Future Climate Projection for Mainland Southeast Asia Countries: Climate Change Scenario of 21st Century

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Abstract
Long term climate projection at high resolution is a fundamental dataset for climate change studies, especially for assessing the impact of climate change at the local scale. This future climate projection, which provides a scenario of climate for Southeast Asia at 20x20 km resolution up to the end of the 21st century, is a result of a dynamic downscaling process using a regional climate model (RCM) from the Hadley Centre, The Met Office of United Kingdom, to simulate high-resolution climate data for the region based on datasets from the Global Circulation Model (GCM) ECHAM4 - A2 GHG emission scenario. Results from the RCM show that a wide area of Southeast Asia will become warmer and the duration of the warm period will extend substantially in the future, especially in the latter half of the century. Even though warmer temperatures are detected for both daily maximum and daily minimum values, the daily minimum temperature tends to have a higher trend. Precipitation tends to fluctuate in the first half of the century but shows an increasing trend with higher intensity, which will be clearly seen in the latter half of the century where higher precipitation will be observed throughout the region.

Keywords: *climate change, Southeast Asia, regional climate model (RCM), PRECIS, ECHAM4*

Introduction
Climate change has become a global concern as it may have many adverse consequences on various systems and sectors that may threaten human wellbeing (IPCC, 2001). Understanding climate change is the foundation for proper planning of adaptation measures to cope with future risk. However, climate change is a slow process and requires rather long-term future climate projections to be able to accurately predict changes in future climate patterns (IPCC, 2007). Therefore, long-term future climate projection is crucial for the assessment of climate change impacts on certain sectors in specific areas, particularly at the local scale. GCMs were developed and have been used to simulate future climate conditions, but most of the simulations, especially those GCMs that were used in the IPCC AR4, were conducted at coarse scales due to limitations in technology. These GCMs are not as effective for climate change impact assessments at local scales where high-resolution future climate data is required.

Typically, there are three types of techniques for obtaining high-resolution regional climate change projections: statistical, dynamical and hybrid (statistical-dynamical) techniques. The use of RCMs falls into the dynamical category. An RCM is a downscaling tool that adds fine scale (high-resolution) information to large-scale projections of GCMs. GCMs are typically run with horizontal scales of a few hundred kilometers, while models can resolve features down to much smaller scales, e.g. 50 km or less. This makes for a more accurate representation of many surface features, such as complex mountain topographies and coastlines (Jones *et al.*, 2004). The present paper discusses approaches and results of dynamic downscaling of GCM data using RCMs to develop high-resolution future climate change scenarios for mainland Southeast Asia over the 21st century.

Methodology
The high resolution climate projection for mainland Southeast Asia was developed based on a dynamic downscaling technique using the PRECIS RCM. PRECIS was developed by the Hadley Centre for Climate Prediction and Research, The Met Office, UK. It can be used as a downscaling tool that adds fine scale (high-resolution) information to the large-scale projections of a GCM. It has been ported to run on a PC (under Linux) with a simple user interface, so that experiments can easily be set up over any region. PRECIS was developed in order to help generate high-resolution climate change information for as many regions of the world as possible. These scenarios can be used in impact, vulnerability and adaptation studies (Simson *et al.*, 2006).

The GCM dataset, which was used as the initial dataset for the simulation was the ECHAM4[1] model from the Max-Planck-Institute for Meteorology (MPI), Germany. It was based on SRES A2 GHG scenario, which represents the scenario that atmospheric GHGs will increase at a relatively high rate (IPCC, 2000). The period of simulation covers the years 1970–2100. The simulation provides output with daily time-step throughout the simulating period. The downscaling process was set to a resolution of 0.22^0 and output was rescaled to 20x20 km resolution. Domain coverage was latitude 0-35^0N and longitude 90^0-112^0E (Figure 1).

