A discussion of "Urban adaptation can roll back warming of emerging megapolitan regions"

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in PNAS

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Outline

- Background
- Objective
- Experiment Details
- Results & Discussion
- Conclusions

1.Background

- Urban areas are hot spots that drive multisector environmental change. Consumption and production of resources for use within urban environments have local and remote implications for ecosystem services, hydroclimate, energy provision, health, and other factors of human wellbeing.

- Continued conversion of existing lands to urban landscapes has the potential to drive significant local and regional climate change, compounding global warming.

- Land use change can have important impacts on local weather and climate, however, the potential for impacts at large regional, continental, and even global scales has been less well-studied.

- US population projections for 2100 range from 380 to 690 million inhabitants, leading to 208,000–261,000 km² of new urban land use relative to 2000 .

2. Objective

- Comparison of several plausible urban growth futures with climate change effects offers an unprecedented exploration of ranges of impacts and adaptation strategies.

- To explore hydro climatic impacts of 21st century urban expansion across the United States and examine the efficacy of commonly proposed urban adaptation strategies in context of long-term global climate change.

3. Experiment Details

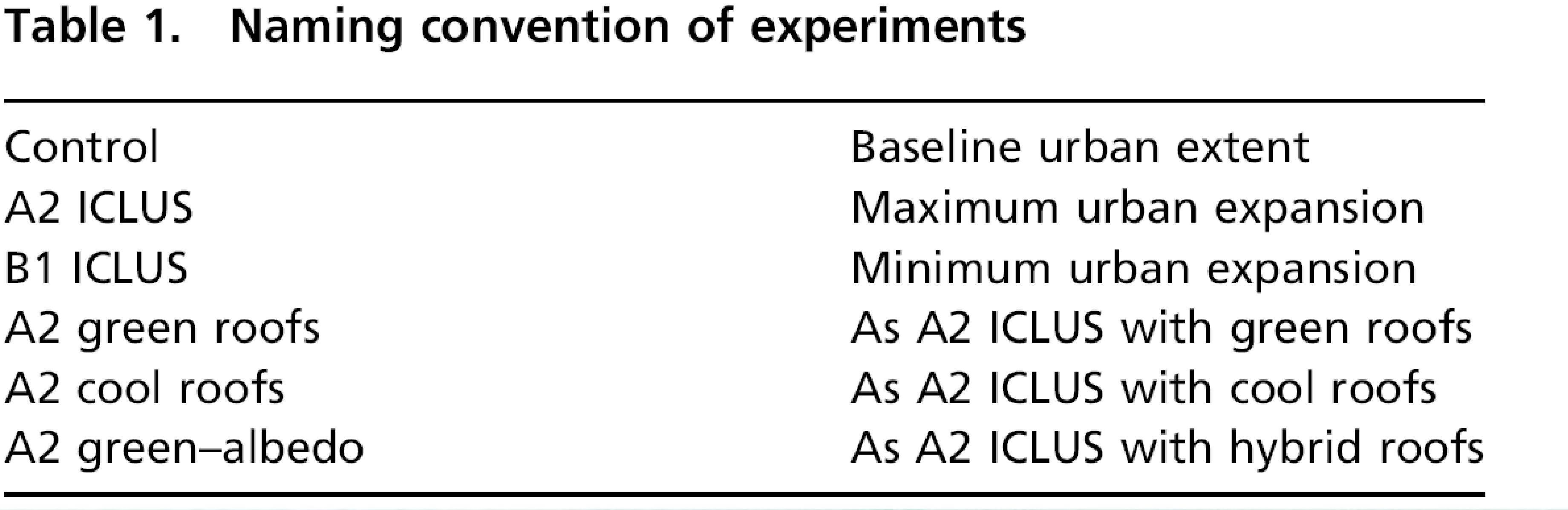


Table 1. Naming convention of experiments

Control	Baseline urban extent
A2 ICLUS	Maximum urban expansion
B1 ICLUS	Minimum urban expansion
A2 green roofs	As A2 ICLUS with green roofs
A2 cool roofs	As A2 ICLUS with cool roofs
A2 green–albedo	As A2 ICLUS with hybrid roofs

Table S2. Model parameterizations used for all experiments.

WRF Specifications

Model Version:	Version 3.2.1
Horizontal Grid:	ΔX, ΔY, 20-km
Number of Points:	310 (X-dir.); 200 (Y-dir.)
Vertical Levels:	30 levels
Initialization Time:	*See Table S*
Terminal Time:	December 31, 21Z 2008
Analysis Time:	January 1, 00Z 2001 - December 31, 21Z 2008
ΔT:	90 seconds
Radiation Scheme:	RRTM (long wave); RRTMG (shortwave)
Surface Model:	Noah
Cumulus Scheme:	Kain-Fritsch
Microphysics Scheme :	WSM-3
PBL Scheme :	Mellor-Yamada-Janjic
Surface Layer :	Eta similarity
Urban Model :	3-category Urban Canopy Model
Initial and Lateral Boundary Conditions:	FNL

Naming Convention	Spin up Period	Analysis Period
Control		
Control_1	JAN 2000 – DEC 2000	JAN 2001 – DEC 2008
Control_2	JUL 2000 – DEC 2000	JAN 2001 – DEC 2008
Control_3	–	JAN 2001 – DEC 2008
A2 ICLUS		
A2_1	JAN 2000 – DEC 2000	JAN 2001 – DEC 2008
A2_2	JUL 2000 – DEC 2000	JAN 2001 – DEC 2008
A2_3	–	JAN 2001 – DEC 2008
B1 ICLUS		
B1_1	JAN 2000 – DEC 2000	JAN 2001 – DEC 2008
B1_2	JUL 2000 – DEC 2000	JAN 2001 – DEC 2008
B1_3	–	JAN 2001 – DEC 2008
A2-GreenRoofs		
A2_GreenR1	JAN 2000 – DEC 2000	JAN 2001 – DEC 2008
A2_GreenR2	JUL 2000 – DEC 2000	JAN 2001 – DEC 2008
A2_GreenR3	–	JAN 2001 – DEC 2008
A2-CoolRoofs		
A2_CoolR1	JAN 2000 – DEC 2000	JAN 2001 – DEC 2008
A2_CoolR2	JUL 2000 – DEC 2000	JAN 2001 – DEC 2008
A2_CoolR3	–	JAN 2001 – DEC 2008
A2-GreenAlbedo		
A2_GreenAlb1	JAN 2000 – DEC 2000	JAN 2001 – DEC 2008
A2_GreenAlb2	JUL 2000 – DEC 2000	JAN 2001 – DEC 2008
A2_GreenAlb3	–	JAN 2001 – DEC 2008

Table S1. Naming convention of all experiments performed.

Materials and Methods

- We have used the advanced research version of the WRF (version 3.2.1).
- Initial and boundary data were obtained from the Research Data Archive.
- The original data are available from the Research Data Archive in dataset number ds083.2.
- We have used US National Centers for Environmental Prediction Final Analyses data, which are available on a 1° × 1° global grid starting in 1999, with a 6-h temporal frequency.
- To compare urban relative to estimated future greenhouse gas-induced climate change, Lawrence Livermore National Laboratory (LLNL)-Reclamation-Santa Clara University (SCU) bias-corrected statistically downscaled climate projection data derived from the World Climate Research Program’s Coupled Model Intercomparison Project Phase 5 multimodel dataset were obtained.

