Investigating the global effects of realistic spatio-temporally varying anthropogenic heat emissions using a high-resolution global climate model

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I. Introduction

To deepen our understanding of the urban climate and to address the societal issues in cities, climate modeling with detailed urban representation (e.g. building morphology, anthropogenic heating) is vital. Typically, these investigations are on neighborhood or regional scales of cities. Hence, global datasets of anthropogenic heat emissions (AHE), which corresponds to the added energy from the surface due to human use of energy, are becoming available at high spatial resolutions (e.g. 1-km).

Meanwhile, global-scale models, ranging from general circulation models to earth system models, are rapidly advancing computationally (i.e. improved efficiency at high spatial resolutions) but with main emphasis on the global climate change. Furthermore, applications of high-resolution global climate models are still lacking. This project aims to bridge the gap by modeling and investigating the spatio-temporal effects of detailed anthropogenic heat emission (AHE) at a global scale using a 14-km spatial resolving general circulation model (GCM).

Research Questions

1. What are the local, regional, and global meteorological effects of AHE with its source coming mainly from cities?
2. Are the effects significant relative to other known anthropogenic forcing such as greenhouse gases?
3. What are the direct influence of cities to meteorology and climate at the global scale?

Objectives

1. To improve high-resolution GCMs, specifically, on how they represent cities (i.e. AHE).
2. To quantify spatio-temporal influence of cities to global climate.
3. To advance urban-climate studies using global-scale climate modeling, and vice-versa.

II. Methodology

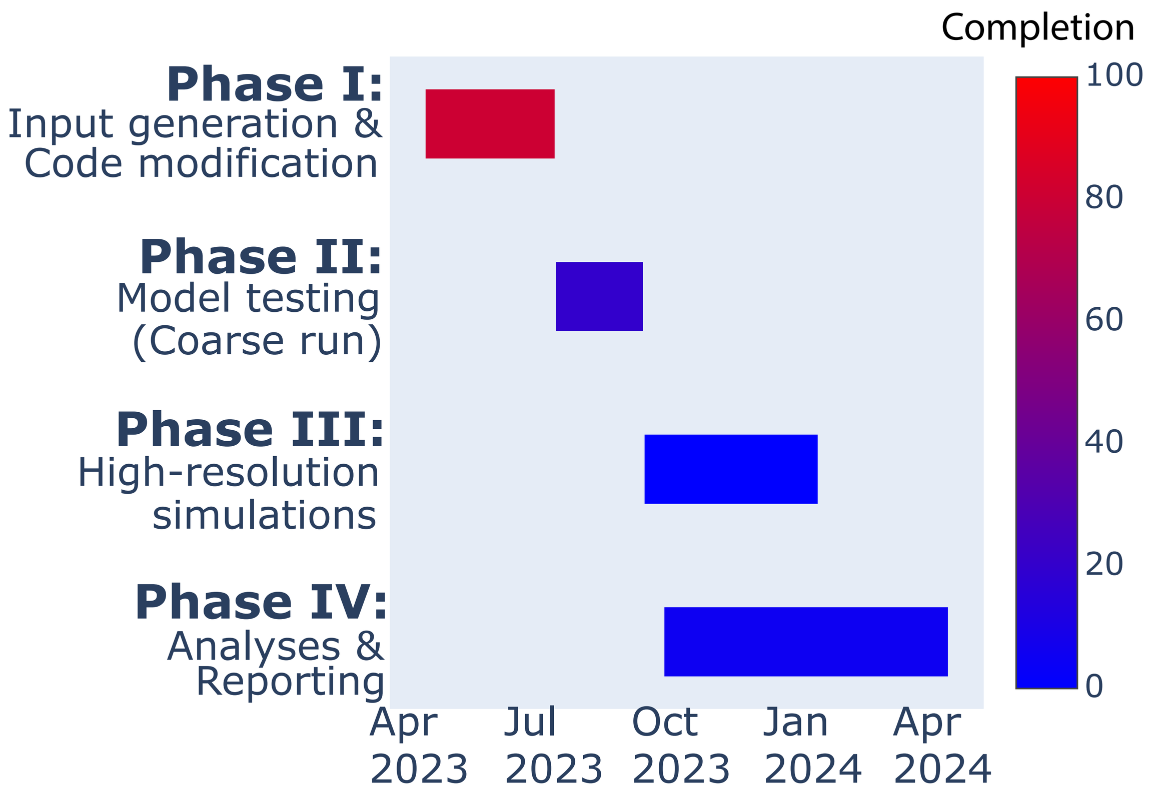
Datasets, tools, and models

***Dataset**: Anthropogenic heat emission*
The monthly-representative hourly AH4GUC dataset (Varquez et al., 2021) is of 30-arc-second resolution (https://urbanclimate.tse.ens.titech.ac.jp/).

