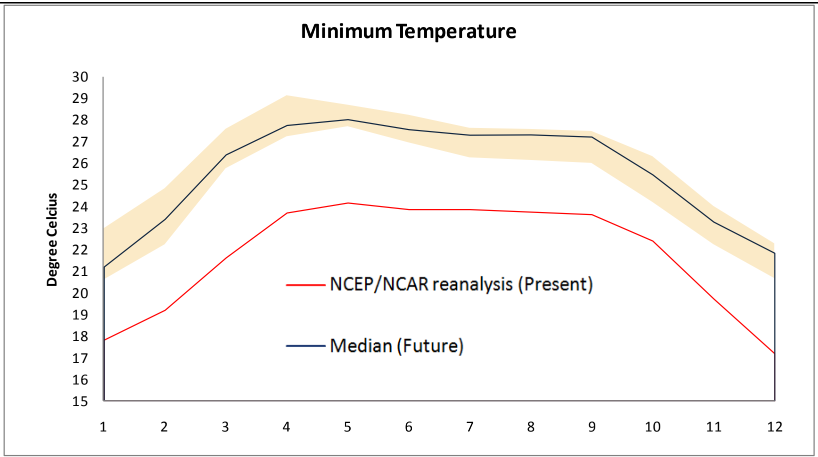
month	NCEP/NCAR reanalysis	cccma_cgcm3_1	cnrm_cm3	csiro_mk3_0	gfdl_cm2_0	giss_model_e_r	ipsl_cm4	mpi_echam5	Max	Min	Median
1	14.95	19.48	18.88	20.37	21.69	23.82	20.66	19.43	23.82	18.88	20.37
2	16.01	20.93	20.34	21.95	23.72	25.25	24.21	21.80	25.25	20.34	21.95
3	19.05	24.26	24.97	25.00	26.01	26.15	26.81	25.45	26.81	24.26	25.45
4	22.44	26.79	27.57	26.39	26.69	26.81	27.89	28.10	28.10	26.39	26.81
5	23.61	27.52	28.45	27.08	26.93	27.09	28.34	28.23	28.45	26.93	27.52
6	23.72	27.47	27.93	26.80	26.91	27.02	28.51	27.75	28.51	26.80	27.47
7	23.76	27.56	27.59	26.57	26.97	27.05	28.32	27.81	28.32	26.57	27.56
8	23.61	27.33	27.43	26.31	26.78	26.73	28.10	27.62	28.10	26.31	27.33
9	23.18	26.79	26.78	25.50	25.51	26.16	27.48	26.96	27.48	25.50	26.78
10	21.58	24.42	24.12	23.66	23.66	24.77	26.19	24.76	26.19	23.66	24.42
11	18.14	21.82	20.55	21.81	22.46	23.45	23.68	21.93	23.68	20.55	21.93
12	15.10	19.39	20.02	20.28	21.22	22.76	21.84	19.58	22.76	19.39	20.28
Ave.	20.43								26.46	23.80	24.82

Central plain and Chao Phraya River basin



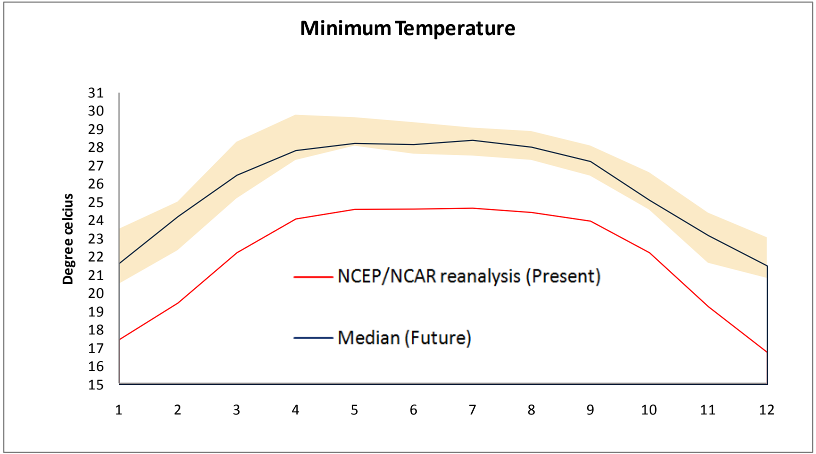
month	NCEP/NCAR reanalysis	cccma_cgcm3_1	cnrm_cm3	csiro_mk3_0	gfdl_cm2_0	giss_model_e_r	ipsl_cm4	mpi_echam5	Max	Min	Median
1	20.80	24.59	24.00	24.44	25.49	25.47	23.57	24.97	25.49	23.57	24.59
2	22.31	26.34	25.50	25.07	27.06	26.81	25.86	27.53	27.53	25.07	26.34
3	24.18	28.59	28.95	27.56	28.87	28.06	28.34	30.18	30.18	27.56	28.59
4	25.46	29.55	30.21	28.82	29.51	28.83	29.77	31.13	31.13	28.82	29.55
5	25.44	29.58	30.40	29.32	29.27	29.13	29.87	30.10	30.40	29.13	29.58
6	25.21	29.22	29.25	28.23	28.38	28.70	29.62	29.29	29.62	28.23	29.22
7	25.22	29.24	28.79	27.60	28.37	28.52	29.27	29.28	29.28	27.60	28.79
8	25.11	29.01	28.73	27.50	28.29	28.31	29.22	29.13	29.22	27.50	28.73
9	24.88	28.76	28.61	27.39	27.85	28.21	28.94	28.87	28.94	27.39	28.61
10	24.09	27.36	27.49	26.58	26.95	27.38	28.27	27.68	28.27	26.58	27.38
11	22.11	25.67	25.28	25.25	25.97	26.15	26.42	25.98	26.42	25.25	25.97
12	20.06	24.14	24.92	24.13	25.08	24.85	24.67	24.52	25.08	24.13	24.67
Ave.	23.74								28.46	26.74	27.67

Western region



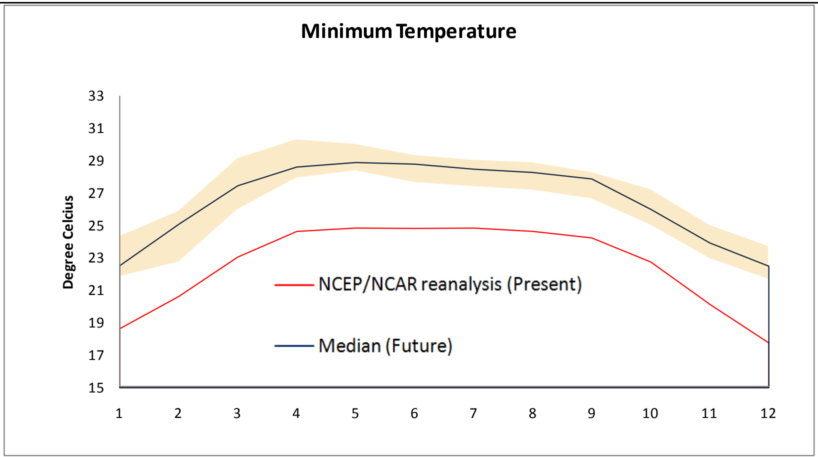
month	NCEP/NCAR reanalysis	cccma_cgcm3_1	cnrm_cm3	csiro_mk3_0	gfdl_cm2_0	giss_model_e_r	ipsl_cm4	mpi_echam5	max	min	Median
1	17.80	21.19	20.69	21.12	22.87	22.98	20.60	21.83	22.98	20.60	21.19
2	19.18	23.34	22.30	22.22	24.81	24.83	23.40	24.63	24.83	22.22	23.40
3	21.60	26.16	26.38	25.75	27.03	26.34	26.52	27.59	27.59	25.75	26.38
4	23.67	27.65	28.25	27.23	27.75	27.50	28.20	29.14	29.14	27.23	27.75
5	24.13	28.02	28.70	27.76	27.69	27.81	28.48	28.56	28.70	27.69	28.02
6	23.83	27.63	27.81	26.94	26.97	27.18	28.23	27.55	28.23	26.94	27.55
7	23.83	27.54	27.30	26.25	26.92	27.01	27.63	27.47	27.63	26.25	27.30
8	23.71	27.37	27.31	26.13	26.93	26.81	27.58	27.52	27.58	26.13	27.31
9	23.60	27.30	27.21	25.99	26.47	26.67	27.48	27.45	27.48	25.99	27.21
10	22.38	25.47	25.39	24.19	24.69	25.46	26.32	25.63	26.32	24.19	25.46
11	19.70	22.92	22.45	22.23	23.27	23.70	24.01	23.36	24.01	22.23	23.27
12	17.17	20.73	21.99	20.66	22.27	22.06	21.83	21.44	22.27	20.66	21.83
Ave.	21.72								26.40	24.66	25.56

Mekong river corridor zone



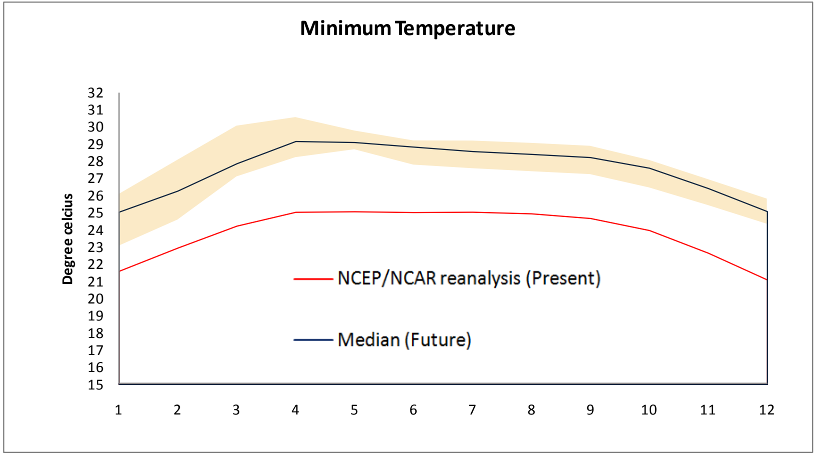
month	NCEP/NCAR reanalysis	cccma_cgcm3_1	cnrm_cm3	csiro_mk3_0	gfdl_cm2_0	giss_model_e_r	ipsl_cm4	mpi_echam5	Max	min	Median
1	17.45	21.03	20.49	21.62	23.31	23.49	21.95	21.43	23.49	20.49	21.62
2	19.47	23.06	22.33	22.35	24.67	24.99	24.20	24.37	24.99	22.33	24.20
3	22.23	26.29	26.47	25.18	26.75	26.30	26.67	28.27	28.27	25.18	26.47
4	24.08	27.82	29.00	27.28	27.74	27.52	28.20	29.75	29.75	27.28	27.82
5	24.61	28.14	29.62	28.18	28.07	28.21	29.08	29.27	29.62	28.07	28.21
6	24.62	28.15	28.68	27.63	27.85	28.05	29.35	28.83	29.35	27.63	28.15
7	24.67	28.38	28.40	27.53	27.93	28.02	29.05	28.78	29.05	27.53	28.38
8	24.44	28.00	28.10	27.29	27.67	27.71	28.86	28.49	28.86	27.29	28.00
9	23.96	27.22	27.48	26.48	26.43	26.73	28.07	27.50	28.07	26.43	27.22
10	22.23	24.60	25.03	24.57	25.10	25.10	26.60	25.40	26.60	24.57	25.10
11	19.27	22.59	21.65	22.90	23.89	23.71	24.39	23.16	24.39	21.65	23.16
12	16.76	20.82	21.12	21.49	23.04	22.73	22.92	21.23	23.04	20.82	21.49
Ave.	21.98								27.12	24.94	25.82

Northeastern plateau



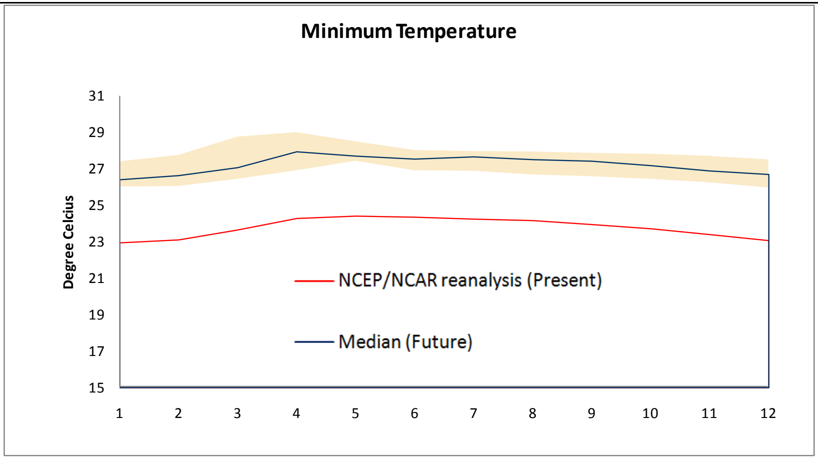
month	NCEP/NCAR reanalysis	cccma_cgcm3_1	cnrm_cm3	csiro_mk3_0	gfdl_cm2_0	giss_model_e_r	ipsl_cm4	mpi_echam5	Max	min	Median
1	18.62	22.29	21.84	21.98	24.18	24.32	22.78	22.50	24.32	21.84	22.50
2	20.60	24.45	23.65	22.73	25.62	25.88	25.05	25.51	25.88	22.73	25.05
3	23.02	27.46	27.80	25.97	27.42	27.15	27.32	29.13	29.13	25.97	27.42
4	24.60	28.74	29.74	27.92	28.24	28.12	28.57	30.31	30.31	27.92	28.57
5	24.81	28.85	30.02	28.55	28.37	28.81	29.17	29.47	30.02	28.37	28.85
6	24.78	28.75	28.82	27.65	27.98	28.35	29.33	29.00	29.33	27.65	28.75
7	24.80	28.95	28.44	27.39	27.99	28.07	28.95	29.04	29.04	27.39	28.44
8	24.60	28.56	28.24	27.17	27.78	27.80	28.88	28.69	28.88	27.17	28.24
9	24.20	27.87	27.84	26.64	26.77	27.27	28.29	27.86	28.29	26.64	27.84
10	22.72	25.63	25.97	25.02	25.58	26.39	27.22	25.99	27.22	25.02	25.97
11	20.12	23.54	22.96	23.15	24.42	24.98	25.02	23.90	25.02	22.96	23.90
12	17.75	21.84	22.47	21.68	23.70	23.55	23.57	22.11	23.70	21.68	22.47
Ave.	22.55								27.59	25.44	26.50

Eastern region



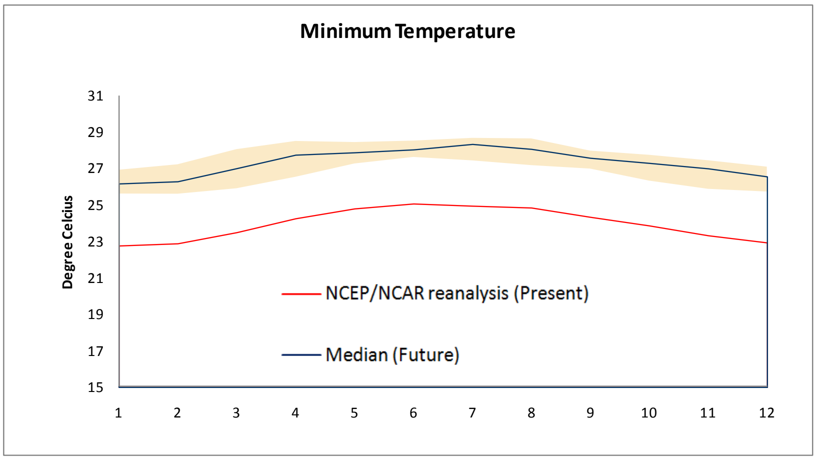
month	NCEP/NCAR reanalysis	cccma_cgcm3_1	cnrm_cm3	csiro_mk3_0	gfdl_cm2_0	giss_model_e_r	ipsl_cm4	mpi_echam5	Max	min	Median
1	21.58	25.70	24.65	24.49	25.16	25.03	23.06	26.04	26.04	23.06	25.03
2	22.94	27.26	25.50	25.08	26.80	26.26	24.59	28.04	28.04	24.59	26.26
3	24.21	28.79	27.85	27.10	28.79	27.74	27.13	30.02	30.02	27.10	27.85
4	25.02	29.15	28.91	28.23	29.37	28.84	29.17	30.52	30.52	28.23	29.15
5	25.05	29.09	29.09	28.69	29.01	29.10	29.26	29.74	29.74	28.69	29.09
6	25.00	28.83	28.60	27.79	28.22	28.82	28.87	29.16	29.16	27.79	28.82
7	25.02	28.87	28.54	27.58	28.33	28.56	28.86	29.15	29.15	27.58	28.56
8	24.93	28.70	28.40	27.41	28.19	28.25	28.90	29.02	29.02	27.41	28.40
9	24.66	28.55	28.21	27.24	28.09	28.21	28.53	28.85	28.85	27.24	28.21
10	23.96	27.59	27.57	26.46	27.43	27.76	27.98	28.03	28.03	26.46	27.59
11	22.64	26.41	26.01	25.43	26.28	26.74	26.49	26.91	26.91	25.43	26.41
12	21.08	25.35	25.58	24.34	25.07	24.80	24.54	25.78	25.78	24.34	25.07
Ave.	23.84								28.43	26.49	27.53

Lower Gulf of Thailand coastal zone



month	NCEP/NCAR reanalysis	cccma_cgcm3_1	cnrm_cm3	csiro_mk3_0	gfdl_cm2_0	giss_model_e_r	ipsl_cm4	mpi_echam5	Max	min	Median
1	22.96	27.40	26.17	26.00	26.41	26.63	26.09	27.38	27.40	26.00	26.41
2	23.12	27.75	26.16	26.03	26.63	26.79	26.25	27.75	27.75	26.03	26.63
3	23.66	28.27	26.43	26.60	27.54	27.07	26.90	28.76	28.76	26.43	27.07
4	24.29	28.13	26.89	27.47	27.96	27.47	27.94	29.01	29.01	26.89	27.94
5	24.42	28.03	27.42	27.56	27.70	27.64	27.88	28.50	28.50	27.42	27.70
6	24.37	27.69	27.54	26.90	27.21	27.38	27.93	28.03	28.03	26.90	27.54
7	24.26	27.66	27.68	26.87	27.24	27.08	27.92	27.97	27.97	26.87	27.66
8	24.18	27.54	27.51	26.67	27.13	26.93	27.94	27.87	27.94	26.67	27.51
9	23.96	27.56	27.42	26.57	27.11	26.95	27.72	27.87	27.87	26.57	27.42
10	23.73	27.52	27.18	26.42	27.02	26.96	27.39	27.82	27.82	26.42	27.18
11	23.41	27.43	26.83	26.23	26.89	26.85	27.16	27.71	27.71	26.23	26.89
12	23.08	27.31	26.69	25.95	26.57	26.65	26.73	27.51	27.51	25.95	26.69
Ave.	23.79								28.02	26.53	27.22

Lower Andaman Coast – Phuket



Month	NCEP/NCAR reanalysis	cccma_cgcm3_1	cnrm_cm3	csiro_mk3_0	gfdl_cm2_0	giss_model_e_r	ipsl_cm4	mpi_echam5	Max	Min	Median
1	22.74	26.87	25.61	25.77	26.17	26.52	25.89	26.91	26.91	25.61	26.17
2	22.86	27.21	25.60	25.75	26.29	26.74	25.98	27.20	27.21	25.60	26.29
3	23.47	27.73	25.90	26.16	27.25	27.01	26.69	28.04	28.04	25.90	27.01
4	24.23	27.75	26.53	26.92	27.83	27.42	27.84	28.49	28.49	26.53	27.75
5	24.77	27.99	27.26	27.58	27.88	27.64	27.89	28.43	28.43	27.26	27.88
6	25.04	28.24	28.04	27.68	27.74	27.62	28.23	28.51	28.51	27.62	28.04
7	24.92	28.34	28.45	27.90	27.89	27.43	28.66	28.48	28.66	27.43	28.34
8	24.82	28.07	28.07	27.44	27.64	27.17	28.63	28.07	28.63	27.17	28.07
9	24.31	27.71	27.58	26.98	27.42	27.23	27.96	27.79	27.96	26.98	27.58
10	23.84	27.38	27.21	26.32	27.30	27.07	27.61	27.73	27.73	26.32	27.30
11	23.30	27.05	26.61	25.87	26.88	27.00	27.24	27.43	27.43	25.87	27.00
12	22.91	26.81	26.17	25.72	26.39	26.59	26.56	27.08	27.08	25.72	26.56
Ave.	23.93								27.92	26.50	27.33

Simulation result from PRECIS regional climate model, after rescaling process, shows spatial representation in trend of increasing average minimum temperature throughout the 21st century. On the high change side, when consider change under rapid increase of atmospheric greenhouse gas under

IPCC SRES A2 GHG scenario, the central plain and Chao Phraya River basin as well as various part of the southern Thailand tends to be the warmest zone in Thailand with average minimum temperature increase from the range of 22ºC – 26ºC to around 26ºC-28ºC or even higher in some sub-areas by the end of the 21st century. The low change side, when consider change under less rapid increase of atmospheric greenhouse gas according to IPCC SRES B2 GHG scenario, also indicate the same trend but at lower degree, as shown in the figures below

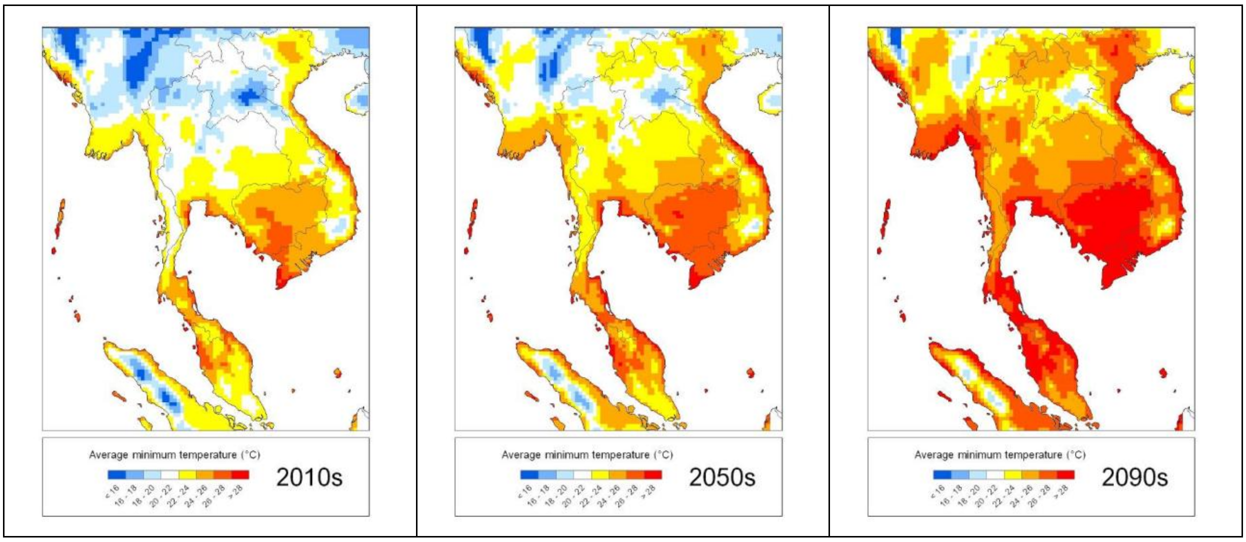


Figure 11: Decadal average daily minimum temperature at beginning, middle and end of 21st century under A2 GHG scenario

