LBNL Heat Island Group

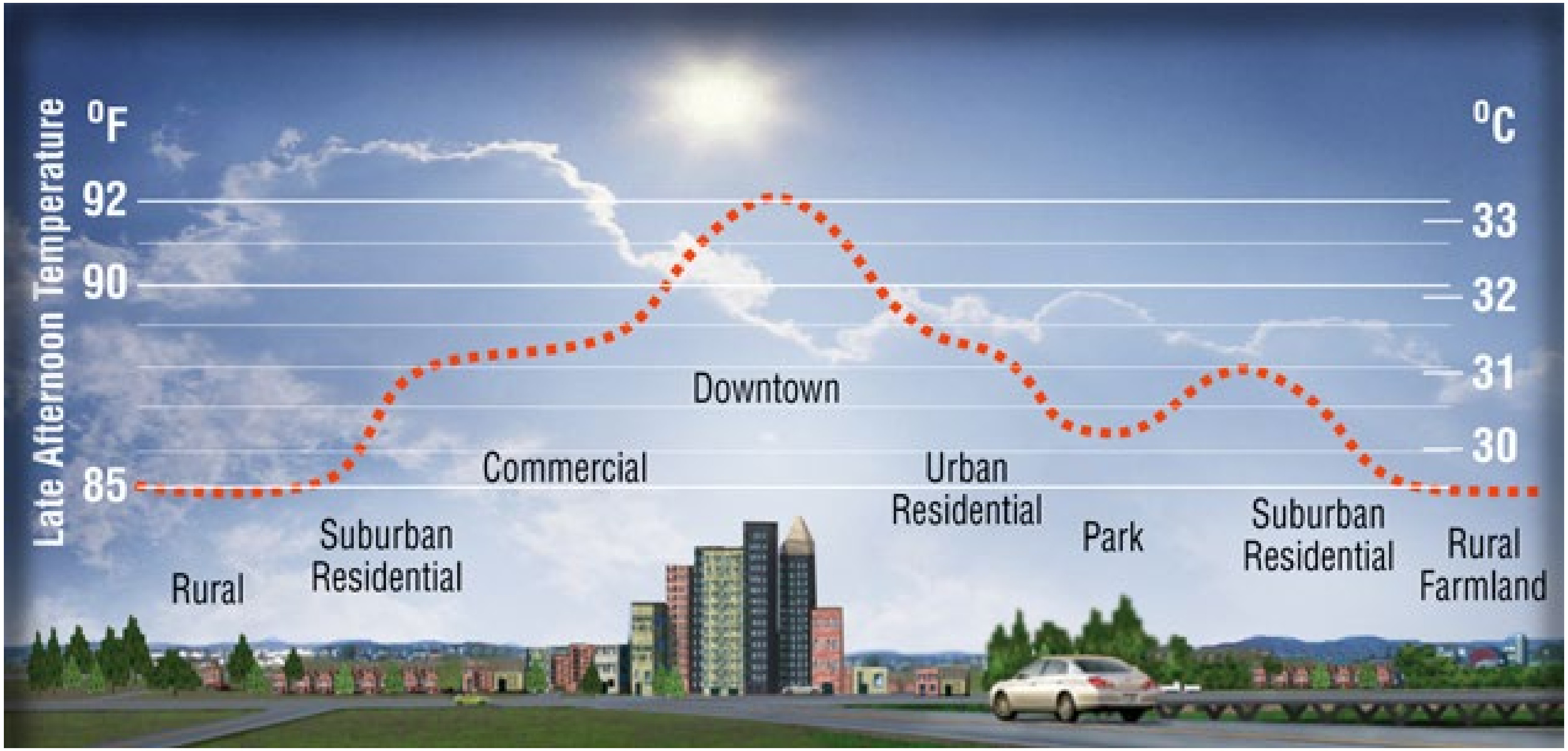
Modeling and Observations to Detect Neighborhood-scale Heat Islands and Inform Effective Countermeasures in Los Angeles

California Climate Change Assessment webinar

5 December 2018

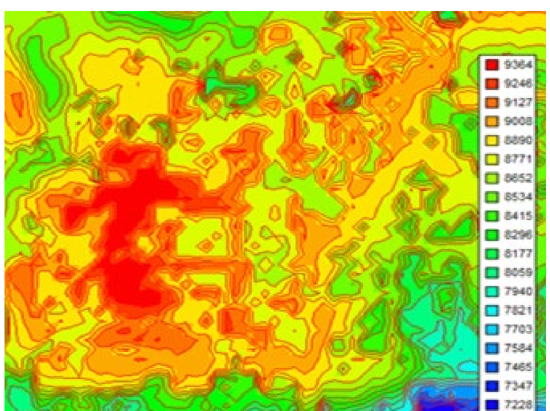
Lawrence Berkeley National Laboratory (LBNL)
University of Southern California (USC)
Altostratus, Inc.

Dark, dry surfaces + man-made heat can create urban "heat islands" of elevated air temperature



a summer urban heat island

We measured and modeled how surface cover affects air temperature in Los Angeles…



…to gauge current and predict future cooling by heat-island countermeasures

Cool roofs & walls

Lawns & shade trees

The core research team includes Berkeley Lab, USC, and Altostratus

Ronnen Levinson, Ph.D.
(Principal Investigator & Staff Scientist, LBNL)

Subcontractor 1:
Haider Taha, Ph.D.
(Scientist, Altostratus)

Haley Gilbert
(Former Project Manager & Principal Research Associate, LBNL)

Subcontractor 2:
George Ban-Weiss, Ph.D.
(Asst. Professor, USC)

Arash Mohegh, Ph.D.
(former Ph.D. student, USC)
(currently post-doc at George Washington University)

We were fortunate to count on the support of project partners and collaborators

Partners

Los Angeles Unified School District · Board of Education ·

City of Los Angeles Founded 1781

LA DWP

LARC

Collaborators

Bureau of Street Services
Dept. of Public Works
City of L.A.

County of Los Angeles California

TreePeople

Climate Resolve

We also received early guidance and feedback from our Technical Advisory Committee members

Name	Organization
Susan Wilhelm	California Energy Commission
Chris Weaver	US Environmental Protection Agency
Ash Lashgari	CA Air Resources Board
William Dean	CA Environmental Protection Agency (CalEPA)
Rupa Basu	CalEPA, Office of Environmental Health Hazard Assessment

Name	Organization
Tom Pyle	CA Department of Transportation
Craig Tranby	Los Angeles Department of Water & Power
Henry Ortiz	Los Angeles Unified School District
Robert Bornstein	San Jose State University

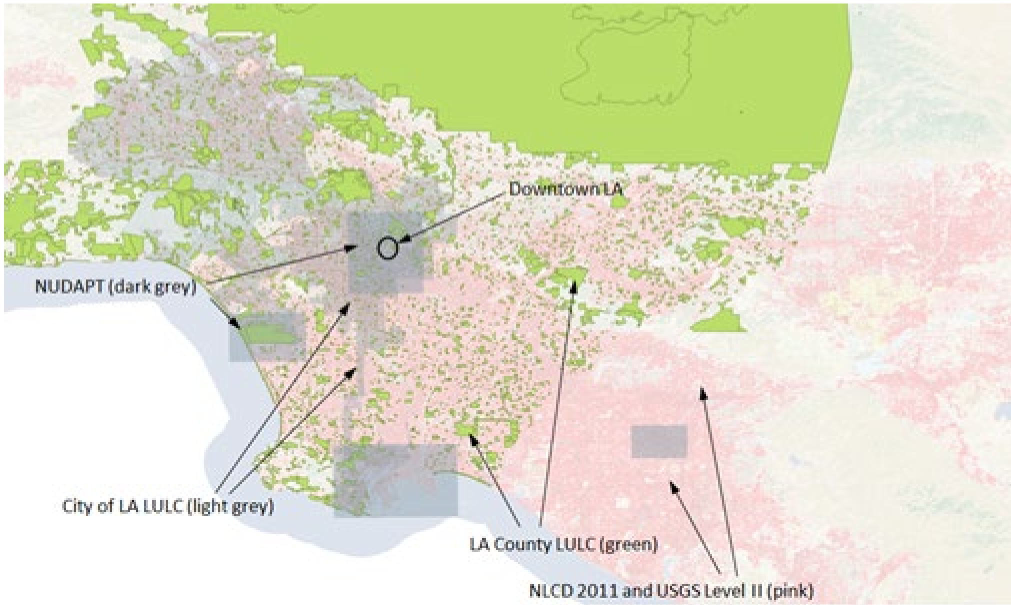
Approach

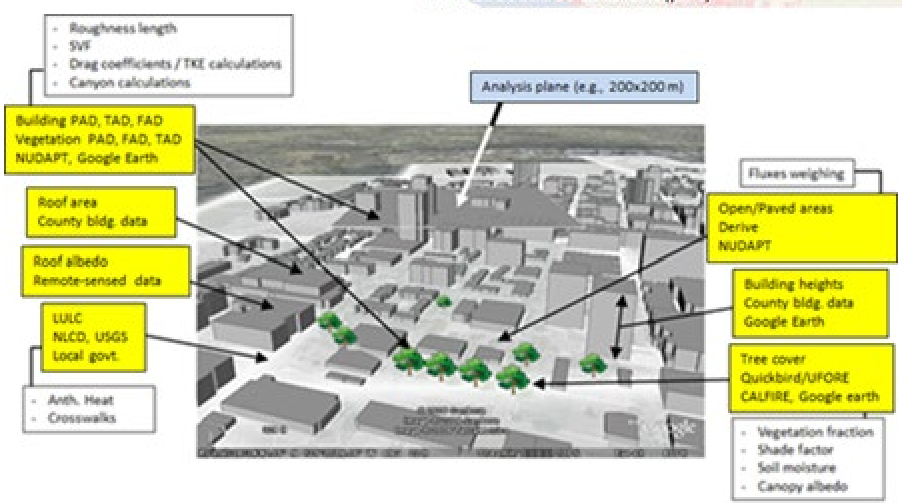
1. Use climate modeling + preliminary measurements to select study regions in Los Angeles
2. Measure air temperatures with stationary and mobile weather monitors
3. Relate air temperature variations to land use/land cover
4. Validate and calibrate climate models for predictions

