Response of JULES to urban parameters at a high-rise residential area in Korea

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Outline

- **High-rise residential area in Korea**
- **Evaluation of the urban SEB**
- **Sensitivity analysis of the urban parameters**

Introduction

Motivation

- Rapid urbanization of the world, especially in Korea, East Asia
  : 91% of the population lives in cities
  (only 17% of the land area).

- Lack of the study for the LSM performance to simulate the urban surface energy balance (SEB) at urban areas in Korea.

Objetives

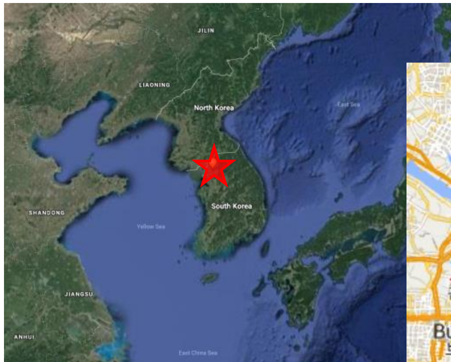
✓ **To quantify the performance of the urban SEB simulation with JULES in high-rise residential area in Korea.**

✓ **To identify the key urban parameters for simulating SEB.**

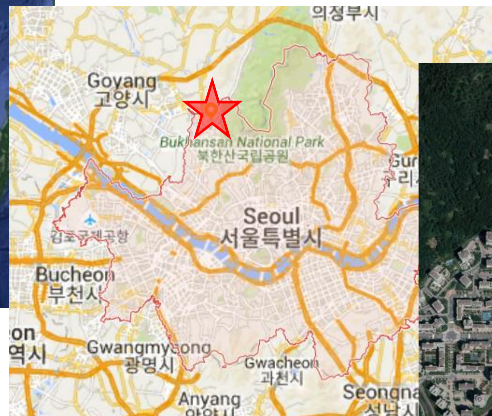
✓ **To know the effect of the change of key urban parameter value to the modeled SEB.**

Methods

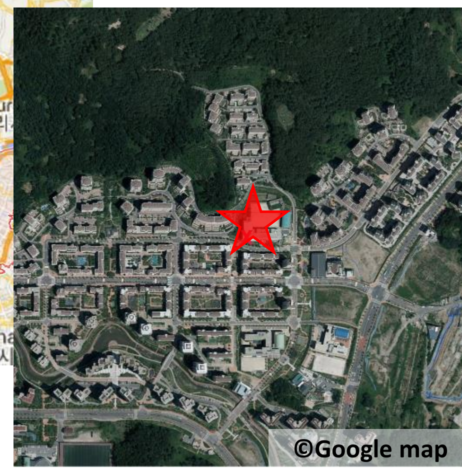
EunPyeong (EP) Newtown



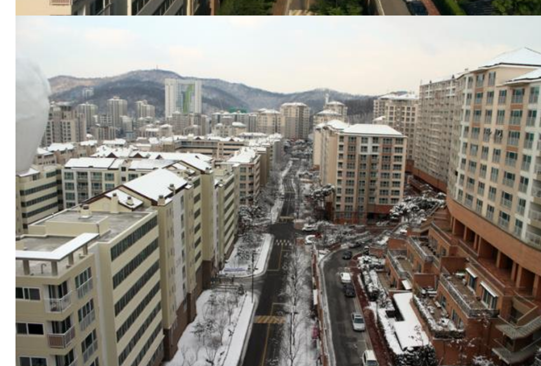
Korea, east Asia



Seoul



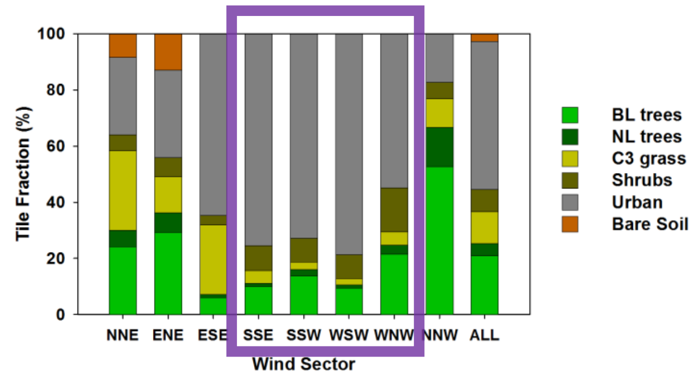
EP

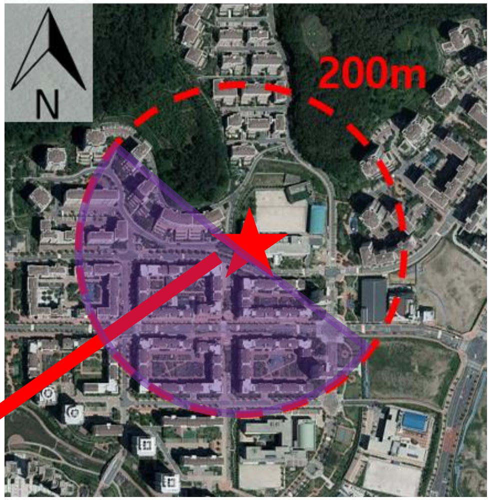


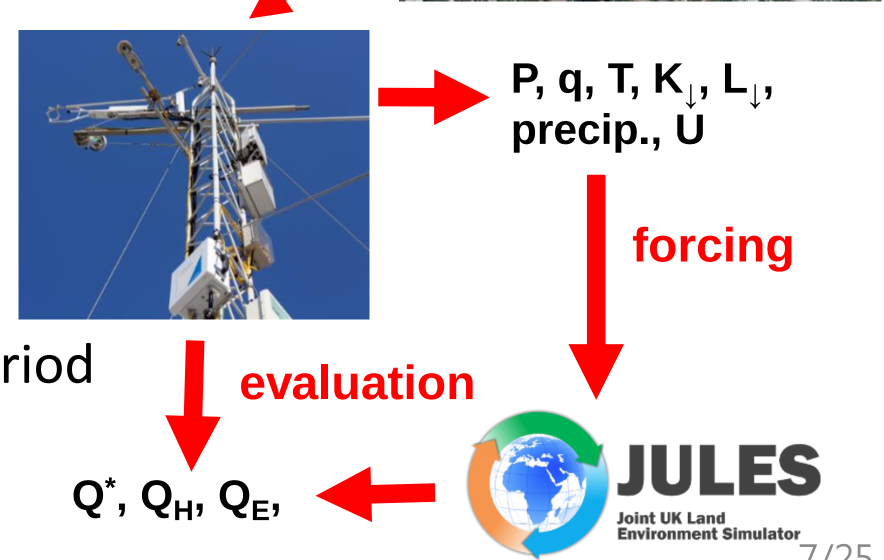
- Large-scale residential area.
- High-density: 4600 people km^{-2}
- High-rise: 6–15 stories of buildings
- Compact high-rise (type1) on LCZ classification (*Stewart and Oke, 2012*).
- Urban green areas (gardens and street trees).