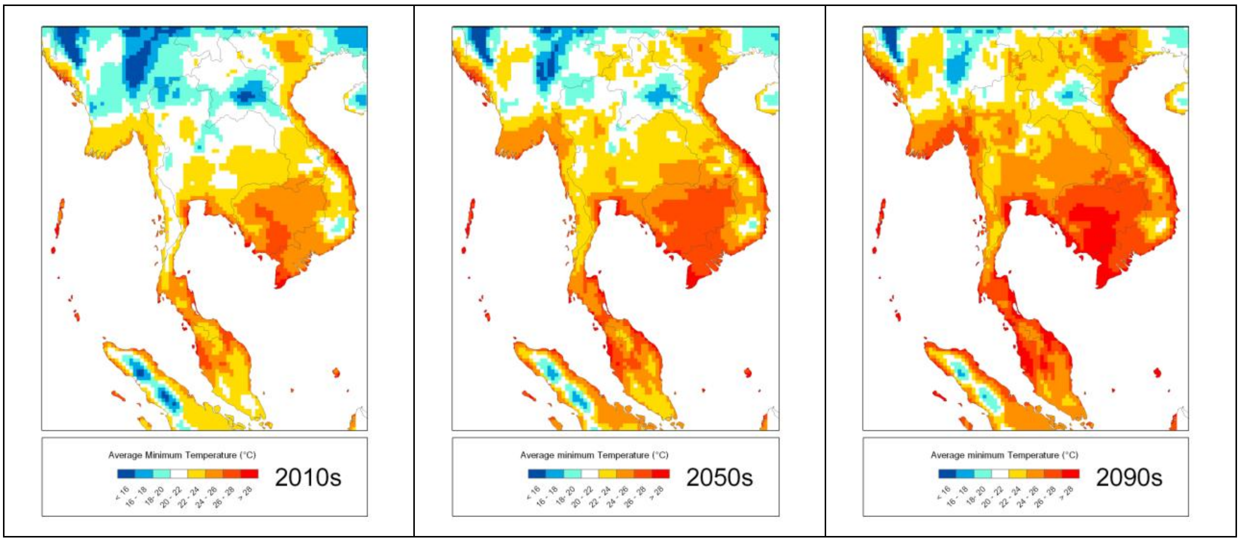


Figure 12: Decadal average daily minimum temperature at beginning, middle and end of 21st century under B2 GHG scenario

Section 3.2 Trend of precipitation change in Thailand (also see appendix 1)

Results from the 8 GCM models show a wide range of plausible futures relating to precipitation in Thailand by middle of the 21st century (2045-2065). The trends described by the different models go in either direction, increased or decreased precipitation. By taking the median value of 8 models to compare with the present time, change in future precipitation in Thailand could be summarized as follows:

The Northern mountainous and valley zone may have higher precipitation during the dry season, from January until April, but precipitation during the rainy season would be slightly less than present time. Annual precipitation in the future may change slightly from the present, approximately by 6%, from 1,055mm. to 1,119mm., when compared to the median value among the results from 8 GCM models.

In the Central plain and Chao Phraya River basin there will be higher precipitation throughout the rainy season. Annual precipitation in the future may increase from present by approximately 10%, from 1,095mm. to 1,210mm., when compared to the median value among the results from 8 GCM models.

The Western region may see its total annual precipitation reduced by 7%, changing from 1,311mm. to 1,213mm. Even though the region may have higher precipitation during the dry season, from January until April, precipitation during rainy season will be less than at the present time. However, the results from 8 GCM models set a wide range of possibilities for rainfall in the future during the rainy season, in the months of June – July – August.

In the Mekong river corridor zone, precipitation may decrease slightly, approximately by 4%, changing from 1,567mm. to 1,494mm. The result from 8 GCM models set a wide range of possibilities for rainfall in the future during the rainy season in the months of June – July – August – September, which suggest that the precipitation could be significantly higher or lower than the median value among the 8 GCM models.

The Northeastern plateau tends to have unchanged annual precipitation, with the potential for slightly higher precipitation during the dry season and slightly lower precipitation during the late part of the rainy season.

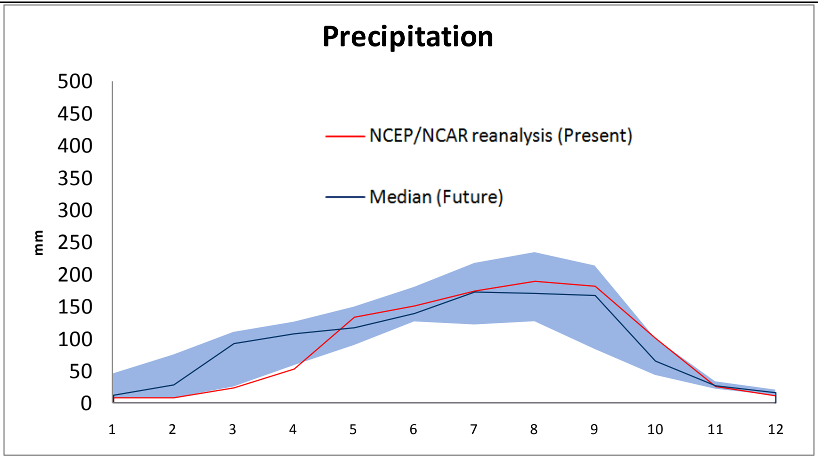
The Eastern region will have significantly higher precipitation, especially during rainy season. Future annual precipitation could change by 14% from 2,224mm to 2,541mm.

In the Lower Gulf of Thailand coastal zone there will be significantly higher precipitation throughout the year. Total annual precipitation could change from 1,857mm to 2,603mm, which is equated to approximately 40%. Result from climate models shows that precipitation will be significantly increased during the north-east monsoon season during November to February.

The Lower Andaman Coast – Phuket will have an 8% increase in precipitation, changing from 2,360mm to 2,555mm. This increase in precipitation may spread throughout the year, except during the north-east monsoon season in the months between October to January.

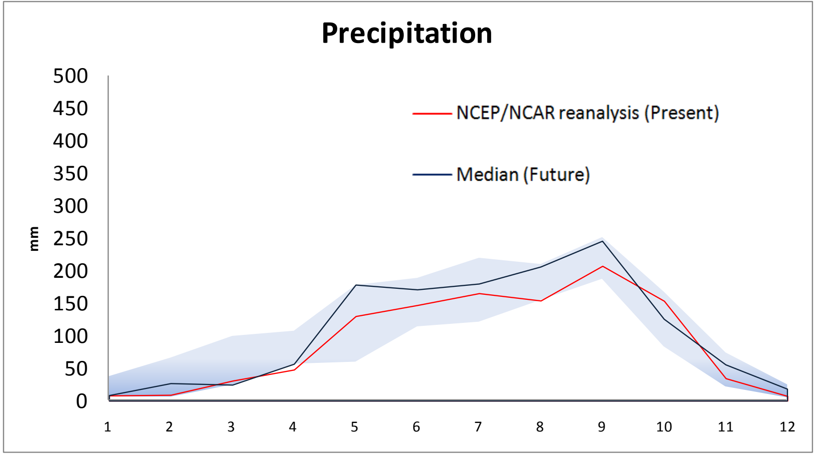
Results from 8 GCM models are summarized in graphs and charts as follows: *(note: NCEP/NCAR reanalysis is used to represent climate of present condition)*

Northern mountain and valley zone



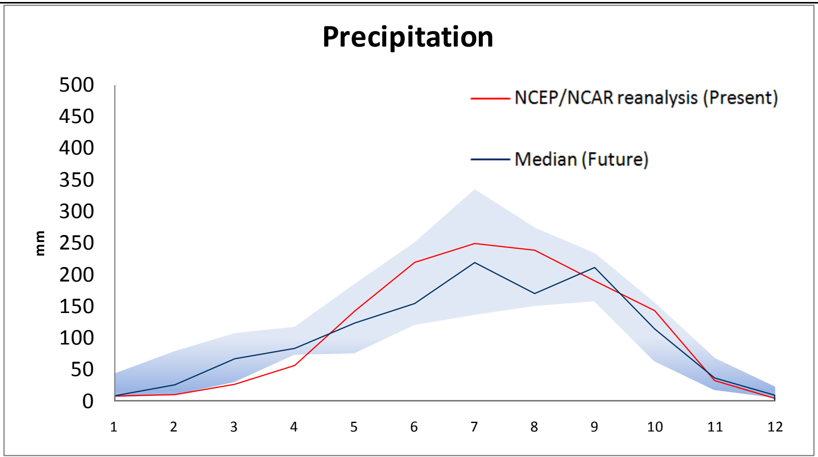
month	NCEP/NCAR reanalysis	cccma_cgcm3_1	cnrm_cm3	csiro_mk3_0	gfdl_cm2_0	giss_model_e_r	ipsl_cm4	mpi_echam5	Max	Min	Median
1	7.81	7.14	6.85	11.86	24.84	45.01	17.88	8.11	45.01	6.85	11.86
2	7.78	13.55	6.90	28.05	60.55	74.33	47.67	21.29	74.33	6.90	28.05
3	23.22	37.49	44.22	92.82	107.75	109.65	97.60	24.66	109.65	24.66	92.82
4	52.50	63.63	72.73	115.80	108.15	115.36	125.47	58.06	125.47	58.06	108.15
5	133.11	136.24	89.66	106.14	116.67	128.60	117.62	148.96	148.96	89.66	117.62
6	150.64	179.75	145.84	131.49	140.01	129.19	126.71	175.45	179.75	126.71	140.01
7	173.83	205.52	173.24	173.63	176.20	152.97	121.90	217.04	217.04	121.90	173.63
8	188.94	209.25	196.67	171.48	167.76	127.00	165.55	233.87	233.87	127.00	171.48
9	181.27	213.09	199.09	155.72	107.02	83.49	168.18	197.89	213.09	83.49	168.18
10	100.50	99.98	74.02	58.96	49.06	42.86	65.43	76.90	99.98	42.86	65.43
11	25.34	26.70	21.22	24.92	26.35	28.95	29.12	32.60	32.60	21.22	26.70
12	10.80	10.79	12.24	14.17	19.64	19.21	19.35	15.83	19.64	10.79	15.83
Total	1055.72								1499.38	720.10	1119.74

Central plain and Chao Phraya River basin



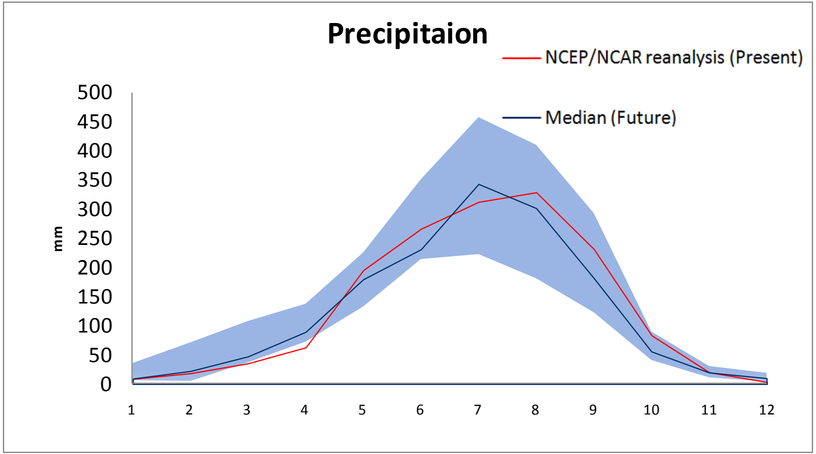
month	NCEP/NCAR reanalysis	cccma_cgcm3_1	cnrm_cm3	csiro_mk3_0	gfdl_cm2_0	giss_model_e_r	ipsl_cm4	mpi_echam5	Max	Min	Median
1	7.83	12.17	7.57	6.10	12.53	37.61	6.47	8.40	37.61	6.10	8.40
2	8.86	20.01	5.83	12.21	33.11	66.21	25.46	26.79	66.21	5.83	25.46
3	30.68	43.79	34.98	67.30	69.27	99.61	65.29	24.48	99.61	24.48	65.29
4	47.80	64.06	63.22	72.95	89.17	107.58	98.86	56.61	107.58	56.61	72.95
5	130.21	156.38	90.66	59.69	139.65	113.93	111.59	178.26	178.26	59.69	113.93
6	147.24	189.07	140.73	114.00	153.84	140.75	138.08	170.88	189.07	114.00	140.75
7	165.50	199.36	158.54	180.59	187.85	220.04	121.18	179.84	220.04	121.18	180.59
8	154.17	181.39	160.39	164.35	173.63	210.43	154.55	205.98	210.43	154.55	173.63
9	207.64	245.29	245.05	187.18	193.67	208.21	251.95	245.58	251.95	187.18	245.05
10	153.73	159.40	126.71	83.22	107.38	167.68	149.59	125.72	167.68	83.22	126.71
11	34.40	54.42	27.20	21.66	43.79	74.12	41.92	55.65	74.12	21.66	43.79
12	7.10	13.67	8.85	4.77	21.37	24.88	12.34	18.26	24.88	4.77	13.67
Total	1095.16								1627.43	839.27	1210.22

Western region



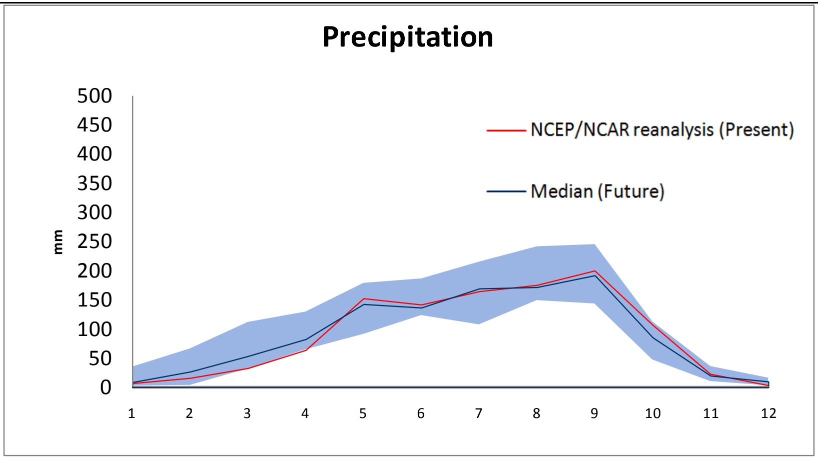
month	NCEP/NCAR reanalysis	cccma_cgcm3_1	cnrm_cm3	csiro_mk3_0	gfdl_cm2_0	giss_model_e_r	ipsl_cm4	mpi_echam5	max	min	Median
1	7.55	8.32	6.79	5.93	11.90	42.60	7.91	4.65	42.60	4.65	7.91
2	9.63	18.31	8.38	14.82	39.75	77.74	25.12	30.15	77.74	8.38	25.12
3	25.99	47.73	41.55	76.38	77.86	106.51	66.27	28.48	106.51	28.48	66.27
4	55.72	78.84	71.58	82.66	93.58	116.44	94.33	76.26	116.44	71.58	82.66
5	141.61	159.48	97.32	73.87	134.20	122.65	107.50	184.58	184.58	73.87	122.65
6	218.39	208.07	198.34	129.34	153.47	132.04	118.42	250.50	250.50	118.42	153.47
7	248.14	272.60	325.60	218.06	184.05	169.52	134.50	334.59	334.59	134.50	218.06
8	237.57	254.71	260.29	169.19	154.51	148.51	156.09	273.93	273.93	148.51	169.19
9	189.17	233.40	221.78	157.57	155.99	174.64	210.30	224.16	233.40	155.99	210.30
10	142.24	154.75	113.29	61.47	86.44	131.65	130.20	106.88	154.75	61.47	113.29
11	31.84	38.55	19.44	16.02	34.19	66.87	38.40	35.94	66.87	16.02	35.94
12	3.88	8.86	6.26	3.75	21.70	16.23	7.91	12.09	21.70	3.75	8.86
Total	1311.73								1863.61	825.62	1213.71

Mekong river corridor zone



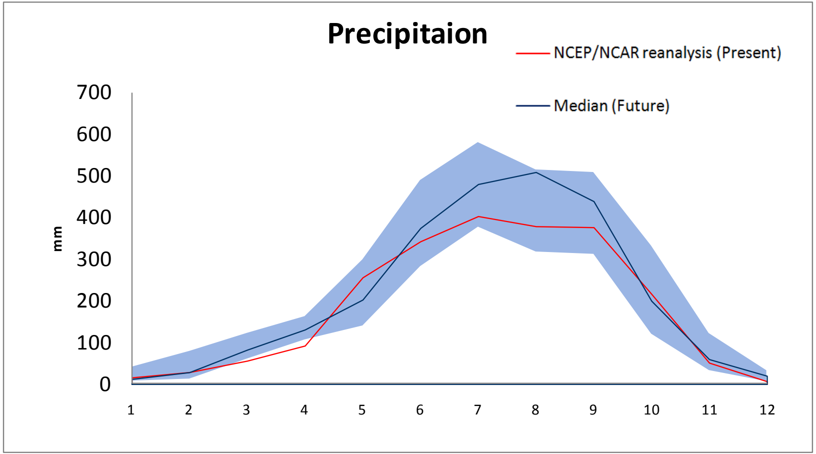
month	NCEP/NCAR reanalysis	cccma_cgcm3_1	cnrm_cm3	csiro_mk3_0	gfdl_cm2_0	giss_model_e_r	ipsl_cm4	mpi_echam5	Max	min	Median
1	8.97	9.47	6.64	6.41	15.56	35.82	9.48	8.44	35.82	6.41	9.47
2	18.58	16.34	5.04	11.05	46.20	71.11	37.92	22.50	71.11	5.04	22.50
3	35.58	45.61	36.77	47.60	96.08	107.76	91.28	40.63	107.76	36.77	47.60
4	62.92	73.49	71.91	89.66	124.83	132.03	137.26	77.84	137.26	71.91	89.66
5	195.40	186.74	142.99	131.81	179.98	201.19	168.74	225.20	225.20	131.81	179.98
6	266.25	313.88	287.53	231.39	212.82	212.62	217.99	350.47	350.47	212.62	231.39
7	312.40	406.42	358.87	343.61	274.28	227.99	221.06	456.87	456.87	221.06	343.61
8	328.78	403.17	365.71	302.15	257.76	179.76	268.29	409.41	409.41	179.76	302.15
9	231.30	265.96	292.56	182.17	121.86	122.83	143.10	240.46	292.56	121.86	182.17
10	83.63	89.64	85.62	40.67	42.34	56.07	50.83	81.66	89.64	40.67	56.07
11	20.25	26.27	11.09	13.97	20.00	24.45	13.39	30.67	30.67	11.09	20.00
12	3.63	12.60	4.07	4.39	18.90	10.18	10.03	10.35	18.90	4.07	10.18
Total	1567.70								2225.66	1043.07	1494.76

Northeastern plateau



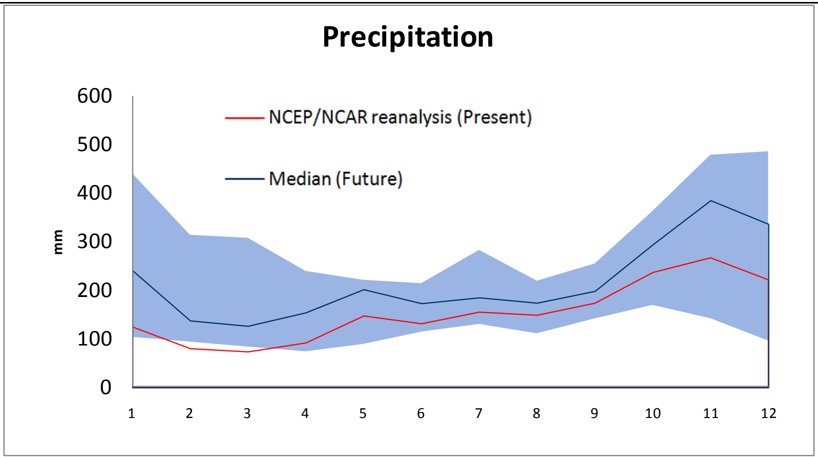
month	NCEP/NCAR reanalysis	cccma_cgcm3_1	cnrm_cm3	csiro_mk3_0	gfdl_cm2_0	giss_model_e_r	ipsl_cm4	mpi_echam5	Max	min	Median
1	6.97	9.07	6.22	2.68	15.87	34.85	8.84	6.94	34.85	2.68	8.84
2	15.98	17.01	3.77	8.59	46.85	65.89	36.44	26.77	65.89	3.77	26.77
3	32.89	47.98	40.37	53.42	96.32	111.06	80.38	31.89	111.06	31.89	53.42
4	63.95	73.33	77.90	82.37	115.42	121.82	128.74	64.91	128.74	64.91	82.37
5	152.70	158.05	114.58	91.32	142.26	147.01	139.99	177.66	177.66	91.32	142.26
6	141.95	184.38	158.08	133.89	131.87	123.62	136.26	185.24	185.24	123.62	136.26
7	164.70	191.11	148.22	142.76	168.92	182.57	107.71	213.84	213.84	107.71	168.92
8	175.59	199.55	177.21	154.34	171.16	171.25	149.31	239.98	239.98	149.31	171.25
9	200.33	224.89	243.70	164.96	143.53	182.49	191.43	225.86	243.70	143.53	191.43
10	107.42	111.65	86.59	47.45	50.20	87.82	73.00	85.23	111.65	47.45	85.23
11	22.94	24.56	11.21	10.35	19.89	35.77	14.73	30.89	35.77	10.35	19.89
12	3.59	8.50	5.39	3.09	16.02	13.78	11.76	9.91	16.02	3.09	9.91
Total	1089.01								1564.38	779.62	1096.54

