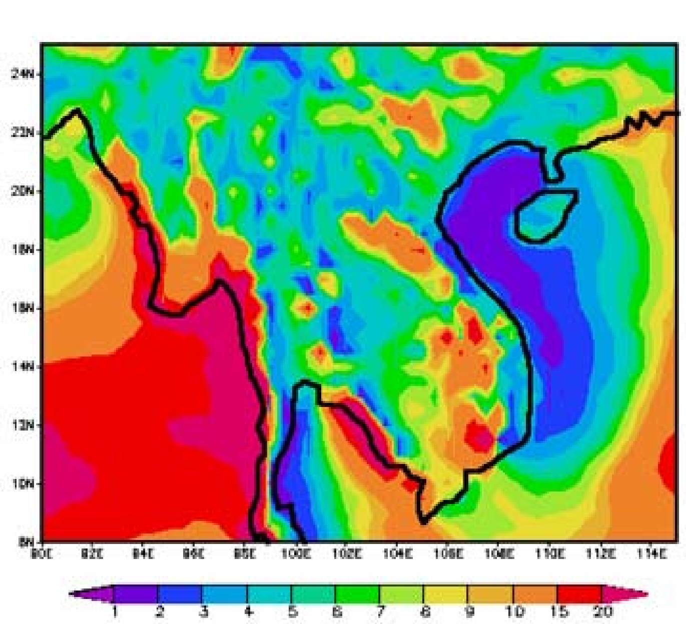
Final Report

on

Climate Change Scenarios for Songkram River Basin



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Executive Summary

Climate change is a slow process; therefore, the study of climate change normally covers long timescale, e.g. 25 – 30 years or even longer, in order to be able to see the changes in climate characteristics from the baseline condition. However, the precise climate prediction for such long timescale is beyond capability of any current forecasting technique to cope with. Therefore, in order to come up with future climate condition for further impact and vulnerability assessment, climate scenarios would be developed to explain plausible future of climate condition. The climate scenarios which is widely used for assessing the consequences of climate change, e.g. change in bio-physical as well as human livelihood under future climate threat, etc., would based on scientific and mathematic approach and a compromise between the prediction and projection.

This report is the summary on climate change scenario for the Songkram River basin which is summarized from the result of high resolution climate simulation for the Southeast Asia subcontinent by using climate modeling software, Conformal Cubic Atmospheric Model (CCAM). The simulation was conducted under condition of increased atmospheric CO_2 concentration by 1.5 and 2 times of present time (to be precise, of the decade of 1980s). The climate scenario gives overview of future climate change condition in the study area that the maximum and minimum temperature in the Songkram river basin will only slightly change. However, the major change in climate characteristic under this scenario would be the change in hot-cool period over the year. The simulation result shows that the annual hot period in the river basin tends to be substantially longer, and on the contrary, the cool period will be shorter. The precipitation tends to be slightly increased throughout the river basin.

This report is outcome of the collaboration between IRG, IUCN and SEA START RC under USAID initiative, in an effort to conduct pilot assessment on impact, vulnerability and adaptation of the people of Songkram River basin to the climate change. This pilot study was intended to be a demonstration on the methodology in the assessment process on climate change vulnerability and adaptation study.

1. Introduction: Climate change scenarios for the Songkram River basin

According to Intergovernmental Panel on Climate Change (IPCC), a scenario is a coherent, internally consistent and plausible description of a possible future state of the world. 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. A set of scenarios assists in the understanding of possible future developments of complex systems, such as climate system. Scenarios help in the assessment of future developments in complex systems that are either inherently unpredictable, or that have high scientific uncertainties. There are several types of climate scenarios that can be used to assess future climate risk and vulnerability of target systems and sectors. They range from scenarios that are devised arbitrarily base on expert judgment to scenarios based on past climate and to scenarios based on climate model output (UNFCCC, 2005). In all stages of the scenario-building process, uncertainties of different nature are encountered. In case of climate change, large uncertainty surrounds future GHG emissions and the possible evolution of their underlying driving forces (IPCC, 2000). In addition, uncertainty also lies in the method and process as well as the limitation of the technology used in the developing of climate scenario.

The method which is widely used for climate scenario development is the use of climate model to generate future climate under given condition on drivers of change. In principle, the simulation of climate scenarios by climate model needs to be performed on global scale because atmospheric system is a single system. The task usually conducted by General Circulation Models (GCMs) which generate the climate scenarios with typical grid size of several hundred kilometers because the simulation process is highly computing intensive. The study of climate change in regional scale or in smaller area would need higher resolution of climate scenarios that can be derived by post processing technique, which is known as downscaling technique. The downscaling process would use data from GCMs as input and transform the GCMs result into smaller grid size that match the requirement of the regional or local climate change study. The downscaling process could be statically downscaled based on observed climate data or dynamically downscaled based on regional climate model (RCM) that capture local condition into the simulation process (Stratus Consulting, 2005).

The climate change scenarios in this report derived from the Mekong River region climate change scenarios, which was outcome of a regional study, Assessment of Impact and Adaptation to Climate Change in Multiple Regions and Multiple Sectors (AIACC), regional study AS07 “Southeast Asia Regional Vulnerability to Changing Water Resource and

Extreme Hydrological Events due to Climate Change" (2003 – 2006). Climate data was extracted from the regional climate scenarios and summarized into climate scenarios for the Songkram River basin. This set of climate scenarios is based on computer simulation using mathematical model, Conformal Cubic Atmospheric Model (CCAM), which is the second-generation regional climate model developed specifically for Australasian region by the Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO), Division of Atmospheric Research (McGregor et al, 1998). The CCAM climate model used different approach from GCMs and conventional downscaling technique by combining concept of GCMs and RCM together. It uses the principle of stretched coordinate of a global model instead of uniform latitude-longitude grid system. This technique allows the model to make calculation at high resolution like RCM in the area that the study would focus and still calculate the climate globally as CGMs, but use larger grid size in the area further away from the study area in order to save computing time (see Figure 1). This technique helps avoid certain errors in the downscaling process and it also allows for other features, such as land and sea surfaces surface land form and land cover be varied and climate be simulated under different combinations of atmospheric and land surface forcing. The CCAM climate model has been evaluated in several international model inter-comparison exercises to be among the best climate model for Asian region. (McGregor and Dix, 2001) The model runs for 18 vertical levels including the stratosphere. It addresses both climate change and climate variability. It generates daily climate output which is necessary for downstream impact study, e.g. for use in the modeling of hydrological regime and crop production.

