Climate Change: Precipitation Projection for Vietnam Simulated by a Super-high-resolution Model

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Abstract: *Climate change is generally recognized as a serious threat to the society driven from human activities. Global warming and many changes in the global climate system during the 21st century are unavoidable. To estimate and reduce risks and impacts of climate change, it is necessary to study and project how the climate will be in the future. This paper aims to present a future precipitation scenario for Vietnam by extracting and analyzing the results of the MRI-AGCM with 20 km-mesh. Under the A1B emission scenario of IPCC, super high-resolution future scenario for the Vietnam climate shows an overall pattern of precipitation with spatially and temporally varying projection. In the rainy season, an increase of precipitation by 10-20% was projected in a large area in the Red River delta and the Mekong River Delta. The remaining area including the Central highland, the South Central coast is projected to decrease with the profound in Phu Yen, Khanh Hoa, Ninh Thuan and Binh Thuan provinces (in the South Central coast). The increase in the two mentioned biggest river deltas where floods often occurring and the decrease in the South Central coast where is considered as the driest area in Vietnam make precipitation more uneven and variable over time and space.*

Keywords: climate change, precipitation scenarios, MRI-AGCM.

1. Introduction

Climate change is generally recognized as a serious threat to the society driven from human activities. According to the fourth assessment report of IPCC [1], global warming and many changes in the global climate system during the 21st century are unavoidable. To estimate and reduce risks and impacts of climate change, it is necessary to study and project how the climate will be in the future.

For climate simulation, the global climate circulation models (GCMs) are often applied, but GCMs regularly fail to capture the fine-scale structures that affect regional climate due to their insufficient resolution. Enhancing the resolution of a GCM can resolve features on better spatial scales, which were till now resolved by utilizing nested high-resolution regional models. With high resolution, the regional–global-scale interactions can be integrated comprehensively and regional climate information such as land–sea distribution, lakes, soil characteristics and orography can be better represented, so that the simulation will be useful for local impact assessments [6].

Having a super computer (the Earth Simulator), Meteorological Research Institute (MRI)/Japan team can run a super-high-resolution atmospheric general circulation model (AGCM) to simulate a future climate. The climate change projection by this AGCM (or 20 km-mesh MRI-AGCM) may provide a basic foundation of adaptive behavior for many countries. Under the cooperation between Japan and the other Asia countries, Vietnam has been invited to take part in the training program which is organized as a three-year program (2008-

2010) to realize the final result for adaptation to climate change – climate change analysis [2].

This paper aims to present and address on a future precipitation scenario for Vietnam by extracting and analyzing the results of the MRI-AGCM with 20 km-mesh. The model simulates the future climate, including precipitation, under the A1B emission scenario of IPCC.

2. Experiment and obseved data

2.1 Experiment

A set of experiments is for the present-day climate simulation. The Atmospheric Model Intercomparison Project (AMIP) has been run using the observed monthly SST and sea-ice concentration dataset to generate the present climate of 25 years for 1979–2003 [7].

For a future climate, the time-slice 25-year simulation towards to the end of the 21st century from 2075 to 2099 was performed. Figure 1 shows how to prepare the boundary Sea Surface Temperature (SST) for the time-slice experiment [3]. It can be seen that the boundary SST data was acquired by superposing, (i) the changes in the multi-model ensemble (MME) of SST projected by the CMIP3 multi-model dataset, (ii) the future changes in MME of SSTs evaluated by the difference between the 20th century simulations and the future simulations of the IPCC A1B emission scenario and, (iii) the detrended observed SST anomalies for the period 1979-2003. Moreover, a linear trend for future climate by the AOGCMs was taken into account. The design retains an observed year-to-year variability and El Niño and Southern Oscillation (ENSO) events in future climate, and with a higher mean and clear increasing trend in SST [3,4].

In order to assess the uncertainty of future climate projections, the ensemble simulations with the 60-km resolution model were executed. Four different SSTs are used for future climate simulations by the 60-km mesh model. One experiment used the CMIP3 model ensemble SST and sea-ice distributions as in the 20-km mesh model experiment. Three other experiments used the SST anomalies of CSIRO-Mk3.0, MRI-CGCM2.3.2 and MIROC3.2 (hires) models. Effective climate sensitivity of each model is 2.21°C, 2.97°C and 5.87°C, respectively, and the global annual mean SST increase becomes larger in this order. The CMIP3 ensemble mean climate sensitivity is 2.98°C. For each of the standard set of AMIP-run and the CMIP3 SST anomaly run, three member simulations are performed with different initial conditions.

