# Impacts of a future city master plan on thermal and wind environments in Vinh city, Vietnam

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## 1. Introduction

Vietnam (Socialist Republic of Viet Nam) is a rapidly developing country, and the recent growth rates of the economy and population are about 6% and 1.2%, respectively. The expansion of urban areas is progressing in the country. Under such a situation, in Vietnam, many city master plans have been proposed in these days. Recently, Nikken Sekkei Civil Engineering Ltd. proposed a city master plan for Vinh city, the capital of Nghe An Province, located in the northern part of Vietnam. The proposed city master plan targets the year of 2030 with a population of 900,000, and the total planning area covers approximately 250 $km^2$.

In this study, future projections of the thermal and wind environments in June (hottest month) of the 2030s in Vinh city were performed by introducing the above-mentioned city master plan. The projections were carried out using a regional atmospheric model, the Weather Research and Forecasting (WRF) model (Skamarock et al. 2008), combined with the pseudo global warming method proposed by Kimura and Kitoh (2007). By comparing with the present land use case, the effects of introducing the city master plan on the future thermal and wind environments in Vinh city were quantitatively investigated. Additional cases with the change in urban structure (northern or southern concentration of the new urban districts) were conducted, and the effects of the modifications of the city master plan on the future thermal and wind environments were also studied.

## 2. Outline of simulations

### 2.1 Simulation model

The WRF modeling system, Version 3.0.1.1, with the ARW dynamic solver (Skamarock et al. 2008) was used for the future (June in the 2030s) projections of the thermal and wind environments in Vinh city, Vietnam. In this study, the pseudo global warming method proposed by Kimura and Kitoh (2007) was introduced to consider the effect of global warming in the 2030s. The components to formulate the pseudo global warming data (horizontal wind components, potential temperature, geopotential height, and sea and ground surface temperatures) were generated using a general circulation model, GFDL-CM3, with the RCP8.5 scenario adopted in the IPCC 5th Assessment Report (IPCC 2014). The generated data were used as the initial conditions for all the nested domains (cf. Section 2.2) and the boundary conditions for the largest domain in the WRF simulations.

### 2.2 Computational domains

Three nested computational domains were used, as shown in Fig. 1. The sizes of Domains 1, 2, and 3 were 585 km × 540 km (4.5 km horizontal resolution), 177 km × 159 km (1.5 km horizontal resolution), and 52.5 km × 46.5 km (0.5 km horizontal resolution), respectively. In all the domains, 34 layers were used in the vertical direction. The region enclosed by a red line in Domain 3 (Fig. 1) indicates the city master plan area.