Observations in EP Flux Site

- Eddy Covariance flux tower (N 37.63°, E 126.93°)
- 200 m flux footprint
- 135°–315° wind dir.
- 70% urban,
  14% BL, 2% NL, 4% C3, 10% Shrubs
- Mar 1st 2015 – Feb 29th 2016 (1 yr.)
  - ✓ Hotter and drier than climatology (+0.8°C, -644 mm)
  - ✓ Less rainfall during the Jang-ma period (-145 mm, 25 June – 29 July)

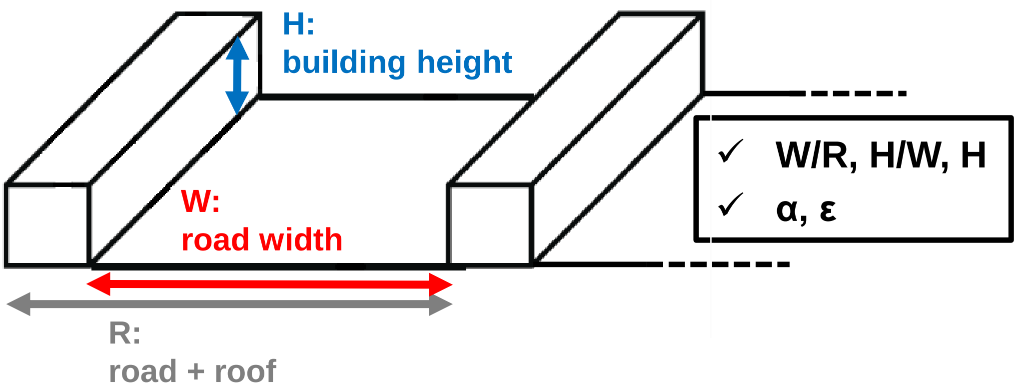






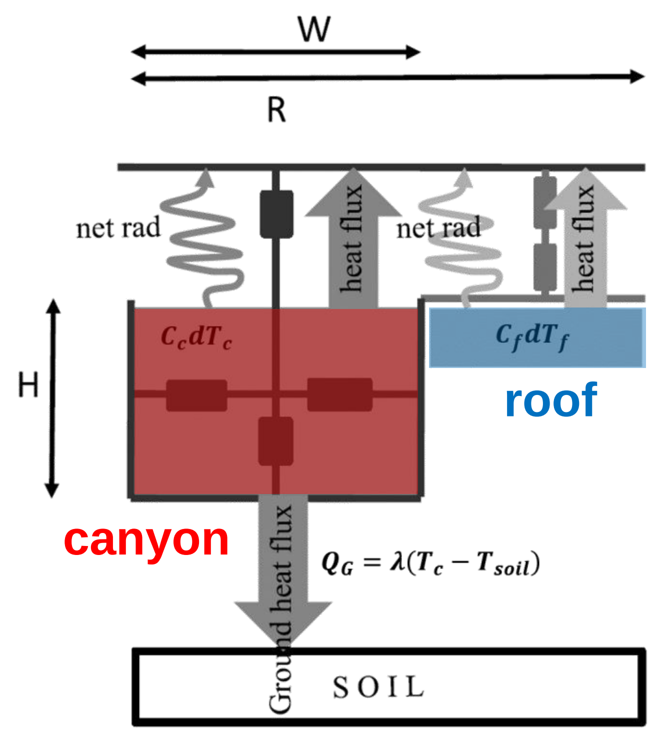
JULES - MORUSES

- JULES (Joint UK Land Environment Simulator) ver. 4.2
- **MORUSES**
  (Met Office Reading Urban Surface Exchange Scheme)



✓ **W/R**: Width to (Road+Roof) ratio
(= “canyon fraction”)
(= 1 - building fraction)

✓ **H/W**: Height to Width ratio



modified from Bohnenstengel et al., 2011

Evaluation of Urban SEB

$$Q^* + Q_F = Q_H + Q_E + \Delta Q_S + \Delta Q_A$$

- Q^*: net radiation
- Q_F: anthropogenic heat
- Q_H: sensible heat flux
- Q_E: latent heat flux
- ΔQ_S: heat storage
- ΔQ_A: heat advection

Q^*, Q_H and Q_E have been evaluated with the direct measured flux data.

Sensitivity Analysis

- One-at-a-time (OAT) method
  : changing one parameter value 10% from default value at a time

- Sensitivity (Δ): $\Delta = \frac{Flux_{10\%} - Flux_{CTL}}{|Flux_{CTL}|} \times 100\ (\%)$

Urban Parameters (22 params.)	
morphological parameters	W/R (wrr) H/W (hwr) H (hgt)
surface material property parameters	albedo (alb_*) emissivity (emis_*) heat capacity (cap_*) …
etc.	anthropogenic heat (anthro) water capacity (catch_*) drag coefficient (cdz) …

Urban SEB
net radiation(Q^*), sensible heat flux(Q_H), latent heat flux(Q_E)

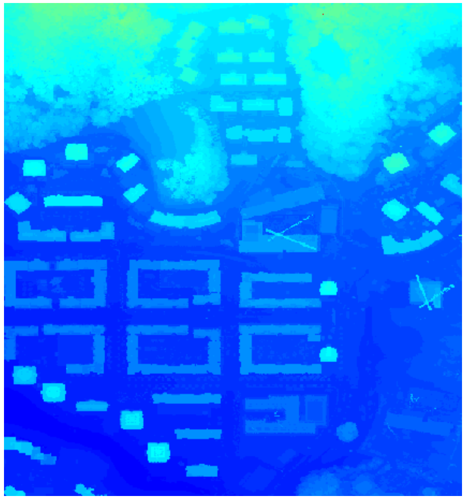
Urban Parameter Settings for EP

- Morphological parameters (wrr, hwr, hgt)
  : calculated from lidar DEM data

✓ W/R (wrr) = 0.61
→ buildings consist 40% of plan area

✓ H/W (hwr) = 0.78
→ building height is 7.8 m when road width is 10 m

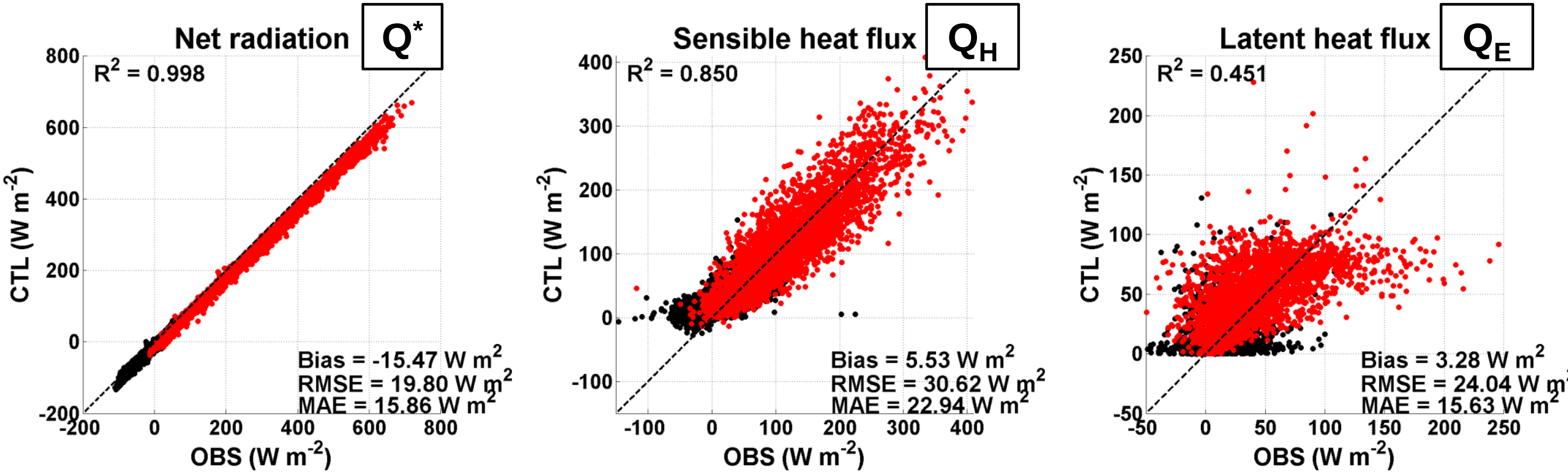
✓ H (hgt) = 21.4 (m)
→ mean building height is 21.4 m