4. Results & Discussion

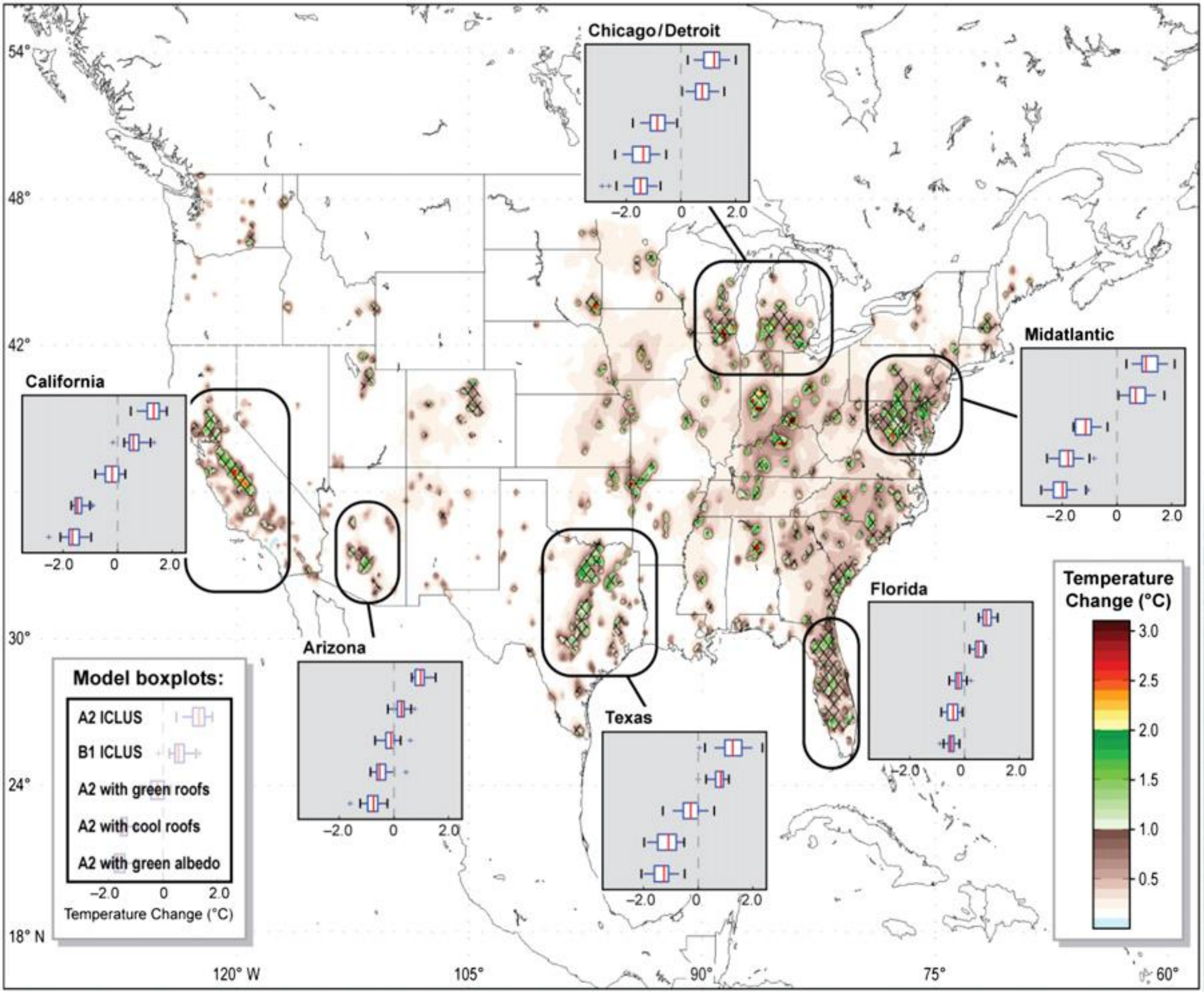


Fig.1. Simulated June–July–August (JJA) 2-m air temperature difference between A2 and control (° C).

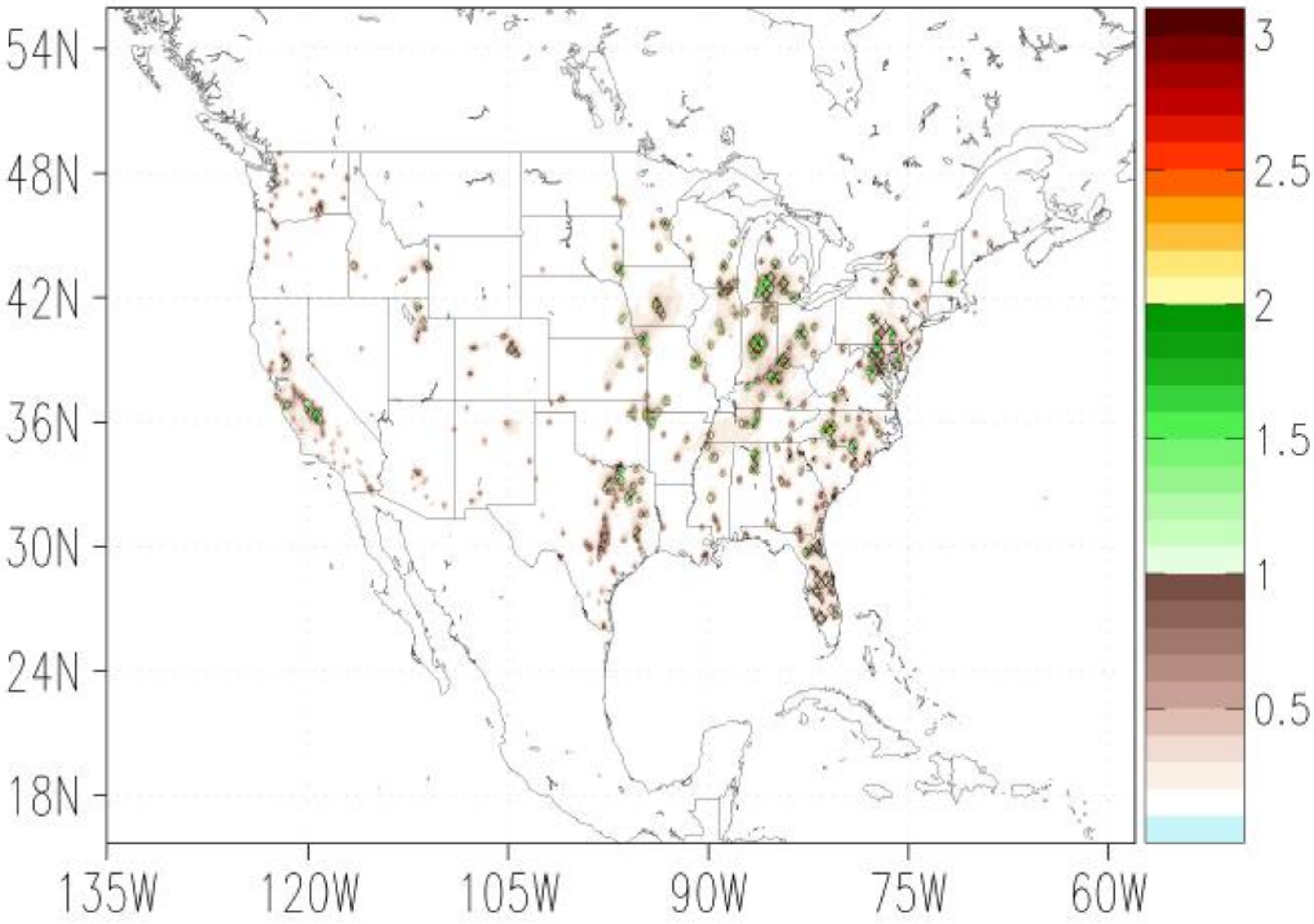


Fig. S4. As Figure 1, but for B1 ICLUS expansion scenario minus Control experiment (° C).