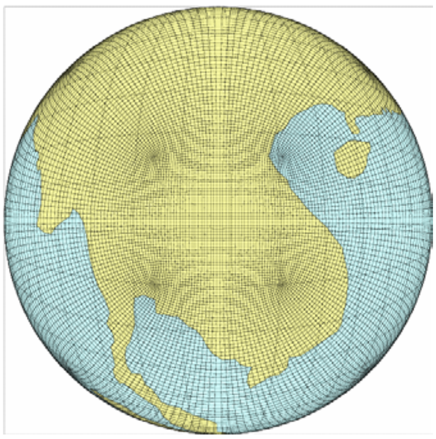


Figure 1: CCAM stretched-grid technique with focused area of calculation on Southeast Asia

The atmospheric CO_2 concentration was used as driving force in generating this set of climate change scenarios because CO_2 is the largest contributor to anthropogenic radiative forcing of the atmosphere (SRES, 2000). The future climate scenarios were simulated based on the condition of different atmospheric CO_2 concentration levels. The atmospheric CO_2 concentration at 360 ppm, which is the CO_2 concentration level approximately at present time (or to be more precise such condition was around the decade of the 1980s), was used for baseline climate condition simulation. The future climate scenarios were simulated under the condition of atmospheric CO_2 concentration of 540 ppm and 720 ppm (or at 1.5 times and double of baseline condition). Increasing atmospheric CO_2 concentration is primarily from the burning of fuel fossil and industry. The rate of atmospheric CO_2 concentration increasing in the future may vary and would reach the condition used for this scenario simulation at different times in the future depends on the emission condition, which is based upon future world socio-economic condition (see Figure 2). For example, under SRES scenario A1FI, the world atmosphere would reach CO_2 concentration level of 540 ppm and 720 ppm around the middle and toward the end of this century or approximately in the 2040s and 2070s respectively (IPCC, 2000).

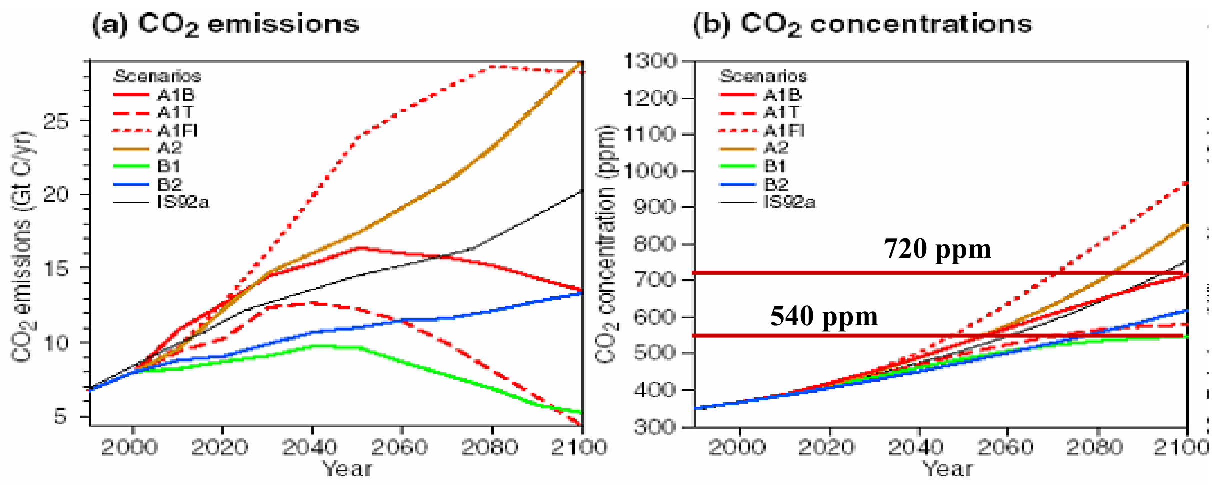


Figure 2: Illustrations show the rising of the atmospheric CO_2 concentration under different Intergovernmental Panel for Climate Change (IPCC) CO_2 emission scenarios

The coverage of climate simulation under the referred study covers the Southeast Asia subcontinent as well as southern part of People Republic of China. (See Fig.3) The output resolution of the simulation was set at 0.1 degree (about 10 km).

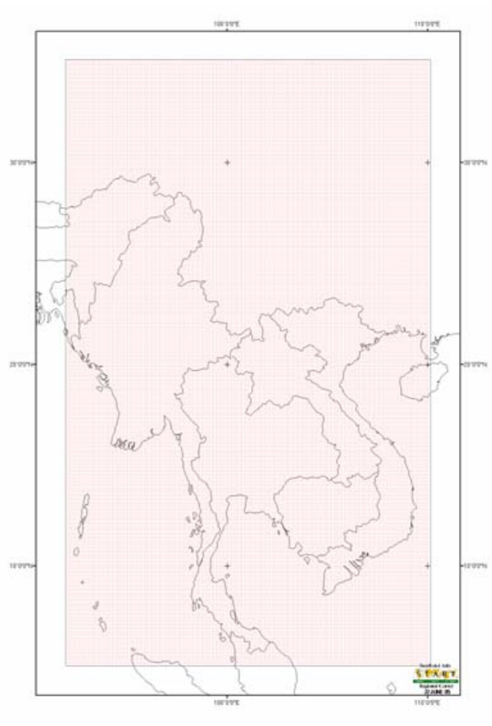


Figure 3: Geographical coverage of the CCAM simulation - Southeast Asia and southern region of People Republic of China

In this simulation, the CCAM model produced daily climate data for the period of 10 years at each atmospheric CO_2 concentration condition, 360ppm / 540ppm / 720ppm, in order to give some senses of climate variability for the decade, even though the period may be too short to conduct analysis on future change in climate variability pattern, especially probability of extreme climate event. The output from the simulation process includes the following parameters:

- Daily maximum, minimum and average temperature (^oC)
- Specific humidity (kg/kg)
- Heat flux (W/m^2)
- Pressure (hPa)
- Cloud cover (%)
- Rainfall (mm/d)
- Wind speed (m/s) and direction
- Radiation (W/m^2)

The climate scenarios simulated from the CCAM model need to be adjusted to compensate error from the model calculation. The adjusting process was primarily focused on the amount of precipitation and was based on observed data from weather observation stations throughout the region. Statistical adjusting was performed on cumulative rainfall using a non-linear function (log-log regression) to exponentially increase the daily variability. An arbitrary rainfall threshold of 3 mm./day was applied to reduce number of rainy days.