- Material properties (alb_*, emis_*, …)
  : asphalt road, concrete wall and roof (Oke, 1987)
- Anthropogenic heat (anthro)
  : inventory data from Lee and Kim (2015)

Results and Discussions

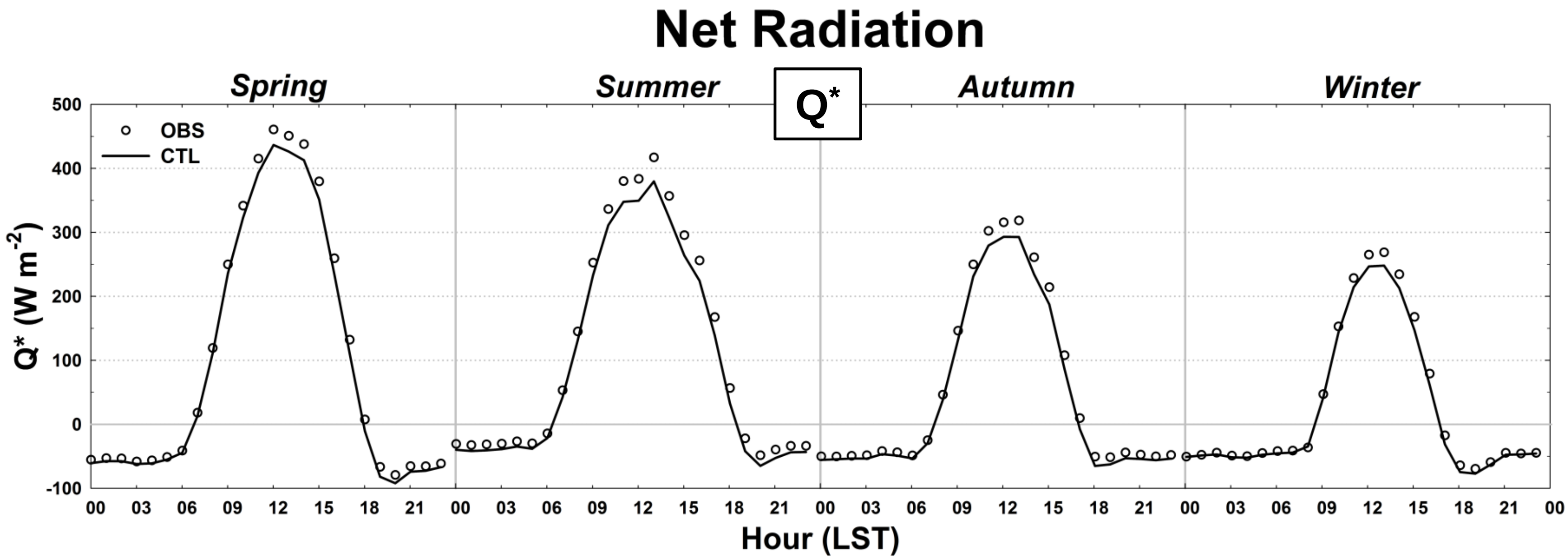
Model performance (1)



(W m^{-2})	Q^*			Q_H			Q_E		
	All-day	Day	Night	All-day	Day	Night	All-day	Day	Night
Mean (OBS)	110.7	279.8	-36.2	59.1	116.7	9	21.9	37.9	8
Bias	-15.5	-24	-8.1	5.5	-1	11.2	3.3	6.5	0.5
RMSE	19.8	26.6	10.8	30.6	36.8	24	24	29.8	17.6
MAE	15.9	24	[illegible]	22.9	28.4	[illegible]	15.6	20.9	11.1
IOA	**0.997**	0.993	0.98	**0.956**	0.938	0.702	**0.81**	0.749	0.491

14% **39%** **71%**

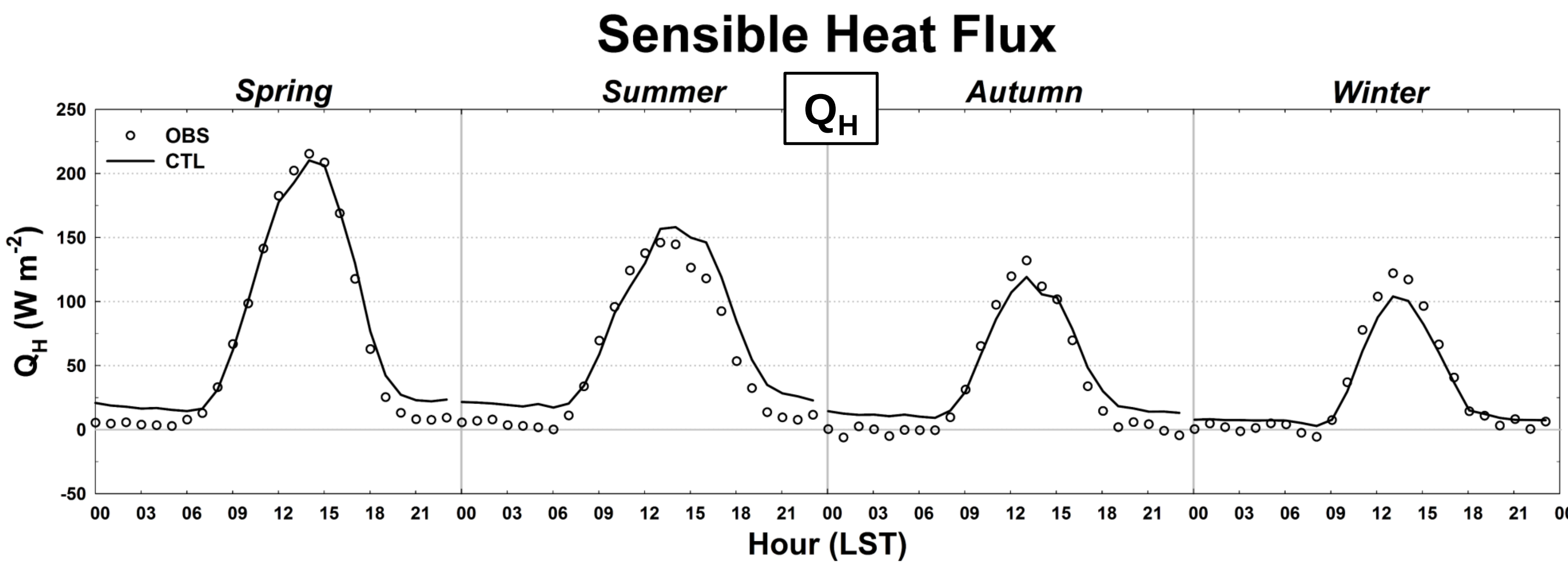
Model performance (2)



