USC University of Southern California

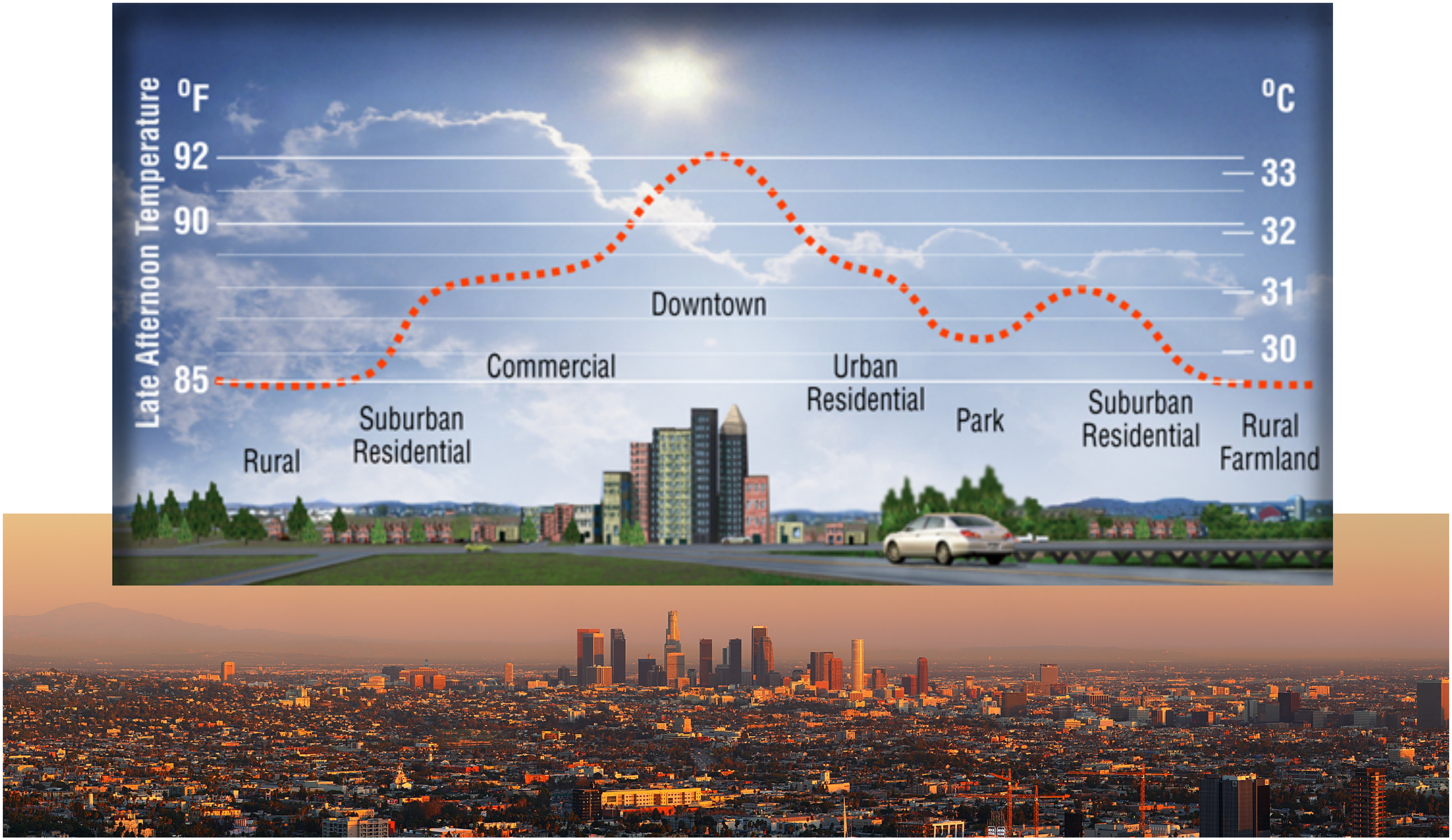
Modeling and observations to identify optimal heat mitigation strategies

George Ban-Weiss
Assistant Professor (banweiss@usc.edu)

USC School of Engineering

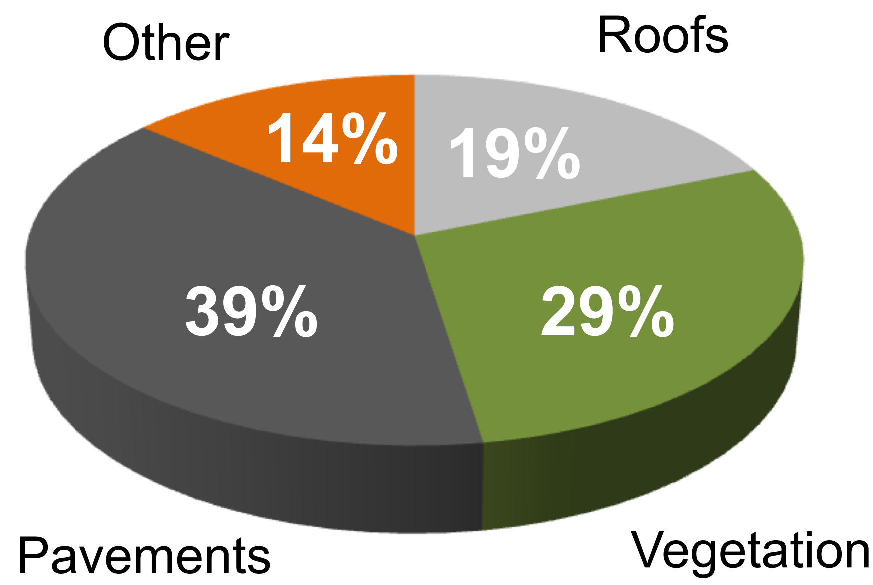
Astani Department of Civil & Environmental Engineering

The urban heat island effect describes cities being warmer than rural surroundings



Causes of the urban heat island

1) Dark surfaces
2) Thermally massive materials
3) Lack of vegetation
4) Anthropogenic heating
5) Urban canyon morphology

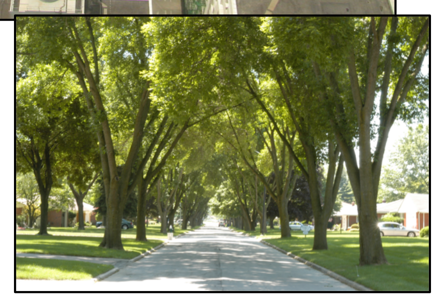


Some actionable measures for reducing urban heat

- Cool roofs
- Cool pavements
- Cool walls
- Vegetative roofs
- Street level vegetation
- Reduce anthropogenic heating



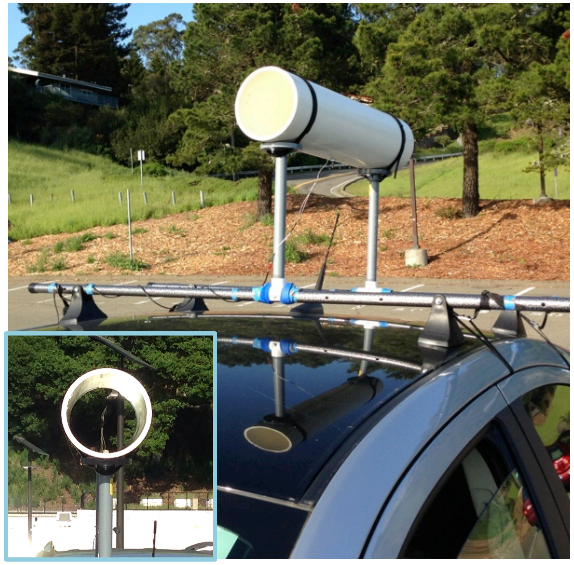




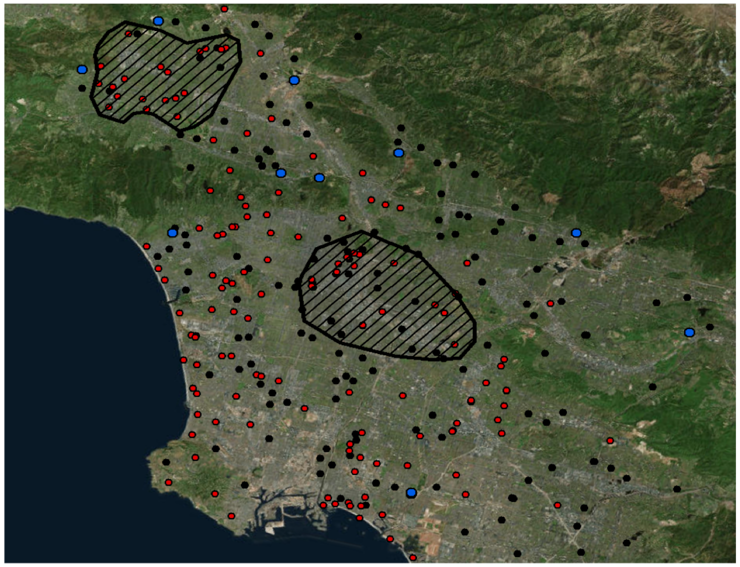
-Which measures should be prioritized?!

-What are the environmental benefits and potential penalties?

