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論 文 要 旨

THESIS SUMMARY

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要旨（英文 800 語程度）
Thesis Summary（approx. 800 English Words）

Global climate change is progressing while urbanization is also progressing rapidly. It is projected by the United Nations that by 2030, 60 percent of the world population will settle in urban areas and 8.8 percent of the world's population will settle in megacities, which are cities with 10 million or more inhabitants. Therefore, there is an increasing need to understand the climatology of cities, especially the combined effect of global warming and urbanization, so that mitigation and adaptation measures can be proposed. For that reason, this study aims at projecting the future climate of the world's 43 megacities with comprehensive consideration of global climate change and urbanization.

Past research has been utilizing general circulation models (GCMs) to study the global climate. However, GCMs with coarse resolution cannot resolve city-scale phenomena while GCMs with high resolution are costly. Therefore, high-resolution regional climate models (RCMs) have been used to investigate urban climate. However, the representation of the heterogeneous surface of cities is still inadequate. Specifically, there is a lack of consideration for the present and the futuristic projection of spatially varying urban morphological parameters (for example, building height and building density) and spatiotemporally varying anthropogenic heat emission. Moreover, a geographical gap exists in previous urban climate studies. Specifically, there are few studies for cities in developing countries even though cities in developing countries are expanding rapidly.

Addressing the research gap, in this study, present (2010s) and future (2050s) realistically projected spatially varying maps of urban morphological parameters and anthropogenic heat emission was constructed aligning with the worst-case scenario of Representative Concentration Pathway 8.5 (RCP8.5) coupling with the Shared Socioeconomic Pathway 3 (SSP3). The map was constructed using only freely downloadable global datasets so that any city, regardless of its development status, can be investigated. The maps were then inputted to the Weather Research and Forecast (WRF) model, which is an RCM, to project the future climate of the 43 megacities. In the simulation setup, the pseudo-global warming (PGW) method was used to account for the effect of global climate change. To contribute to the urban climate research community, the model, together with the input datasets used, was made public and incorporated into the widely used WRF model.

In a case study to investigate the feasibility of the method, the present and future August climate of the 43 megacities was simulated. It was found that the model could adequately reproduce the present August climate conditions of the 43 megacities. Temperature change due to urbanization (urbanization effect) is strongest in newly urbanized areas and in rapidly developing cities. For cities in developed countries with saturated urbanization and declining populations, fully accounting for the contribution of (de)urbanization produces a milder warming projection than the projection with only global warming considered. Urbanization effect was also observed in surrounding rural areas due to the advection of hot air from the urban area to its surroundings.

After confirming the performance of the model, a full-year investigation of the future climate for all 43 megacities was conducted. Model verification confirmed that the model could reproduce the present climate adequately. Urbanization effect was found to always have large variances even though it may have small spatiotemporal means. When urbanization is not considered, 65 percent of megacities population is projected to be exposed to 2.5 °C warming. When urbanization is considered, the exposure increases drastically to 78 percent. This change in exposure may lead to a change in future heat-related illness risks. This finding emphasizes the importance of considering urbanization in future urban climate projections. In addition, a simple semi-empirical equation was derived to connect socioeconomic factors (gross domestic product (GDP) and population) with the magnitude of urban warming. Urban warming was found to be proportional to GDP and population but inversely proportional to city surface area and atmospheric boundary layer height. This equation can be used to quickly estimate the impact of economic and population growth without running climate simulations.

Going beyond climate (that is, average weather conditions), extreme weather events were also studied. Specifically, three heatwave events in 2022 in Delhi, London, and Tokyo were investigated. If these heatwaves repeat in the 2050s, the temperature will be 0.8 to 1.6 °C higher. The effect of anthropogenic heat is strongest at nighttime, reaching 0.21 °C in Delhi. There was also statistical evidence suggesting that the urbanization effect is dependent on background climate. Like the previous chapters, it was also confirmed that the urbanization effect is highly spatially heterogeneous.

Finally, the limitations of this study were identified and recommendations for future research were made. Specifically, future research should consider projecting future climate for cities under various socioeconomic and climatological scenarios, estimating heat-related illness risks to urban dwellers, constructing anthropogenic heat maps for extreme weather conditions, modeling indirect effects of urbanization, attributing the urbanization induced-warming to each urban morphological factor, and investigating the possibility of teleconnection caused by regional development.

備考 ： 論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 1 部提出してください。

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