***Model:** Global Climate Model*
The Nonhydrostatic ICosahedral Atmospheric Model (NICAM) (Satoh et al., 2008) is a global cloud-resolving model.

***Platform:** Tsubame 3.0 Supercomputer*
managed by Global Scientific Information and Computing Center (GSIC) at Tokyo Institute of Technology. Theoretical performance: 47.2 Pflops
***Target simulation period:** July heatwave*
***Spatio-temporal resolution:** 14-km, hourly*

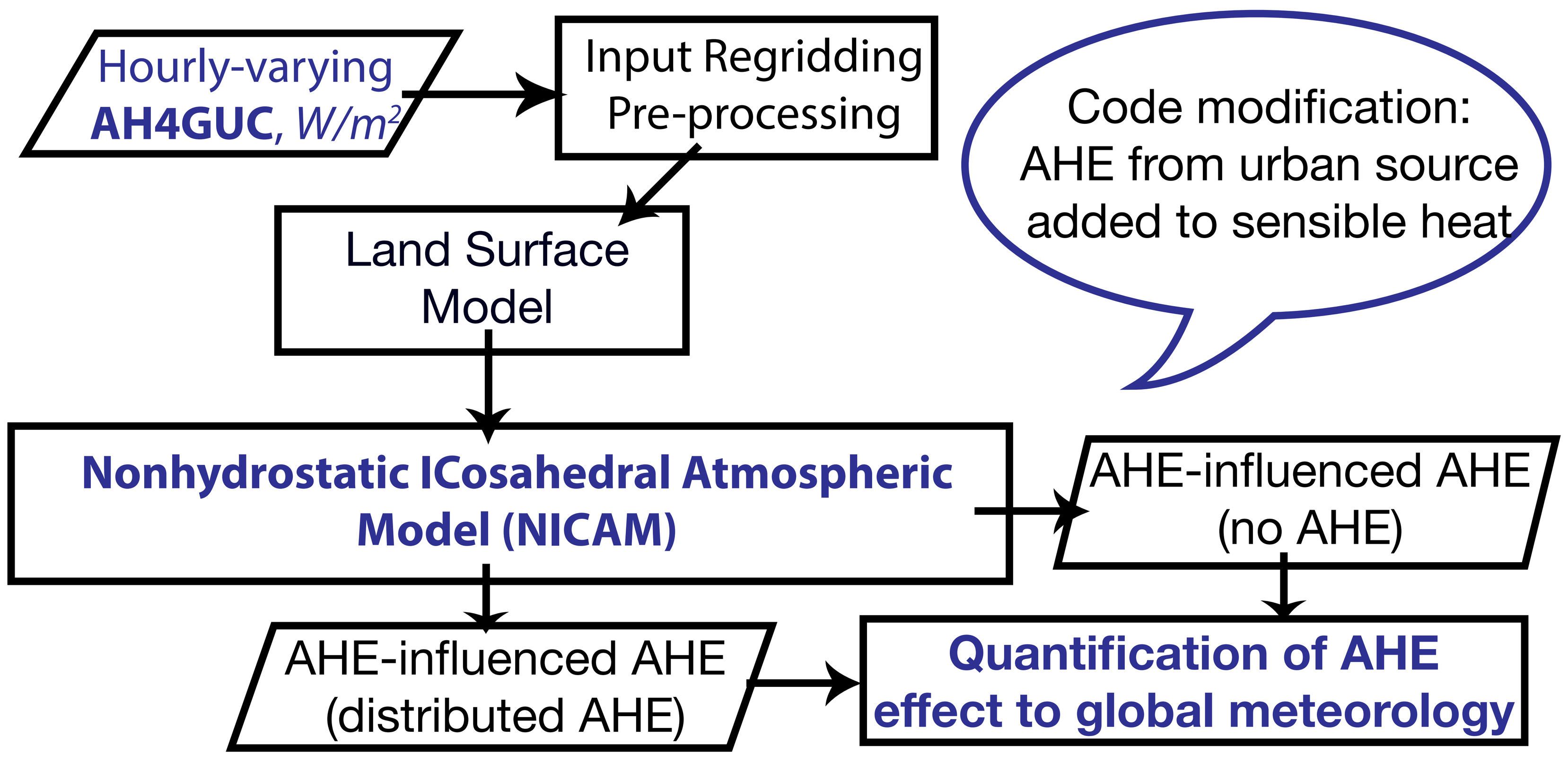
Project Timeline (Fig. 1)



Coarse Resolution
228-km horizontal,
78 vertical levels (50-km)

Fine Resolution
14-km
78 vertical levels (50-km)

Generalized Flowchart (Fig. 2)



III. Progress

Dataset conversion for coarse tests

1. *File conversion and conservative regridding of AHE*
Using geospatial tools and Climate Data Operators (cdo)
30-arcsecond (~1-km) to 2.5-arcdegrees (~200-km)
Hourly-representative AHEs for July, 2023.

