Supporting Information for "Impact of Spatially Continuous Urban Surface Properties on Summertime and Heatwave Simulations: A Multi-City Analysis"

Timothy Jiang[1], TC Chakraborty[1], Yifan Cheng[2], Rohit Mukherjee[1], Lei Zhao[2], and Alberto Martilli[3]

[1]Pacific Northwest National Laboratory, Richland, WA, USA

[2]University of Illinois, Urbana-Champaign, IL, USA

[3]CIEMAT, Madrid, Spain

Contents of this file

1. Tables S1 to S3
2. Figures S1 to S10

Introduction

This Supporting Information file contains additonal figures and tables referred to in the main text. The additional figures are either reproductions of figures in the main text for additional cities analysed, or figures included for model evaluation beyond what was presented in the main text. The tables included present summary statistics for model evaluation.

Table S1. Summary statistics comparing impervious fraction from three datasets against ESA world cover built-up fraction within city limits. A positive mean bias error indicates an overestimation with respect to ESA world cover.

	r			MAE			MBE		
	Default	U-Surf	U-Surf-WRF	Default	U-Surf	U-Surf-WRF	Default	U-Surf	U-Surf-WRF
atl	0.35	0.19	0.73	0.30	0.61	0.11	0.28	0.61	0.03
bos	0.38	0.25	0.58	0.21	0.37	0.16	0.12	0.33	0.06
bwi	0.35	0.38	0.60	0.18	0.36	0.13	0.08	0.36	0.01
dca	0.43	0.33	0.60	0.22	0.33	0.17	0.06	0.30	-0.03
dfw	0.44	0.61	0.66	0.24	0.37	0.14	0.19	0.35	0.02
iah	0.59	0.68	0.73	0.25	0.35	0.11	0.23	0.34	0.01
lax	0.22	0.54	0.75	0.26	0.22	0.17	0.02	0.16	-0.06
mia	0.60	0.75	0.74	0.22	0.19	0.18	0.05	0.17	0.08
nyc	0.55	0.60	0.68	0.19	0.21	0.16	0.02	0.17	-0.01
ord	0.69	0.69	0.79	0.15	0.25	0.10	0.07	0.23	-0.00(07)
phl	0.35	0.44	0.57	0.22	0.29	0.18	0.00(2)	0.24	0.00(2)
sea	0.38	0.40	0.49	0.19	0.35	0.15	0.14	0.34	0.04
sfo	0.59	0.75	0.70	0.17	0.13	0.14	-0.03	0.03	-0.03

Table S2. Summary statistics comparing height to width ratio from three datasets against ESA world cover built-up fraction within Chicago city limits. A positive mean bias error indicates an overestimation with respect to HiTAB.

	r	MAE	MBE
Default	0.18	0.46	+0.26
U-Surf	0.58	0.25	+0.03
U-Surf-WRF	0.61	0.36	+0.25

Table S3. Summary statistics comparing height to width ratio from three datasets against ESA world cover built-up fraction within Houston city limits. A positive mean bias error indicates an overestimation with respect to UT-Globus.

	r	MAE	MBE
Default	0.16	0.46	-0.11
U-Surf	0.25	0.59	-0.53
U-Surf-WRF	0.37	0.45	+0.13