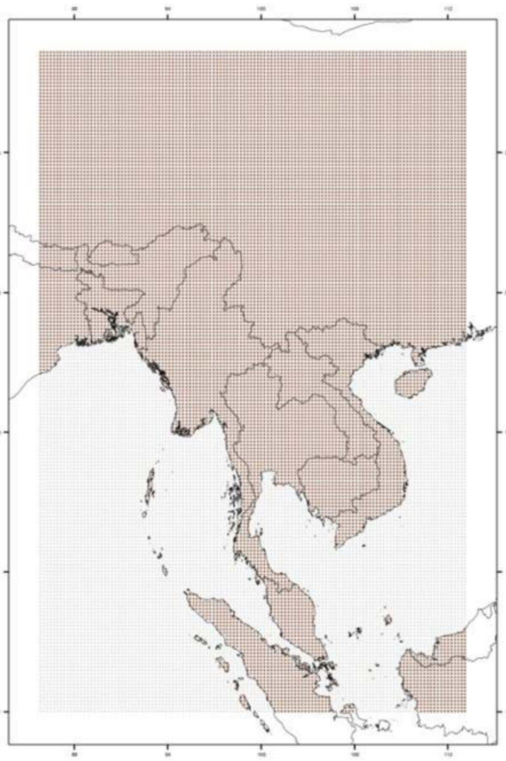

Figure1. Domain of future climate projection

The results from PRECIS RCM were verified by comparing against data from observation stations and the period of 1980s was selected as the baseline for verification. The comparison shows that the RCM result is somewhat different from the observed weather data. The PRECIS model tends to overestimate temperature and underestimate precipitation in many areas. A "rescaling" technique was developed and applied to the simulation results from the PRECIS model in order to adjust the simulated data to better match real conditions based on the observed data.

Results and Discussion

The simulation results from the PRECIS RCM, after the rescaling process, shows that the average maximum temperature as well as average minimum temperature in Southeast Asia in will increase in the future, with increases tending to be more prominent from the middle of the century onward. The warming trend is clearly seen in the central plain of Thailand and most of Cambodia as well as the Malaysian peninsular (Figures 2 and 3).

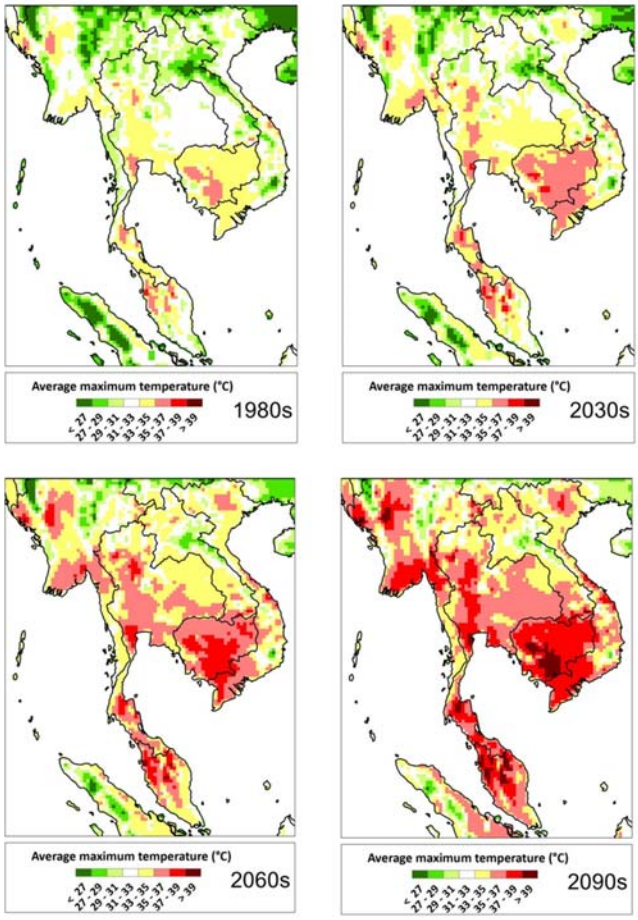

Figure 2. Average daily maximum temperature

In addition to the changing magnitude aspect, change in future temperature also occurs in the temporal aspect. Southeast Asia tends to have longer hot periods over the year. This change in temporal aspect can be seen in the changes in the number of hot days in a year, or in other words the length of summer-time, i.e., the number of 'hot days,' (defined in this study as days where maximum temperature exceeds 35^{o}C) will increase in the future, which could be longer by a few months in a year (Figure 4). On the other hand, PRECIS results also show a slight trend of change for the 'cool period,' (defined in this study as days where minimum temperature is 16^{o}C or below). The cool period, or in other words, winter-time, in Southeast Asia will become shorter than the baseline climate pattern, even though not as prominent as the trends in the 'hot period' (Figure 5).

Annual total precipitation may fluctuate in the early decades of the 21st century, but simulation results show a trend of higher precipitation throughout Southeast Asia in the future, especially towards the end of the century, which could be around 25-50% in some areas (Figure 6).