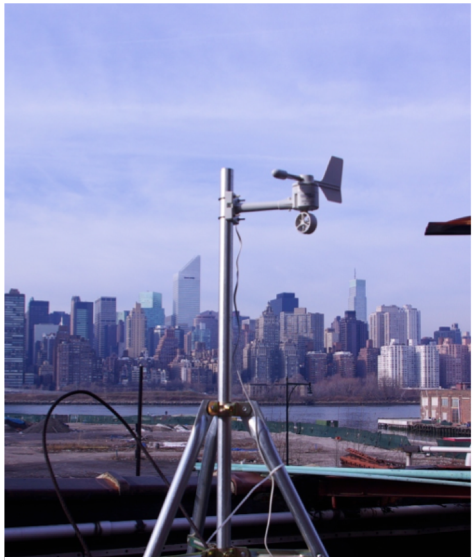
Modeling and observations to detect neighborhood-scale heat islands to inform effective countermeasures in Los Angeles



Mobile transect sensor (front & side view)



Existing weather stations (dots) with the black outline denoting study areas in Los Angeles



Example of rooftop station

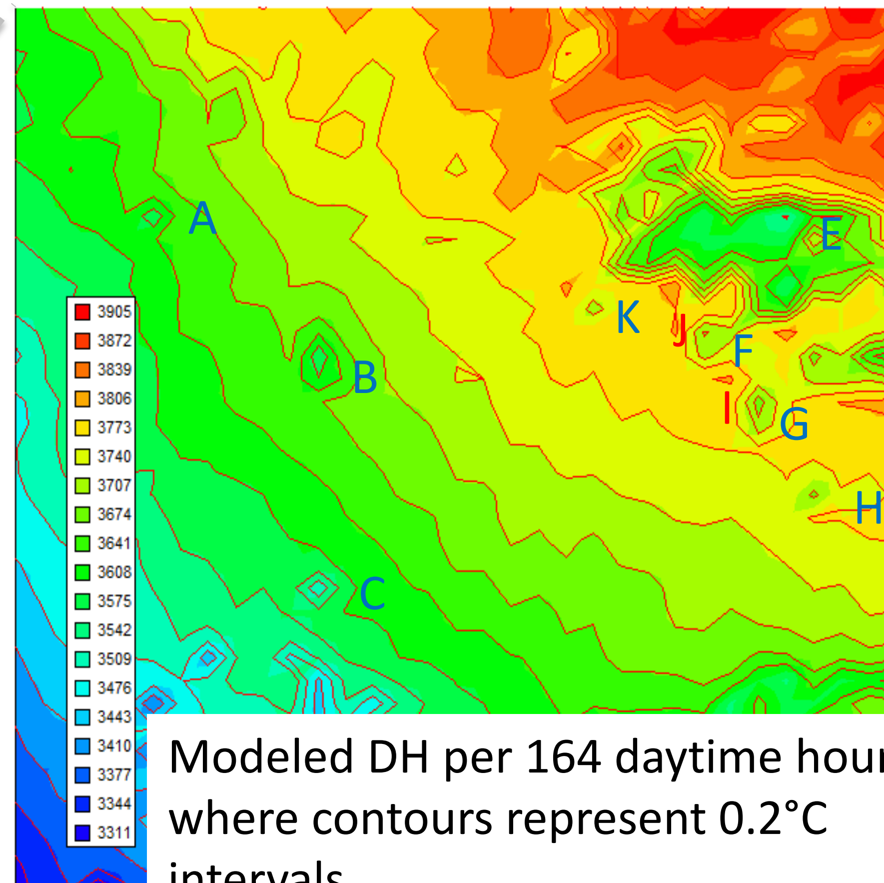
BERKELEY LAB

USC University of Southern California

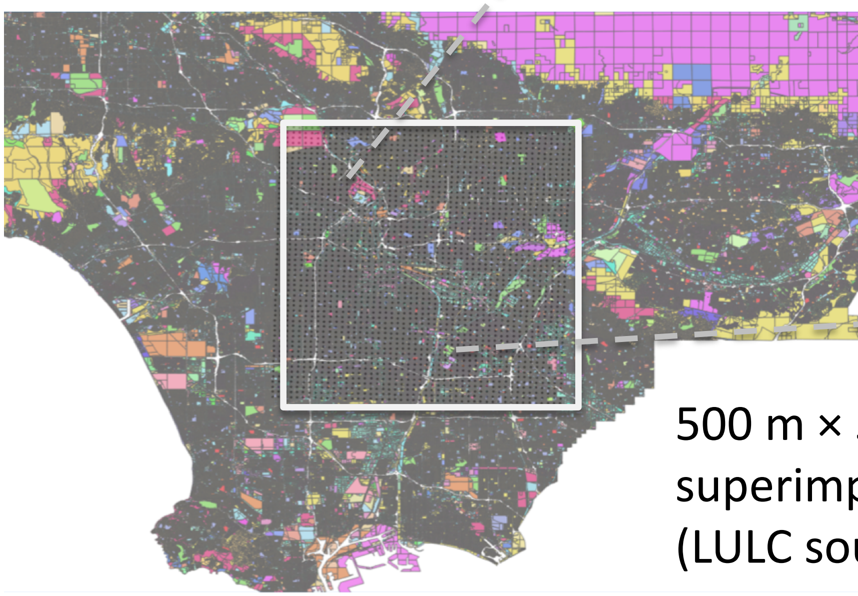
Altostratus Inc.

The project included three tasks

1. **Identify study regions in Los Angeles (detailed urban climate modeling)**
2. **Develop monitoring plan (mobile transects and fixed site measurements)**
3. **Analyze measurements to assess the UHI, relate UHI to Land Use/Land Cover (LULC), and establish a baseline for future UHI mitigation**



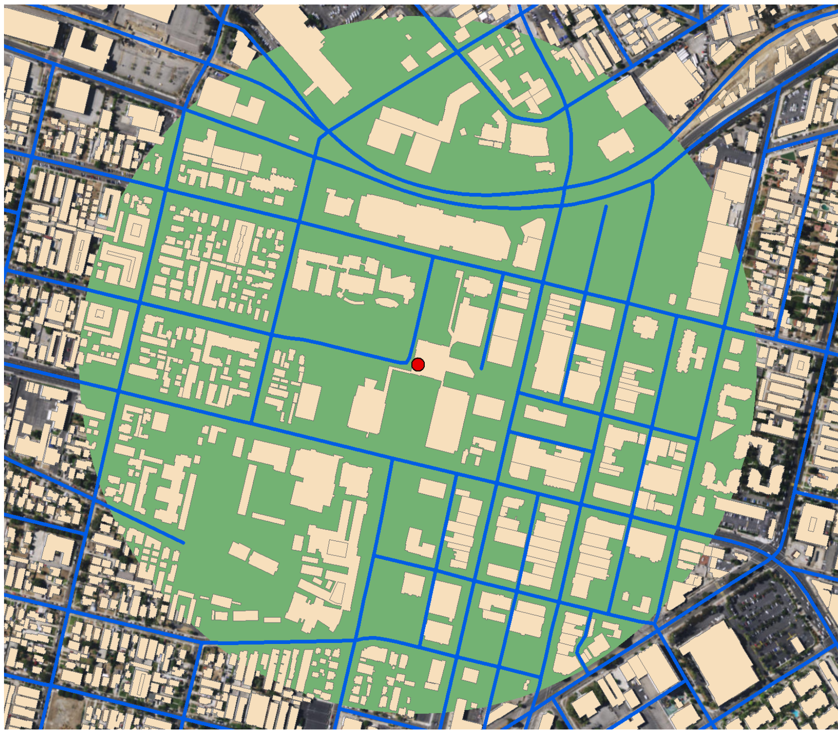
Modeled DH per 164 daytime hours where contours represent 0.2°C intervals

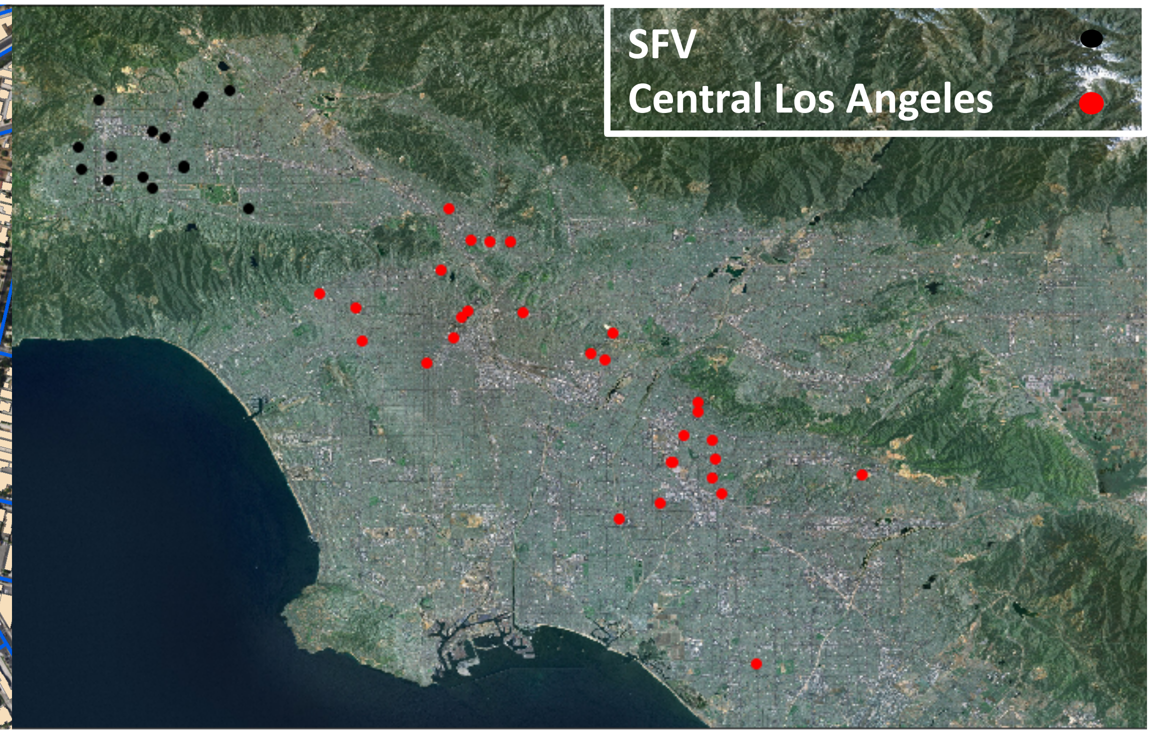


500 m × 500 m modeling area (gray outline) superimposed over LULC (LULC source: SCAG)

Taha et al. Climate (2018)

