Development of a Land-Surface-Physics-Based Urban Thermal Environment Prediction System: *Performance Verification for the Tokyo Metropolitan Area*

Lingbo XUE

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1 Introduction

Urban Climate Projection

- Dynamical downscaling (DD)

(Hamdi et al. 2014)

  - Adequate city-atmosphere interactions
  - Computationally too expensive

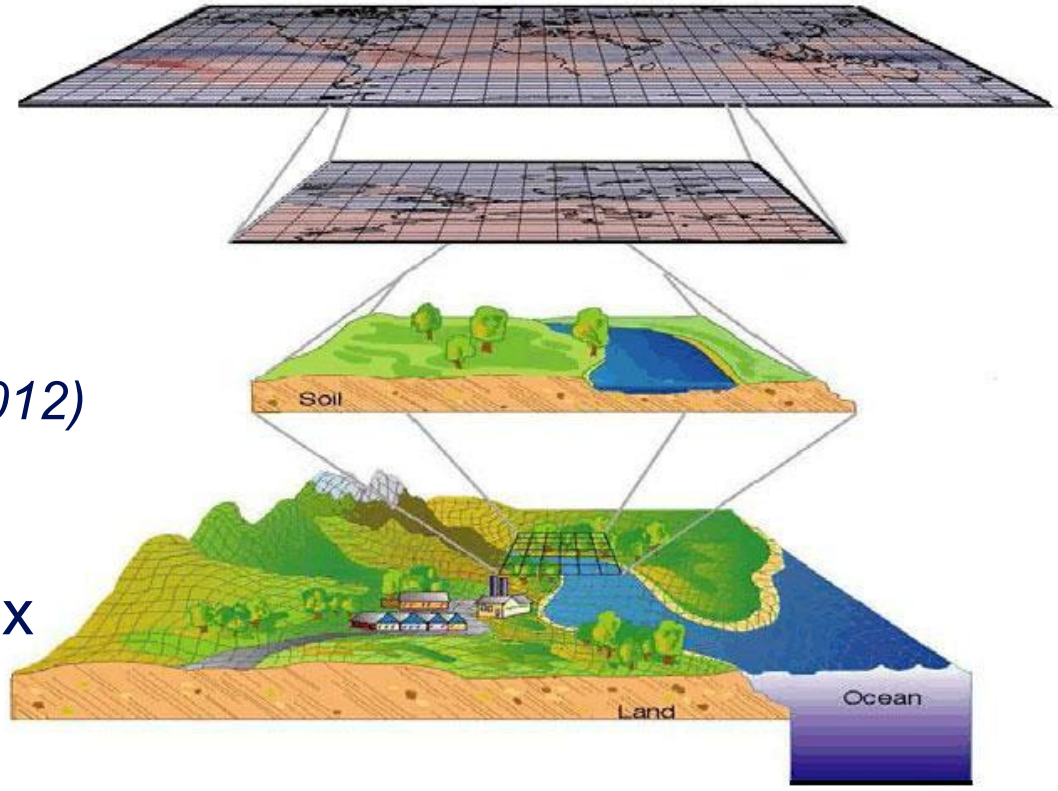
- Statistical downscaling (SD)

(Hoffmann et al. 2012)

  - Computationally very inexpensive
  - Only for a few cities and fail to capture complex interactions

- Statistical-dynamical downscaling (SDD)

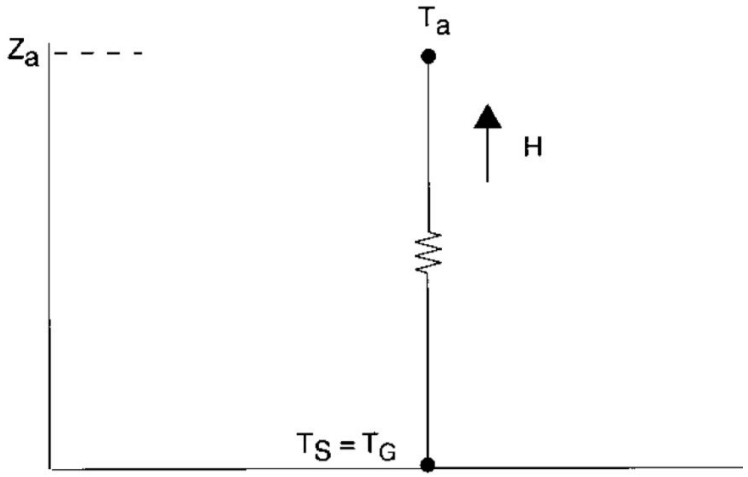
(DuchÊne et al. 2020)



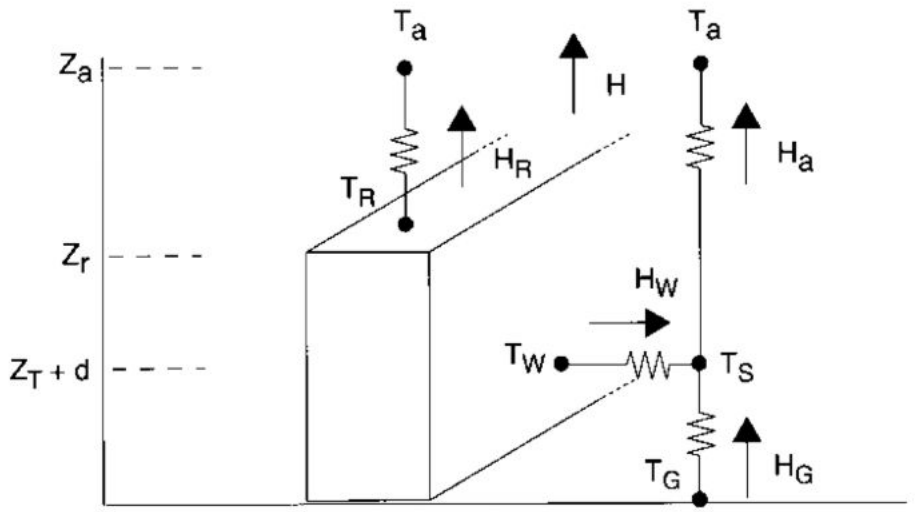
(Khan and Pilz, 2018)