Q^* (W m^{-2})	Spring			Summer			Autumn			Winter		
	All-day	Day	Night	All-day	Day	Night	All-day	Day	Night	All-day	Day	Night
Mean (OBS)	150.8	327.5	-48.1	130.7	295.9	-21.6	76	252.7	-35.6	68.4	203.7	-41
Bias	-15.7	-22.2	-8.4	-20.1	-29.7	-11.3	-13.8	-24.2	-7.2	-10.9	-18.3	-4.9
RMSE	19.2	24.2	11.2	24.6	32.7	13.5	18.1	26.8	9.1	14.6	19.8	8.2
MAE	16.2	22.2	9.3	20.3	29.7	11.5	14	24.2	7.5	11.8	18.5	6.4
IOA	0.998	0.995	0.981	0.996	0.99	0.959	0.997	0.99	0.985	0.997	0.991	0.988

very GOOD performance

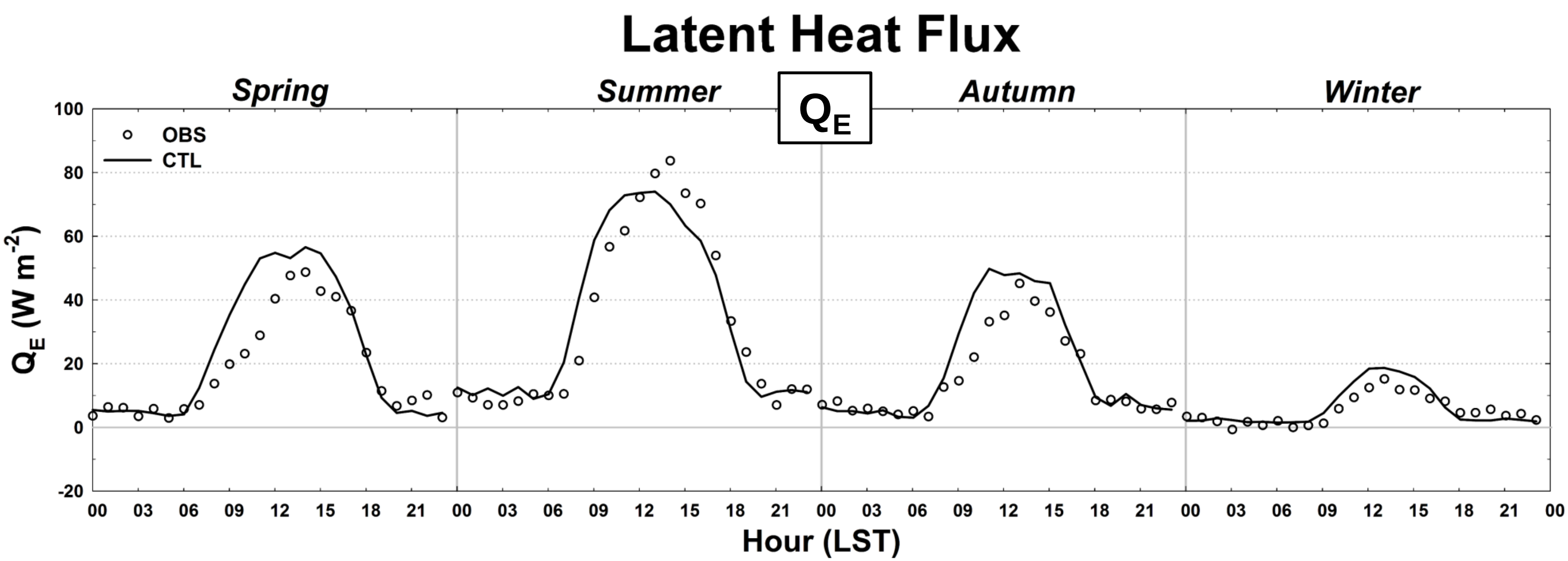
Model performance (3)



Q_H (W m^{-2})	Spring			Summer			Autumn			Winter		
	All-day	Day	Night	All-day	Day	Night	All-day	Day	Night	All-day	Day	Night
Mean (OBS)	85.6	148.3	14.9	58.1	110	10.3	39.9	96.6	4.1	45.7	93.6	6.8
Bias	5.7	0.5	11.5	12.7	8	17	5.7	-3.1	11.3	-4.6	-14.2	3.1
RMSE	32.3	38.1	24.1	33.6	39.9	26.6	28.3	33.6	24.4	26.3	32.7	19.7
MAE	25	30.1	19.3	25.5	31.2	20.3	20.9	26	17.7	18.9	24.2	14.6
IOA	0.967	**0.946**	**0.735**	0.942	**0.921**	**0.647**	0.936	**0.911**	**0.586**	0.945	**0.917**	**0.787**

fairly good at daytime but weak at nighttime

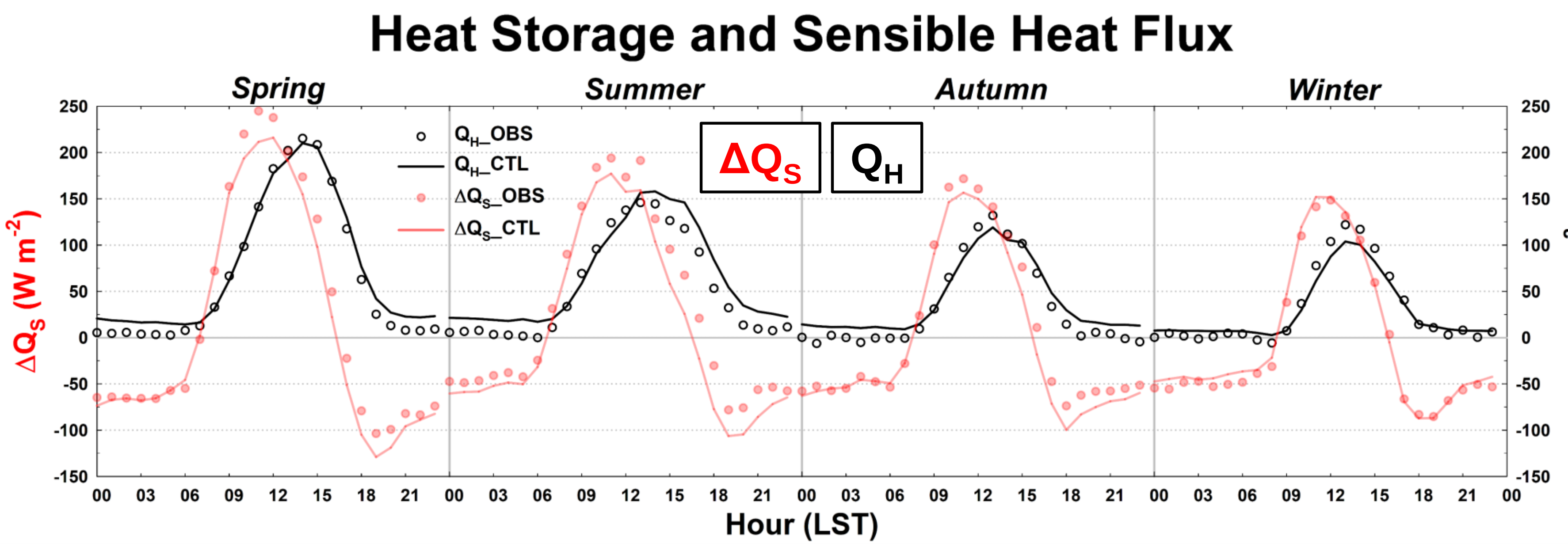
Model performance (4)