For the purpose of this pilot study, the numerical climate data of the Songkram River basin was extracted from the result of regional climate simulation, which was adjusted at regional scale, and summarized into climate change scenarios of the Songkram River basin. There was no further statistical rescaling process performed at the river basin scale in this set of climate scenarios. *(Remark: This due to the limited scope of work as well as time and resources.)* The summary in this report was focused on the change in temperature and precipitation in the river basin, however, the numerical data from this set of scenarios also consist of other parameters, e.g. humidity, wind speed, wind direction, etc., which were also extracted from the regional climate scenarios and were used as input for other mathematical model to analyze climate change impact, e.g. impact of climate change on hydrological regime of the river basin.

2. Summary on climate change in the Songkram River basin

The Songkram River basin is a river basin in the northeastern region of Thailand. It is sub-basin of the Mekong River basin, with the catchments of approximately 12,000 km^2 (see fig.4).

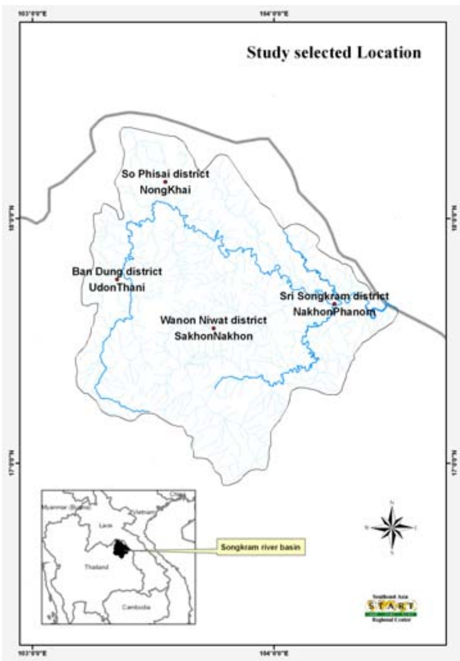


Figure 4: Study site – Songkram River basin, Thailand

The summary of climate scenarios is based on average daily climate data for the period of 10 years under each CO_2 concentration condition in grid size of approximately 10km x 10km.

2.1 Temperature change in the Songkram River basin under climate change scenario:

The climate change scenarios for the Songkram River basin, which was summarized from Mekong River region climate scenarios, show the plausible future change in temperature pattern in the river basin as follows:

2.1.1 Future change in daily maximum temperature

The simulation result on the baseline climate condition, which is the condition when atmospheric CO_2 concentration is 360ppm, shows that the average maximum daily temperature in the river basin varies within the range of approximately 30.5^{o}C to 32.3^{o}C, while most area has average daily maximum temperature around 31^{o}C – 32^{o}C. The northwestern part of the basin is slightly hotter than the lower part of the basin by approximately 2^{o}C (see Figure 5).

Under future climate condition when atmospheric CO_2 increases to 540ppm, the river basin will be slightly cooler and the range of average maximum temperature will be 30.2^{o}C to 32^{o}C, the "warm zone" would diminish and "cool zone" expand (See Figure 5). The cooling down effect in the basin may cause by higher cloud overcast effect *(remark: the change in future solar radiation and cloud cover in the area is not included in this summary report).*

However, the river basin tends to get warmer than the baseline condition when atmospheric CO_2 increases to 720ppm. The average daily maximum temperature in the river basin varies in the range of 31.3^{o}C – 33.2^{o}C. The spatial pattern of warm zone is similar to the baseline condition, where the upper part and the northwestern area of the river basin are slightly warmer than the other area (see Figure 5).

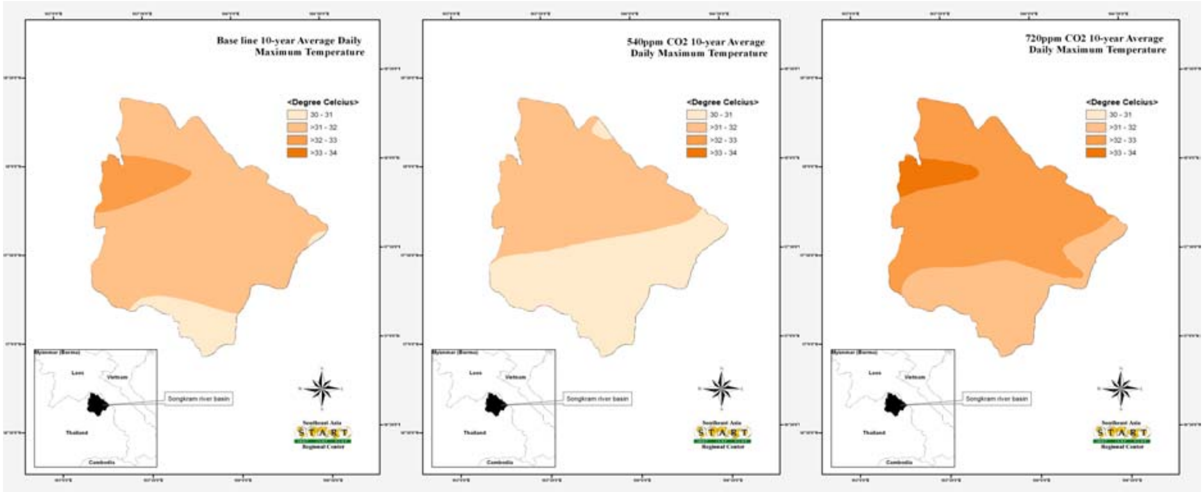


Figure 5: Average daily maximum temperature in Songkram River basin under different climate conditions

The illustration below shows spatial comparison of change in average daily maximum temperature in the Songkram River basin between the baseline condition and the climate condition at atmospheric CO_2 concentration of 540ppm and 720ppm. The change in average maximum temperature in the river basin would change uniformly, which will be cooler by 0.5°C – 1°C and warmer by 0.5°C – 1°C under the climate condition at atmospheric CO_2 concentration of 540ppm and 720ppm respectively throughout the river basin.