2. *Icosahedral grid conversion and binary creation*
Revert back to geospatial format
using NICAM built-in tools for final confirmation.

3. *Automized geospatial scripts*
To flexibly set across coarse and fine spatial resolutions for all AH4GUC datasets

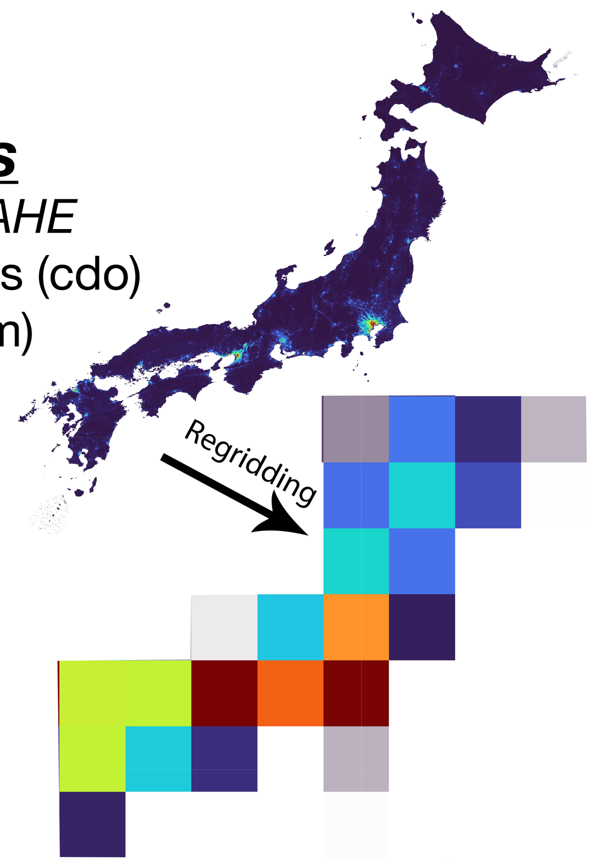


Fig. 3 Resampling from 30" to 2.5° focused in Japan

Coarse test run in the Tsubame 3.0

Entry	Settings (default)
Governing Equation	Fully compressible, non-hydrostatic
Spatial Descritization	Finite Volume Method (Tomita et al. 2001, 2002) Icosahedral in horozintal Lorenz in vertical
Temporal Scheme	3rd-order Runge-Kutta
Advection Scheme	Miura (2004)
Turbulence Scheme	Mellor-Yamada Nakanishi Niino (2)
Land Surface Mode	MATSIRO (Takata et al., 2003)
Trial process count	1 (fastest)
Trial process count	12
Walltime	1.4 hours for 2 days