Associating land cover and land use to spatial temperature variations



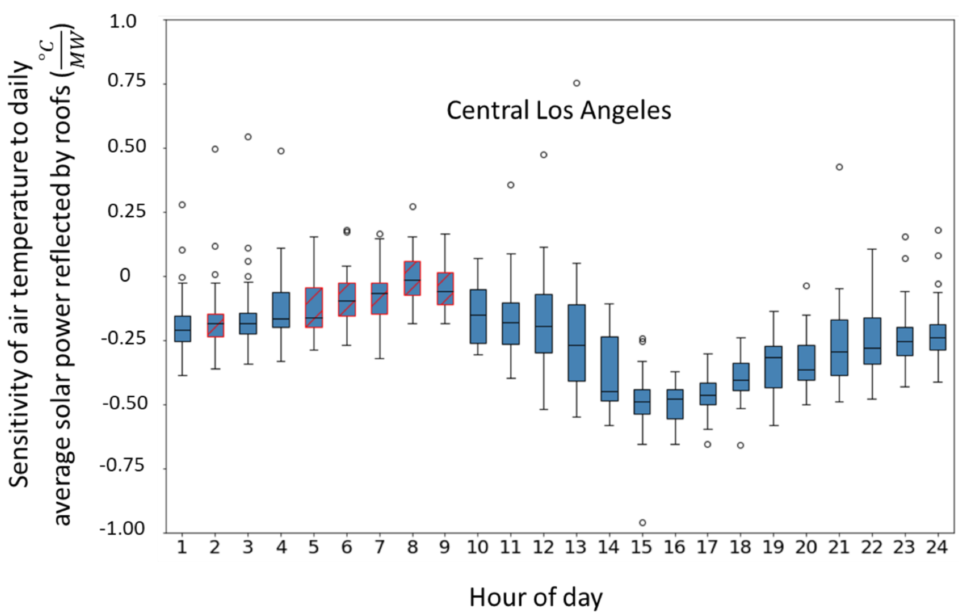


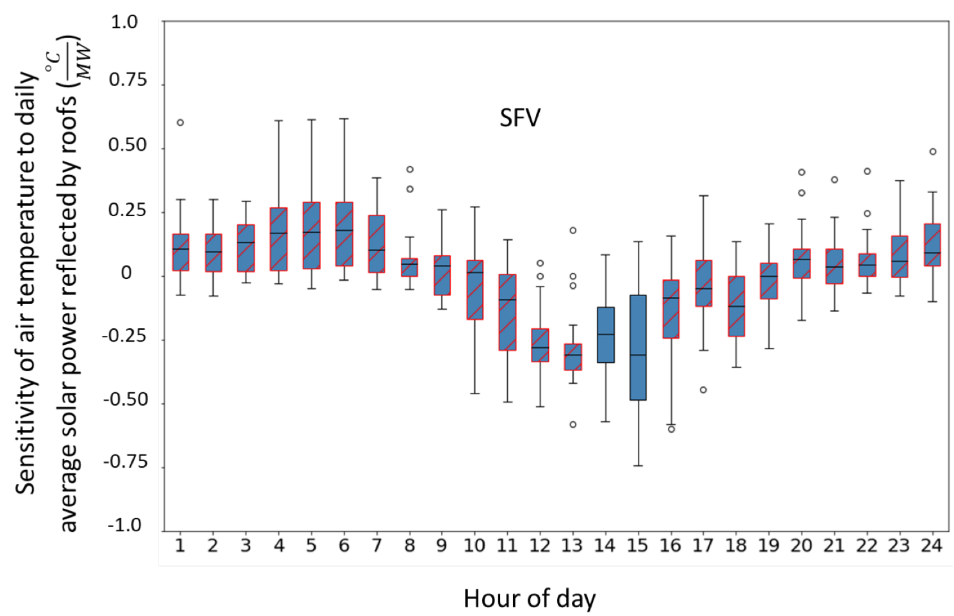
Aggregated area around each weather station, overlaid with building footprint dataset

Weather Underground stations in two regions of interest: SFV and central Los Angeles

Mohegh et al. (in submission)

First <u>observational</u> evidence that cool roof deployment is associated with neighborhood scale cooling (i)

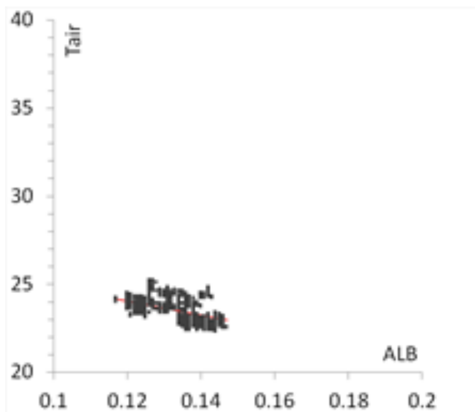


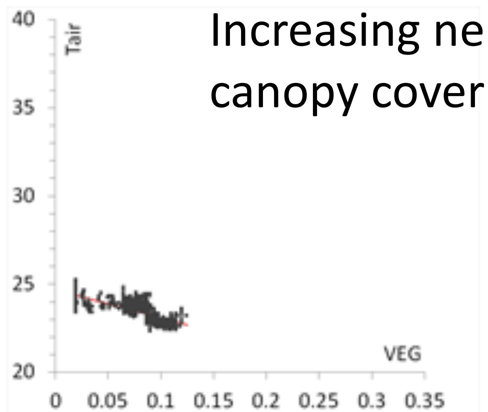


Neighborhoods with increased cool roof coverage have lower temperatures

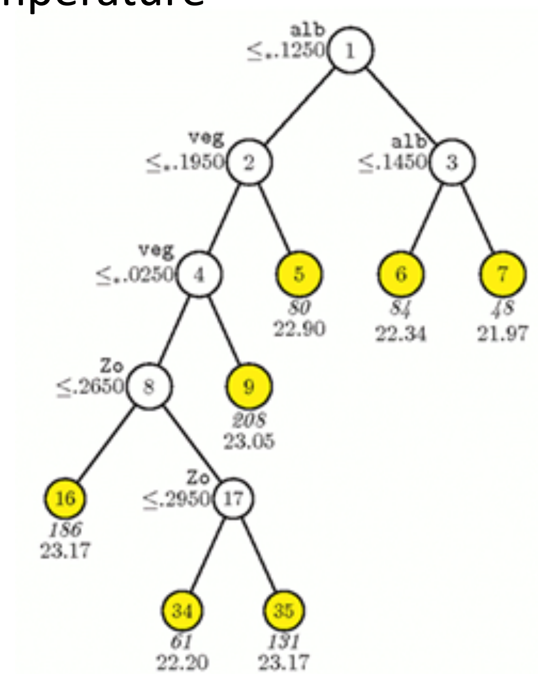
Mohegh et al. (in submission)

First observational evidence that cool roof deployment is associated with neighborhood scale cooling (ii)

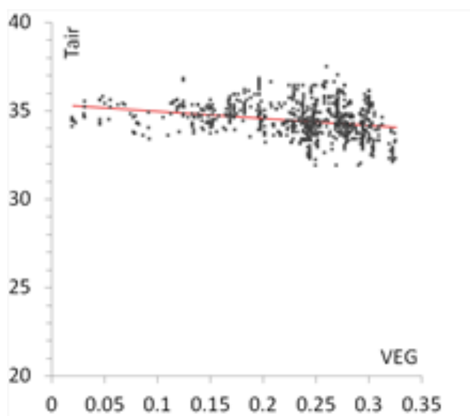




Increasing neighborhood-scale albedo and/or canopy cover reduces air temperature



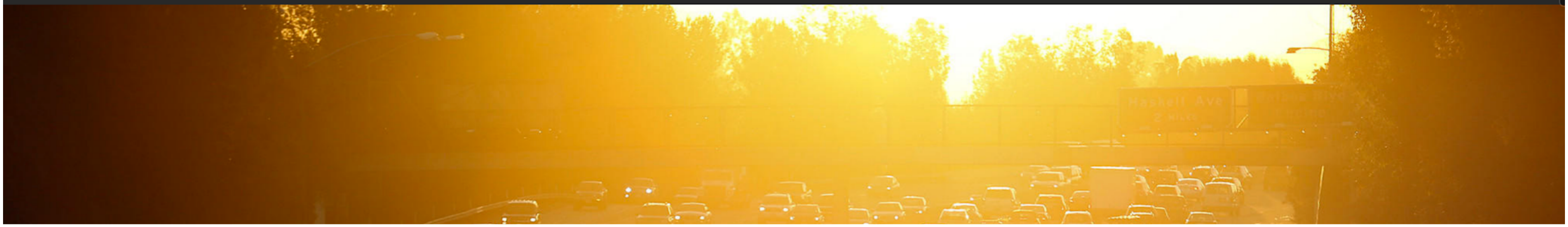
TR07: Downtown area, 2017-08-28 night P1; WSP: 1.10 m/s; SOLAR: 0 W/m^2
ALB: -4.00°C/0.1, p-value: <0.0001; VEG: -1.61°C /0.1, p-value: <0.0001



CART for transect TR13 (Downtown area)

TR09: San Fernando Valley, 2017-07-27 day P1; WSP: 1.70 m/s; SOLAR: 912 W/m^2
VEG: -0.40°C /0.1, p-value: <0.0001

Taha et al. Climate (2018)



L.A.'s mayor wants to lower the city's temperature. These scientists are figuring out how to do it

By DEBORAH NETBURN

Graphics by PRIYA KRISHNAKUMAR

George Ban-Weiss, right, with environmental engineering graduate student Arash Mohegh, removes a mobile thermometer sensor from the roof of the car the team drives through Los Angeles neighborhoods searching for pockets of heat.(Gary Coronado / Los Angeles Times)

To what extent could solar reflective “cool roofs” mitigate the urban heat island effect in Los Angeles?

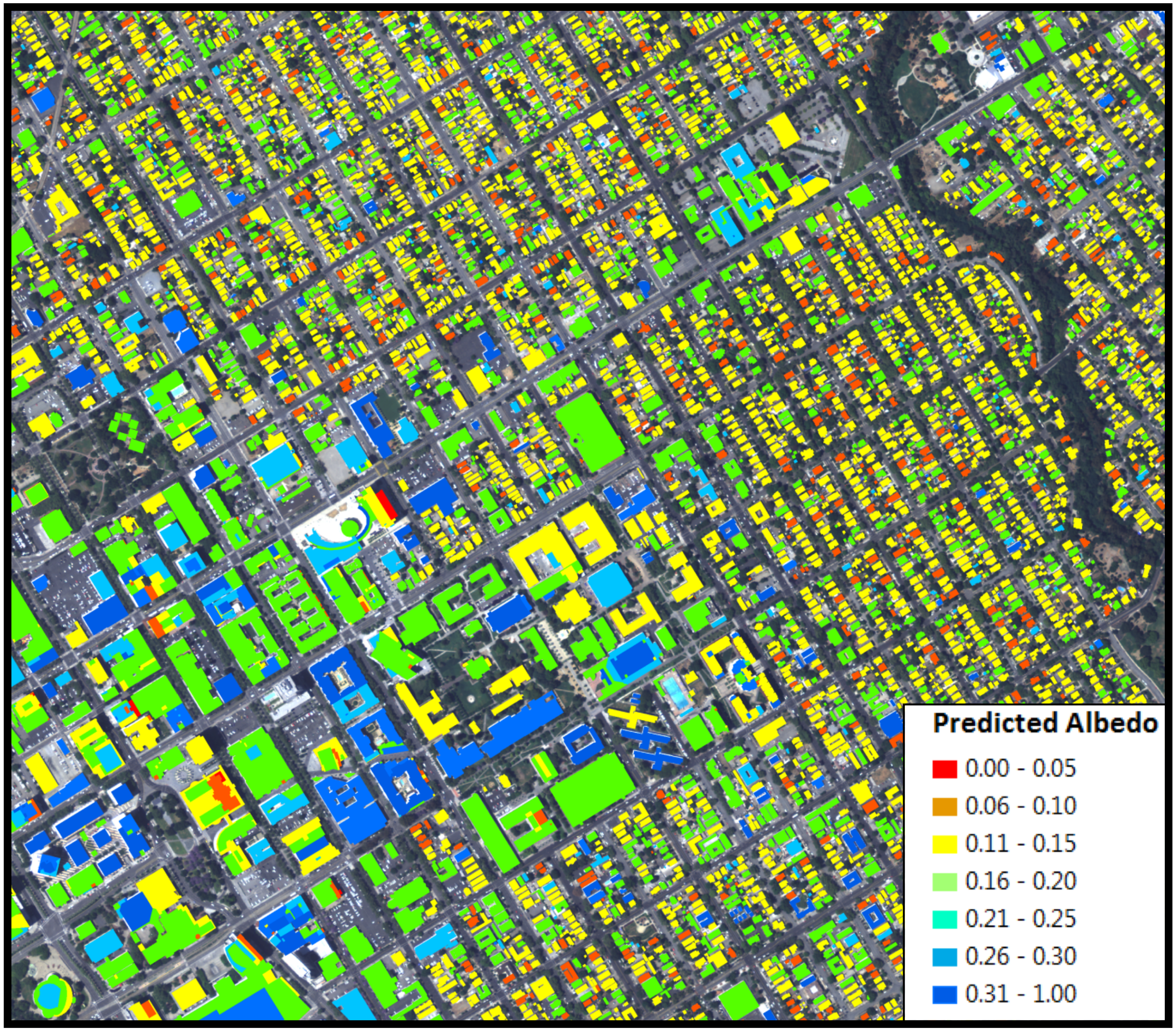
Using remote sensing to quantify solar reflectance of roofs in California's seven largest cities

- What is the maximum increase in roof reflectivity attainable in cities?

