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Development of climate change scenarios for small areas in Vietnam by using the MAGICC/SCENGEN software in combination with statistic correction

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Abstract. Climate change has been happening in scales of the global, regional as well as in Vietnam because of human activities which impulse greenhouse gas increasing in the atmosphere. To cope effectively with climate change, the understanding of future climate based on climate change scenarios, particularly scenarios for small areas, is essential. This paper concerns on the application of MAGICC/SCENGEN 5.3 software in combination with statistic correction to develop climate change scenarios for small areas in Vietnam. Results showed that the temperature is increased, while rainfall is changed heterogeneity and seasonally in the regions in Vietnam.

Keywords: climate change scenario, MAGICC/SCENGEN.

1. Introduction

Climate change is a global essential issue with increases in temperature, changes in precipitation, and sea level rise that cause earth's climate system changed and affected the natural environment [1].

Development of the detailed climate change scenarios for Vietnam, especially at local scale and main economic regions is very important. Those scenarios are bases for assessing climate change impact on different sectors of nature, socio-economics and building target program of climate change adaptation and mitigation. In which, agriculture and forestry, water source management, and construction are the most important.

2. MAGICC/SCENGEN software

MAGICC has been used as the primary model by IPCC to project the future global-mean temperature and sea level rise since 1990. The software has been studied and upgraded continually and thoroughly with three versions: the 2.4 version was used in the IPCC Second Assessment Report, the 4.1 version used in the IPCC Third Assessment Report, and the 5.3 version used in the IPCC Fourth Assessment Report [1].

MAGICC (stands for Model for Assessment of Greenhouse-gas Induced Climate Change), a combination of models of coupled gas-cycle,

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climate and ice-melt, can be used to estimate the mean global temperature and effects of sea level rise under the different emission GHGs and aerosol scenarios. MAGICC model is developed by T.Wigley and S.Raper at CRU (in the UK) and NCAR (in the USA) – two main supporting organizations of IPCC [2, 3, 4].

SCENGEN (stands for Regional Climate SCENario GENeretor) is used to generate a range of geographically explicit climate change projections by using combination results of MAGICC together with General Circulation Model (GCM), coupled Atmospheric–Ocean General Circulation Models (AOGCM) and local observed data. In combination with the observed data, SCENGEN can generate climate scenarios for any regions and any time period in the 21st century. The baseline climate data used in the model is the period of 1961-1990 and results are given as array files on a standard 2.5x2.5 degree latitude/longitude grid.

The first step to use the software is to select a pair of emissions scenarios: with and without policy SRES scenarios. After that users can select/change climate model parameters that may affect climate compositions as well as future climate. The next step is to select model of gas-cycle to convert emission into concentration of species. Concentration of gas-house will be used to estimate the radiation which added from GHG mentioned above. These parameters are essential need to run sub-models in MAGICC model. These results of model are given in change in future mean temperature and sea level rise which are input conditions of SCENGEN model.

The other input parameters of SCENGEN model are: an AOGCM from 17 global models, a set of observed data, predictands, time and areas for predicting. SCENGEN converts changes of regional model into exact values of selected climate variables. It means that SCENGEN can replace a regional value by a climate standard value corresponding to a choosing time. Because baseline climate data using in SCENGEN is 30 years from 1961-1990, the results of model are only given as averaged values of 30 years in future.

The results of SCENGEN can be changed following the predictands at grid points at the choosing time under selected emission scenarios. The results are displayed as follows: change levels, errors, observed values of baseline period, changes in comparison with baseline. The grid outputs of SCENGEN can be of temperature, precipitation, and sea level rise at different time-scales such as monthly, seasonally, annually.

In the latest version of the software (5.3 version), the results of the IPCC Fourth Assessment Report (AR4) with many different coupled types are updated. Additionally, this version has projected mean sea level pressure with the resolution of 2.5x2.5 degree latitude/longitude for all emission scenarios instead of 5x5 degree latitude/longitude.

IPCC recommends that MAGICC/SCENGEN software can be used as a useful tool for nations to regions in terms of developing climate change scenarios.

3. Developing climate change scenarios for small areas of Vietnam

Based on software MAGICC / SCENGEN, we have built climate change scenarios for small areas of Vietnam such as the Red River basin, the Lao Cai area, Thua Thien Hue region, and other climatic regions of Vietnam as well [5] and most recently climate change scenarios for Da Nang, Quy Nhon and Can Tho.

To build climate change scenarios for Da Nang, Quy Nhon and Can Tho, we use a combination of software MAGICC / SCENGEN 5.3 with statistic downscaling method. Calculation process is as follows:

♦ Determining scenarios directly from MAGICC / SCENGEN 5.3

Running software MAGICC/SCENGEN 5.3 with high (A1FI-MI, A2-MES) and medium (B2-MES) GHG emission options to develop scenarios of decadal changes in temperature and rainfall for the 21st century for the domains [15-17,5^{0}N/107,5-110^{0}E], [12,5-15^{0}N/107,5-110^{0}E], [10-12,5^{0}N/105-107,5^{0}E] covering Da Nang, Quy Nhon and Can Tho respectively.