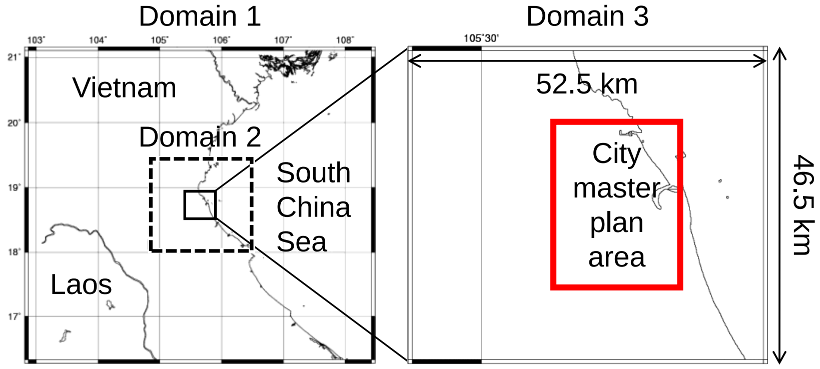



*Fig. 1 Computational domains.*

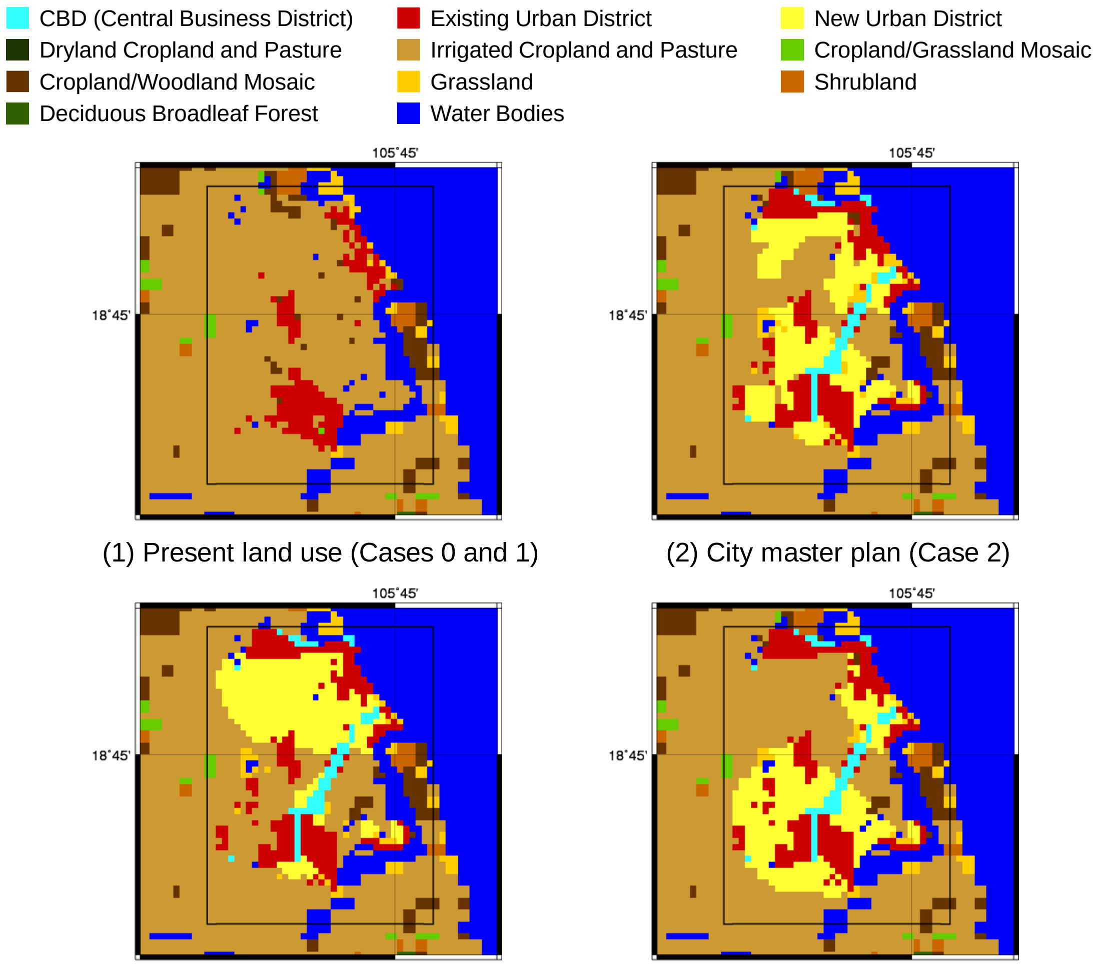
### 2.3 Simulated cases

A total of five cases were studied, as shown in Table 1. The target period was the month of June in the 2030s. Four land use models, i.e., the present land use (Case 1; Fig. 2(1)), the city master plan proposed by Nikken Sekkei Civil Engineering Ltd. (Case 2; Fig. 2(2)), and two modified models of the city master plan (Cases 3 and 4; Figs. 2(3) and (4)), were introduced in this study. As a comparison, the present (June in 2011) climate case with the present land use model (Case 0) was also conducted.

In the city master plan and its modifications (Cases 2-4), the urban areas were classified into three categories; (1) central business district (CBD), (2) existing urban district, and (3) new urban district. For the two modifications of the city master plan, the new urban districts were concentrated in the northern (Case 3; Fig. 2(3)) or southern (Case 4; Fig. 2(4)) part of the planning area. The average height of buildings and the building (green) coverage ratio were 26 m and 50% (50%) in CBD, 12 m and 70% (30%) in the existing urban district, and 12 m and 60 % (40%) in the new urban district. The amount of anthropogenic heat release in the urban areas was set to be the same as that in the present situation (the daily maximum anthropogenic heat release: 6 W/m$^2$) estimated by considering the present power consumption and the number of vehicles (cars and motorbikes) and their running efficiencies. However, this amount is probably small for future projections. Further investigation of the condition will be pursued in the next phase of this study.