- Need to quantify current stock of roofs at city scale

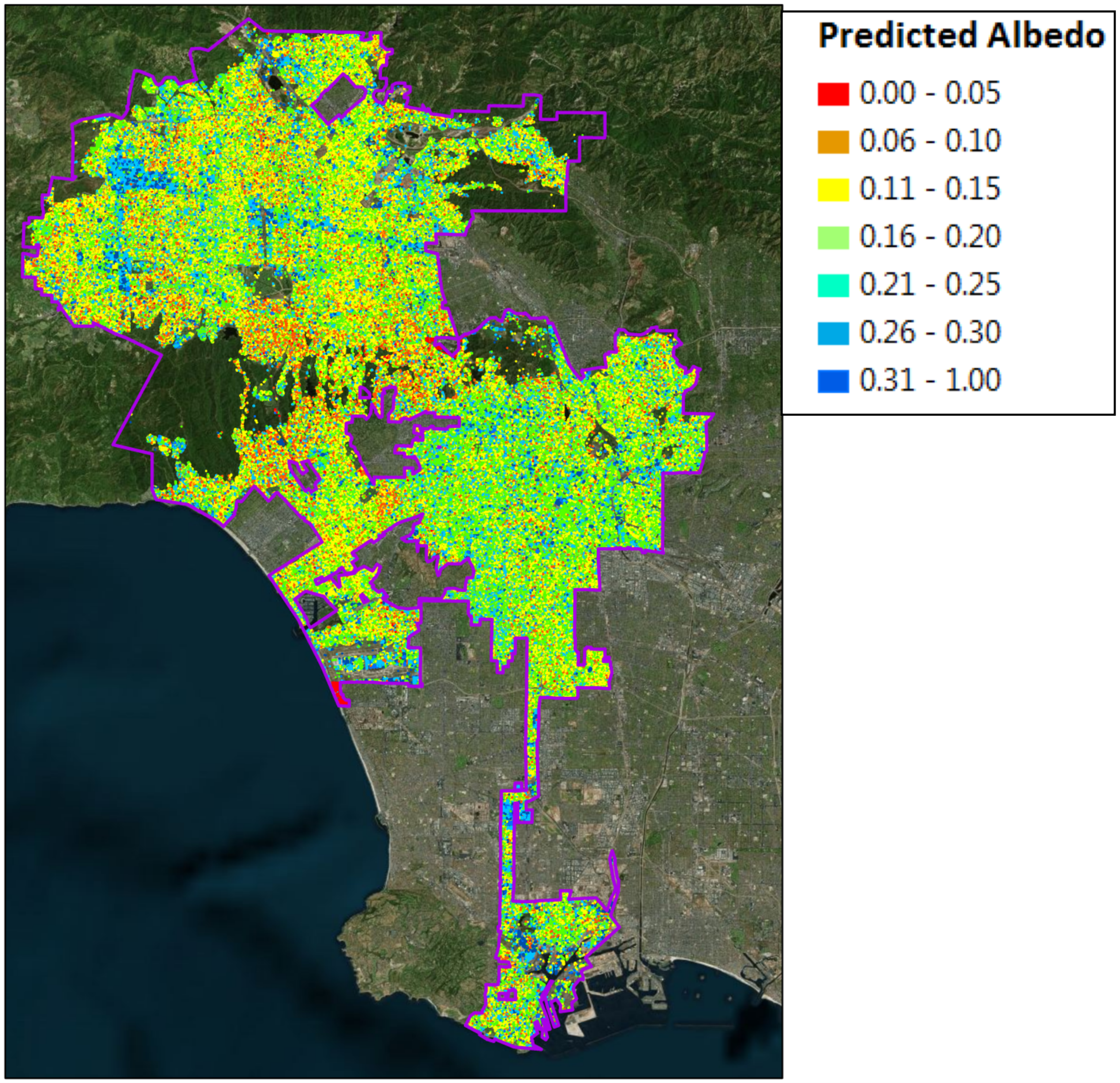
Ban-Weiss et al. (2015a,b)
Solar Energy

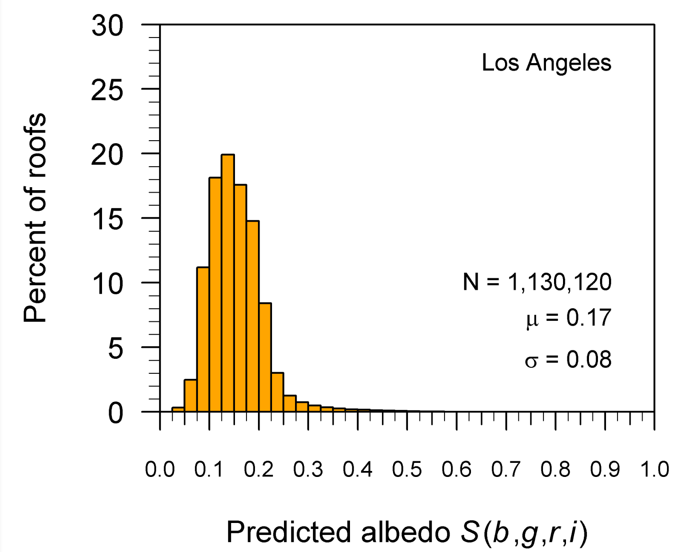
Using remote sensing to quantify solar reflectance of roofs in California's seven largest cities

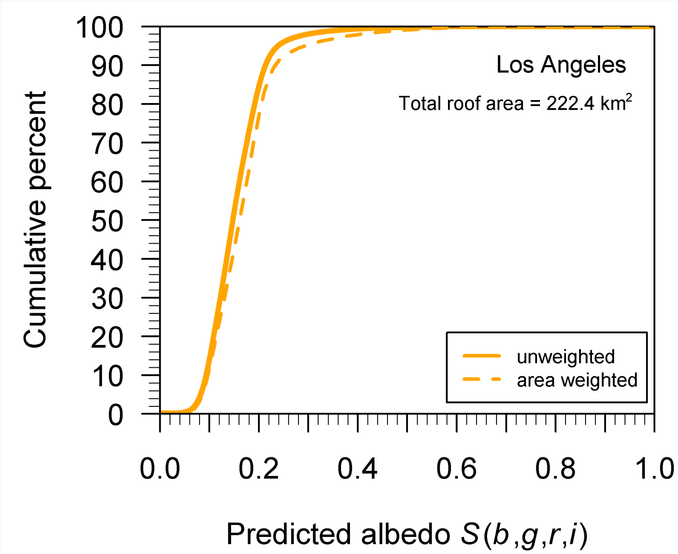


Ban-Weiss et al. (2015a,b)
Solar Energy

Most roofs have low albedo in Los Angeles

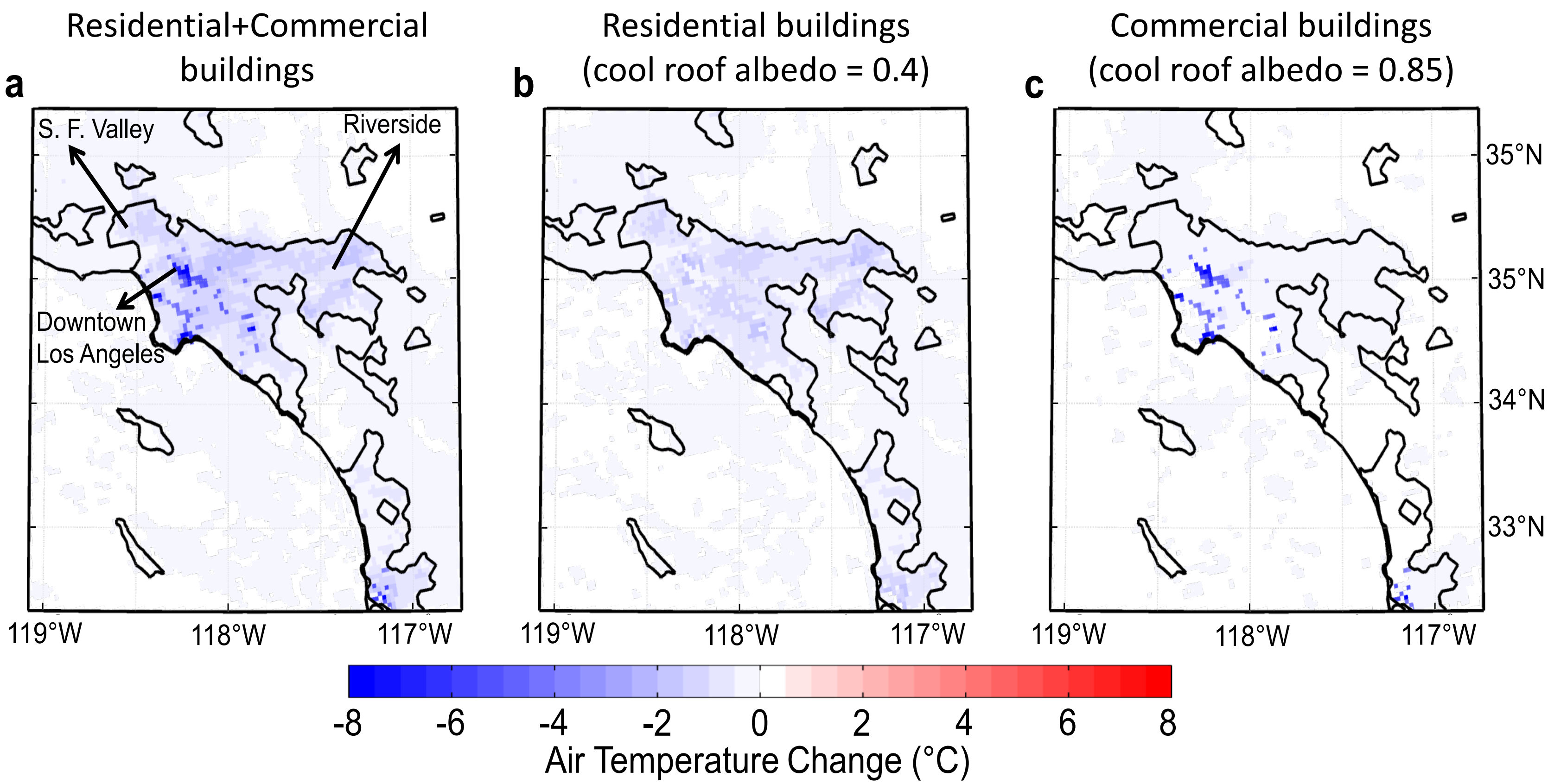






Ban-Weiss et al. (2015a,b) Solar Energy

Climate impacts of adopting cool roofs (2pm)



