Future urban climate projection for a mega city in Asia: Greater Ho Chi Minh City metropolitan area, Vietnam

Quang-Van Doan [1], Hiroyuki Kusaka [2]

[1] *Graduate School of Life and Environmental Sciences, University of Tsukuba, Tsukuba, Japan. Email: doanquangvan@gmail.com*

[2] *Center for Computational Sciences, University of Tsukuba, Tsukuba*

1. INTRODUCTION

General Circulation Models (GCMs) are used to predict the global climate change in response to the increasing of greenhouse gas forcing. However, the spatial resolution of GCMs is still low and not enough to deal with the changes in regional scale such as cities. Moreover, urban climate not only influenced by global climate change, but also modified by local factors, e.g. the expansion of urban areas. It is true, especially, for big cities in developing countries, that is expected to have rapid urbanization in next several decades.

This study examines climatic responses to the coupled effects of greenhouse gas-induced global warming and the future urban expansion over one of mega cities in Southeast Asia countries, the metropolis of Greater Ho Chi Minh City (GHCM) to the mid of 21th century.

2. METHOD AND DATA

A dynamical downscaling approach using a high-resolution Weather Research and Forecasting (WRF) model V3.1.1 coupled to a single-layer urban canopy model was adopted to simulate the meteorological conditions in GHCM during April of 2009–2011. The model's domains are a nested system with highest horizontal resolutions of 1 km.

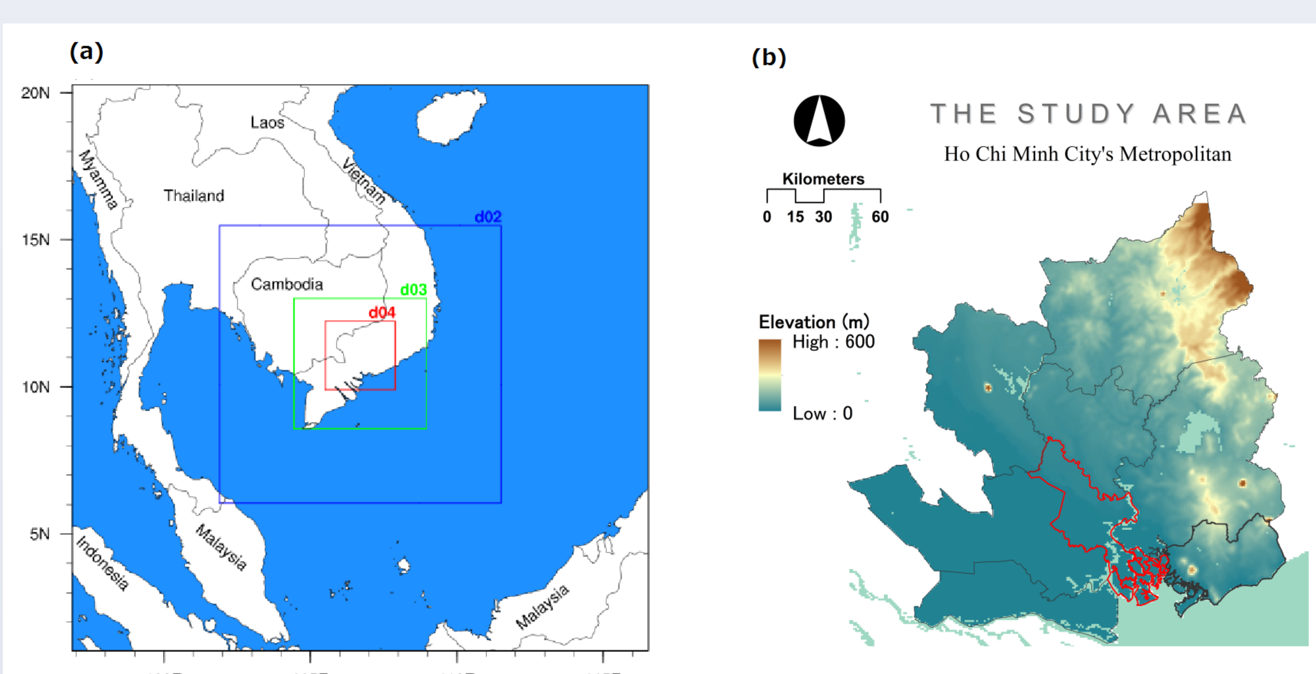

Fig. 1 (a) shows configured simulation domains. The outer boundary is the parent domain d01. (b) shows the study area. Fuzzy grey lines indicate provinces' administrative borders. Ho Chi Minh City is red line.