Methodology

MODELING EFFORTS

Nine different land-use and land-cover datasets were included in the analysis



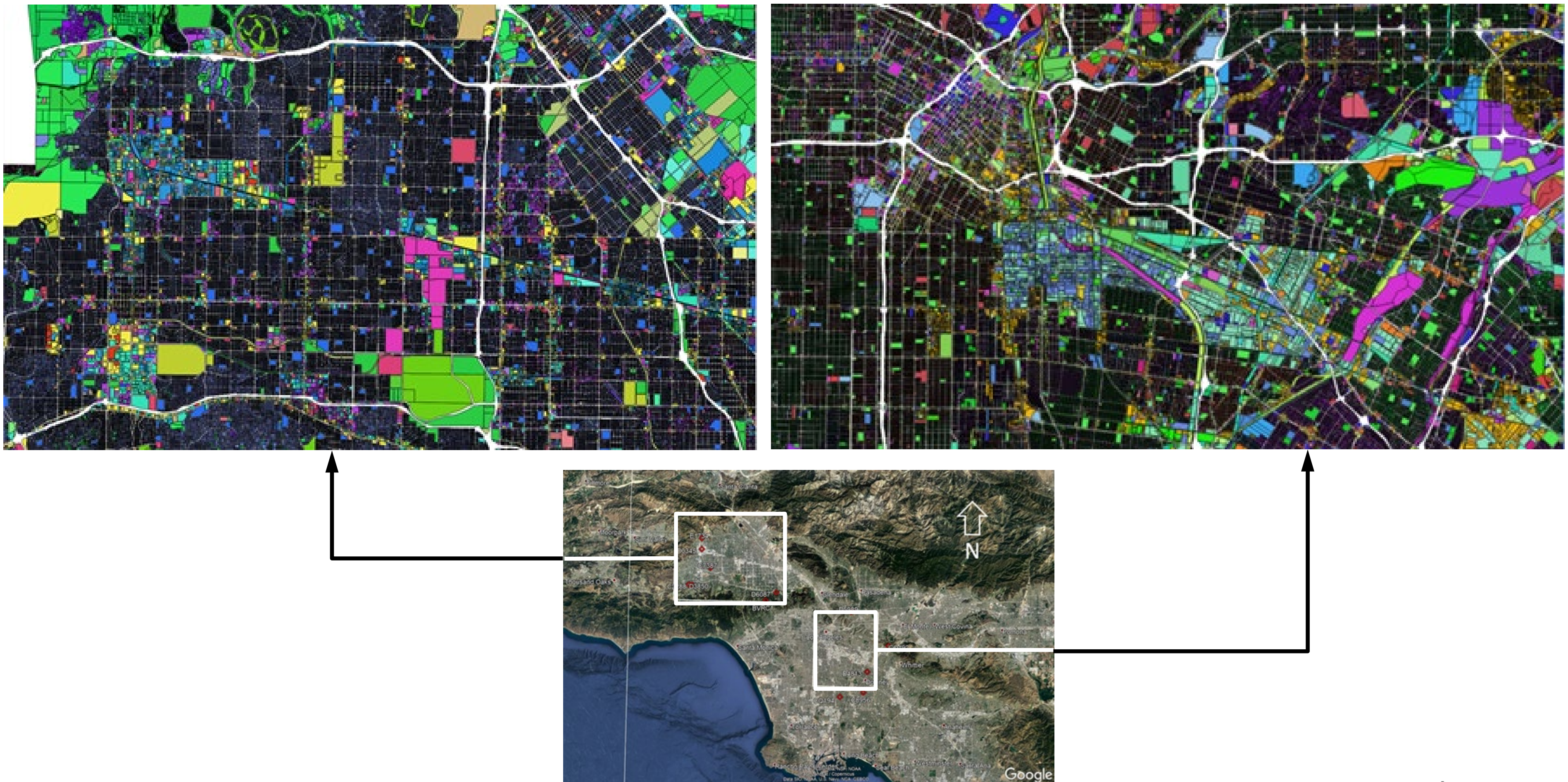


- 30-m National Land Cover Data (NLCD)
- 30-m USGS Level-II LULC classification
- Area-specific LULC, City of Los Angeles
- Area-specific building footprints and geometry, County of Los Angeles
- Google Earth urban morphological and land-cover data (canopy layer)
- 1-m area-specific satellite-derived roof albedo (Lawrence Berkeley Lab)
- 1-m area-specific urban morphological and geometrical data from the National Urban Datasets and Portal Tool (N/WUDAPT)
- Fine-scale USGS Level-IV LULC (SCAG)
- 1-m EarthDefine / CAL FIRE urban tree canopy cover

Sample from the Anderson Level-IV SCAG LULC classification system showing parts of Downtown Los Angeles and San Fernando Valley

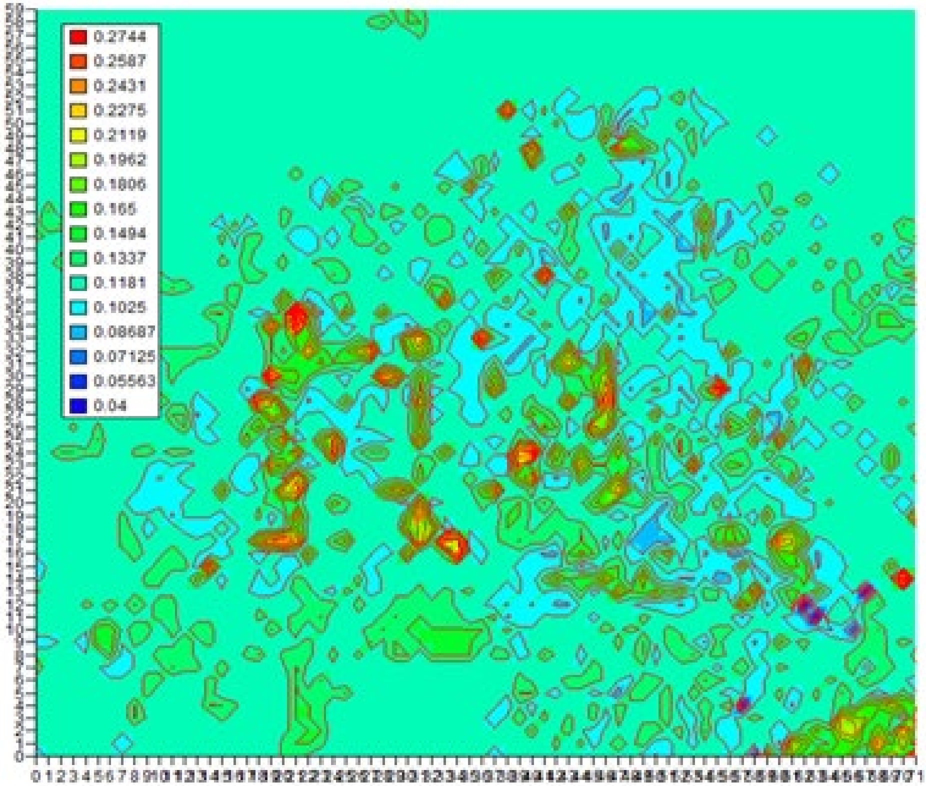
San Fernando Valley (SFV)

Downtown Los Angeles



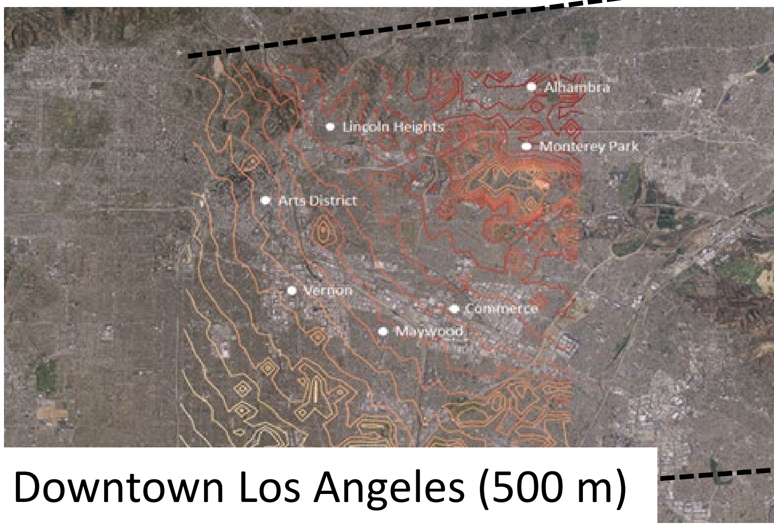
LULC data were used in development of cell-specific surface characterization input to the model

