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

DOAN Quang Van
Center for Computational Sciences, University of Tsukuba

1. Project Purpose

Meteorological phenomena at the scales of cities and mountains are still not sufficiently understood due to the complicated nature associated with interactions between localized geographical factors and synoptic atmospheric circulations. High-resolution numerical atmospheric models are expected to help to advance our understanding of such phenomena. This project is primarily aimed to (a) advance our understanding of future urban climate change in the tropics with focus on quantifying the climatic response of extreme rainfall to the warmer atmosphere; (b) elucidate the mechanism of local winds such as foehn and gap winds, primarily focusing on coastal areas of the sea of Japan such as Toyama and Niigata.

2. Results

Dynamical downscaling results using the convection-permitting WRF model revealed that future warmer climate will significantly modify the localized rainfall climate over a tropical city like Singapore. The results, which were obtained with different greenhouse-gases emmision scenarios, i.e., CMIP5 RCP8.5 and RCP4.5 with future climate is considered in the 2090s, consistently showed the increase in extreme rainfall, i.e., which at above quantiles of 0.9, 0.95, and 0.99, over the simulated domain. The increase in extreme rainfall occurs at so-called super Clausius Clapeyron scaling, that is much higher than the expectation value of rainfall change per degree of temperature increase at 7 % / K. This results implies that a future city can experience severe urban flooding once the rainfall extreme value will exceed the limitation of current-time infrastructure.

Regarding the study on Japan's south foehn, we have conducted the comprehensive climatological study employing both numerical simulations and observational analysis. We revealed that near to 70 % of the foehns is associated with extratropical cyclones passing through the Sea of Japan. Remaining are related to anticyclone and typhoon events. Foehns tended to occur more frequently in spring, when there is migratory anticyclones and cyclones. Foehns tended to initiate at night and cease during the day, which can be attributed to the colapse of nocturnal stable layer and the development of a localized pressure gradient on the lee side.

３．Roles of the MCRP and its significance

High-spatiotemporal-resolution is essential when studying fine-scale meteorological phenomena such as those occur at the scale of cities and mountains. In such the scale, atmosphere processes are strongly influenced the geographical factors such as topography, urban morphology. For example, in cities, there are small cumulus clouds that can be formed in the sky, and in mountainous areas, there are gap winds that blow only a few kilometers downwind from the valley, and cap clouds that can only be formed on the mountaintop. For atmospheric phenomena with high uncertainty such as extreme rainfall, it usually needs long term simulation time to obtain robust results.

４．Future plan

Understanding the change in extreme precipitation over cities is very important issue. However, there is many uncertainties involved in the process to simulate it. To have robust results, there needs ensemble approach which take into account multiple simulation area, period. We have plan to simulate the future rainfall climate for multiple large cities over multiple climate zones to robustify what obtained in this year.

５．Publications and conference presentations

(1) Journal papers

Kusaka, H, Nishi, A, Kakinuma, A, Doan, Q-V, Onodera, T, Endo, S. 2021. Japan's south foehn on the Toyama Plain: Dynamical or thermodynamical mechanisms? *International Journal Climatology*, 1– 18. https://doi.org/10.1002/joc.7133

(2) Presentations

日下博幸, Quang-Van Doan, Lidia Vitanova, 中村真悟, Ronald Estoque. 2020. アジアのメガシティの都市気候・日本地理学会 2020 年度秋季大会

(3) Others

Supercomputer	Use	Allocated resources*	
		Initial resources	Additional resources
Cygnus	No		
Oakforest-PACS	Yes	250000	
*in units of node-hour product			