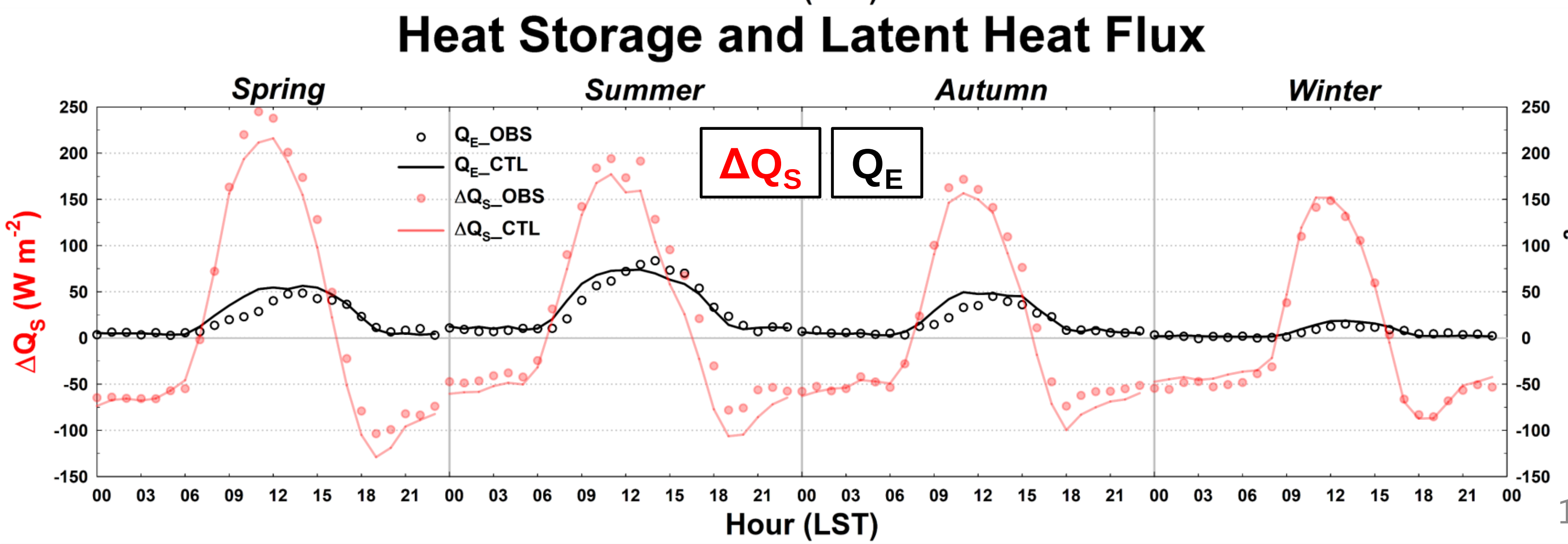


Q_E (W m^{-2})	Spring			Summer			Autumn			Winter		
	All-day	Day	Night	All-day	Day	Night	All-day	Day	Night	All-day	Day	Night
Mean (OBS)	22.8	36.4	7.5	35.8	60.2	13.2	17.9	35.3	7	6.8	11	3.4
Bias	5.8	11.2	-0.3	0.9	0.6	1.2	4.2	9.2	1	1.7	4.2	-0.3
RMSE	23.4	28.6	15.6	33.2	40.5	24.7	20.7	26.4	16.2	9.6	11.3	8
MAE	16.1	21.2	10.3	23.1	30	16.8	14.1	19.6	10.7	6.8	8.6	5.3
IOA	0.81	0.717	0.423	0.763	0.589	0.456	0.8	0.688	0.486	0.709	0.618	0.541

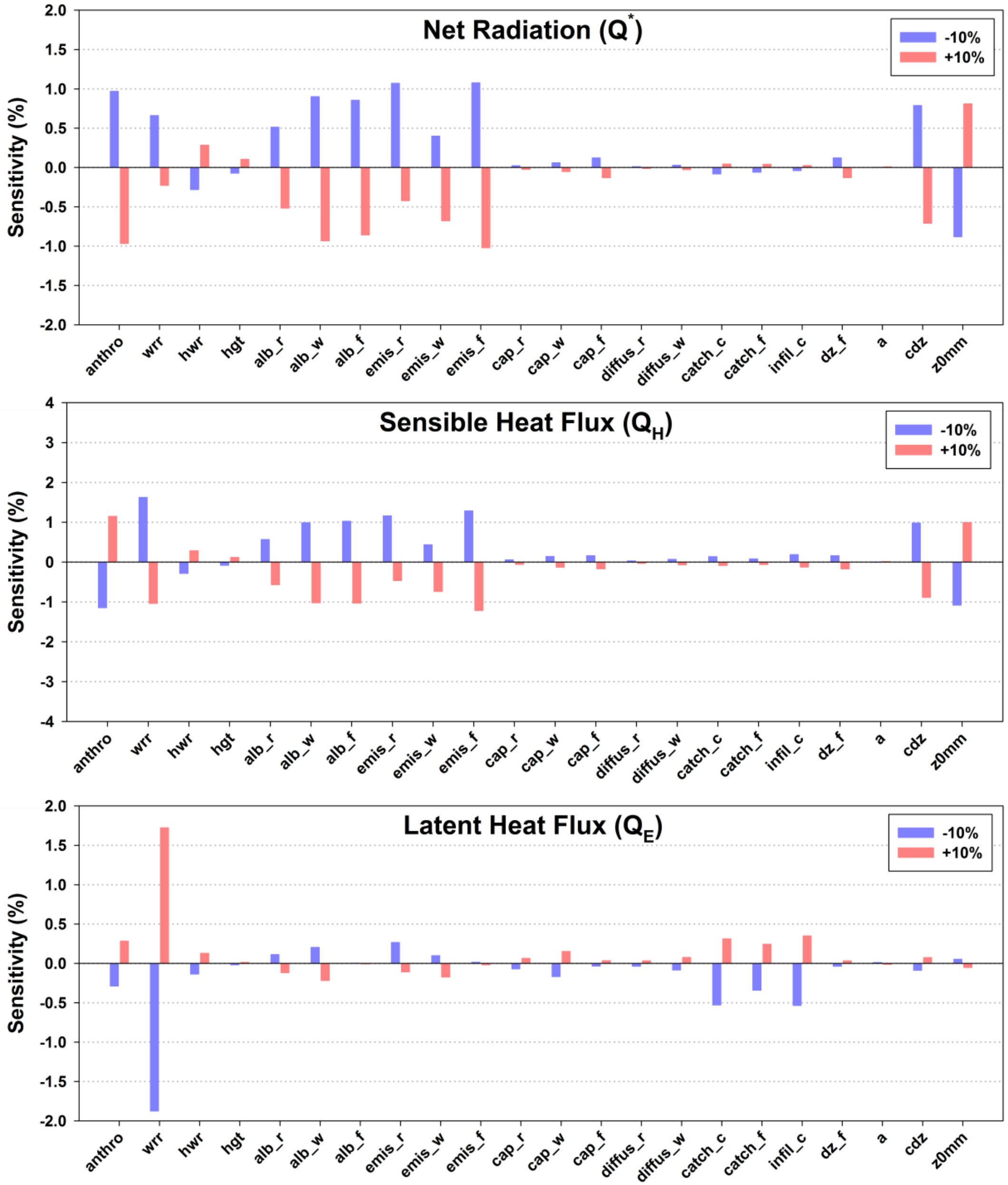
fairly WEAK performance

Model performance (5)



