

High-resolution Simulations of a Hot-and-polluted Event with Detailed Local Climate Zone Information over the Greater Bay Area in South China

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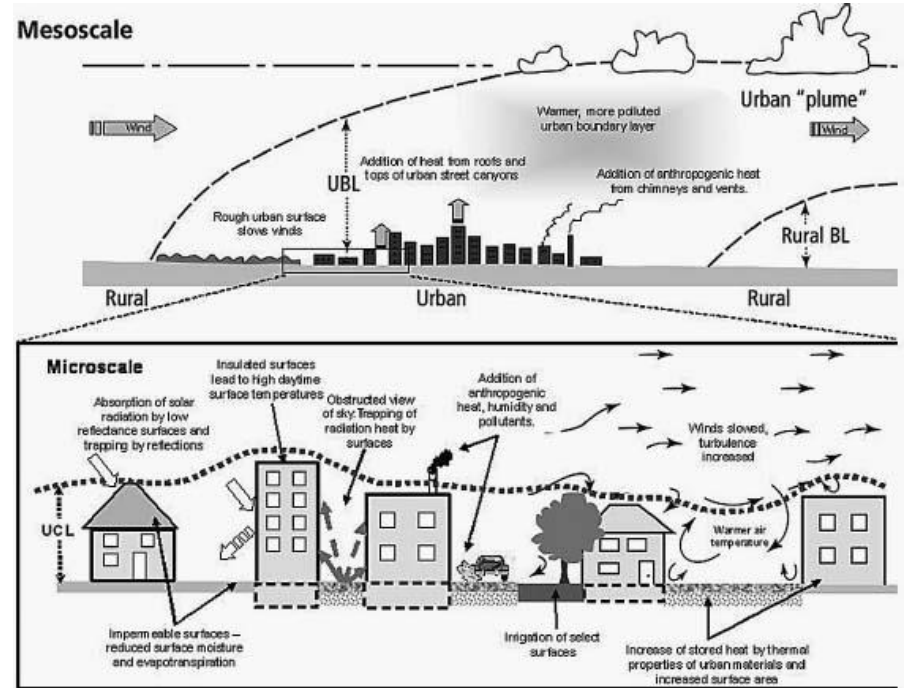
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May 7, 2020

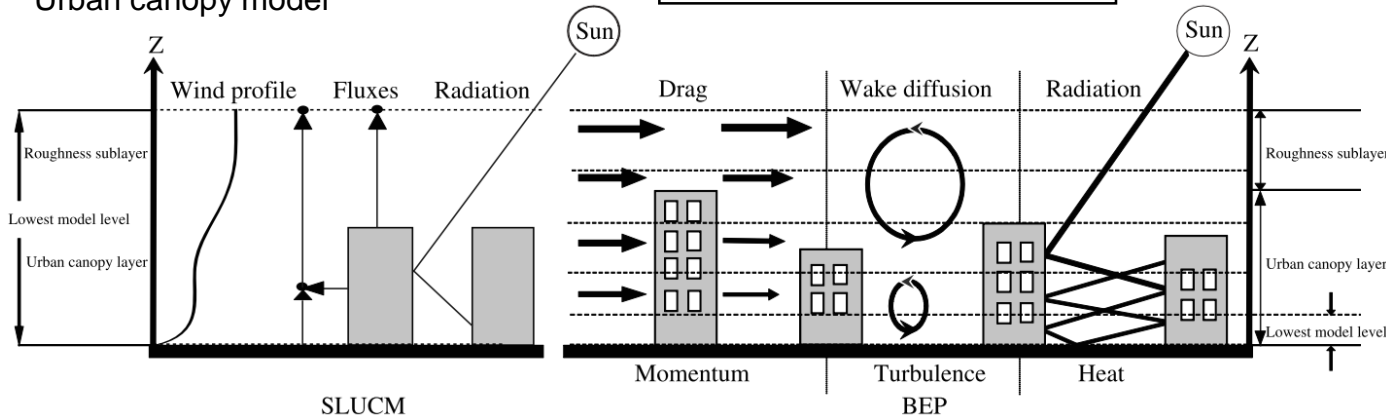
1. Background
2. WUDAPT datasets
3. Hot and polluted event
4. Experiments
5. Results
6. Discussion

1. Background

- Weather:
 - Representation of urban morphology in different space scale.
 - Anthropogenic latent and sensible heat (diurnal cycle and weekly cycle).
 - Temporospatial variation of temperature, humidity, winds, clouds, and precipitation.
- Air-quality:
 - Uncertainties in the meteorological fields.
 - Emissions of air pollutants.
 - Dispersion of air pollutants.

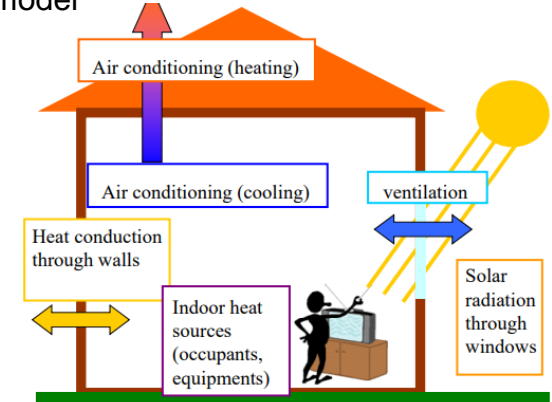


Urban canopy model



- 1: Low-density Residential;
- 2: High-density Residential;
- 3: Commercial and Industrial;

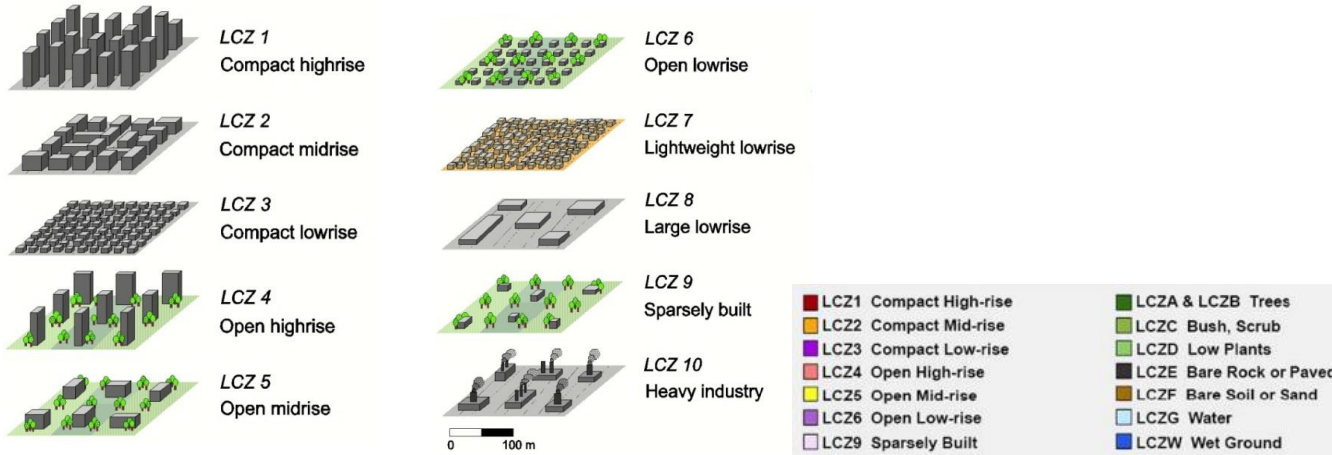
Building energy model



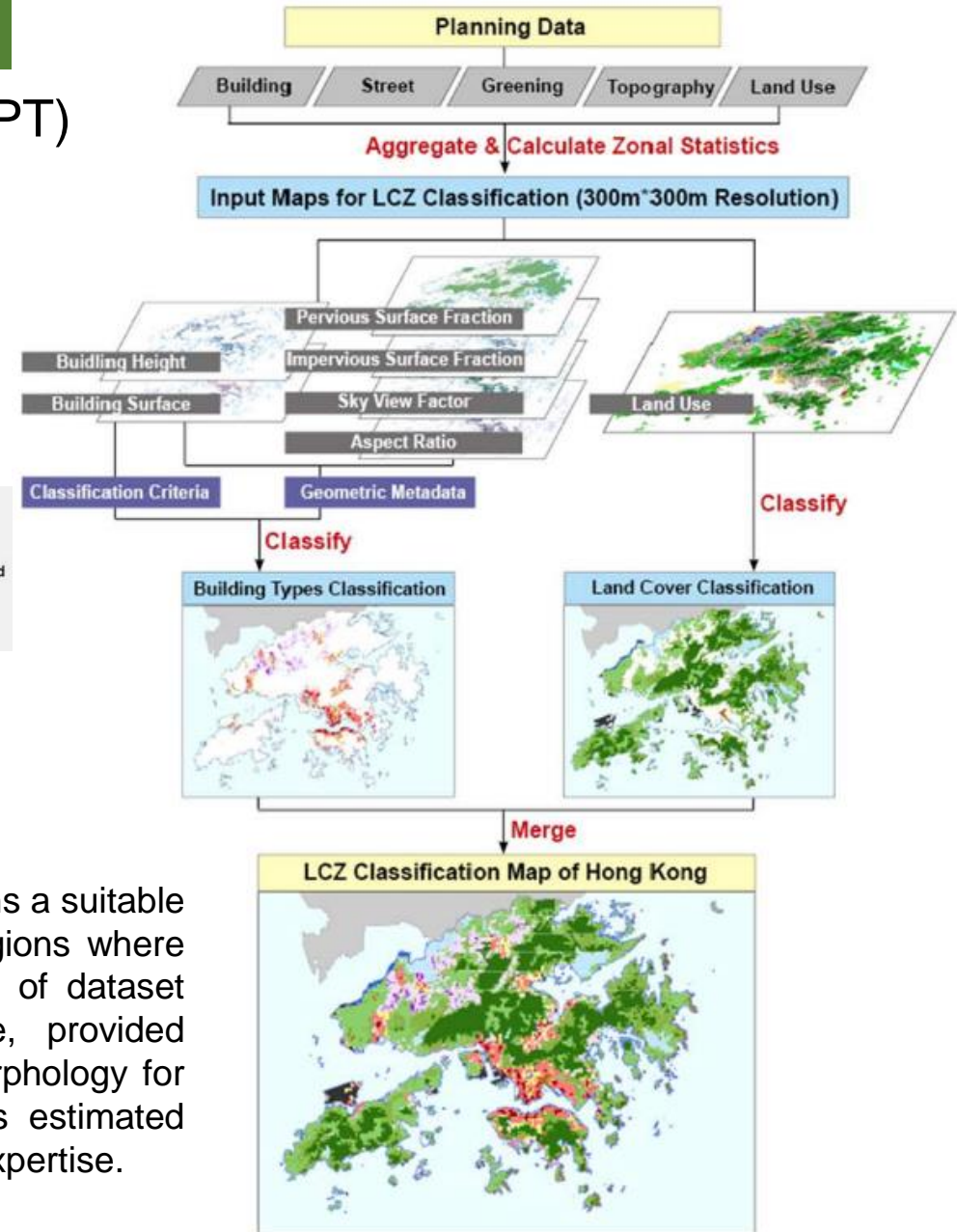
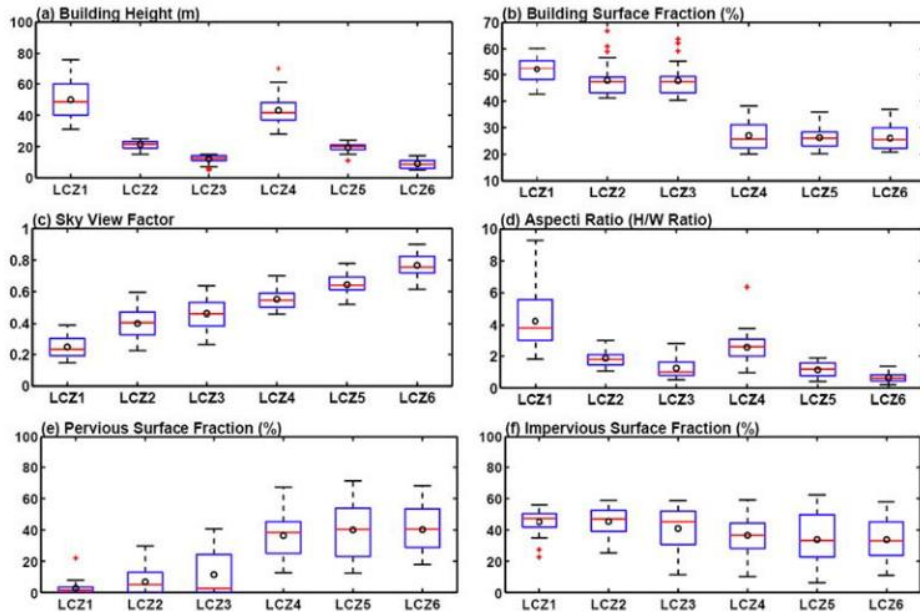
1. Background