Eastern region



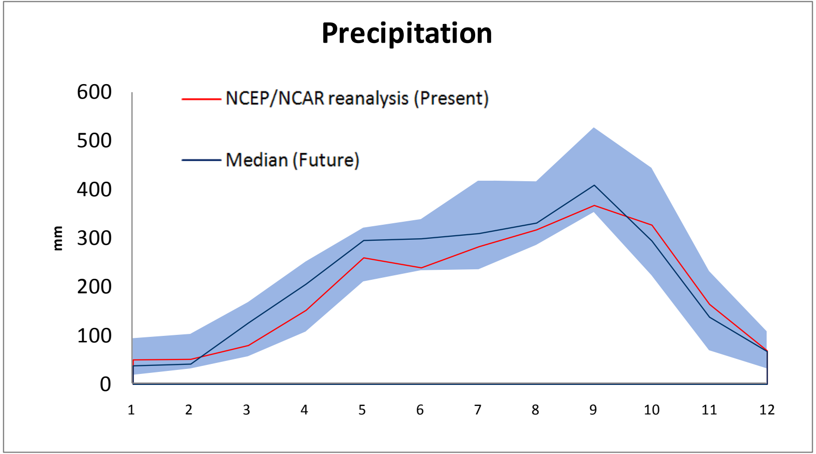
month	NCEP/NCAR reanalysis	cccma_cgcm3_1	cnrm_cm3	csiro_mk3_0	gfdl_cm2_0	giss_model_e_r	ipsl_cm4	mpi_echam5	Max	min	Median
1	15.98	24.65	12.30	9.41	11.89	41.05	7.82	14.85	41.05	7.82	12.30
2	28.74	47.32	12.70	19.18	28.54	78.93	20.11	47.50	78.93	12.70	28.54
3	56.12	111.69	60.84	93.50	82.58	122.39	64.34	68.70	122.39	60.84	82.58
4	92.35	138.35	106.66	120.63	134.62	162.62	131.02	108.57	162.62	106.66	131.02
5	255.95	266.17	161.98	139.96	289.77	202.94	189.63	298.89	298.89	139.96	202.94
6	342.45	403.61	374.84	282.26	489.88	337.19	331.75	477.14	489.88	282.26	374.84
7	402.90	506.59	480.40	376.61	580.90	436.19	434.76	548.80	580.90	376.61	480.40
8	378.64	466.91	442.11	317.09	515.25	511.24	512.36	509.27	515.25	317.09	509.27
9	376.32	439.37	455.63	311.53	432.17	509.00	507.84	408.14	509.00	311.53	439.37
10	216.48	215.93	200.06	120.23	186.53	332.59	257.48	164.41	332.59	120.23	200.06
11	51.34	58.99	33.04	33.27	68.61	121.99	59.83	61.34	121.99	33.04	59.83
12	6.84	17.63	11.55	6.58	27.41	32.50	19.99	26.53	32.50	6.58	19.99
Total	2224.08								3285.97	1775.29	2541.13

Lower Gulf of Thailand coastal zone



month	NCEP/NCAR reanalysis	cccma_cgcm3_1	cnrm_cm3	csiro_mk3_0	gfdl_cm2_0	giss_model_e_r	ipsl_cm4	mpi_echam5	Max	min	Median
1	125.08	311.06	255.60	102.64	134.65	438.99	122.25	240.60	438.99	102.64	240.60
2	80.36	241.91	155.86	106.69	92.92	312.54	119.89	137.26	312.54	92.92	137.26
3	73.80	194.04	136.17	109.67	111.60	306.38	126.22	82.70	306.38	82.70	126.22
4	92.32	181.67	97.97	73.17	153.95	238.41	157.60	121.31	238.41	73.17	153.95
5	147.84	207.30	121.74	88.29	220.06	212.39	193.27	201.49	220.06	88.29	201.49
6	131.79	179.92	126.24	113.35	172.76	213.29	180.46	168.27	213.29	113.35	172.76
7	155.69	214.24	158.62	129.07	195.09	281.65	136.81	184.71	281.65	129.07	184.71
8	149.28	173.76	147.26	109.94	178.99	218.34	158.26	179.94	218.34	109.94	173.76
9	174.12	198.06	196.04	140.45	200.51	195.08	245.37	253.70	253.70	140.45	198.06
10	237.30	328.47	282.60	168.05	314.94	286.98	293.76	361.65	361.65	168.05	293.76
11	267.63	406.62	476.84	140.75	360.72	360.32	384.63	466.52	476.84	140.75	384.63
12	222.35	335.99	449.16	95.01	279.99	484.06	232.45	363.03	484.06	95.01	335.99
Total	1857.56								3805.88	1336.35	2603.17

Lower Andaman Coast – Phuket



month	NCEP/NCAR reanalysis	cccma_cgcm3_1	cnrm_cm3	csiro_mk3_0	gfdl_cm2_0	giss_model_e_r	ipsl_cm4	mpi_echam5	Max	Min	Median
1	50.16	78.52	37.94	31.25	31.55	93.57	18.25	51.93	93.57	18.25	37.94
2	51.32	94.60	32.17	41.52	39.80	102.41	31.24	63.88	102.41	31.24	41.52
3	79.76	167.71	56.24	87.38	144.18	126.02	86.59	132.45	167.71	56.24	126.02
4	152.00	205.81	106.74	129.64	251.12	205.75	214.95	244.20	251.12	106.74	205.81
5	259.89	309.52	209.44	229.86	295.53	300.06	272.99	320.72	320.72	209.44	295.53
6	239.38	262.77	259.71	232.30	323.39	309.77	338.24	299.00	338.24	232.30	299.00
7	282.81	309.71	307.17	234.32	417.88	391.52	243.26	411.86	417.88	234.32	309.71
8	317.47	312.19	305.08	284.10	401.19	410.89	331.31	415.90	415.90	284.10	331.31
9	367.61	412.80	400.91	351.44	435.82	409.18	526.84	406.19	526.84	351.44	409.18
10	327.16	335.53	294.47	222.25	287.58	443.78	339.17	223.04	443.78	222.25	294.47
11	164.28	129.14	135.95	68.53	157.00	231.57	137.86	138.83	231.57	68.53	137.86
12	68.87	67.29	67.08	31.58	70.29	107.77	48.70	72.53	107.77	31.58	67.29
Total	2360.71								3417.51	1846.43	2555.64

Simulation result from PRECIS regional climate model, after rescaling process, shows higher detail spatial representation in trend of increasing average annual precipitation throughout the 21st century. Result from the simulation, based on ECHAM4 GCM model, show a clear trend of increased precipitation which will be significantly higher toward the end of the 21st century, especially in the lower Gulf of Thailand coastal zone, eastern region as well as Mekong River corridor zone. Trend of increasing precipitation in the future is obvious both under high change scenario (A2 scenario) and low change scenario (B2 scenario), however, the change that might occur under B2 scenario is of lesser degree.

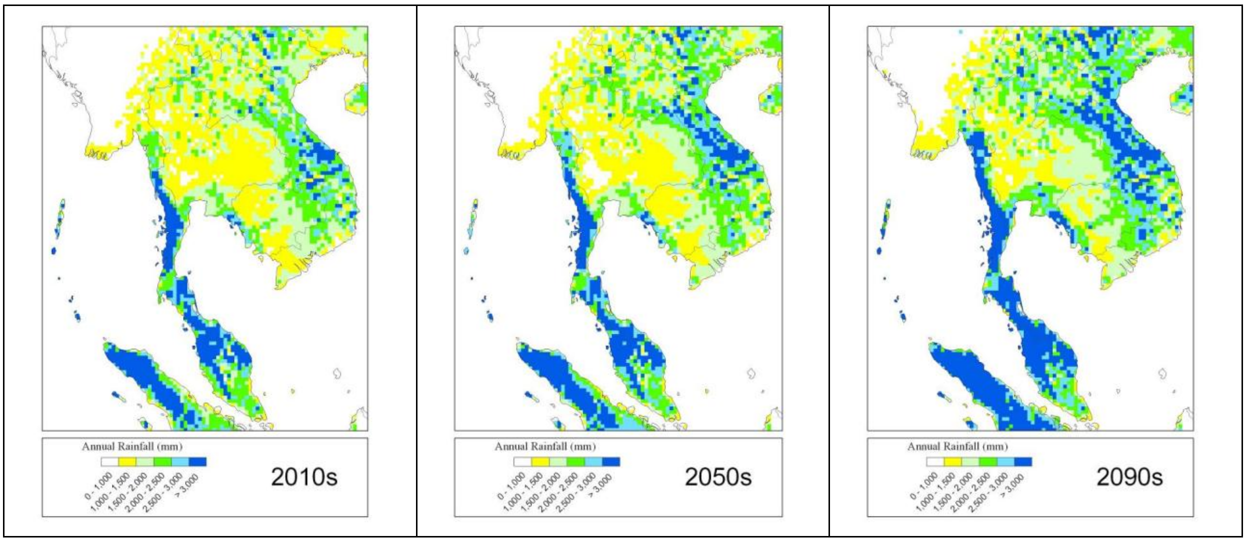


Figure 13: Annual precipitation in Thailand at beginning, middle and end of 21st century under IPCC SRES A2 GHG scenario

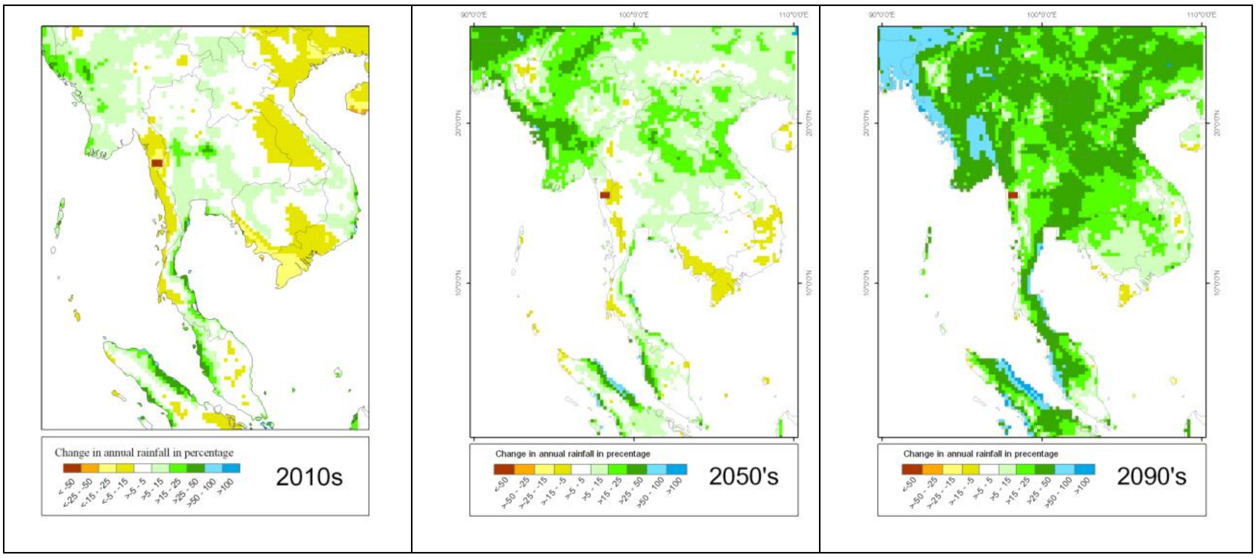


Figure 14: Change in annual precipitation (%) at beginning, middle and end of 21st century under IPCC SRES A2 GHG scenario compare to baseline condition of 1980s

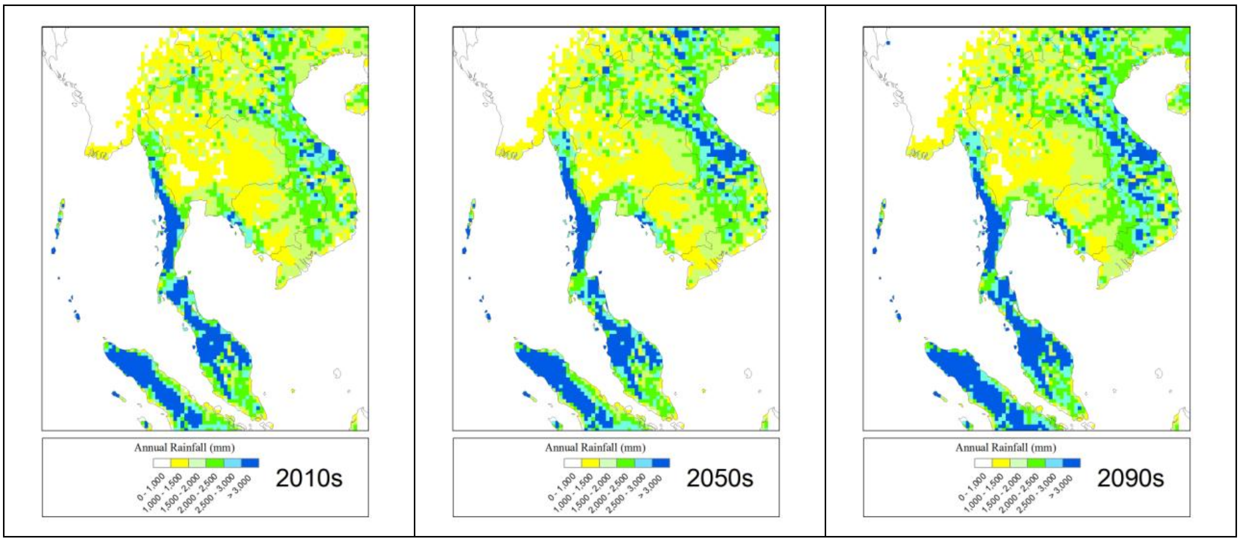


Figure 15: Annual precipitation in Thailand at beginning, middle and end of 21st century under IPCC SRES B2 GHG scenario

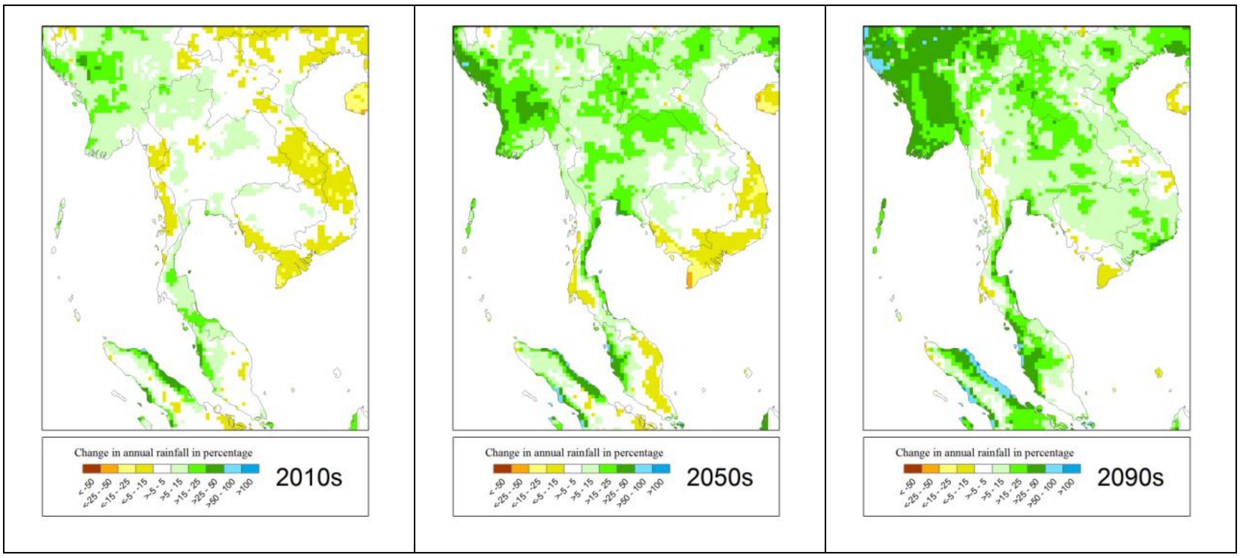


Figure 16: Change in annual precipitation (%) at beginning, middle and end of 21st century under IPCC SRES B2 GHG scenario compare to baseline condition of 1980s

Section 3.3 Seasonal change in Thailand

Not only the annual average but also the pattern of climate change needs to be considered. Climate change will not be uniform throughout the year, each season may change differently. To this end, this report provides a summary on a brief analysis of future climate change in Thailand from a seasonal perspective.

Trend toward longer summertime and shorter wintertime

Simulation results from a PRECIS regional climate model, based on ECHAM4 GCM as initial dataset, suggest that Thailand will have a longer and warmer summertime and a shorter and warmer wintertime. The trend of this change can be observed from warming temperature, both maximum and minimum temperature, as discussed in Section 3.1 *(Note: also see appendix 6, 8, 13 and 15 which show change in maximum and minimum temperature at different seasons over the year throughout the 21st century.)*

In addition, the number of hot days and cool days over the year was analyzed and the result shows that number of days in which the maximum temperature is over 35ºC also tends to increase and, on the contrary, number of days that minimum temperature is under 16Cº over the year tends to decrease throughout the country and throughout the 21st century as shown in the table below:

Number of hot days over the year (days with maximum temperature >35ºC):

Station	**Number of days**				
	1980s	**2030s**	**2050s**	**2070s**	**2090s**
1.Chiangrai	102	107	122	141	152
2.Maehongson	122	133	154	173	195
3.Chiangmai	118	128	147	171	191
4.Nan	114	134	149	181	199
5.Utaradit	158	196	214	240	249
6.Udonthani	95	107	132	166	177
7.Nakhornphanom	73	93	113	134	152
8.Khonkaen	103	119	138	175	195
9.Ubonratchathani	102	136	162	190	210
10.Nakhonratchasima	118	139	162	198	219
11.Nakhon Sawan	137	169	188	231	251
12.Kampangphet	48	59	172	207	232
13.Lopburi	126	162	184	226	153
14.Bangkok	105	138	165	208	242
15.Cholburi	80	107	164	232	278
16.Rayong	48	59	107	189	265
17.Trad	5	34	71	123	170
18.Hua hin	34	68	105	148	182
19.Chumporn	26	51	87	119	165
20. Nakornsrithammarat	213	262	296	218	332
21.Pattani	18	53	97	152	211
22.Ranong	3	26	52	86	129
23.Phuket	0	0	0	0	0
24.Satun	11	55	112	180	226

Number of cool days over the year (days with minimum temperature <16ºC):

Station	**Number of days**				
	1980s	**2030s**	**2050s**	**2070s**	**2090s**
1.Chiangrai	95	83	66	47	33
2.Maehongson	85	61	43	20	10
3.Chiangmai	79	61	48	27	16
4.Nan	53	39	34	14	13
5.Utaradit	33	20	18	4	4
6.Udonthani	63	52	48	23	17
7.Nakhornphanom	37	32	32	8	5
8.Khonkaen	33	25	25	3	3
9.Ubonratchathani	9	6	6	0	0
10.Nakhonratchasima	28	19	21	2	2
11.Nakhon Sawan	17	7	6	0	1
12.Kampangphet	47	34	32	12	11
13.Lopburi	7	3	4	0	0
14.Bangkok	10	6	5	0	0
15.Cholburi	0	0	0	0	0
16.Rayong	0	0	0	0	0
17.Trad	0	0	0	0	0
18.Hua hin	0	0	0	0	0
19.Chumporn	0	0	0	0	0

Station	Number of days				
	1980s	2030s	2050s	2070s	2090s
20. Nakornsrithammarat	0	0	0	0	0
21.Pattani	0	0	0	0	0
22.Ranong	0	0	0	0	0
23.Phuket	0	0	0	0	0
24.Satun	0	0	0	0	0

Simulation results from a PRECIS regional climate model after rescaling (shown in the figures below) show a detail spatial representation of the number of hot days in a year throughout the 21st century. The results from the simulation, based on ECHAM4 GCM model, show a clear trend that the central plain and Chao Phraya river basin as well as the southern region will have a longer summertime (defined by the number of days that maximum temperature is over 35ºC). The summer could become as long as 7-8 months by the end of the century. However, most of the regions throughout the country will have a longer summertime, which could expand 1-2 months by the middle of the century and by up to 3-4 months by the end of the century. Simulations under both IPCC greenhouse gas scenarios, A2 and B2, show a tendency to have a longer summertime, but the change under B2 scenario is of lesser degree.

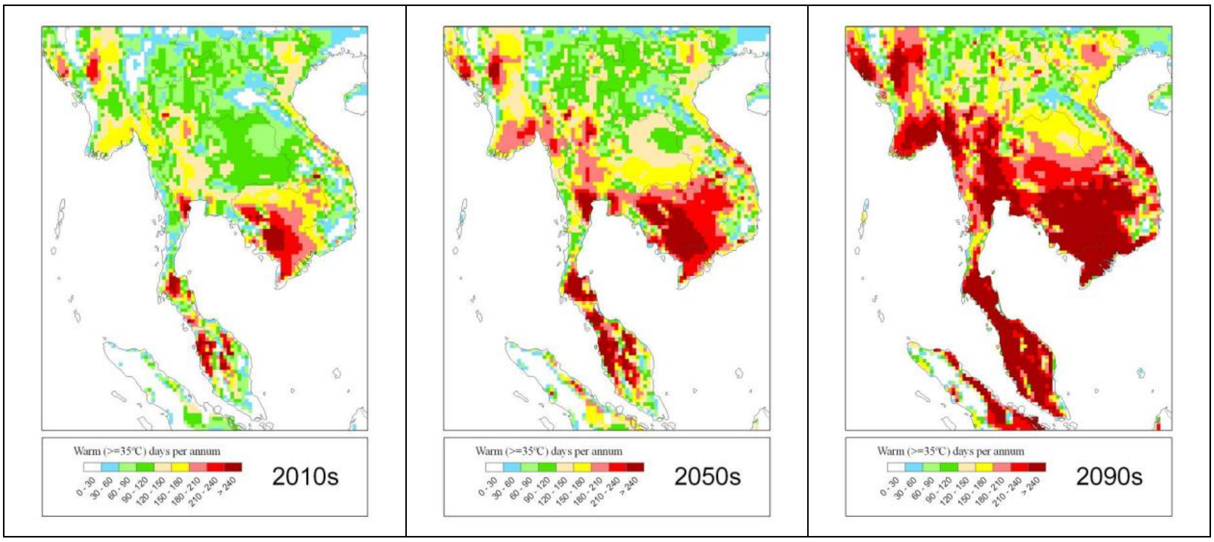


Figure 17: Length of hot period over the year at beginning, middle and end of 21st century under GHG scenario A2

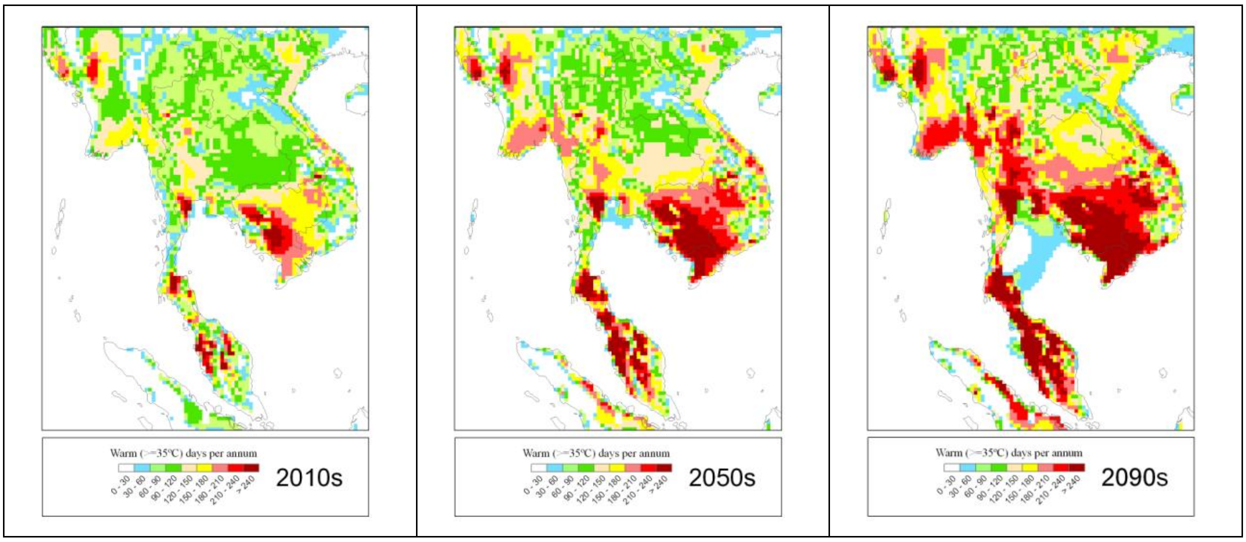


Figure 18: Length of hot period over the year at beginning, middle and end of 21st century under GHG scenario B2

Just as the summer will get longer, the winter in Thailand will get shorter. The figures below are the results of a simulation using PRECIS regional climate model, based on ECHAM4 GCM and rescaled. These figures show a detailed spatial representation of the winter throughout the 21st century. According to this model, it is clear that for most of the country the winter will disappear, and only the north and upper northeast regions of Thailand will continue to have days below 16ºC. Even in these regions, the wintertime will only last between 1-2 months. By the end of the century, the winter could be restricted only to the mountain range and may not last over one month.