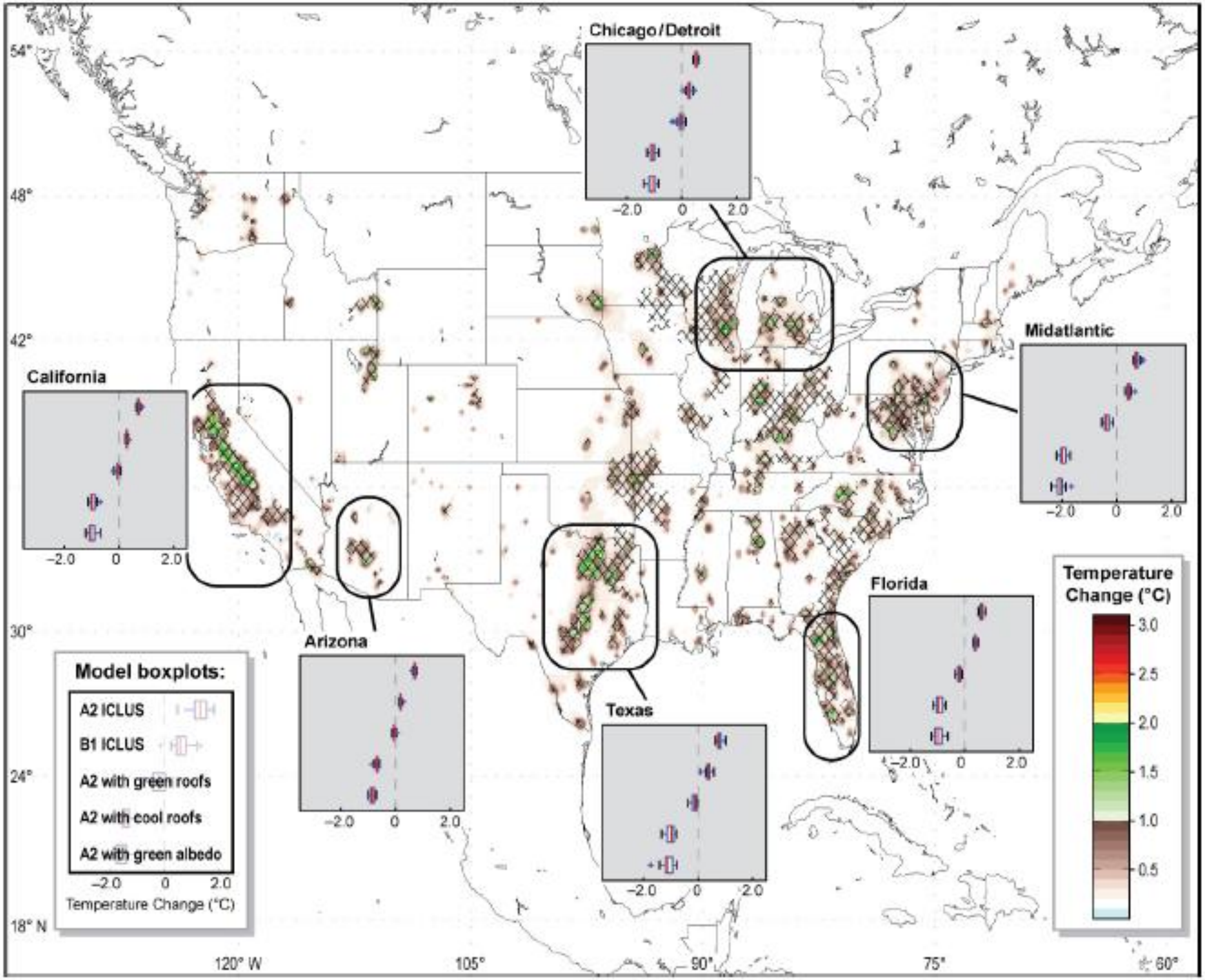


Fig. S5. As Figure 1, but for MAM.

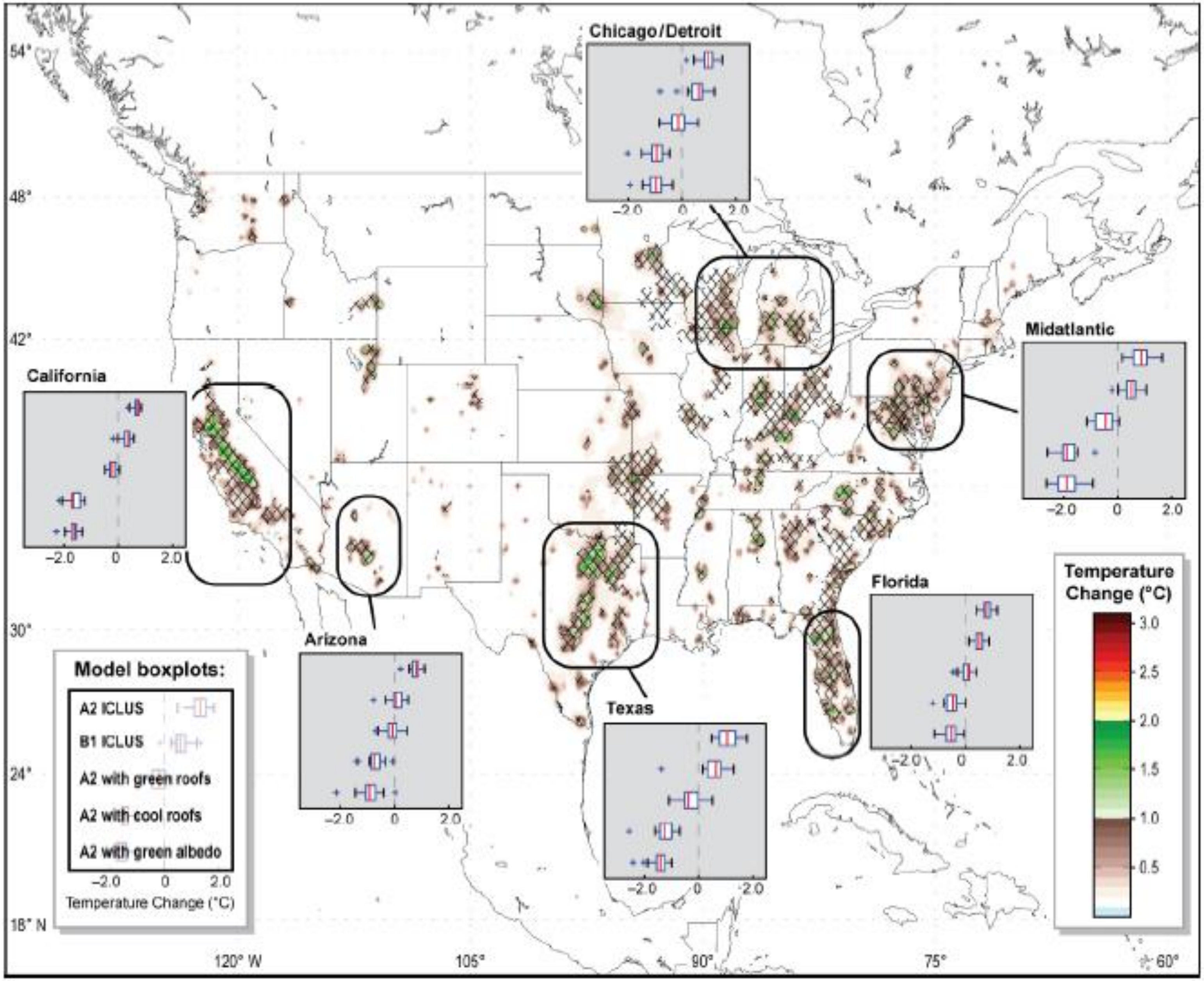


Fig. S6. As Figure 1, but for SON

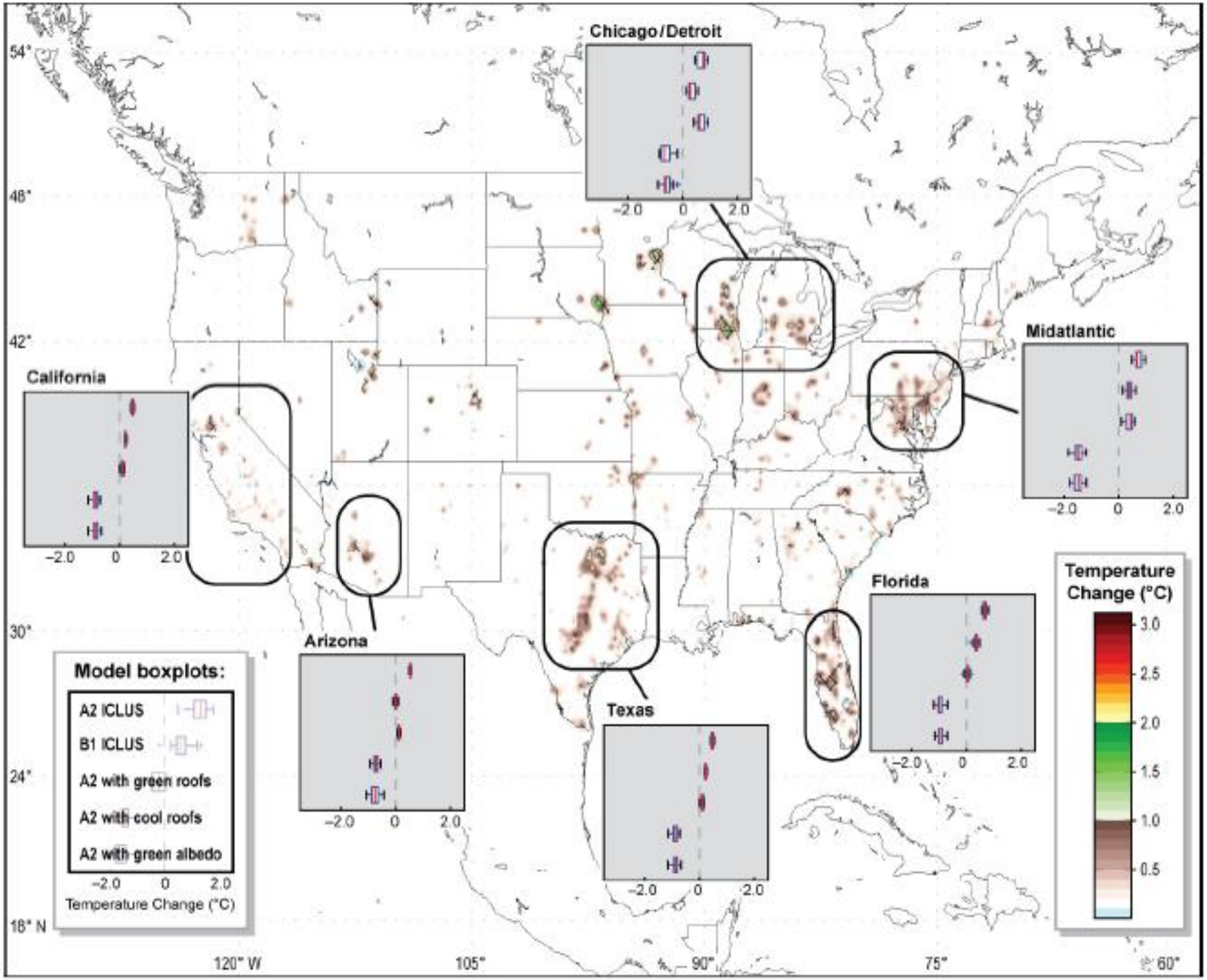


Fig. S7. As Figure 1, but for DJF.