- Residential cool roofs were responsible for 67% of urban cooling
- Daytime cooling (0.9°C) was larger than nighttime cooling (0.5°C)

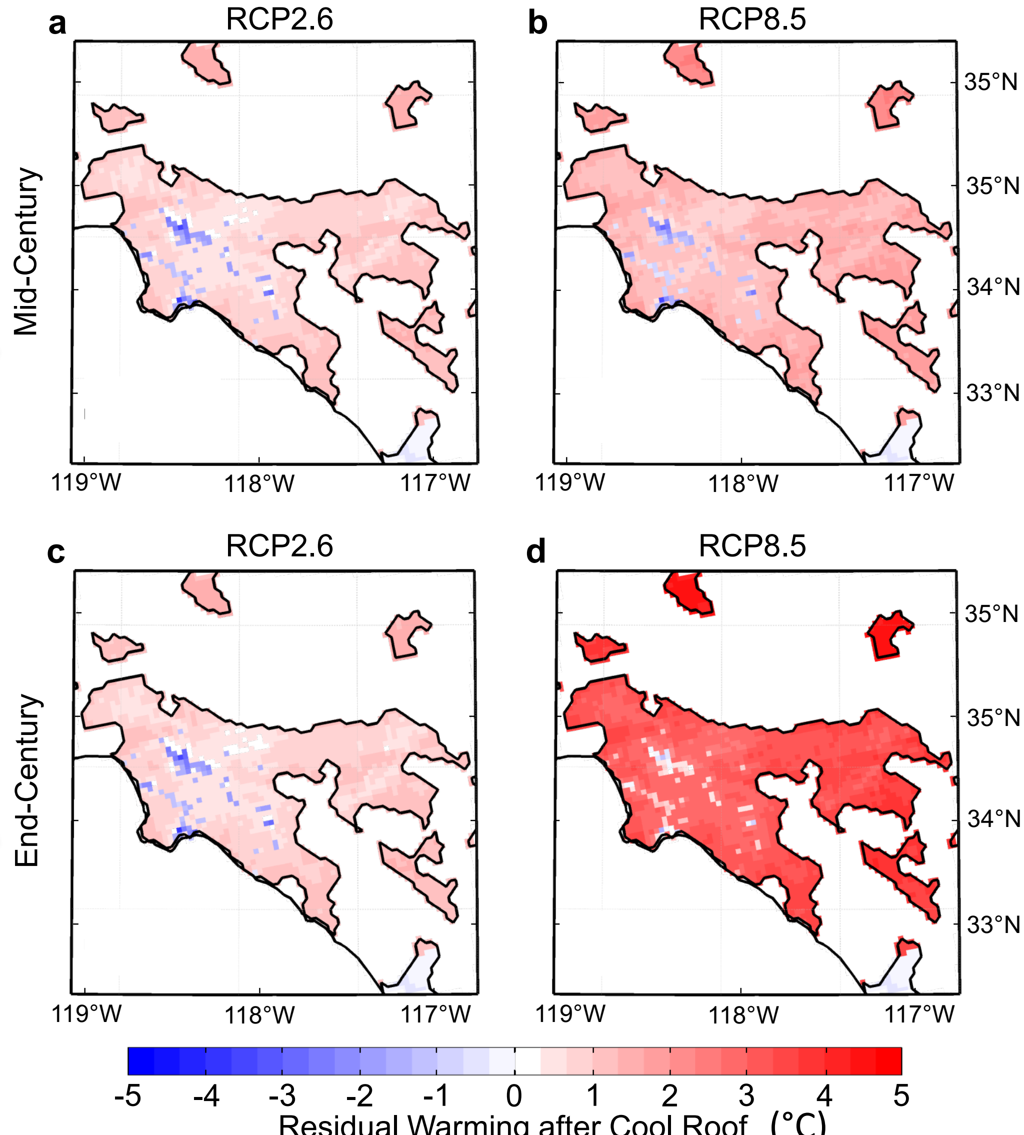
Vahmani et al. ERL (2016)

To what extent could cool roofs counter future climate change induced temperature increases in Los Angeles?

Residual warming after adopting cool roofs in a warming world (relative to current climate)

Cool roofs reduce warming from 2.0° to 1.0°C

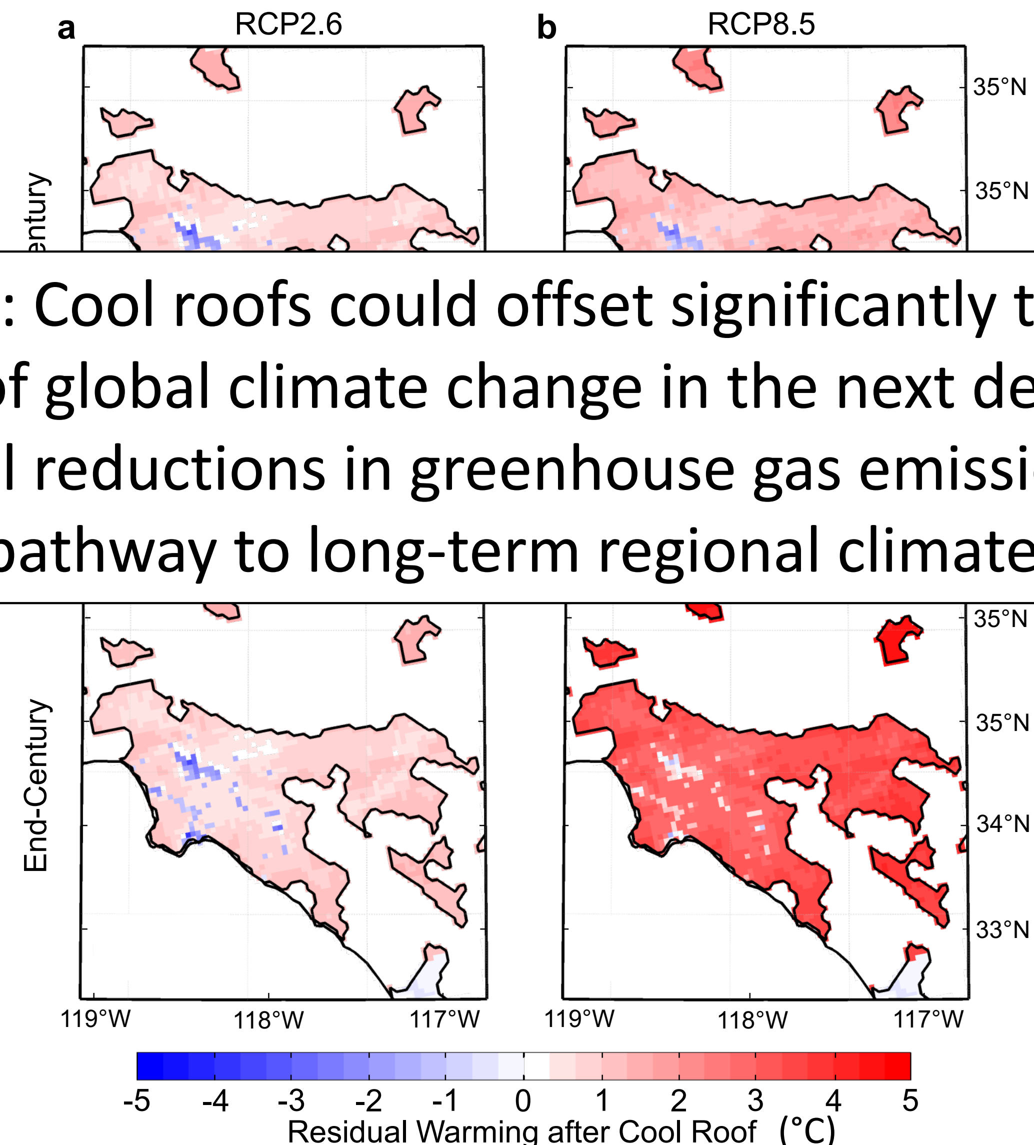
Cool roofs reduce warming from 1.4° to 0.6°C



Residual warming remains large after cool roof implementation (2.0°C)