Urban Parameterization in Climate Models

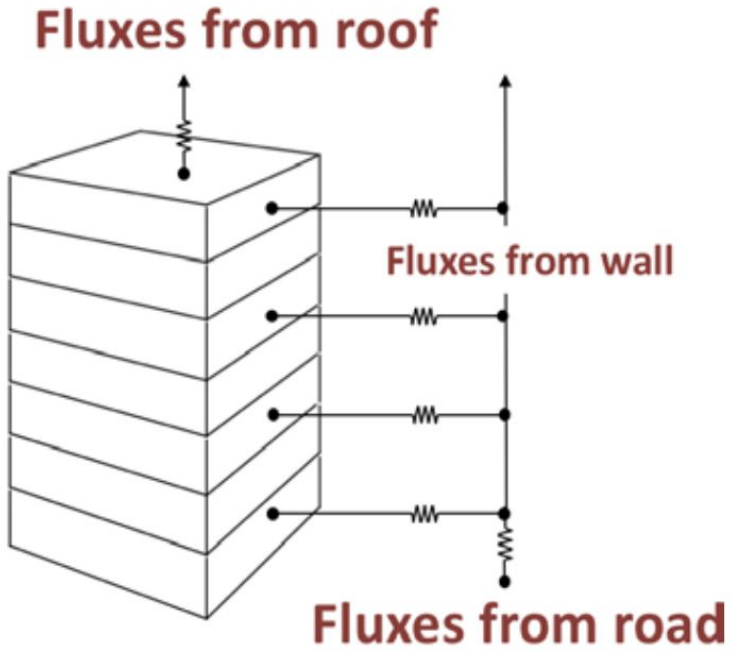
Single-layer parameterization is sufficient for UHI modelling at a regional scale
(Kusaka et al. 2012; Best and Grimmond 2015; Trusilova et al. 2016; Daniel et al. 2018)



(a) Slab Model
(Kusaka et al. 2001)



(b) Single-Layer Model
(Kusaka et al. 2001)



(c) Multi-Layer Model
(Doan and Kusaka 2019)

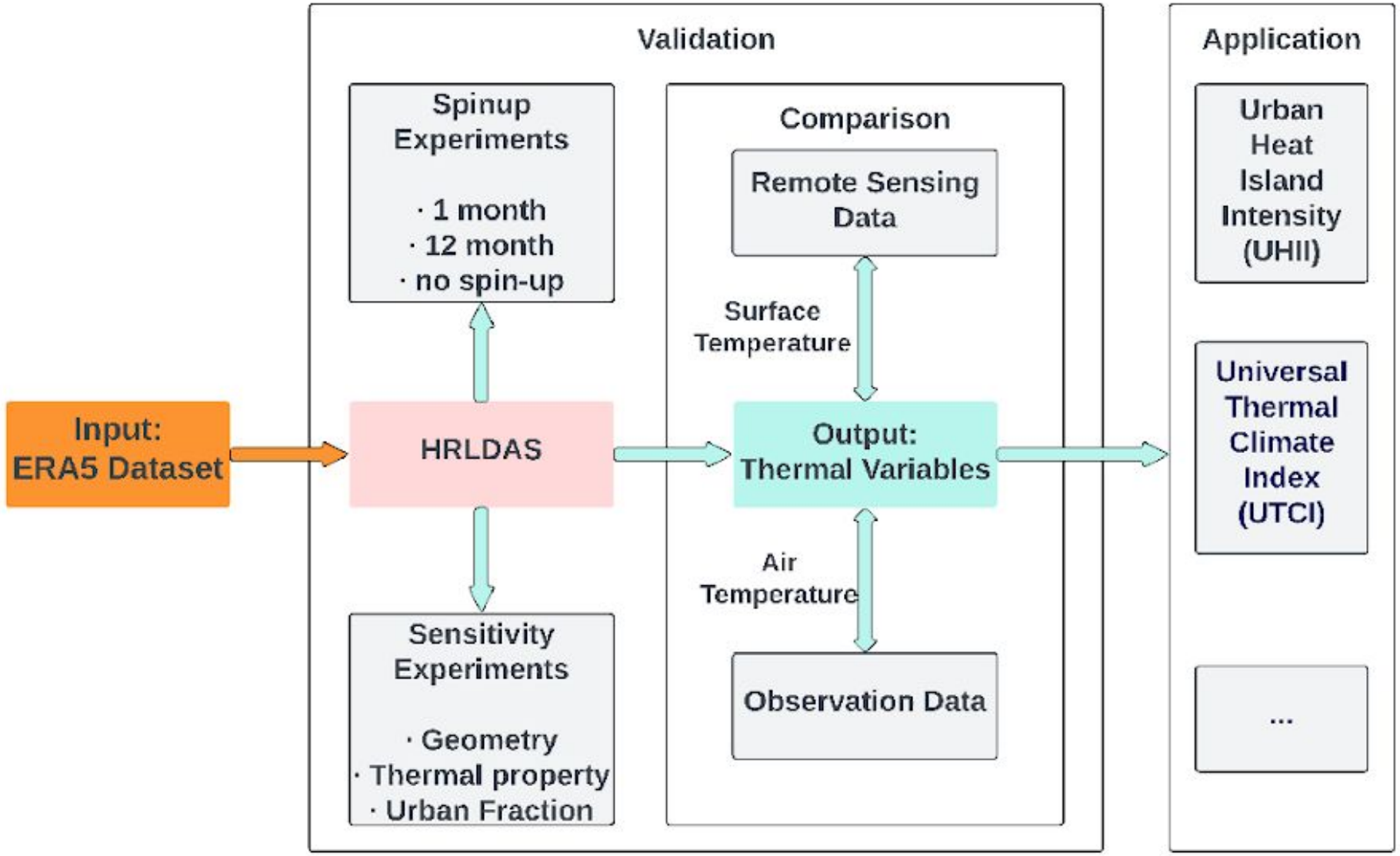
Purpose

- Propose a new **land-surface-physics-based** downscaling approach for urban thermal environment
  - More effective, easy to apply
  - Require fewer computational resources (~15min for 1 month by PC)
  - Can be widely used by policymakers