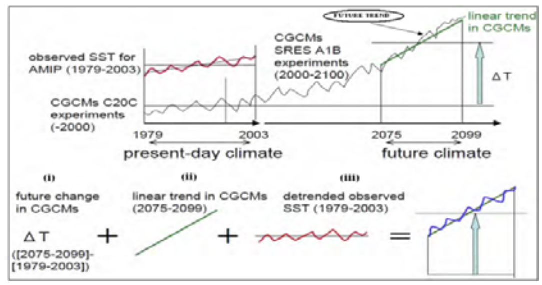

Figure 1. Schematic diagram of the estimation method for the future sea surface temperatures toward the end of 21st century [3]

2.2 Observed data

In this study, the GPCP One-Degree Daily Precipitation Data Set for 10 years (1998-2007) and 8 years (1997-2004) on a 1.0° lat/lon grid was used for precipitation verification. Besides, the monthly mean data of rainfall amount and average temperature from 1979 to 2007 of 45 meteorological stations which contributed rationally over Vietnam were used to verify the simulation over Vietnam.

3. Present simulation

The MRI AGCM simulates realistically the rainfall over the country in terms of spatial and temporal distribution. Figure 2 illustrates the rainfall simulated by the model, while Figure 3 shows the obseved rainfall. The rainfall season starts mainly from the early June (sometimes from the late May) in the North and gradually moving to the South. In the rainy season, the model captures an important aspect of the country distribution. This is the large rainfall center in Vietnam which located in the Northern mountain region of the North. With season going on, the rainfall center moves southwards to the South Central coast (Figure 2, 3).

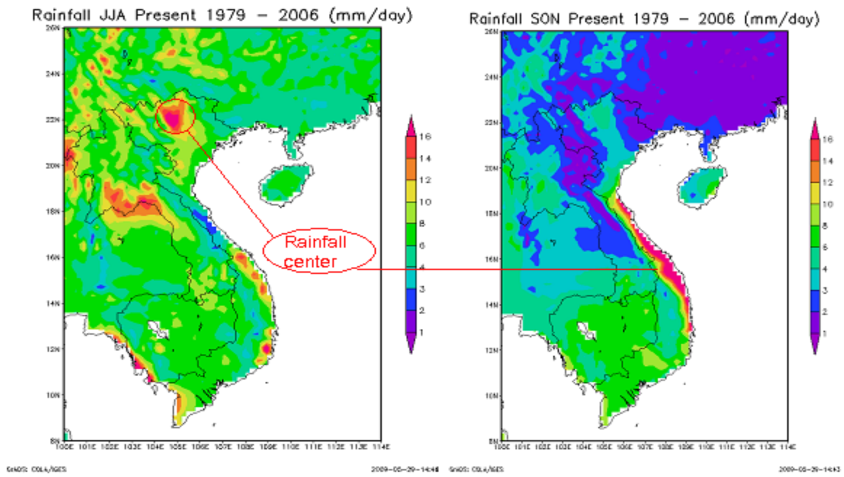

Figure 2. Rainfall distribution over Vietnam, simulated by MRI-AGCM 20km resolution