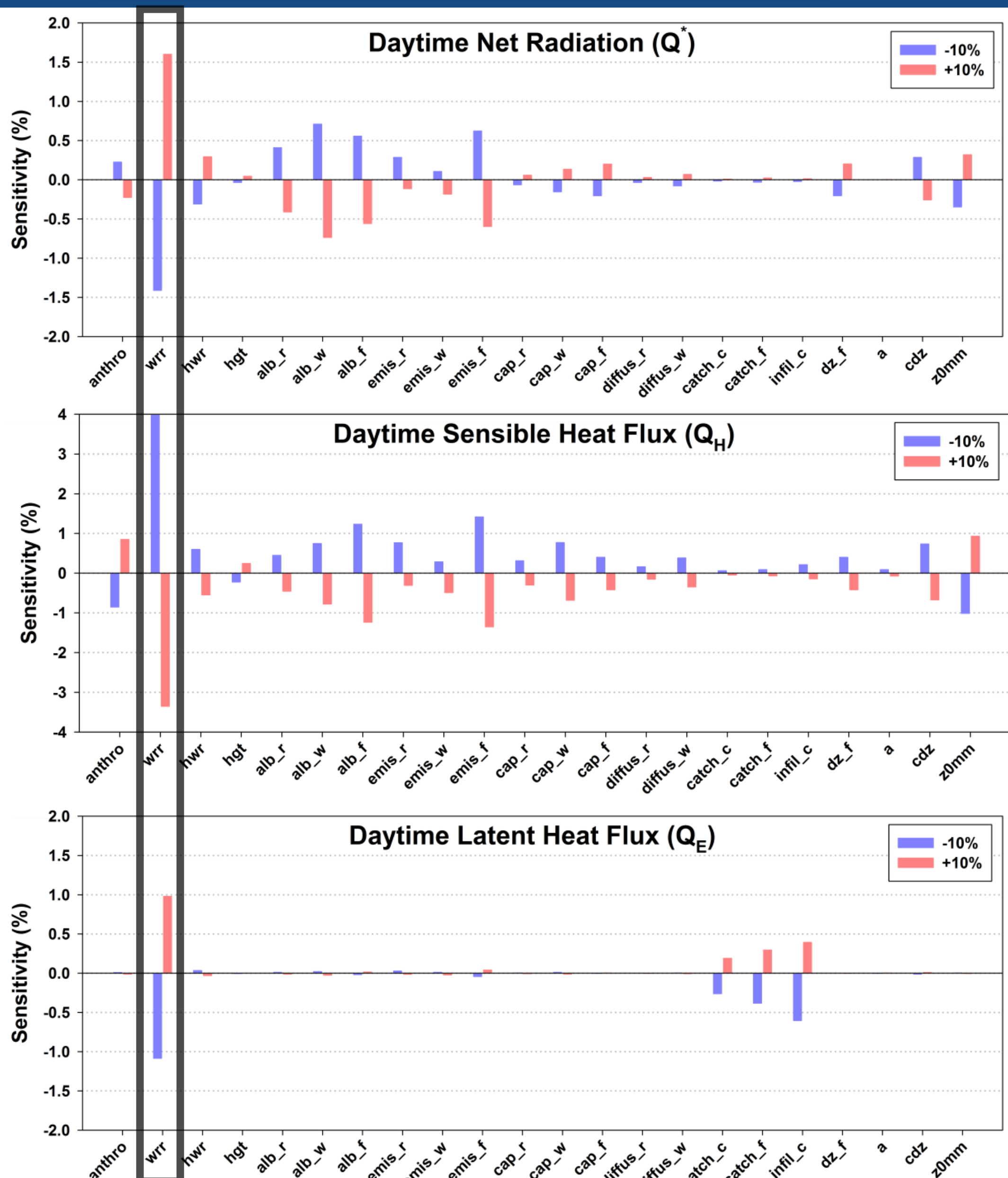


Model response (1)



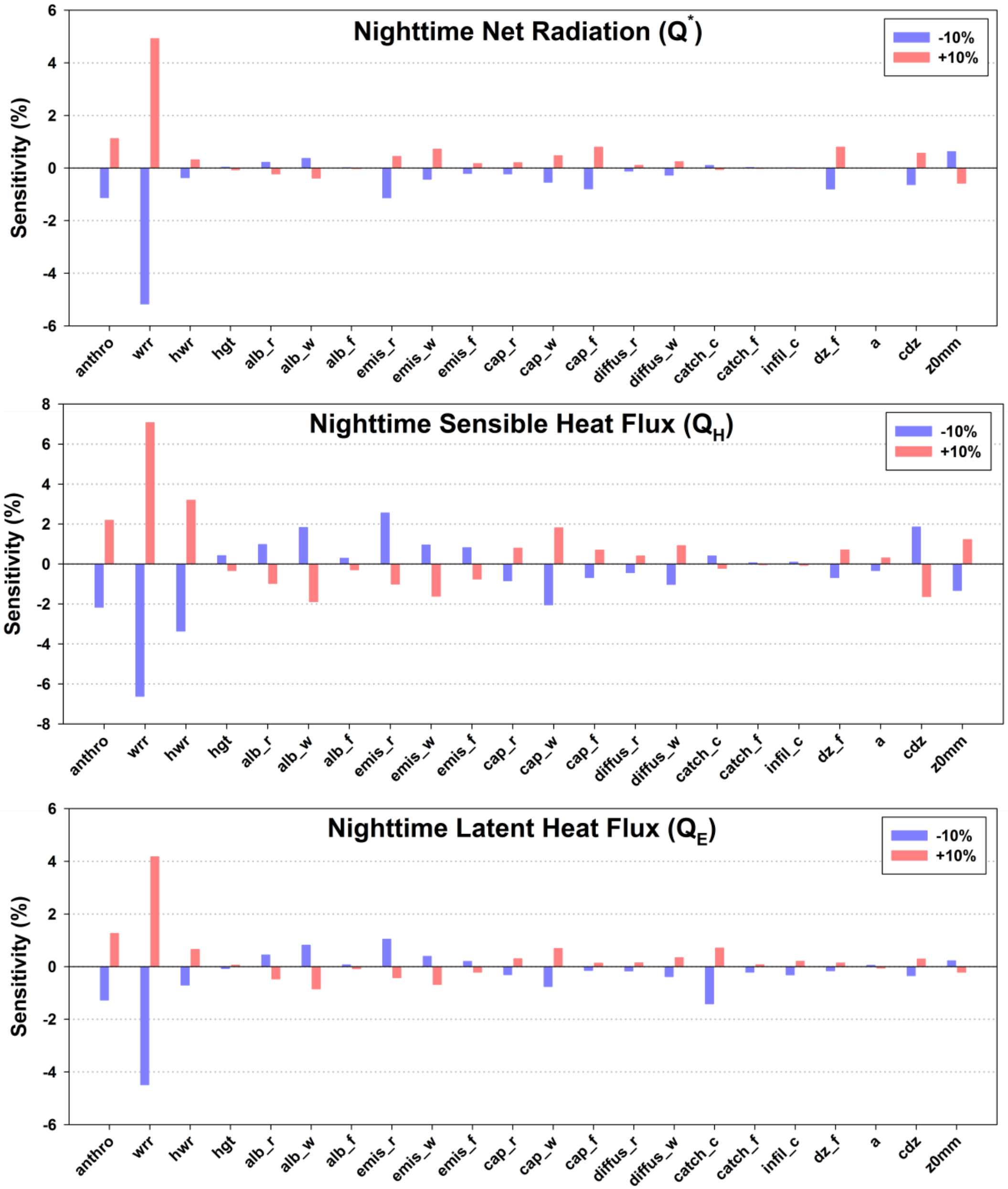
	Q^*	Q_H	Q_E
anthro	–	+ +	
wrr		– –	+ + +
alb_r	–	–	
alb_w	–	– –	
alb_f	–	– –	
emis_r	–	–	
emis_w	–	–	
emis_f	– –	– –	
cdz	–	–	
z0mm	+	+ +	

