Studies on the Urban Climate and Mountain Weather Using the WRF and CM1 Models

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1. Project Purpose

This project aims to achieve two main objectives: (i) Explore urban climate change, particularly emphasizing high-impact weather and climate events in cities, by considering the combined influences of localized urbanization and global climate changes. (ii) Elucidate the mechanisms governing local winds through case studies of foehn and gap winds that occur in coastal areas.

2. Results

Numerical climate projections were carried out using the dynamical downscaling method with the convection-permitting Weather Research and Forecasting (WRF) model for multiple areas with different climate background such as Japan, Vietnam, Singapore and Nigeria. Through analysis of the results, the mechanisms of urban precipitation is revealed. Urban heat island due to modification of land surface enhances the convection, encourages the horizontal moisture convergence which results in the increase in rainfall over the city (Doan et al., JAMC, 2023). Also, the asymmetric warming is confirmed by long term climate simulation with convection-permitting model. The asymmetric warming characterized by “underwarming” of daily maximum temperature which is attributed to increase of cloud cover in future climate that reduce the incoming solar radiation (Doan et al., GRL, 2022).

3. Roles of the MCRP and its significance

To comprehensively investigate regional atmospheric phenomena, fine-resolution numerical simulations are crucial. For instance, the urban heat island effect has a known impact on localized thunderstorms by intensifying atmospheric instability and convection. Similarly, terrain plays a pivotal role in shaping patterns of localized wind, cloud formation, and precipitation. These effects are often overlooked in simulations with coarse resolutions. Furthermore, the formation of precipitation involves intricate atmospheric microphysical processes, leading to high uncertainty in its simulation. To obtain robust results, long-term model runs are necessary to capture the full range of variability.

4. Future plan

Examining the change in extreme urban precipitation and local wind is a critical

task, albeit a challenging one due to significant uncertainties in simulations. To address this, it is necessary to expand the scope of research to encompass various regions with diverse climates and geographical characteristics. Additionally, investigating how extreme precipitation and local wind in different seasons responds to the effects of global warming holds substantial value and can provide valuable insights.

５. Publications and conference presentations

(1) Journal papers

Doan Q-V, Kobayashi S, Kusaka H, Chen F, He C, Niyogi D. 2023. Tracking Urban Footprint on Extreme Precipitation in an African Megacity. Journal of Applied Meteorology and Climatology. American Meteorological Society, 62(2): 209–226. https://doi.org/10.1175/JAMC-D-22-0048.1.

Doan Q-V, Chen F, Asano Y, Gu Y, Nishi A, Kusaka H, Niyogi D. 2022. Causes for Asymmetric Warming of Sub-Diurnal Temperature Responding to Global Warming. Geophysical Research Letters, 49(20): e2022GL100029. https://doi.org/10.1029/2022GL100029.

Doan Q-V, Chen F, Kusaka H, Wang J, Kajino M, Takemi T. 2022. Identifying a New Normal in Extreme Precipitation at a City Scale Under Warmer Climate Regimes: A Case Study of the Tokyo Metropolitan Area, Japan. Journal of Geophysical Research: Atmospheres, 127(21): e2022JD036810. https://doi.org/10.1029/2022JD036810.

Nguyen VT, Doan Q-V, Tran NN, Luong LTM, Chinh PM, Thai PK, Phung D, Le HHTC, Dang TN. 2022. The protective effect of green space on heat-related respiratory hospitalization among children under 5 years of age in Hanoi, Vietnam. Environmental Science and Pollution Research. https://doi.org/10.1007/s11356-022-21064-6.

Okada M, Yamaguchi K, Kodama R, Ogasawara N, Kato H, Doan VQ, Ishizaki NN, Kusaka H. 2022. Development of a wind power ramp forecasting system via meteorological pattern analysis. Wind Energy, doi: https://doi.org/10.1002/we.2774.

(2) Presentations

Vitanova LL, Yamamura S, Doan Q-V. 2022. Assessment of solar panel application in favor of carbon-neutralized cities. AGU Fall Meeting, Dec 2022.

Nguyen TH, Nagashima T, Doan Q-V. 2022. Source Contribution and Future Simulations of PM2.5 in Hanoi, Vietnam. AOGS 2022 Annual Meeting.

Vitanova LL, Yamamura S, Doan Q-V. 2022. Potential Installation of Solar Panels for Dissemination of Wide Carbon-neutral Area in Kanto Region, Japan. AOGS 2022 Annual Meeting.

Doan Q-V, Kobayashi S, Kusaka H, Chen F, He C, Niyogi D. Urban Footprint on Extreme Precipitation in Lagos, Nigeria. AOGS 2022 Annual Meeting.

Doan Q-V, Kusaka H, Vitanove L, Estoque R, Nguyen TH, Chen F. 2022. Uncertainties in Urban Climate Downscaling Associated with Future Urbanization. AOGS 2022 Annual Meeting

(3) Others

Supercomputer	Use	Allocated resources*	
		Initial resources	Additional resources
Cygnus	Yes/No		
Wisteria/BDEC-01	Yes/No	55,080	
*in units of node-hour product			