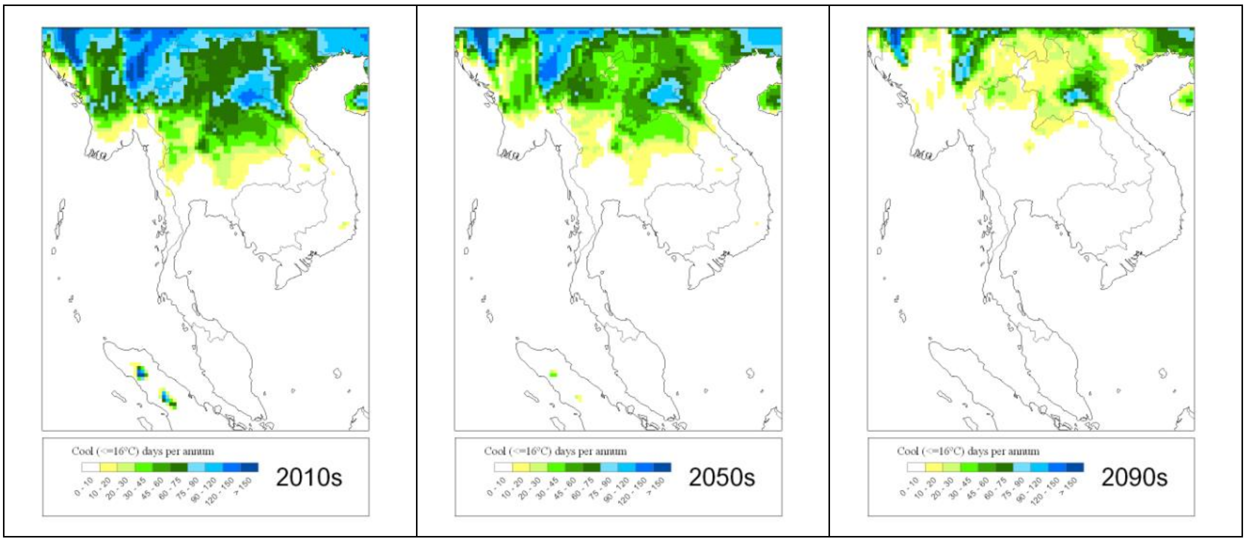


Figure 19: Length of cool period over the year at beginning, middle and end of 21st century under GHG scenario A2

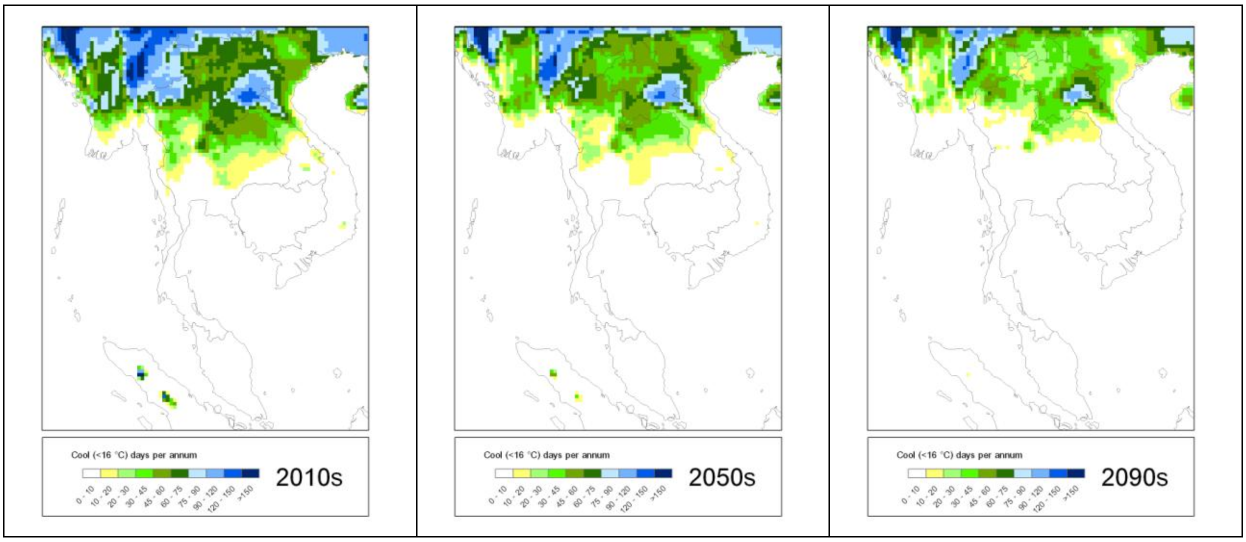


Figure 20: Length of cool period over the year at beginning, middle and end of 21st century under GHG scenario B2

Trend toward wetter rainy season.

The figures below are the results of a simulation using PRECIS regional climate model, based on ECHAM4 GCM and rescaled. These figures show a detailed spatial representation of annual precipitation throughout the 21st century. Rainy season is defined as the number of days that rainfall is over 3mm.

The simulation results from both A2 and B2 scenarios show a trend for annual precipitation to increase. This trend becomes more distinct in the second half of the century, and it is significantly higher toward the end of the century. However, the overall number of rainy days will only slightly change (except at the end of the 21st century under A2 scenario, when there will be more rainy days). This indicates that in the future Thailand may have a rainy season of the same duration but with higher intensity of rainfall.

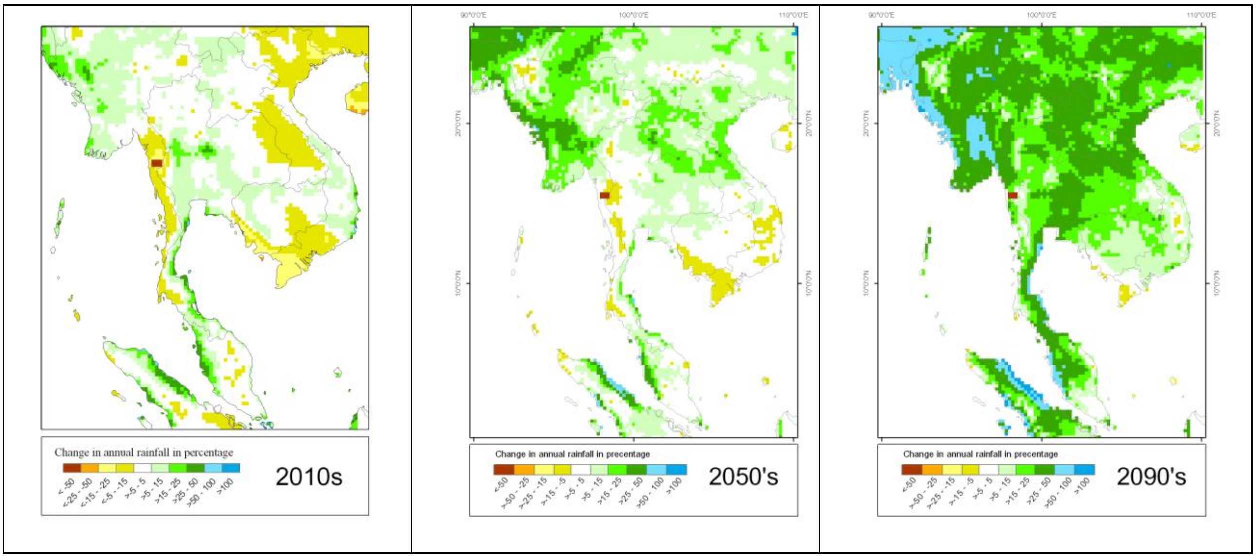


Figure 21: Change in annual precipitation (%) at beginning, middle and end of 21st century under IPCC SRES A2 GHG scenario compare to baseline condition of 1980s

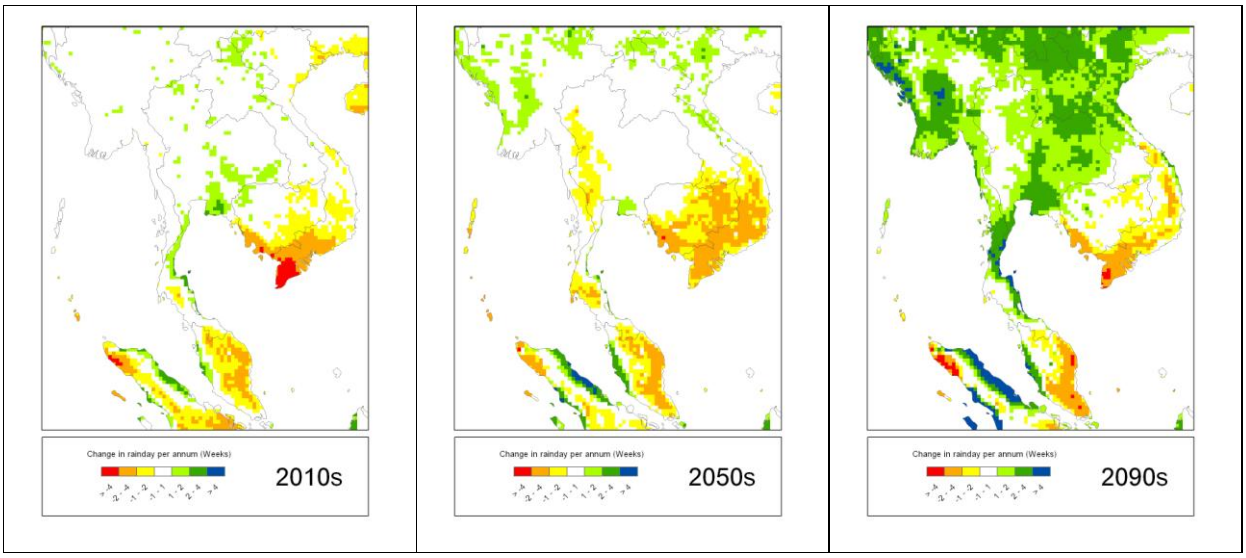


Figure 22: Change in number of day with rainfall over 3 mm at beginning, middle and end of 21st century under IPCC SRES A2 GHG scenario compare to baseline condition of 1980s

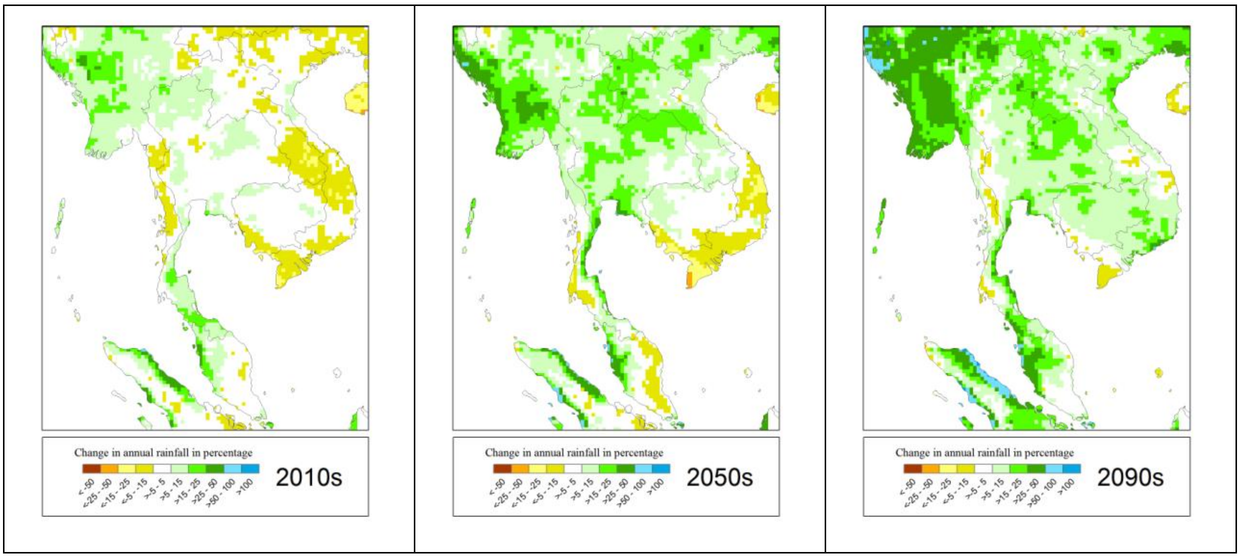


Figure 23: Change in annual precipitation (%) at beginning, middle and end of 21st century under IPCC SRES B2 GHG scenario compare to baseline condition of 1980s

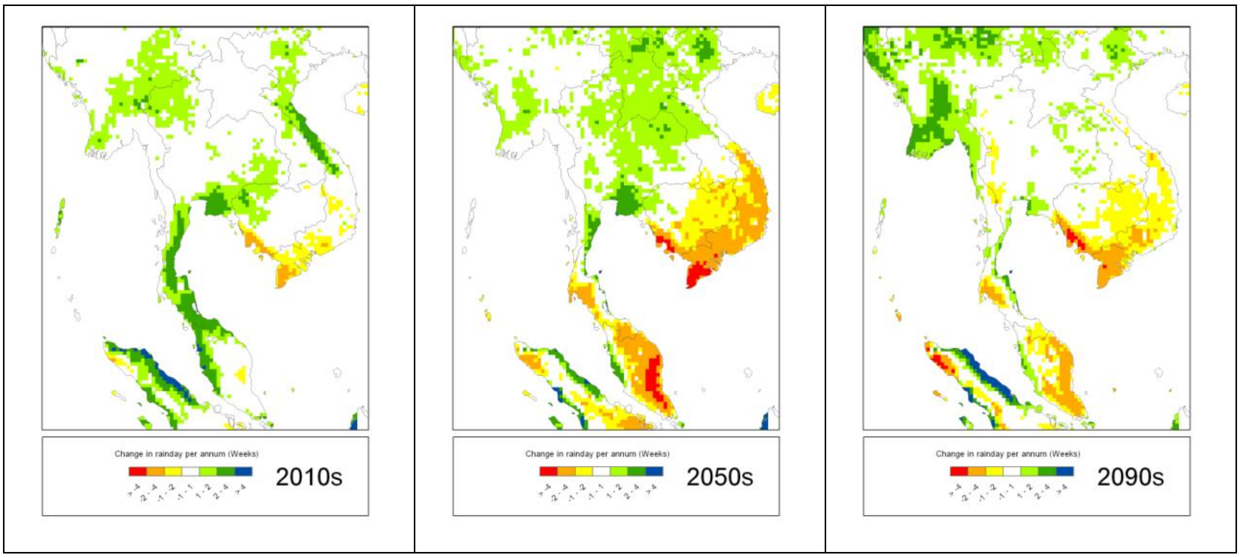


Figure 24: Change in number of day with rainfall over 3 mm at beginning, middle and end of 21st century under IPCC SRES B2 GHG scenario compare to baseline condition of 1980s

Conclusion

In brief, the results of these analyses suggest that the future climate in Thailand and surrounding countries will get warmer, have a longer summertime, a shorter and warmer wintertime and a rainy season with higher intensity of rainfall resulting in higher annual total precipitation. These changes are unlikely to be irreversible and would have impact on various systems and sectors.

High resolution climate scenarios from long-term climate projections can be used to assess impact of climate change in various sectors as well as to support long term planning. However, a climate scenario is only a plausible future and cannot be taken as long-term forecast. There is certain degree of uncertainty in this method. One way to cope with the uncertainty of long-term climate projections is the use of multiple scenarios, which are developed using various climate models and/or under different conditions. The use of multiple scenarios in strategic planning or long-term policy planning requires a change in the thinking paradigm of policy planners. They must first get familiar with the use of multiple climate datasets for strategic planning. Having multiple datasets is a contrast to the approach currently used for making decisions involving climate, where only a single dataset based on observations is used. Even though the single dataset approach has been successful in the past, it will not be suitable for planning in the context of climate change, because the future climate may not have the same pattern as it has had so far, due to the influence of global warming. Climate scenarios, which are simulated based on future changes in earth system, should be used as foundation for such planning exercise. When using multiple scenarios, the goal is not to seek the "best" scenario. Instead, they are all possible and wide range of scenarios should be used in planning exercise in order to formulate strategy that is resilient enough to be able to cope with the outcome of all the scenarios

Another concern in using long-term climate projection for strategic planning to cope with climate change impacts is that there are many aspects in the change of climate variable, all of which need to be considered. The change in mean value is commonly used to explain climate change of any region, but that only gives a broad idea on how future climate change might be. In planning process, policy planners need to include changes in other aspects into consideration, especially change in the extreme value of any climate variable and also the temporal aspect of change, e.g. change in the length of season and shifting of season, etc.

Chapter 4: Sea Level Rise scenario

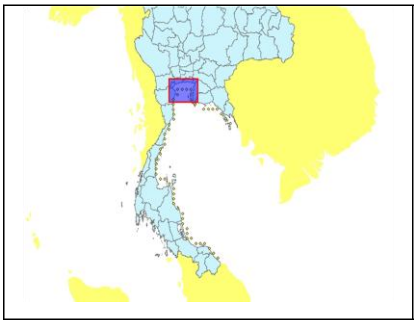
Global warming and climate change will have effect on sea level change by causing sea level rise (IPCC, 2007). The primary factors driving current sea level rise include:

- the expansion of ocean water caused by warmer ocean temperatures
- melting of mountain glaciers and small ice caps and melting of the Greenland Ice Sheet and the Antarctic Ice Sheet
- Change in wind speed and wind direction, especially the monsoon system in Asia

Thailand has long coastline which would be under influence of climate change and sea level rise may have consequences on shoreline stability, which may affect coastal community or coastal ecosystem.

The development of sea level rise scenario for the Gulf of Thailand was estimated by combining the effects of sea level rise and changing sea surface fluctuations. Global mean sea level rise was assessed with the Dynamic Interactive Vulnerability Assessment (DIVA) tool (Hinkel and Klein, 2006), and sea surface fluctuations caused by changing wind conditions were simulated with the Princeton Ocean Model (POM), which is a community general circulation numerical (computer) ocean model that can be used to simulate and predict oceanic currents, temperatures, salinities and other water properties (Mellor, 2004). The POM used as input the wind speed and wind direction simulated by the PRECIS regional model based on ECHAM4 A2 global circulation model as initial data for the simulation, and it was run at a resolution of 0.2° x 0.2°. POM output was combined with change in sea level from other global warming effects, primarily the expansion of ocean water, from DIVA output.

Sea level rise scenario is summarized for 3 zones in the Gulf of Thailand, where each zone may get influence from Asian monsoon differently, as shown in the illustration below:

		
Inner Gulf of Thailand	Southern east coast	Eastern coast

The median values from result of DIVA and POM were summarized to show change in sea level of each zone and variations over 2 periods of time, during 2010-2029 and 2030-2049, which are summarized in the tables below:

Change in sea level in the Inner Gulf of Thailand (compare to average sea level of 1985-2000):

Unit: cm

Month	2010-2029			2030-2049		
	Upper range	Lower range	**Average**	Upper range	Lower range	**Average**
Jan	14.88	2.36	**9.92**	26.56	14.44	**19.88**
Feb	19.80	-0.89	**9.70**	31.33	10.36	**20.14**
Mar	17.61	2.20	**10.27**	31.48	5.92	**21.60**
Apr	16.50	6.86	**10.36**	32.03	3.81	**19.13**
May	17.63	5.39	**10.43**	25.90	1.94	**19.70**
Jun	19.29	3.62	**12.21**	34.60	11.16	**21.35**
Jul	19.46	-12.99	**7.20**	27.68	7.66	**18.88**
Aug	17.17	-10.02	**6.77**	29.15	14.77	**22.38**
Sep	12.89	2.04	**9.19**	27.32	12.09	**19.57**
Oct	15.21	2.86	**8.20**	28.31	10.52	**19.31**
Nov	18.21	4.80	**10.62**	27.19	13.00	**20.45**
Dec	14.95	-19.02	**8.11**	25.40	-7.41	**17.79**
Average	16.97	-1.07	**9.41**	28.91	8.19	**20.02**

Change in sea level in the Southern East Coast (compare to average sea level of 1985-2000):

Unit: cm

Month	2010-2029			2030-2049		
	Upper range	Lower range	**Average**	Upper range	Lower range	**Average**
Jan	11.19	0.17	**6.90**	21.48	7.03	**13.62**
Feb	16.72	-2.42	**6.27**	23.02	4.25	**13.46**
Mar	12.39	-0.67	**6.66**	22.56	0.31	**14.47**
Apr	11.51	3.26	**6.40**	23.02	-1.50	**12.01**
May	12.91	3.19	**6.84**	17.77	-3.39	**12.68**
Jun	14.85	-2.39	**9.03**	27.32	6.55	**15.08**
Jul	15.49	-15.65	**4.07**	21.73	1.92	**12.63**
Aug	12.66	-12.45	**3.30**	21.27	7.81	**15.74**
Sep	9.34	-0.86	**5.48**	19.20	5.74	**12.59**
Oct	9.63	0.21	**4.54**	20.09	5.30	**12.45**
Nov	12.32	1.73	**7.10**	19.34	6.80	**13.54**
Dec	10.43	-10.56	**5.22**	17.88	-13.23	**10.89**
Average	12.45	-3.04	**5.98**	21.22	2.30	**13.26**

Change in sea level in the Eastern Coast of Thailand (compare to average sea level of 1985-2000):

						Unit: cm
Month	2010-2029			2030-2049		
	Upper range	Lower range	**Average**	Upper range	Lower range	**Average**
Jan	8.77	-0.75	**5.23**	15.30	5.86	**10.46**
Feb	12.68	-2.59	**5.18**	19.34	2.49	**10.73**
Mar	10.54	-0.73	**5.70**	19.47	-0.48	**12.09**
Apr	10.08	2.73	**5.70**	19.67	-3.13	**9.92**
May	11.43	2.91	**6.00**	15.34	-4.71	**10.61**
Jun	13.39	-0.38	**7.71**	23.05	3.37	**12.12**
Jul	12.86	-16.16	**3.25**	18.17	-0.23	**10.09**
Aug	10.91	-12.48	**2.62**	18.58	5.57	**13.18**
Sep	8.66	-1.09	**5.02**	16.72	4.91	**10.79**
Oct	9.29	-0.61	**4.08**	16.78	3.65	**10.41**
Nov	11.37	1.35	**6.09**	15.99	5.56	**11.37**
Dec	9.07	-21.28	**3.75**	14.52	-12.52	**8.86**
Average	10.76	-4.09	**5.03**	17.74	0.86	**10.89**

In summary, sea level rise along the coast of the Gulf of Thailand during the next 20 years (2010-2029) could be in the range of 5 to 10 cm, where the Inner Gulf of Thailand would be most severe, followed by the Southern East Coast and the Eastern Coast of Thailand. The trend of sea level rise will be more severe in the following 2 decades period (2030-2049), which change in sea level could be higher than current condition by 10-20 cm and the level of severity of area will still be the same. It should also be noted that the change in sea level will vary from month to month due the effect of monsoon season.