Bottom-up, cell-level surface characterization

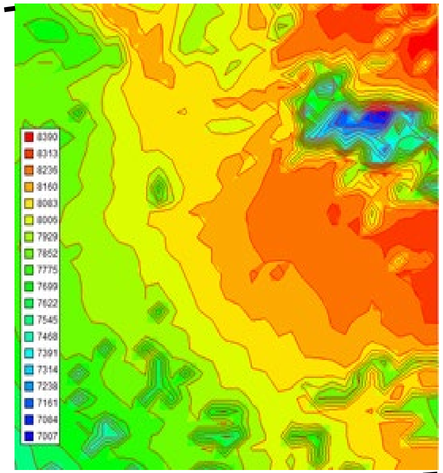


Model input development example for 500-m resolution SFV domain: gridded albedo (left) and tree canopy cover (right).

Meteorological modeling to identify local urban heat and cool islands

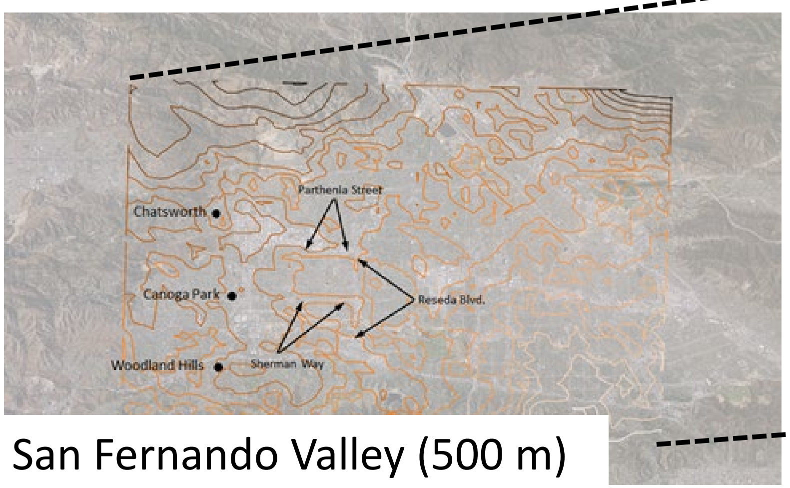


Downtown Los Angeles (500 m)

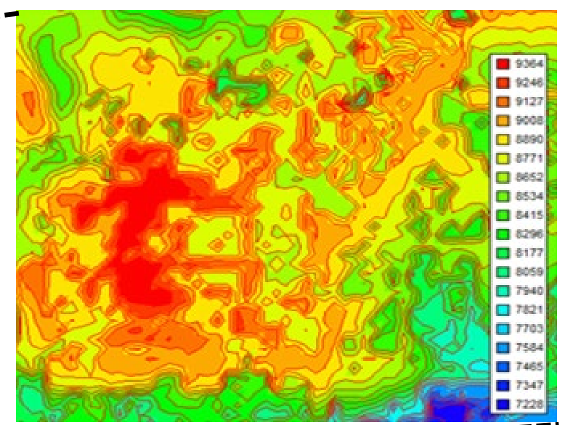


Total DH (°C·hr) May 30 – June 16, 2013

The derived average temperature (DH/hour), blue to red, is 17.2–20.6 °C for this period.



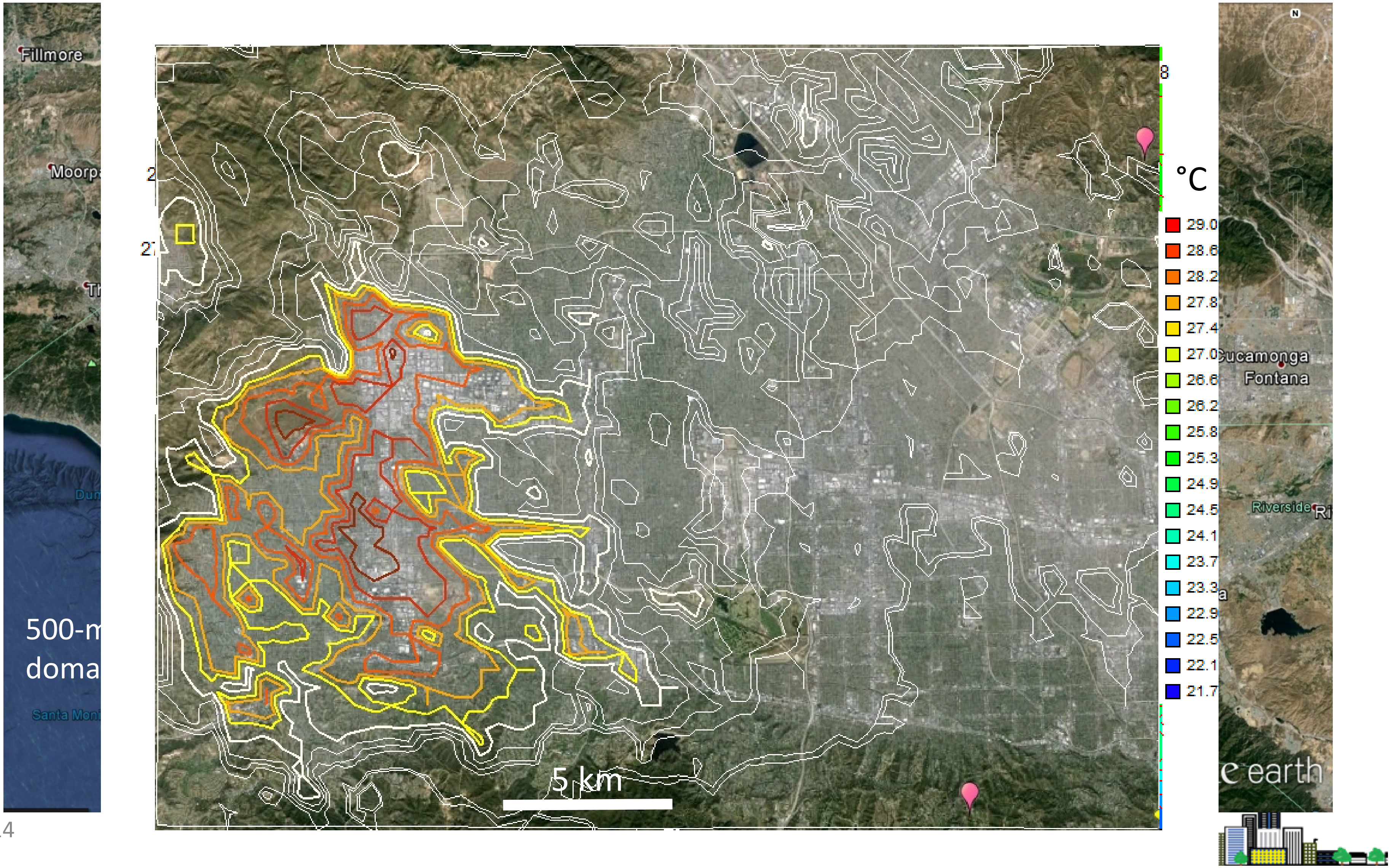
San Fernando Valley (500 m)



Total DH (°C·hr) May 30 – June 16, 2013

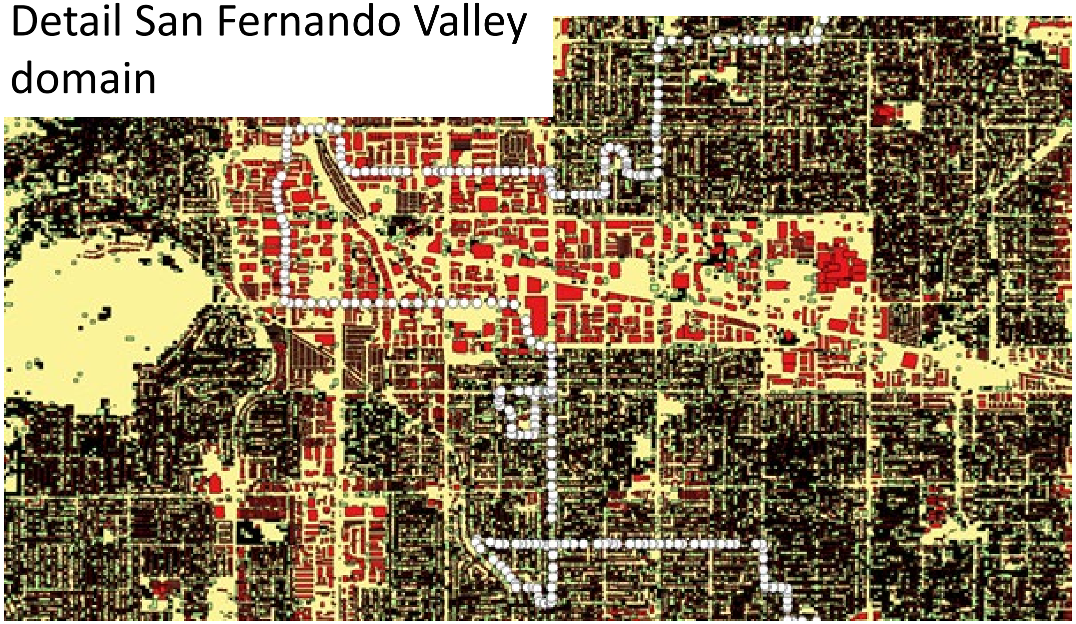
The derived average temperature (DH/hour), blue to red, is 17.7–22.9 °C for this period.