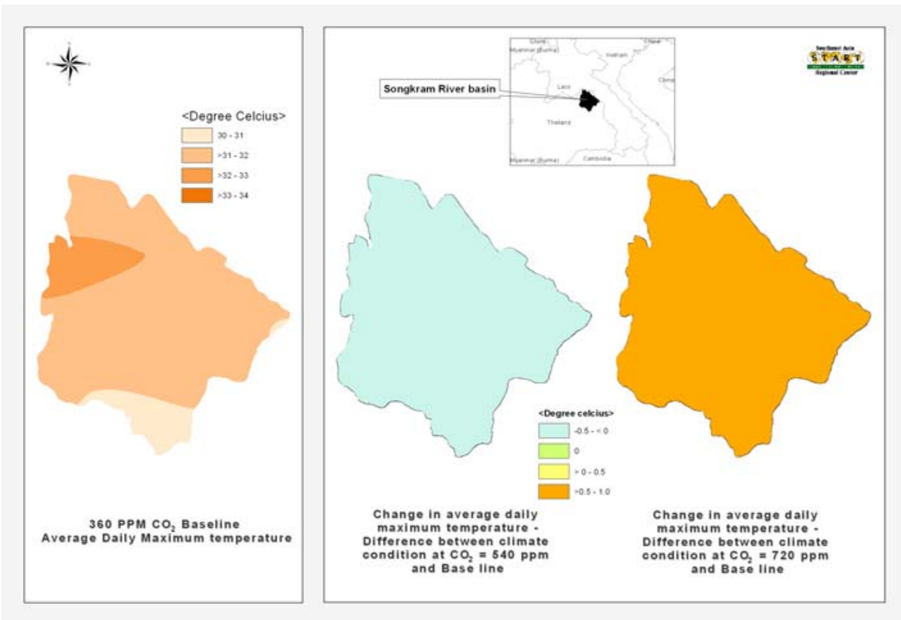


Figure 6: Change in average daily maximum temperature – geographical distribution in Songkram River basin

The trend of temperature change in the river basin may also be presented by 10-year average daily maximum temperature information, which is extracted from climate scenario, at different time of the year at various locations in the river basin. The information in Table 1 is extracted for demonstration purpose from some selected locations, which are scattered around the river basin. It shows that the average daily maximum temperature in January and April, which is considered winter time and summertime respectively, tends to rise higher by 1- 2 degrees in every location. However, the average maximum daily temperature during the rainy season, which is the month of July and October, would be more or less the same; probably because rain would help stabilize the temperature (see Table 1).

Unit: ^{o}C

Location	Lat.	Long.	Climate scenario: CO_2 Level (ppm)	Jan	Apr	Jul	Oct
Wanon Niwat District, Sakhonnakhon	17.55	103.75	360	27.8	38.7	29.4	28.6
			540	27.1	39.0	29.4	28.6
			720	29.0	40.4	29.9	29.0
Sri Songkram District, Nakhonphanom	17.65	104.25	360	28.4	38.8	29.1	28.6
			540	27.9	39.2	29.2	28.7
			720	29.8	40.5	29.7	29.1
Ban Dung District, Udonthani	17.75	103.35	360	28.9	40.0	29.7	28.7
			540	28.3	40.2	29.7	28.6
			720	30.0	41.5	30.3	29.1
So Phisai District, Nongkhai	18.15	103.55	360	28.3	38.3	30.1	29.2
			540	27.7	38.5	30.1	29.2
			720	29.6	40.0	30.7	29.9

Table 1: 10-year average daily maximum temperature at selected locations in Songkram River basin

Another indicator which shows that the river basin tends to be warmer in the future is the change in length of hot period in a year, which is indicated by the number of annual "hot days". For the purpose of this summary report, the "hot day" is defined as the day that maximum temperature is higher than $33^{o}C$. The table below shows that the number of "hot day" tends to increase at every location selected for this demonstration, even though, the hot period will be slightly shorter under climate condition when CO_2 is at 540ppm (see Table 2).

Unit: Day			
Location	**Climate scenario: Climate condition at**		
	CO_2 = 360 ppm	**CO_2 = 540 ppm**	**CO_2 =720 ppm**
Wanon Niwat District, Sakhonnakhon	121	112	138
Sri Songkram District, Nakhonphanom	122	106	144
Ban Dung District, Udonthani	131	126	149
So Phisai District, Nongkhai	123	113	146

Table 2: Average annual "hot day" at selected locations in Songkram River basin

The illustration below shows spatial distribution of change in number of "hot day" per annum in Songkram River basin. Even though, the hot period in the basin may be slightly shorter under climate conditions when atmospheric CO_2 is 540ppm, but in the longer term the summertime tends to get longer by 2-3 weeks in the upper part of the river basin under climate condition when atmospheric CO_2 is 720ppm.

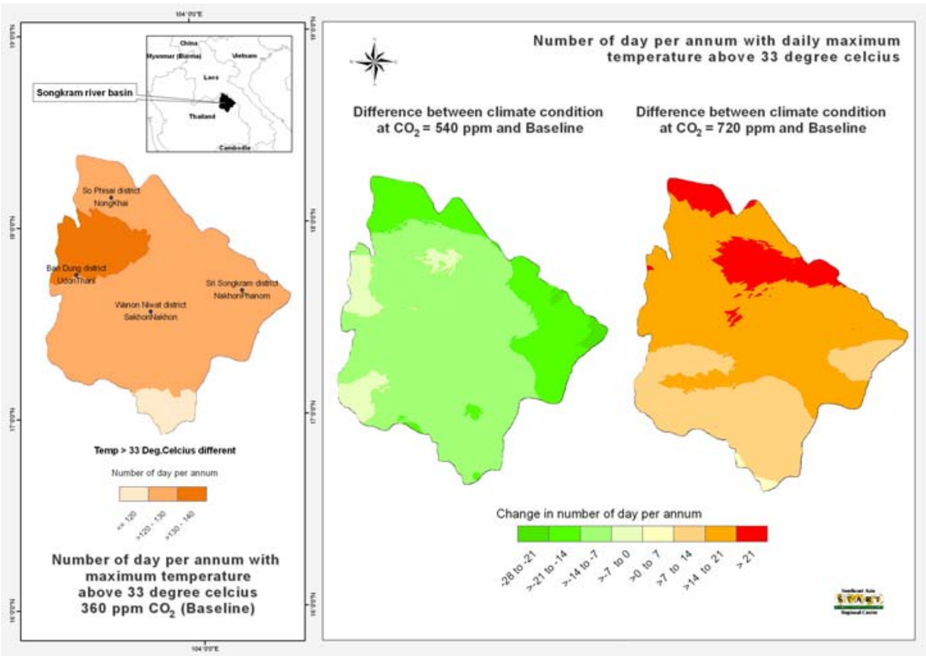


Figure 7: Change in number of "hot day" – geographical distribution in Songkram River basin

2.1.2 Future change in daily minimum temperature

The simulation result on the baseline climate condition, which is the condition when atmospheric CO_2 concentration is 360ppm, shows that the average daily minimum temperature in the river basin varies in the range of approximately 20.1°C to 21.6°C. The rim zone of the basin is slightly cooler than the central zone by approximately 1°C. Under future climate condition when atmospheric CO_2 increases to 540ppm, Songkram River basin tends to be slightly cooler. The spatial pattern of temperature zone would be the same as the baseline condition, whereas the central zone is slightly warmer than the rim zone of the river basin. However, under climate condition when atmospheric CO_2 increases to 720ppm, most area of the river basin would be warmer than baseline condition (see Figure 8).