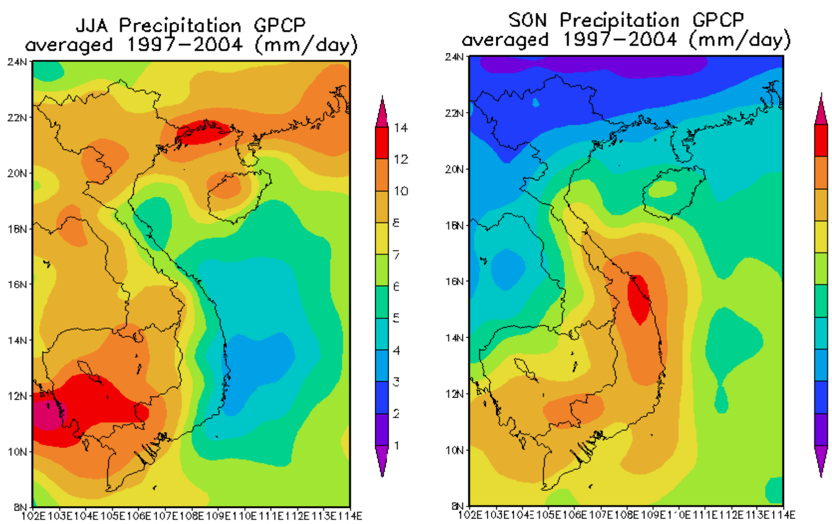

Figure 3. Schematic graph of One-Degree Daily Precipitation Data Set for 8 years (1997-2004) distribution over Vietnam

The MRI – AGCM produces and shows the important role of monsoon circulations in the seasonal distinction in precipitation. The sudden enhancement in monthly precipitation associated with the onset phase, the persistence of intense rainfall during June to August in the north, from August to November in the Central, and from June to November in the South is well illustrated (Figure 4). The rainfall amount reduction after the withdrawal of monsoon circulations is also well captured in Figure 4. The model also produces appropriate figures of the rainfall amount. However, the model tends to overestimate the precipitation during the rainy season in some places in the Central (for example at Tamky in Figure 4).

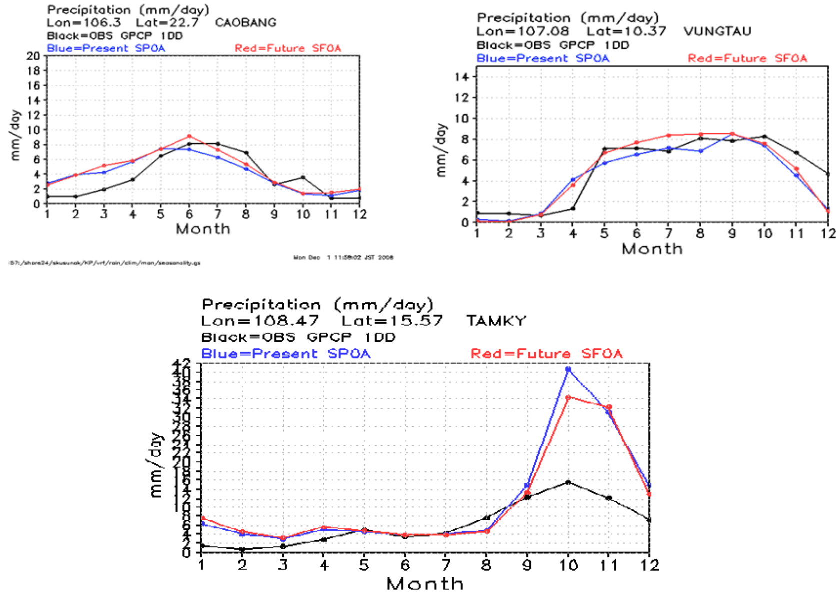

Figure 4. Yearly rainfall evolution of obseved (black lines) and simulated (blue and red lines) at the North (CAOBANG), Central (TAMKY) and South (VUNGTAU)

On the other hand, unsatisfied features occur in some areas where the topography is complicated. For example, the rainfall at Nhatrang station, where is near the East Sea and blocked from the north by a high mountain pass named Deo Ca, is not well simulated by the model (Figure 5). The areas with the unsatisfied simulations should be studied in detail and need to correct the bias.

4. Climate change projections

4.1 Precipitation

This section analyses and discusses the projected changes at the end of the 21st century (2075-2099) compared to the present (1979-2003) climate using the MRI outputs.

In the rainy season, the model predicts an overall pattern of precipitation with changes which is not the same from regions to regions (Figure 6). An increase of precipitation by 10-20% was projected in a large area in the Red River delta and the Mekong River Delta. The remaining area including the Central Highlands, and the South Central is projected to decrease with the profound in Phu Yen, Khanh Hoa, Ninh Thuan and Binh Thuan provinces (in the South Central coast). Increases in the two biggest river deltas where floods often occurr and decreases in the South Central coast where is considered as the driest area in Vietnam make precipitation more uneven and variable over time and space.