*Table 1 Simulated cases.*

| | Period | Land use |
|---|---|---|
| Case 0 | June in 2011 | Present land use |
| Case 1 | June in the 2030s | Present land use |
| Case 2 | | City master plan |
| Case 3 | | Northern concentration of the new urban districts |
| Case 4 | | Southern concentration of the new urban districts |




(1) Present land use (Cases 0 and 1)

(2) City master plan (Case 2)

(3) Northern concentration of the new urban districts (Case 3)

(4) Southern concentration of the new urban districts (Case 4)

*Fig. 2 Land use distributions.*

## 3. Results and discussion

### 3.1 Effect of global warming in the 2030s

Fig. 3 shows the space-averaged (over the whole existing urban districts) and monthly-averaged (during June in the 2030s) diurnal variation of the difference in air temperature at a height of 2 m between Case 1 (future climate) and Case 0 (present climate). The time-averaged temperature difference over 24 hours depicted in the figure (namely, the monthly-averaged temperature difference) was 1.76 °C. This indicates a temperature increase by an estimated global warming in the 2030s.

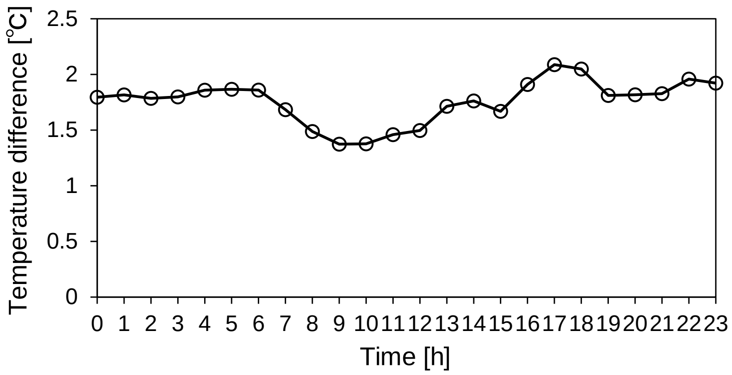



*Fig. 3 Space-averaged and monthly-averaged diurnal variation of the difference in air temperature at a height of 2 m between Cases 1 and 0.*

### 3.2 Effect of introducing the city master plan

Fig. 4 shows the space-averaged (over the whole urban areas) and monthly-averaged (during June in the 2030s) diurnal variation of the difference in air temperature at a height of 2 m between Case 2 (city master plan) and Case 1 (present land use). Here, note that only the existing urban districts are included in the urban areas in Case 1; on the other hand, CBD and the existing and new urban districts exist in the urban areas in Case 2. The temperature difference in the nighttime is larger than that in the daytime, and the maximum temperature difference is 0.33 °C (8 p.m.). This is considerably smaller than the temperature increase by the global warming in the 2030s (1.76 °C; cf. Section 3.1). However, the small temperature difference is never negligible, considering the fact that the increase in the global average surface temperature over the period from 1880 to 2012 was 0.85 °C (IPCC 2014). Therefore, active actions to mitigate the temperature increase by the expansion of urban areas (cf. Fig. 2) will be necessary in the near future.

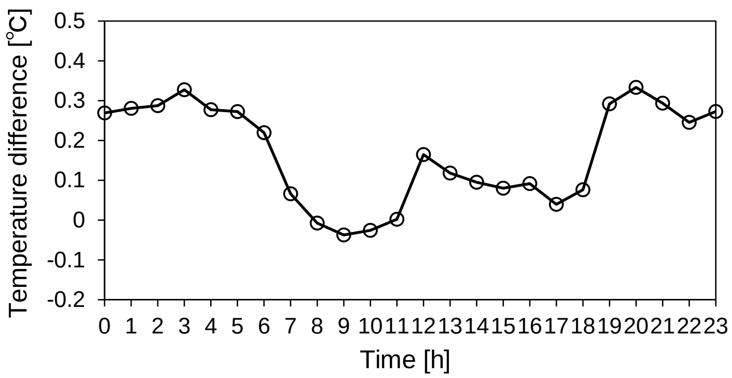



*Fig. 4 Space-averaged and monthly-averaged diurnal variation of the difference in air temperature at a height of 2 m between Cases 2 and 1.*