Fig. 5 Relevant numerical settings

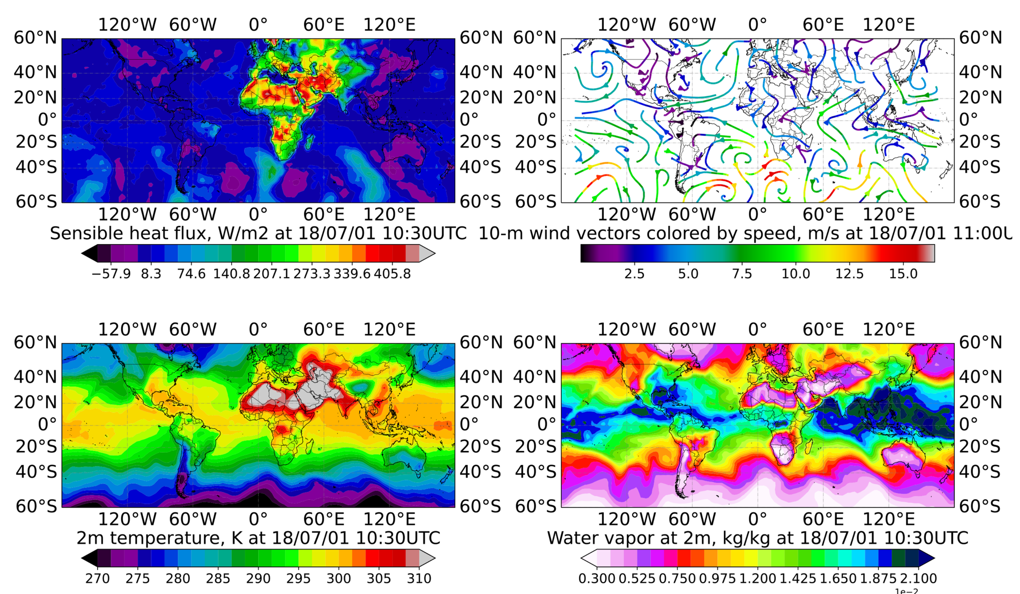


Fig. 4 Simulated global distribution of metoeorological parameters 10 hours the start of the coarse simulation.

IV. Expected outcomes and prospect knowledge

- Spatio-temporal maps, charts, and statistics of AHE effects to July 2018 heat-wave case (e.g Fig. 6 CESM simulations by Varquez et al)
- Impacts to human-level thermal / climate comfort by Nakayoshi et al.
- Further advancement of NICAM by integration with land-use model (e.g. Fig. 7, ILS+SLUCM by Takane et al) and detailed urban parameters
- Contribute to climate-change projection studies

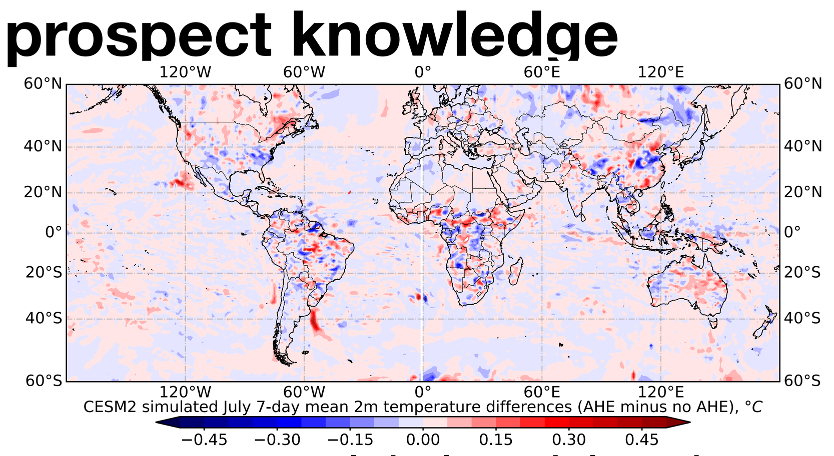


Fig. 6 CESM global model studies

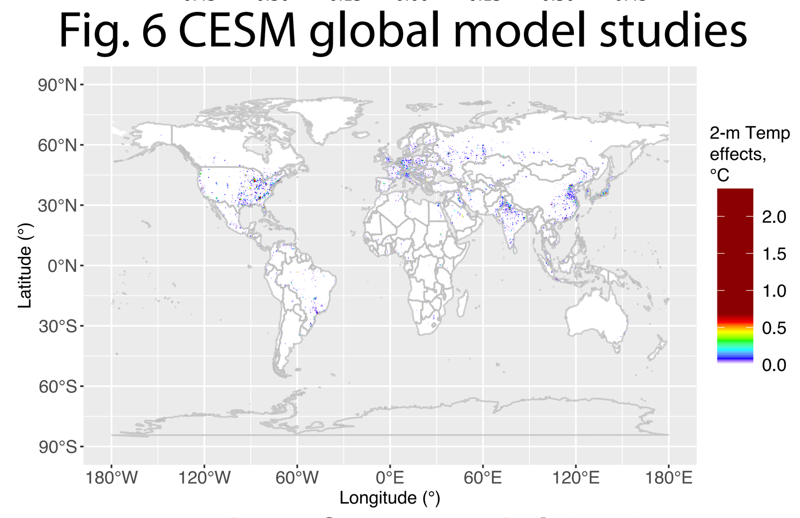


Fig. 7 Land surface model (ILS)+SLUCM

V. References

Satoh, M., Matsuno, T., Tomita, H., Miura, H., Nasuno, T., & Iga, S. I. (2008). Nonhydrostatic icosahedral atmospheric model (NICAM) for global cloud resolving simulations. *Journal of Computational Physics*, 227(7), 3486-3514.
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