- Assessment of the system in urban thermal environments
  - Case study of Tokyo Metropolitan Area

2 Method

Method of Performance Verification

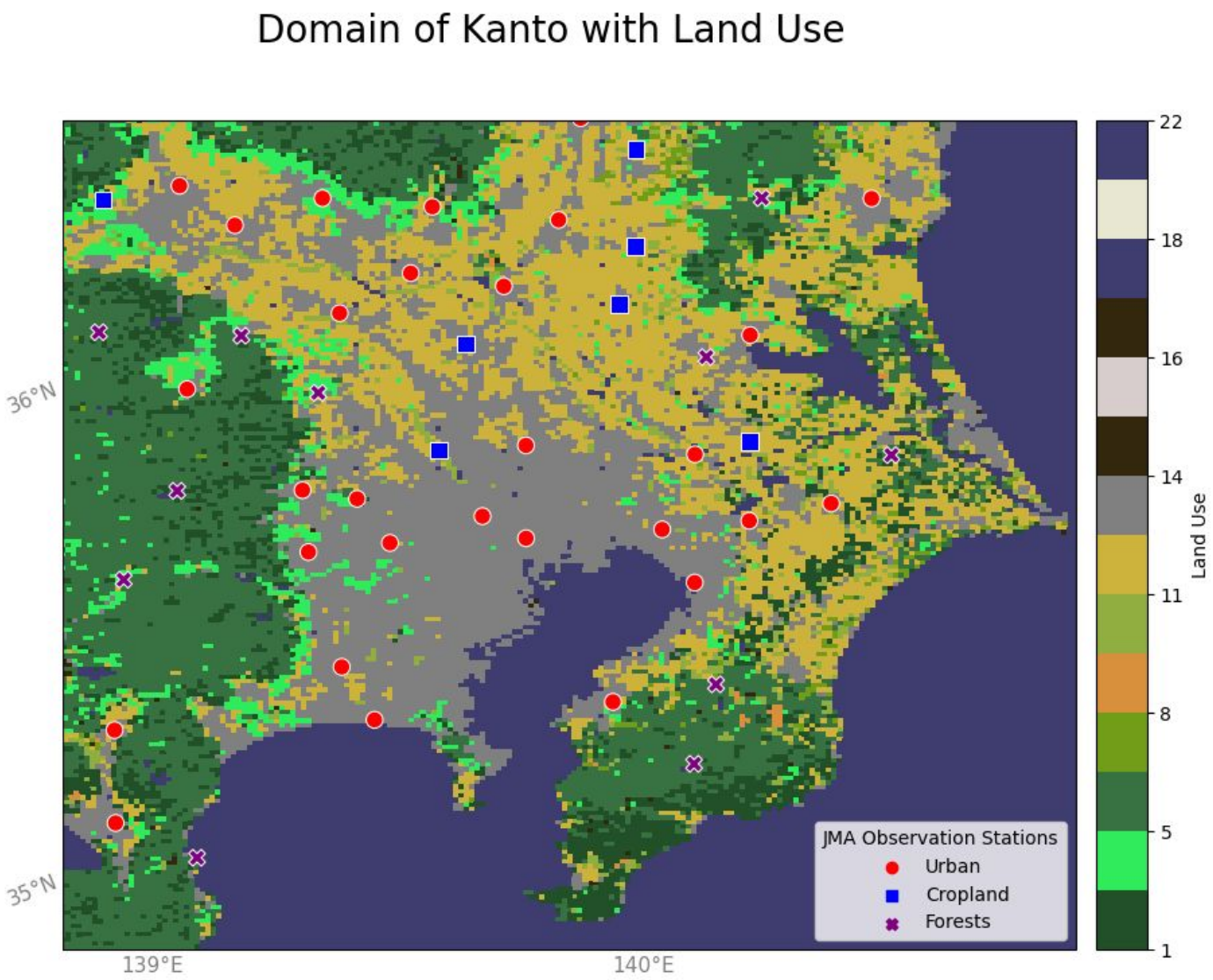


Data

- Observation stations: JMA (~90 stations in this domain)
- Remote sensing data:
  - NASA MOD11A1(Daily, Global, 1km)
  - JMA Himawari (Japan, 1km)
- Forcing data for HRLDAS:
  - ERA5-Land Dataset (radiation, precipitation, surface pressure)
  - ERA5 model levels Dataset (temperature, wind, specific humidity)