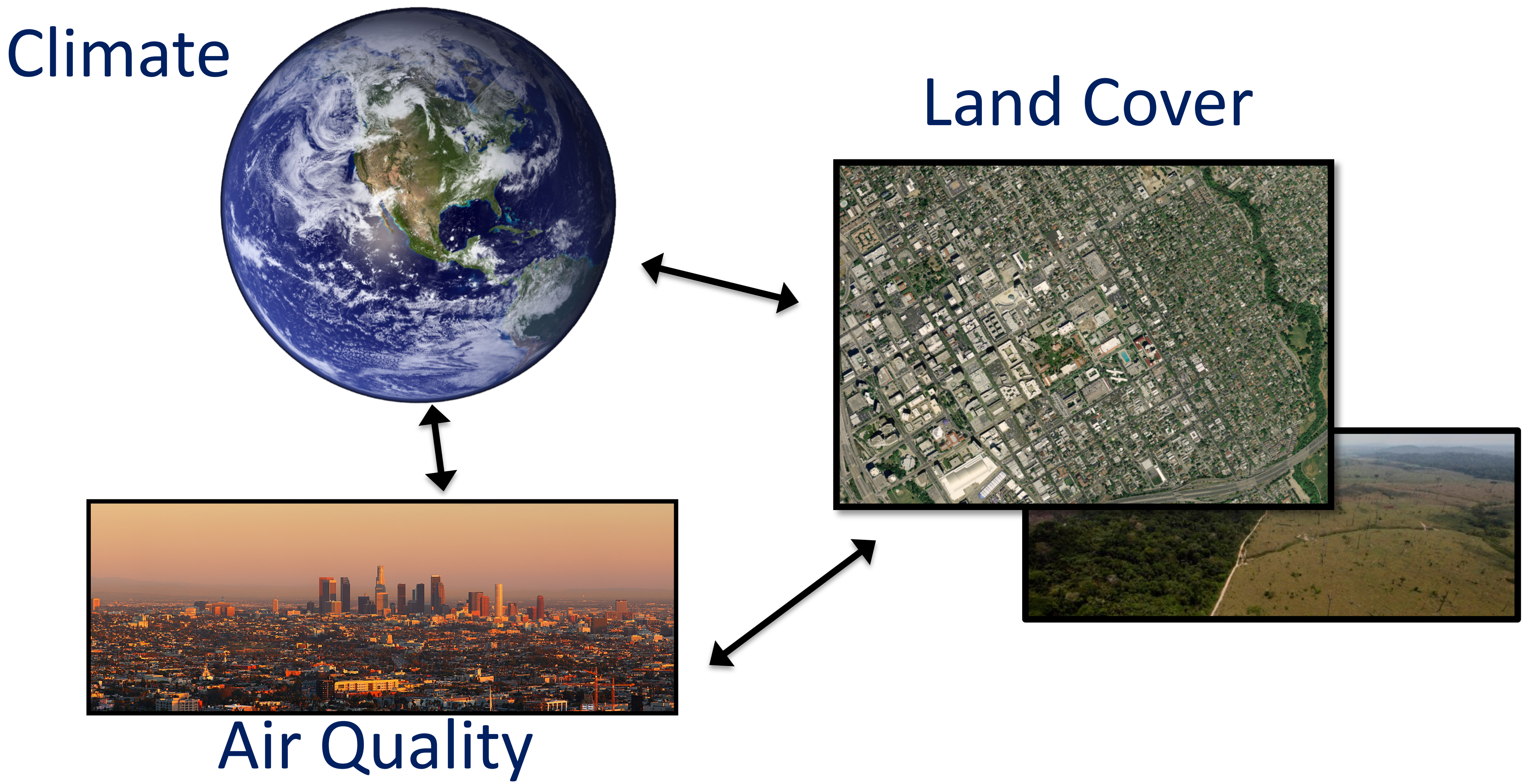
Vahmani et al. ERL (2016)

Residual warming after adopting cool roofs in a warming world (relative to current climate)



Key point: Cool roofs could offset significantly the local impacts of global climate change in the next decades, but global reductions in greenhouse gas emissions are the only pathway to long-term regional climate stability

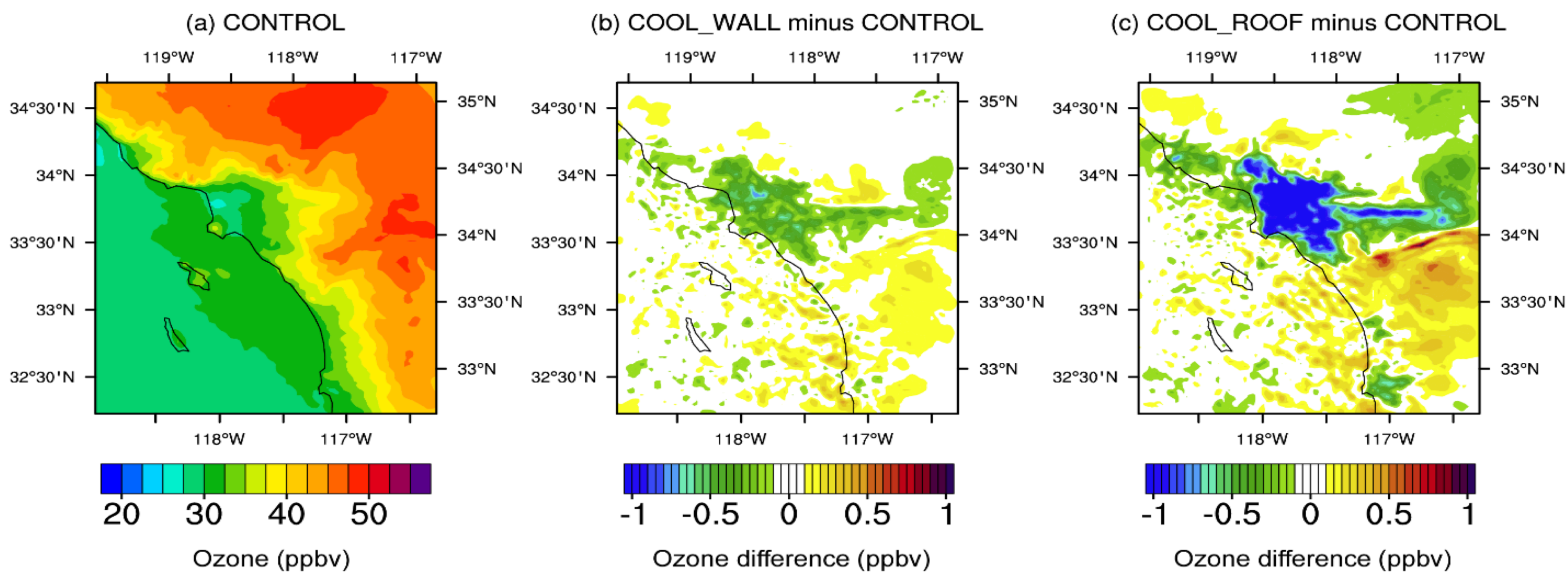
Vahmani et al. ERL (2016)



Taking a systems approach to understanding environmental benefits and penalties of solutions to environmental problems

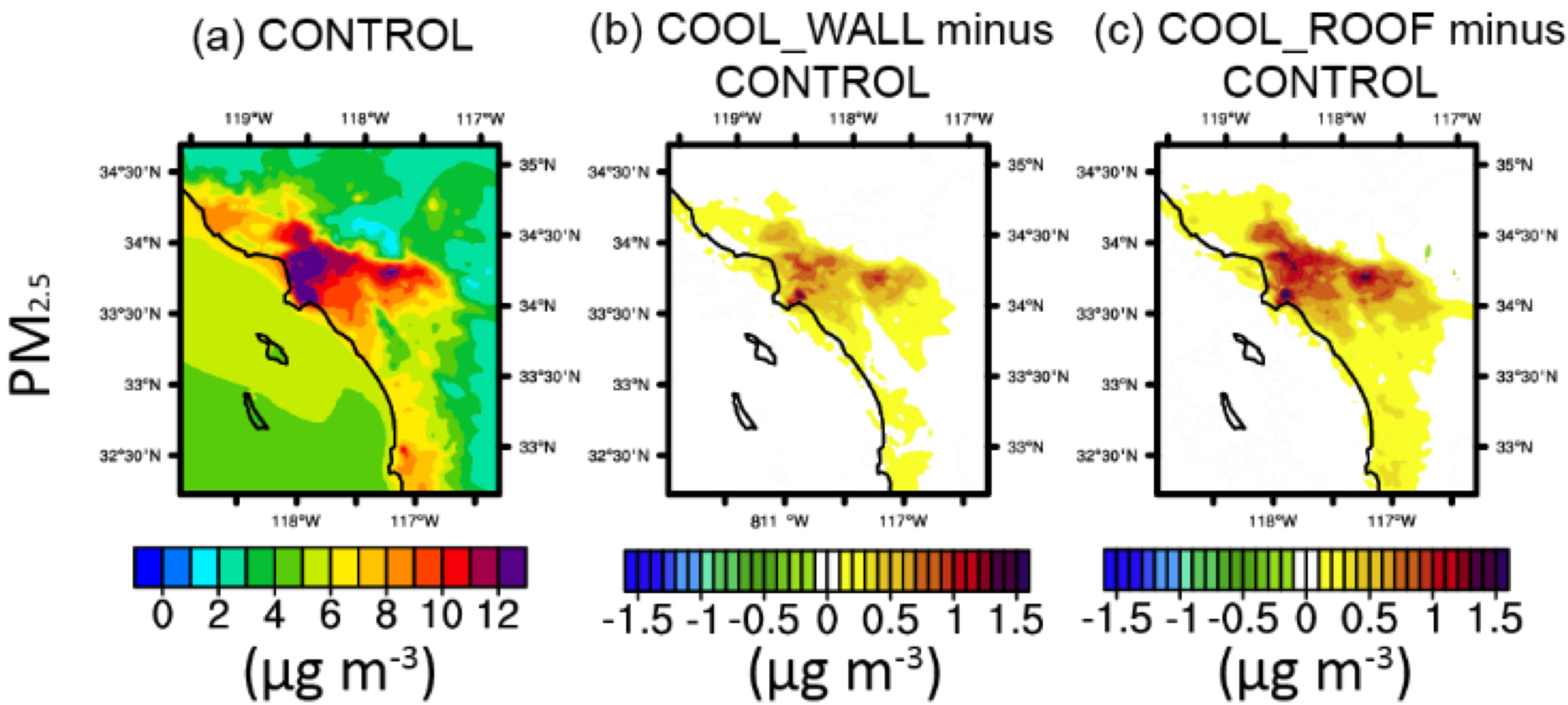
How could widespread deployment of cool roofs and walls impact air pollution in Los Angeles?