This long-term climate projection can be used to assess the impacts of climate change in various sectors as well as

[1] ECMWF Atmospheric General Circulation Model coupled with University of Hamburg Ocean Circulation Model (http://www.ipcc-data.org/is92/echam4_info.html)

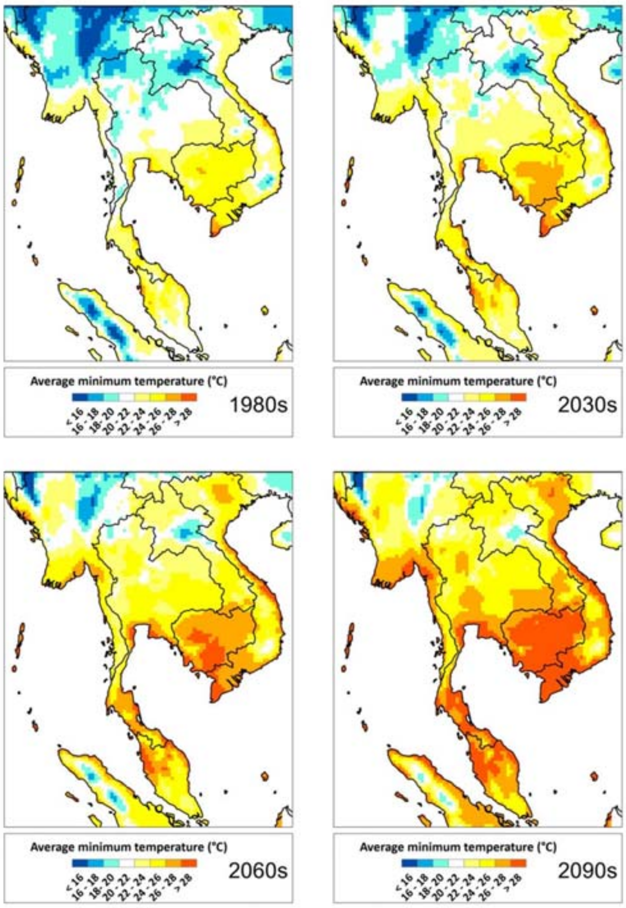

Figure 3. Average daily minimum temperature

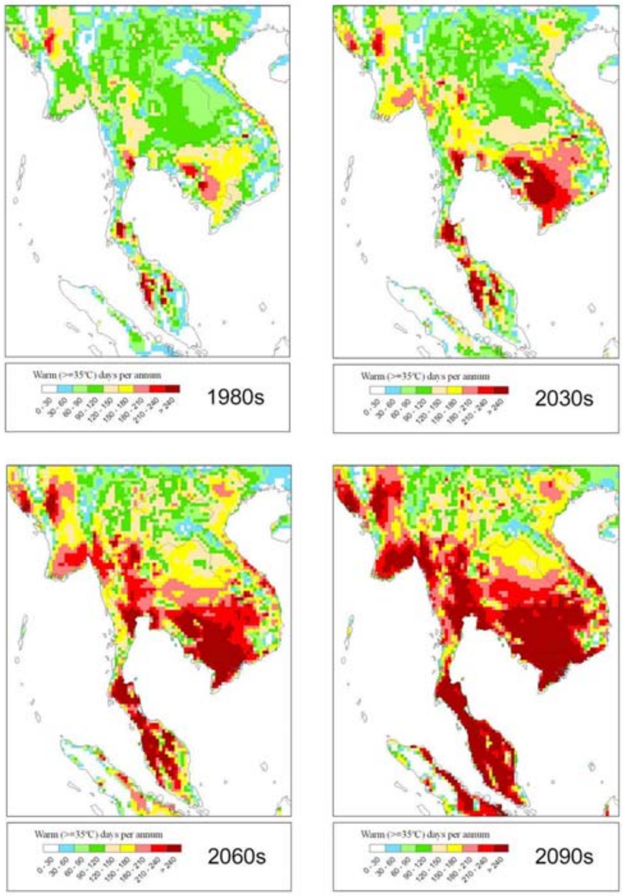

Figure 4. Length of hot period over the year - number of days with maximum temperature ≥35°C