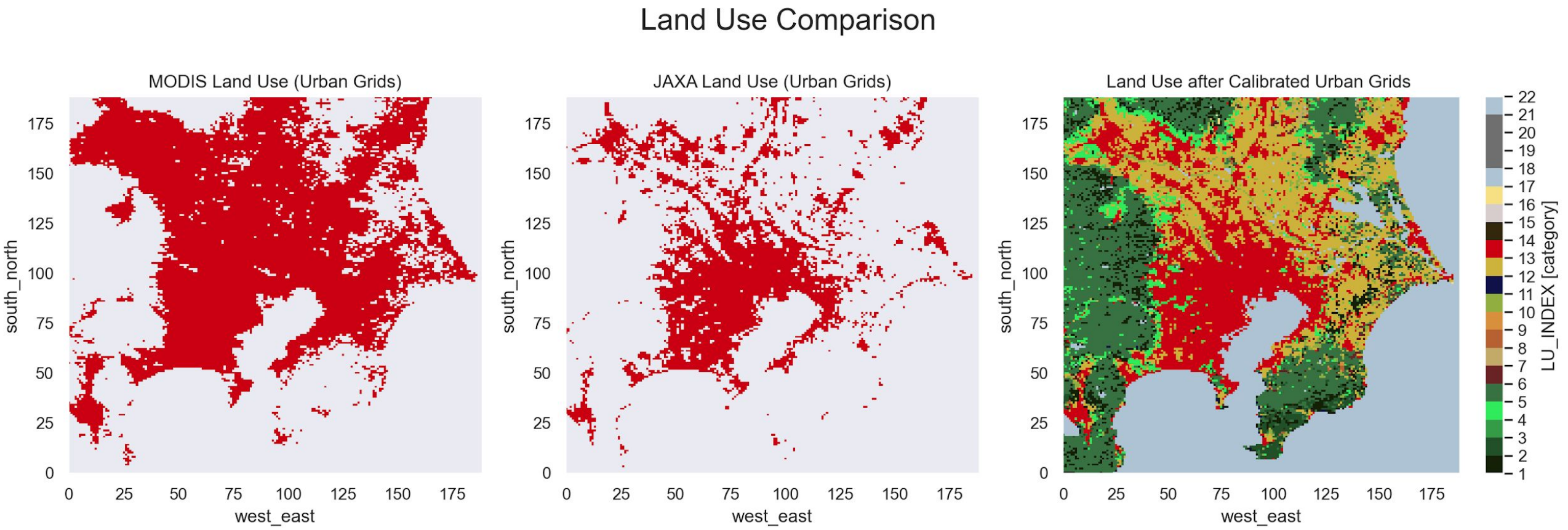
Study Area

- Area: Kanto area of Japan, the centre is Tokyo
- Resolution: 1 km (190*190 grids)



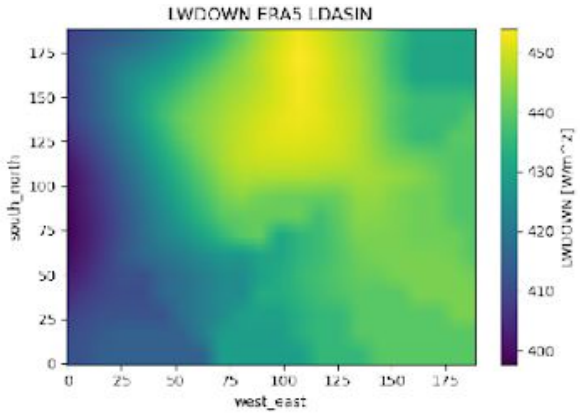
Input of HRLDAS
GEO_EM: Combined MODIS with JAXA

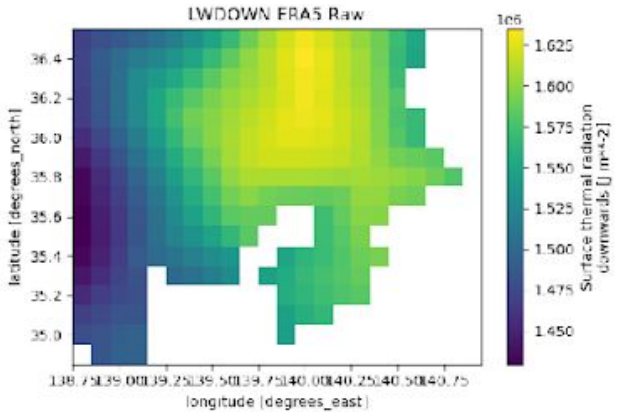
MODIS overestimate the urban area of Tokyo.