World Urban Database and Access Portal Tools (WUDAPT)

BUILT SERIES 10-type urban local climate zone (LCZ)

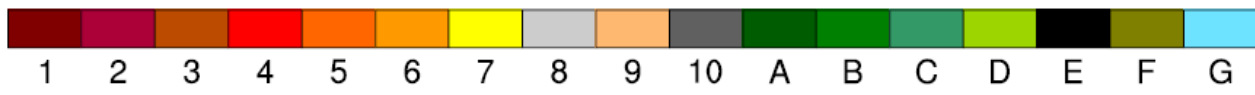
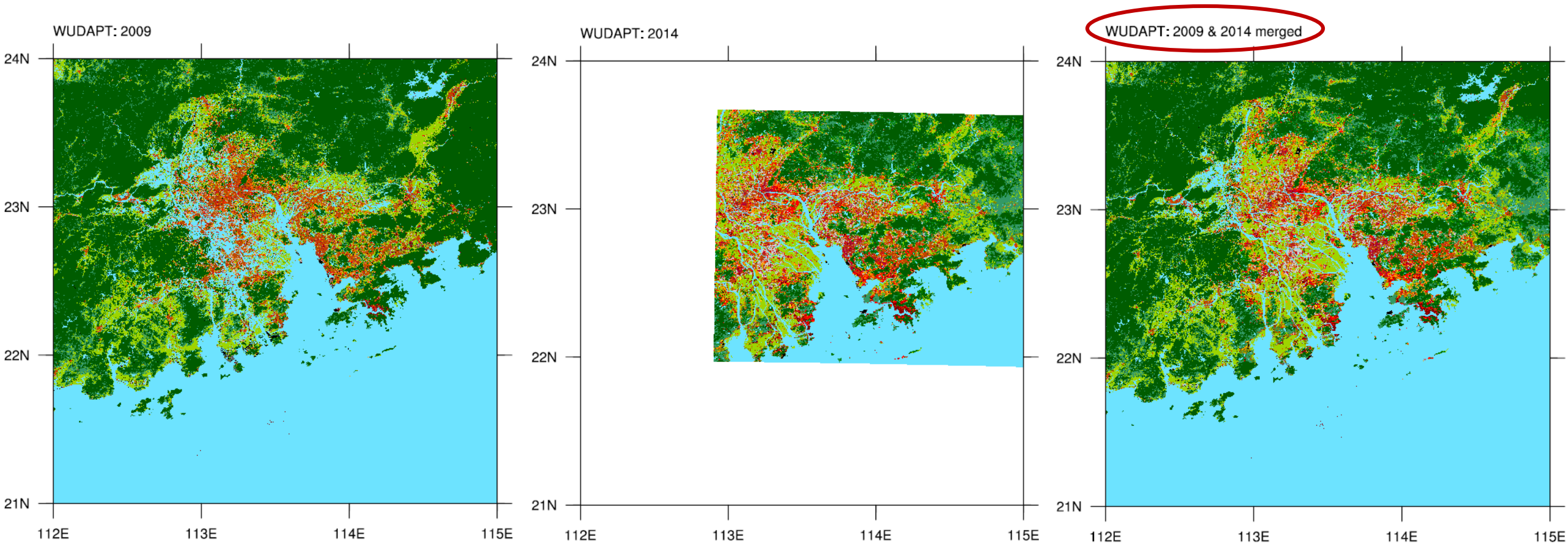


Localized parameters



WUDAPT remains a suitable alternative in regions where a NUDAPT type of dataset is not available, provided that building morphology for different LCZs is estimated based on local expertise.

2. WUDAPT datasets over the GBA



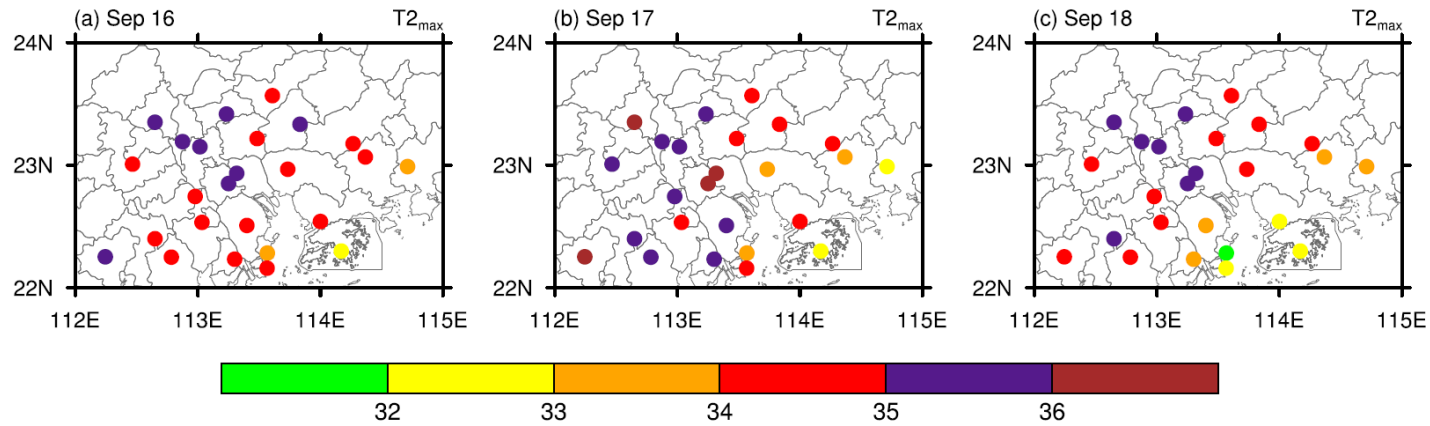
- | | | | | |
|---------------------|------------------------|-------------------|----------------------|----------------|
| 1 Compact High-Rise | 5 Open Mid-Rise | 9 Sparsely Build | C Bush, Scrub | G Water Bodies |
| 2 Compact Mid-Rise | 6 Open Low-Rise | 10 Heavy Industry | D Low Plants | |
| 3 Compact Low-Rise | 7 Lightweight Low-Rise | A Dense Trees | E Bare Rock or Paved | |
| 4 Open High-Rise | 8 Large Low-Rise | B Scattered Trees | F Bare Soil or Sand | |

From Prof. Chao Ren (HKU)

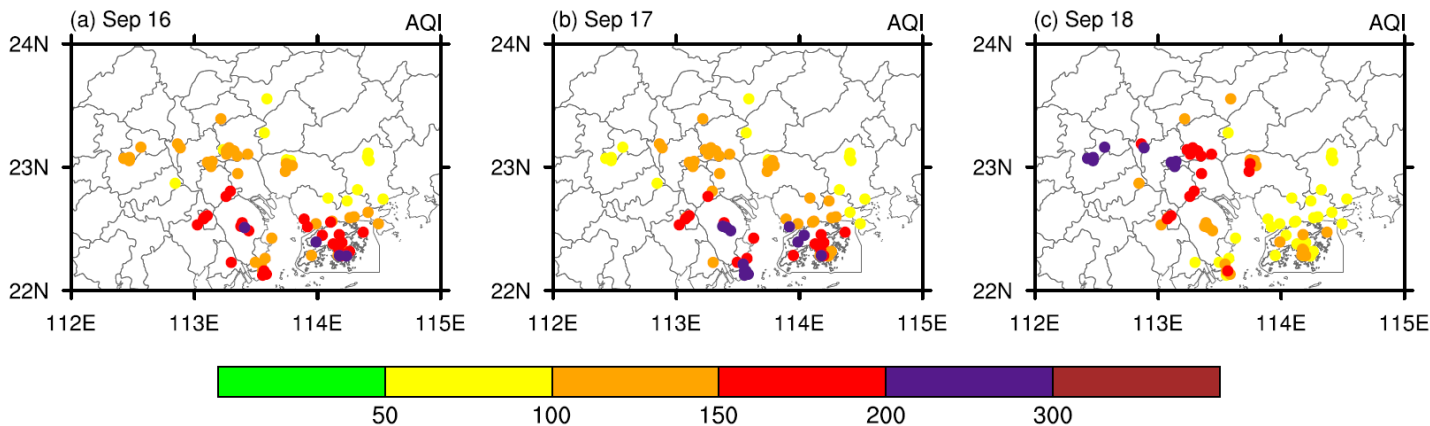
3. Hot and polluted event

Hot and polluted event: Sep. 16 to 18, 2017.

