# Using WRF-Urban to assess summertime air conditioning electric loads and their impacts on urban weather in Beijing

**Xiaoyu Xu [a, b, c], Fei Chen [c], Shiguang Miao [b] and Michael Barlage [c]**

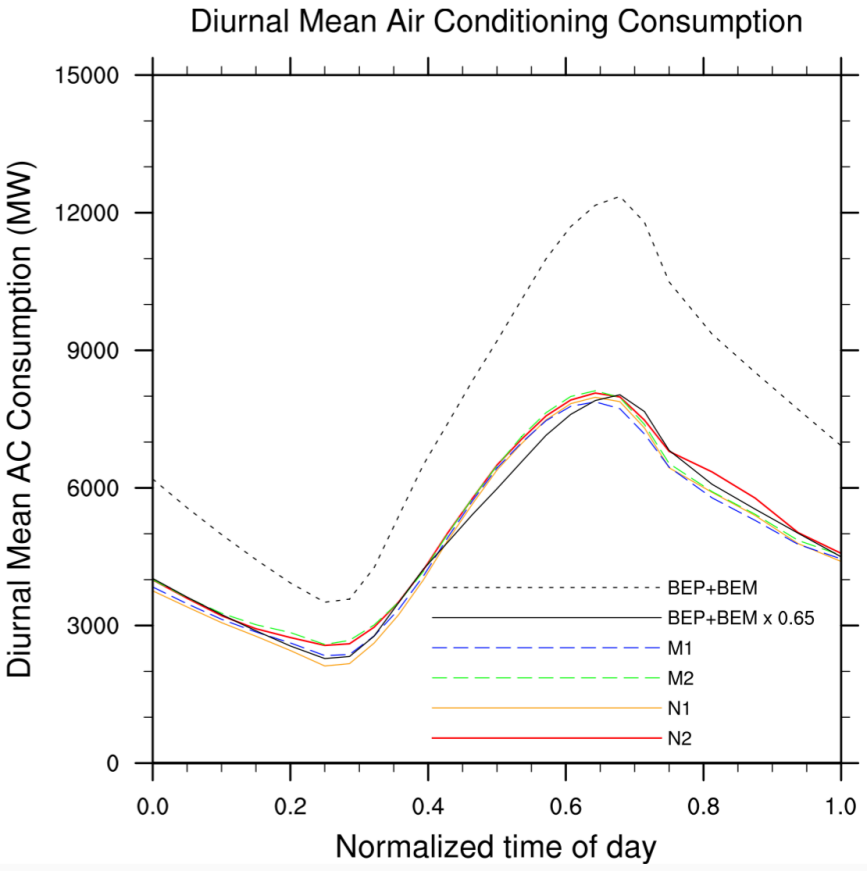
[a] NUIST, Nanjing, China

[b] IUM, Beijing, China

[c] RAL/NCAR, Boulder, USA

# 1 Background

- **More frequent and intense extreme heat days** in the context of global warming (Tebaldi et al. 2006);
- **More** air conditioning (AC) **cooling energy consumption** in cities with hot summers like Beijing during extreme heat days;
- **Few research on validation of AC consumption** against observation. One example is Salamanca et al.(2013), in which only average diurnal cycle over Phoenix was evaluated and **spatial verification was overlooked**.

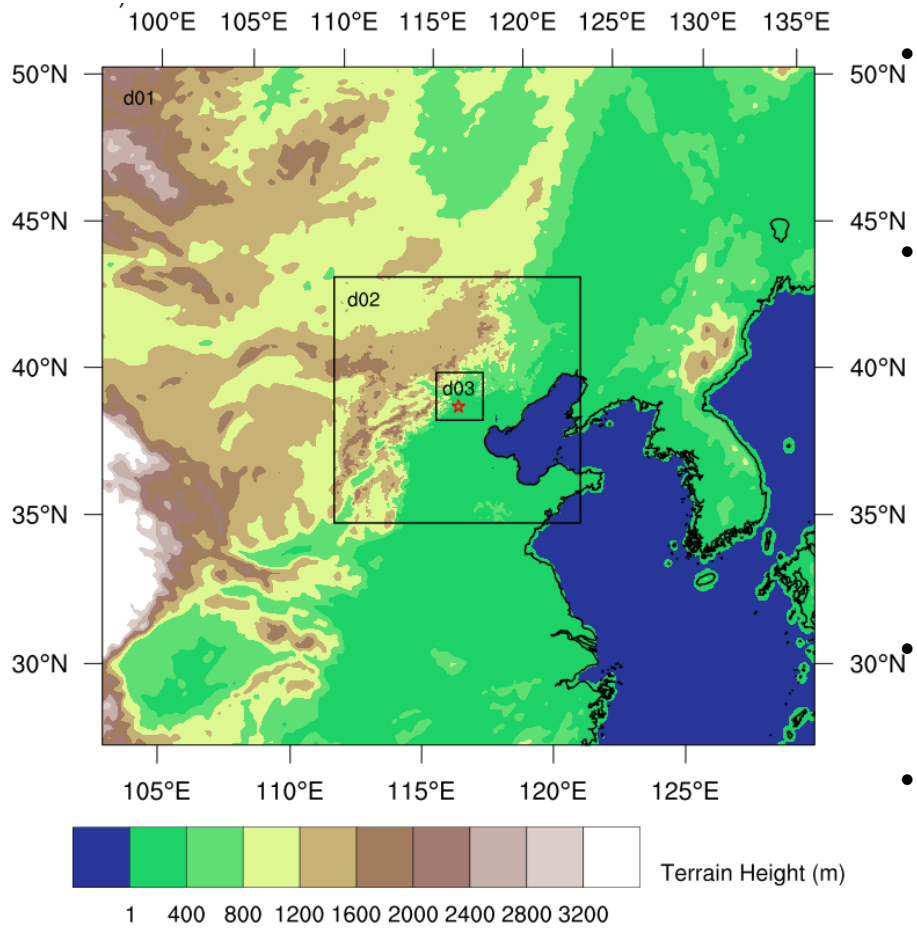



From Salamanca et al.(2013)