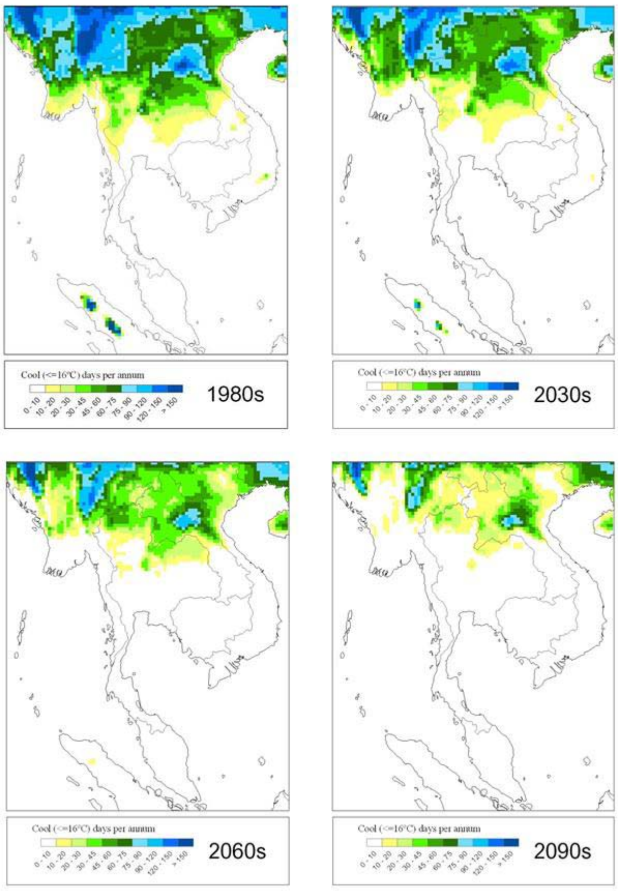

Figure 5. Length of cool period over the year - number of days with minimum temperature ≤16°C

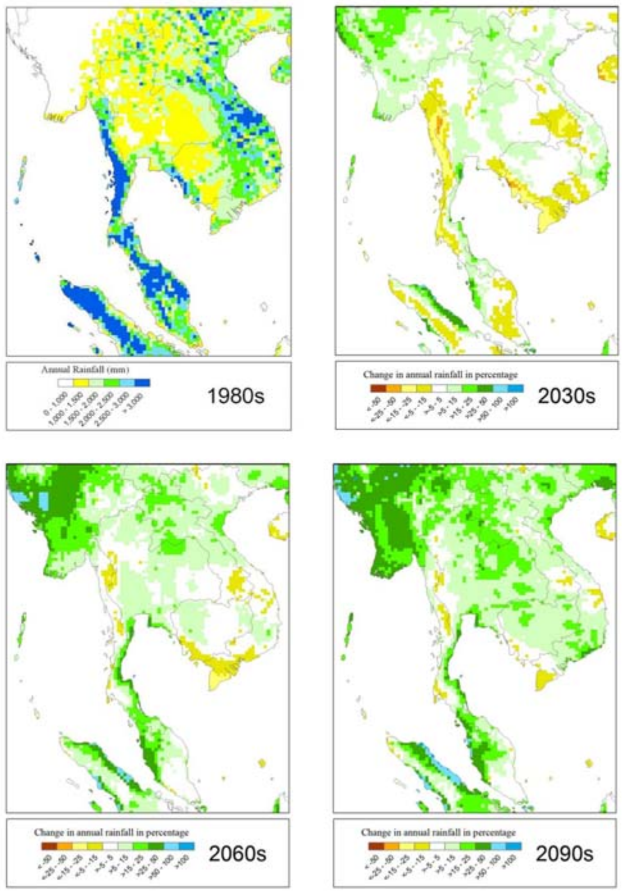

Figure 6. Annual precipitation (mm) and future change compared to 1980s (%)

support long-term planning. Using long-term climate projections for strategic planning to cope with climate change should not only consider change in average climate variables but also take various aspects of changes in climate pattern into consideration too; especially, change in the extreme value of any climate parameters and also the temporal aspect of change, e.g., changes in the length of seasons and shifting season patterns, etc. Moreover, it is important to be aware that this projection is a scenario of plausible future and cannot be taken as a long-term forecast. While there is a certain degree of uncertainty in the simulation result, however, it can still be used for strategic planning purposes.

One way to cope with uncertainty of long-term climate projection 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 also requires changes in the thought paradigm of policy planners to become familiar with the use of multiple climate datasets for policy planning. The use of multiple scenarios is not a matter of placing effort to seek the 'best' scenario, thus should be selected for the planning exercise; but the planning process should be based on a wide range of scenarios and examine whether or not plans for the future are resilient to various future conditions under climate change.

Conclusion

In brief, future climate in Southeast Asia tends to be warmer with longer summer-time and higher rainfall intensity during the rainy season with higher annual total precipitation. These changes are unlikely to be irreversible and would have impact on various systems and sectors. However, this future climate projection is just one plausible future scenario, which was simulated by a single climate model and single initial dataset. Additional climate change scenarios need to be further developed to address the uncertainty of long-term climate projection. Moreover, inter-comparison among other climate models is required to evaluate the results of the present study thus leading to improvement in future regional climate scenario simulations in the future.

Announcement

The dataset of future climate projection for A2 and B2 GHG scenarios is available for download at http://cc.start.or.th/.

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