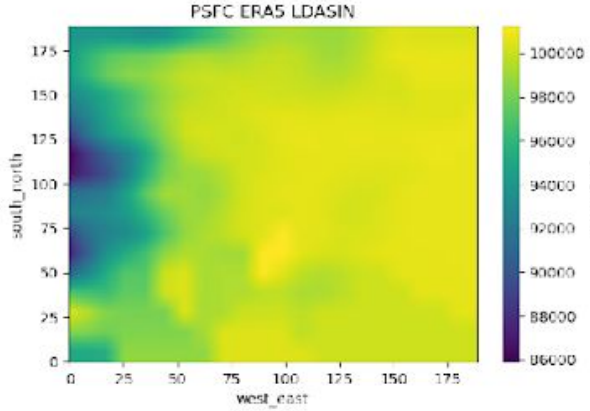


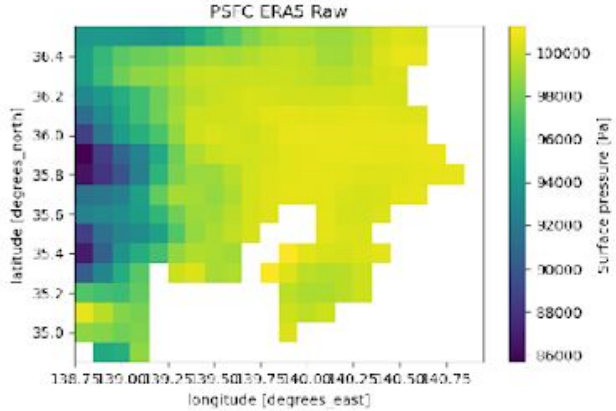
Input of HRLDAS

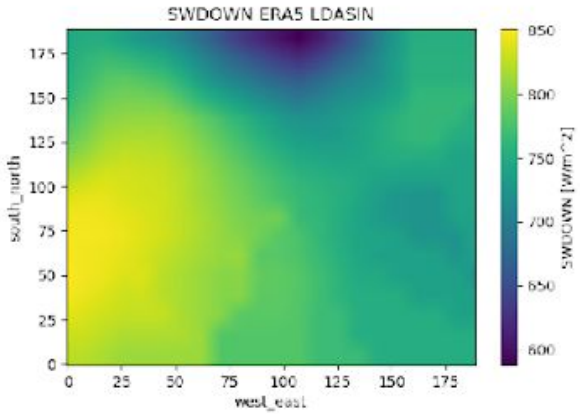
ERA5 Data: Smooth coastline

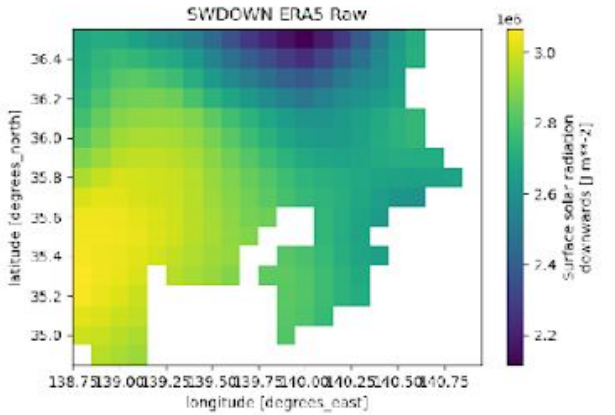


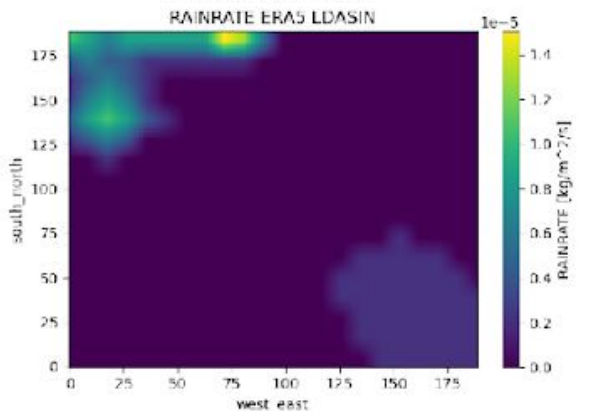


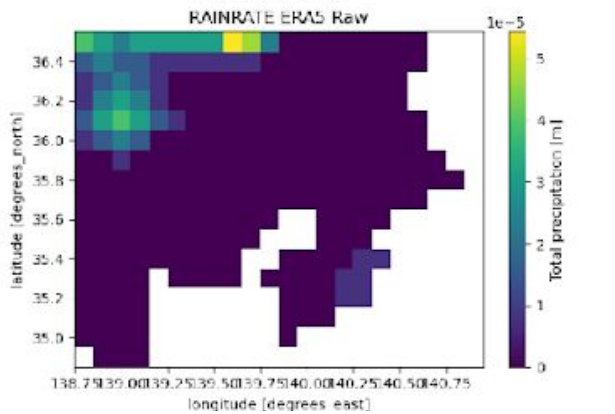












How to Calculate the Air Temperature in Urban?

- Set VegFrac to a fix value (instead of 0.0 in the code)
  - Mean value of VegFrac in Grassland, Cropland and Mix forests.
- Set LAI to read from the input LeafAreaIndex time series (instead of 0.0 in the code)
- Set SAI to max(0.05, 0.1*LeafAreaIndex) (instead of 0.0 in the code)

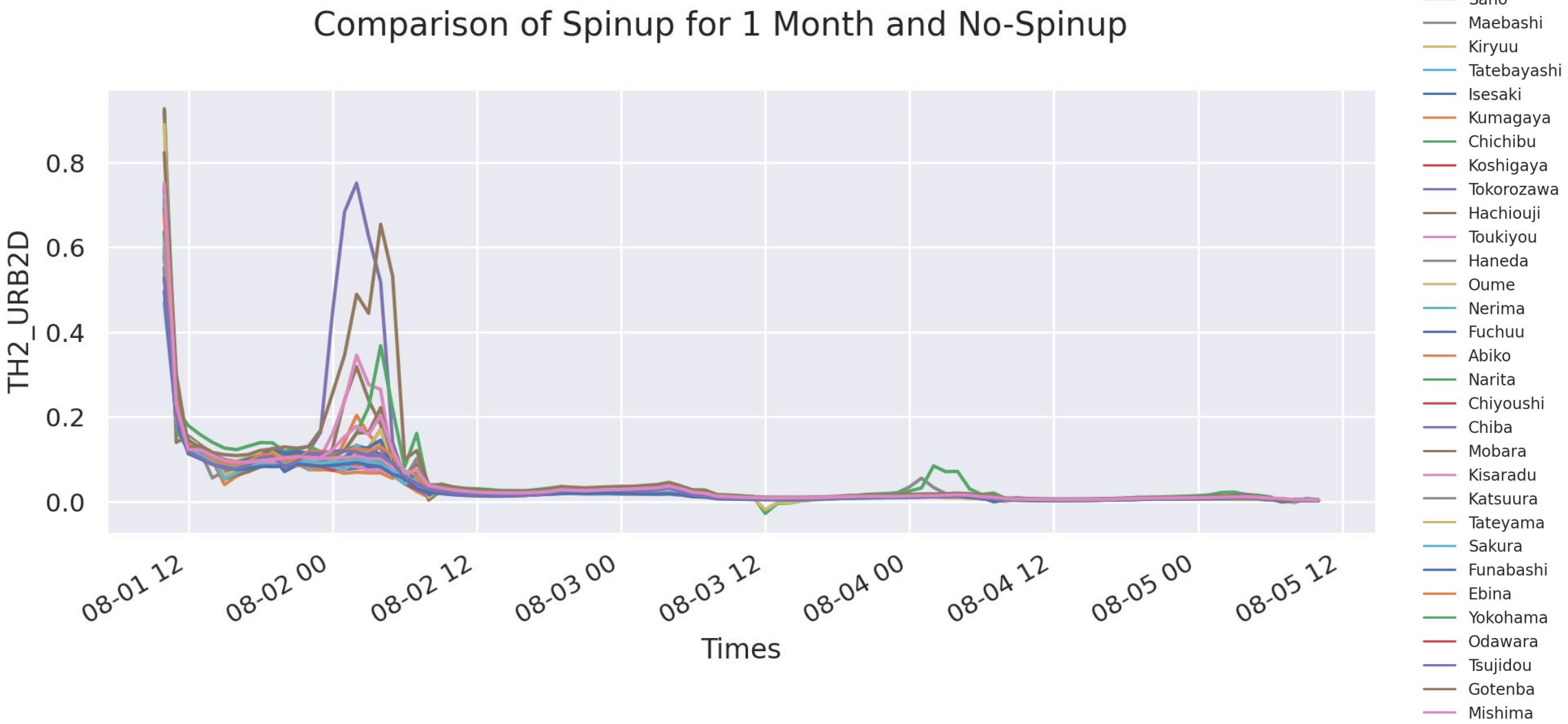
$$TH2 = \underbrace{TH2\_URB2D * FRC\_URB}_{\text{Urban}} + \underbrace{\left(T2MV * VegFrac + T2MB * (1 - VegFrac)\right) * (1 - FRC\_URB)}_{\text{Non-Urban}}$$