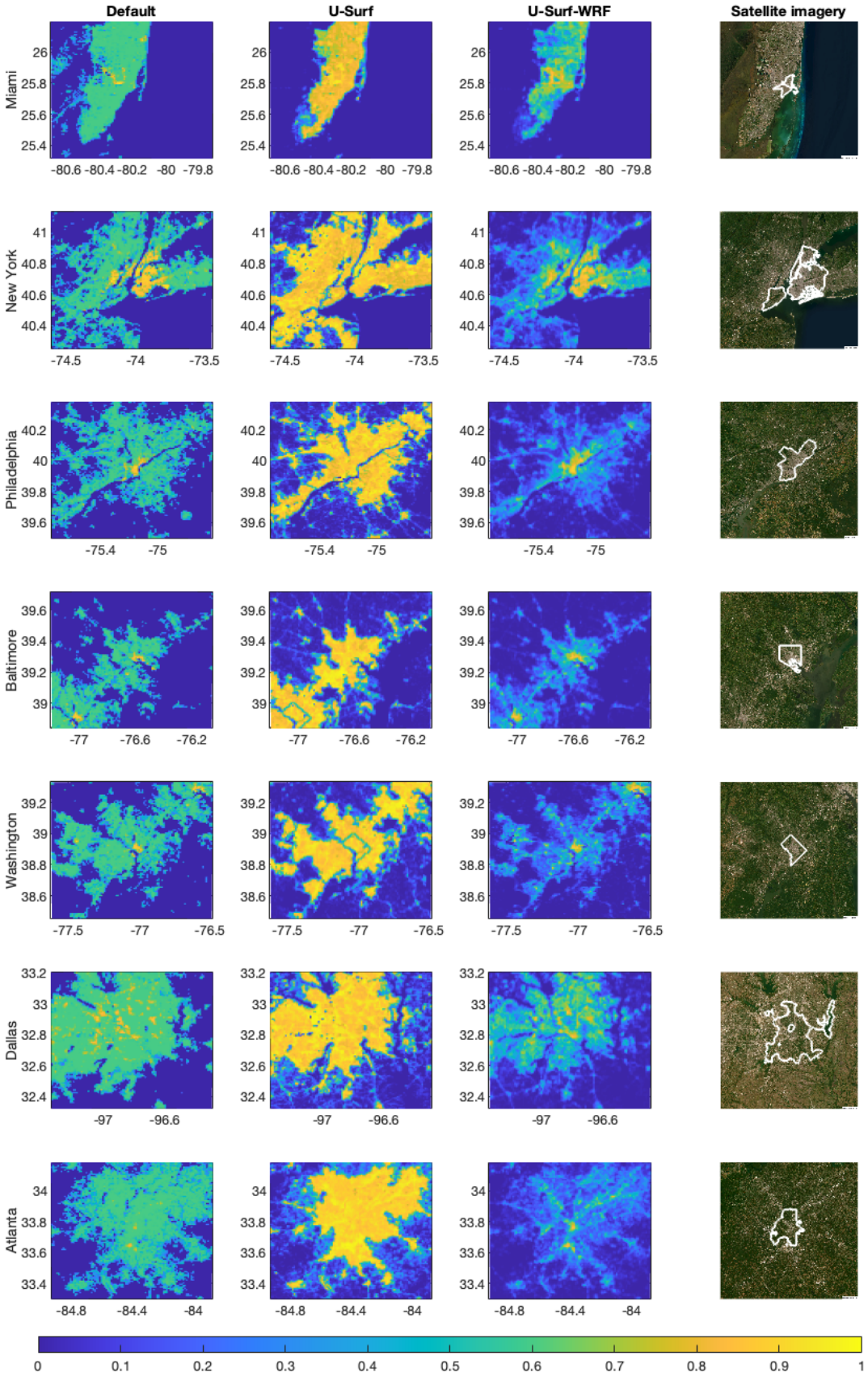


Figure S1. As Figure 2, but for the remaining 7 examined cities.