Table 1. Model configuration

	Domain 01	Domain 02	Domain 03	Domain 04
Run time	03-25:00 - 05-01:00 (UTC) of 2009 - 2011			
Time period for analysis	04-01:00 - 04-30:23 (LST) of 2009 – 2011			
Grid distance	27 km	9 km	3 km	1 km
Grid number	80 x 80	118 x 118	166 x 166	262 x 262
Number of vertical layers	35 layers			

Separate numerical simulations with current-urban (CU) and future-urban (FU) land-use condition were conducted using boundary conditions of current climate (i.e. NCEP/FNL) and future climate to 2050s (i.e. output from GCMs). Future-climate boundary-conditions were generated by pseudo-global warming method using different warming increments from phase 5 the Coupled Model Intercomparison Project (CMIP5) model experiments.

Due to uncertainty of green-gas emission scenarios as well as GCMs outputs, warming increments from multiple CMIP5 models for the two warming scenarios RCP8.5 and RCP4.5 were used (Table 2). These GCMs were selected because they could relatively accurately simulate current climate condition in Vietnam region and because they produced lower, moderate, and higher warming rates, respectively.

Table 2. GCM selection

	CMIP5 RCP 8.5	CMIP5 RCP 4.5
Higher warming rate	MIROC-ESM	GFDL-CM3
Moderate warming rate	CMCC-CM	MIROC5
Lower warming rate	CNRM-CM5	CNRM-CM5

Current land-use datasets were estimated from Landsat satellite images in 2009; meanwhile future land-use datasets were estimated based on the future master plan of the city.

Anthropogenic heat release's maps were derived using statistic data as well as the future prospect of energy consumption and the population density for districts and counties of GHCM .

Observed meteorological data (used to evaluate the performance of WRF) were collected from the Hydro-Meteorological Data Center of Vietnam.