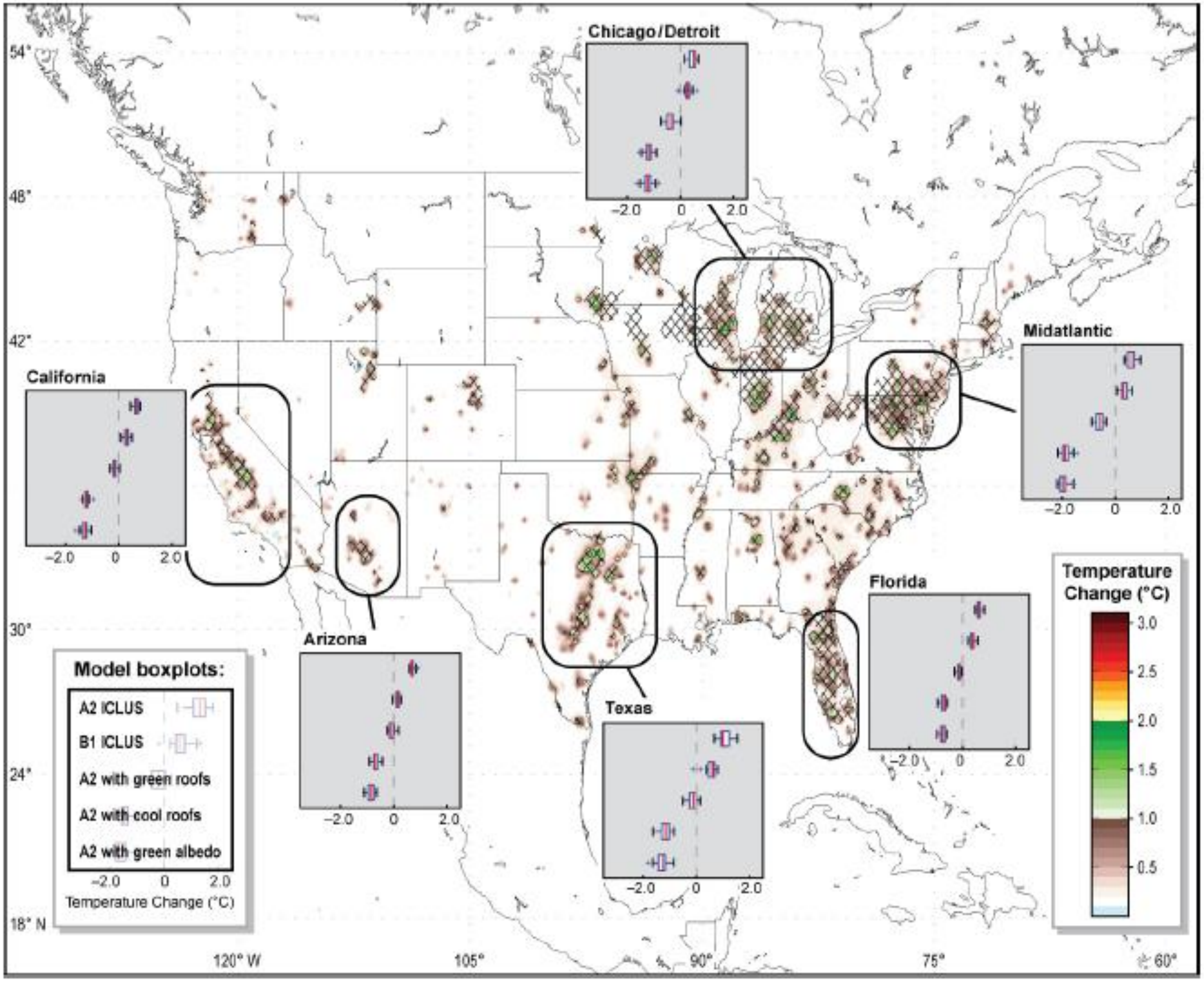


Fig. S8. As Figure 1, but for entire year.

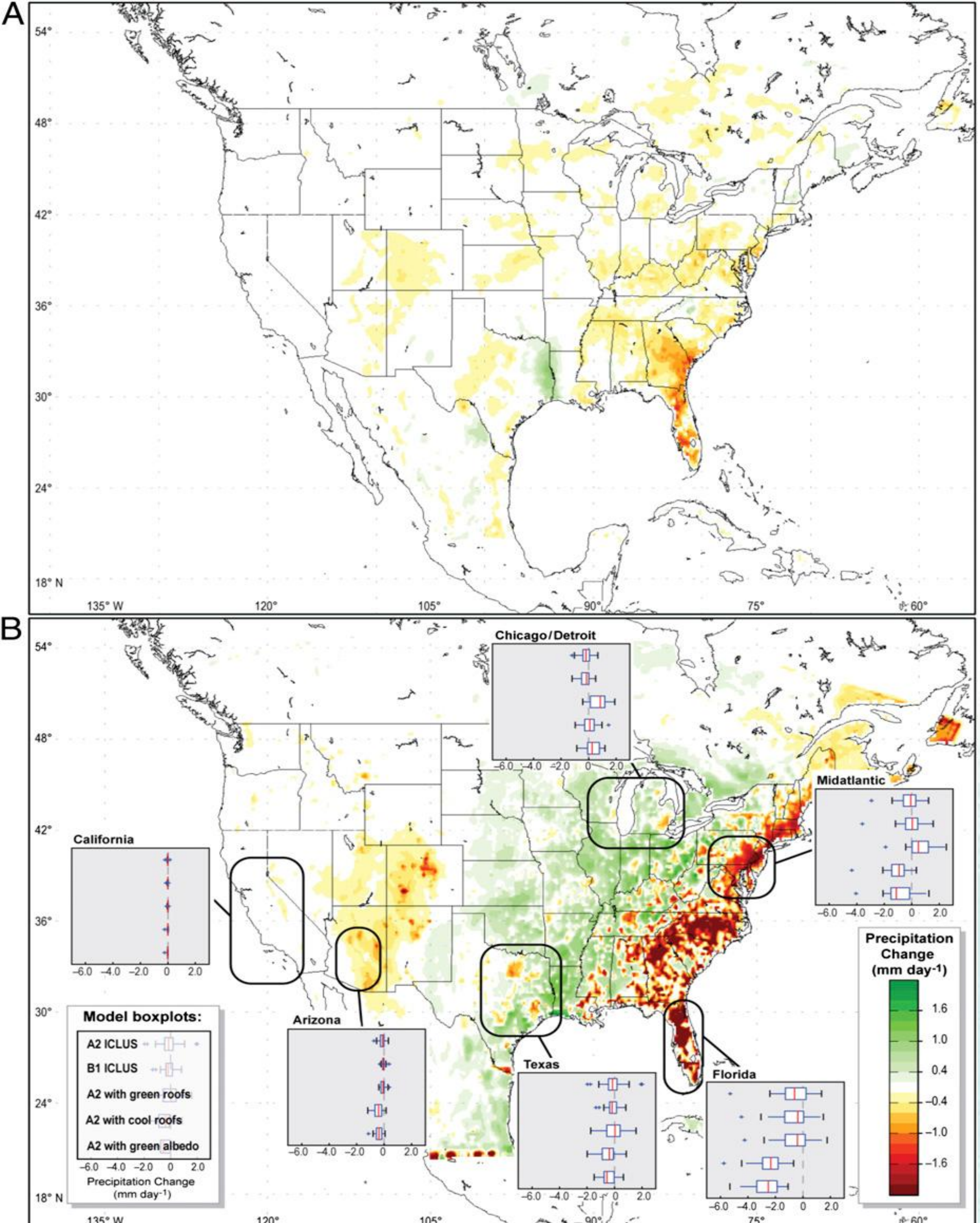


Fig.2. Simulated JJA precipitation difference between
(A) A2 and control and
(B) cool roofs and control.
Units are millimeters day^{-1}.