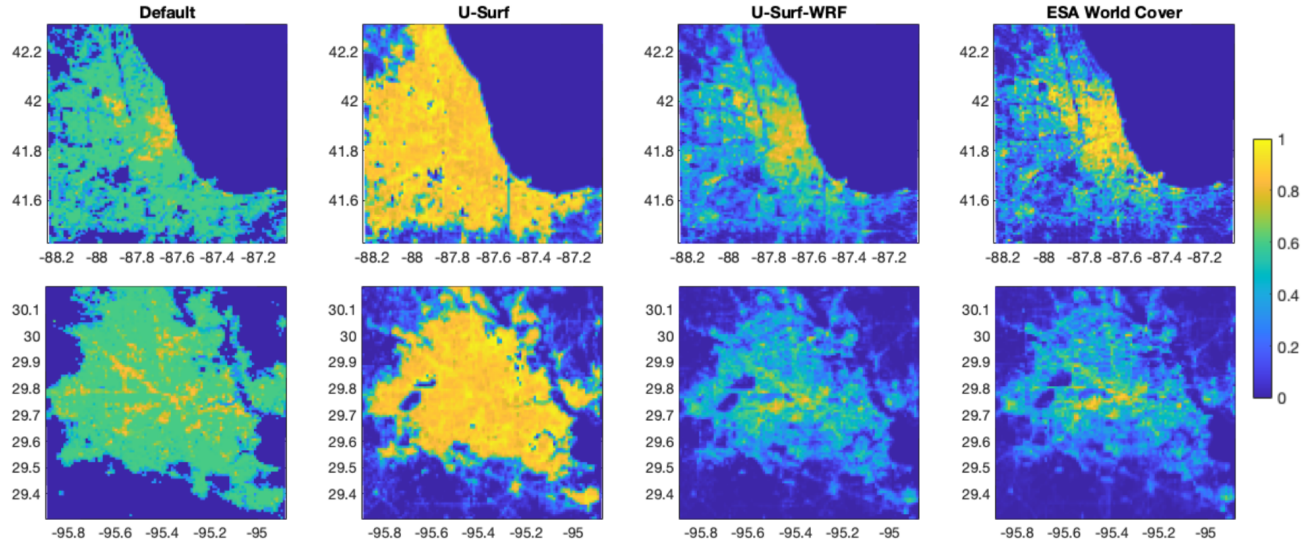


Figure S2. Impervious fraction for Chicago (top) and Houston (bottom) as estimated by four datasets. Summary statistics for Default, unmodified U-Surf, and U-Surf-WRF against ESA World Cover are presented in Table S1.

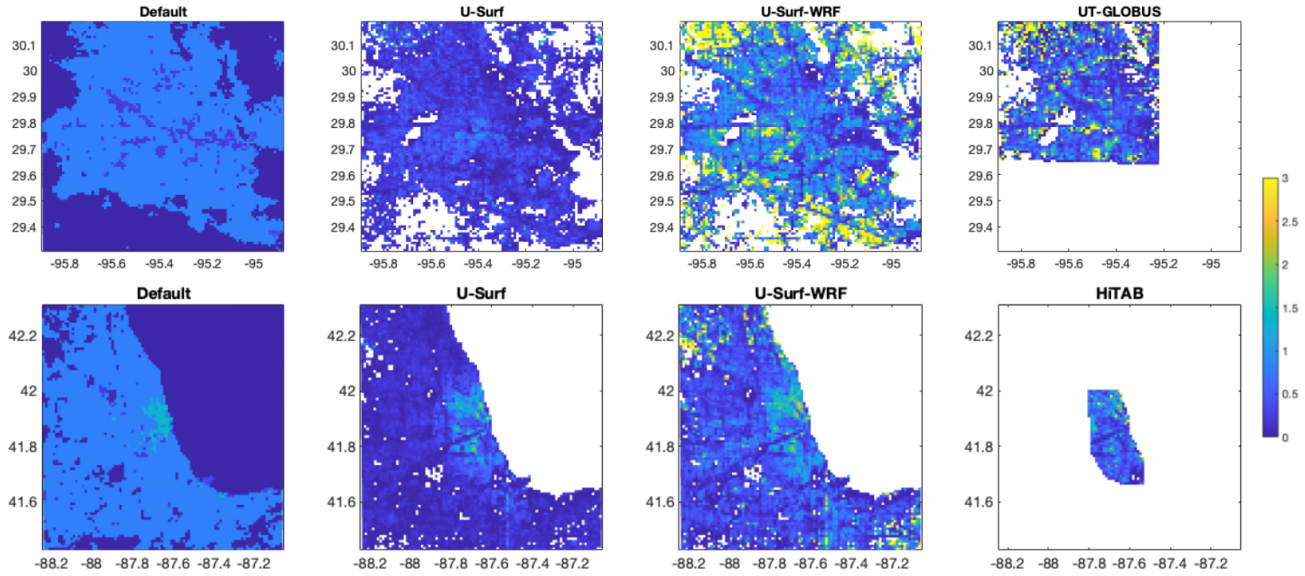


Figure S3. Height-to-width ratio for Chicago (top) and Houston (bottom) as estimated by four datasets. Summary statistics for Default, unmodified U-Surf, and U-Surf-WRF against HiTAB/UT-Globus are presented in Tables S2 and S3.