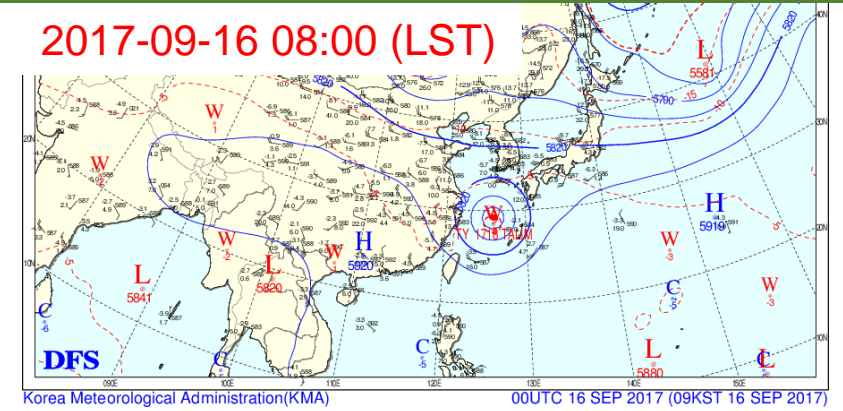
Daily maximum 2-m temperature (°C)



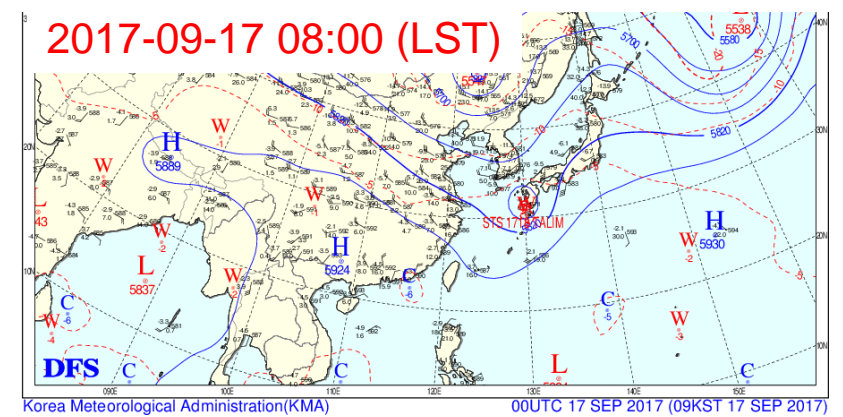
Daily Air quality index (AQI, Mainland China standard)



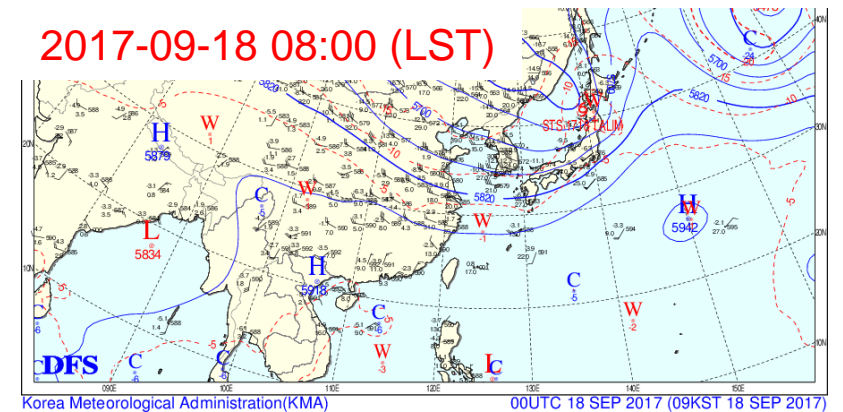
2017-09-16 08:00 (LST)



2017-09-17 08:00 (LST)

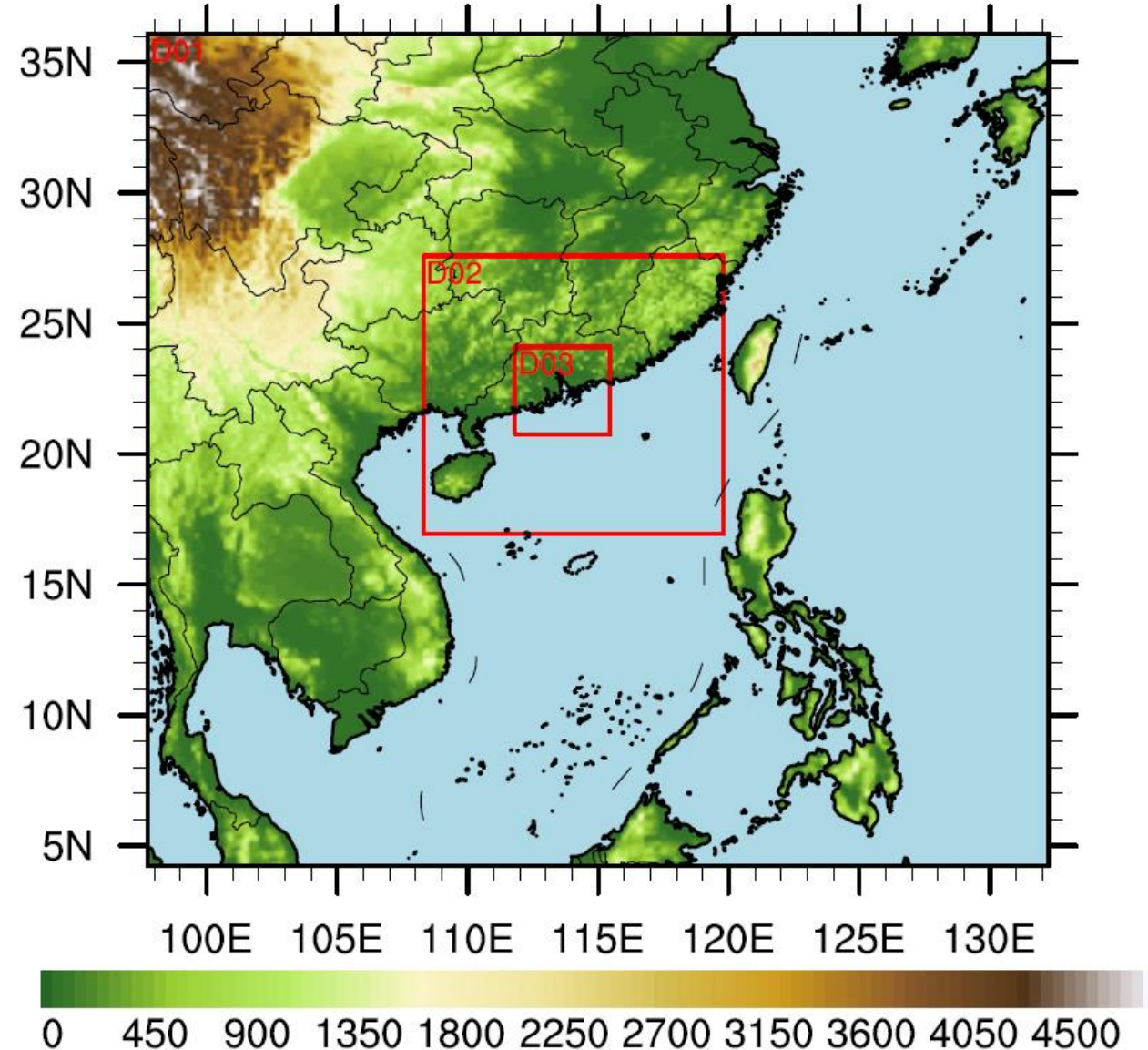


2017-09-18 08:00 (LST)



4. Experiments

- WRF 4.1.4, 9-3-1 km resolution, two-way nested, 45 hybrid sigma-pressure vertical levels with 12 levels in the lowest 1 km.
- Initial and lateral conditions, and SSTs: ERA5, 0.25°, hourly, SSTs: daily.
- **Physical packages:** Morrison double-moment microphysics scheme, Grell 3D cumulus scheme in the D01, RRTMG longwave and shortwave radiation schemes, BouLac PBL scheme, Noah-MP land surface physics scheme, the revised MM5 similarity surface layer scheme, **BEP-BEM multi-layer urban canopy scheme.**
- **Hot-humid-polluted event: Sep. 14 to 18, 2017, Sep. 16 to 18 analyzed, hourly output.**
- **No anthropogenic heat from transportation.**

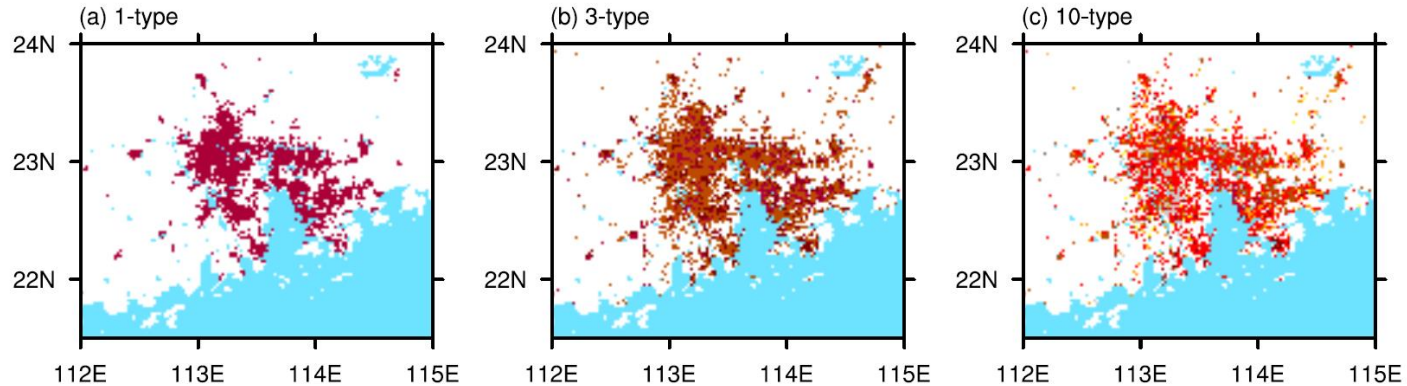


4. Experiments

Hot and polluted event: Sep. 16 to 18, 2017.

Exp.	1type (Default WRF)	3type (Re-grouped)	10type (WUDAPT)
LCZ types	1	3	10
UCM	BEP-BEM	BEP-BEM	BEP-BEM
UCM parameters	Default	Default	Updated (localized)

Urban LCZ



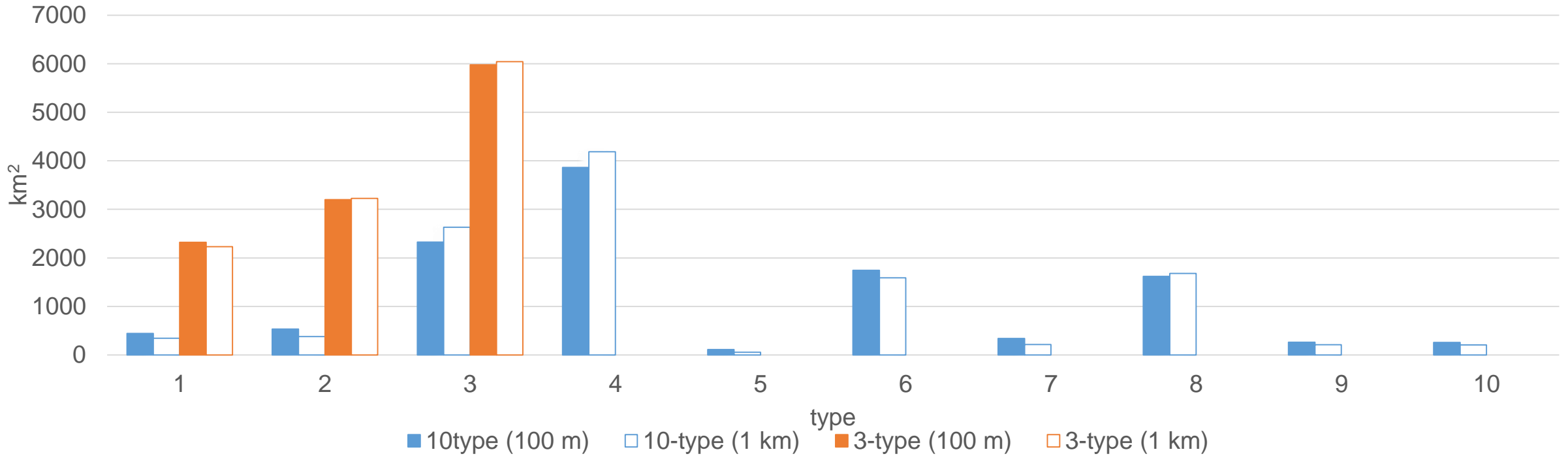
1-type:
1 High-density Residential

Re-grouped 3-type:
1 Commercial and Industrial: 1, 8, 10.
2 High-density Residential: 2, 3, 7.
3 Low-density Residential: 4, 5, 6, 9.