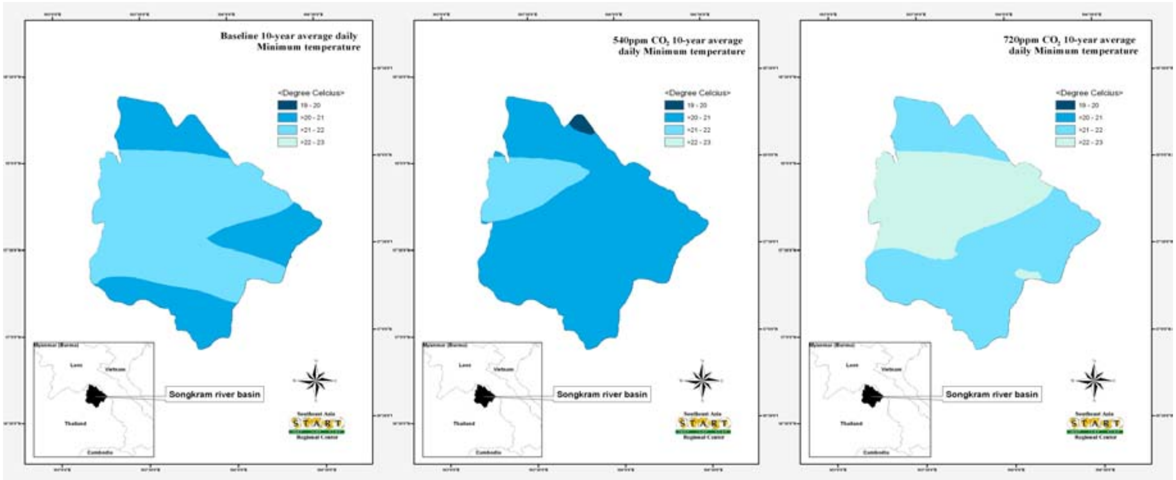


Figure 8: Average daily minimum temperature in Songkram River basin under different climate conditions

The illustration below shows spatial comparison of change in average daily minimum temperature in the Songkram River basin between the baseline condition and the climate condition at atmospheric CO_2 concentration of 540ppm and 720ppm. The change in average minimum temperature in the river basin would change uniformly, which is cooler by 0.5^oC – 1^oC and warmer by 0.5^oC – 1^oC throughout the river basin under the climate condition at atmospheric CO_2 concentration of 540ppm and 720ppm respectively.

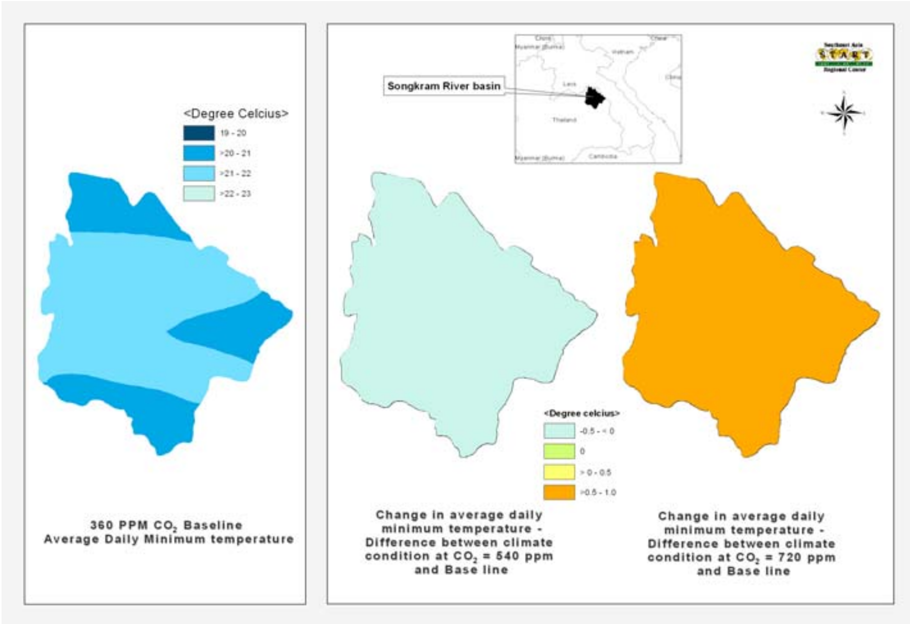


Figure 9: Change in average daily minimum temperature – geographical distribution in Songkram River basin

The trend of temperature change in the river basin may also be presented by 10-year average daily minimum temperature information, which is extracted from climate scenario, at different time of the year at various locations in the river basin. The information in Table 3 is extracted for demonstration purpose from some selected locations, which are scattered around the river basin. It shows that the average daily minimum temperature in January and April, which is considered winter time and summertime respectively, tends to rise higher by 1- 2 degrees in every location. However, the average maximum daily temperature during the rainy season, which is the month of July and October, would be more or less the same; probably because rain would help stabilize the temperature (see Table 3).

Unit: °C							
Location	**Lat.**	**Long.**	**Climate scenario under CO_2 level (ppm)**	**Jan**	**Apr**	**Jul**	**Oct**
Wanon Niwat District, Sakhonnakhon	17.55	103.75	360	14.6	26.8	22.3	20.2
			540	13.7	26.7	22.5	19.9
			720	16.0	28.3	23.3	20.5
Sri Songkram District, Nakhonphanom	17.65	104.25	360	15.0	26.2	22.1	20.3
			540	14.0	26.1	22.3	20.0
			720	16.2	27.8	23.1	20.6
Ban Dung District, Udonthani	17.75	103.35	360	15.4	27.0	22.4	20.6
			540	14.5	26.8	22.6	20.2
			720	16.8	28.4	23.4	20.8
So Phisai District, Nongkhai	18.15	103.55	360	14.7	24.5	22.1	20.1
			540	14.0	26.1	22.3	20.0
			720	16.0	25.8	23.1	20.4

Table 3: 10-year average daily minimum temperature at selected locations in Songkram River basin

Another indicator which shows that the river basin tends to be warmer in the future is the change in the length of cool period in a year, which is indicated by annual number of "cool days". For the purpose of this summary report, the "cool day" is defined as the day that minimum temperature is lower than 15°C. The table below shows that the annual number of "cool day" tends to reduce at every location selected for this demonstration (see Table 4).