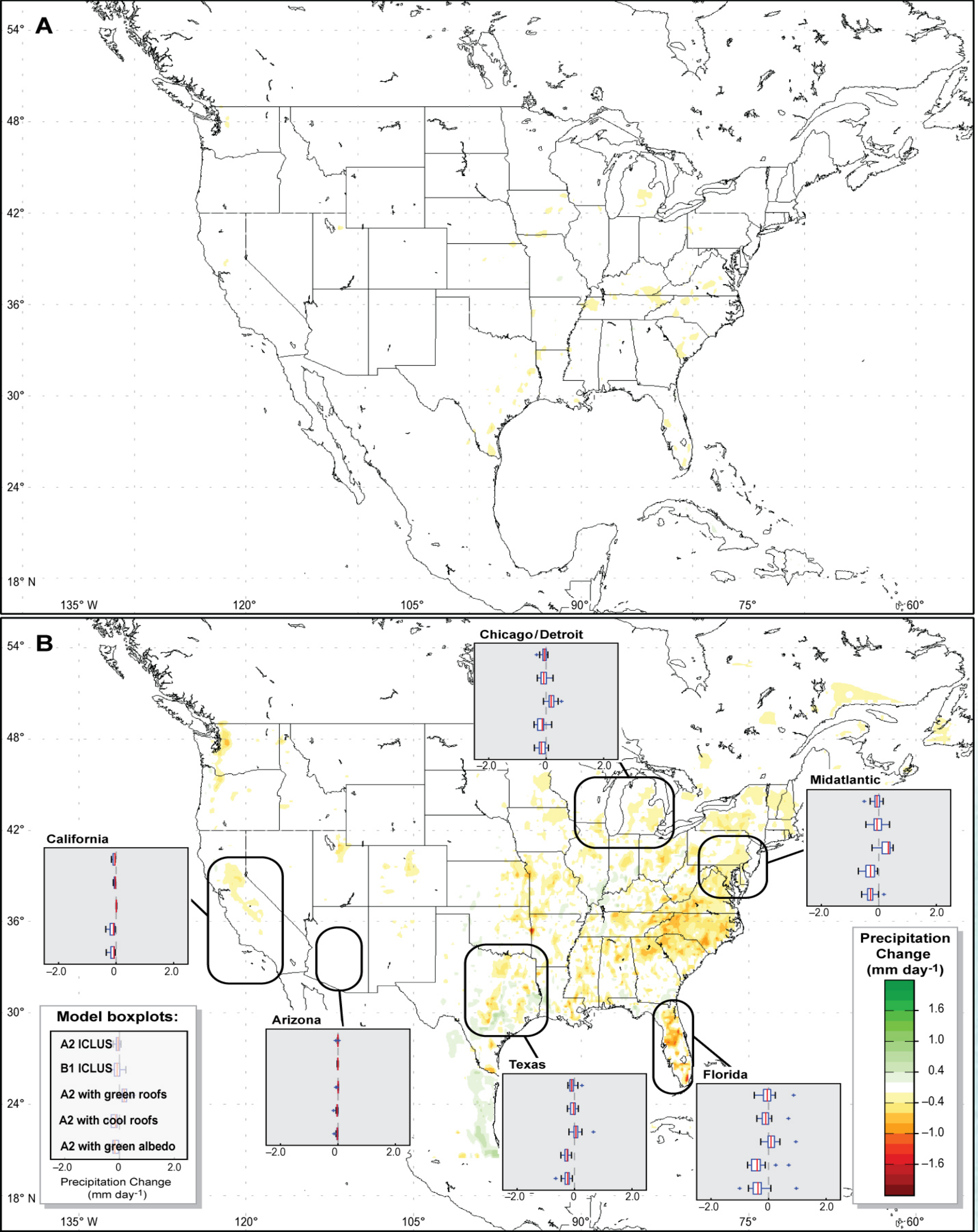


Fig. S13. As Figure 2 but for MAM.

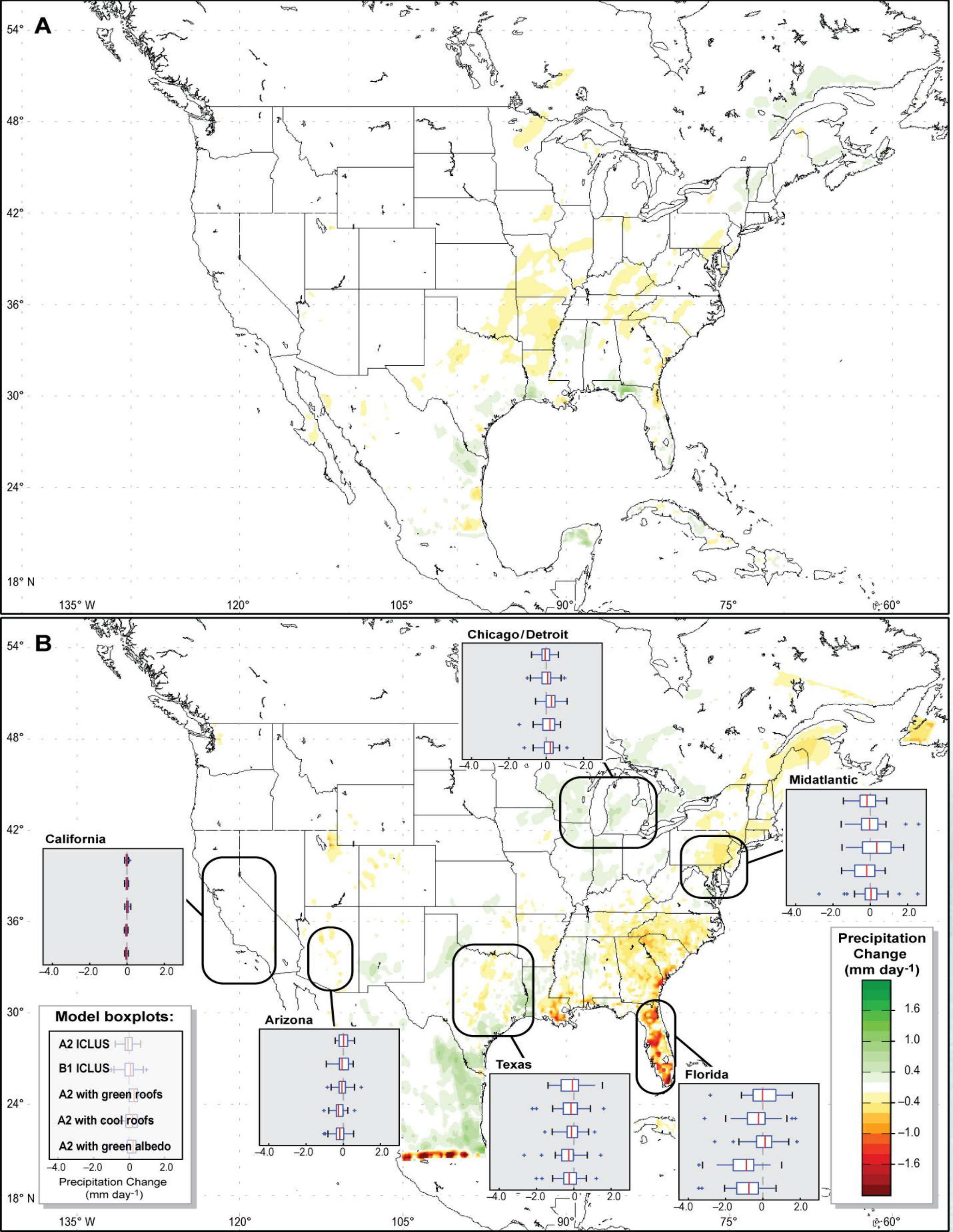


Fig. S14. As Figure 2 but for SON.