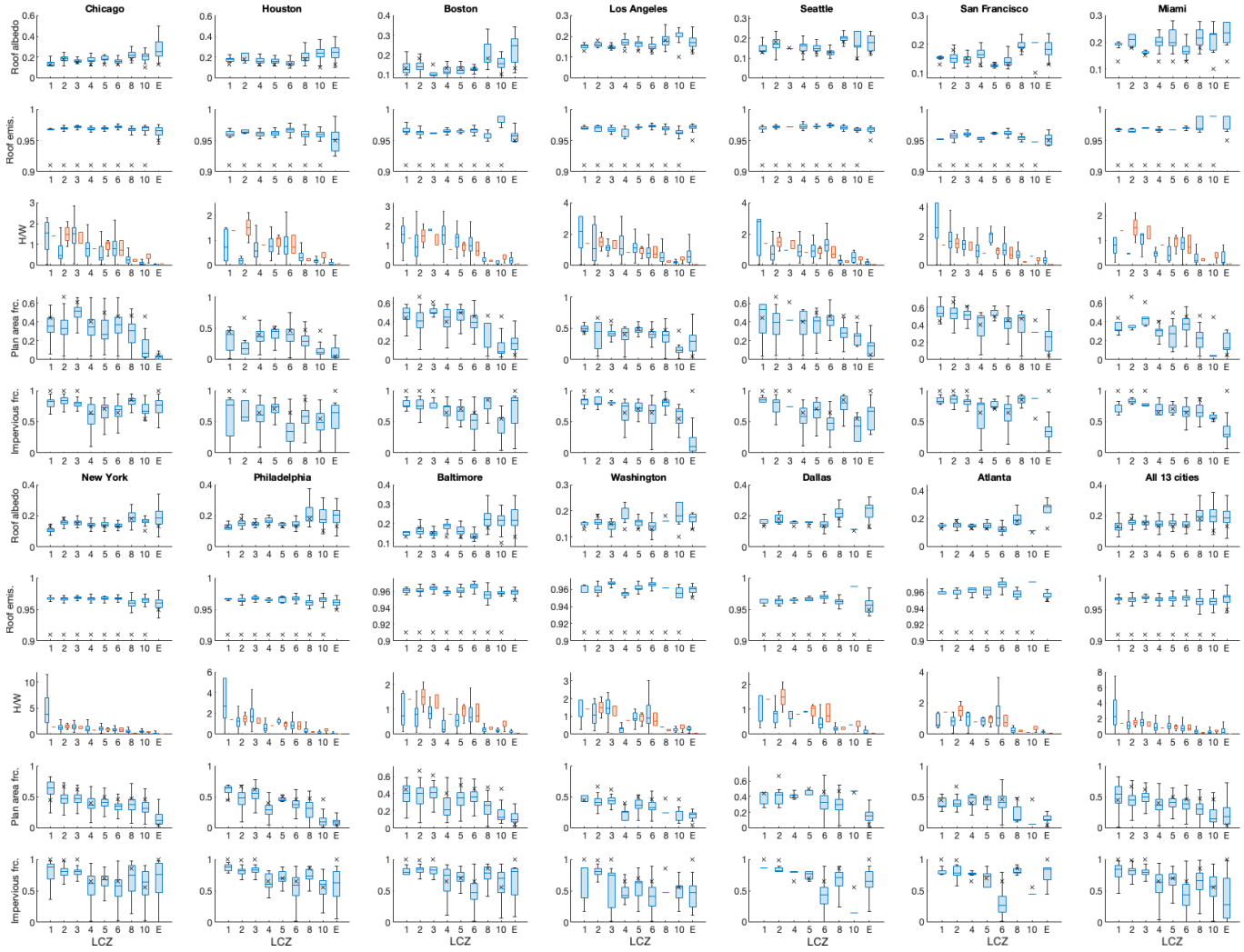
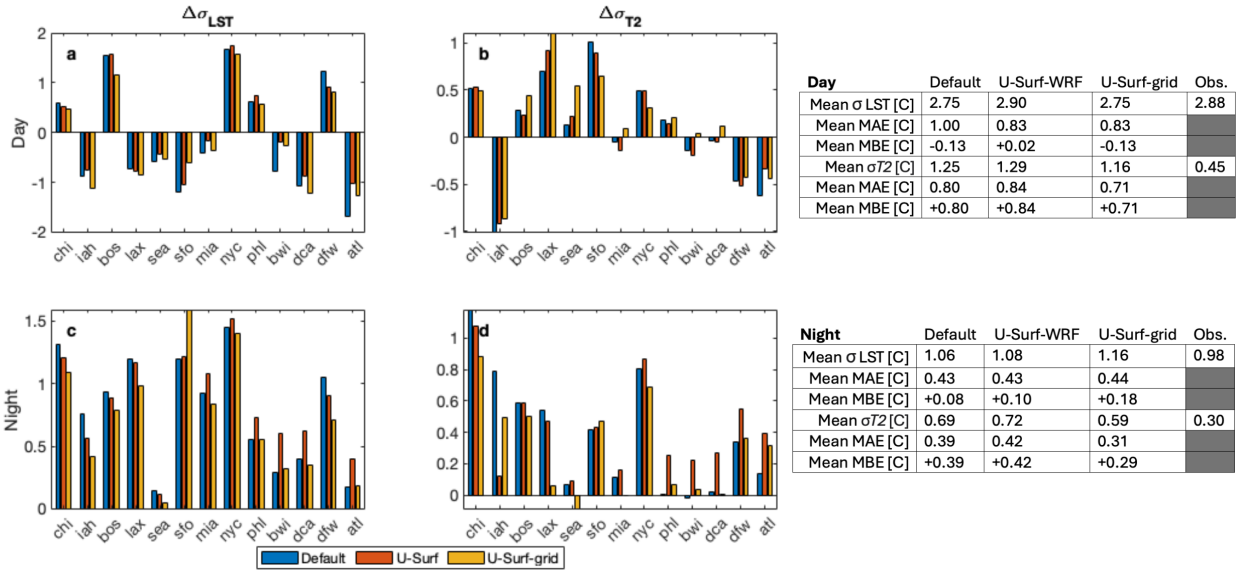