10-type:
1 Compact High-Rise 6 Open Low-Rise
2 Compact Mid-Rise 7 Lightweight Low-Rise
3 Compact Low-Rise 8 Large Low-Rise
4 Open High-Rise 9 Sparsely Build
5 Open Mid-Rise 10 Heavy Industry

4. Experiments

Urban LCZ distributions in the WUDAPT datasets over the GBA
(100-m original resolution and resampled 1-km resolution in the model)



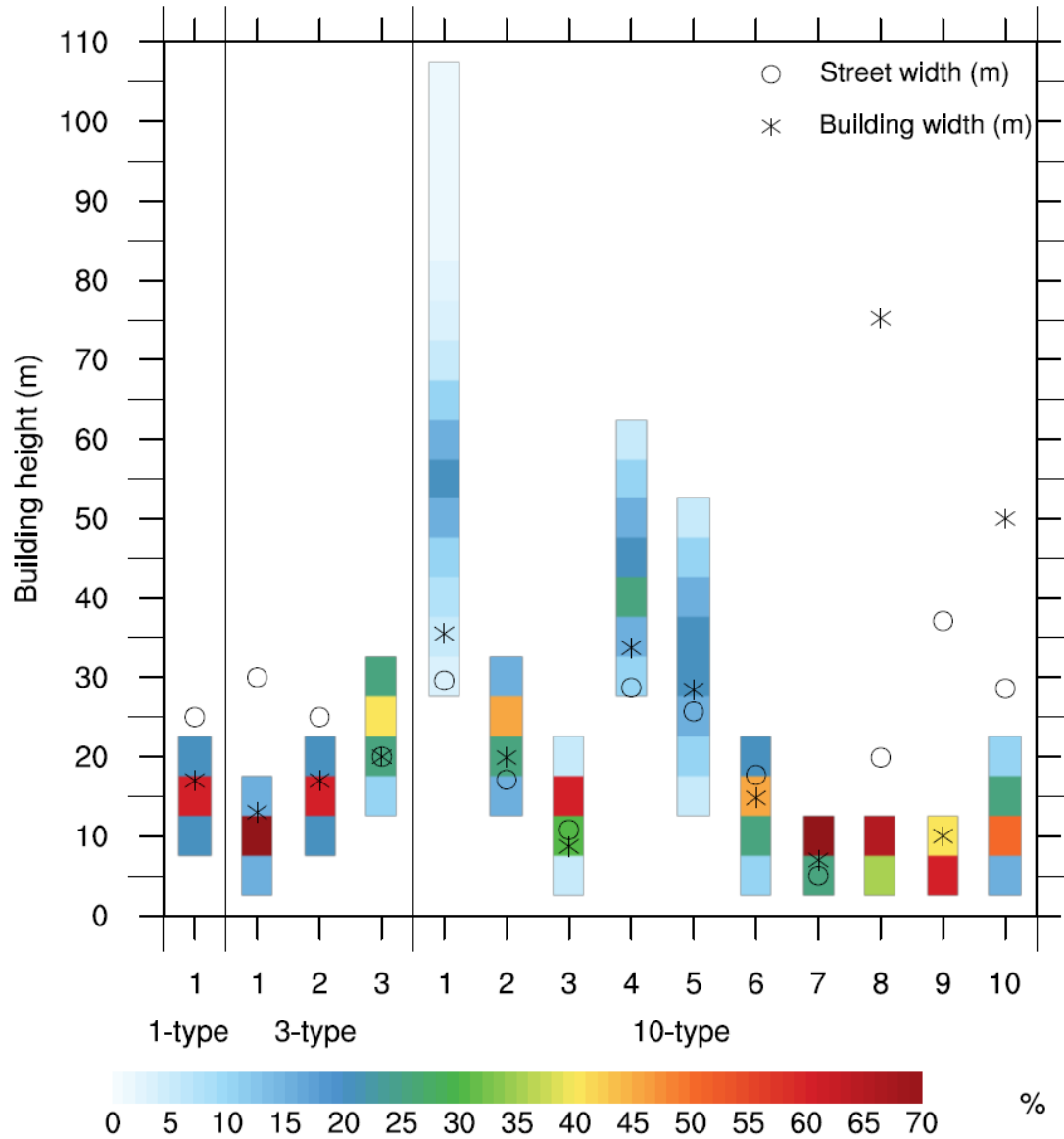
1-type:
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Re-grouped 3-type:
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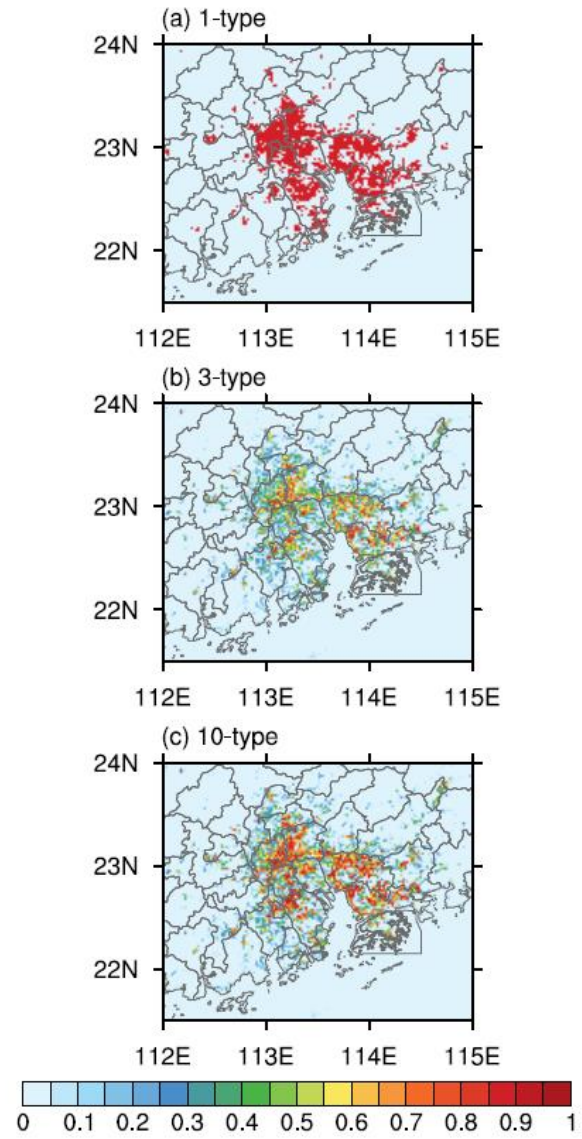
10-type:
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2 Compact Mid-Rise 7 Lightweight Low-Rise
3 Compact Low-Rise 8 Large Low-Rise
4 Open High-Rise 9 Sparsely Build
5 Open Mid-Rise 10 Heavy Industry

4. Experiments

Urban morphology parameters used in the urban canopy model



Urban fraction



The building height was too low in the default WRF settings.

The urban fraction was overestimated in the default WRF settings (a vs. c).

Air conditioning usage settings in the building energy model

(Zheng et al. 2015)

Exp.	1-type	3-type			10-type									
Type	1	1	2	3	1	2	3	4	5	6	7	8	9	10
Name	H-dens. Res.	Comm. & Indust.	H-dens. Res.	L-dens. Res.	Comp. H-Rise	Comp. M-Rise	Comp. L-Rise	Open H-Rise	Open M-Rise	Open L-Rise	Light. L-Rise	Large L-Rise	Sparsely Built	Heavy Indust.
COP	3.5	3.5	3.5	3.5	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
TEMP. (°C)	25	24	25	25	24.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5
TIME ON	0	0	0	0	8	18	18	18	18	18	18	8	18	8
TIME OFF	24	24	24	24	18	8	8	8	8	8	8	18	8	18
RESH/RELH	100/0	100/0	100/0	100/0	21/79	21/79	21/79	21/79	21/79	21/79	21/79	21/79	21/79	21/79

COP: A/C efficiency (larger means more efficient);
 RESH: released waste heat (sensible heat);
 RELH: released waste heat (latent heat);

1-type:
 1 High-density Residential

Re-grouped 3-type:
 1 Commercial and Industrial: 1, 8, 10.
 2 High-density Residential: 2, 3, 7.
 3 Low-density Residential: 4, 5, 6, 9.