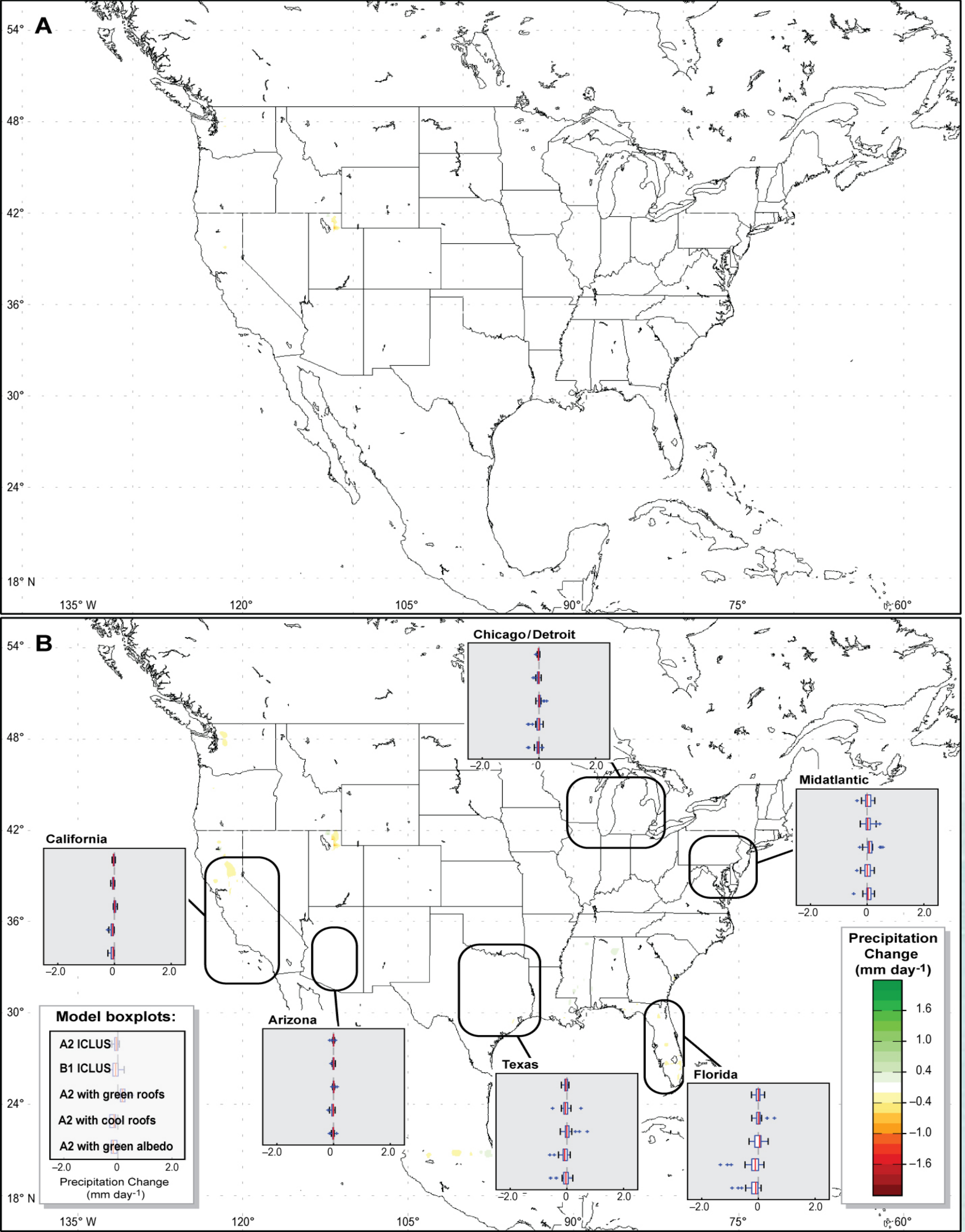


Fig. S15. As Figure 2 but for DJF.

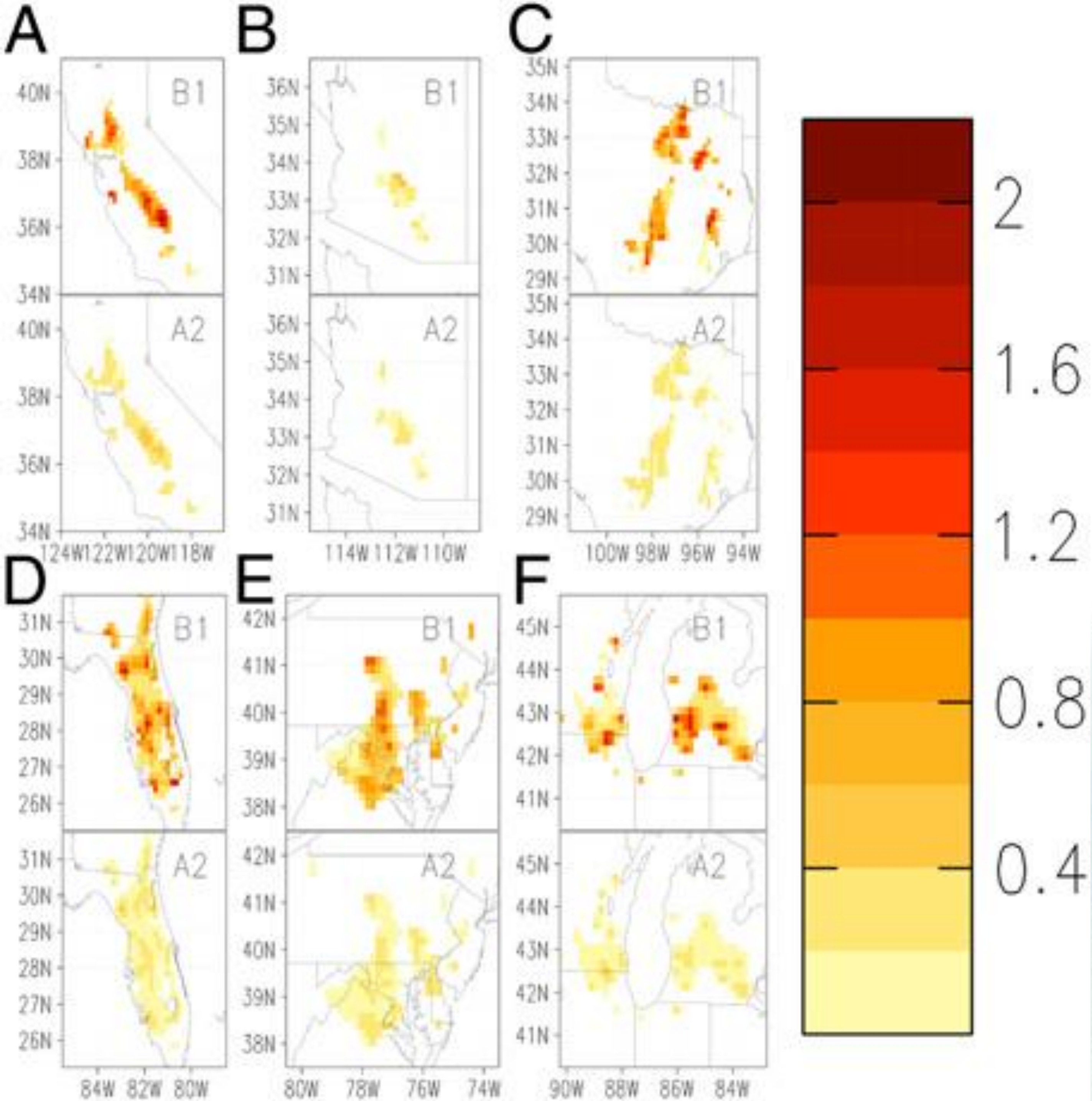
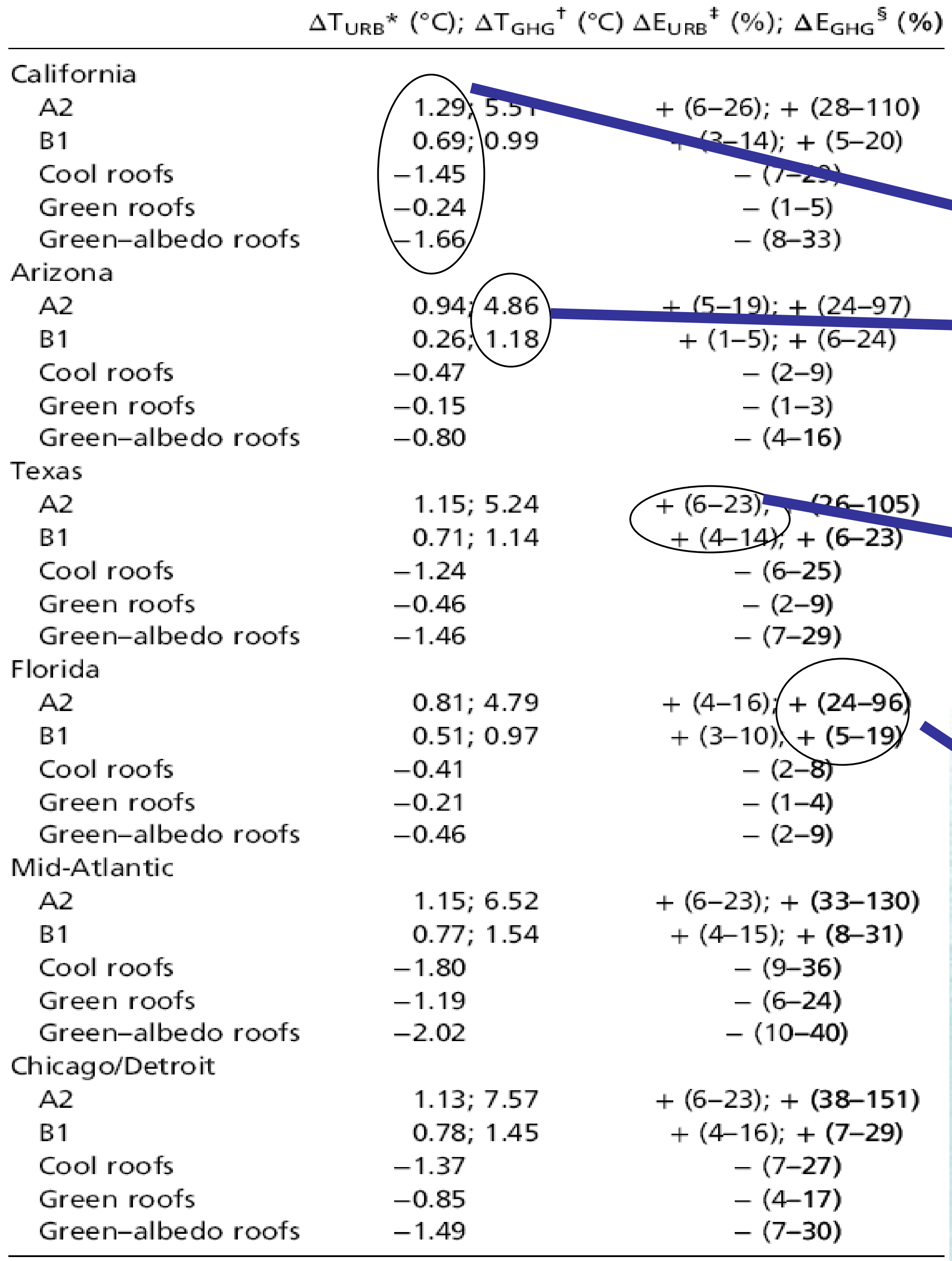