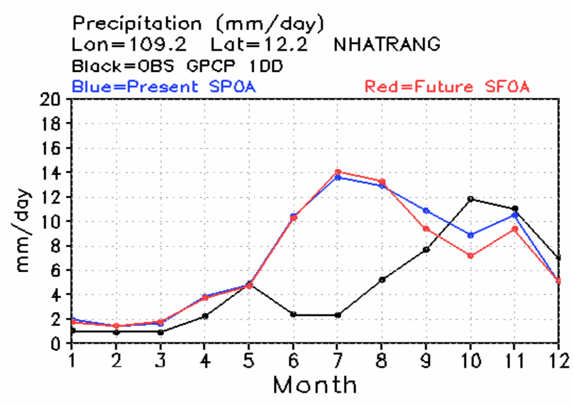

Figure 5. Schematic graph of unsatisfied simulations in comparison with observations

It can be seen an agreement between monthly and seasonal variations in each region. For example, the increase is projected in the Red River Delta and the South in the early months of the rainy season (May to July), whereas the decrease is projected in the Central Highlands and the South Central throughout the rainy season (Figure 8). For the whole country, however, the monthly rainfall is decreasing in May, June, August and increasing in July, September to November (Figure 7, 8). A small disagreement between this remark and the Ministry of Natural Resources and Environment (MoNRE) statement is that the rainfall decreases in the July [5].

In addition, there is a remarkable dissimilarity between the MRI precipitation outputs and MoNRE's study in terms of the changing percentage. MoNRE projects an increase of up to 8.8 % (MoNRE, 2003), while the model projects a more significant increase of about 20 % by the end of the 21st century. However, the MRI result is correspondent with the UNDP report [8].

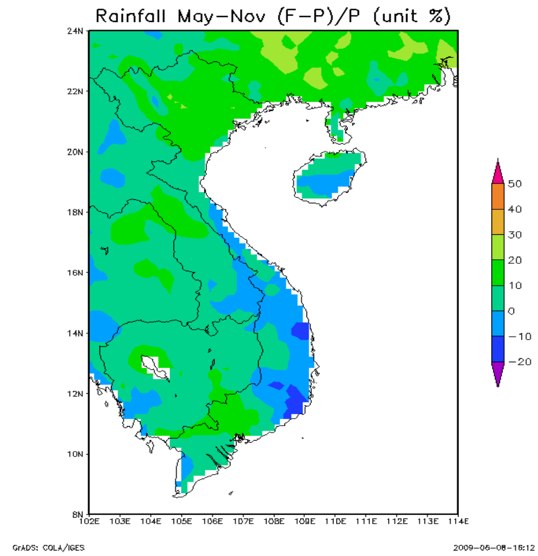

Figure 6. Difference rate (%) of mean precipitation between future projection and present-day simulation of the 20km model, from May to November

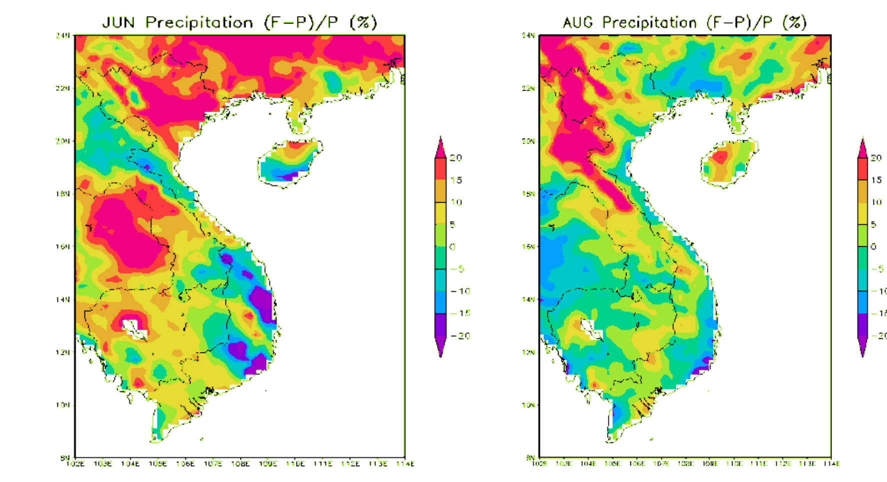

Figure 7. Precipitation increases in the Red River Delta and the South, but generally decreases in the whole country in the early months of rainy season (except July), simulated by MRI model