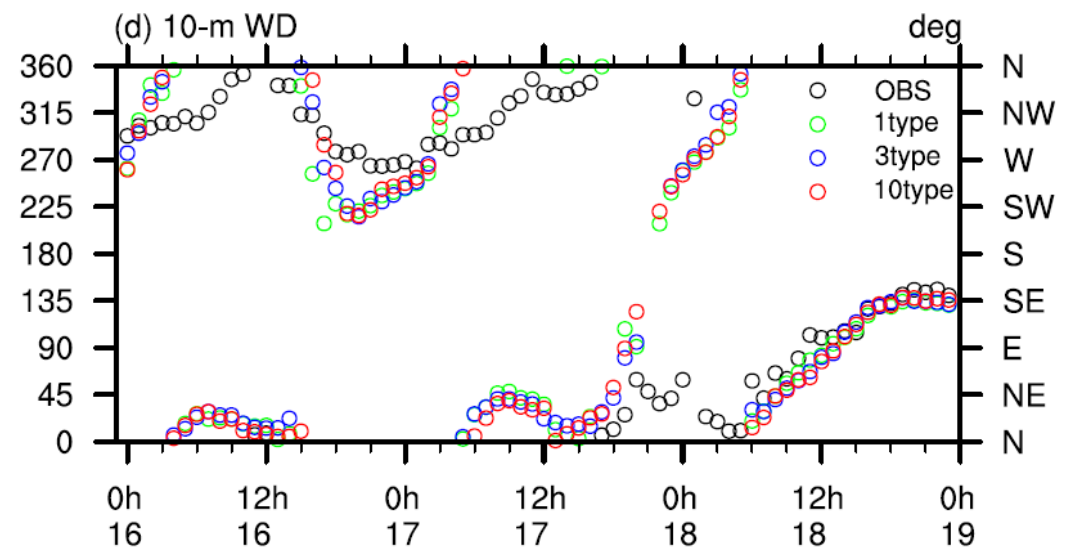
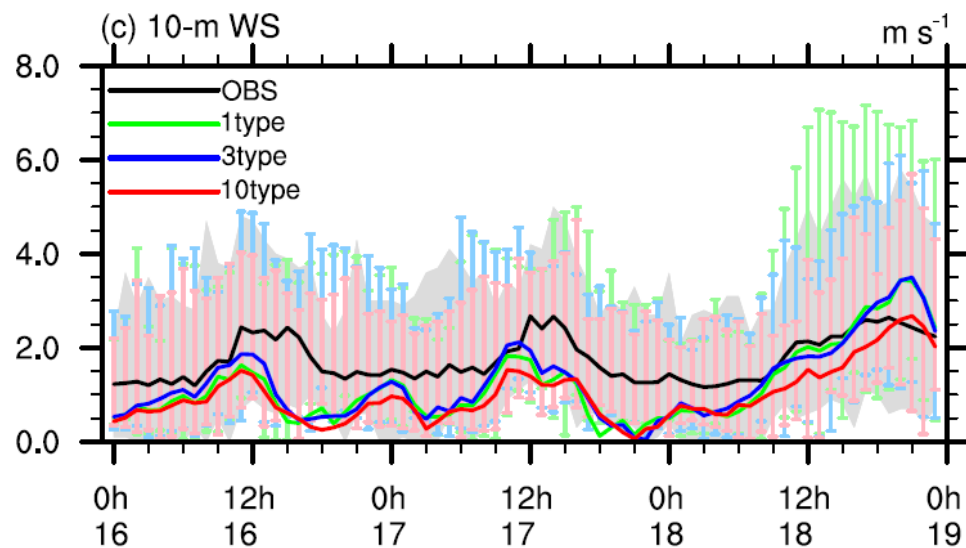
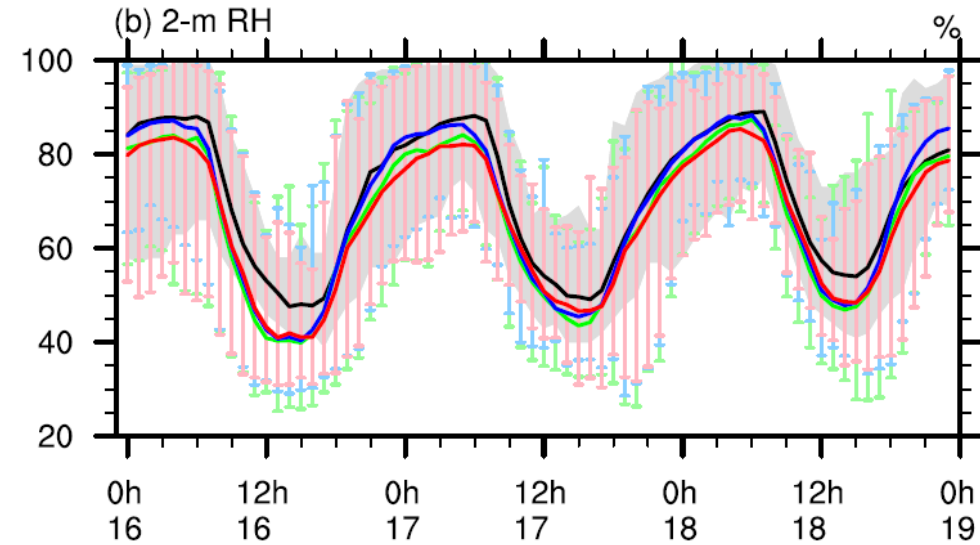
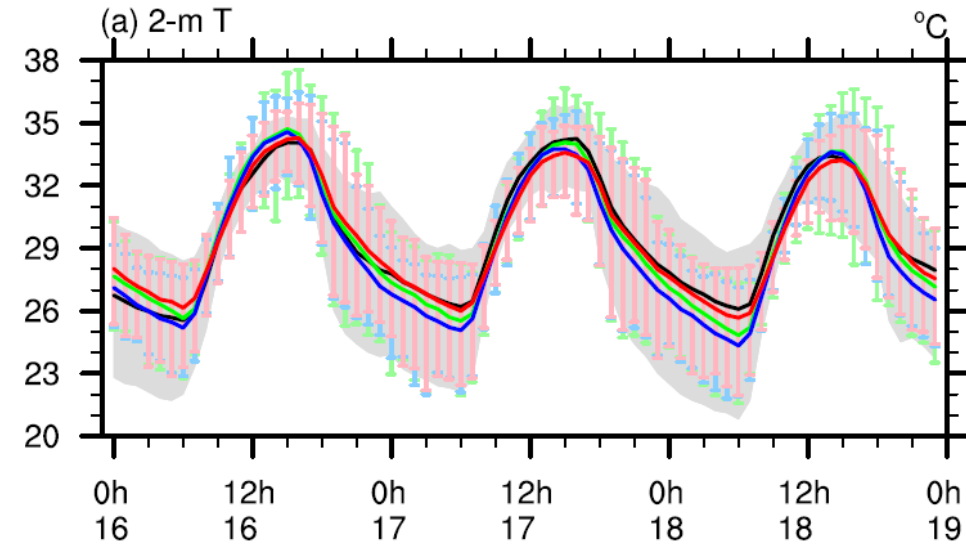
10-type:
 1 Compact High-Rise 6 Open Low-Rise
 2 Compact Mid-Rise 7 Lightweight Low-Rise
 3 Compact Low-Rise 8 Large Low-Rise
 4 Open High-Rise 9 Sparsely Build
 5 Open Mid-Rise 10 Heavy Industry

Model results vs. in-situ observations (hourly)

Exp.	2-m temperature (K)			2-m relative humidity (%)			10-m wind speed (m/s)			10-m wind direction (deg)		
	R	MBE	RMSE	R	MBE	RMSE	R	MBE	RMSE	R	MBE	RMSE
1type	0.94	-0.18	1.42	0.85	-4.74	12.05	0.38	0.12	1.09	0.17	9.50	70.57
3type	0.94	-0.58	1.43	0.85	-2.62	11.79	0.38	0.10	1.08	0.17	10.45	69.47
10type	0.93	-0.08	1.32	0.84	-4.86	11.58	0.40	-0.25	1.00	0.16	7.10	70.10

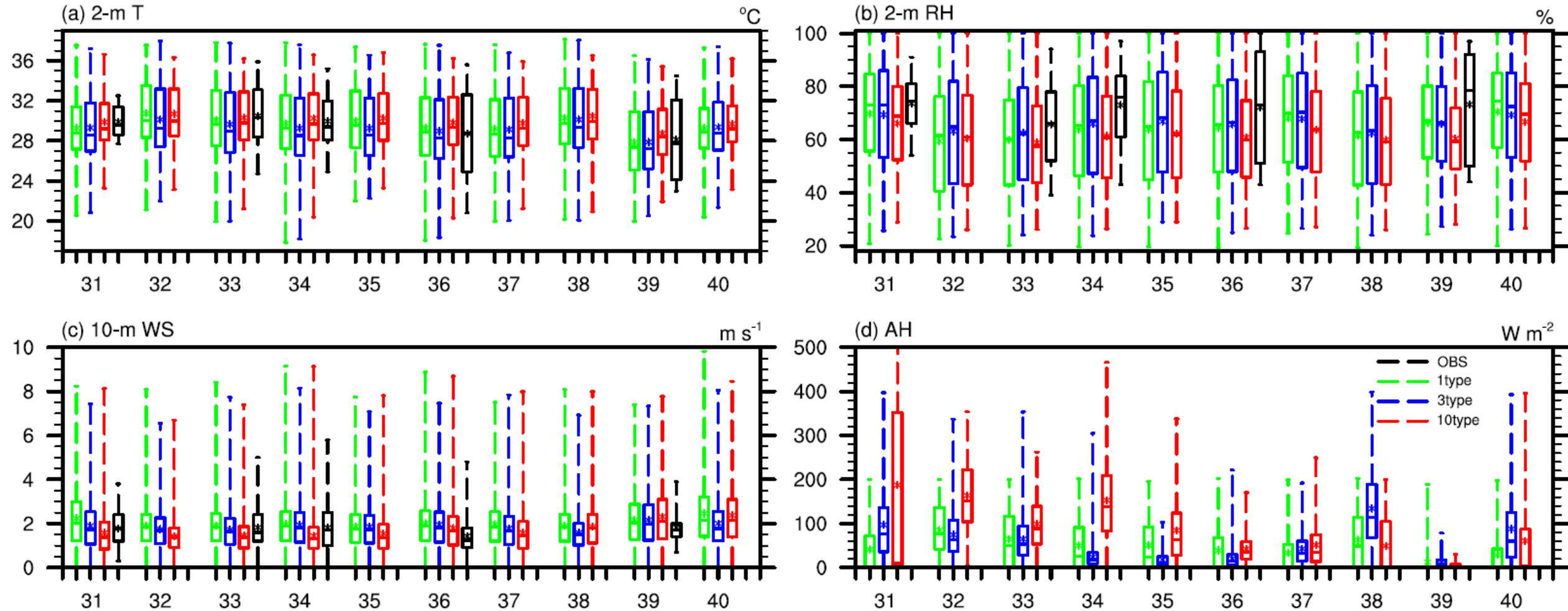
In the 10type run, the biases of the modeled air temperature, humidity, and wind speed are smaller than those in the 1type run and 3type run.

Model results vs. in-situ observations (hourly)



5. Results

Model results vs. in-situ observations (box plot based on urban LCZ)

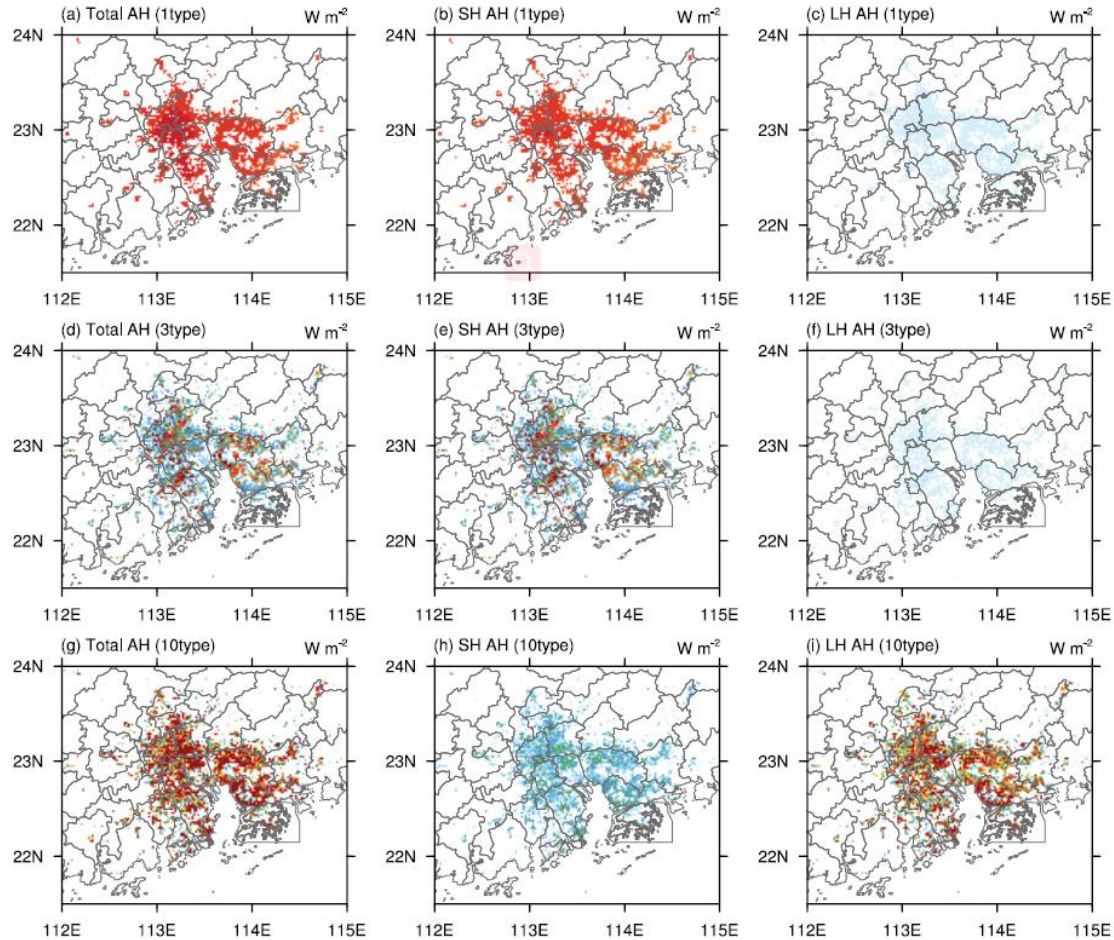


Note that the sample sizes of observation are much smaller than those of the urban LCZ grids.