# Objectives

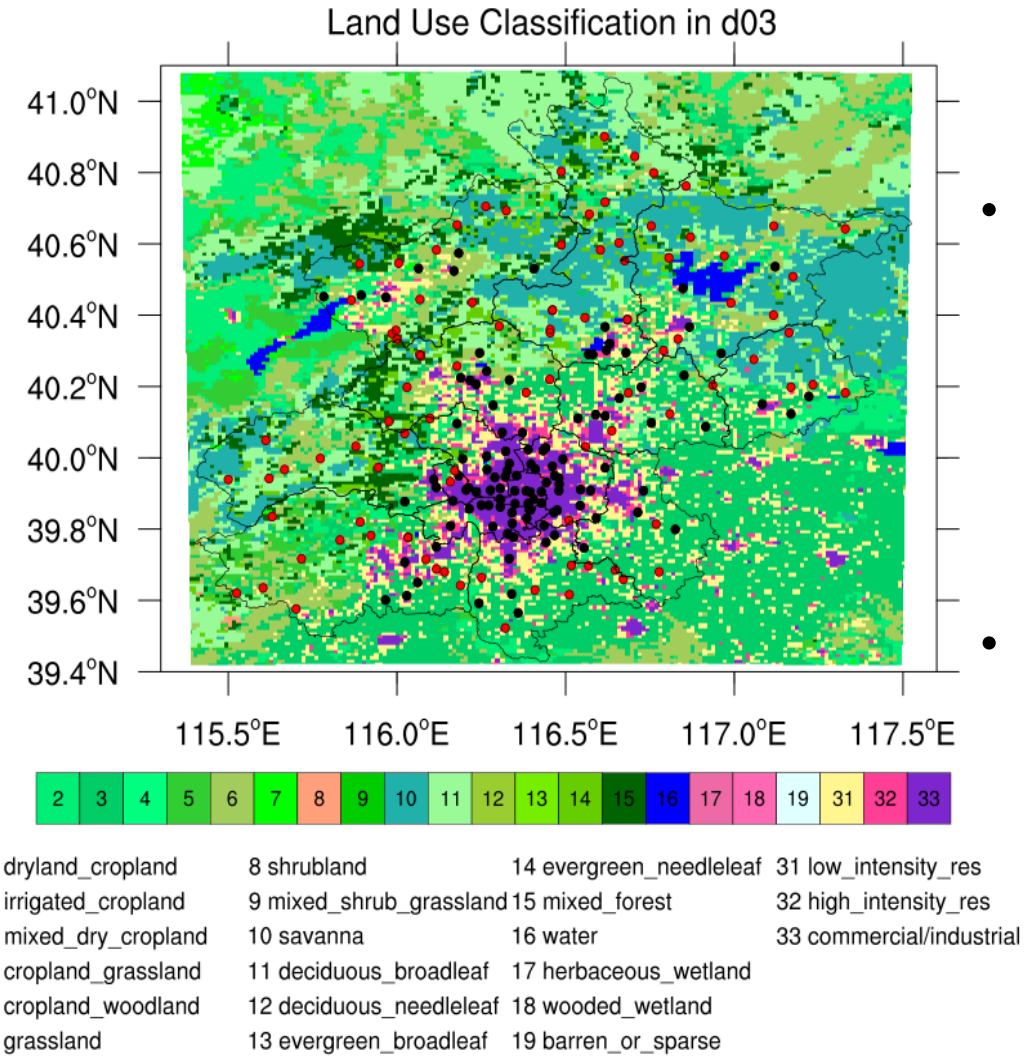
- **Validating** WRF-Urban results against observed AC electric loads **spatially** and **temporally** during a 5-day **heatwave event** (02/July/2010 – 06/July/2010) in Beijing.
- Assessing **impacts** of waste heat release due to AC systems on urban weather (2-m air temperature).

# 2 Methodology — model configuration




- **WRF Version 3.9**
- **Tree two-way nested domains**
  - 9km (299285), 3km (310310) and 1km (178181)
  - 38 sigma levels with 13 levels in the lowest 1km
- **Physical parameterizations**
  - **RRTMG** shortwave and longwave radiation ;
  - **WDM6** microphysics;
  - **K-F** cumulus scheme for d01 and d02;
  - **MYJ** PBL scheme;
  - **Noah-MP** with default options coupled to BEP+BEM.
- **Initial and boundary conditions**: 6-hrly GFS (1°1°)
- **Heatwave case:** 1200 UTC 1 July - 1800 UTC 6 July 2010, with a spin-up of 4 h