### 3.3 Effect of concentrating and decentralizing the new urban districts

Figs. 5 and 6 show the space-averaged and monthly-averaged (during June in the 2030s) diurnal variations of the difference in air temperature at a height of 2 m between Case 3 (northern concentration of the new urban districts) and Case 2 (city master plan) and those between Case 4 (southern concentration of the new urban districts) and Case 2, respectively. With regard to space averaging, averaging over each urban category (CBD, existing urban district, and northern and southern new urban districts) is introduced in the figures.

In Case 3 (northern concentration of the new urban districts), the temperature in CBD is only a little lower than that in Case 2; however, the temperature in the northern new urban districts is higher than that in Case 2. The time-averaged temperature increase over 24 hours is 0.23 °C. There is almost no difference in the temperature in the existing urban districts between Cases 2 and 3.

In Case 4 (southern concentration of the new urban districts), the temperatures in CBD and the existing urban districts are almost the same as the corresponding results in Case 2. The temperature in the southern new urban districts is a bit higher than that in Case 2. The time-averaged temperature increase over 24 hours is 0.11 °C.

Considering the above results, the original city master plan, in which the new urban districts are decentralized in both northern and southern parts of the planning area, is better than the two modified models (northern or southern concentration of the new urban districts) from the viewpoint of thermal environment.

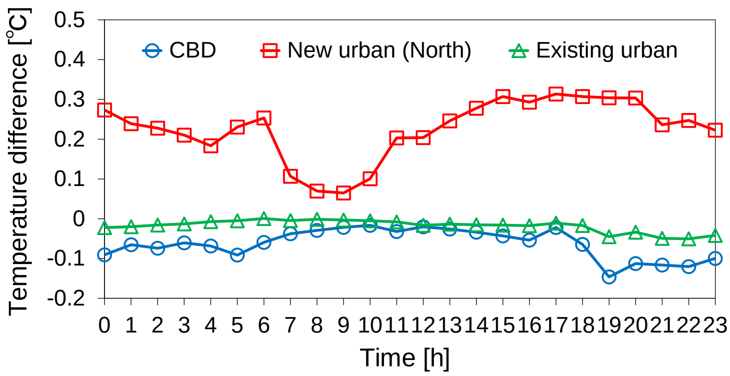



*Fig. 5 Space-averaged and monthly-averaged diurnal variations of the difference in air temperature at a height of 2 m between Cases 3 and 2.*

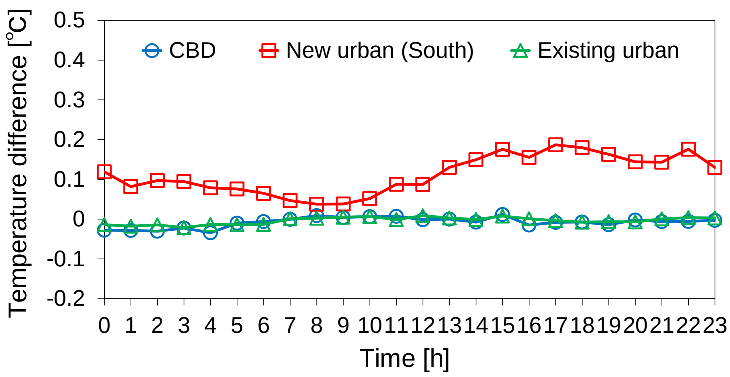



*Fig. 6 Space-averaged and monthly-averaged diurnal variations of the difference in air temperature at a height of 2 m between Cases 4 and 2.*

## 4. Summary

In this extended abstract, the effects of introducing a city master plan for Vinh city, Vietnam, and its modifications (northern or southern concentration of the new urban districts) on the urban thermal environment in the summer of the 2030s were quantitatively investigated using the WRF model. We will also discuss the effects on the wind environment and thermal sensation in our presentation in the conference.

## References

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