Urban climate simulations guide placement of rooftop weather stations & routes for mobile transects



Model performance was evaluated against observations from mobile transects

Detail San Fernando Valley domain



- 30-m tree cover (yellow, light green, black)
- Building-specific roof albedo (red, orange, light orange)
- Sample mobile transect segment (white dots)

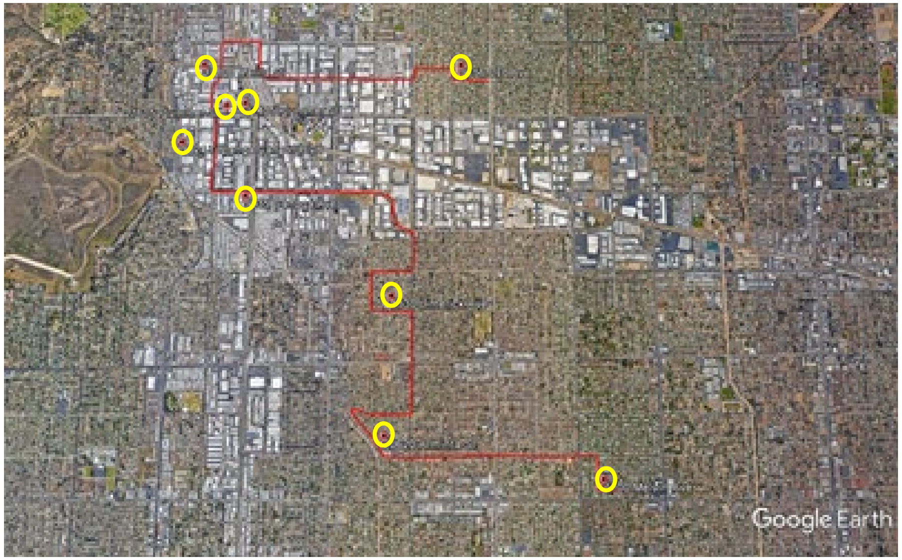
Model performance metrics

TRANSECT	MAE (°C)	RMSE (°C)
2016_04_22 (west basin)	1.15	1.33
2017_06_14 Part 1 (west basin)	0.88	1.00
2017_06_14 Part 2 (west basin)	0.61	0.76
2017_06_14 Part 3 (west basin)	0.80	0.94
2017_06_14 Part 4 (west basin)	0.70	0.86
2017_06_21 (San Fernando)	1.73	2.00
2017_07_27 day Part 1 (San Fernando)	0.97	1.20
2017_07_27 day Part 2 (San Fernando)	0.92	1.10
2017_07_27 night Part 1 (San Fernando)	0.55	0.68
2017_07_27 night Part 2 (San Fernando)	0.85	1.00
2017_08_28 day Part 1 (west basin)	0.48	0.60
2017_08_28 day Part 2 (west basin)	0.71	0.94
2017_08_28 night Part 1 (west basin)	1.00	1.10
2017_08_28 night Part 2 (west basin)	0.82	0.92

Example:
Transect-specific simulated temperatures compared to mobile-transect observations. Benchmark is 2 °C.

Modeling results informed the siting of fixed monitors and routes for transects

San Fernando Valley (SFV)



Downtown Los Angeles

Mobile-observation route

Potential site for fixed monitor

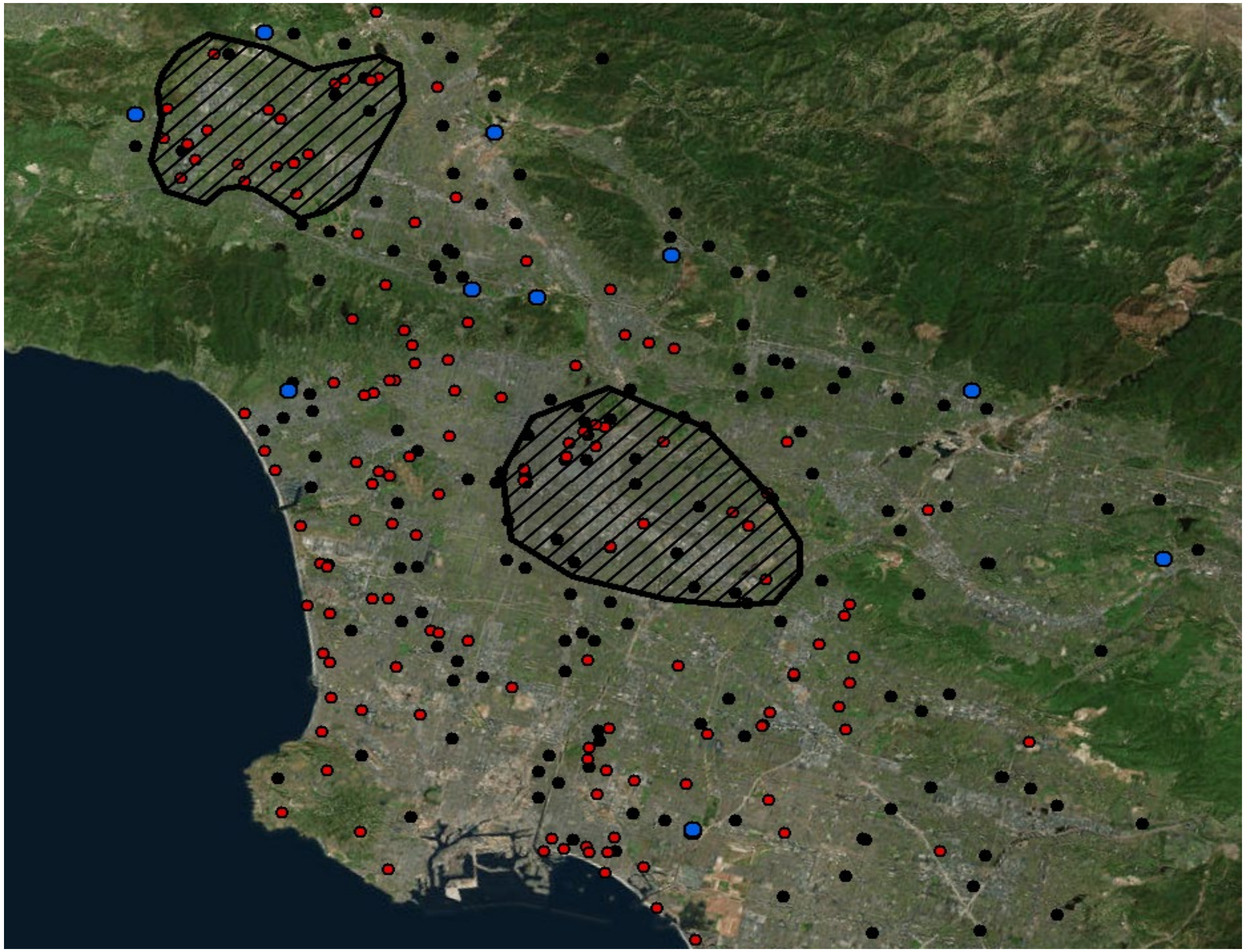
Methodology

OBSERVED TEMPERATURES

We had three methods to collect the intra-urban temperature variations

1. Existing weather station networks in Los Angeles Basin
2. Mobile transects in various neighborhoods on different days and times
3. New fixed monitors that the team installed