♦ *Statistic correction*

To supplement regional features in climate change scenarios, we have used statistic Downscaling method with conversion functions built from two datasets: Observed data at Da Nang, Quy Nhon and Can Tho stations and analytical data from global model of European Centre for Medium-Range Weather Forecasts (ECWMF). The conversion function which has been used to adjust climate change scenarios is the product of MAGICC/SCENGEN.

The conversion functions formed as $y = ax+b$ (Table 1) have been tested for the statistic reliability through:

+ Assumption testing the magnitude of the correlation coefficient Rxy

+ Assumption testing the magnitude of the coefficient of regression equation

+ Assumption testing the efficiency of regression equation

The test result showed that the regression equation for the temperature ensures statistical reliability with significance level 0.05. However, most of the regression equations for the rainfall are not reliable enough and as the result, the scenarios for rainfall generated by the products of MAGICC/SCENGEN 5.3 software need more consideration.

In the study, the temperature and rainfall scenarios are built in the monthly form of decades of the 21st century. However, within the scope of this paper, we only introduce climate change scenarios that are summarized in the four main seasons in Vietnam.

Table 1. Calculating results of coefficients of regression equations for temperature of Da Nang, Quy Nhon and Can Tho.

Month	Da Nang		Quy Nhon		Can Tho	
	a	**b**	**a**	**b**	**a**	**b**
Jan.	1.14	0.02	0.91	0.01	0.92	-0.03
Feb.	1.05	0.00	0.88	0.02	0.71	-0.01
Mar.	1.02	0.02	1.06	0.01	0.65	-0.01
Apr.	0.95	0.01	1.16	0.00	0.58	-0.01
May	1.08	0.00	0.78	-0.01	1.23	-0.05
Jun.	0.83	-0.01	0.69	0.01	1.14	-0.04
Jul.	0.65	-0.01	0.49	0.02	0.43	-0.02
Aug.	0.72	0.00	0.66	0.03	0.93	-0.01
Sep.	0.96	0.00	0.85	0.01	0.66	-0.01
Oct.	0.94	0.00	0.91	0.00	0.69	0.00
Nov.	1.09	0.00	0.99	0.00	0.54	-0.01
Dec.	1.31	-0.07	1.13	-0.05	0.96	-0.03

3.1. Temperature scenarios

Climate change scenario for temperature (Table 2) shows that temperature increases gradually to the end of 21st century in all emission scenarios from medium (B2) to high (A2) and to the highest (A1FI) scenarios. Of which, Da Nang is a city with the highest value in increasing level, followed by Quy Nhon and Can Tho. This is quite compatible with the temperature happening in the past (increasing level declined southwards). In addition, temperatures in all three cities in winter (from

Dec. to Feb.) can increase faster than those in summer (from Jun. to Aug.).

By the end of the 21st century, annual mean temperatures under the emission scenarios from medium to high can increase by 2.2 to 3.8°C in Da Nang, 2.0 – 3.5 °C in Quy Nhon and 2.0 – 3.4 °C in Can Tho relative to the baseline period (1980 - 1999). The months with highest increase in temperatures are often December to February in Da Nang with 2.5-4.2 °C of the increase, March to May in Quy Nhon and Can Tho with 2.4 - 4.2 °C and 2.3 – 3.9 °C respectively. On the contrary, the months with lowest increase in temperatures are often June to August in all three cities with 1.7 - 2.9 °C in Da Nang, 1.5-2.6 °C in Quy Nhon and 1.4-2.5 °C in Can Tho.

3.2. Rainfall scenarios

Rainfall scenarios show that rainfall in dry season can decrease whereas rainfall in rainy season can increase and annual rainfall can increase in all research areas under the emission scenarios from highest (A1FI), to high (A2) to medium (B2). By the end of the 21st century, under the emission scenarios from medium to high, annual rainfall can increase about 5-9% in Da Nang, 2– 4% in Quy Nhon and 2% in Can Tho. In dry season, the months with the highest decrease are from March to May with 5-10% of decrease in Da Nang, 13-24% in Quy Nhon and 18-31% in Can Tho; the months with the lowest decrease are from December to February with 2-5% of decrease in Da Nang, 10-18% in Quy Nhon and 13-23% in Can Tho. In the rainy season, on the contrary, the months with the highest increase are from September to November with 10-18% in Da Nang, 11-20% in Quy Nhon and 13-23% in Can Tho; the months with the lowest increase are from June to August with 8-15% in Da Nang, 1- 9% in Quy Nhon and below 1% in Can Tho.

Table 2. Changes in Annual Mean Temperature (°C) in the 21st century relative to period from 1980-1999 under emission scenarios from A1FI – A2 – B2.

