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# Observed and projected changes in temperature and rainfall in Cambodia

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ABSTRACT

Temperature and rainfall patterns in Cambodia are governed by monsoons and characterized by two major wet and dry seasons. The average annual rainfall is 1400 mm in the central low land regions and may reach 4000 mm in certain coastal zones or in highland areas. The annual average temperature is 28 °C, with an average maximum temperature of 38 °C in April and an average minimum temperature of 17 °C in January. This paper presents the climate change scenarios using MAGICC–SCENGEN program, which links emissions scenarios with global and regional climate change and has adopted the regional climate model (PRECIS) in combination with a number of GCM models with resolution of 50 × 50 km, using observation data and two historical and future climate data sets generated by RCM model downscaling under the two emission scenarios SRES A2 and SRES B2. Projections of maximum and minimum temperatures and rainfall patterns from 2008 to 2099 are described. For future studies, daily data are required perform vulnerability and adaptation assessments.



## 1. Introduction

Climate scenarios rely on the use of numerical climate models and the continuous evolution of these models over recent decades has been enabled by a considerable increase in computational capacity, with supercomputer speeds increasing by roughly a factor of a million in the three decades from the 1970s (IPCC, 2007). These models have been used to evaluate future climate changes over time. Most of the ground breaking work on $CO_2$ induced climate change was based on atmospheric general circulation models coupled to simple ocean models. Climate change modeling advances at the present make it possible to generate the best estimates and provide the likely assessed uncertainty ranges for the projected warming for different emissions scenarios. The models project global average surface warming for the end of the 21st century (2090–2099) relative to 1980–1999 for both lower and higher SRES emission scenarios.

The global climate models provide a laboratory for numerical experiments of climate transitions during the past, present and future. General Circulation Models (GCMs) are a class of computer-driven models for weather forecasting, understanding of climate and for projecting climate change. There are both atmospheric GCMs (AGCMs) and ocean GCMs (OGCMs) which can be coupled together to form an atmosphere–ocean coupled general circulation model (AOGCM) (IPCC, 2007).

Global climate models drive the regional climate models; time-dependent large-scale lateral boundary forcing is imposed from GCM simulations. These simulations are 10 year time slices from the UKMO HadCM2 of the Hadley Centre in Reading (Johns et al., 1997). The 2 time slices from ECHAM4 are both from its transient greenhouse gas simulation. One of the time slices corresponds to present-day conditions in the simulation and the other to a doubling of greenhouse gases. Consequently, the global mean warming between the control and scenario time slices is virtually the same (2.6 °C). The model employs the proposed discretization of vertical terms as well as recently derived horizontal diffusion and dissipation forms (Becker, 2002). This circulation imposes strong northward heat transport, making the northern North Atlantic about 4 °C warmer than corresponding latitudes in the Pacific. Variations in ocean circulation therefore have the potential to cause significant large-scale climate change (Stute et al., 2001). The high computational cost is exacerbated by the requirement of ensemble and/or long simulations for statistical significance of the results. In practice, given the currently available computing power of climate research centers, most CGCMs employ computational meshes with grid-point spacing in the horizontal of some hundreds of km (Laprise, 2008).

Regional Climate Modeling (RCM) approach affords an increase of resolution over a region of the globe in comparison to the CGCMs, with regional grid-point spacing of a few tens of km in the horizontal, for operational use on climate timescales. The RCM approach could still be useful and to reach resolution of a few km for the same computational load (Laprise, 2008). A variation of this technique is to also force the large-scale component of the RCM solution throughout the entire domain (Evans et al., 2012). Dynamical downscaling is often seen as the alternative to statistical downscaling though most statistical approaches also can be applied to obtain point location data. The Regional Climate Model

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version 3, RegCM3, (Pal et al., 2007) data cover the time period from 1958 to 2001, excluding years 1961 and 1982 due to bad boundary condition data.

Future climate change modeling at national and regional scales is in its early days, but it is showing that the pace and scale of change is gaining momentum with potential effects on existing and future infrastructure and sector development. A rise in sea levels of 16 cm by 2030 and up to 45 cm by 2070 is expected and the extremes between wet and dry season rainfall would increase with some areas experiencing more extended dry periods (MRC, 2010a). Countries in the Lower Mekong Basin (LMB) are among the most vulnerable locations in the world with respect to climate change. While the future impact of climate change is difficult to forecast, projections for the Mekong River Basin for the next 20 to 30 years show that temperature is projected to increase by 0.023 °C/year. (Hoanh et al., 2010; MRC, 2010b).

### 1.1. National climate model

Cambodia's Initial National Communication to the UNFCCC includes the first attempt to assess the country's future climate using two General Circulation Models (GCMs), (MoE, 2002). The GCM models used in this analysis (CCSR and CSIRO) were developed for use in Japan and Australia which are two very different geographical regions. However, at the time of the assessment, there was an absence of more suitable models. The analyses showed that the deviation from the observed rainfall data was very significant (MoE, 2001). The projections conducted are in changes in the average temperatures and rainfall. With the caution that there was significant deviation between observed rainfall data output, the following projections were made for Cambodia: (i) mean annual temperatures could increase between 0.3 and 0.6 °C by 2025 and between 1.6 and 2.0 °C by 2100; (ii) mean annual rainfall could increase between 3% and 35% by year 2100 with the magnitude of change varying with time and location. Lowland areas would have higher increase in rainfall than highlands.