Chapter 5: Review key studies on climate change assessment in Thailand

This chapter reviews key studies in the field of climate change which have been conducted in Thailand. It includes impact, risk, vulnerability and adaptation studies. The chapter aims to provide background in the state of knowledge on climate change and highlight the gaps, so that it could be used as guideline for planning future studies on climate change in Thailand. This review primarily focuses on those climate change studies which are based on scenarios from future climate projections.

Section 5.1 Future Climate projection

One of the earliest high-resolution long-term climate projections that became available for Thailand and Southeast Asia was simulated using Conformal Cubic Atmospheric Model (CCAM) (Southeast Asia START Regional Center, 2006). CCAM is a second-generation regional climate model developed specifically for the Australasian region by the CSIRO Division of Atmospheric Research, Australia. The projection had a resolution of 0.1 degrees (approximately 10 km). The CCAM model uses the principle of stretched coordinates of a global model instead of uniform latitude-longitude gridding system and runs for 18 vertical levels including the stratosphere. Several published studies comparing multiple models regarded CCAM as one of the best climate models for the Asian region (McGregor et al, 1998).

The input conditions for the creation of this climate projection were: a baseline atmospheric CO_2 concentration of 360ppm, with two possibilities, an increase to 540ppm and a more dramatic increase to 720ppm. With the CO_2 concentration rising to 540ppm, the result was that the Southeast Asia region would get slightly cooler, whereas with a CO_2 rising to 720ppm it would be warmer.

The future temperature under these climate scenarios would be within a range of 1-2ºC from the present. However, the change in number of annual hot and cool days will be more dramatic. Hot days (which are defined as those with maximum temperature over 33ºC) will increase by 2-3 weeks over the year, whereas cool days (defined as the days with minimum temperature under 15ºC) will decrease by 2-3 weeks throughout the region. In other words, summertime in the region will be longer in the future and the wintertime will become shorter. The simulation result also shows a trend of increasing precipitation by 10-30% throughout the region under future climate condition at CO_2 concentration of 540ppm and 720ppm (Southeast Asia START Regional Center, 2006).

The same trend of change can also be observed in another high-resolution regional climate scenario for Thailand and Southeast Asia region. This one is the output of a simulation forThailand and surrounding countries at high resolution, a grid size 20x20 km. It covers a baseline period from the year 1960 – 1999, and the future period covers the year 2010 – 2099. This simulation used the PRECIS (Providing REgional Climates for Impacts Studies) regional climate model and used the Global Circulation Model (GCM) ECHAM4 dataset as initial data for calculation. It considered emission scenarios A2 and B2 from the Intergovernmental Panel on Climate Change (IPCC). The result from PRECIS model was post-processed by rescaling technique in order to make the final result more comparable with the observed weather data. The final projection shows trend of increasing temperature throughout Thailand, especially in the central plain of Chao Phraya river basin and the lower part of north-eastern region. It also predicts more hot days in the future. Total annual precipitation may fluctuate in the early part of the century but the projection shows a trend for increasing precipitation from the middle of the century onwards, especially in the area near Mekong River as well as the southern region. On the western border precipitation may remain almost unchanged. Change in wind speed and wind direction in the coastal zone will also be affected, with south-west wind speed increasing by 3-5%. (Chinvanno, et al. 2009)

The projections derived using climate models are to some extent biased by the calculation of the model itself, and so sometimes inconsistencies are seen with the data observed for the same period. The ECHAM4 GCM, which was downscaled by PRECIS regional climate model, tends to overestimate temperature and underestimate precipitation in many areas. A "rescaling" technique was developed in this study and applied to the simulation result from PRECIS model in order to adjust the simulated data to match the observed data better. This rescaling technique calculates an adjustment-coefficient for temperature and precipitation, based on the difference between the simulated and observed data. The observed data is taken from 130 weather observation stations in Thailand, China, India, Myanmar, Lao PDR, Vietnam, Malaysia and Indonesia during the 1980s. Using the adjustment-coefficient, the simulated data is then 'suppressed' or 'lifted' throughout the simulation domain for the period of the simulation (Chinvanno, et al. 2009).

The inconsistency of results between modeled and observed data can also be due to the lack of precision of land form used in the climate model, especially the topography of the area. This bias can be corrected with the help of a topography analysis. A study in Ping River basin, focused on correcting the bias of a precipitation model (an ECHAM4 GCM under A2 and B2 scenarios) and it successfully improved the dataset for further hydrological analysis of the river basin (Sharma, et al. 2007).

When using global circulation model (GCM) datasets for climate change impact assessment, one should be aware of the impact of local phenomena on global climate systems. For example, the change in micro climate of a zone due to change in land cover. An experiment conducted in Chiengmai province shows that deforestation can lead to a decrease in precipitation, especially when the forest is changed into grassland (Giambelluca, et al. 1999). Another example of local climate effects on the climate system is the monsoon season. The monsoon season is critical for Thailand because most of the agriculture is rain-fed and relies on monsoonal rainfall. The monsoon rain is in itself influenced by the sea surface temperature and this varies from year to year (Kanae, et al. 2002). These local effects are important and should be taken into consideration when applying a bias correction on the climate model.

Section 5.2 Climate change impact, risk, vulnerability and adaptation:

The selected publications on climate change impact, risk, vulnerability and adaptation assessment can be grouped as follows;

	Impact	**Risk & Vulnerability**	**Adaptation**
Ecosystems & biophysical systems	• Trisurat, Y., Alkemade, R. and Alets, E. 2009. Projecting forest tree distributions and adaptation to climate change in northern Thailand. Journal of Ecology and Natural Environment, 1(3): 55-63.		
Agriculture system	• Agarwal, A. 2008. Forecasting rice yield under climate scenarios and evaluation of agro-adaptation measures for Mekong basin region: a simulation study. Thesis of master degree of engineering in water engineering and management. Asian Institute of Technology. • Buddhaboon, C., Kongton, S. and Jintrawet, A. 2005. Climate scenario verification and impact on rain-fed rice production. The study of future climate changes impact on water resource and rain-fed agriculture production. In Chinvanno, S. and A. Snidvongs, (eds.) The Study of Future Climate Changes Impact on Water Resource and Rain-fed Agriculture Production. Proceedings of the APN	• Chinvanno, S., Boulidam, S., Inthavong, T., Souvanalath, S. Lersupavithnapa, B., Kerdsuk, V. and Thuan, N.T.H. Climate risk and rice farming in the lower Mekong River basin, 2008a. In N. Leary, C. Conde, J. Kulkarni, A. Nyong ad J. Pulhin (eds) Climate Change and Vulnerability, Earthscan, London • Kerdsuk V. and Kersuk V., 2006. Assessment on vulnerability and adaptation to climate change impact: Case study on rain-fed farmer in Kula Field, Thailand. Southeast Asia START Regional Center, Bangkok, Thailand. (Thai) • Pannangpetch, K., Sorawat, V., Boonpradub, S., Ratanasriwong, S., Kongton, S., Nilaphan, S.,	• Agarwal, A. 2008. Forecasting rice yield under climate scenarios and evaluation of agro-adaptation measures for Mekong basin region: a simulation study. Thesis of master degree of engineering in water engineering and management. Asian Institute of Technology. • Chinvanno, S., Souvanalath, S., Lersupavithnapa, B., Kerdsuk, V. and Thuan, N.T.H., 2008b. Strategies for managing climate risks in the lower Mekong River basin: A place-based approach. In N. Leary, J. Adejuwon, V. Barros, I. Burton, J. Kulkarni and R. Lasco (eds) Climate Change and Adaptation, Earthscan, London. • Matthews, R.B., Kropff, M.J.,

	Impact	Risk & Vulnerability	Adaptation
	CAPaBLE CB-01 Synthesis Workshop, Vientiane, Lao PDR, 29 - 30 July 2004. SEA START RC Technical Report No. 13. • Chinvanno, S. 2004. “Climate Change and Future of Agricultural Base”. In Food and water: Key factors to sustainable happiness of Thai people. (Thai language). Bangkok: National Health Foundation, pp.307-322. • Chinvanno, S., Boulidam, S., Inthavong, T., Souvanalath, S. Lersupavithnapa, B., Kerdsuk, V. and Thuan, N.T.H. Climate risk and rice farming in the lower Mekong River basin, 2008a. In N. Leary, C. Conde, J. Kulkarni, A. Nyong ad J. Pulhin (eds) Climate Change and Vulnerability, Earthscan, London • Chinvanno, S., Souvanalath, S., Lersupavithnapa, B., Kerdsuk, V. and Thuan, N.T.H., 2008b. Strategies for managing climate risks in the lower Mekong River basin: A place-based approach. In N. Leary, J. Adejuwon, V. Barros, I. Burton, J. Kulkarni and R. Lasco (eds) Climate Change and Adaptation, Earthscan, London. • Jintrawet, A. and Prammanee, P. 2005. Simulating the impact of climate change scenarios on	Putthisimma, I., Gapetch, P., Ekoun, C., Damrikemtrakul, W., Buddhaboon, C., Khunket, K. 2009. Impacts of global warming on rice, sugarcane, cassava, and maize production in Thailand. Final technical report to Thailand Research Fund, Bangkok	Horie, T. and Bachelet, D. 1997. Simulating the impact of climate change on rice production in Asia and evaluation option for adaptation. Agricultural Systems, 54(3):399-425. • Pannangpetch, K., Sorawat, V., Boonpradub, S., Ratanasriwong, S., Kongton, S., Nilaphan, S., Putthisimma, I., Gapetch, P., Ekoun, C., Damrikemtrakul, W., Buddhaboon, C., Khunket, K. 2009. Impacts of global warming on rice, sugarcane, cassava, and maize production in Thailand. Final technical report to Thailand Research Fund, Bangkok. • Southeast Asia START Regional Center. 2006. Final technical report AIACC AS07: Southeast Asia Regional vulnerability to changing water resource and extreme hydrological events due to climate change. Southeast Asia START Regional Center Technical Report No.15, Bangkok, Thailand.

	Impact	**Risk & Vulnerability**	**Adaptation**
	sugarcane production systems in Thailand. ISSCT 25th, 31 January 2005 - 4 February 2005, Columbia, Guatema: 120-124. • Kerdsuk, V., Kongton, S., Jintrawet, A., 2004. Impact of Climate Change on Rice Production in Kula Field. Journal of Remote Sensing and GIS Association of Thailand. Vol. 5, No. 2, May – August 2004. (Thai) • Kongton, s., Sorawat, V., Ratanasriwong, S. 2004. Impact of Climate Change on Maize, Sugarcane and Cassava Production in N.E. Thailand: Case study at Khon Kaen province. In Chinvanno, S. and A. Snidvongs, (eds.) The Study of Future Climate Changes Impact on Water Resource and Rain-fed Agriculture Production. Proceedings of the APN CAPaBLE CB-01 Synthesis Workshop, Vientiane, Lao PDR, 29 - 30 July 2004. SEA START RC Technical Report No. 13. (Thai) • Matthews, R.B., Kropff, M.J., Horie, T. and Bachelet, D. 1997. Simulating the impact of climate change on rice production in Asia and evaluation option for adaptation. Agricultural Systems, 54(3):399-425.		

	Impact	**Risk & Vulnerability**	**Adaptation**
	• Pannangpetch, K., Sorawat, V., Boonpradub, S., Ratanasriwong, S., Kongton, S., Nilaphan, S., Putthisimma, I., Gapetch, P., Ekoun, C., Damrikemtrakul, W., Buddhaboon, C., Khunket, K. 2009. Impacts of global warming on rice, sugarcane, cassava, and maize production in Thailand. Final technical report to Thailand Research Fund, Bangkok • Southeast Asia START Regional Center. 2006. Final technical report AIACC AS07: Southeast Asia Regional vulnerability to changing water resource and extreme hydrological events due to climate change. Southeast Asia START Regional Center Technical Report No.15, Bangkok, Thailand.		
Water resource	• Chaowiwat, W. and Likitdecharote, K. 2009. Effect of climate change on potential evapotranspiration case study: lower Chaopraya basin. In proceeding of the 1 NPRU Academic Conference: 75-83. • Eastham, J., F. Mpelaskoka, M. Mainuddin, Ticehurst C, P. Dyce, G. Hodgson, R. Ali, and M. Kirby. 2008. Mekong River Basin Water Resources Assessment: Impacts of Climate Change. CSIRO: Water for a Healthy Country		• Koch, M. 2008. Challenges for future sustainable water resources management in the face of climate change.

	Impact	Risk & Vulnerability	Adaptation
	National Research Flagship. • Noimunwai, W. 2008. Estimation of potential evapotranspiration under climate change using data mining: a case study of Thailand. Thesis of master degree of Science (Appropriate Technology for resources and environmental development), Faculty of Environment and resource studies, Mahidol University. • Rojrungtavee, C. 2009. Assessment of water supply and demand under future climate change conditions in the Maeklong river basin, Thailand. Thesis of master degree of engineering in water engineering and management, Asian Institute of Technology. • Southeast Asia START Regional Center. 2006. Final technical report AIACC AS07: Southeast Asia Regional vulnerability to changing water resource and extreme hydrological events due to climate change. Southeast Asia START Regional Center Technical Report No.15, Bangkok, Thailand. • Vongsa, S., Ekkawatpanitch and Triritwittaya, K., 2009. Effect of Global Warming on Hydrolic and Salinity Behaviors in Thachin		

	Impact	Risk & Vulnerability	Adaptation
	River. Proceeding the 4th THAICID National SYMPOSIUM, 19 June 2009, Miracle Grand Hotel, Bangkok. (Thai)		
Health	• Jonathan, A.P., Willem, J.M., Martens, D.A. Focks and Theo, H. J. 1998. Dengue fever epidemic potential as projected by general circulation model of global climate change. Environmental Health Perspectives, 106 (3): 147-153.		
Coastal zone – Sea level rise	• Southeast Asia START Regional Center and WWF. 2008. Climate change impacts in Krabi province, Thailand. • Vongvisessomjai, S. 2006. Will sea-level really fall in the Gulf of Thailand? Songklanakain J. Sci. Technol., 28(2): 227-248.	• Southeast Asia START Regional Center and WWF. 2008. Climate change impacts in Krabi province, Thailand.	• Southeast Asia START Regional Center and WWF. 2008. Climate change impacts in Krabi province, Thailand.
Urban area	• Parkpoom, S. and Harrison, G.P. 2008. Analyzing the impact of climate change on future electricity demand in Thailand. IEEE Transactions on Power Systems, 23(3): 1441-1448.		
Tourism	• Chula Unisearch. 2009. The Assessment of Impact of Climate Change on Thailand Tourism Clusters. Final report to Ministry of Tourism & Sports (Thai)	• Chula Unisearch. 2009. The Assessment of Impact of Climate Change on Thailand Tourism Clusters. Final report to Ministry of Tourism & Sports (Thai)	• Chula Unisearch. 2009. The Assessment of Impact of Climate Change on Thailand Tourism Clusters. Final report to Ministry of Tourism & Sports (Thai)

Impact of climate change and Ecosystems & biophysical systems

A change in temperature and rainfall distribution will impact on ecosystems. Some species will favor from climate change while some may lose their ecological niche. An assessment in the northern region of Thailand, looked at the impact of climate change on selected 22 plant species, based on future climate projection from HadCM3 GCM A2 scenario. The study reported that the total number of plant species did not change significantly between current and predicted climate change condition in 2050, however, spatial configuration and turnover rate were high, especially for evergreen species. Out of the 22 species in the study, 10 species would no longer have suitable condition while another 12 species would gain a habitat. The deciduous species would expand their distribution range. The major change would be expected to occur in the west and the north of the Northern region (Trisurat et al. 2009).

Rising temperatures will most likely force upland ecosystems (in particular Krabi's hill evergreen forests, protected in Khao Phnom Benja N.P.) to retreat to higher elevations where possible. Research is needed to develop a strategy that protects the high conservation value of these ecosystems (Southeast Asia START Regional Center and WWF, 2008).

The mangrove forests that fringe much of Krabi's coastline play an important role in buffering coastal settlements and croplands from storm surges. They are also spawning grounds for fish and shellfish; a source of food and firewood for subsistence communities; and by filtering out nutrients flowing from upstream, a contributor to improved water quality. The mangroves will need to retreat inland as water levels rise. Preliminary calculations suggest that Krabi's mangrove forests may by thinned by an average of 18 meters on the seaward side under influence of climate change in the next 25 years. Thus it is critically important that roads and other structures on the landward side not be sited close to the current mangrove forest boundaries, to allow room for their inland migration (Southeast Asia START Regional Center and WWF, 2008).

Impact of climate change and agriculture

Climate is an important factor affecting on agricultural sector, especially the agriculture in Thailand which majority is rain-fed system. Changing in climate pattern, the increasing in temperature as well as changing in rainfall distribution pattern, will directly affect the productivity of various crops. There have been number of study on climate change and agriculture in Thailand and results from various analyses, which mostly focus on annual field crops, vary from techniques and climate data used in the analysis. Crop model is the primary tool which was used to simulate the growth and yield of plant under given necessary inputs, soil properties, weather data, genetic coefficient of target plant, and management of plant cultivation.

One of the early works on simulating the impact of climate change on rice production used 2 rice crop simulation models, ORYZA1 and SIMRIW, running under 'fixed-change' climate scenarios predicted by 3 GCMs, namely, GFDL, GISS and UKMO for double CO_2 scenario. In general, an increase in CO_2 was found to increase yields while increases in temperature reduced yield. Temperature increases in these scenarios is estimated in the range of 4-5ºC and precipitation increase in the range of 8-15%. Overall, the estimation of future rice yield in Thailand by ORYZA1 range from +9.3% to -0.9% under climate change conditions from the 3 GCMs and future yield would range from +6.4% to -11.6% as predicted by SIMRIW (Matthews et al.,1997).

The fixed change climate scenario may not well represent the future climate change in the analysis of climate change impact because the change in climate pattern is not uniform across the year. A better alternative is the high resolution climate scenario which provides future climate data on daily time step, and which could be used to simulate future crop yield capturing the fluctuations in weather condition over the season.

An analysis about the impact of climate change on rice production in 3 latitudes in Thailand was performed (Buddhaboon et al., 2004). It looked at 3 locations: Chiang Rai, Sakonnakorn and Sakaeo province. The analysis used Decision Support System for Agro Technology Transfers (DSSAT version 4.0) crop modeling software (Hoogenboom et al, 1998) with daily climate data from climate scenario. The climate scenario data was generated by CCAM climate model and it included maximum and minimum temperature, precipitation and solar radiation. This data was then coupled with a crop management scheme and soil properties to calculate the yield of rice productivity. The results showed that rice yields did not change significantly under three climate scenarios: a baseline condition and atmospheric CO_2 increase of 540 ppm and 720 ppm. Although the average rice yields under climate scenario of atmospheric CO_2 increase to 720 ppm was slightly increased compared to other two scenarios, it also had higher standard deviation. Over the three locations, the simulated yields were 2522kg ha-1 (+216) for the baseline scenario, 2552kg ha-1 (+270) for the 540ppm scenario, and 2836kg ha-1 (+540) for the 720ppm scenario. In addition rice yields were not significantly affected under dry, medium and wet year scenarios for any of the 540ppm and the 720ppm atmospheric CO_2 scenarions (Buddhaboon et al., 2004).

Another simulation of rice productivity at the study site in Ubonratchathani province, Thailand, based on DSSAT crop model and weather data from CCAM climate model, shows that climate change has positive impact on the rice production in the area. The simulation result shows a trend of increasing yield of rice productivity under future climate condition, which could be in the range of +1.48% up to +15.29%. The increase in productivity yield could be as high as 10-15% in some areas (Southeast Asia START Regional Center, 2006 and Chinvanno et al., 2008a). The analysis on KDML105 rice variety in Kula Field also shows the same trend. (Kerdsuk et al., 2004)

Other major field crops in Thailand are maize, sugarcane and cassava. Climate change will have different impacts on these crops. It was found that climate change increased maize and sugarcane yield in Khon Kaen but decreased cassava yields. Applying fertilizer could reduce the fluctuation of impact and even reduce 2 – 4 anthesis days and 3 – 10 maturity days. Sugarcane develops faster with higher CO_2 concentration, however cane biomass at 14th leaf stage shows a slightly increase. For wet years, biomass at 14th leaf stage decreases with higher CO_2 concentration. Like biomass, sucrose and stalk yield at 14th leaf stage in dry years noticeable increases. The storage root yield of cassava decreased in the dry and median year but remarkable increased for the wet year when CO2 concentrations increase to 540ppm and 720ppm compared to baseline condition. Also, cassava's first branching is earlier when atmospheric CO_2 increase to 540 ppm and 720 ppm compare to baseline condition. The harvest index decreased with higher CO_2 concentrations while LAI increased, except for dry years (Kongton et al., 2004). Positive impact of climate change on sugarcane production in Khon Kaen and Chiengmai province was also observed on another assessment, which also uses the same tool and dataset (Jintrawet and Prammanee, 2005).