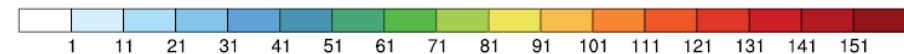
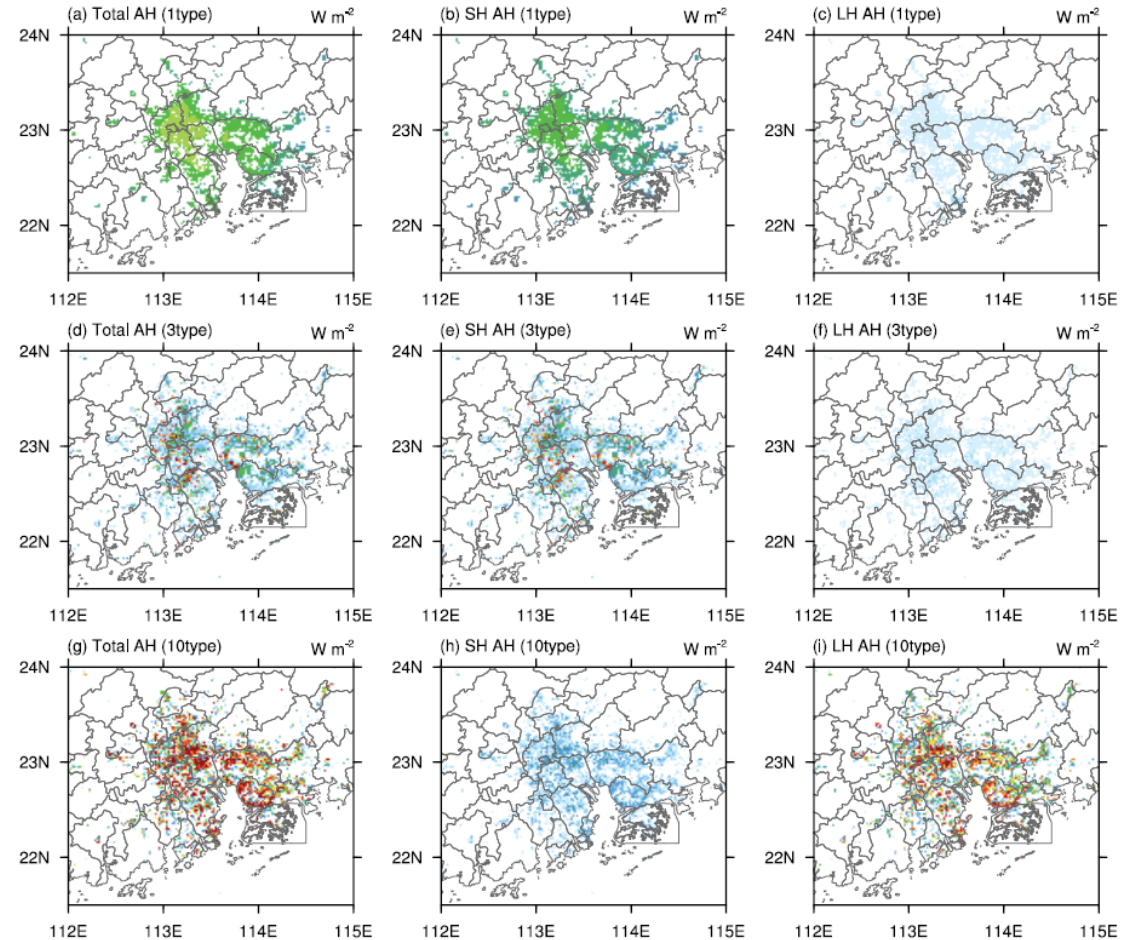
AH: anthropogenic heat released from the building, including A/C usage (dominated), ventilation, conduction.

Daily mean anthropogenic heat released from the building

Daytime

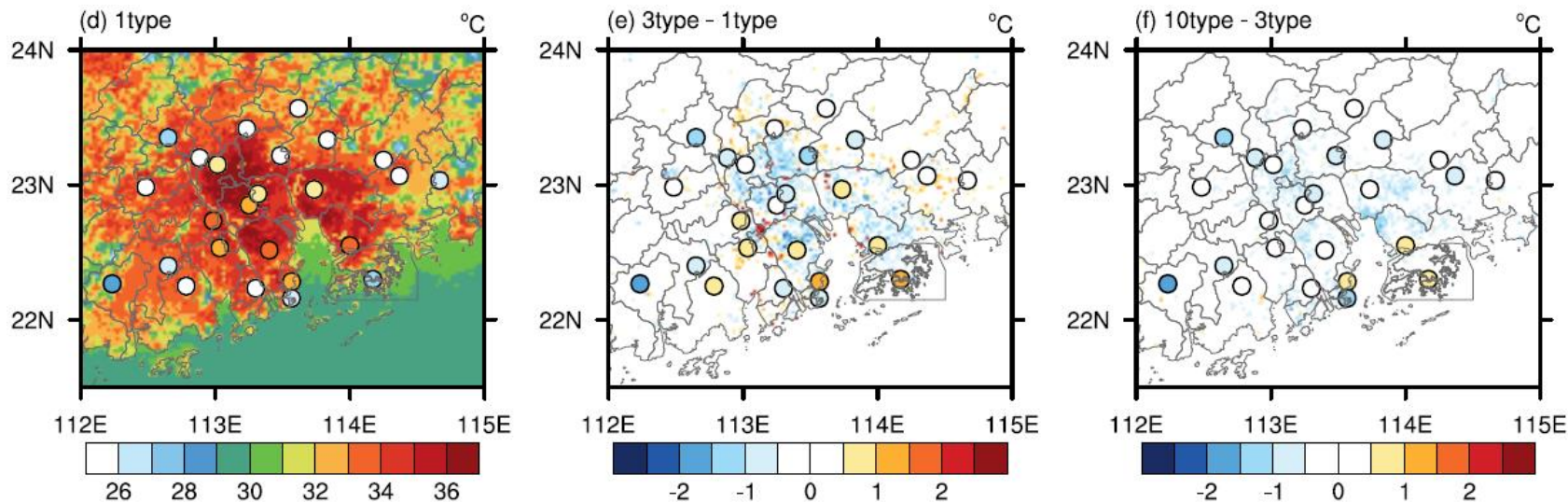


Nighttime

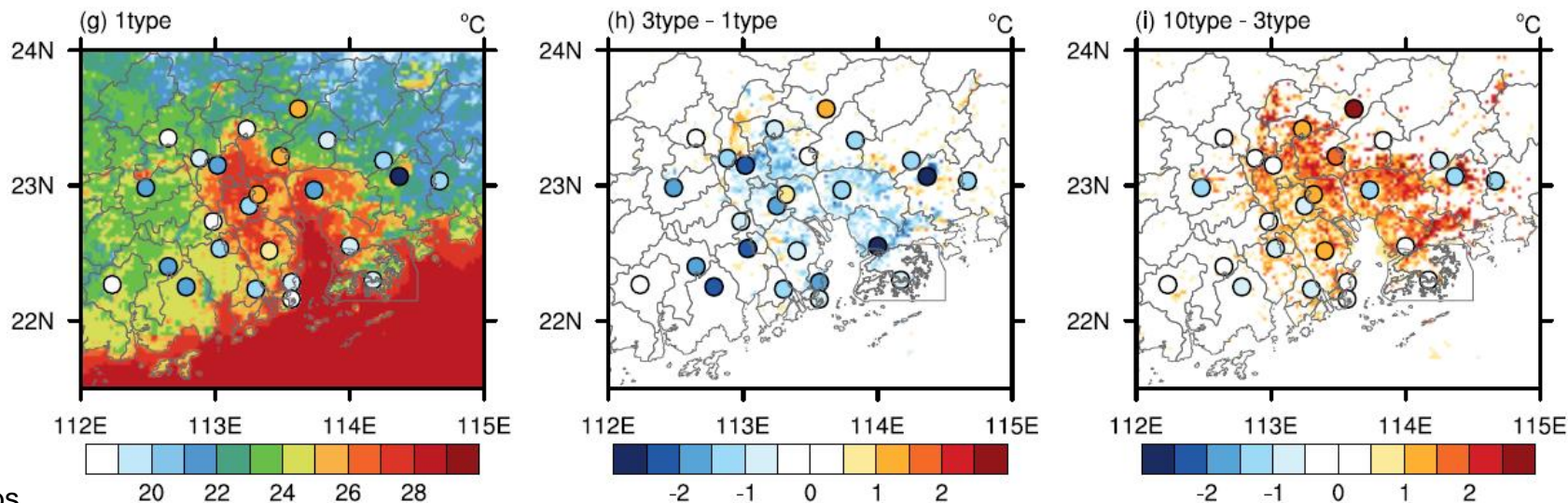


The total AH was larger in the 10type run compared to the 1type run and 3type run, particularly during nighttime. The AH was dominated by the latent heat in the 10type run due to the changes of partition of waste heat from A/C usage (page 11). © Authors. All rights reserved