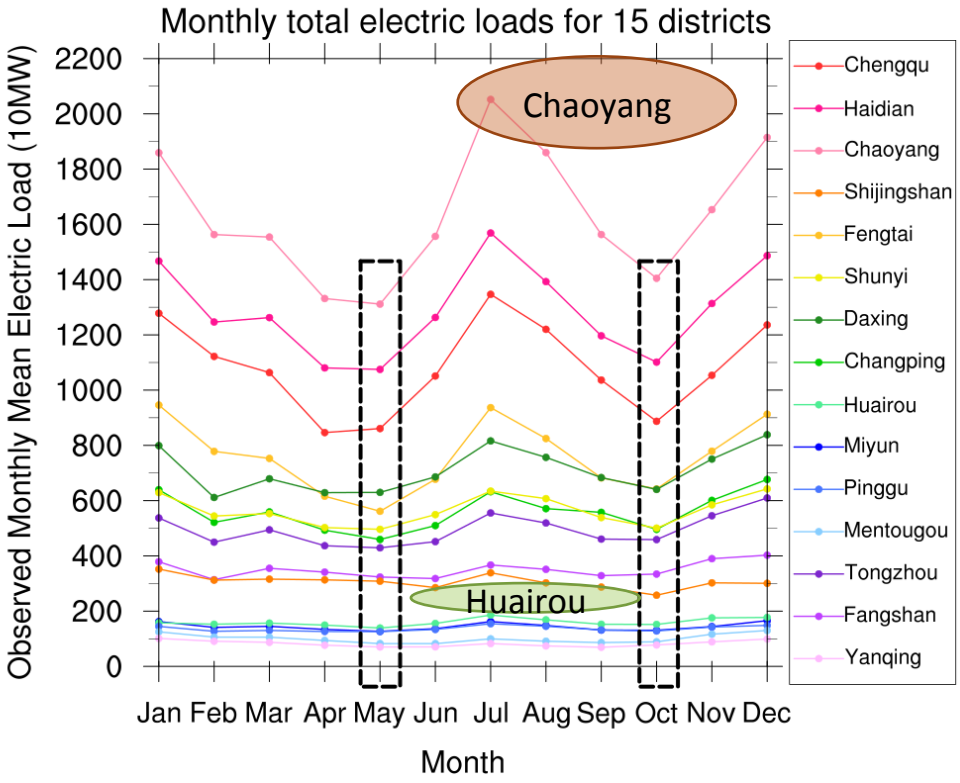
# 2 Methodology — evaluation data

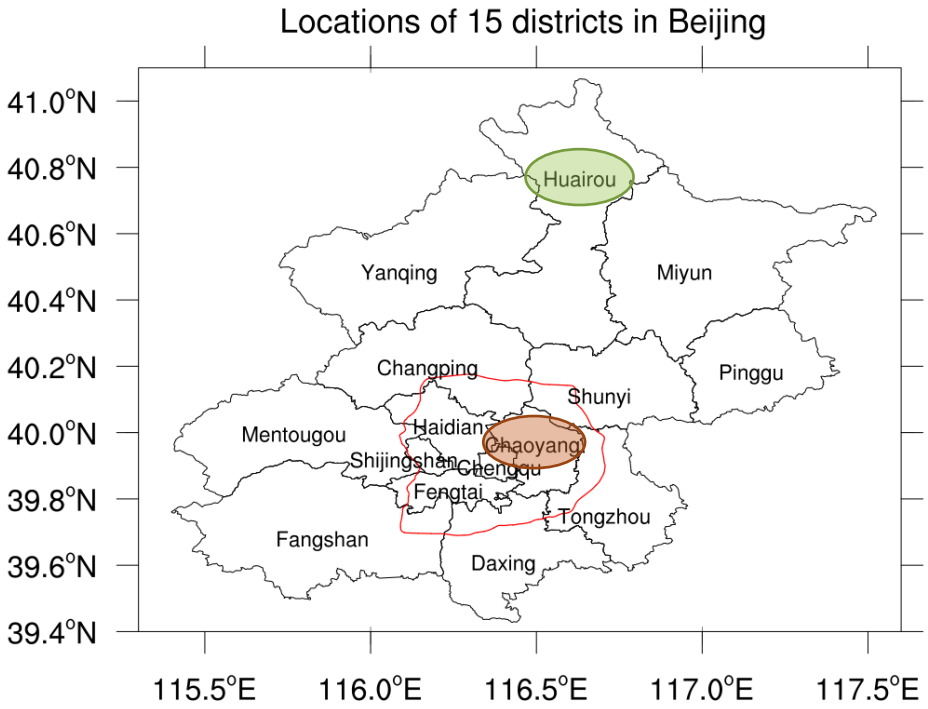



- **Surface-meteorology data (hourly)**
  - 2-m air temperature, humidity and 10-m wind speed
  - 115 urban stations (**black** dots)
  - 95 rural stations (**red** dots)
- **Total electric loads in 15 districts in Beijing (quarter-hourly)**