Using different climate scenario datasets and different tools may result in different outcomes. An analysis on impact of future climate change on rice yield at Ubon Ratchathani, Khon Kaen and Roi-et province shows contrasting results to those above (Ansul, 2009). This study used CRES, a rice crop growth model and based on future climate data from ECHAM4 GCM A2 scenario, which was downscaled by PRECIS regional climate model, for the periods of 2020s, 2050s and 2080s. The results show that rice yield is expected to decline up to 24% when compared to the yield during the baseline period of 1997-2006. The yield is predicted to decline by 15% for the rice cultivar KDML105 and 5.5% for the RD6 rice cultivar with each degree rise in temperature from the ambient level. On the contrary, an increase in yield is expected by 8.7% for KDML105 and 17.45% for RD6 with every 100ppm rise in CO2 from the ambient level. (Ansul, 2009)

The most extensive assessment on future climate change on annual field crop so far is the work of a research project called: Impacts of Global Warming on Rice, Sugarcane, Cassava, and Maize Production in Thailand, funded by Thailand Research Fund during 2008-2009 (Pannangpetch et al., 2009). The study assessed the countrywide impact of climate change on rice, maize, sugarcane and cassava, using DSSAT4 crop model and future climate data from ECHAM4 GCM A2 and B2 scenario throughout the 21st century, downscaled by PRECIS regional climate model. It found that in general there will be no severe long term impact of climate change on annual field crop productivity in Thailand, except cassava. However, the variability of climate pattern in the future will cause the annual productivity to fluctuate a lot. Therefore, even though the total production of the country may not be severely changed, some areas will be critically affected from climate change. The critical production area of rain-fed / wet season rice as well as sugarcane and cassava under impact of climate change are in the northern region, however, the affected area of the dry season rice will widely spread out over the country, which is also the same for the maize. The assessment also found out that the main causes affecting rice productivity are declining of soil fertility and rainfall distribution. For cassava, the soil properties and amount of rainfall would be the main causes behind the declined productivity in the upper part of the northern region of Thailand, but temperature would be main problem for the lower northern region of Thailand. The declined maize productivity would be caused by the lack of water during flowering stage, especially during silking and tasselling period. (Pannangpetch et al., 2009)

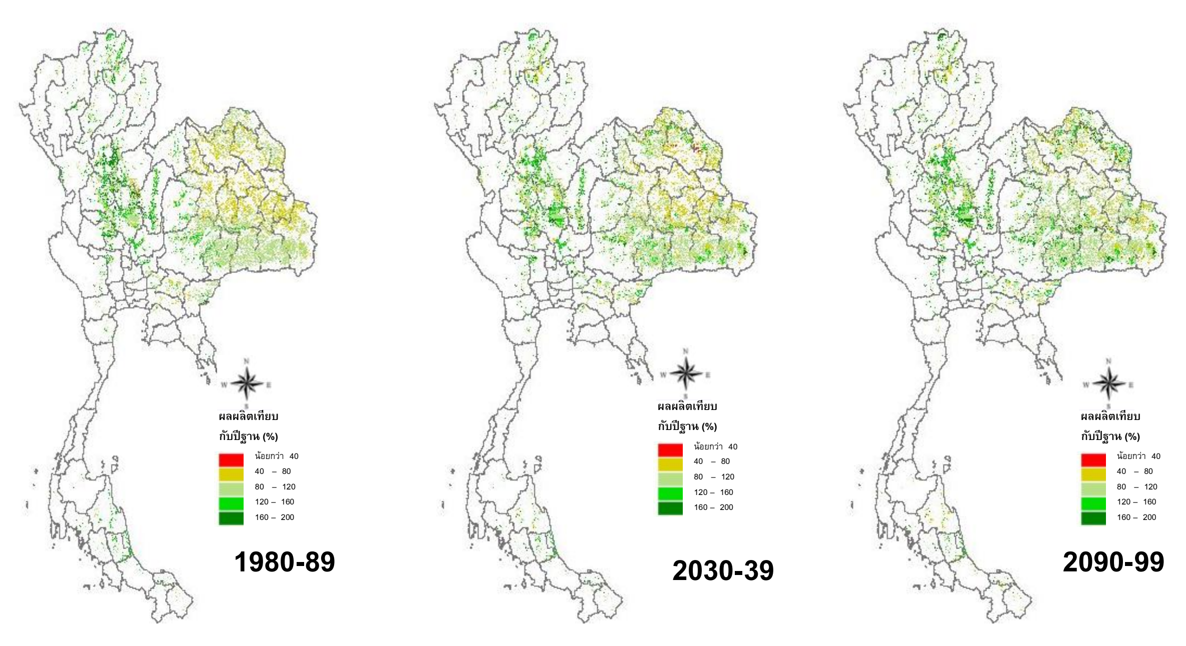


Figure 25: Change in rain-fed / wet season rice yield under different climate conditions in the future (Pannangpetch, et al. 2009)

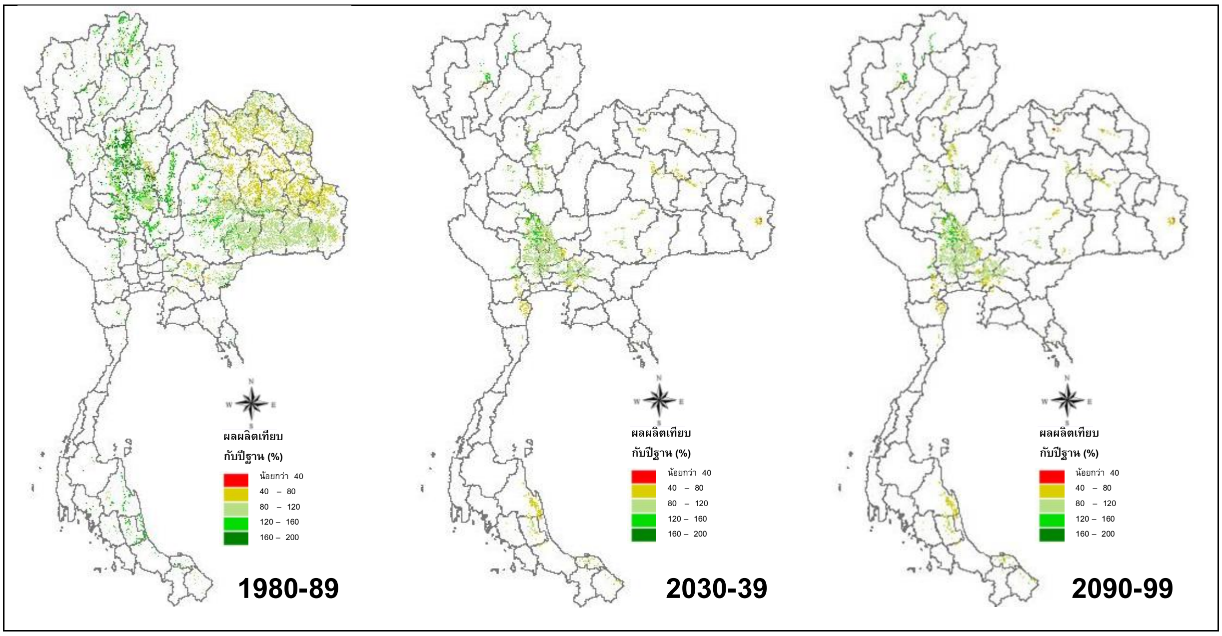


Figure 26: Change in irrigated / dry season rice yield under different climate conditions in the future (Pannangpetch, et al. 2009)

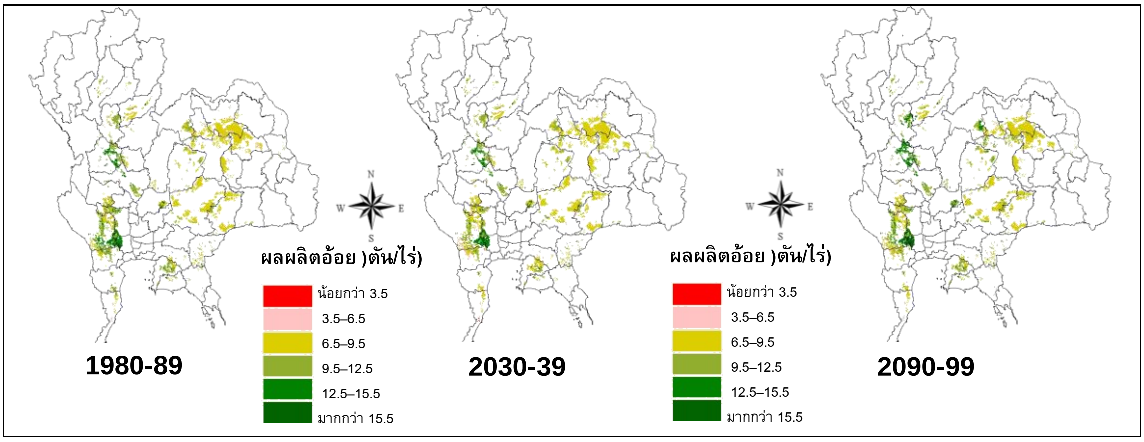


Figure 27: Change in sugarcane productivity under different climate conditions in the future (Pannangpetch et al., 2009)

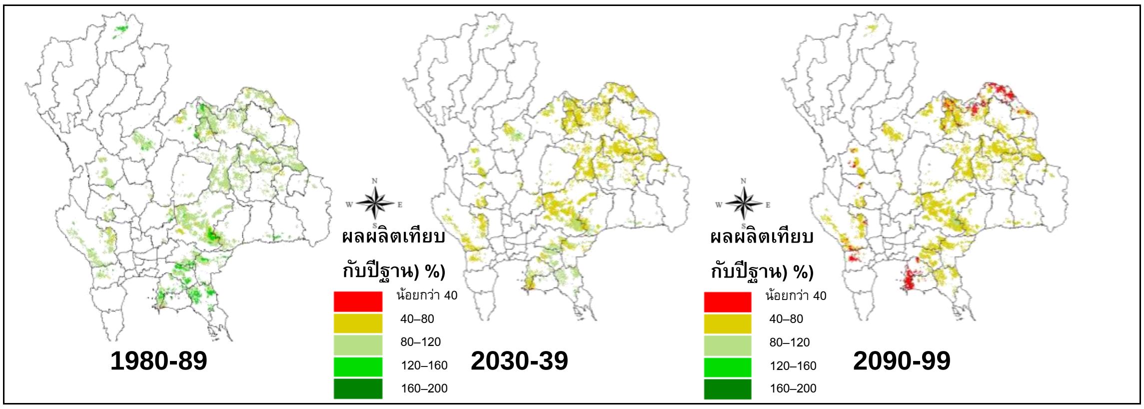


Figure 28: Change in cassava productivity under different climate conditions in the future (Pannangpetch et al., 2009)

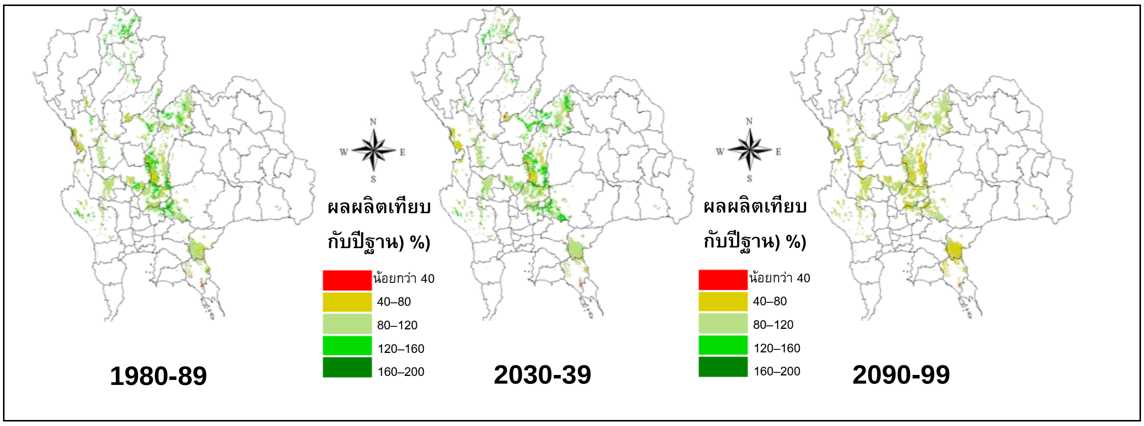


Figure 29: Change in maize productivity under different climate conditions in the future (Pannangpetch, et al., 2009)

Impact of climate change and water resources

Climate change will have direct impact on water supply, especially from the changes in precipitation distribution and amount of annual rainfall. Changes in temperature and wind speed as well as wind direction will also contribute to the change in water supply, which is determined by discharge of the river basin. The result from a simulation, using future climate data from CCAM climate model and VIC hydrological model, shows that most of the major sub-watershed of Mekong River in Lao PDR and Thailand will tend to have more water in the future due to higher precipitation. For the wet year scenario, almost every watershed will have higher discharge under CO_2 concentration of 540 ppm and increase further under CO_2 concentration of 720 ppm. However, in the dry year scenario, many sub-basins will have slightly less water under CO_2 concentration of 540 ppm, but the discharge will increase under CO_2 concentration of 720 ppm (Southeast Asia START Regional Center. 2006).

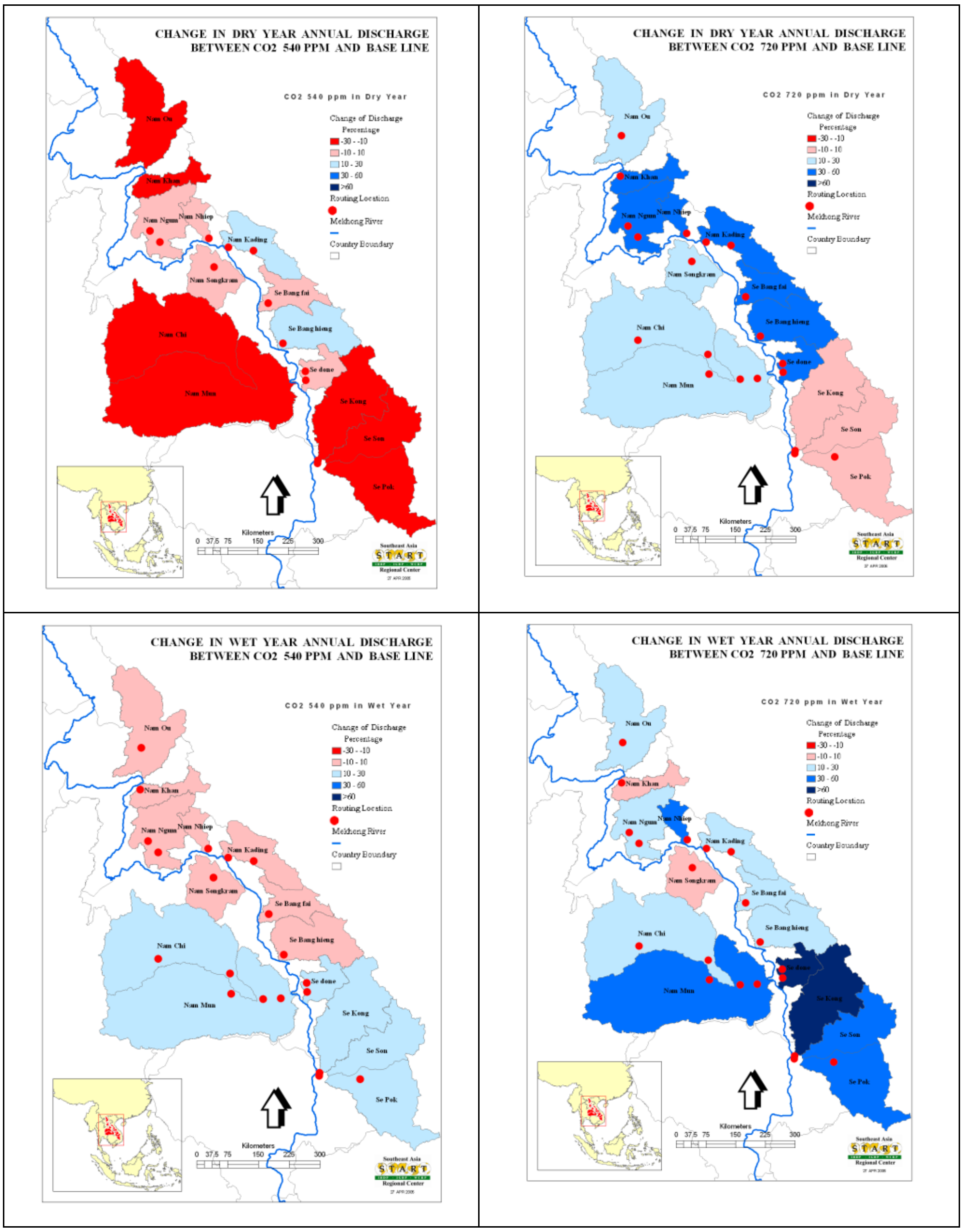


Figure 30: Change in discharge of Mekong River tributaries in Lao PDR and Thailand under different climate scenarios (Southeast Asia START Regional Center. 2006)

An assessment of the Mekong River basin to 2030 projected that dry season rainfall would increase in northern and decrease in eastern Thailand. Overall annual precipitation was expected to increase because of higher wet season rainfall. Run-off and floods were expected to increase. A strong feature of this study was the use of a subset of 11 global climate models that could capture current seasonal patterns adequately (Eastham et al., 2008).

For Krabi province, urbanization, deforestation and land use conversion for agriculture have already put some pressure on natural water sources and stores. Near-term consequence of global warming will include a decrease in rainfall and a longer dry season. The longer dry season will in turn increase tourism and hence the demand for water. If demand for palm oil remains high, either due to market forces or government policies, producers may resort to irrigation which will put further increase the water demand. Finally, rising sea levels will increase salt-water intrusion into shallow aquifers in coastal areas (Southeast Asia START Regional Center and WWF, 2008).

Increasing temperature and longer warm period will affect the potential evapotranspiration, thus result in water demand and water balance in the river basin. The climate scenarios from 2 GCMs, CCGCM2 and HadCM3 GCM under A2 and B2 scenarios for the period of 2020s, 2050s and 2080s, and downscaled to the lower Chao Phraya river basin using SDSM technique, show that the future maximum temperature and minimum temperature are expected to increase, while the relative humidity may decrease. The climate change under CCGCM2 GCM and HadCM3 would result in increasing annual potential evapotranspiration (PET) by 0.4% - 2.67% and 0.06% - 1.17% respectively when compare to the baseline period of 1974-1985 (Chaowiwat and Likitdecharote, 2009).

Changing in evapotranspiration will also affect the water demand. An analysis based on future climate scenarios under CO_2 concentrations of 540ppm and 740ppm as simulated by CSIRO (Southeast Asia START Regional Center, 2006), shows that the evapotranspiration tends to decrease slightly under climate condition when atmospheric CO_2 increases to 540ppm but will increase under climate condition when atmospheric CO_2 increases to 740ppm. However, the analysis result shows a seasonal fluctuation. Evapotranspiration will increase in the dry season and decrease during the wet season. The calculation of water efficiency shows that rice paddy mat require less water supply during the wet season under climate condition when atmospheric CO_2 increases to 540ppm but would require more water supply during the beginning of the crop season under climate condition when atmospheric CO_2 increases to 720ppm (Noimunwai, 2008).

Change in rainfall distribution may bring one more complication to water resource management in the future. A study on water balance in Mae Klong River basin, which is based on future climate projection from ECHAM4 GCM A2 scenario and downscaled using PRECIS software (Chinvanno et al., 2009) during the period of 2025, 2050 and 2095, shows that even though the water demand for irrigation may be reduced due to increasing rainfall, the operation of the dams at Srinakarind and Vajiralongkorn could become more complicated because more water may be required to control salinity intrusion at the mouth of the river, especially during the low flow period in the dry season (Rojrungtavee, 2009). Moreover, the salinity intrusion could also become more severe in the future due to changing of sea level. This was addressed in the Thachin river study. The results show that under all range of IPCC climate change scenarios, from A1FI to B1 scenarios, the salinity intrusion will become more severe (Vongsa et al., 2009).

Impact of climate change and health

Climate change would post threat to human health as increase in temperature and precipitation in many areas could induce the vector borne and water borne disease (Parry et al., 2007). By the middle of 21st century, in 2050s, average temperature from 3 GCMs namely ECHAM1, UKTR and GFDL89, may increase by 1.16ºC from the baseline period of 1931-1980. The increase in future temperature would also increase epidemic potential of dengue fever. Result from dengue Epidemic Potential model (EP model) indicates that annual epidemic potential for dengue fever would increase, with peak during April through May. With an estimated 3-month duration of the log growth phase, this suggests a peak in human case during July and August. (Jonathan et al., 1998)

Impact of climate change on coastal zone – sea level rise

Impact of climate change is expected to affect sea level, especially in the low latitudes such as Thailand, due to the melting of glacial ice sheet and also water expansion from the warming up ocean (Parry et al., 2007). However, the analysis of sea level in the Gulf of Thailand at Ko Lak in Prachuabkirikhan and Satahip, Chonburi using historical dato over 56 years during 1940 – 1996, shows no trend of sea level rise. On the contrary, the trend of sea level in the Gulf of Thailand over the past 56 years shows falling trend of 36cm per century which could be due to plate tectonic activity. The major concerns of the coastline in the Gulf of Thailand could be on the erosion due to decreasing silt supply from the major rivers (Vongvisessomjai, 2006).

However, the change in the future may not be of the same pattern as the past. Future climate pattern may change due to the progressive global warming effect. According to an assessment using Dynamic Interactive Vulnerability Assessment (DIVA), which is tool develop by DINAS-COAST Consortium (www.dinas-coast.net), the mean sea level rise for Krabi province for 2020 and 2035 could be 11cm and 21cm relative to 1995 baseline and higher when local wind effect is taken into consideration (Southeast Asia START Regional Center and WWF, 2008).

Changing in sea level will also bring other consequence impacts to the coastal ecosystems, especially destabilizing coastline and contamination of aquifer. (Southeast Asia START Regional Center and WWF, 2008).