Model response (2)



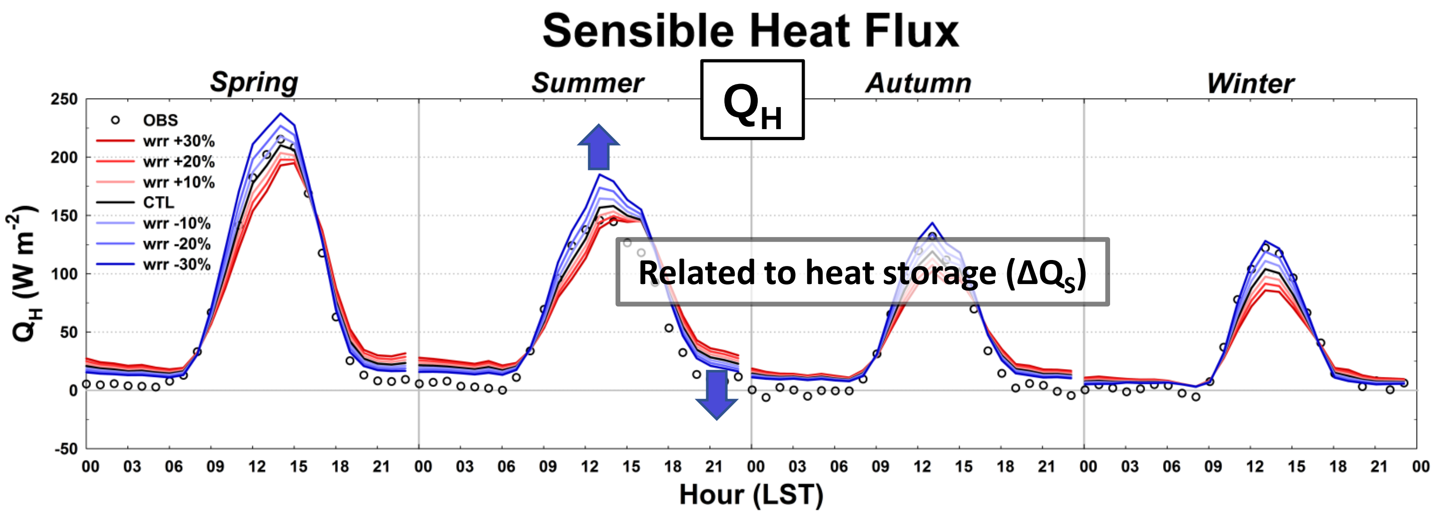
	Q^*	Q_H	Q_E
anthro		+	
wrr	+ + +	7 –	+ +
hwr		–	
alb_w	–	–	
alb_f	–	– –	
emis_r		–	
emis_f	–	– –	
cap_w		–	
cdz		–	
z0mm		+	

Model response (3)

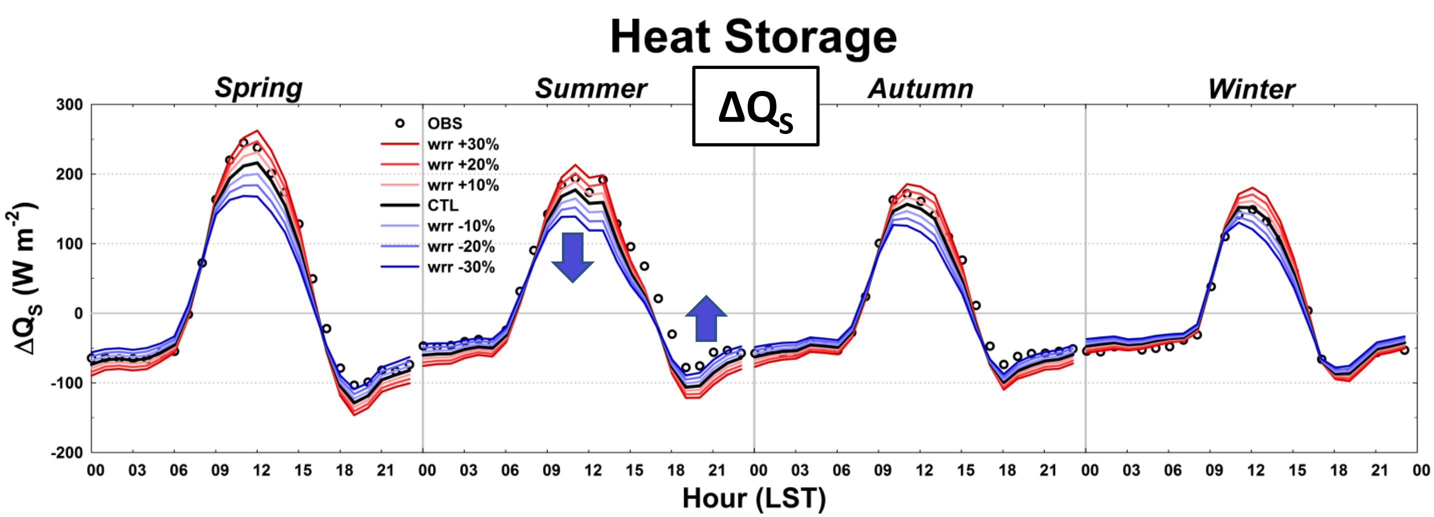


	Q^*	Q_H	Q_E
anthro	+ +	+ + + +	+ +
wrr	10 +	13 +	8 +
hwr		6 +	+
alb_r		−	
alb_w		− − −	−
emis_r	+	+ + +	−
emis_w	+	+ +	−
emis_f		−	
cap_r		+	
cap_w	+	+ + + +	+
cap_f	+	+	
diffus_w		+	
dz_f	+	+	
catch_c			+ +
cdz	+	− − −	
z0mm	−	+ +	