# 2 Methodology — how to separate AC loads from total electric loads?

***Following the method of Salamanca et al. (2013) to calculate AC electric loads***



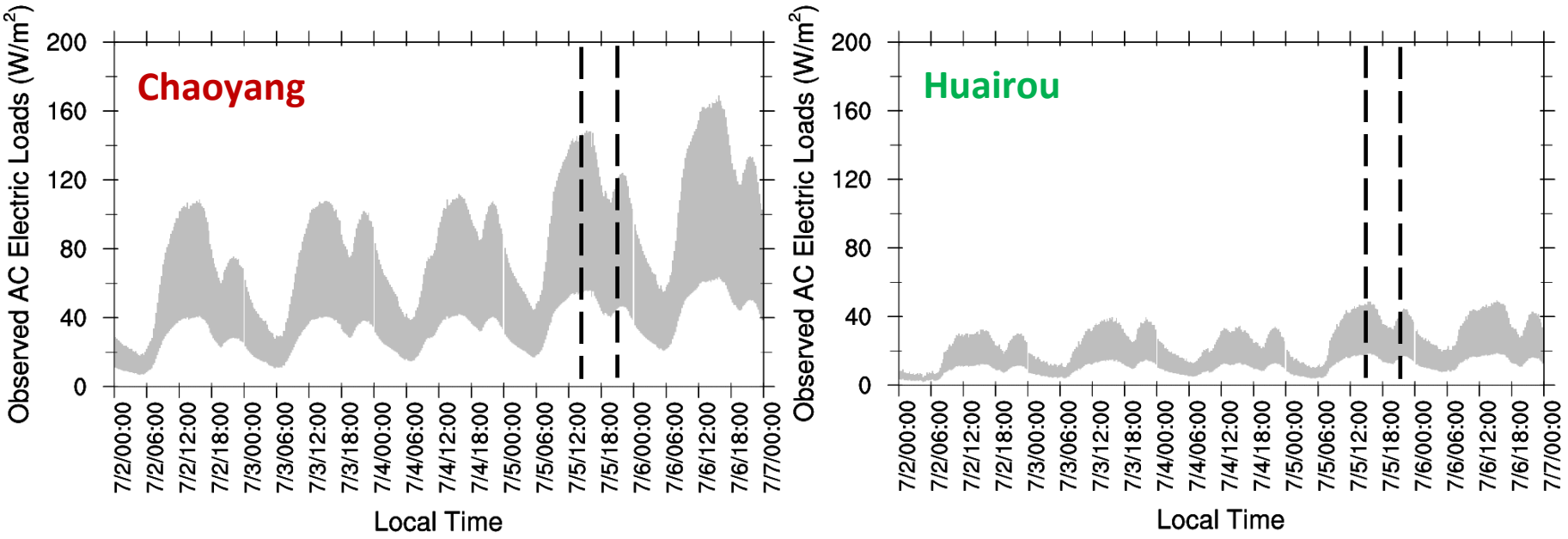



# 2 Methodology
## — AC load uncertainty range

Total area, impervious surface percentage and built-up area

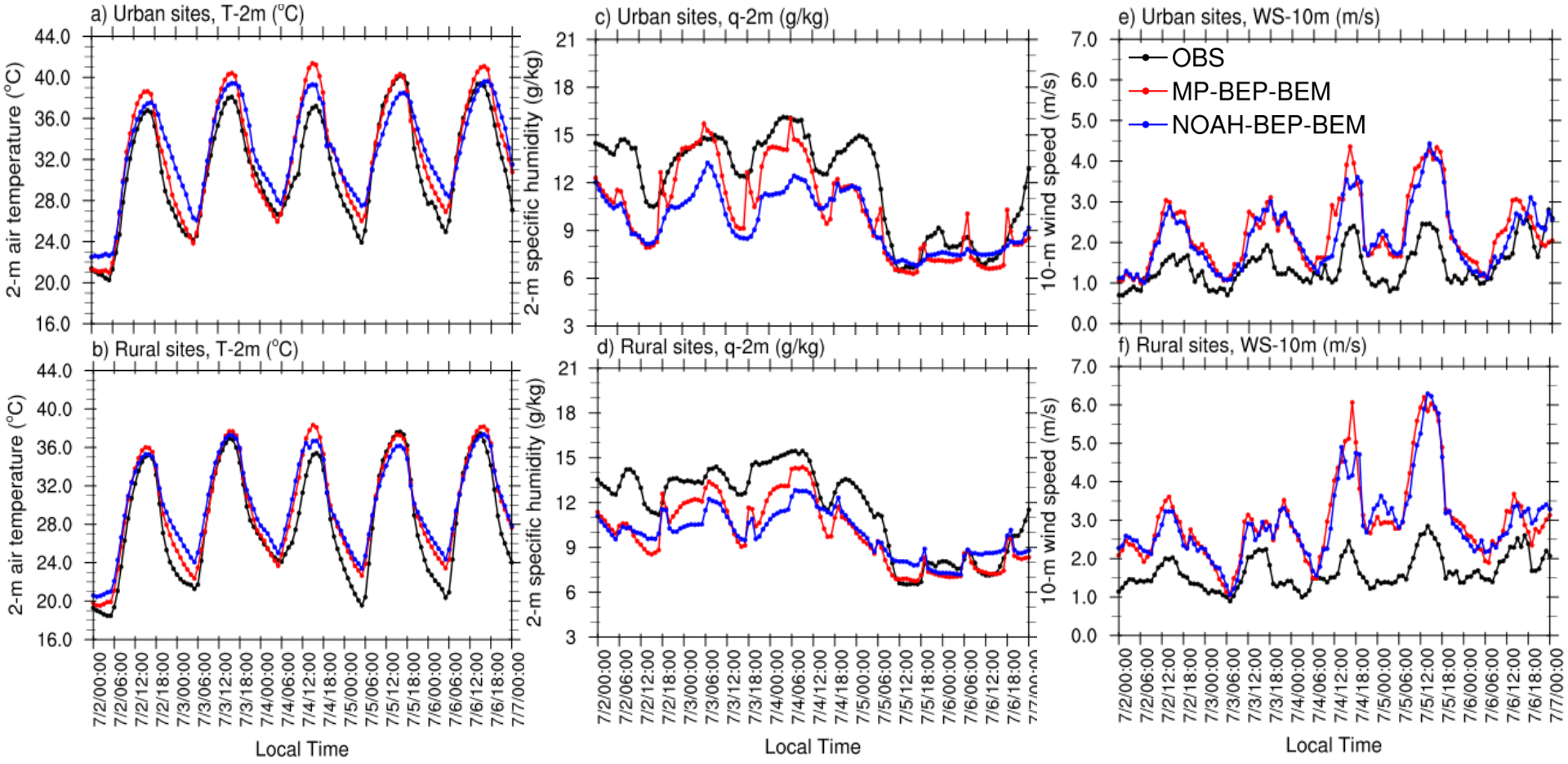
| District Name | Total Area ($10^6$ m$^2$) | Impervious Surface Percentage (%) | Min Built-up Area ($10^6$ m$^2$) | Max Built-up Area ($10^6$ m$^2$) |
|---|---|---|---|---|
| **Chaoyang** | 470.8 | 65.9 | 93.1 | 248.2 |
| **Huairou** | 2557.3 | 2.6 | 19.9 | 53.2 |