Cambodia has developed climate change scenarios and the associated impacts on sectors. The climate change scenarios were developed using the Model for the Assessment of Greenhouse-Gas Induced Climate Change–A Regional Climate Scenario Generator (MAGICC–SCENGEN) (Hulme et al., 2000; MoE, 2002), a program which links emission scenarios with global and regional climate change. In the second national communication, Cambodia has adopted regional climate models in combination with a number of GCM models run by the Climate Risk Assessment Division, Center for Global Environmental Research, National Institute for Environmental Studies (NIES) with a resolution of $100 \times 100$ km (Masutomi et al., 2009). To cope with the scarcity of historical climate data in evaluating the impact of current climate variability on sectors, long time historical climate data have been reconstructed using PRECIS for Cambodia as a whole. A dynamic-based impact model was adopted for the agriculture sector.

Cambodia is among a group of 52 developing countries for which Oxford University has completed climate change country profiles (McSweeney et al., 2008). The profiles are based on data collected from national weather stations through the World Climate Research Programme (WCRP) and available on the Global Historical Climatology Network (GHCN). Cambodia's profile includes average time series of observed data over the period 1960–2006, and projected future climate under three IPCC emission scenarios (A2, A1B and B1). The respective storylines of the scenarios are differentiated world, market oriented world, and convergent world. The climate models consist of a subset of 15 from the 22 used by the IPCC in its Fourth Assessment Report. Maps depict projected changes for decade long time slices in 2030, 2060 and 2090 on a $2.5 \times 2.5$ degrees grid.

The modeling of changes in precipitation projected that the increase would mainly be in the central agricultural plains stretching from the southeast to the northwest, where rainfall has historically been below the national average. The adjustment was necessary because the RCM data for this period includes some extreme values, for example, some daily precipitation RCM values are between 500 and 1000 mm and some are even over 1000 mm; values which were not recorded in the observed dataset. These values result in too high water yields and river flows in several catchments in the model outputs. The adjustment is first applied to the precipitation data, then for other parameters such as maximum and minimum temperatures, wind speed and solar radiation. After running the SWAT model for all sub-basins, the Integrated Quantity Quality Model (IQQM) model was also run for the whole Basin. In addition, the ISIS model was run for the Tonle Sap and the Delta (MRC-IWMI, 2010). Information and data on the climate change model situation at the national level in Cambodia predicted that there will be an increase in mean annual temperature of between 1.4 and 4.3 °C by 2100. Mean annual rainfall is also predicted to increase, with the most significant increase experienced in the wet season. As with the other countries in the LMB, flooding and droughts are expected to increase in frequency, severity and duration. The potential impacts of climate change include changes to rice productivity, with increases in wet season crops in some areas and decreases in others; acceleration of forest degradation including the loss of wet and dry forest ecosystems; inundation of the coastal zone and higher prevalence of infectious diseases (MRC, 2009).

Future climate projections on a daily basis for the two IPCC Special Report on Emission Scenarios (SRES) scenarios (A2 and B2) provided by the Southeast Asia System for Analysis Research and Training Regional Center (SEA START Regional Centre) were based on the European Centre Hamburg for Medium Range Weather Forecast (ECHAM4) GCM from the Max Planck Institute for Meteorology, Germany and downscaled to the Mekong region using the Providing Regional Climate for Impact Studies (PRECIS) system. The PRECIS data for the baseline 1985–2000 period were adjusted by comparing them with the available observed data in the Decision Support Framework (DSF). Adjustment methods were applied in an effort to calibrate the models to match the flow regime outputted from the DSF for Scenario S2 with that from Scenario S1 using the available observed data. Such adjustment, called bias-correction by Fujihara et al. (2008), is needed to make the downscaled monthly values of the simulated climate for the past period match the observed monthly values and observed precipitation data at stations aggregated to sub-basins by using the program in the DSF and RCM data aggregated to sub-basins with a resolution of $0.2^\circ \times 0.2^\circ$. The Soil and Water Assessment Tool (SWAT) model was run to identify the suitable adjustment methods by comparing outputs from model runs with adjusted RCM data and with observed climate data for 1985–2000 (MRC-IWMI, 2010). Highly-reproduced horizontal resolution along with more accurate topography in an RCM simulation carries strong influences on model physics and dynamics, and produces better simulation results over a particular region. This provides more eligible results compared to the global circulation model output, particularly for presenting information to support impacts assessment studies (MoE, 2010). The objective is to assess past and future climate change of Cambodia using reconstructed data from PRECIS and GCM models.

## 2. Methodology

### 2.1. Approach process

In the approach process, the first step is to reconstruct long term historical climate data using analysis data from PRECIS downscaling. This analysis was performed to cope with data gaps. The second step is