Daily mean maximum 2-m temperature



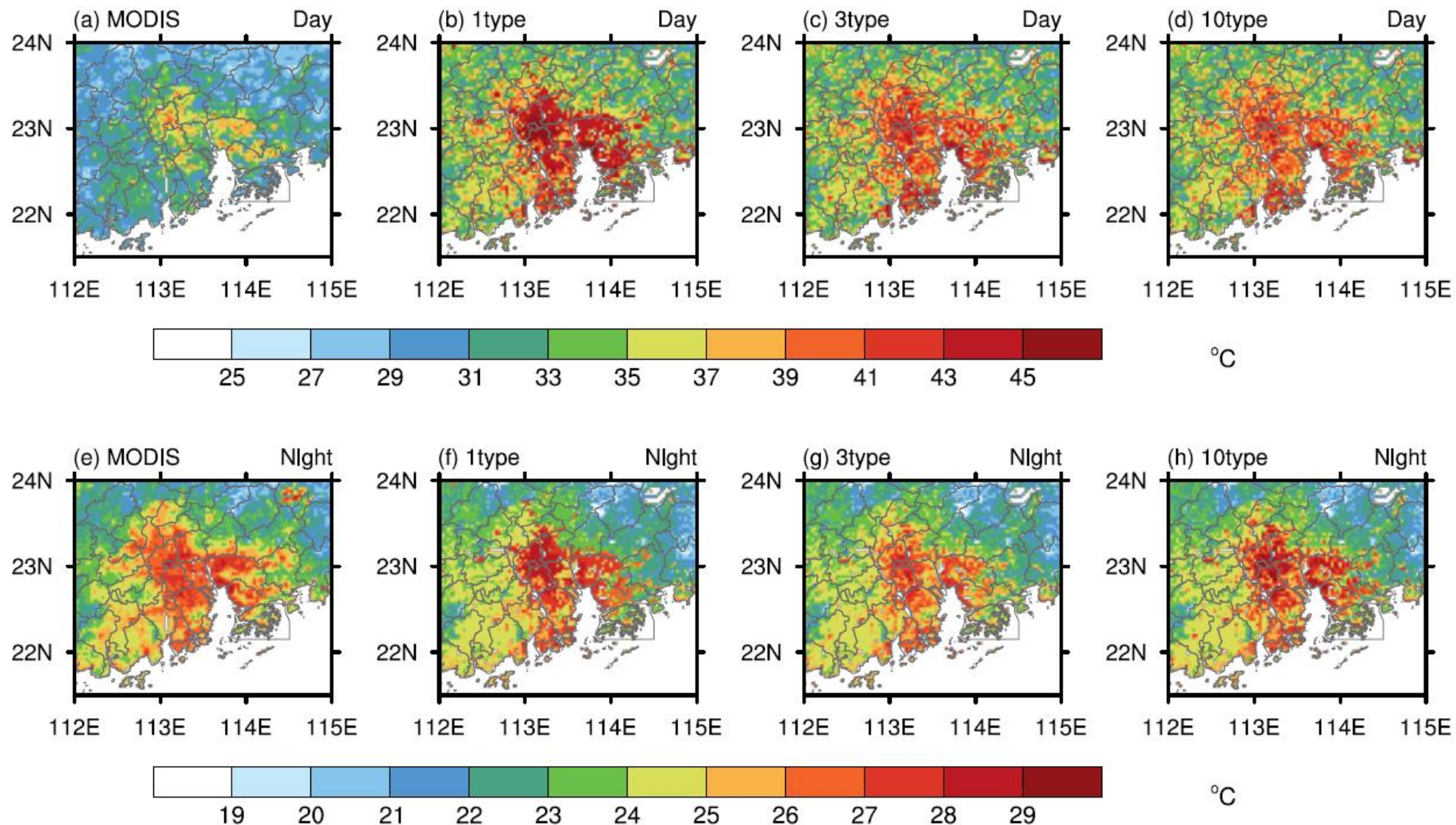
Daily mean minimum 2-m temperature



The nighttime anthropogenic heat increased a lot in the 10type run (page 15).

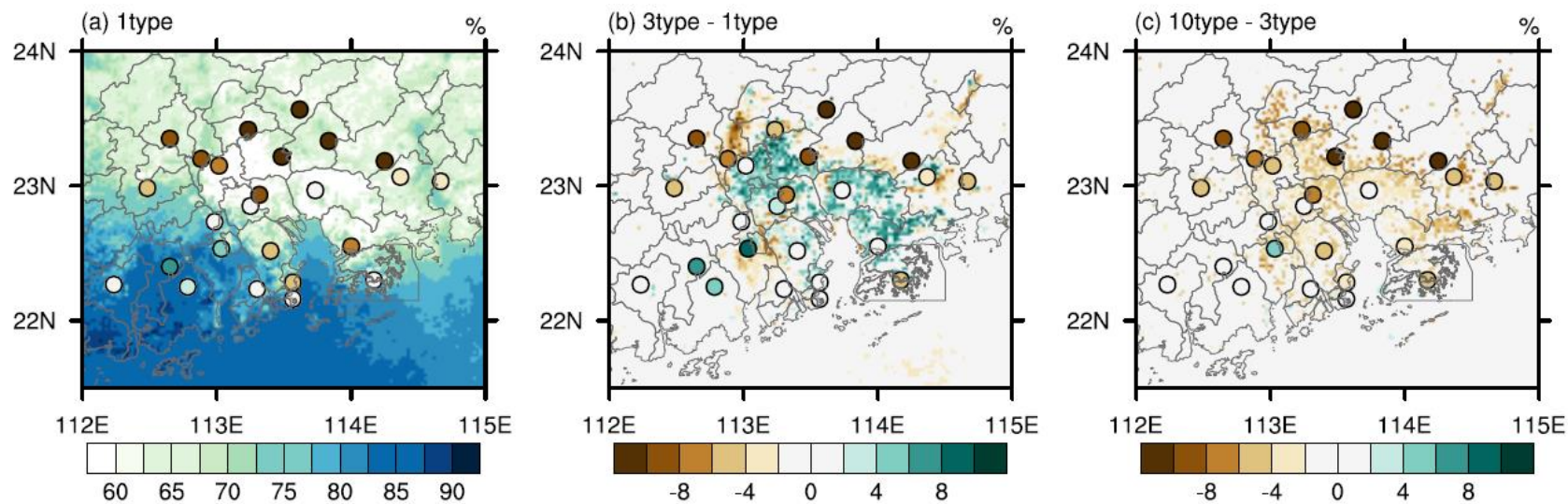
Dots mean exp. minus obs.

Daytime and nighttime mean land surface temperature

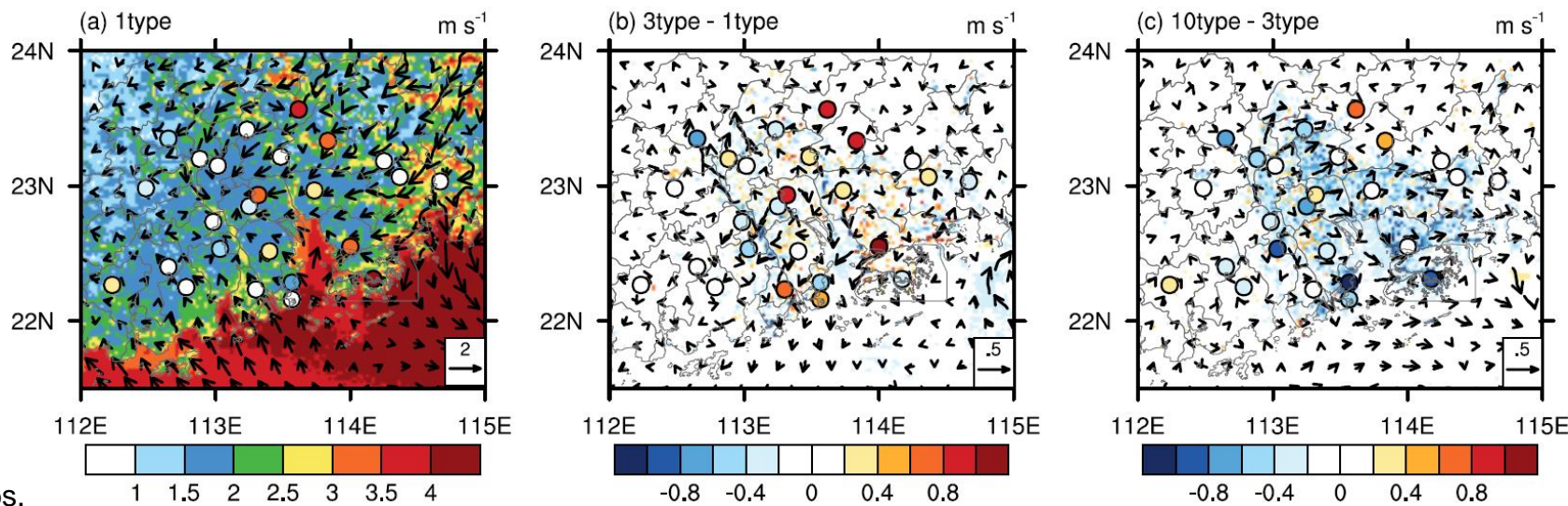


Dots mean exp. minus obs.

Daily mean 2-m relative humidity

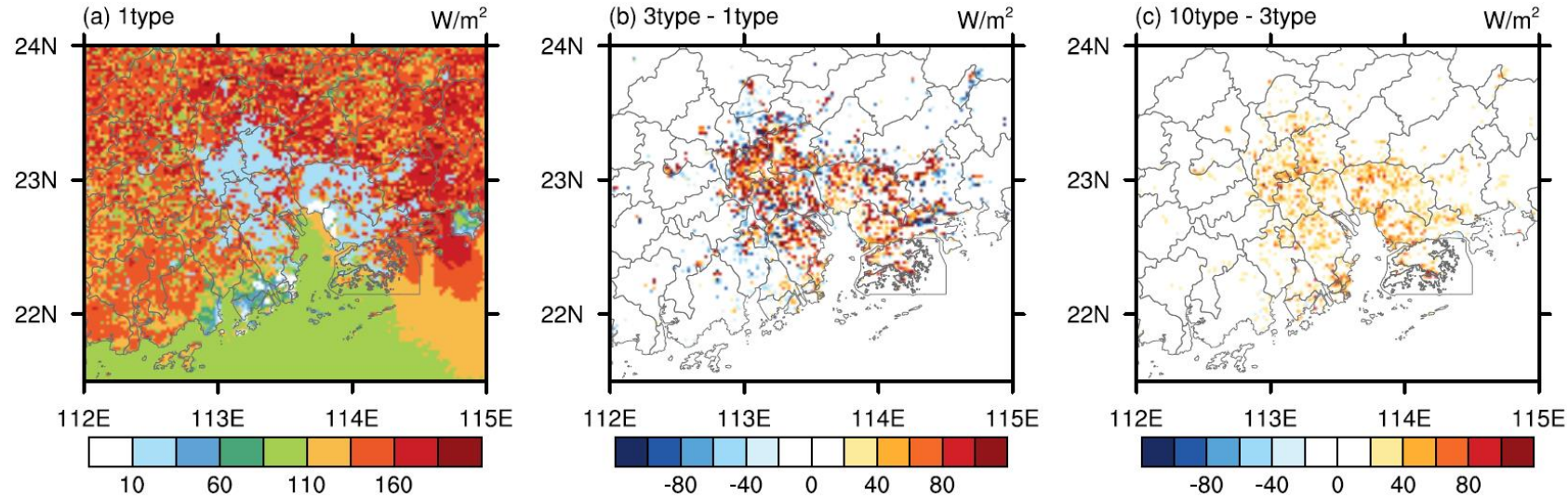


Daily mean 10-m wind

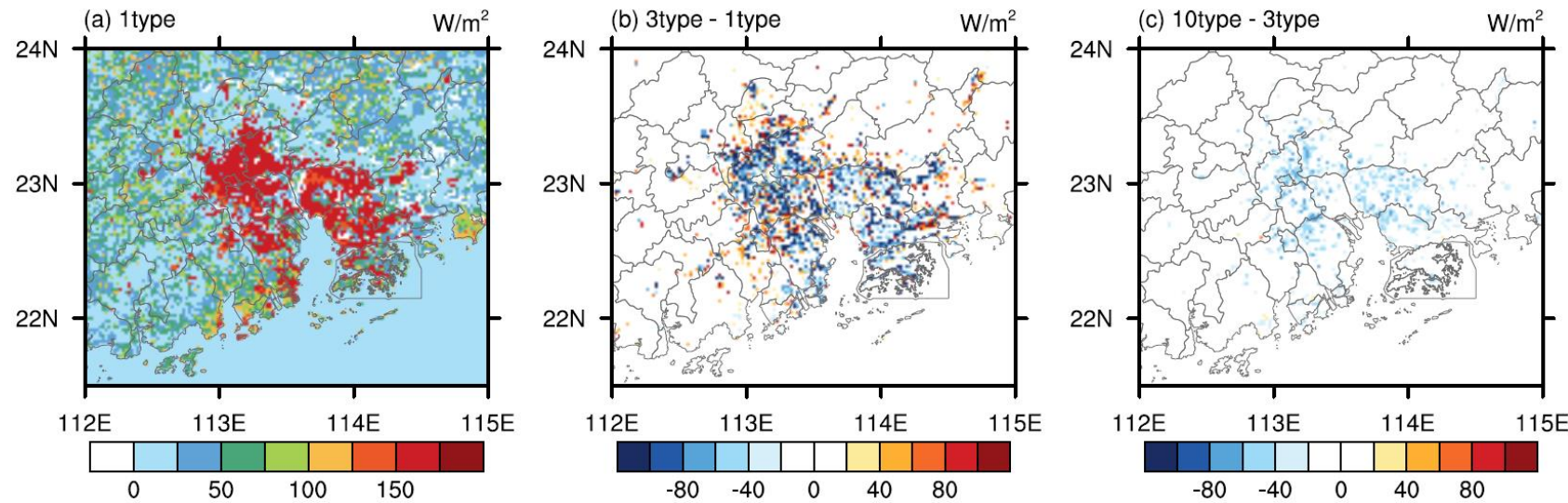


Dots mean exp. minus obs.