We compiled historical weather observations from 6 sources over the past decade



Location of fixed weather stations in LA county featured in study

- Weather Underground
- WeatherBug
- CIMIS

Personal weather stations (PWS) have more spatial coverage than other sources

We had three methods to collect the intra-urban temperature variations

1. Existing weather station networks in Los Angeles Basin
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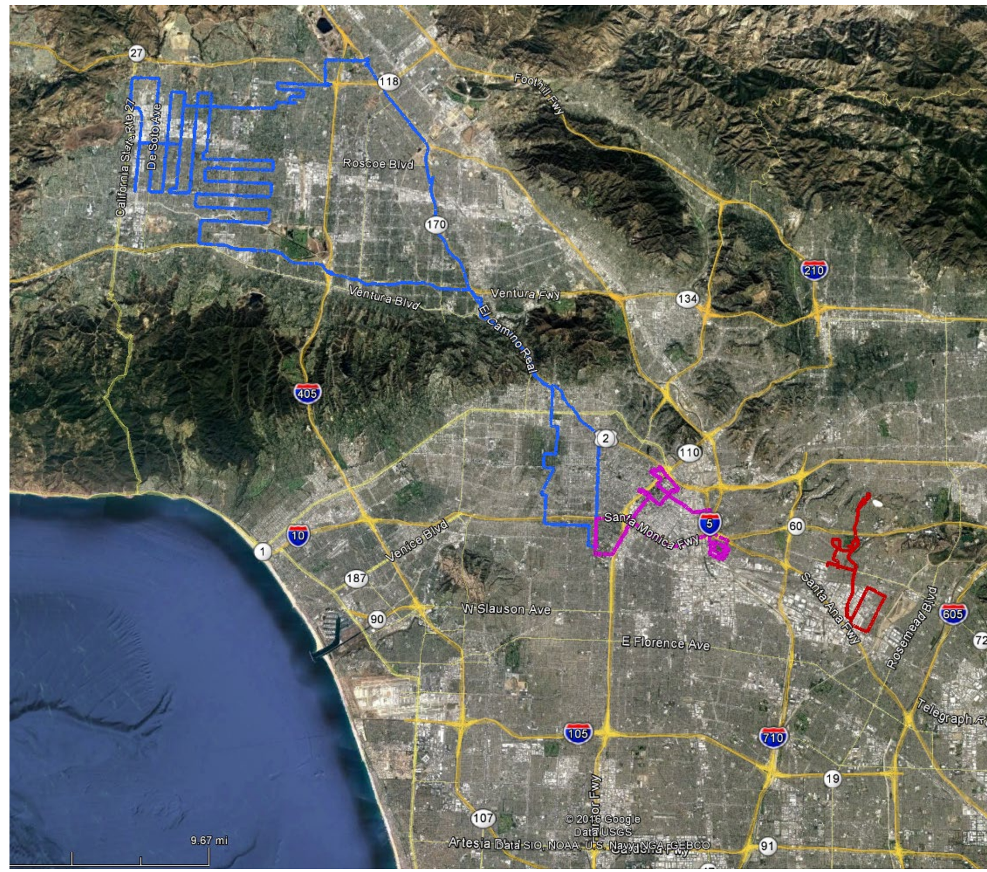
Mobile transects (car + thermometer + GPS) used to check modeled air temperature simulations

Mobile transect sensor (front & side views)

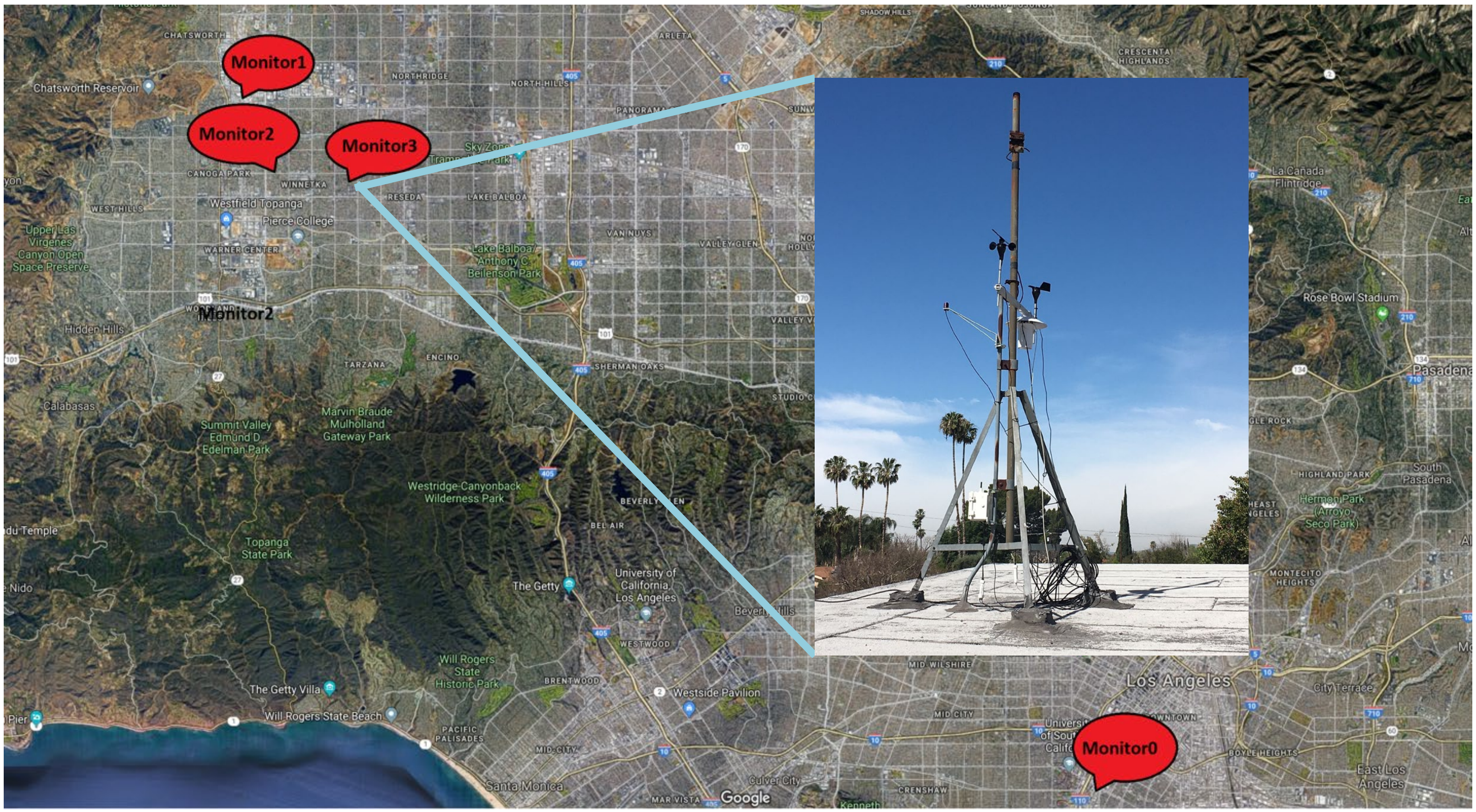


Three different mobile transects routes

We had three methods to collect the intra-urban temperature variations

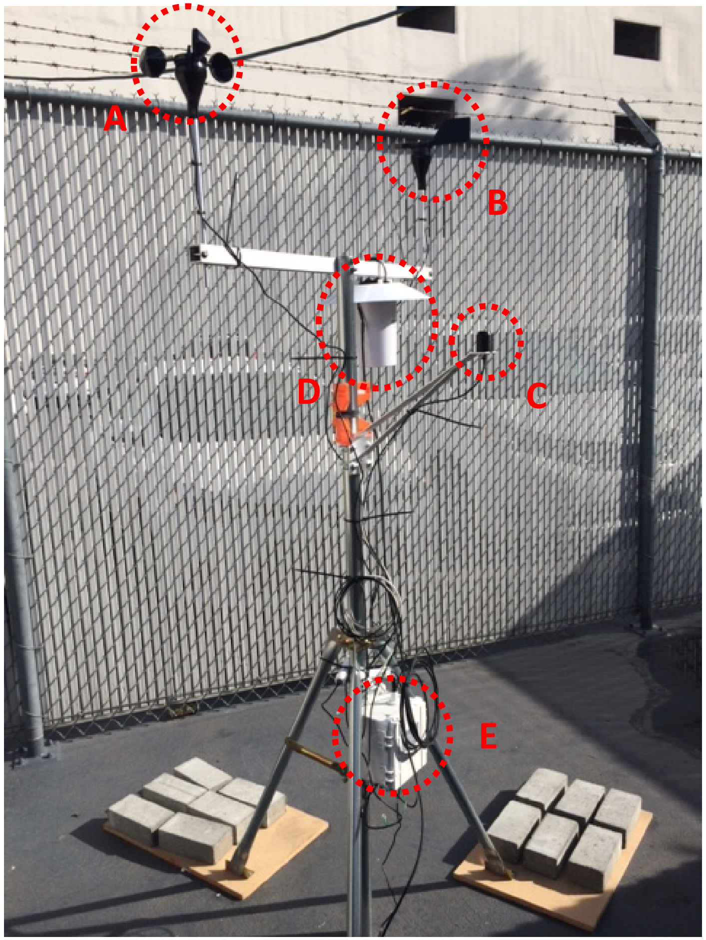
1. Existing weather station networks in Los Angeles Basin
2. Mobile transects in various neighborhoods on different days and times
3. New fixed monitors that the team installed

We installed four fixed monitors across the County in partnership with BSS, LAUSD, & USC



Location of four installed stations and view of Monitor3

We designed monitors to measure temperature, humidity, incoming solar radiation, and wind



Monitor0, installed near USC, and its components

Item	Description
A	Wind speed sensor
B	Wind direction sensor
C	Sunlight intensity sensor
D	Temperature/RH sensor
E	Data logger