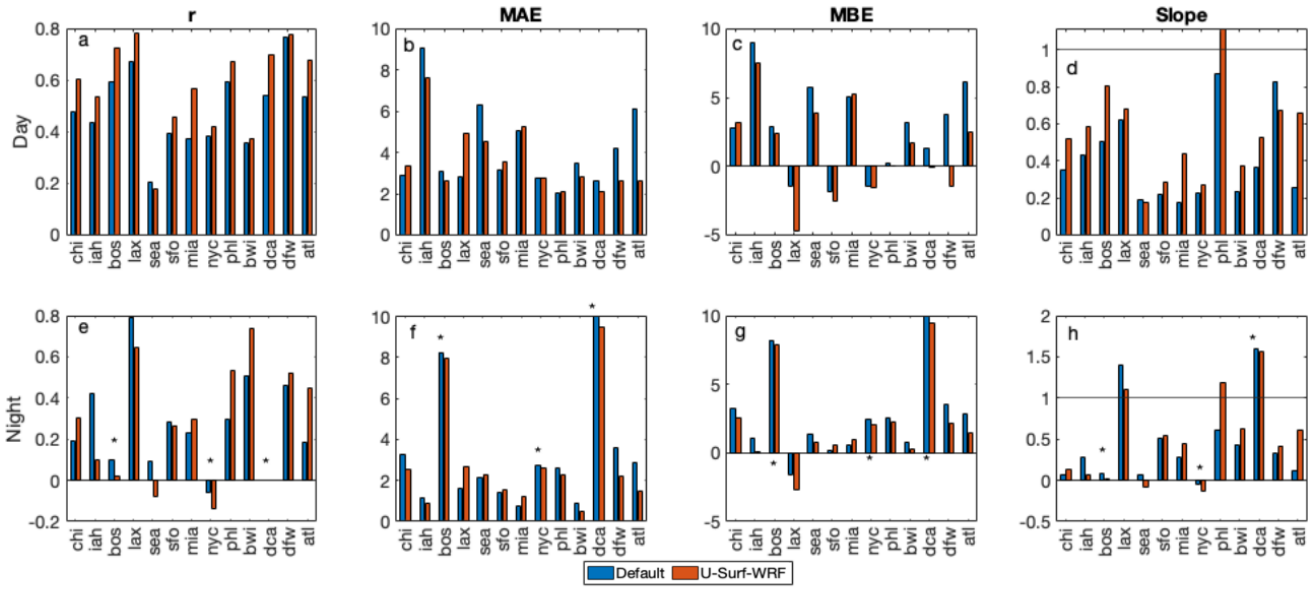
Figure S4. Select U-Surf-WRF urban properties (blue) compared with WRF defaults (orange bars for H/W and x's for other variables). Each data point is one grid square within administrative city limits for each of the 13 simulated cities.



Day	Default	U-Surf-WRF	U-Surf-grid	Obs.
Mean σ LST [C]	2.75	2.90	2.75	2.88
Mean MAE [C]	1.00	0.83	0.83	
Mean MBE [C]	-0.13	+0.02	-0.13	
Mean σ*T2* [C]	1.25	1.29	1.16	0.45
Mean MAE [C]	0.80	0.84	0.71	
Mean MBE [C]	+0.80	+0.84	+0.71	

Night	Default	U-Surf-WRF	U-Surf-grid	Obs.
Mean σ LST [C]	1.06	1.08	1.16	0.98
Mean MAE [C]	0.43	0.43	0.44	
Mean MBE [C]	+0.08	+0.10	+0.18	
Mean σ*T2* [C]	0.69	0.72	0.59	0.30
Mean MAE [C]	0.39	0.42	0.31	
Mean MBE [C]	+0.39	+0.42	+0.29	

Figure S5. Difference between the spatial standard deviation of (a,c) surface temperature, (b,d) air temperature and that of their reference data – (a,c) MODIS; (b,d) Zhang et al. (2022). (a) "Day" refers to 1:30 PM local time;(b) "Day" refers to the maximum air temperature; (c) "Night" refers to 1:30 AM local time; (d) "Night" refers to the minimum air temperature. Units are [∘ C]. MAE refers to Mean Absolute Error, and MBE refers to Mean Bias Error. A positive MBE indicates an overestimation by the model. Each point is one $1km^2$ grid point within administrative city limits.