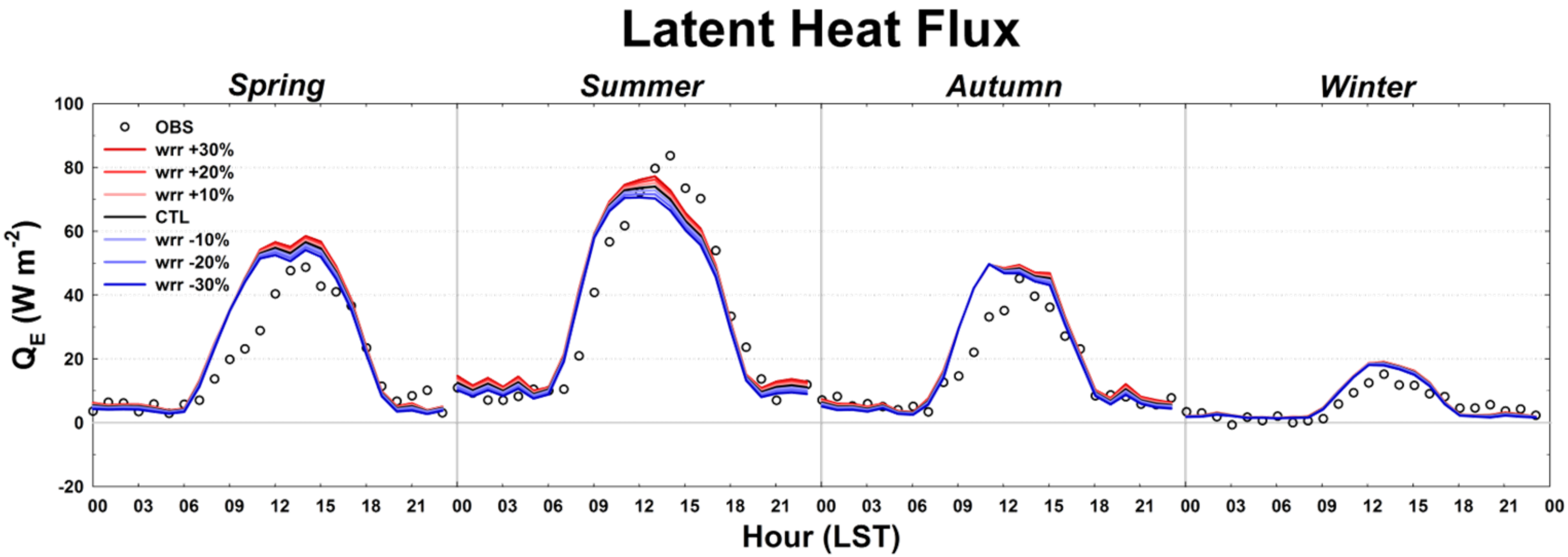
Response to W/R (1)



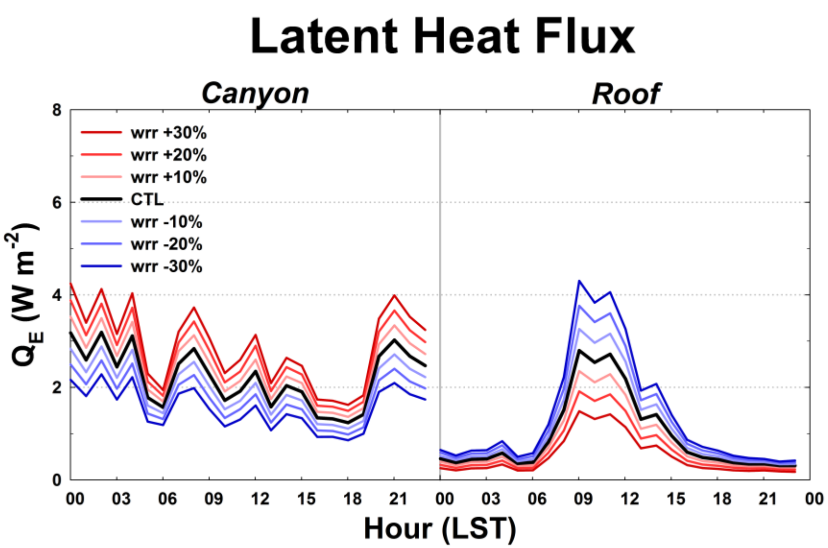
wrr↓ → building fraction↑ → roughness↑ → turbulent mixing↑ → daytime Q_H↑ → daytime ΔQ_S↓ → nighttime Q_H↓ → nighttime ΔQ_S↑

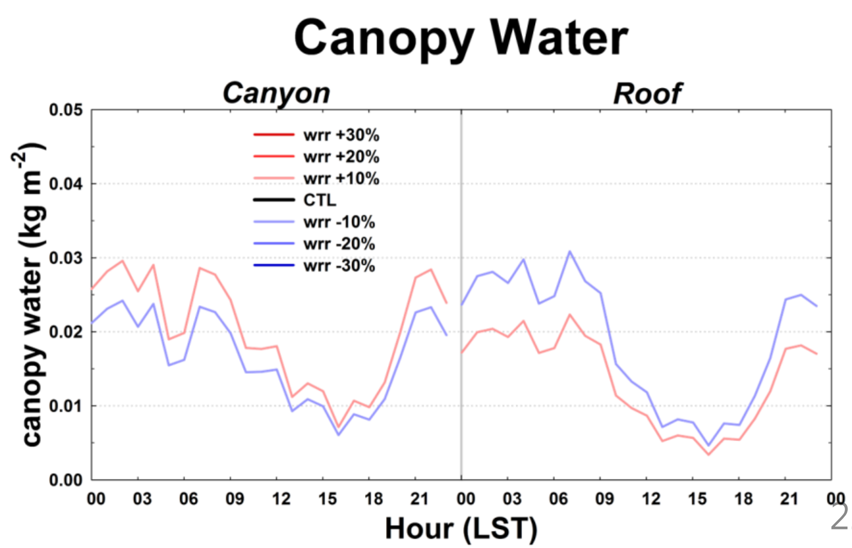


Response to W/R (2)



wrr↓ → Q_E of Canyon↓ & Q_E of Roof↑ → Q_E↓





Summary

Summary

- The urban surface energy balance (SEB) was evaluated with in-situ observed flux data at a high-rise urban residential area in Korea.
  - ✓ The modeled net radiation(Q^*) was relatively consistent with the observed one, and the modeled sensible heat flux (Q_H) was moderately accurate, but the latent heat flux (Q_E) had significant errors (14%, 39% and 71% of MAE compare to the mean obs., respectively).
  - ✓ The model showed the overestimation of the sensible heat flux at nighttime over the year, and the underestimation at daytime in autumn and winter.
  - ✓ The latent heat flux was overestimated most of the time, but underestimated at afternoon in summer.
- The sensitivity analysis of the 22 urban parameters for simulating urban SEB using MORUSES scheme was conducted.
  - ✓ The key parameter to estimate three SEB fluxes (Q^*, Q_H, Q_E) was the canyon fraction (W/R).
  - ✓ The value of wrr had negative (positive) correlation with the sensible heat flux during the daytime (nighttime). This response was related to the response of the heat storage.
  - ✓ The response of the latent heat flux to the change of wrr value needs to be investigated further.


Thank you
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