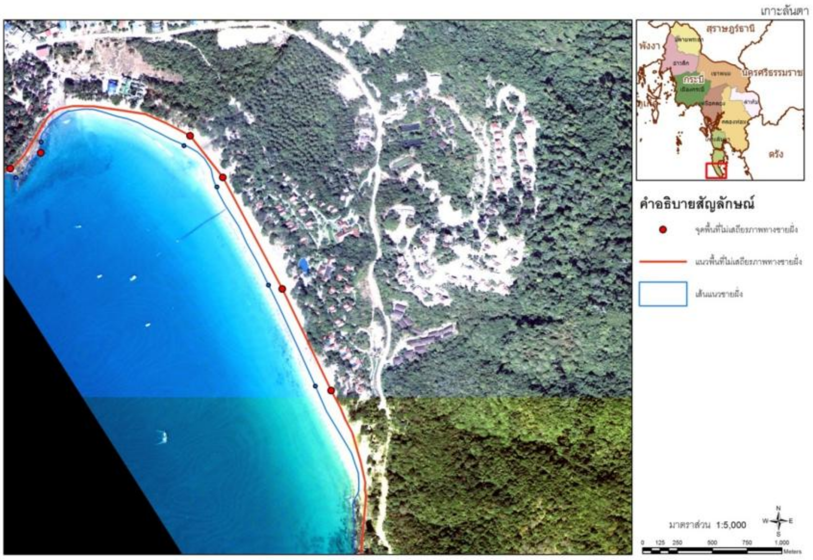


Figure 31: Example of impact of sea level change and coastline destabilizing in Krabi province (Southeast Asia START Regional Center and WWF, 2008)

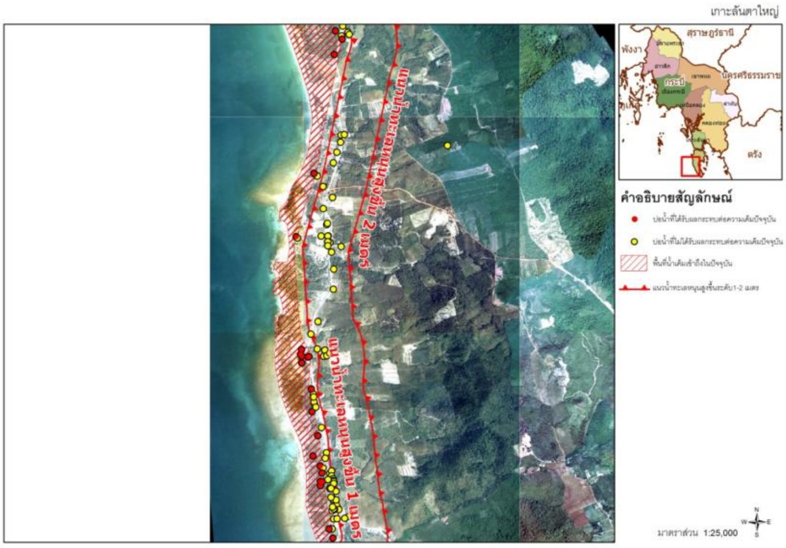


Figure 32: Example of impact of sea level change and shallow aquifer wells salinity contamination in Krabi province (Southeast Asia START Regional Center and WWF, 2008)

Impact of climate change to urban area

Electricity demand may also be driven by climate change, especially the increasing temperature. An assessment on how climate change may influence electricity demand in Thailand, which examines daily and seasonal demand profile, shows that the highest change in temperature based on HadCM3 GCMs will occur during summertime which coincides with the demand for electricity of the country. The temperature change, under A1/A2/B1 and B2 GHG scenarios, may induce the peak demand for electricity by 1.5%-3.1% in 2020s, 3.7%-8.3% in 2050s and 6.6%-15.3%. Therefore, the demand projection based on economic growth alone may be underestimated if not taking climate change into consideration. (Parkpoom, and Harrison, 2008)

Impact of climate change on tourism

Tourism is the key economic sector in Thailand and could have impact from climate change, especially from the change in various variable e.g. annual precipitations and its distribution pattern, temperature as well as other oceanographic factor. However, even though impact of climate change on the tourism sector in Thailand has not been well assess, but 14 tourism clusters as defined in tourism development policy of Ministry of Tourism and Sports will expose to risk from climate change and vulnerability of each cluster was assessed, which vary from cluster to cluster. (Chula Unisearch, 2009)

Risk, vulnerability and adaptation to climate change

- **Agriculture**

Risk in the agriculture sector can be determined by decline in yield. While most of the studies which conducted assessment on impact of climate change on agriculture at site scale or provincial scale can state risk at the study sites as mentioned in the previous section, a countrywide assessment can illustrate risk area from climate change impact of major annual field crops in Thailand, which vary from crop to crop. (Pannangpetch, et al., 2009)

The analysis on agriculture risk area to climate impact, which is categorized by area where yield is less than 70% of country average yield during baseline period, shows that the critical area of rain-fed / wet season rice is mostly in the northeastern region, e.g. Nongbualumpuu, Udonthani, Sakonnakorn, Nakornpanon, Kalasin, Roiet, Mukdaharn, Yasothorn, Amnajchareon, Surin, Srisaket. In the future, the risk area tends to expand and cover wider coverage, but with less density.

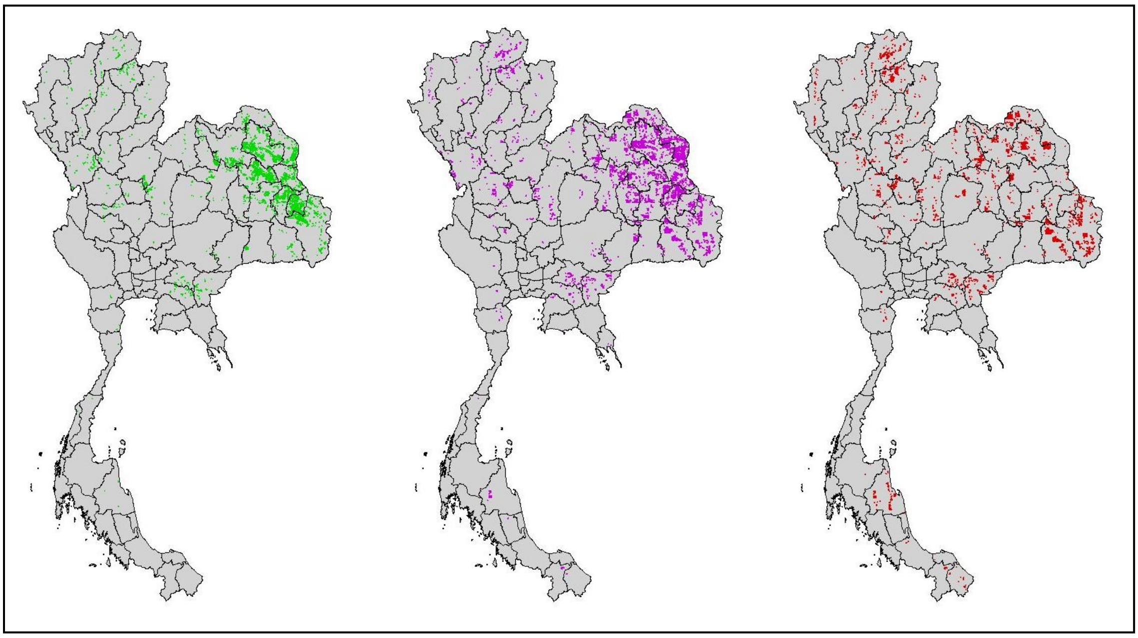


Figure 33: Risk area of rain-fed / wet season rice production to climate impact (left 1980s / middle 2030s / right 2090s) (Pannangpetch, et al., 2009)

For the irrigated / dry season rice, which average productivity tends to decrease throughout the country, the critical area to climate impact are wide spread in various provinces, e.g. Chiengmai, Pitsanulok, Nakornsawan, Chainat, Singburi, Suphanburi, Saraburi, Petchburi, Rachaburi, Nakornpatom, Ayudthaya, Nakornnaypk, Chachoengsao, Sakonnakorn, Khonkaen, Mahasarakham, Kalasin, Songkla, Pattani, Yala and Narathiwas. Future risk area tends to be the same as baseline period.

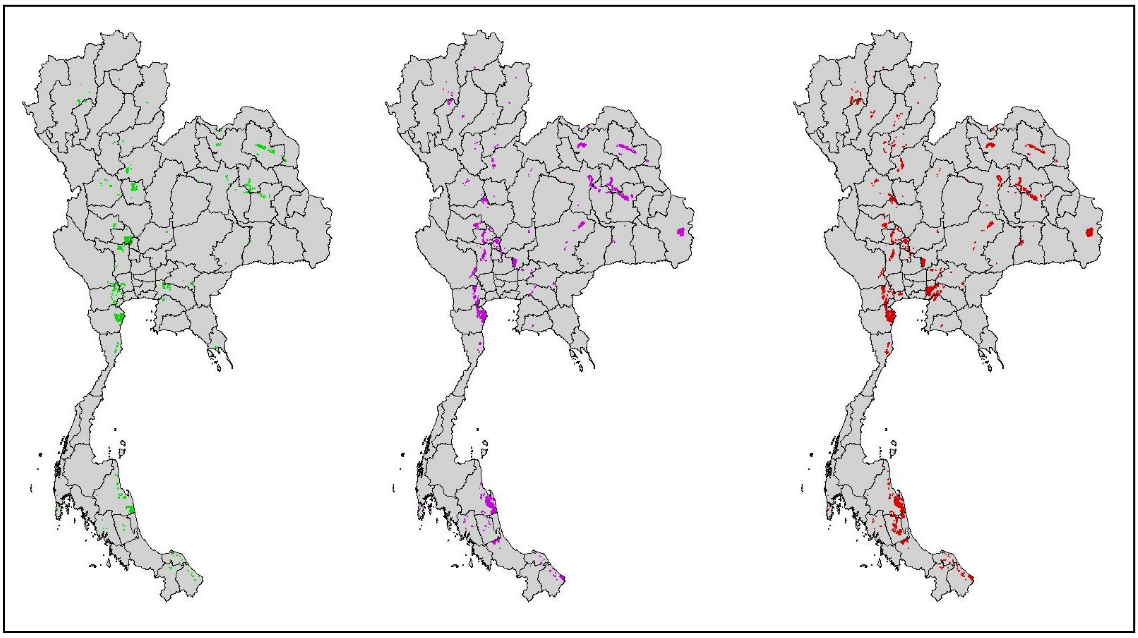


Figure 34: Risk area of irrigated / dry season rice production to climate impact (left 1980s / middle 2030s / right 2090s) (Pannangpetch, et al., 2009)

The critical area for sugarcane production to climate impact is in northeastern region of Thailand, especially Kalasin and Udonthani as well as part of Mahasarakham, Khonkaen and Nakornrachasima. In the future, climate change tends to favor sugarcane production and risk area tends to decline.

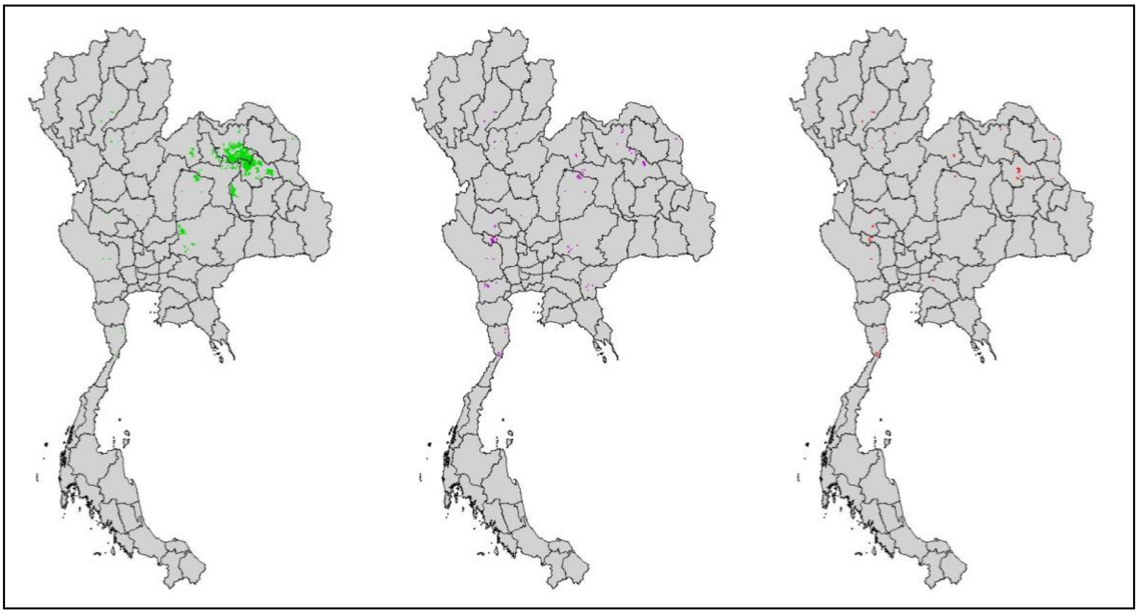


Figure 35: Risk area of sugarcane production to climate impact (left 1980s / middle 2030s / right 2090s) (Pannangpetch, et al., 2009)

For cassava production, the production area at risk to climate impact is minimal. However, in the future, climate change will induce risk area to expand significantly wider. Most of the risk areas ares in Nongkai, Udonthani, Nongbualumpuu, Khonkaen, Kalasin, Sakonnakorn, Nakornrachasima, Rachaburi, Kanjanaburi, Uthaithani and Rayong.

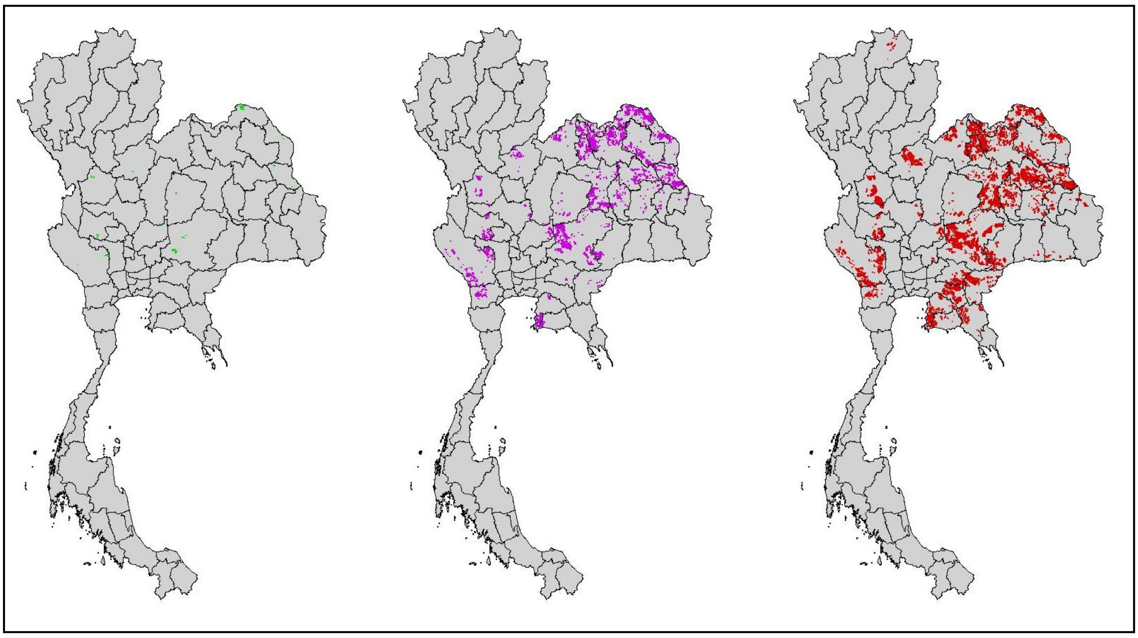


Figure 36: Risk area of cassava production to climate impact (left 1980s / middle 2030s / right 2090s) (Pannangpetch, et al., 2009)

For maize production, risk area to climate impact in the near term future will decline when compare to the baseline period, however, in the long term future, risk area will significantly expand. The critical area can be divided into 4 zones.

Zone 1: Loei, Petchaboon and Nakornrachasima

Zone 2: Nakornsawan, Uthaithani, Kanjanaburi, Kampangpetch, Tak and Lumpoon

Zone 3: Sa-kaew and Chantaburi

Zone 4: Chiengrai, Payao, Lampang and Prae

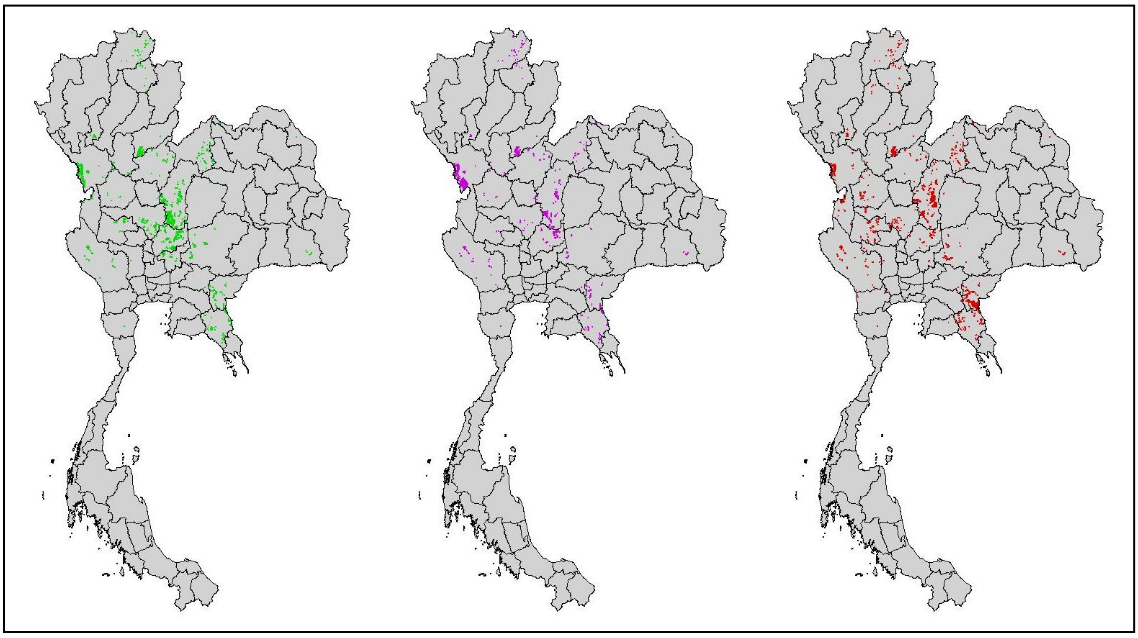


Figure 37: Risk area of maize production to climate impact
(left 1980s / middle 2030s / right 2090s) (Pannangpetch, et al., 2009)

In general, in order to cope with risk from climate change in agricultural system, various adaptation measures are suggested, which include changing cultivar, zoning policy, crop management especially adjusting soil fertility and crop calendar. (Pannangpetch, et al. 2009) In particular case of rice production, decrease in yield under future climate change condition can be mitigated significantly using proper management practices in terms of nutrient management and altering planting dates. It can prevent the crop from harmful effect of temperature during spikelet sterity. Hybrid rice cultivar having high temperature tolerance will also help to meet challenges imposed by changed climate scenarios. (Agarwal, 2008)

Adjustments to management practices may also help to offset any detrimental effects of climate change on rice production. Shorter maturity variety could also help in better risk management as it could also be used for second crop planting, if water availability is sufficient. (Matthews, et al.1997)

Risk and vulnerability in agriculture sector would need to be considered on the aspect of livelihood of people in the sector, farmer. Farmers in northeastern region of Thailand are already exposed to climate risk, which extreme weather events may cause substantial losses on farm output and threaten their livelihoods. Extreme events identified by farmers as threats to rice cultivation include prolonged mid-season dry-spells, floods and late ending rainy seasons. The dry-spell can damage young rice plants or impose additional costs on farmers for water procurement to sustain the rice plants while waiting for the rains to resume. If plants are lost and the resumption of rains does not come too late, the farmer can replant to salvage his harvest, but again at higher costs. In the worst case, the mid-season dry-spell is prolonged and rains resume too late for replanted rice to mature before the rainy season will end. When very prolonged dry-spells occur, farmers are at risk of losing a substantial portion of their crop and income. Flood, which usually occurs at the end of the crop season, is also another major threat to the farmer. (Chinvanno et al., 2008a)

The level of climate risk faced by farm households is a function of three broad determinants: the sensitivity of the household to stresses in climate variations and changes, the exposure of the household to climate stresses, and the capacity of the household to cope with climate impacts. An assessment based on data from 560 household interviews at Ubon Ratchathani shows that only about one-third of the surveyed population is classified as low risk while approximately 15-25 per cent of the households are in the high risk category. The moderate risk group is the largest group. The most important factor contributing to their risk level is a very limited coping capacity due to having little saving and high debt. In addition, the surveyed farmers in Thailand have little diversification in their production and income sources and are highly dependent on income from rice production. Their dependency on rice production creates conditions of high exposure and sensitivity to climate impacts. (Chinvanno et al., 2008a)

Scenarios of changes in rice yields in response to changes in average climate and extreme climate, which include scenarios of average climate conditions corresponding to the steady-state CCAM projections for CO_2 concentrations of 540 and 720ppm, was used as the single proxy of climate stress in the analysis of farmer household vulnerability to climate change. The analysis shows that there is no substantial change in the risk groups for the scenarios of changes in average climate and the moderate risk group is still the largest group. Because rice yields are projected to increase at the Thai sites for the CCAM projected changes in average climate. However, in the extreme climate scenarios, there are noticeable changes in the moderate and high risk group, with some households moving from the moderate to the high risk group. Approximately up to 50 per cent of households are vulnerable to climate impact under the climate extreme scenarios compared to the baseline case, consider from higher risk scores. (Chinvanno et al., 2008a)

Another assessment in Kula Ronghai Field in northeastern region of Thailand, which is one of the most important rice production areas in Thailand, was conducted under the same methodology. The field interview was conducted on 628 households during April-May 2005 and result from risk analysis shows that under normal climate stress, farmers could be categorized into low risk, moderate risk and high risk to climate impact at 8.8%, 61.6% and 29.6%, respectively. For the case of extreme weather event, the climate related disaster that affected the rain-fed farmers in this area during 1990s were mostly from drought and followed by flood which could cause damage to rice production at average of 45.5% of total household's productivity. When applied this factor as proxy of climate impact to the risk analysis, number of household at risk under stress from extreme climate event changed to 7.6%, 50% and 42.0% for the low risk, moderate risk, and high risk category respectively. The analysis also shows that 77% of total surveyed household are vulnerable to climate impact from the extreme climate event, while only 23% may be consider as non-vulnerable or climate resilience group. Majority of the household's livelihood is not sustained as main income came from rice production. Most of the vulnerable household has high debt and if the climate change may cause more frequent extreme climate event, these farmers are likely to unable to recover the debt condition and may be forced out of the rice production system to other sectors. (Kerdsuk et al, 2006)

Farmers in Thailand have been adapting to climate impacts throughout history and strategies for managing climate risks have evolved through time. However, it is difficult to separate adaptations made in response to climate pressures from actions taken in response to other forces emanating from demographic, social, economic, technological, environmental and other changes. In many cases, farm practices are a response to multiple risks from a variety of sources. (Chinvanno et al, 2008b)

Some on-farm adaptation measures for reducing climate risk practiced by rice farmers in Thailand include changing seedling technique, using hired machinery, growing alternate crops between rice seasons and raising livestock. Some farmers make investments to increase and sustain the productivity of their farms in ways that make them more resilient with respect to climate variations and changes e.g. small scale irrigation systems to provide an alternate source of water for mid-season dry spells or for growing a crop during the dry season and embankments to protect their fields from flood damage. But greater use is limited by financial requirements for investment and maintenance. A small number of farmers with large land holdings implement mixed farming practice or switch part of their farmland from rice to a crop that is more resistant to climate stresses. Harvesting of natural products from forests, a common practice in Lao PDR, is limited at the study sites in Thailand because of high population densities and the degraded nature of forests that are adjacent to farm lands. (Chinvanno et al, 2008b)

National level policies and measures that serve to reduce vulnerability to climate hazards were not motivated by concerns about climate stress, especially climate change, but mainly by poverty reduction goals. Yet, national measures in Thailand have supported financial needs, infrastructure development, transitions to more diversified farming systems, marketing of local farm products, and farm planning that have helped to improve livelihoods of farmers and increase their resilience to climatic stresses. Research and development by government research facilities have provided new varieties of rice that are more resilient to climate variations while maintaining the quality that is required by the market. (Chinvanno et al, 2008b)

A new and innovative mechanism should also be introduced to help farmer and farming system be more resilience to climate risk. Climate insurance instruments have been recommended under the United Nations Framework Convention on Climate Change but have not yet progressed very far (Linnerooth-Bayer and Mechler, 2006). An important exception is the World Bank pilot project in Pak Chong district of Nakhon Ratchasima province. The project was carried out with maize farmers and implemented in full first in 2007 to handle risk from drought (Hellmuth et al., 2009). Several factors were relevant to initial success. First there was high quality historical weather data that could be used as basis for contracts and premiums. Second the Bank for Agriculture and Agricultural Cooperatives (BAAC) was the key operational partner; farmers were motivated to join the scheme because of their trust in (and long term relationships with) BAAC, which acted as an intermediary for nine other national insurance companies. Third significant effort was put into communication and learning activities. For instance the initial contract designed by World Bank team was modified based on feedback from farmers, BAAC, insurance companies and other stakeholders. In addition a test run of the scheme was done in 2006 leading to adjustments in rainfall data used (Hellmuth et al. 2009). In 2008 the scheme was expanded further. Activities like these should be an integral part of a wider package of business risk management tools that could help smaller farms deal with risks from variable and changing climates (Lebel, 2008).