Day	Default	U-Surf-WRF
Mean r	0.49	0.58
Mean MAE [C]	4.13	3.61
Mean MBE [C]	+2.72	+1.25
# of cities with a greater r	1/13	12/13
# of cities with lower MAE	6/13	7/13
# of cities with smaller MBE	5/13	8/13
# of cities with slope closer to 1	2/13	11/13

Night	Default	U-Surf-WRF
Mean r	0.35	0.38
Mean MAE [C]	2.03	1.77
Mean MBE [C]	+1.47	+0.86
# of cities with a greater r	4/10	6/10
# of cities with lower MAE	4/10	6/10
# of cities with smaller MBE	3/10	7/10
# of cities with slope closer to 1	2/10	8/10

Figure S6. Model land surface temperature performance for each city during an extreme heat event. Summary statistics are shown for MODIS observed versus WRF simulated land surface temperature, where each data point is one $1km^2$ grid point. MAE refers to Mean Absolute Error, and MBE refers to Mean Bias Error. A positive MBE indicates an overestimation by the model. A slope greater than 1 indicates the model is less sensitive than observations, and plots of the slopes (d,h) have a reference line at slope = 1. Day (a-d) refers to 13:30 local time, and Night (e-h) refers to 1:30 local time. An asterisk indicates that there were data available in the MODIS observations for fewer than 33% of grid points. Only two data points were available for dca at night, precluding a calculation of r. Tables show statistics for all cities analysed that had greater than 33% of grid points available in the MODIS observations.

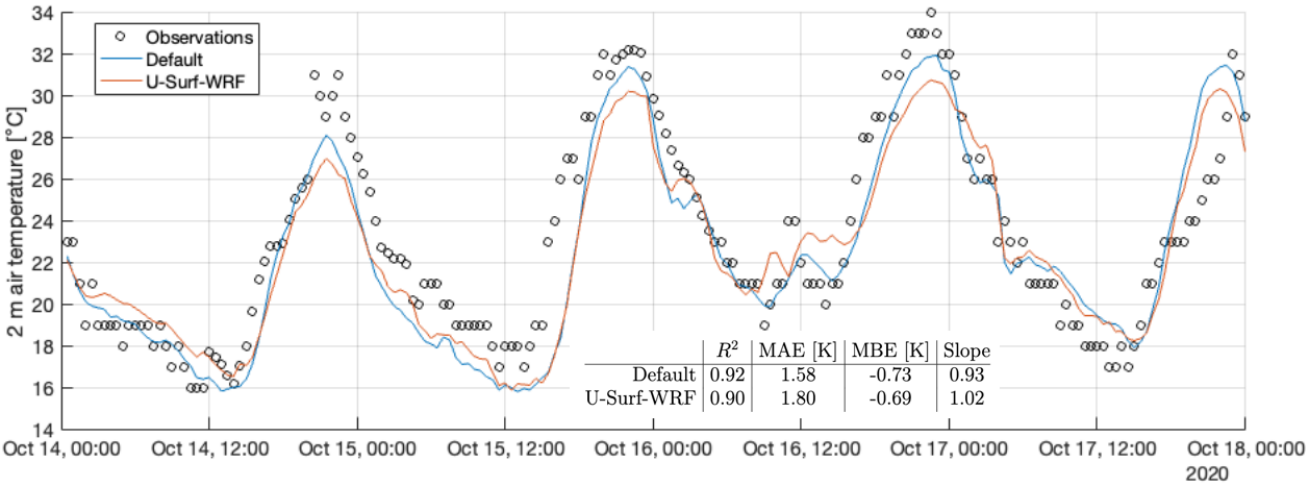


Figure S7. Observed and WRF modeled air temperatures during a heatwave for San Francisco airport using two urban parameter datasets. Table presents summary statistics for this evaluation.