Setup

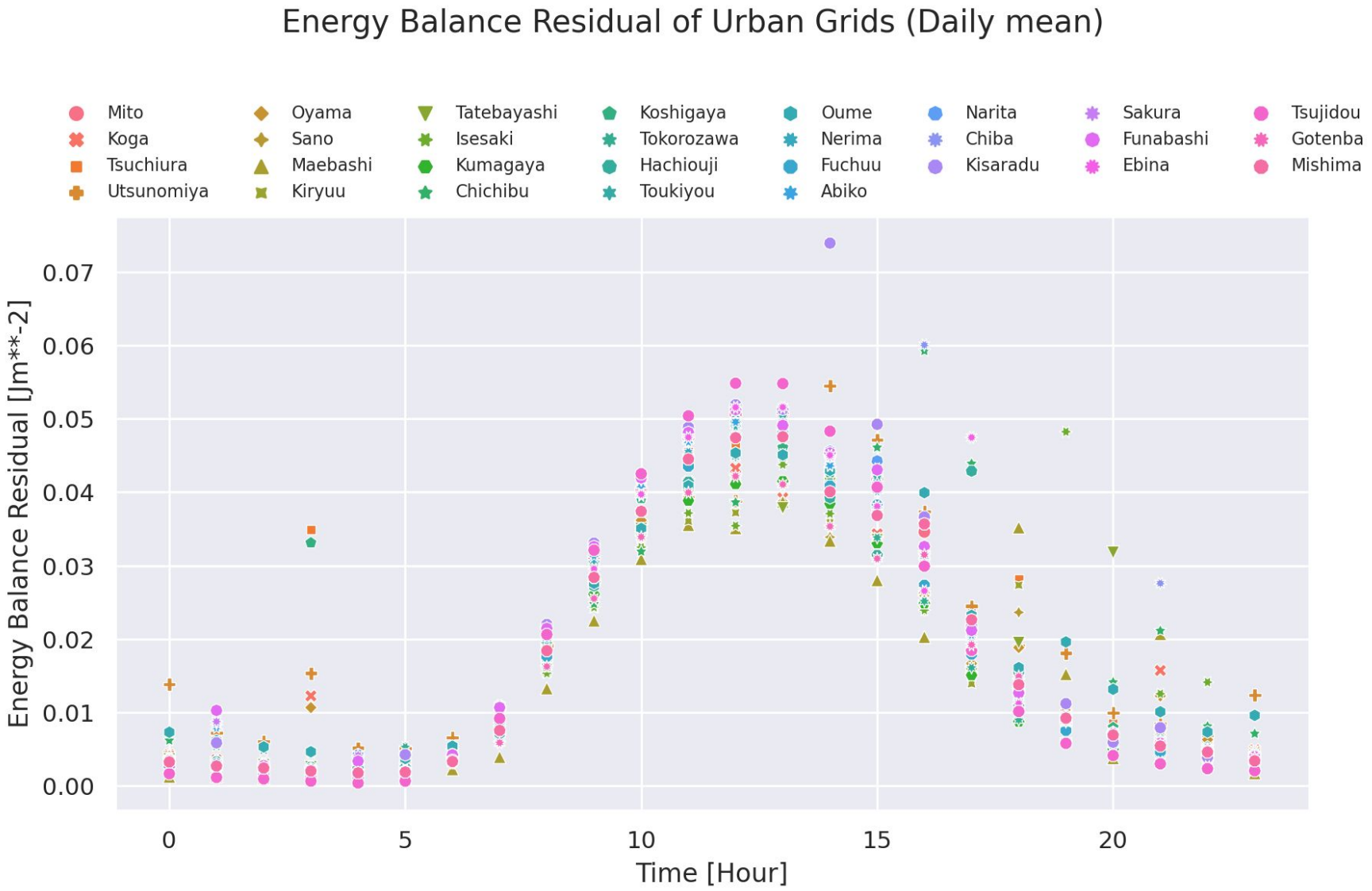
- URBPARAM.TBL (Kusaka et al. 2014)
  - ZR: 9.0
  - FRC_URB: 0.7
  - DYNAMIC_VEG_OPTION = 7 (no dymamic vegetation, use input LAI)
  - ZLVL = 30
  - SF_URBAN_PHYSICS = 1 (single-layer urban canopy model)
- VEGFRAC for URBAN: 0.70