Some data from the new monitors is available via Weather Underground

(•) Reseda **KCAWINNE11** About this PWS | Report | Comments

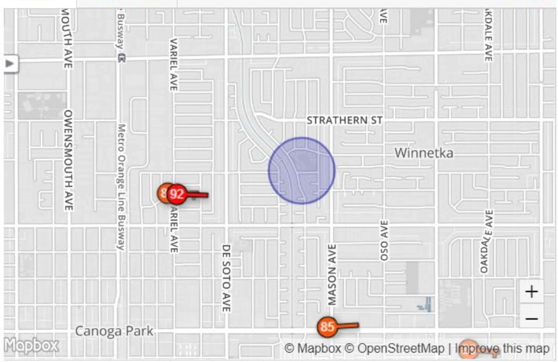
Forecast for Winnetka, CA > 34.212 -118.582 > 814 ft

PWS Data PWS Widgets WunderStation

Status:

PWS viewed 20 times since June 1, 2018

Radar Webcam Icon



Rain Mixed Frozen
Light Heavy Light Heavy Light Heavy

View WunderMap

Weather History for Winnetka, CA [KCAWINNE11]

Previous | Daily Mode | June | 4 | 2018 | View | Next

Summary
June 4, 2018

	High	Low	Average
Temperature	**88.3** °F	**58.8** °F	**71.8** °F
Dew Point	**58.3** °F	**53.5** °F	**55.9** °F
Humidity	%	%	%
Precipitation	**0** in	--	--

	High	Low	Average
Wind Speed	**4** mph	--	**1** mph
Wind Gust	**14** mph	--	--
Wind Direction	--	--	**North**
Pressure	**0** in	in	--

Graphs Table

Website & location for four project monitors

Location	URL
University of Southern California	https://www.wunderground.com/personal-weather-station/dashboard?ID=KCALOSAN765
Chatsworth, SFV	https://www.wunderground.com/personal-weather-station/dashboard?ID=KCACHATS19
Winnetka, SFV	https://www.wunderground.com/personal-weather-station/dashboard?ID=KCAWINNE11
Reseda, SFV	https://www.wunderground.com/personal-weather-station/dashboard?ID=KCARESED8

PWS tends to be less accurate with better spatial coverage; fixed monitors and mobile transects are more accurate and have higher costs

	PWS	Mobile transects	Installed fixed monitors
Pros	• High spatial coverage • Acquiring data is affordable	• Quick to deploy • Highly customizable • Accurate sensors • Inexpensive for short-term measurements	• Provide spatial coverage where we need them • Very accurate sensors
Cons	• Sensors and data collection methods can be unreliable • Placement is limited	• 24-hr monitoring is not readily available • Low spatial coverage • Expensive if using for long-term measurements	• Securing long-term locations can be difficult and time consuming • High short-term costs

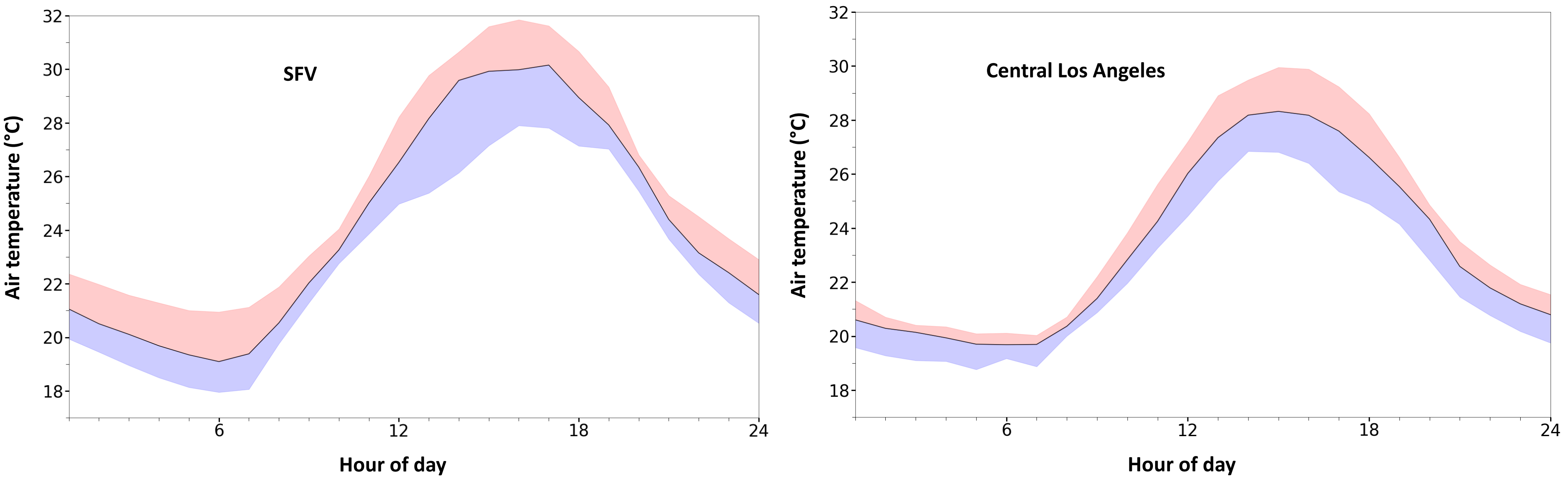
Analysis & results

PERSONAL WEATHER STATIONS

We considered two main regions of interest: SFV and central Los Angeles

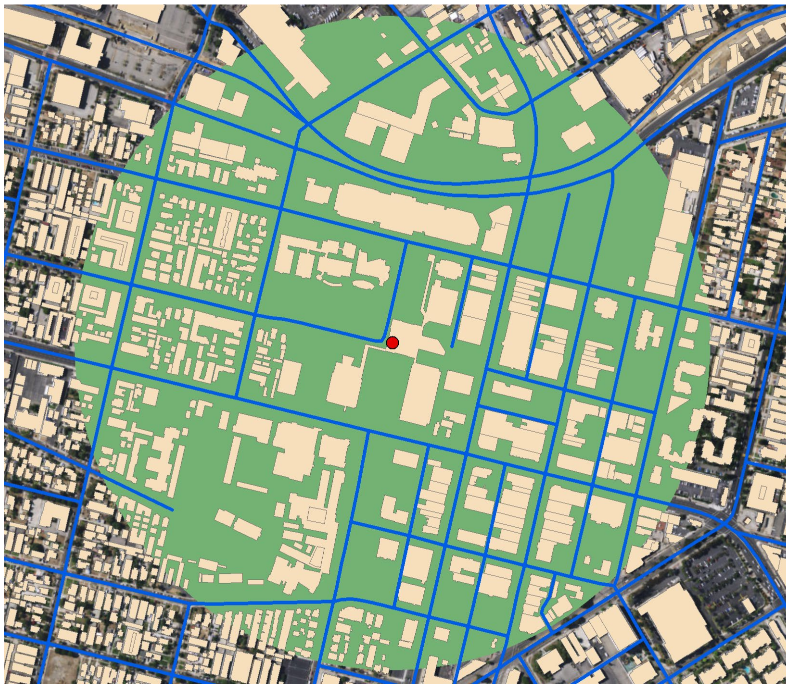
Daily statistics for observed temperature in two regions of interest

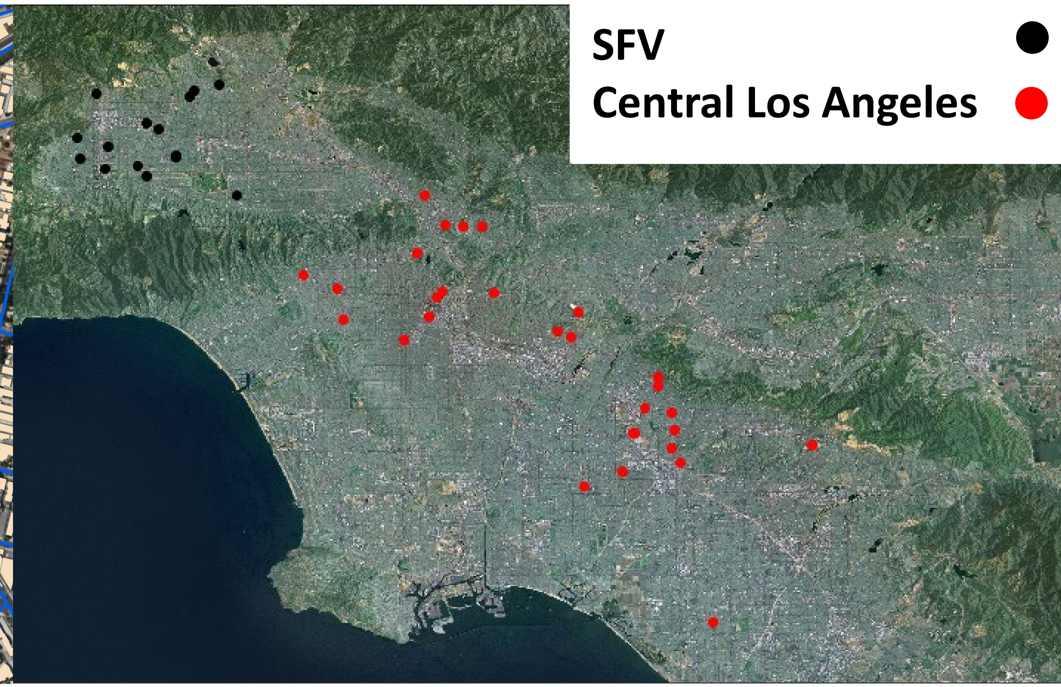
Region	Daily min temperature (°C)	Daily max temperature (°C)	Daily mean temperature (°C)	Diurnal temperature range (°C)
SFV	19.4	30.5	24.3	11.1
Central Los Angeles	18.9	27.7	22.5	8.8