Increasing wall (roof) albedo by 0.80 leads to MDA8 ozone concentration reductions of 0.26 ppbv (0.83 ppbv)



Zhang et al. (in submission)
See also Epstein et al. (2017) PNAS

Cool walls (roofs) slightly increase daily average $PM_{2.5}$ concentrations by 0.029 (0.043) µg m^{-3}



Zhang et al. (in submission)
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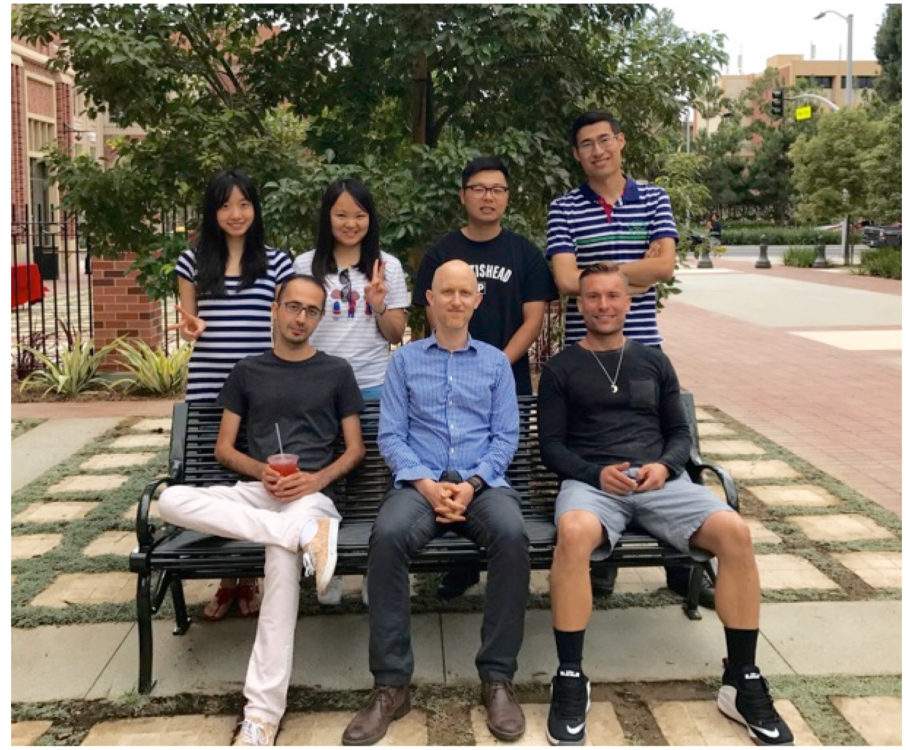
Acknowledgements
(My group at USC)



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-California Air Resources Board

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NSF

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CALIFORNIA ENERGY COMMISSION

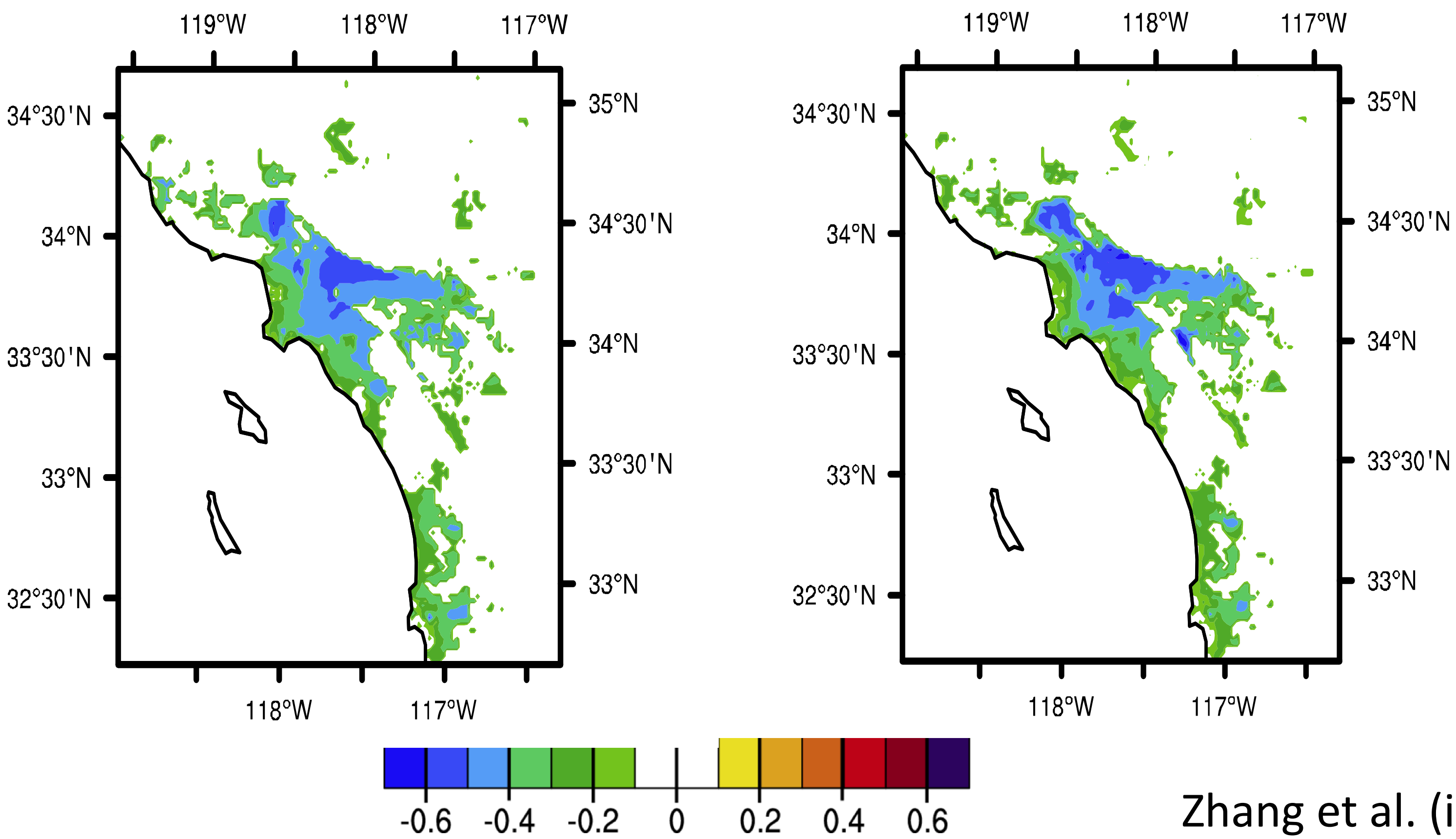
Supplemental Slides

Cool walls reduce canyon air temperatures throughout the LA basin

Implemented a new parameterization to diagnose "canyon" air temperature (Theeuwes et al., 2014)

2 pm LST

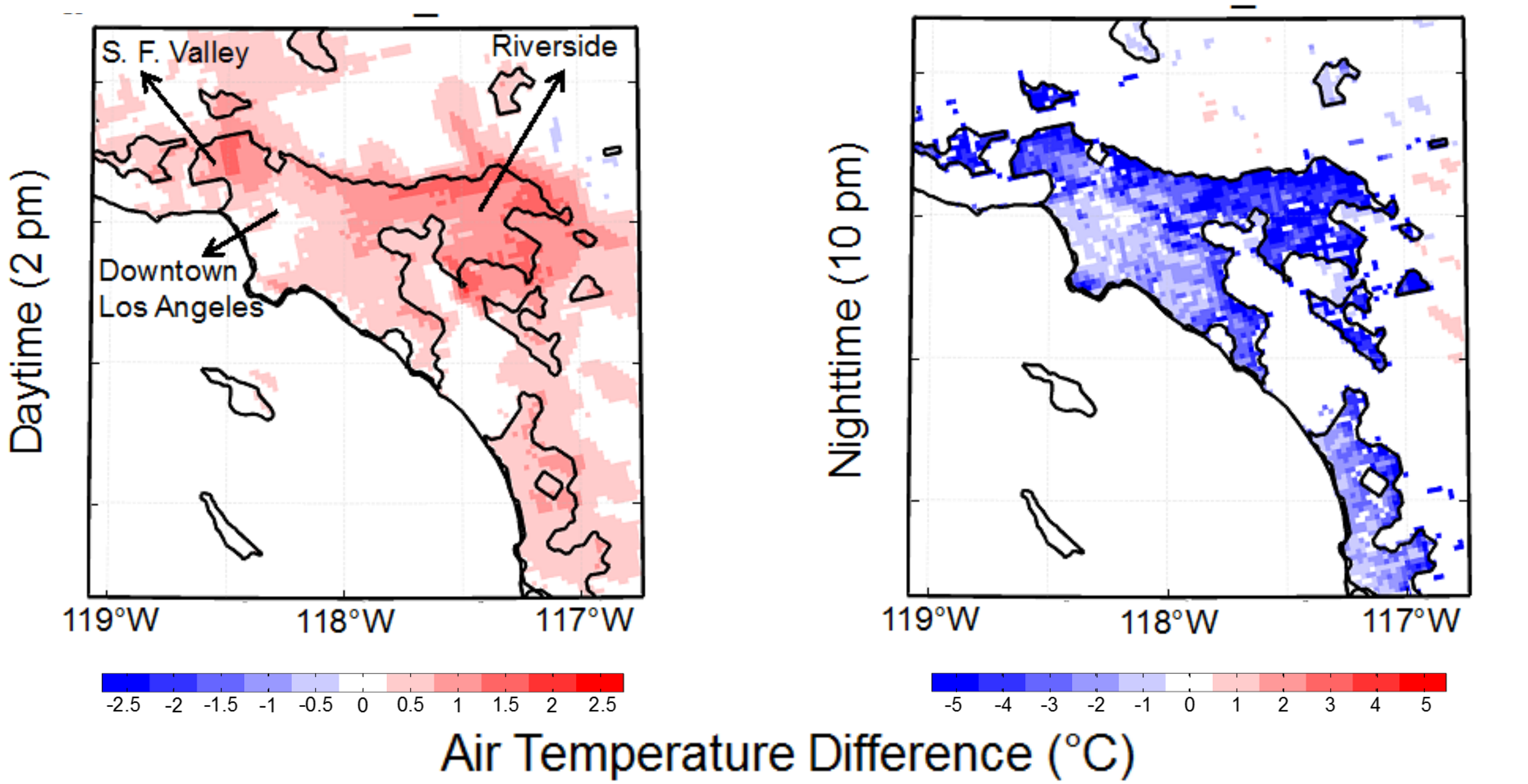
8 pm LST



Change in canyon air temperature (K)

Zhang et al. (in review) ES&T

Climatic consequences of replacing lawns with drought tolerant vegetation: daytime warming and nighttime cooling