Cities	Season	Time period in the 21st century								
		Medium (B2)			High (A2)			Highest (A1FI)		
		2050	2070	2100	2050	2070	2100	2050	2070	2100
Da Nang	Dec. – Feb.	1.3	1.8	2.5	1.4	2.1	3.5	1.8	2.9	4.2
	Mar.–May	1.2	1.7	2.4	1.3	2.1	3.4	1.7	2.9	4.1
	Jun.–Aug.	0.9	1.2	1.7	1.0	1.4	2.4	1.2	2.0	2.9
	Sep.–Nov.	1.2	1.6	2.2	1.2	1.9	3.2	1.6	2.6	3.8
	Year	1.2	1.6	2.2	1.2	1.9	3.1	1.6	2.6	3.8
Quy Nhon	Dec. – Feb.	1.1	1.5	2.1	1.2	1.8	2.9	1.5	2.5	3.6
	Mar.–May	1.3	1.8	2.4	1.4	2.1	3.5	1.8	2.9	4.2
	Jun.–Aug.	0.8	1.1	1.5	0.9	1.3	2.1	1.1	1.7	2.6
	Sep.–Nov.	1.1	1.5	2.1	1.2	1.8	3.0	1.5	2.5	3.7
	Year	1.1	1.5	2.0	1.2	1.8	2.9	1.5	2.4	3.5
Can Tho	Dec. – Feb.	1.1	1.5	2.1	1.2	1.8	2.9	1.5	2.5	3.6
	Mar.–May	1.2	1.7	2.3	1.3	2.0	3.2	1.7	2.7	3.9
	Jun.–Aug.	0.8	1.1	1.4	0.9	1.3	2.0	1.1	1.7	2.5
	Sep.–Nov.	1.1	1.5	2.2	1.2	1.9	3.0	1.5	2.6	3.7
	Year	1.1	1.4	2.0	1.1	1.7	2.8	1.4	2.4	3.4

Table 3. Changes in Annual Rainfall (%) in the 21st century relative to period from 1980-1999 under emission scenarios from A1FI – A2 – B2

Cities	Season	Time period in the 21st century								
		Medium (B2)			High (A2)			Highest (A1FI)		
		2050	2070	2100	2050	2070	2100	2050	2070	2100
Da Nang	Dec. – Feb.	-1.5	-2.1	-2.9	-1.7	-2.5	-4.1	-2.1	-3.4	-5.0
	Mar.–May	-2.8	-3.9	-5.5	-3.0	-4.7	-7.7	-3.9	-6.4	-9.3
	Jun.–Aug.	4.5	6.2	8.6	4.8	7.4	12.2	6.2	10.1	14.6
	Sep.–Nov.	5.5	7.6	10.6	5.9	9.2	15.0	7.6	12.4	18.0
	Year	2.8	3.8	5.3	3.0	4.5	7.4	3.8	6.2	9.0
Quy Nhon	Dec. – Feb.	-5.3	-7.2	-10.1	-5.7	-8.7	-14.2	-7.3	-11.9	-17.2
	Mar.–May	-7.1	-9.7	-13.6	-7.5	-11.7	-19.1	-10.3	-15.9	-23.1
	Jun.–Aug.	0.6	0.7	1.1	0.6	0.9	1.5	0.8	1.2	8.1
	Sep.–Nov.	5.9	8.1	11.3	6.3	9.7	15.9	8.2	13.8	19.2
	Year	1.2	1.7	2.3	1.3	2.0	3.2	1.7	2.7	3.9
Can Tho	Dec. – Feb.	-6.9	-9.4	-13.5	-7.2	-11.4	-18.6	-9.5	-15.5	-22.5
	Mar.–May	-9.4	-12.9	-18.1	-10.0	-15.5	-25.4	-13.0	-21.2	-30.8
	Jun.–Aug.	0.1	0.2	0.3	0.1	0.2	0.3	0.2	0.3	0.4
	Sep.–Nov.	7.0	9.6	13.5	7.4	11.6	18.9	9.7	15.7	22.8
	Year	0.4	0.5	0.7	0.4	0.6	1.0	0.5	0.8	1.2

In short, the temperature increases and rainfall changes in Da Nang, Quy Nhon and Can Tho are compatible with the temperature and rainfall scenarios that developed for the climatic zones in Vietnam [5-7].

4. Conclusions

By the end of the 21st century, annual mean temperatures can increase by 2.2 to 3.8°C in Da Nang, 2.0 – 3.5 °C in Quy Nhon and 2.0 – 3.4 °C in Can Tho relative to the baseline period (1980 - 1999) under the emission scenarios from medium to high.

Annual rainfall and rainfall in rainy season can increase whereas rainfall in dry season can decrease in all cities: Da Nang, Quy Nhon and Can Tho. By the end of the 21st century, annual rainfall can increase about 5-9% in Da Nang, 2–4% in Quy Nhon and 2% in Can Tho under the emission scenarios from medium to high.

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