A varying normalized roof width **[0.3, 0.8]** from Wang et al. (2011) is used to estimate the min and max built-up area.



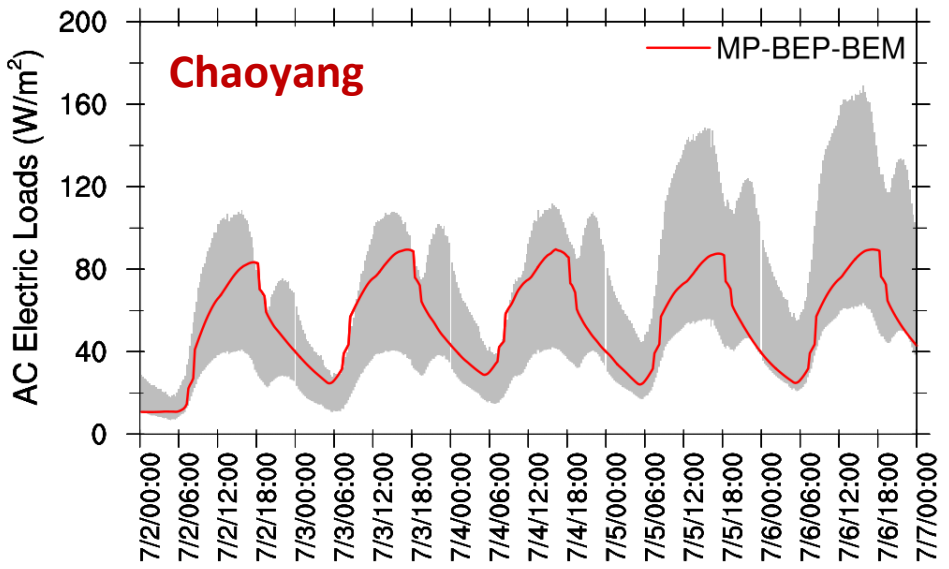
# 3 Model performance — surface meteorology

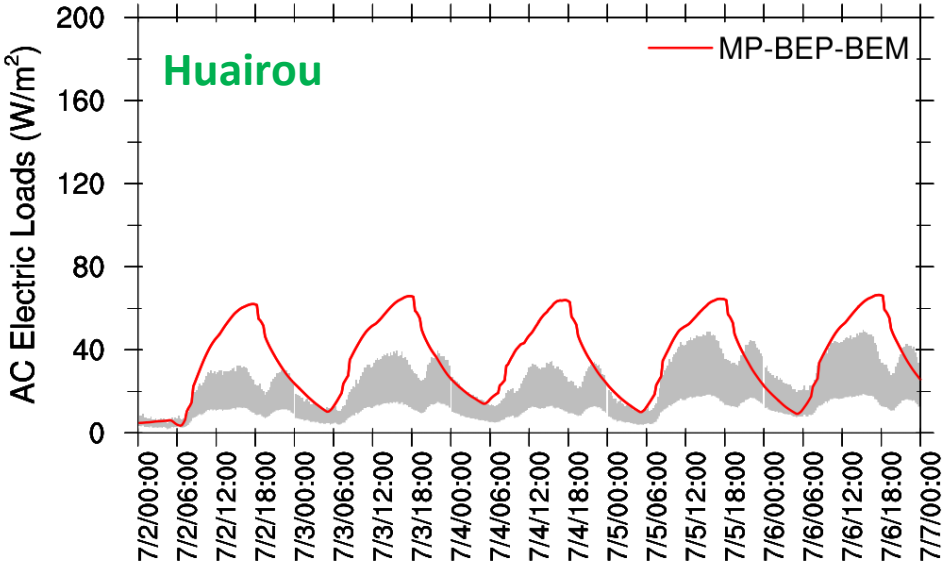
| Numerical experiments | Model setup |
|---|---|
| **MP-BEP-BEM** | Model configuration described above |
| **NOAH-BEP-BEM** | Same as MP-BEP-BEM, but with **Noah** coupled to BEP+BEM |