Fig. 3. Simulated JJA urban relative to greenhouse gas-induced impacts on 2-m air temperature (units are ° C ° C^{-1}).

supporting information

- Representative Concentration Pathway 2.6 (RCP2.6)： The RCP2.6 emission and concentration pathway is representative of the literature on mitigation scenarios aiming to limit the increase of global mean temperature to 2° C. Compared to the total set of Representative Concentration Pathways RCP2.6 corresponds to the pathway with the lowest greenhouse gas emissions.

- Representative Concentration Pathway 8.5(RCP8.5)： The RCP8.5 combines assumptions about high population and relatively slow income growth with modest rates of technological change and energy intensity improvements, leading in the long term to high energy demand and GHG emissions in absence of climate change policies. Compared to the total set of Representative Concentration Pathways RCP8.5 thus corresponds to the pathway with the highest greenhouse gas emissions.



	ΔT_{URB}* (°C); ΔT_{GHG}† (°C)	ΔE_{URB}‡ (%); ΔE_{GHG}§ (%)
California		
A2	1.29; 5.51	+ (6–26); + (28–110)
B1	0.69; 0.99	+ (3–14); + (5–20)
Cool roofs	−1.45	− (7–29)
Green roofs	−0.24	− (1–5)
Green–albedo roofs	−1.66	− (8–33)
Arizona		
A2	0.94; 4.86	+ (5–19); + (24–97)
B1	0.26; 1.18	+ (1–5); + (6–24)
Cool roofs	−0.47	− (2–9)
Green roofs	−0.15	− (1–3)
Green–albedo roofs	−0.80	− (4–16)
Texas		
A2	1.15; 5.24	+ (6–23); + (26–105)
B1	0.71; 1.14	+ (4–14); + (6–23)
Cool roofs	−1.24	− (6–25)
Green roofs	−0.46	− (2–9)
Green–albedo roofs	−1.46	− (7–29)
Florida		
A2	0.81; 4.79	+ (4–16); + (24–96)
B1	0.51; 0.97	+ (3–10); + (5–19)
Cool roofs	−0.41	− (2–8)
Green roofs	−0.21	− (1–4)
Green–albedo roofs	−0.46	− (2–9)
Mid-Atlantic		
A2	1.15; 6.52	+ (6–23); + (33–130)
B1	0.77; 1.54	+ (4–15); + (8–31)
Cool roofs	−1.80	− (9–36)
Green roofs	−1.19	− (6–24)
Green–albedo roofs	−2.02	− (10–40)
Chicago/Detroit		
A2	1.13; 7.57	+ (6–23); + (38–151)
B1	0.78; 1.45	+ (4–16); + (7–29)
Cool roofs	−1.37	− (7–27)
Green roofs	−0.85	− (4–17)
Green–albedo roofs	−1.49	− (7–30)

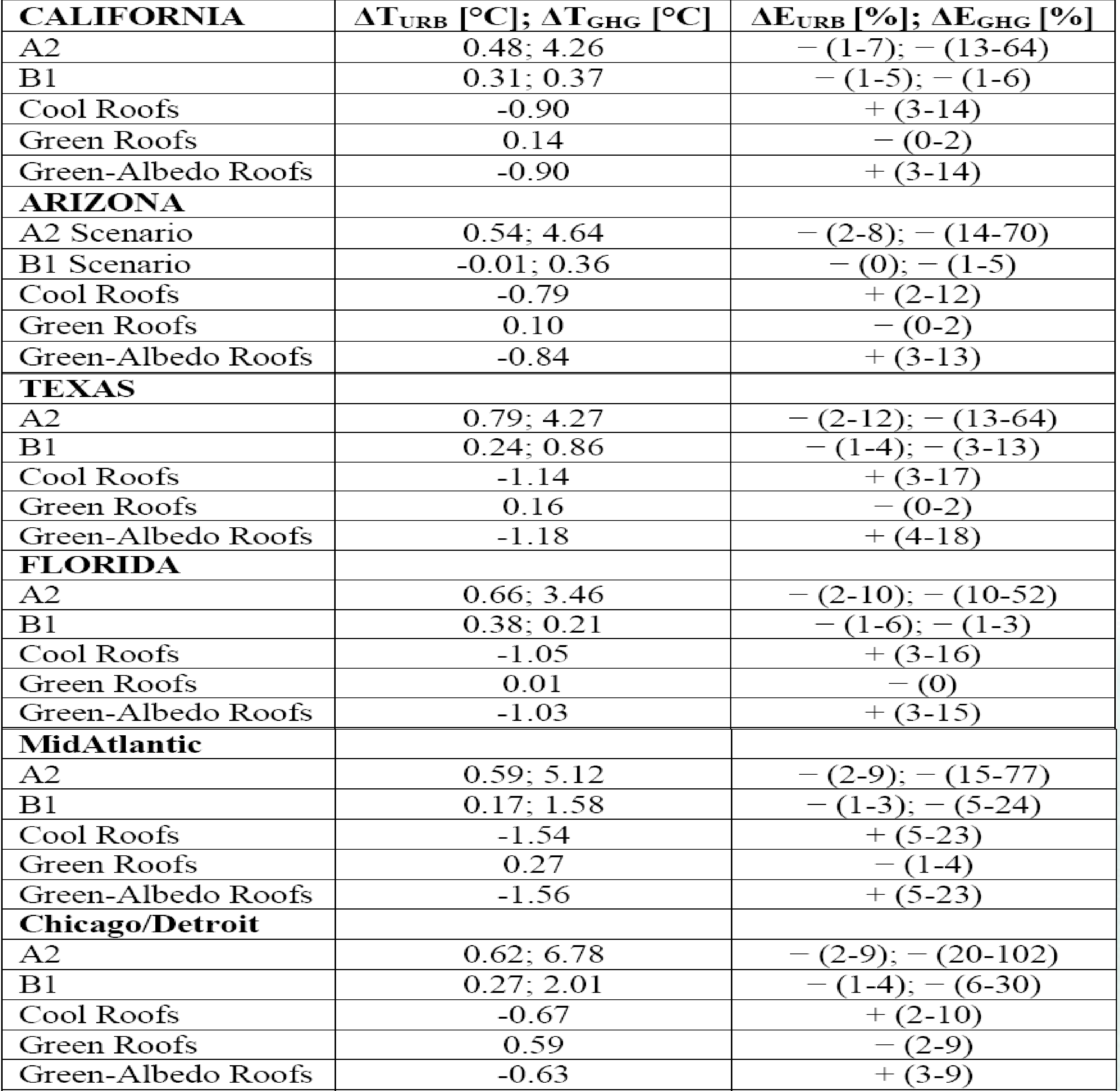
***** : Urban expansion/adaptation scenario minus control.

† : Greenhouse gas-induced (mean of 2079–2099 minus mean of 1990–2010) climate change.

‡ : Projected changes on energy demand for urban-induced climate change.