Unit: Day			
Location	**Climate scenario under CO_2 conditions:**		
	CO_2 = 360 ppm	**CO_2 = 540 ppm**	**CO_2 = 720 ppm**
Wanon Niwat District, Sakhonnakhon	79	70	31
Sri Songkram District, Nakhonphanom	76	67	29
Ban Dung District, Udonthani	64	61	26
So Phisai District, Nongkhai	67	59	24

Table 4: Number of "cool day" at selected locations in Songkram River basin

The illustration below shows spatial distribution of change in number of "cool day" per annum in Songkram River basin. The winter time may be significantly shorter by over a month under climate condition when atmospheric CO_2 at 720ppm, especially in the lower part of the river basin.

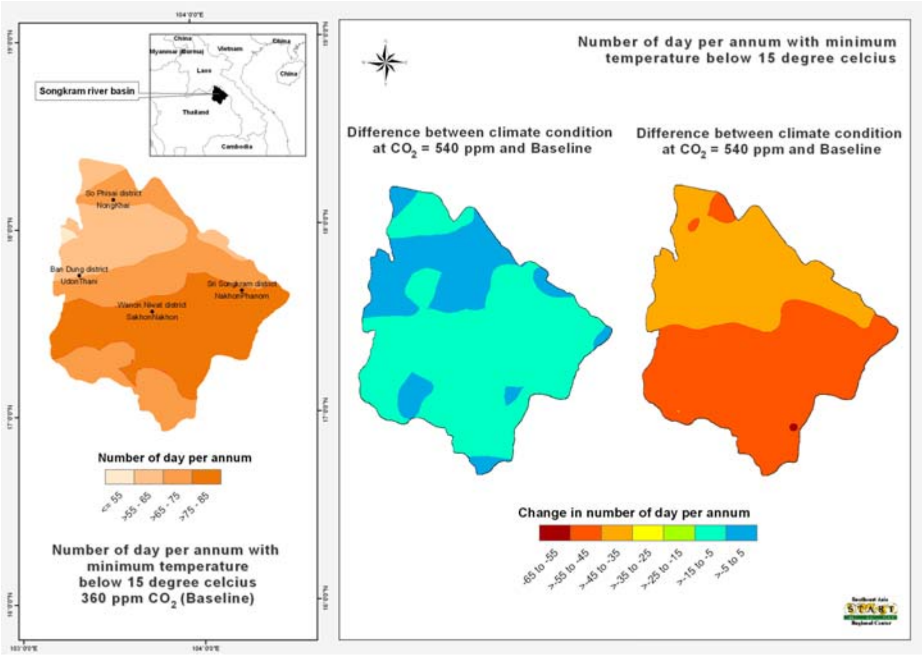


Figure 10: Change in number of "cool day" – geographical distribution in Songkram River basin

2.2 Precipitation change in the Songkram River basin under climate change scenario:

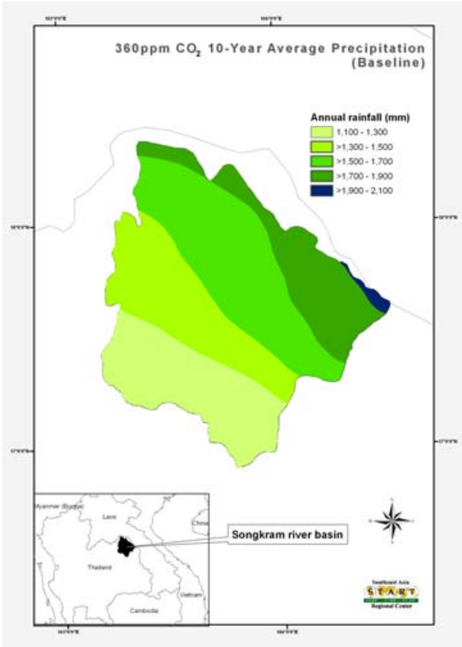
The summary of climate change scenarios for the Songkram River basin covers the average annual precipitation under each period of simulated climate condition and also year-to-year comparison of the wet and dry year scenarios from each period of simulated climate condition in order to give idea on the range of precipitation change in the future under different circumstances. It shows the plausible future change in precipitation in the river basin as follows.

2.2.1 Change in average annual precipitation

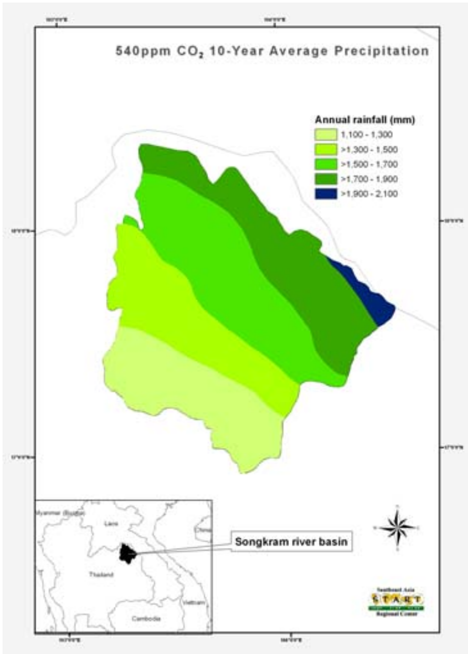
From the simulation result, the summary on 10-year average precipitation in Songkram River basin from each period of simulated climate condition shows trend of increasing precipitation from baseline condition. Average annual precipitation in the river basin will increase by few per cent under climate condition when atmospheric CO_2 is 540ppm and continue rising to over 8% increased under climate condition when atmospheric CO_2 is 720ppm (See Table 5).