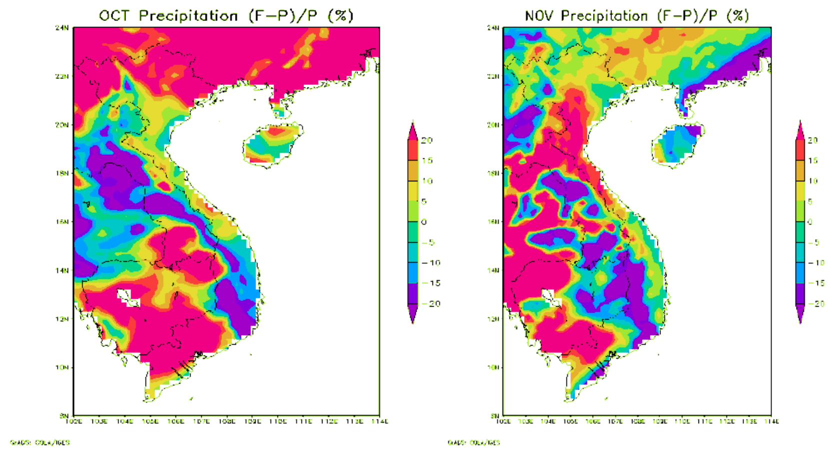

Figure 8. Precipitation generally increases in the whole country in the late months of rainy season, simulated by MRI model

In the dry season, an outstanding figure is the difference in the overall pattern compared to that in the rainy season. This is an opposite trend in the precipitation changes in North mountain region of the North and downstream of Mekong River Delta. The decline in these regions down to 10 % and even more than 20 % in Tra Vinh and Ben Tre provinces (located in the Mekong River Delta). The MRI model also produces a significant decrease, in the same situation as the rainy season, with more than 20 % in Dac Nong (in Central Highland), Phu Yen and Binh Thuan (in the South Central coast) provinces (Figure 9). Climate change, therefore, may lead to an exacerbation of drought problems in the Central Highland and the South Central coast.

4.2 Extreme events

Extreme events can be affected by global warming in their frequency, intensity and occurring time. Extreme events such as typhoons, floods, droughts and heavy rain threaten to lives and property all over the world. Thus, it is important to determine how the character of such events could change in response to GHG-induced global warming in future. In the different ways, recent studies for Vietnam (Stweeney *et al*, 2008; MoNRE, 2003; UNDP, 2007) have shown that there are positive trends in the frequency heavy rain or in some places reduced

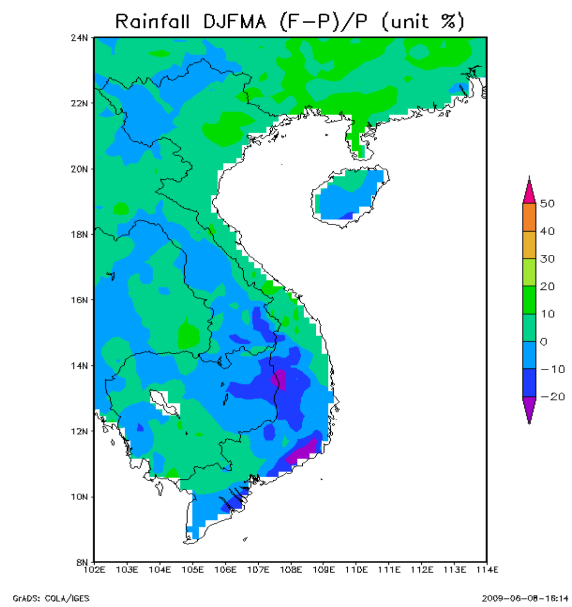

Figure 9. Difference rate (%) of mean precipitation between future projection and present-day simulation of the 20km model, from December to April

precipitation events. The changes in floods, droughts as well as typhoon patterns were reported with agreements between these studies. However, some differences exist, which may result from the different emission scenario chosen and many other reasons. Therefore, studying these extreme event changes are needed more in depth with variety methods.