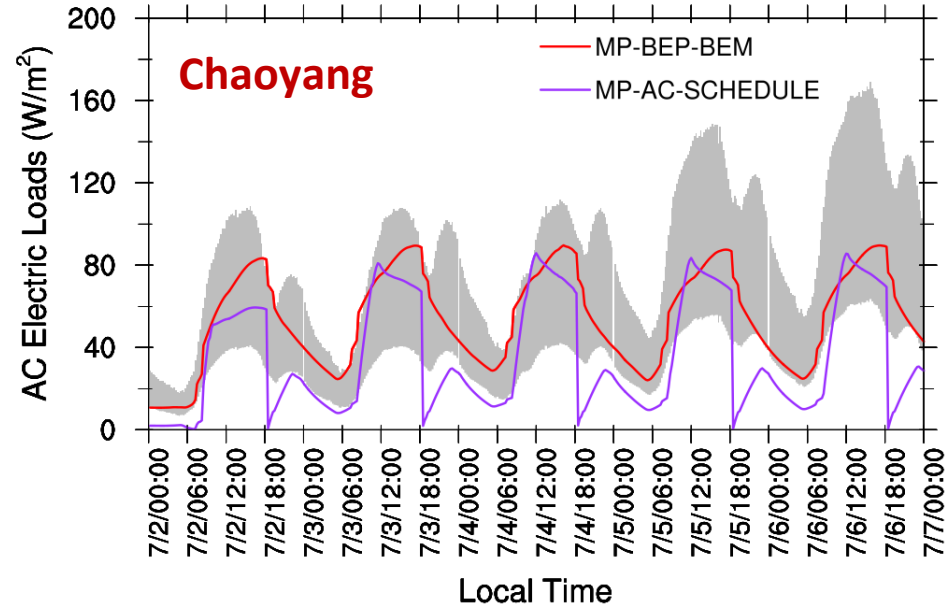


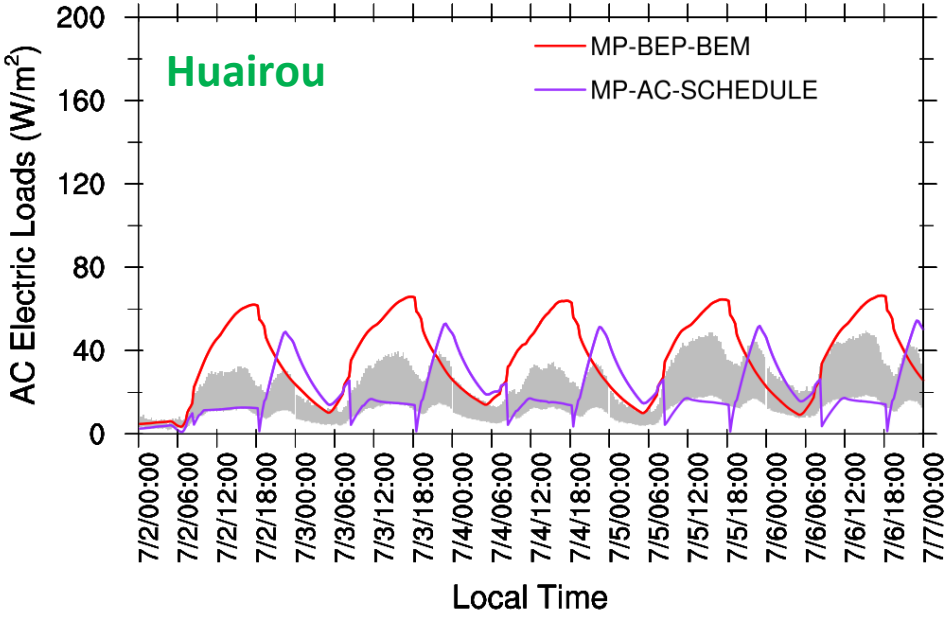

**T-2m, unit: °C** **q-2m, unit: g/kg** **WS-10m, unit: m/s**

# 3 Model performance — AC electric loads



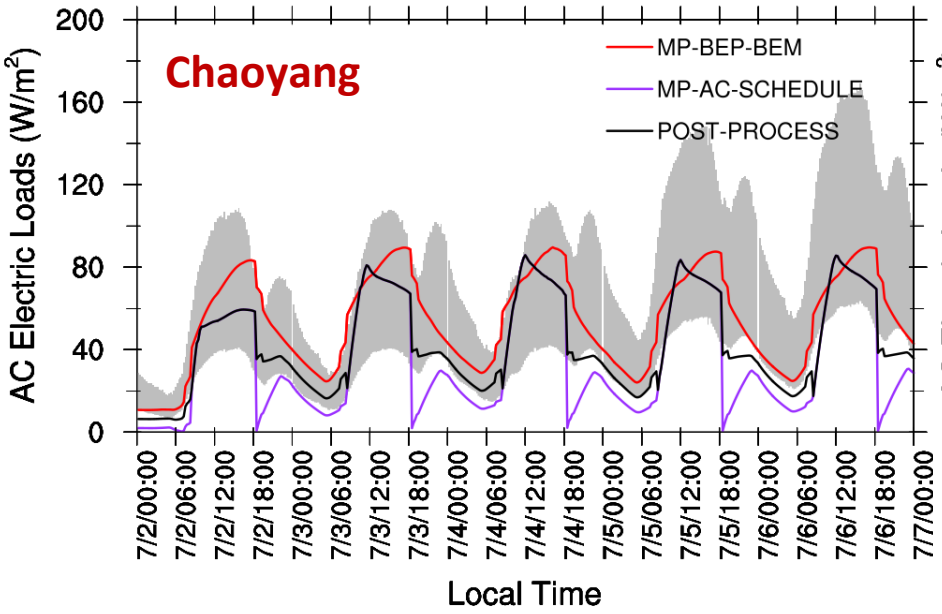



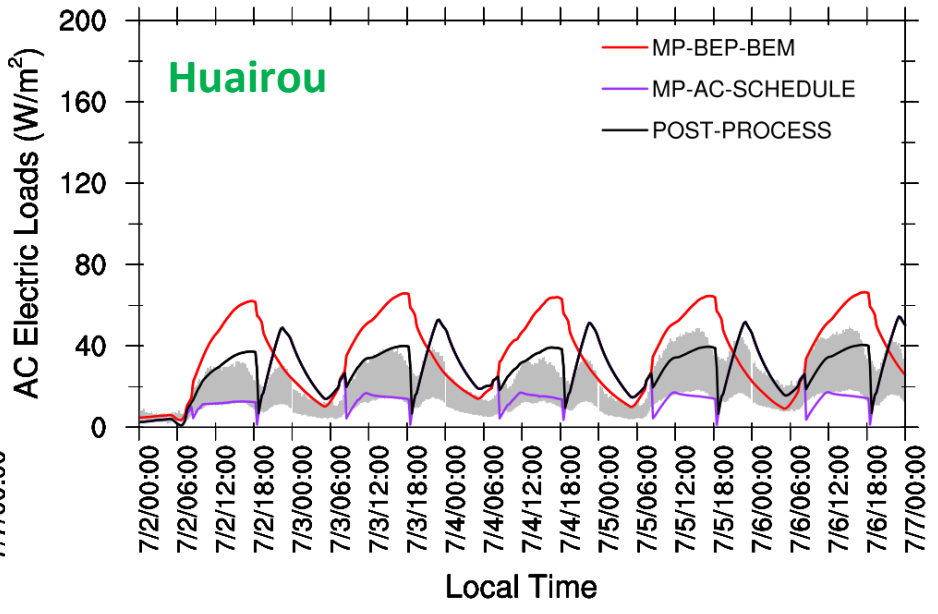



# 3 Model performance — AC electric loads

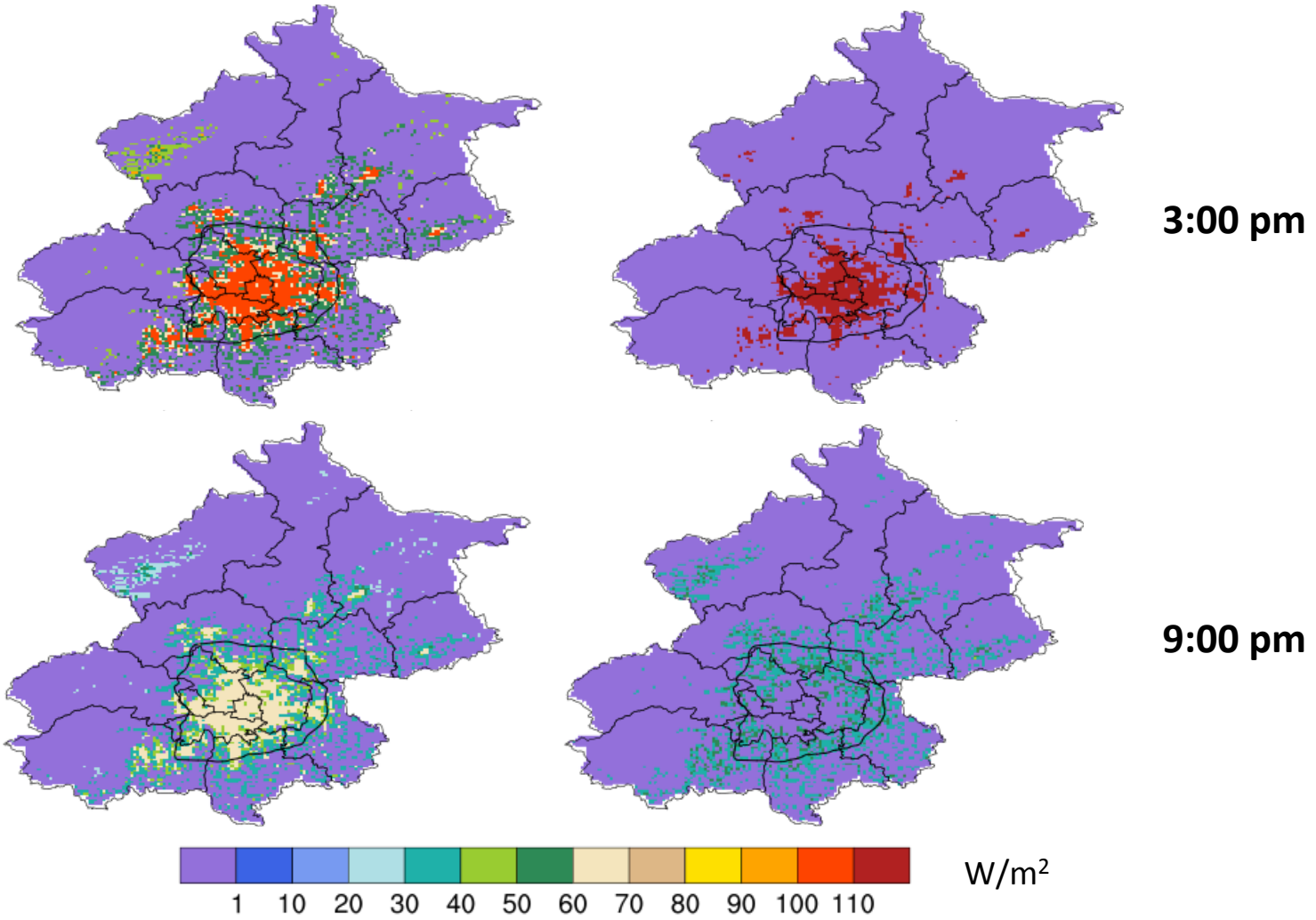
| | Chaoyang (commercial-dominant) | Huairou (residential-dominant) |
|---|---|---|
| **POST-PROCESS (based on MP-AC-SCHEDULE)** | **Daytime:** all commercial AC working<br>**Nighttime:** all residential AC working + **50%** commercial AC working | **Daytime:** all commercial AC working + **50%** residential AC working<br>**Nighttime:** all residential AC working |