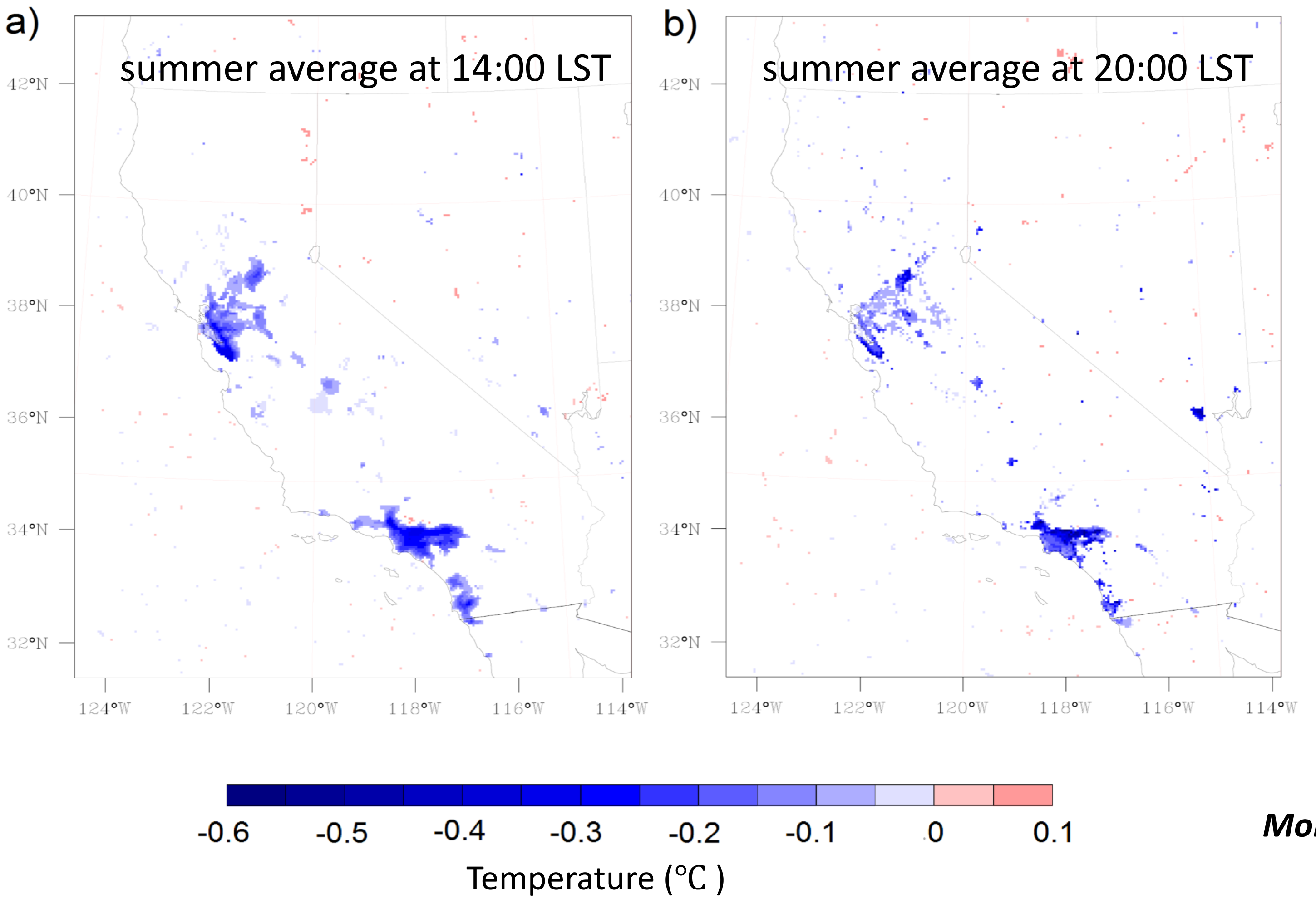


- The daytime signal (warming up to 1.9°C) is dominated by changes in irrigation, though changes in roughness length and leaf stomatal resistance play a role too.
- The nighttime signal (mean cooling of 3.2 °C) is from reductions in soil moisture causing decreases in upward ground heat flux at night

Vahmani and Ban-Weiss, GRL (2016)

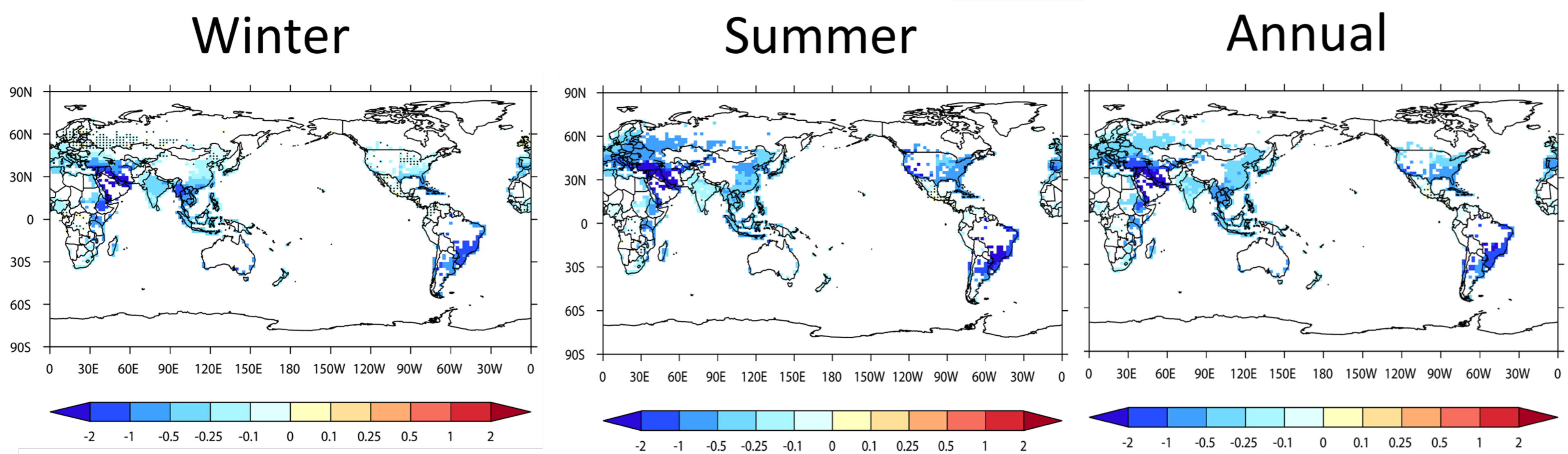
Cool pavements can reduce surface air temperature in California cities

Difference in surface air temperature (℃) from hypothetical wide-spread adoption of cool pavements



Mohegh et al. JGR (2017)

Cool roofs reduce urban heat islands over the globe



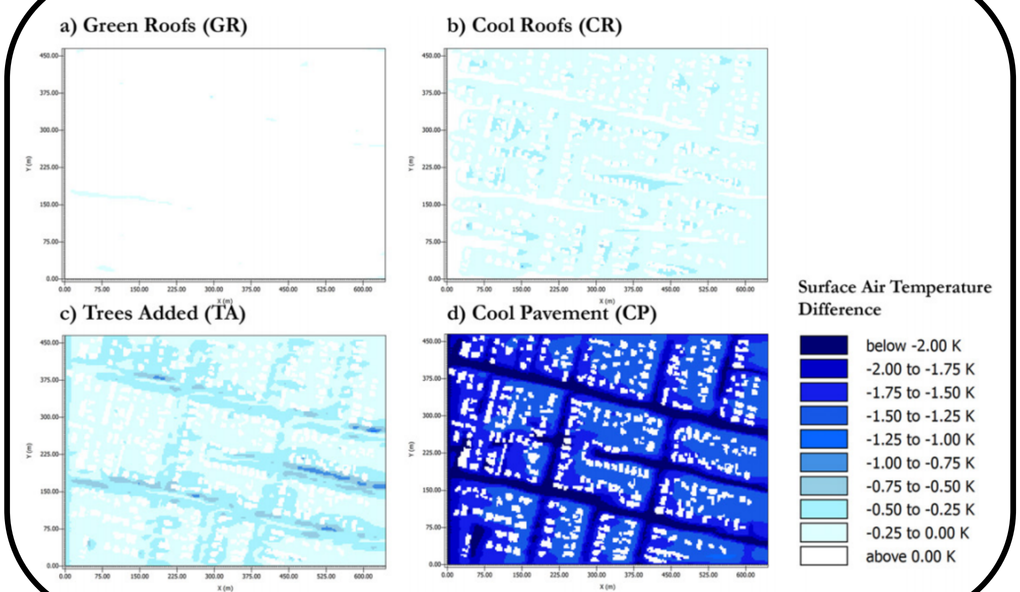
Cool roof induced change in urban minus rural surface air temperature (°C)

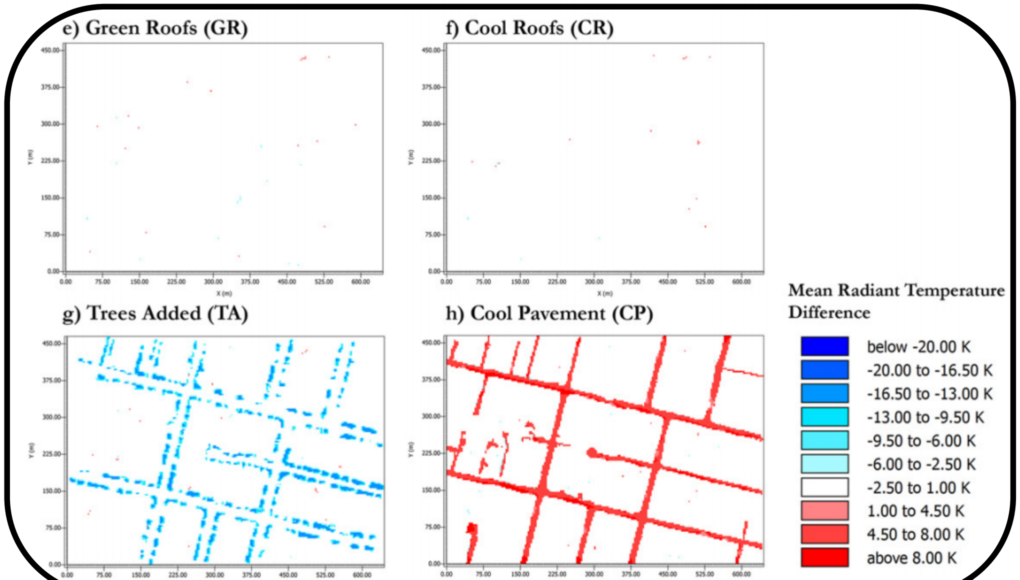
The annual- and global-mean urban heat island is reduced from 1.6 °C to 1.2 °C

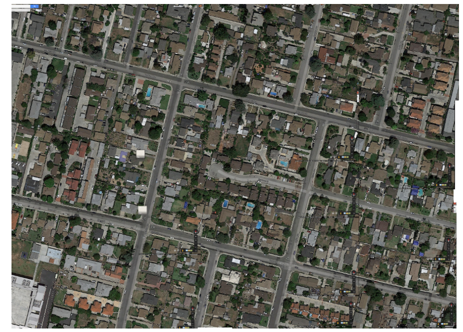
Implementing cool roofs exert a statistically insignificant cooling effect (0.0021 ±0.026 °C).

Zhang et al. ERL (2016)

Impacts of heat mitigation strategies on **pedestrian thermal comfort in a vulnerable LA neighborhood**







- Adding street trees was found to be the most effective strategy for improving thermal comfort of pedestrians.
- Cool pavements reduce surface air temperature, but can reduce the thermal comfort of pedestrians **near roadways during the day**.
- Cool pavements improve thermal comfort **away from roadways, and at night**

Taleghani et al. (2016) ERL

Arizona State University