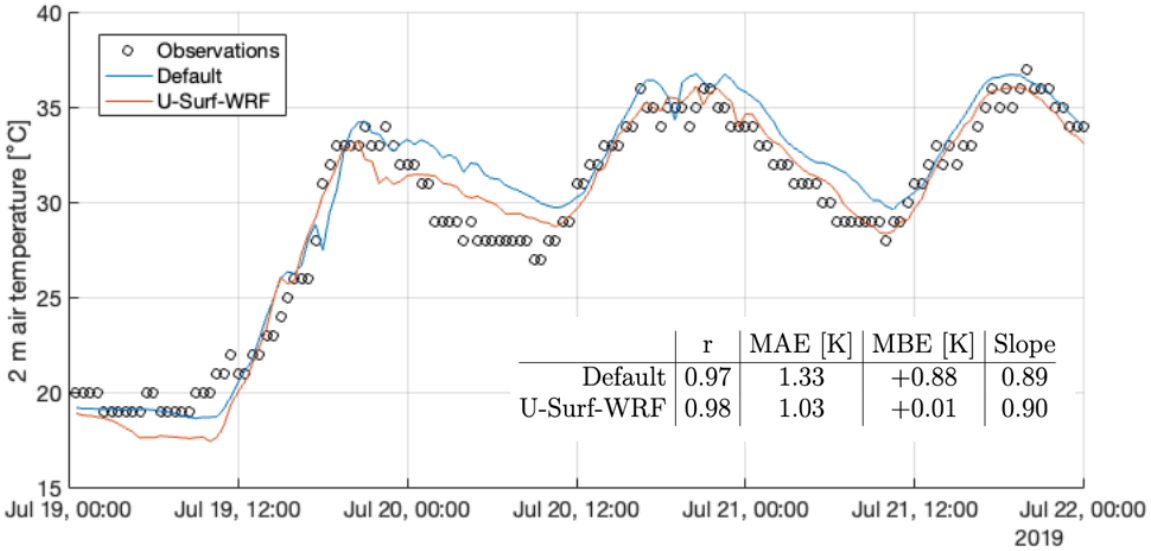


Figure S8. Observed and WRF modeled air temperatures during a heatwave for Boston airport using two urban parameter datasets. Table presents summary statistics for this evaluation.