			Unit: mm.
	Climate scenario under CO_2 conditions:		
	CO_2 = 360 ppm	**CO_2 = 540 ppm**	**CO_2 =720 ppm**
10-year average precipitation	1,492	1,526	1,617

Table 5: 10-year averaged precipitation in Songkram River basin under different climate conditions

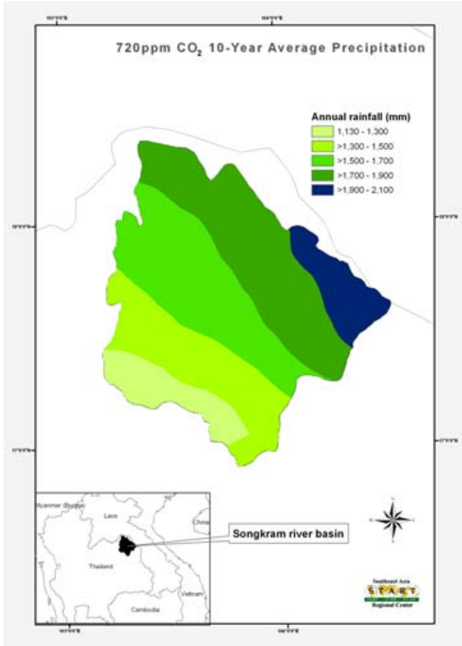


The spatial distribution of precipitation of baseline climate condition, which was summarized from the simulation result as illustrated, shows that the northeastern zone of the river basin which is closer to the Mekong River tends to have higher annual precipitation than the inner zone. The difference in annual precipitation between the wettest and driest zone could be in the range of 900 mm. per annum or higher. The wet zone of the river basin may have annual rainfall around 1,700 mm. up to slightly over 2,000 mm. per annum, while the dry zone in the lower part of the river basin may have annual rainfall around 1,200 mm. per annum.



The simulated future climate condition based on the condition of atmospheric CO_2 concentration of 540ppm, shows slight change in the pattern of the wet zone, which is the northeastern part of the river basin. Even though, overall pattern of precipitation distribution does not change much from the baseline condition, but the wet zone tends to expand slightly. The range of average annual precipitation is also the same as the baseline condition, which is over 2,000 mm. per annum in the wet zone and around 1,200 mm. per annum in the dry zone of the river basin.

Under climate condition when atmospheric CO_2 concentration is 720ppm, the simulation result shows that Songkram River basin average annual precipitation will increase further. The wet zone will expand from the zone along the Mekong River further inland, but overall pattern of rainfall distribution remains in the same characteristic, which is wetter in the in the north – northeastern part of the basin and drier in the south – southwestern region of the basin. The range of average annual precipitation remains the same as the baseline condition, which is over 2,000 mm. per annum in the wet zone and less than 1,300 mm. per annum in the dry zone of the river basin.



The illustration below shows spatial distribution and magnitude of change in average annual precipitation as a result of the comparison between baseline climate condition and future climate conditions. The river basin tends to get slightly wetter under climate condition when atmospheric CO_2 increases to 540ppm, particularly the northern and southeastern part of the basin where annual precipitation may increase by 10mm. to 70mm. per annum. The annual precipitation will increase throughout the river basin in the range of 100 mm. to 150 mm. under climate condition when atmospheric CO_2 increases to 720ppm. The simulation result shows significant increase in annual precipitation in the eastern and southeastern part of the region, which could be around 130 mm. – 140 mm. per annum (see Figure 11).

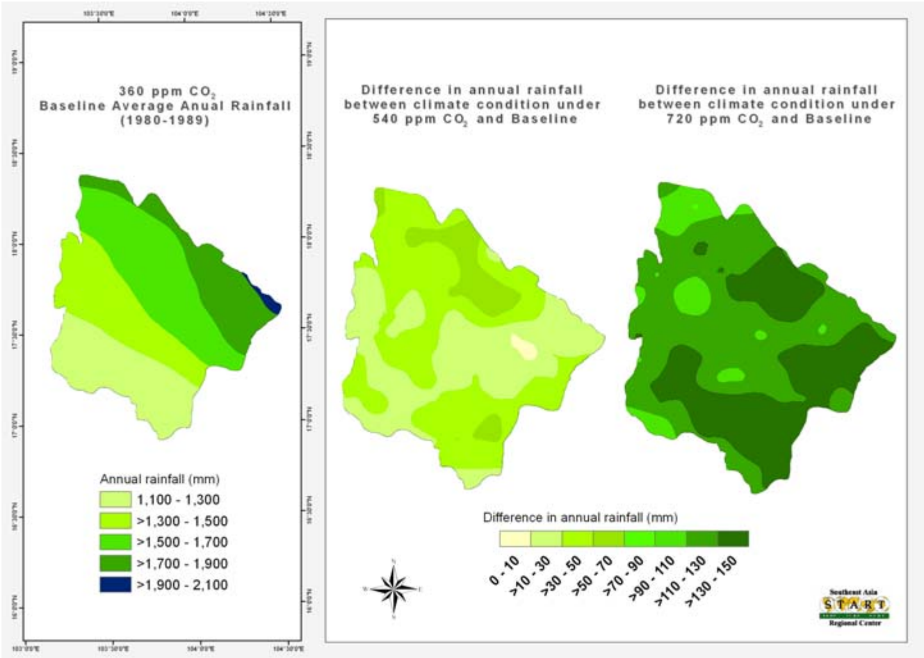


Figure 11: Change in average annual precipitation – geographical distribution

2.2.2 Year to year comparison: Annual precipitation

In order to get better understanding about future change in rainy season pattern in the Songkram River basin under influence of climate change, this report gives a closer look into more details of the precipitation pattern by comparing the wettest years as well as driest years of each decade under different climate conditions at atmospheric CO_2 concentration of 360ppm, 540ppm and 720ppm. However, by looking at a single year of climate simulation result, one has to aware that there are there are a lot of uncertainty and possible error involved. This information can only be used as a rough indicator on how climate change may have impact on seasonality in the study area.

From the simulation, the wettest year of the baseline decade has quite heavy rainfall and has highest annual precipitation when compare to other wettest years under different climate conditions. The driest year of the baseline decade is also the driest among the driest years of different climate conditions, but when compare year-to-year, it shows upward trend of future annual precipitation in the future dry year. For details figures, see Table 6 below.