Diurnal cycle of observed temperature across the county (black bar showing median)

Land cover and land use was associated to inter-urban temperatures from PWS

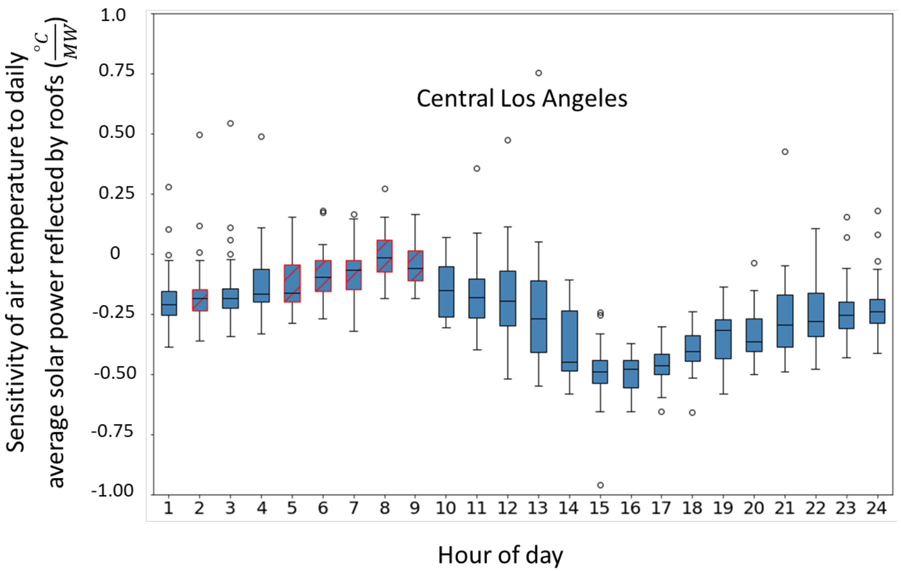


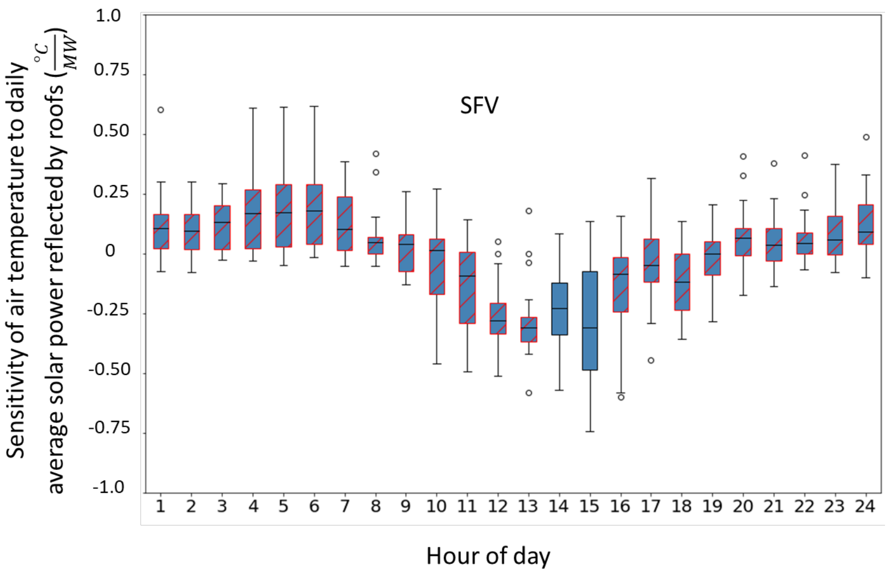


Aggregated area around each weather station, overlaid with building footprint dataset

Weather Underground stations: SFV and central Los Angeles

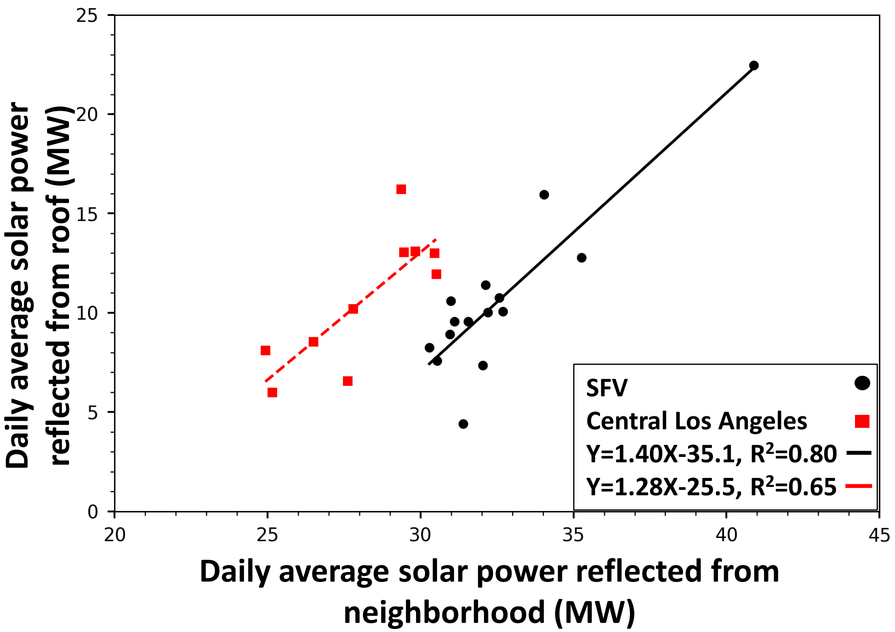
Results showing cooling effects from roofs—more effective during warmest hours of the day

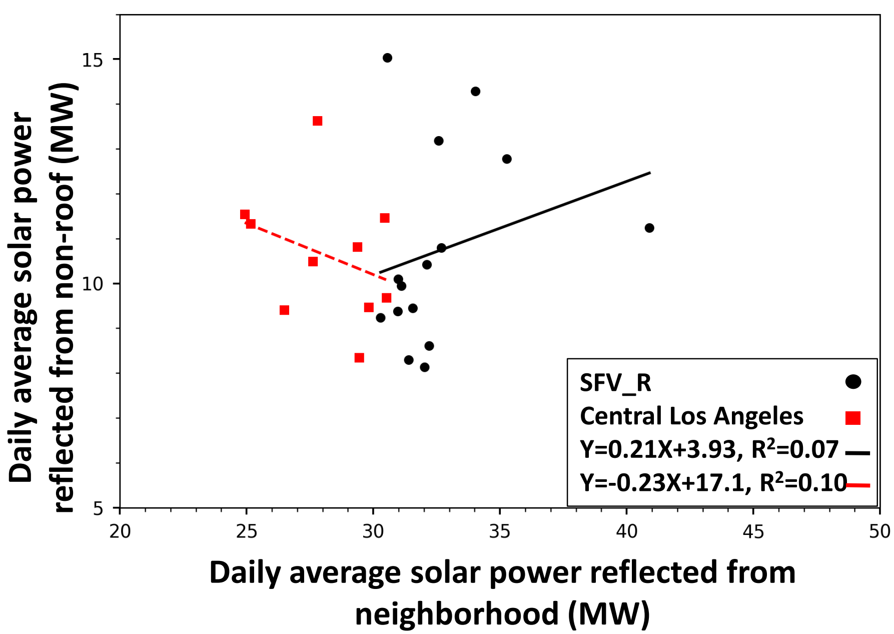




Diurnal cycle of sensitivity of air temperature to average daily reflected solar radiation in two regions of interest

Roofs are responsible for most of the variation of average daily reflected solar radiation