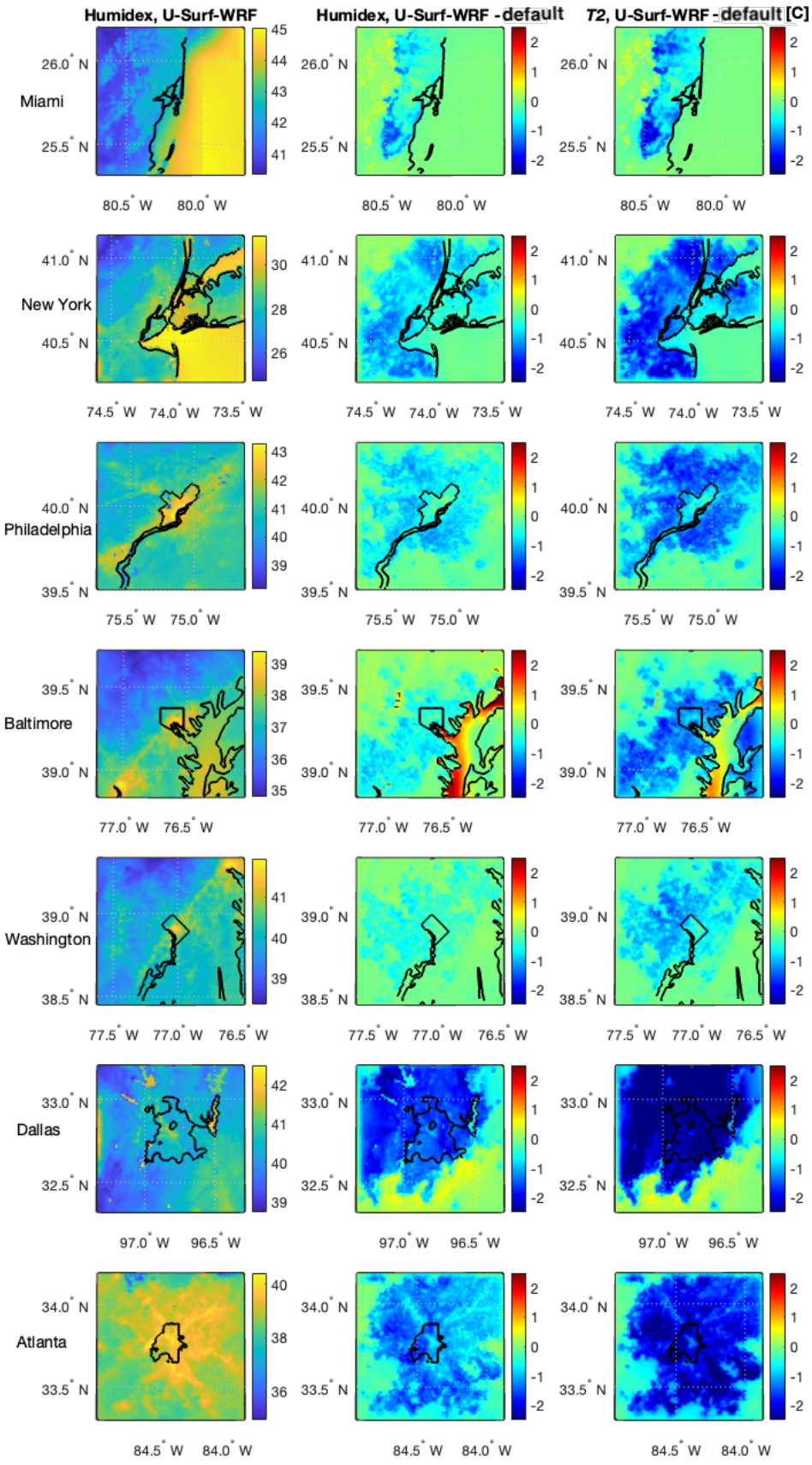


Figure S9. As Figure 9, for the remaining 7 cities.

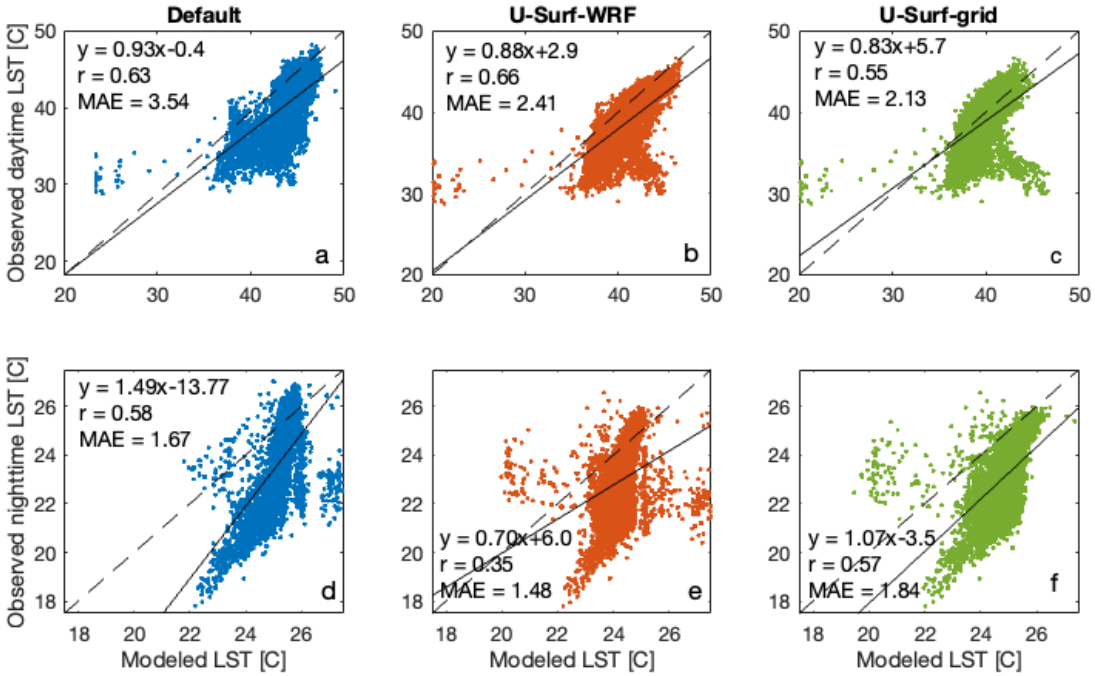


Figure S10. Observed vs. modeled land surface temperature for Houston summer 2020 at (a-c) 13:30 and (d-f) 1:30 local time. (a,d) are simulations using default parameters; (b,e) are U-Surf simulations using city-specific parameters by LCZ; and (c,f) are U-Surf-Grid simulations with parameters assigned spatially continuously for every grid point. Each data point corresponds to one $1km^2$ grid square. Dashed lines are 1:1 lines, and solid lines are least-squares regression lines.