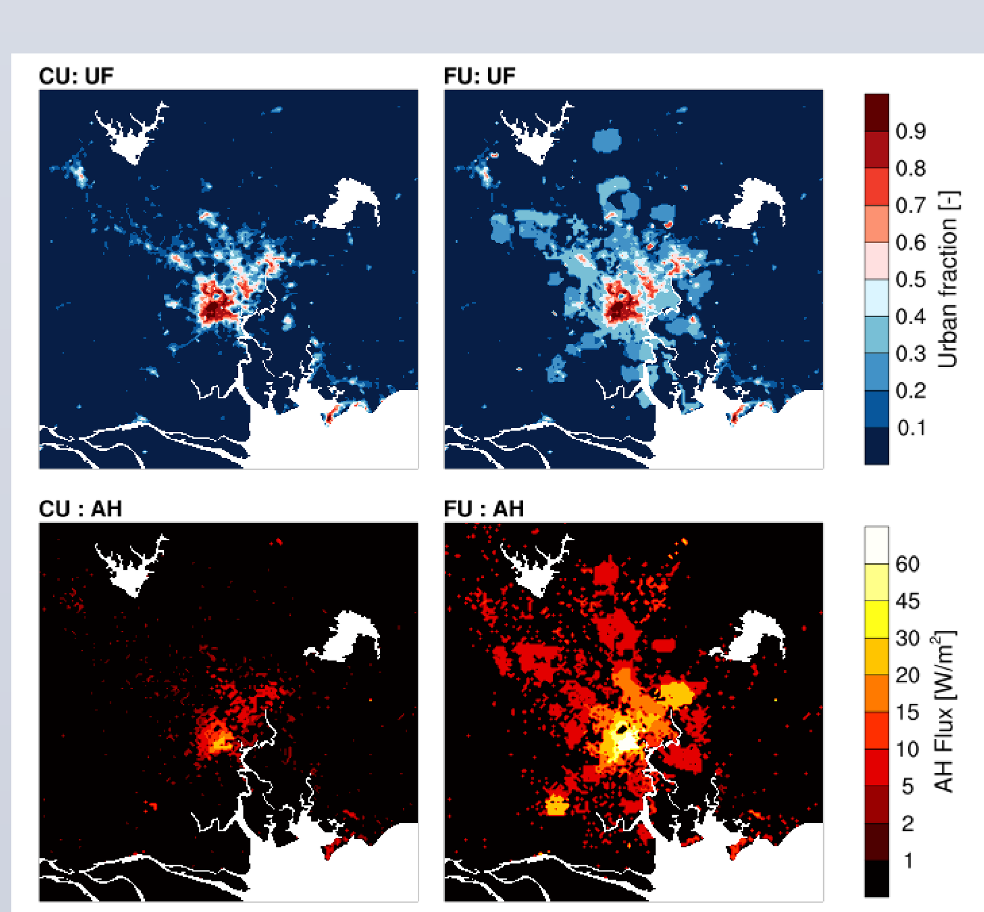

Fig. 2 Changes in urban fraction (UF) and anthropogenic heat release (AH) from current urban (CU) to future urban (FU)

3. RESULTS AND DISCUSSION

Diurnal behavior of simulated April surface air temperature agrees well with observations.

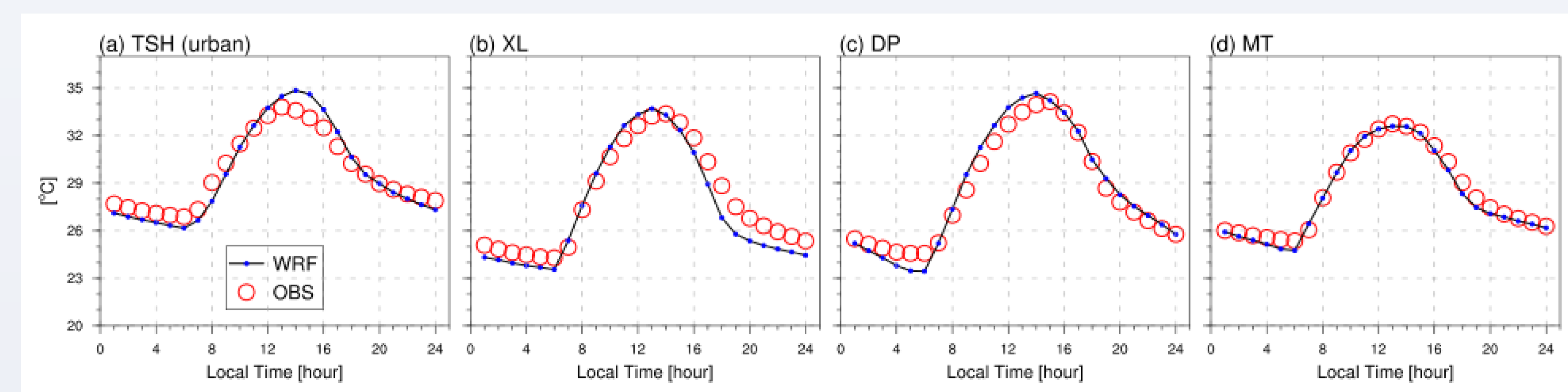

Fig. 3 Diurnal variation of the surface air temperature in April for both WRF-results and observations at 4 weather stations: (a) TSH, (b) XL, (c) DP, and (d) MT.

The simulated results show that, the future urbanization, alone and separate from greenhouse gas-induced forcing, can be expected to raise near average surface air temperature about 0.2 ° C in the pre-existing urbanized areas and about 0.4 ° C in newly urbanized areas of the GHCM. On the other hand, greenhouse gas-induced global warming for two warming scenarios RCP8.5 and RCP4.5 is expected to raise surface air temperature about 1.4 ° C and 1 ° C over the region in 2050s, respectively. This highlighted that the future urbanization will considerably contribute to the warming of local urban climate of GHCM besides the effects of global warming.