Daily mean surface latent heat flux

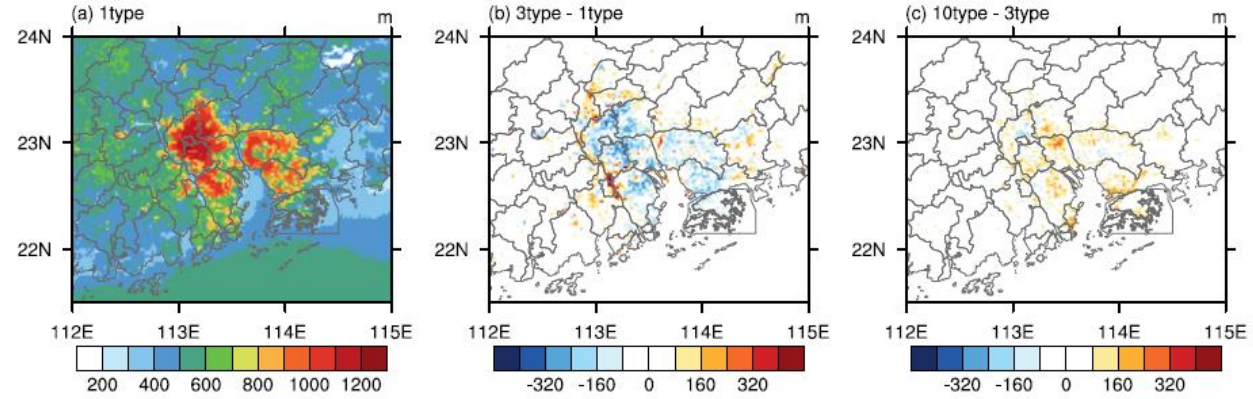


Daily mean surface sensible heat flux

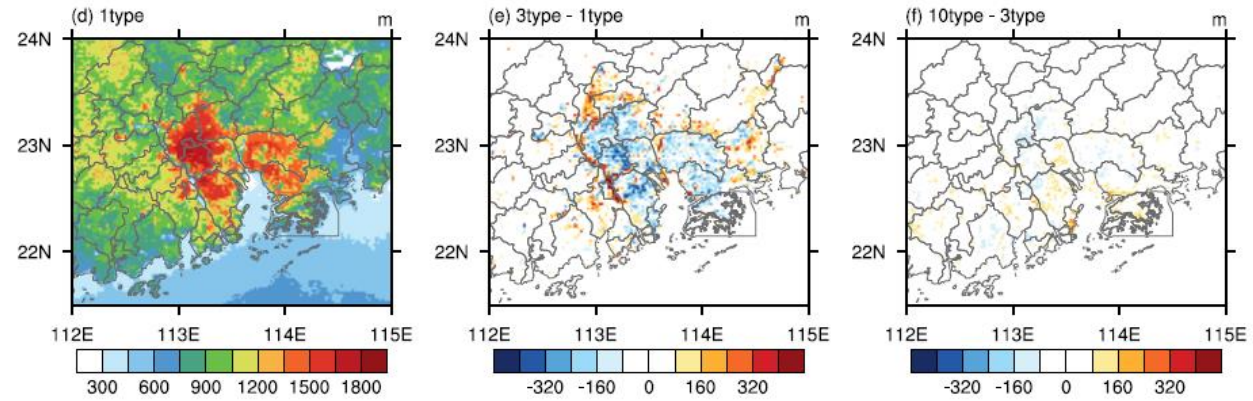


Related to the changes of partition of waste heat from A/C usage (page 11).

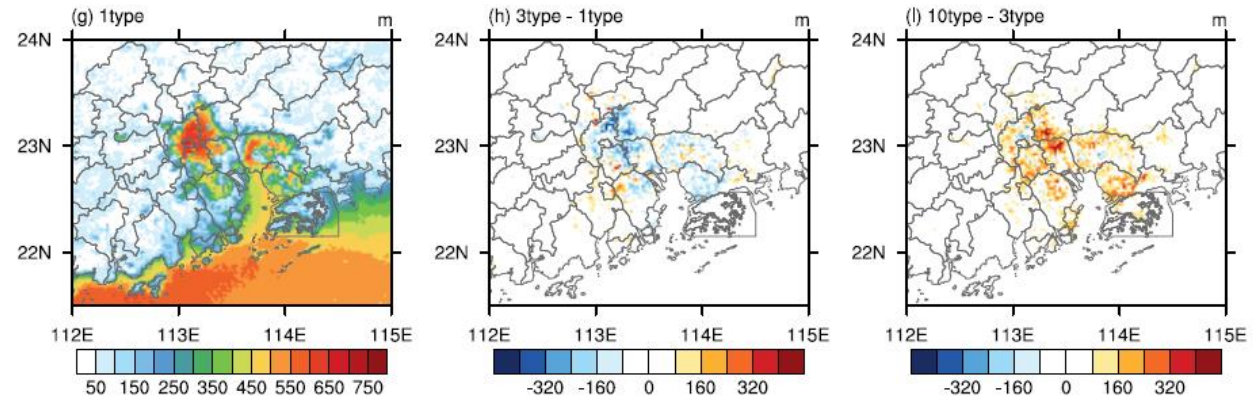
PBL Height
(daily mean)



PBL Height
(daytime mean)

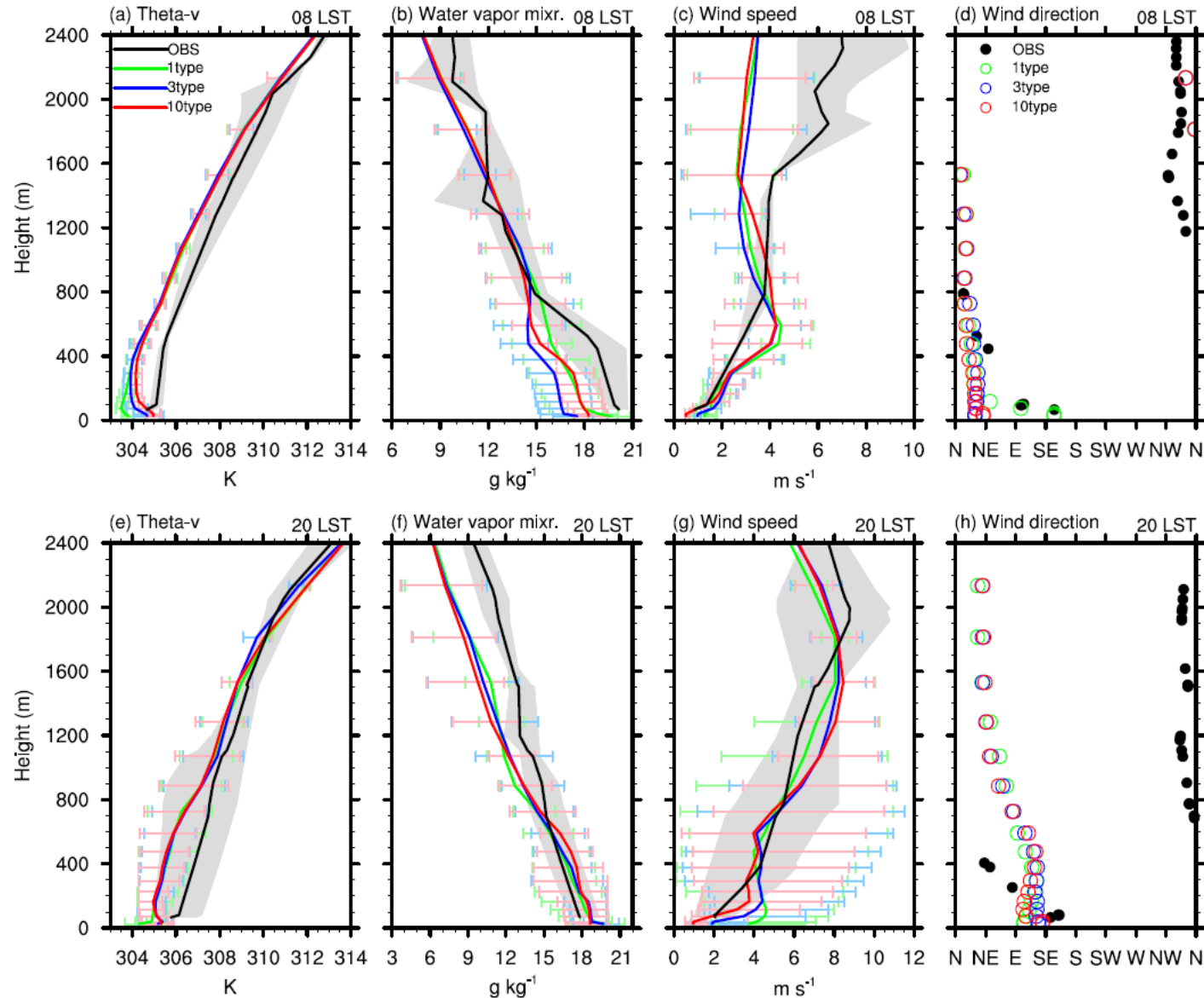


PBL Height
(nighttime mean)



In-situ sounding observation at the King's Park

The vertical profiles of 10type run in general are closer to the observation, particularly for the wind profile. Cold and dry biases are found in the model runs.



1. A new 10-type urban LCZ classification with 100-m resolution was developed and incorporated into the BEP-BEM multi-layer urban canopy scheme used by the WRF model, with key parameters determined from local building morphology and energy consumption patterns.
2. The modeled land surface temperature (nighttime), surface air temperature (nighttime), humidity and wind speed in the 10-type LCZ run were in closer agreement with in-situ observations, demonstrating the value of detailed urban LCZ data in improving the model performance.
3. The anthropogenic heat released from building was dominated by the A/C usage in form of latent heat in the 10-type LCZ run, which was much larger (particularly during nighttime) due to increased building height.
4. These improvements should be further validated through seasonal or longer simulation.
5. Owing to the improvement in capturing the urban meteorology, incorporating more detailed LCZ classification might also improve air-quality simulations.
6. Anthropogenic heat from transportation with diurnal or weekly cycle should be included to reduce the daytime surface air clod biases.

Thank you

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