- **Water resource**

Water balance in river basin may be used as indicator to indicate risk of climate change in water resource sector. However, there has not been comprehensive study on the issue. Moreover, water balance in the future, in the timescale of climate change, needs to also take changes in water demand due to change in socio-economic and consequences of other development scheme into consideration, which still require further study. However, a suggestion on alternate source of water, the conjunctive use of surface water and groundwater as in some irrigation projects in Thailand may help manage risk of weathering possibility climate change induced long period of droughts. Groundwater system tends to response much less to long term climate condition than surface-water systems. However, better understanding of large-scale physical hydrology and its effects on the subsurface recharge process is required. (Koch, 2008)

- **Coastal zone**

Risk, vulnerability and adaptation of the coastal zone as well as any other areas may need to be assessed in an integrated way as they are linked together both physically and through social and economic activity. Different communities or sectors could be vulnerable to climate change differently and also response to climate change differently, however, the way that one sector or community response to climate risk may have consequences to the others. In a case study at Krabi province, the area can be divided into 3 zones, i.e. coastal zone, upland area and urban zone. (Southeast Asia START Regional Center and WWF, 2008)

Krabi's 48 coastal villages are especially vulnerable to climate change impacts due to their proximity to the sea and their fisheries-dependent livelihoods and limited agricultural land. Although the direct effects of climate change on offshore fisheries in Krabi province was not well examined, the indirect effects may be substantial. Longer dry seasons will permit additional days of fishing, increasing the pressure on available stocks of fish and shellfish. This adds to the urgency of developing, thorough consultations with all concerned parties, an equitable, enforceable and scientifically-based regulatory system to ensure that coastal marine resources are not depleted by either commercial or subsistence fishing. (Southeast Asia START Regional Center and WWF, 2008)

In contrast to the coastal communities, the upland communities in Krabi province will be less vulnerable to climate change. Rubber growers, in particular, may actually benefit over the next 25 years from climate change. Although rainfall will decrease during this period, it will remain sufficient to meet the needs of rubber cultivation, and the shorter monsoon season will permit additional days of tapping. Productivity per tree is expected to rise by 10-15 percent. Reduced rainfall, on the other hand, may reduce the productivity of oil palms. This provides another incentive to Krabi smallholders, already vulnerable to abrupt income swings traceable to market conditions, to diversify their crop base so as to increase resilience to economic and climate changes. (Southeast Asia START Regional Center and WWF, 2008)

A lengthening dry season will increase the demand for tourism services, and hence place additional burdens on coastal resources and key ecosystems. Urban zones are likely to face water scarcity during the dry season, in response to which basin-wide water management systems will be essential. Engineering for infrastructure, including a municipal water supply as well as storm and wastewater management, should anticipate increasing climate change impacts over a 100-year horizon. Provincial planners should engage stakeholders in a discussion of the province's capacity for tourism growth that takes into account near and long-term climate change impacts; the best strategy may be to cap or slow growth in visitor volume while emphasizing migration to higher value and 'greener' services for tourists. (Southeast Asia START Regional Center and WWF, 2008)

- **Tourism**

Ministry of Tourism and Sports has defined tourism in Thailand into 14 clusters, which are diverse in terms of geographic locations, physical conditions and tourism activities. Diversity of the 14 tourism clusters make each cluster to be at risk from climate change differently and vulnerability of each cluster does not depend on the risk, it vary from cluster to cluster.
Sensitivity of these tourism clusters to climate condition and risk to future climate change was evaluated base on meteorological variables, i.e. temperature and future change in maximum as well as minimum temperature, total annual precipitation and rainfall distribution especially number of rainy day over the year, wind and wave condition. Moreover, geographic locations, physical conditions and tourism activities, were also taken into consideration in order to determine vulnerability of these 14 tourism clusters. Strategy and plan has been identified for these tourism clusters to prepare to cope with future risk from climate change, which focus on increasing resilience of the cluster to climate change impact and ability to maintain its integrity in order to continue its tourism function. (Chula Unisearch, 2009)

The analysis shows risk to climate change and vulnerability of each tourism cluster as follow:

Tourism cluster	**Climate risk**		**Cluster vulnerability**		**Conclusion**	
	2020s	**2050s**	**Geographic**	**Activity**	**2020s**	**2050s**
Hot spring	Low	High	High	High	Moderate	High
Eco-tourism / adventure	Low	High	High	High	Moderate	High
Northern cultural	Low	High	Low	Low	Low	Low
World heritage – eco-tourism	Low	High	Moderate	Moderate	Low	Moderate
Tropical forest eco-tourism	Low	Moderate	High	High	Moderate	High
Central region river basin livelihood	Low	Low	Moderate	Moderate	Moderate	High
Mekong River corridor	Low	Low	Low	Moderate	Moderate	Moderate
Dinosaur track	Low	Low	Low	Low	Low	Low
Pilgrimage	Low	Low	Low	Low	Low	Low
Lower Northern region cultural	Low	Low	Low	Low	Low	Low
Jewel track and agro tourism	Low	High	High	Low	Low	High
Active beach	Low	High	High	High	Moderate	High
Royal coast	Low	Moderate	High	High	Moderate	High
2-Ocean cluster	Low	Low	High	High	Moderate	High

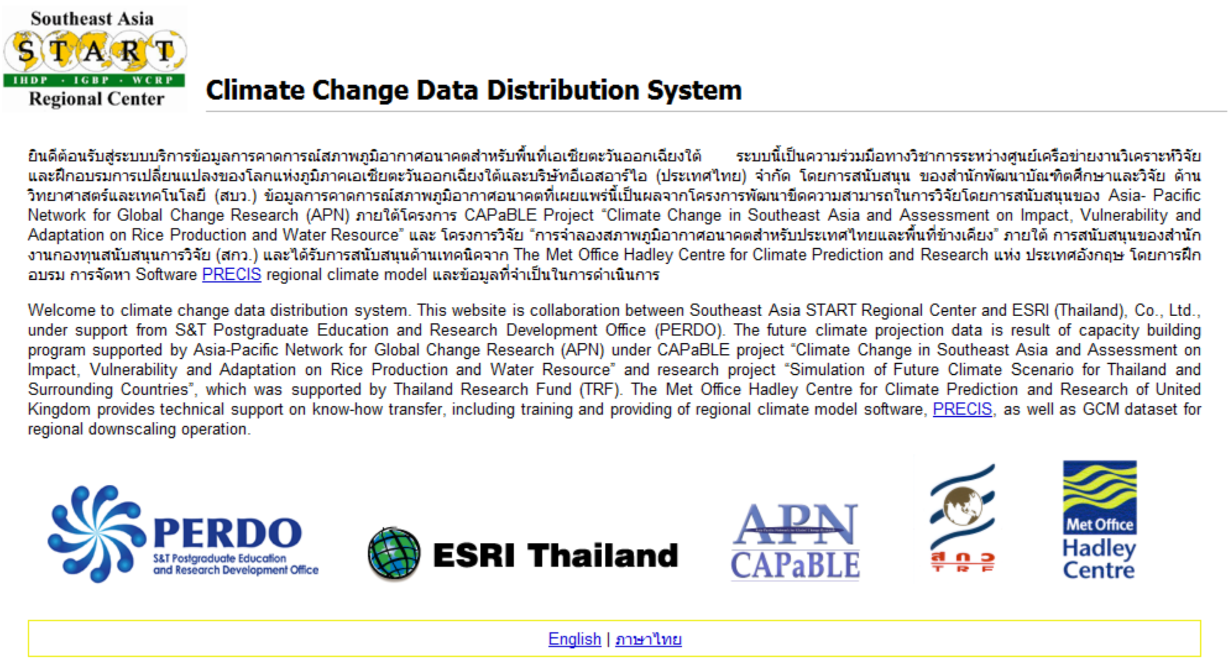
Chapter 6: On-line distribution system of climate scenario data for climate change impact study

As foundation for climate change impact study, climate scenario data from long term climate projection is required as input for further climate change impact assessment. In order to facilitate the research community, Climate Change Data Distribution System has been developed and opens for technical users, who need future climate data for their research purposes, to extract data and download via Internet. The system can be accessed at the following URL:

http:cc.start.or.th

Key variables data of climate projection from 2 selected climate scenarios, which is result of dynamic downscaling of ECHAM4 A2 and B2 scenarios using PRECIS regional climate model and rescaled to match local observed climate characteristic, include the following variables;

- Daily maximum temperature
- Daily minimum temperature
- Daily precipitation
- Daily solar radiation
- Daily wind speed
- Daily wind direction
- Daily relative humidity



Climate Change Data Distribution System

ยินดีต้อนรับสู่ระบบบริการข้อมูลการคาดการณ์สภาพภูมิอากาศอนาคตสำหรับพื้นที่เอเชียตะวันออกเฉียงใต้ ระบบนี้เป็นความร่วมมือทางวิชาการระหว่างศูนย์เครือข่ายงานวิเคราะห์วิจัยและฝึกอบรมการเปลี่ยนแปลงของโลกแห่งภูมิภาคเอเชียตะวันออกเฉียงใต้และบริษัทอีเอสอาร์ไอ (ประเทศไทย) จำกัด โดยการสนับสนุน ของสำนักพัฒนาบัณฑิตศึกษาและวิจัย ด้านวิทยาศาสตร์และเทคโนโลยี (สบว.) ข้อมูลการคาดการณ์สภาพภูมิอากาศอนาคตที่เผยแพร่นี้เป็นผลจากโครงการพัฒนาขีดความสามารถในการวิจัยโดยการสนับสนุนของ Asia- Pacific Network for Global Change Research (APN) ภายใต้โครงการ CAPaBLE Project "Climate Change in Southeast Asia and Assessment on Impact, Vulnerability and Adaptation on Rice Production and Water Resource" และ โครงการวิจัย "การจำลองสภาพภูมิอากาศอนาคตสำหรับประเทศไทยและพื้นที่ข้างเคียง" ภายใต้ การสนับสนุนของสำนักงานกองทุนสนับสนุนการวิจัย (สกว.) และได้รับการสนับสนุนด้านเทคนิคจาก The Met Office Hadley Centre for Climate Prediction and Research แห่ง ประเทศอังกฤษ โดยการฝึกอบรม การจัดหา Software PRECIS regional climate model และข้อมูลที่จำเป็นในการดำเนินการ

Welcome to climate change data distribution system. This website is collaboration between Southeast Asia START Regional Center and ESRI (Thailand), Co., Ltd., under support from S&T Postgraduate Education and Research Development Office (PERDO). The future climate projection data is result of capacity building program supported by Asia-Pacific Network for Global Change Research (APN) under CAPaBLE project "Climate Change in Southeast Asia and Assessment on Impact, Vulnerability and Adaptation on Rice Production and Water Resource" and research project "Simulation of Future Climate Scenario for Thailand and Surrounding Countries", which was supported by Thailand Research Fund (TRF). The Met Office Hadley Centre for Climate Prediction and Research of United Kingdom provides technical support on know-how transfer, including training and providing of regional climate model software, PRECIS, as well as GCM dataset for regional downscaling operation.

English | ภาษาไทย

Using Climate Change Data Distribution System is explained in the following steps:

Start from “Tools” icon – select “Export Data”

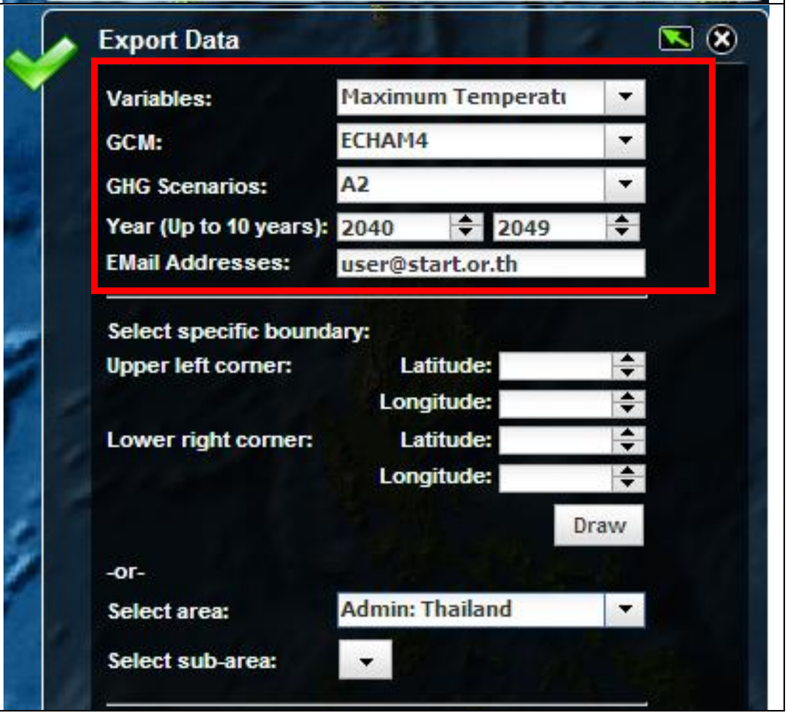
System will prompt a menu for the user to specify the conditions for extracting the data.

Variables: Maximum Temperat
GCM: ECHAM4
GHG Scenarios: A2
Year (Up to 10 years): 2040 2049
EMail Addresses: user@start.or.th
Select area: Admin: Thailand
Select sub-area:
Status:
Found 77 features

STEP 1: Select variables

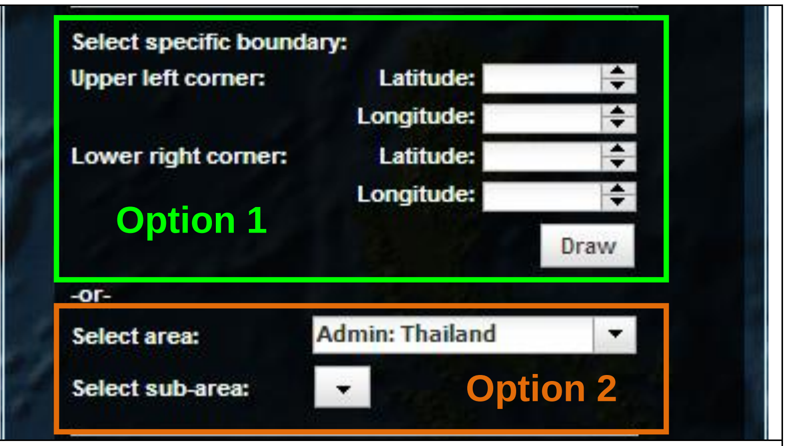
- Weather variables
- GCM initial dataset
- GHG scenario
- Year (maximum 10 years for each retrieval)
- Fill in e-mail address for e-mail notification for data downloading

Note: Upon specifying GCM dataset, the system will show the domain boundary where the data is available.



Variables: Maximum Temperat
GCM: ECHAM4
GHG Scenarios: A2
Year (Up to 10 years): 2040 2049
EMail Addresses: user@start.or.th
Select area: Admin: Thailand
Select sub-area:

Step 2: Delimit area for data retrieval.(2 options)



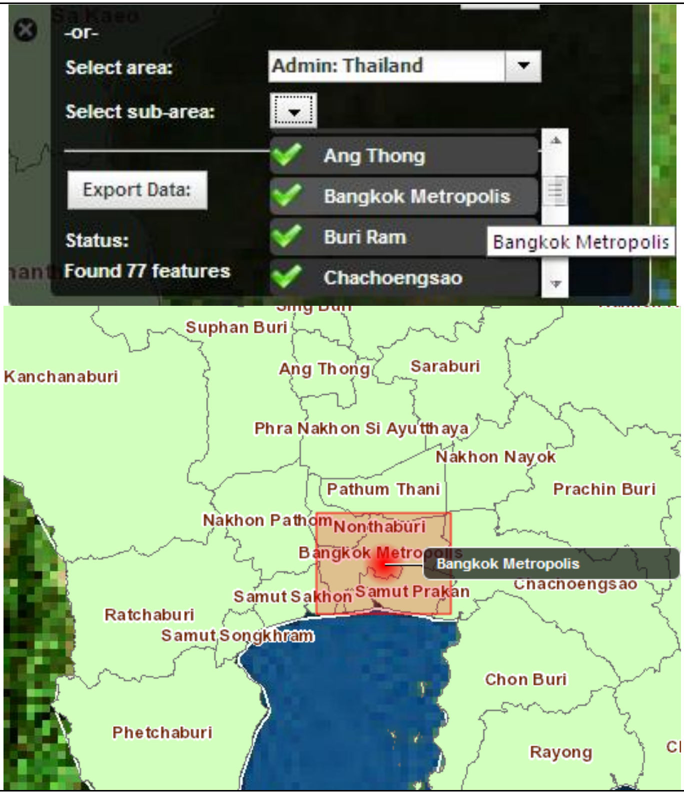
Select specific boundary:
Upper left corner: Latitude:
Longitude:
Lower right corner: Latitude:
Longitude:
Option 1
Draw
-or-
Select area: Admin: Thailand
Select sub-area:
Option 2

***Option 1*:** Select area by delimiting boundary using latitude and longitude to specify upper left corner and lower right corner of the target area.

Select specific boundary:
Upper left corner: Latitude: 16
Longitude: 100
Lower right corner: Latitude: 14
Longitude: 103
Draw

Click “Draw” to see selected boundary.

Option 2: Select target area from the pre-defined boundaries, i.e. river basin and river sub-basin, country and province boundary.



-or-

Select area: Admin: Thailand

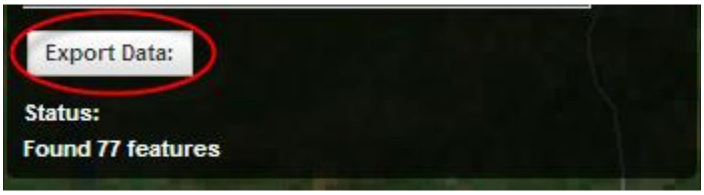
Select sub-area:

- ✓ Ang Thong
- ✓ Bangkok Metropolis
- ✓ Buri Ram
- ✓ Chachoengsao

Export Data:

Status:
Found 77 features

Step 3: Click "Export Data"

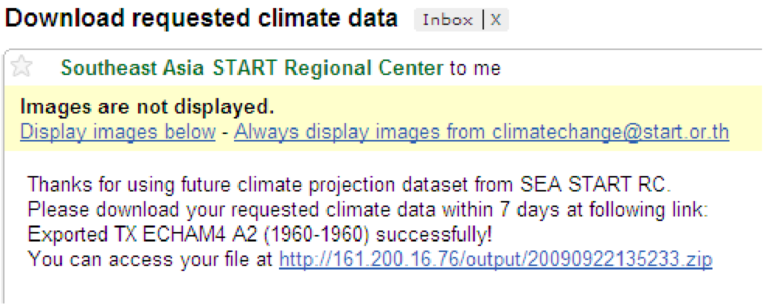


Export Data:

Status:
Found 77 features

System will send e-mail to user to notify the URL for data downloading. Please note that the file name format will be date and time of data extracting, weather variables, year, GCM and GHG Scenario, For example,

20090919094807_TX2030_ECHAM4_A2.txt



Download requested climate data Inbox | X

Southeast Asia START Regional Center to me

Images are not displayed.
Display images below - Always display images from climatechange@start.or.th

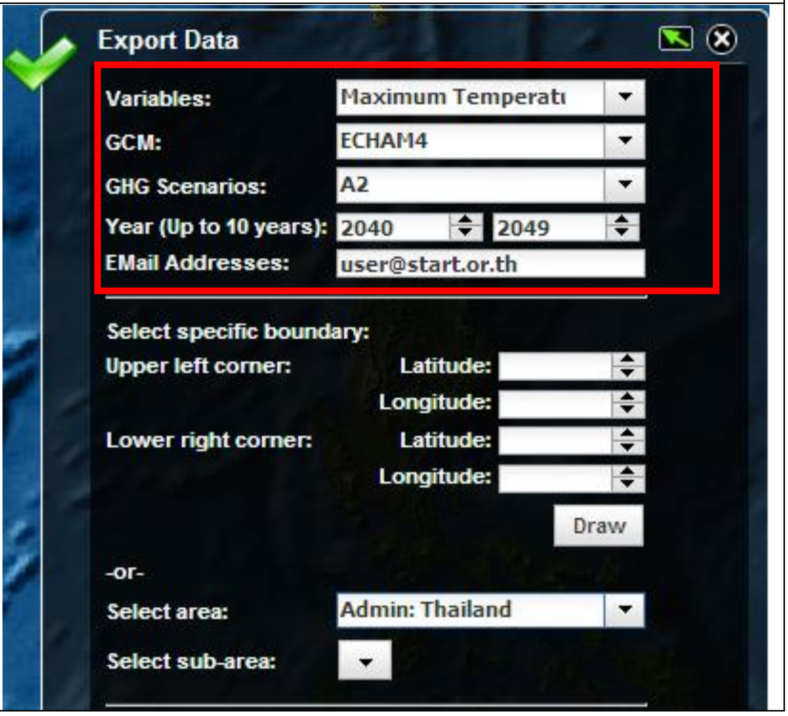
Thanks for using future climate projection dataset from SEA START RC.
Please download your requested climate data within 7 days at following link:
Exported TX ECHAM4 A2 (1960-1960) successfully!
You can access your file at http://161.200.16.76/output/20090922135233.zip

Note:

1) **The system will extract and send the requested data in files. There will be 1 file for every variable for every year.**
2) **Code for weather variables:**

- **TX - Maximum temperature**
- **TM- Mean temperature**
- **TN-Minimum temperature**
- **PC – Precipitation**
- **SL - Solar Radiation**
- **WD - Wind Direction**
- **WS - Wind Speed**

STEP 4: Repeat the variables selection procedure (Step 2) to extract other climate data and time period for the same selected area.



Export Data

Variables: Maximum Temperat

GCM: ECHAM4

GHG Scenarios: A2

Year (Up to 10 years): 2040 2049

EMail Addresses: user@start.or.th

Select specific boundary:

Upper left corner: Latitude: Longitude:

Lower right corner: Latitude: Longitude:

-or-

Select area: Admin: Thailand

Select sub-area:

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Appendices