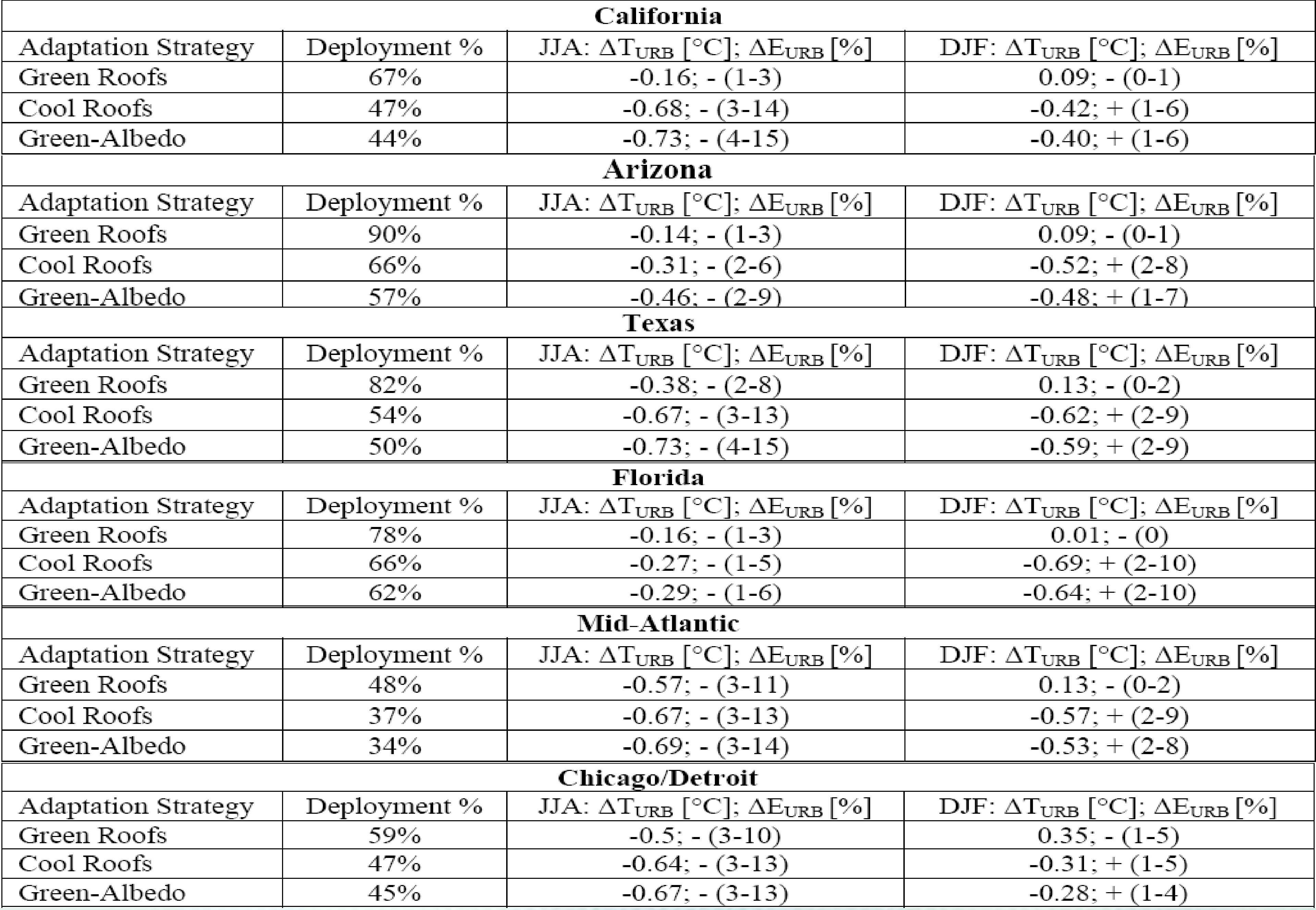
§ : Projected changes on energy demand for greenhouse-gas-induced climate change.

Table 2. Average JJA near-surface temperature difference for urban and greenhouse gas-induced (mean of 2079–2099 minus mean of 1990–2010) climate change.



CALIFORNIA	ΔT_{URB} [°C]; ΔT_{GHG} [°C]	ΔE_{URB} [%]; ΔE_{GHG} [%]
A2	0.48; 4.26	− (1-7); − (13-64)
B1	0.31; 0.37	− (1-5); − (1-6)
Cool Roofs	-0.90	+ (3-14)
Green Roofs	0.14	− (0-2)
Green-Albedo Roofs	-0.90	+ (3-14)
ARIZONA		
A2 Scenario	0.54; 4.64	− (2-8); − (14-70)
B1 Scenario	-0.01; 0.36	− (0); − (1-5)
Cool Roofs	-0.79	+ (2-12)
Green Roofs	0.10	− (0-2)
Green-Albedo Roofs	-0.84	+ (3-13)
TEXAS		
A2	0.79; 4.27	− (2-12); − (13-64)
B1	0.24; 0.86	− (1-4); − (3-13)
Cool Roofs	-1.14	+ (3-17)
Green Roofs	0.16	− (0-2)
Green-Albedo Roofs	-1.18	+ (4-18)
FLORIDA		
A2	0.66; 3.46	− (2-10); − (10-52)
B1	0.38; 0.21	− (1-6); − (1-3)
Cool Roofs	-1.05	+ (3-16)
Green Roofs	0.01	− (0)
Green-Albedo Roofs	-1.03	+ (3-15)
MidAtlantic		
A2	0.59; 5.12	− (2-9); − (15-77)
B1	0.17; 1.58	− (1-3); − (5-24)
Cool Roofs	-1.54	+ (5-23)
Green Roofs	0.27	− (1-4)
Green-Albedo Roofs	-1.56	+ (5-23)
Chicago/Detroit		
A2	0.62; 6.78	− (2-9); − (20-102)
B1	0.27; 2.01	− (1-4); − (6-30)
Cool Roofs	-0.67	+ (2-10)
Green Roofs	0.59	− (2-9)
Green-Albedo Roofs	-0.63	+ (3-9)

Table S3. As Table 2 but for December-January-February (DJF).



California

Adaptation Strategy	Deployment %	JJA: ΔT_{URB} [°C]; ΔE_{URB} [%]	DJF: ΔT_{URB} [°C]; ΔE_{URB} [%]
Green Roofs	67%	-0.16; - (1-3)	0.09; - (0-1)
Cool Roofs	47%	-0.68; - (3-14)	-0.42; + (1-6)
Green-Albedo	44%	-0.73; - (4-15)	-0.40; + (1-6)

Arizona

Adaptation Strategy	Deployment %	JJA: ΔT_{URB} [°C]; ΔE_{URB} [%]	DJF: ΔT_{URB} [°C]; ΔE_{URB} [%]
Green Roofs	90%	-0.14; - (1-3)	0.09; - (0-1)
Cool Roofs	66%	-0.31; - (2-6)	-0.52; + (2-8)
Green-Albedo	57%	-0.46; - (2-9)	-0.48; + (1-7)

Texas

Adaptation Strategy	Deployment %	JJA: ΔT_{URB} [°C]; ΔE_{URB} [%]	DJF: ΔT_{URB} [°C]; ΔE_{URB} [%]
Green Roofs	82%	-0.38; - (2-8)	0.13; - (0-2)
Cool Roofs	54%	-0.67; - (3-13)	-0.62; + (2-9)
Green-Albedo	50%	-0.73; - (4-15)	-0.59; + (2-9)

Florida

Adaptation Strategy	Deployment %	JJA: ΔT_{URB} [°C]; ΔE_{URB} [%]	DJF: ΔT_{URB} [°C]; ΔE_{URB} [%]
Green Roofs	78%	-0.16; - (1-3)	0.01; - (0)
Cool Roofs	66%	-0.27; - (1-5)	-0.69; + (2-10)
Green-Albedo	62%	-0.29; - (1-6)	-0.64; + (2-10)

Mid-Atlantic

Adaptation Strategy	Deployment %	JJA: ΔT_{URB} [°C]; ΔE_{URB} [%]	DJF: ΔT_{URB} [°C]; ΔE_{URB} [%]
Green Roofs	48%	-0.57; - (3-11)	0.13; - (0-2)
Cool Roofs	37%	-0.67; - (3-13)	-0.57; + (2-9)
Green-Albedo	34%	-0.69; - (3-14)	-0.53; + (2-8)

Chicago/Detroit

Adaptation Strategy	Deployment %	JJA: ΔT_{URB} [°C]; ΔE_{URB} [%]	DJF: ΔT_{URB} [°C]; ΔE_{URB} [%]
Green Roofs	59%	-0.5; - (3-10)	0.35; - (1-5)
Cool Roofs	47%	-0.64; - (3-13)	-0.31; + (1-5)
Green-Albedo	45%	-0.67; - (3-13)	-0.28; + (1-4)

Table S4. As Table 2 but with urban adaptation deployment to a value that offsets urban induced summertime warming.

5. Conclusions

- In the absence of any adaptive urban design, urban expansion across the United States imparts warming over large regional swaths of the country that is a significant fraction of anticipated temperature increases resulting from greenhouse gas-induced warming.
- Adapting to urban-induced climate change is geographically dependent, and the robust analysis that we present offers insights into optimal approaches and anticipated tradeoffs associated with varying expansion pathways.

Thank you ！