3 Results

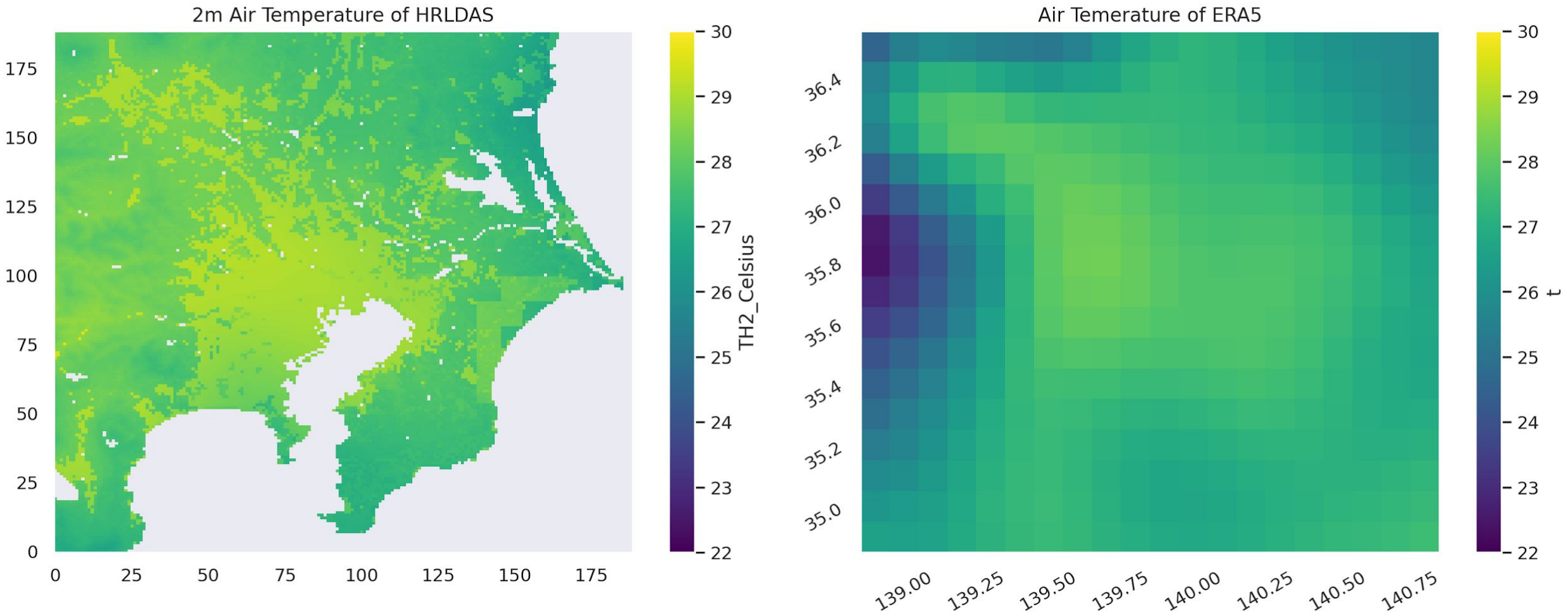
Spin-up Experiments



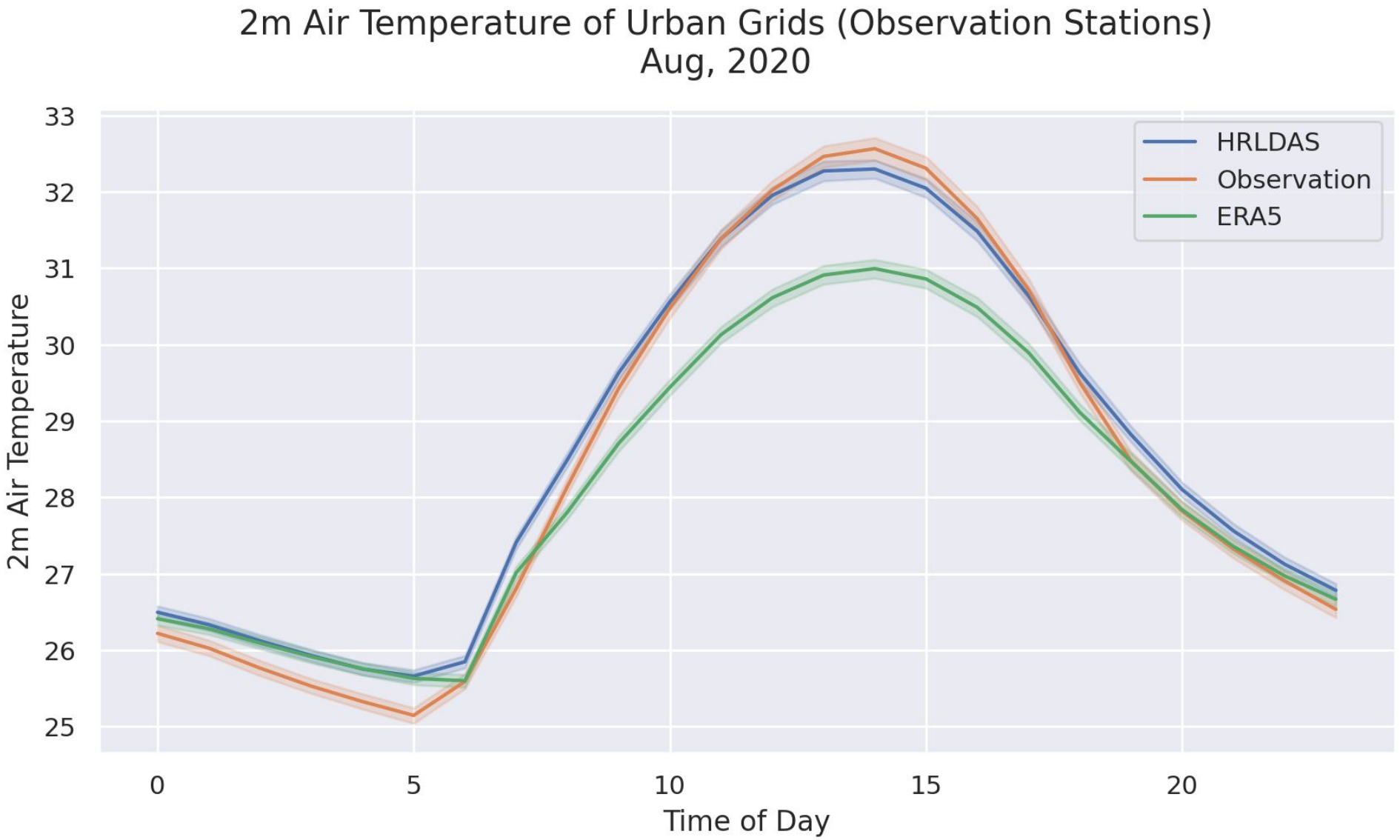
Engery Budgets



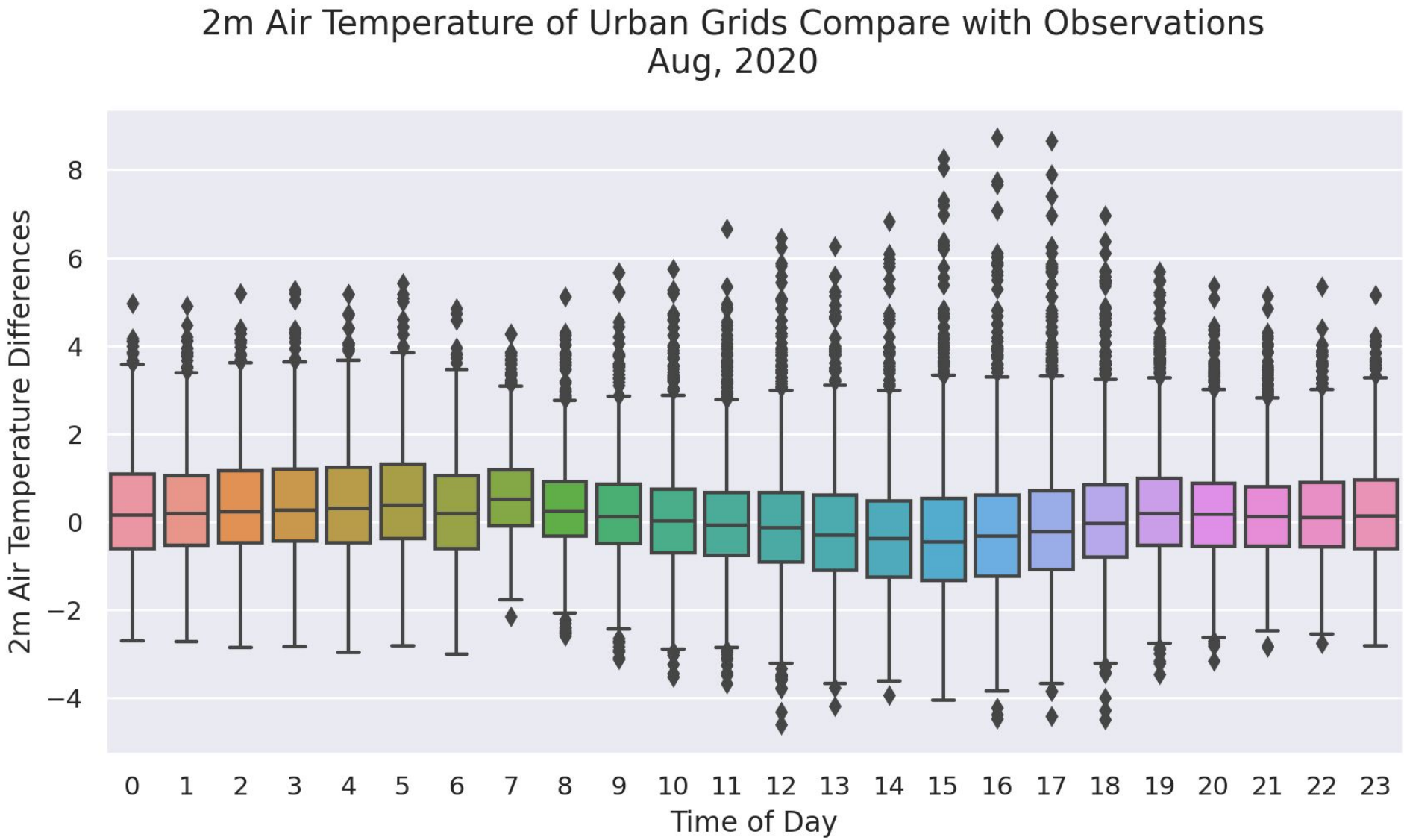
Compare Air Temperature with ERA5



Compare Air Temperature with Observations



Compare Air Temperature with Observations



4 Next Steps

Next Steps

- Plots of Sensitivity experiments
  - Urban geometry
  - Thermal Property
  - Urban Fraction
- Compare with remote sensing data
- Application of Urban Heat Island Intensity(UHII), especially under heat waves
  - Air temperature
  - Surface temperature
- Application of the thermal index
  - Universal Thermal Climate Index (UTCI) *(Jendritzky 2012)*

Thank you