			Unit: mm.
	Climate scenario under CO_2 conditions:		
	CO_2 = 360 ppm	**CO_2 = 540 ppm**	**CO_2 =720 ppm**
Dry year scenario	1,378	1,392	1,520
Wet year scenario	1,827	1,634	1,798

Table 6: Annual precipitation in Songkram River basin under different climate conditions

The result of simulation on annual precipitation as summarized in the Table 6 also shows that rainy season in the future tends to be less fluctuating. The range of fluctuation in annual precipitation between the wettest year and the driest year in the decade would reduce from approximately 450mm. in the baseline climate condition to approximately around 250 mm. in the future.

The pattern of rainy season is also illustrated in the accumulated precipitation graphs in Figure 12 and Figure 13.

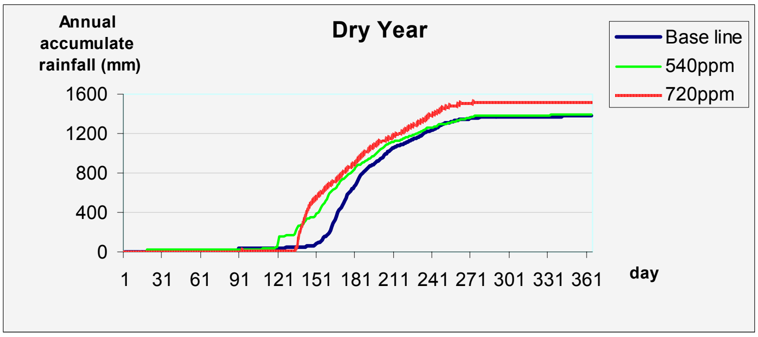


Figure 12: Comparison on accumulate precipitation in Songkram River basin – Dry year scenario under different climate conditions

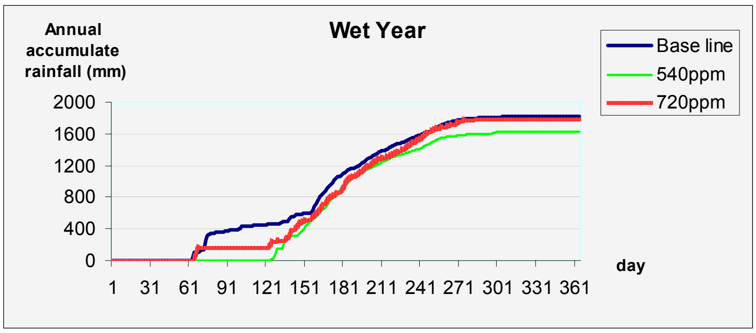


Figure 13: Comparison on accumulate precipitation in Songkram River basin – wet year scenario under different climate conditions

3. Summary:

The climate change scenarios of the Songkram River basin, which were summarized from regional climate scenarios of the Mekong River region, show that temperature in river basin may only slightly change from the baseline condition. It tends to be slightly warmer in the future, even though the basin may cool down slightly for a period of time during the period of climate condition when atmospheric CO_2 concentration is 540ppm. The warmer time will be in the dry season, which covers both winter time and summertime. However, even though the change in average maximum and minimum temperature may be minimal, which is in the range of 1^{o}C, but the length of hot period in a year will be much longer in most area of the river basin and, on the contrary, the cool period of the year will be shorter in the future. In other words, the summer season will be longer under influence of climate change, which could be longer by 4-6 weeks in most area of the river basin. Longer hot period may affect various bio-physical systems, particularly the change in life cycle of insect/pest that would affect human health as well as agriculture.

For the change in precipitation pattern, Songkram River basin tends to have higher annual precipitation in the future. There may be slight shifting of the rainy season and the mid-season dry spell may be more prominent in the future. The fluctuation in annual precipitation from year to year may be lesser, but this would need to be verified with the climate scenarios that cover longer period of time. Extreme climate event, especially future flood risk, is also serious issue, but it was not clearly captured in this climate scenario, however, the higher precipitation while the length of rainy season remains the same may indicate higher flood risk in the future.

Even though, the climate scenarios for Songkram River basin in this report show certain changes in future climate pattern, but they should only be taken as a plausible future that roughly show trend in and give idea on possible magnitude of change future climate condition in the study area only. It is not a precise prediction and cannot be interpreted as such. In addition, there still are uncertainties and possible errors between the simulation result and the actual observed weather data in this set of climate scenarios. This could be due to several factors, e.g. the capability of climate model that cannot capture some of the drivers which drive local climate condition and / or the precision in downscaling and rescaling process. In order to get a more precise climate scenario for the study of climate change in the scale of small river basin in the future, it may need regional climate model as tool for downscaling the global climate scenarios into small grid size and perhaps also combined with rescaling process based on statistical analysis with substantial amount of observed historical weather data in the study area.

In addition, uncertainty of long term climate scenarios is still an issue due to the limitation in technology of climate models that are available today, therefore, multiple scenarios using different tools are required to cope with such uncertainty. The study with aims to develop actual climate change adaptation policy may need to base future climate risk analysis upon the inter-climate models comparison of at least 3-5 scenarios, which could base upon different tools or assumption on drivers of future change. Some organizations who develop global climate scenarios and may also have tools for downscaling include, Hadley Center of UK, CSIRO of Australia, Max-Plank Institute for Meteorology of Germany and Danish Meteorological Institute of Denmark, National Center for Atmospheric Research of USA, Center for Climate Study and National Institute for Environmental Research of Japan, etc.

The climate data from climate change scenarios would be used as input for further analysis to assess impact of climate change on other biophysical systems, such as hydrological regime or crop productivity and identify future climate risk from climate change that may threaten vulnerability of various systems and sectors.

Reference

IPCC. 2000. Special Report on Emission Scenarios. Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge.

McGregor, J. L., Katzfey, J. J. and Nguyen, K. C. 1998: Fine resolution simulations of climate change for Southeast Asia. Final report for a research project commissioned by Southeast Asian Regional Committee for START (SARCS). Aspendale, Vic. CSIRO Atmospheric Research, 35 p.

McGregor, J.L., and M.R. Dix. 2001: The CSIRO conformal-cubic atmospheric GCM. In IUTAM Symposium on Advances in Mathematical Modelling of Atmosphere and Ocean Dynamics, P.F. Hodnett (Ed.), Kluwer, Dordrecht, 197-202.

Stratus Consulting Inc. 2005. Compendium on methods and tools to evaluate impacts of, vulnerability and adaptation to, climate change, UNFCCC Secretariat, Bonn, Germany.

UNFCCC Secretariat. 2005. Handbook on Vulnerability and Adaptation Assessment. Bonn, Germany. Available http://unfccc.int/resource/cd_roms/na1/v_and_a/index.htm