# 4 Results spatial distribution

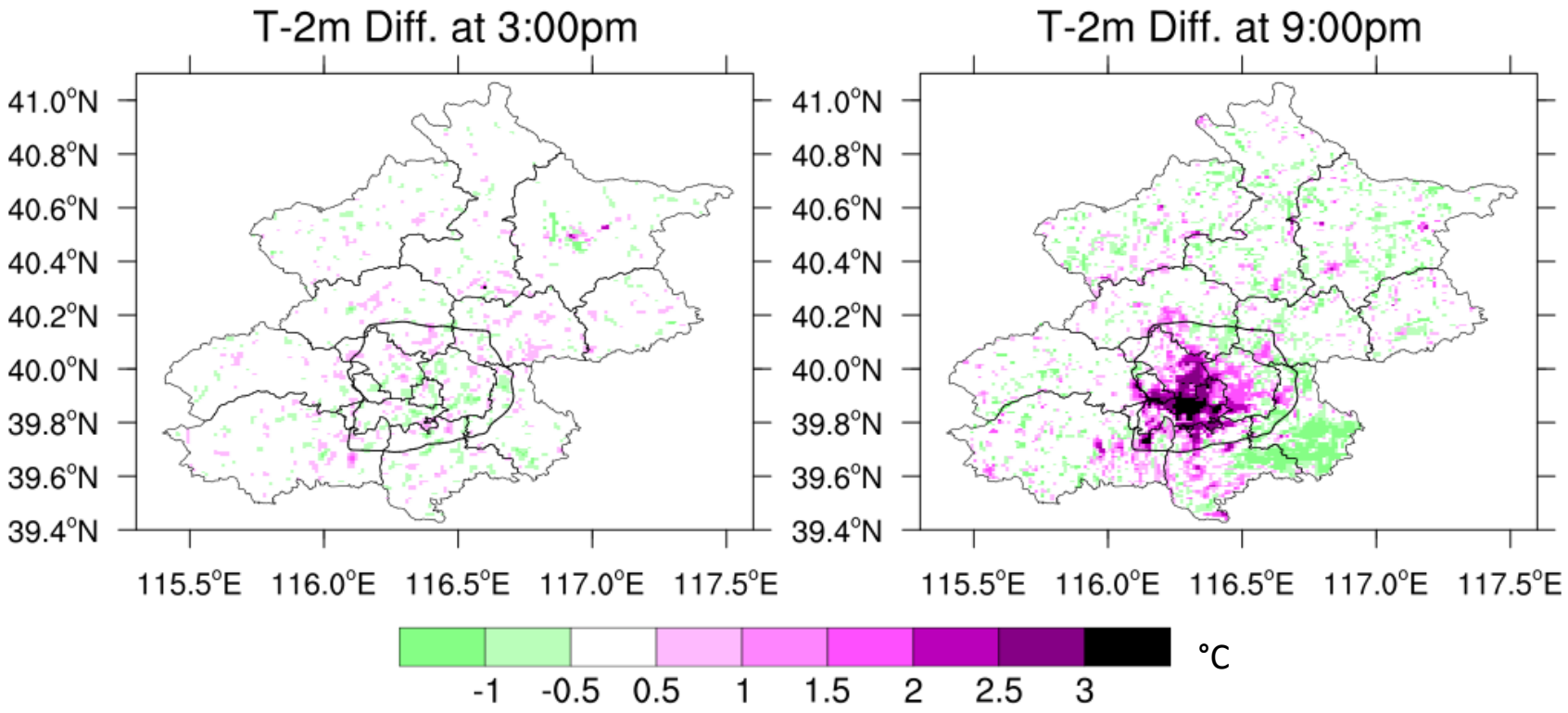
## at two peaks (July 5th)



# 4 Results Impacts on T-2m

## at two peaks (July 5th)

**MP-BEP-BEM** minus **MP-AC-SCHEDULE**



# 5 Conclusions

In this study, the newly-released WRF-Urban modeling system is used to explore the AC electric loads for Beijing during a 5-day heatwave event in 2010. Results show that,

- Compared to Noah coupled to BEP+BEM, **Noah-MP better reproduces 2-m air temperature and humidity** in both urban and rural areas; 10-m wind speed is still overestimated at both sites;

- Temporally, the **double-peak structure** (at 3pm and 9pm local time) in the diurnal variation profile of observed AC loads can be captured by WRF-Urban to some extent by applying **different working schedules** of AC systems to commercial and residential grids;

- Spatially, **high electric energy consumption** due to AC cooling is concentrated in urban districts roughly encircled by the 6$^{th}$ ring road, featuring a very **similar pattern to urban land use classification**;

- Anthropogenic heating **increases the evening 2-m air temperature** in urban districts by more than 2 °C though AC loads peak in the afternoon, when negligible impacts are found.

***Thank you!***

***Any questions?***