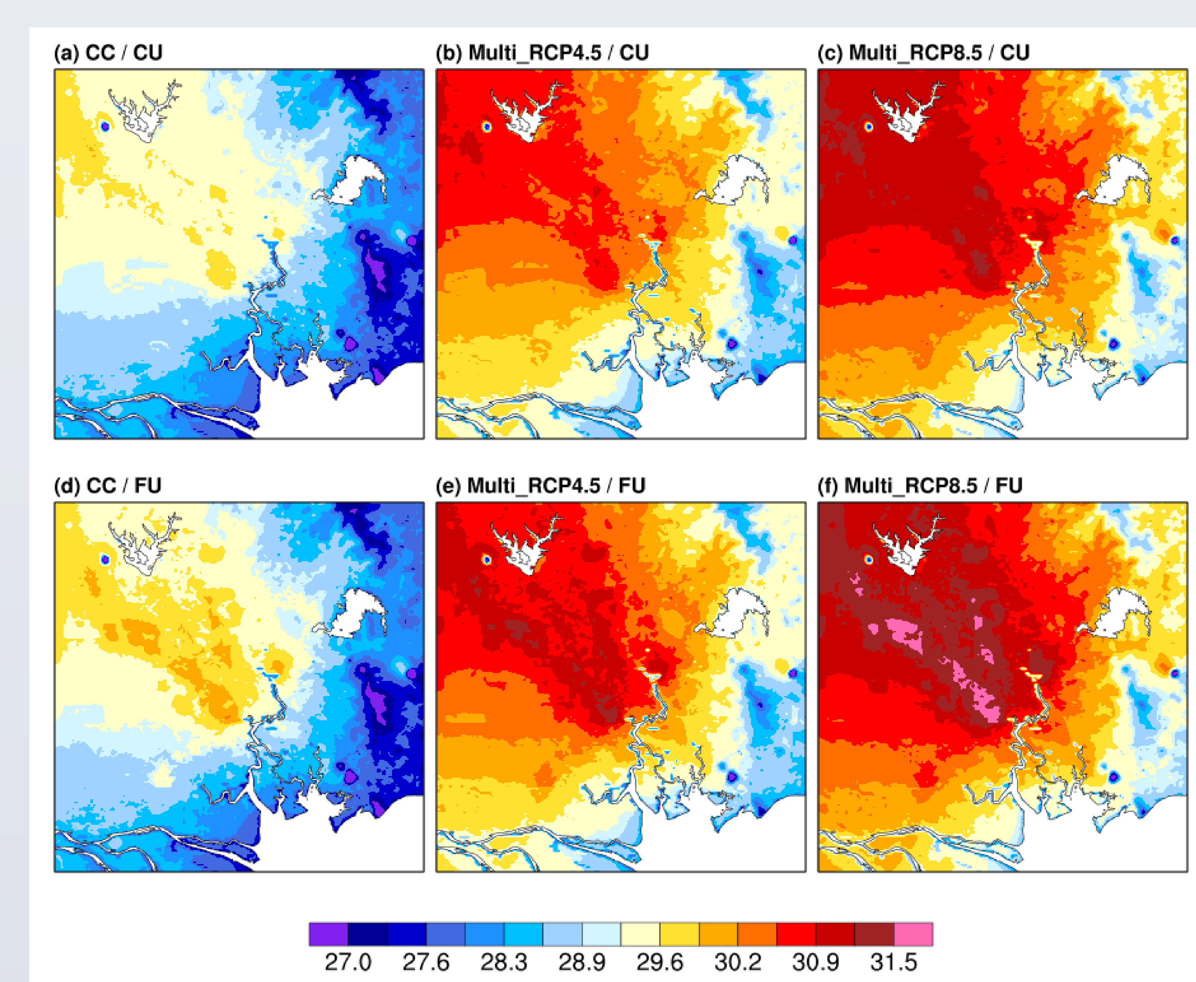

Fig. 4 Surface air temperature change from current time to the 2050s. Multi_RCP8.5 and Multi_RCP4.5 denote average results from multiple CMIP5 GCMs for two warming scenarios RCP8.5 and RCP4.5.