However, it is a fact that these extreme events such as typhoons are poorly captured by GCMs and thus potential changes in frequency and intensity in the future is very uncertain. Therefore, the report will focus on "extreme indices" proposed by Frich *et al.* (2002) as they are widely used in recent studies and adopted as IPCC standard output data for the IPCC 4th Assessment Report (Table 1) (Kamiguchi *et al.*, 2006).

Table 1. Extreme indexes on precipitation (modified from Kamiguchi *et al.*, 2006).

Index	Unit	Definition
CDD	days	Consecutive dry days: The annual maximum number of consecutive dry days with rainfall amount less than 1mm/day
R5d	mm	Maximum 5-day precipitation total: The annual maximum consecutive 5-day precipitation total
R10	days	The number of days in a year with precipitation ≥10mm/day
SDII	mm/ day	Simple daily intensity index: Total annual precipitation divided by the number of days with ≥ 1mm/day

Figure 9 shows the maps of changes in the precipitation extreme indices between the future climate simulation and present-day simulation of the 20-km model. The dry spell index (CDD) increases up to 10 days per year in the South, and slight decreases in the North mountain region of the North, whereas changes insignificant in the remaining of the country (Figure 9a). On the other hand, heavy rain indices (SDII, R5d, R10) change extensively in the country. In detailed, all three heavy rain indices decrease in the coastal zone from Quang Binh province southwards to Binh Thuan province, and increase in the large remainder of the country (Figure 9 b,c,d).

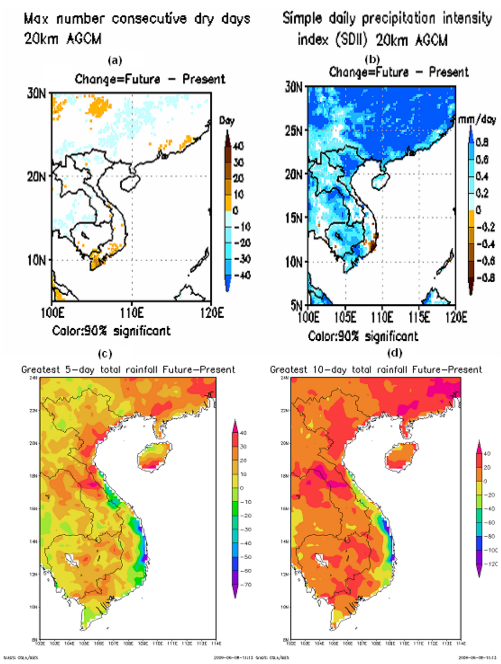

Figure 9. The maps of future change in the precipitation extreme indices between the future climate simulation and present-day simulation of the 20-km model.

Conclusions

The MRI AGCM well simulates rainfall over Vietnam in terms of spatial and temporal distribution. The precipitation characteristics are well captured by the model in almost the country. However, the model produced unsatisfied features in some areas, especially in the place with complex topography. In these areas, the bias of the model which is not mentioned in this paper should be studied in detailed and an adjustment or correction should be applied for future projection.

Under the A1B emission scenario, the super high-resolution future scenario for the Vietnam climate shows an overall pattern of precipitation with spatially and temporally varying projection. In the rainy season, an increase of precipitation by 10-20% was projected in a large area in the Red River delta and the Mekong River Delta. The remaining areas including the Central Highlands, the South Central coast are projected to decrease with the profound in Phu Yen, Khanh Hoa, Ninh Thuan and Binh Thuan provinces (in the South Central coast). The increase in the two mentioned biggest river deltas where floods often occurr and the decrease in the South Central coast where is considered as the driest area in Vietnam make precipitation more uneven and variable over time and space.

During the rainy season, the monthly rainfall is projected to decrease in May, June, August and increase in July, September to November. This remark is in agreement with the MoNRE result except the trend of rainfall in July.

In the dry season, the model outputs show a rainfall deficit in many areas from the North to the South. The rainfall amount might fall down to 10 % and even more than 20 % in the Central Highlands and the South Central coast. Therefore, the climate change may lead to an exacerbation of drought problems in these areas.

The model projects significant spatially heterogeneous change in heavy precipitation over the country by the end of the 21st century with a positive trend overwhelming in terms of heavy rainfall.

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