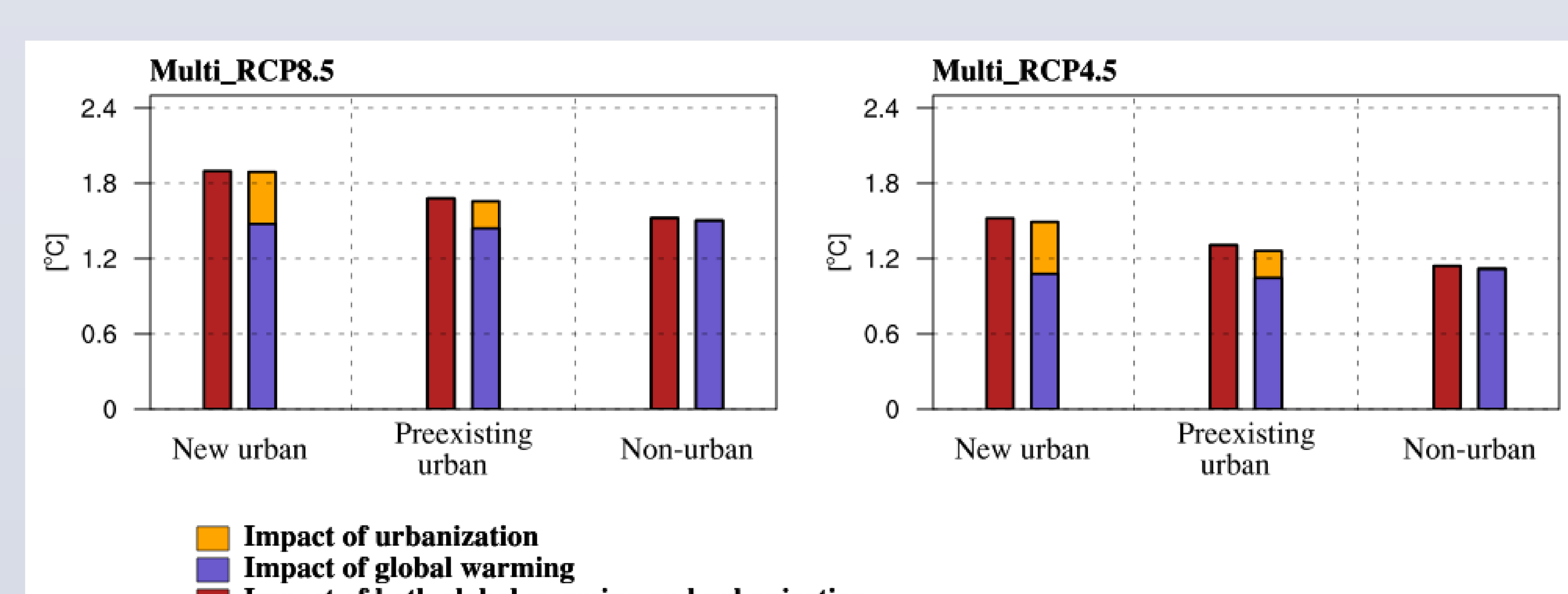

Fig. 5 Surface air temperature change from current time to the 2050s. Multi_RCP8.5 and Multi_RCP4.5 denote average results from multiple CMIP5 GCMs for two warming scenarios RCP8.5 and RCP4.5.

4. CONCLUSIONS

Agreement between simulated results and observations demonstrates that the WRF/UCM is able to reproduce the urban climate of GHCM.

In the mid of 21th century, the surface air temperature in GHCM is expected to rise from 1. ° C to 1.8 ° C according to variability of warming scenarios. Temperature response appeared to have strong linear characteristics to both local changes in land use and climate forcing.

Future urbanization is expected to considerably contribute to the total urban warming besides of global warming effects. This implies that and appropriate adaptive urban design is promising in terms of reducing negative side of this urban warming.

Acknowledgments: *This study was conducted under supports of the Social implementation program on climate change adaptation technology (SI_CAT), and the Interdisciplinary computational science program at the Center for computational sciences, university of Tsukuba.*