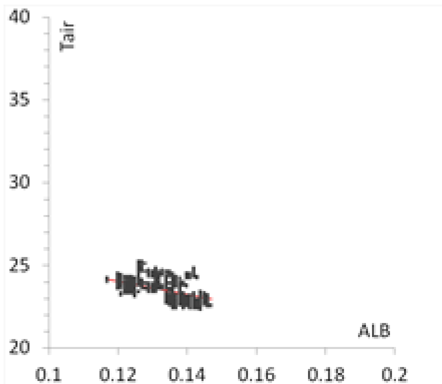


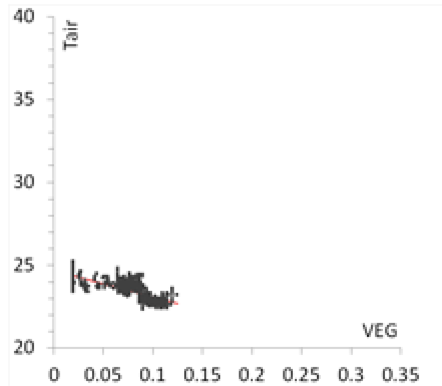
Analysis & results

MOBILE TRANSECTS & MODELING

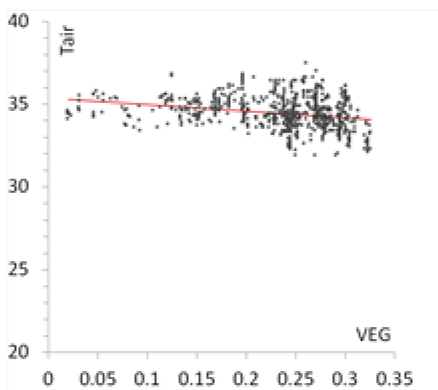
Increasing neighborhood-scale albedo and/or canopy cover reduces air temperature

Examples of correlations between observed temperature and transect albedo or canopy cover

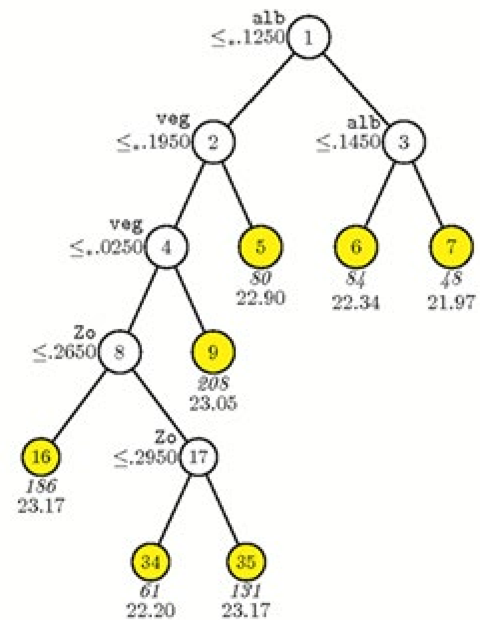




TR07: Downtown area, 2017-08-28 night P1; WSP: 1.10 m/s; SOLAR: 0 W/m^2
ALB: -4.00°C/0.1, p-value: <0.0001; VEG: -1.61°C /0.1, p-value: <0.0001

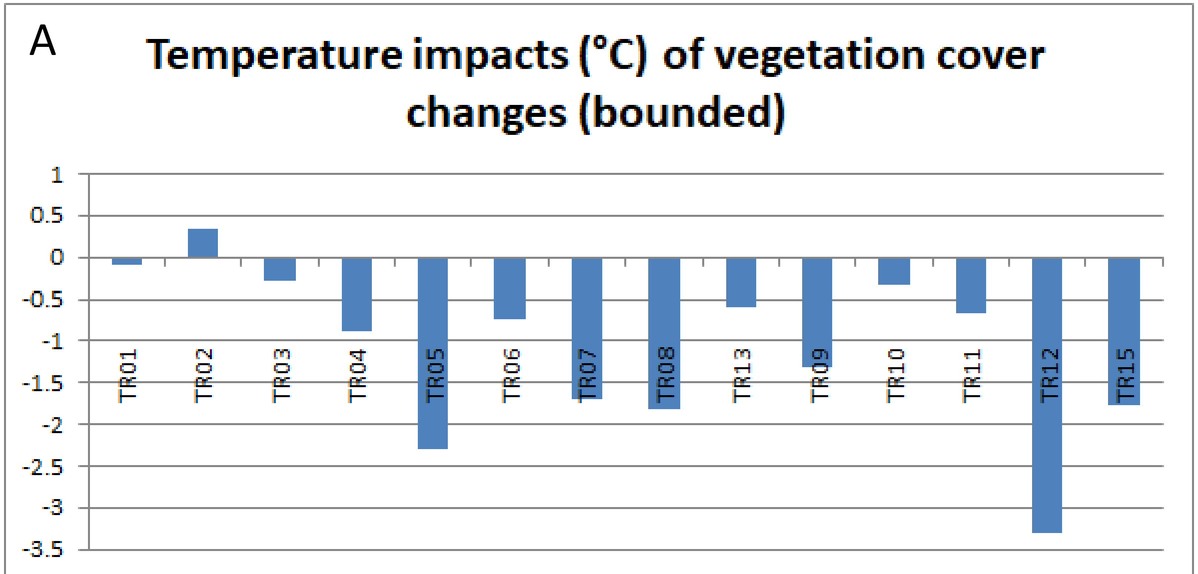


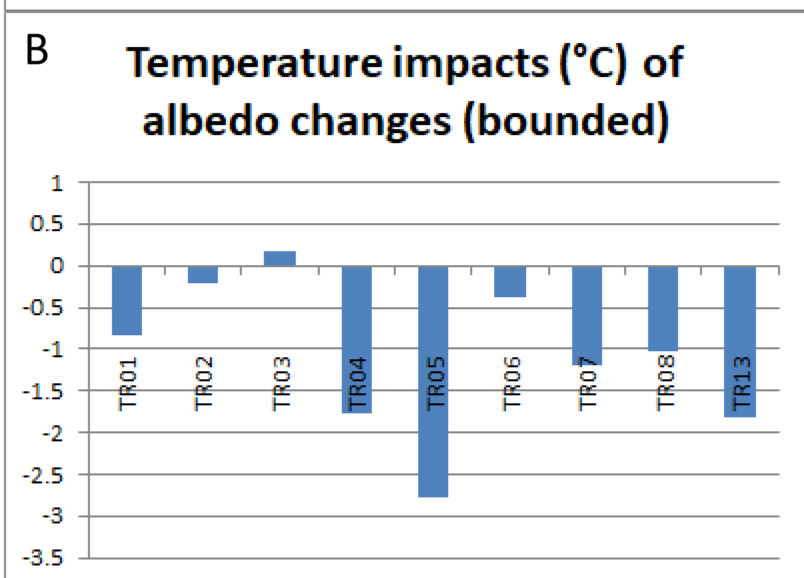
TR09: San Fernando Valley, 2017-07-27 day P1; WSP: 1.70 m/s; SOLAR: 912 W/m^2; VEG: -0.40°C /0.1, p-value: <0.0001

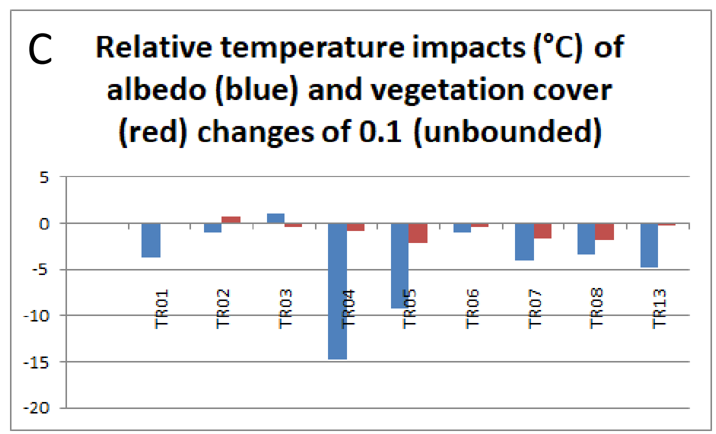


CART for transect TR13 (Downtown area)

Simple and multiple regression: Correlations with albedo and canopy cover



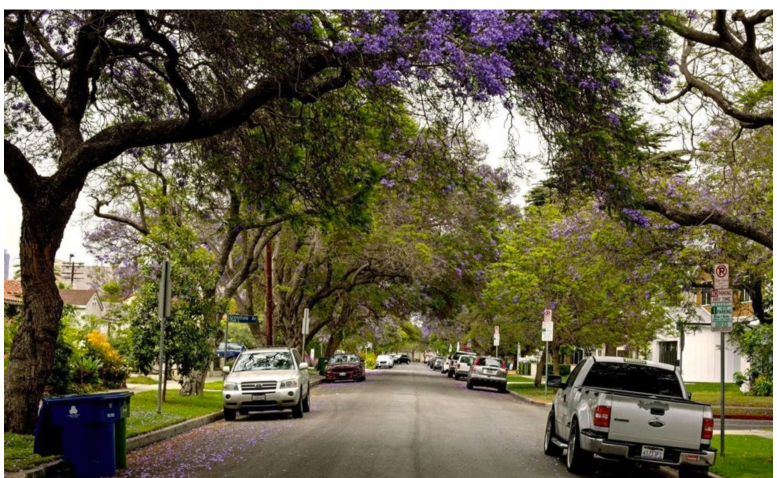




Application of results

Increases in albedo and tree cover were found to reduce air temperatures

Source: Central Roofing



Source: Los Angeles Times

- PWS analysis revealed increases in roof albedo at neighborhood scale are associated with reductions in air temperature
- Analysis from mobile transects also found a cooling effect from area-wide increase in albedo and/or canopy cover

These findings affect local implementation in California communities

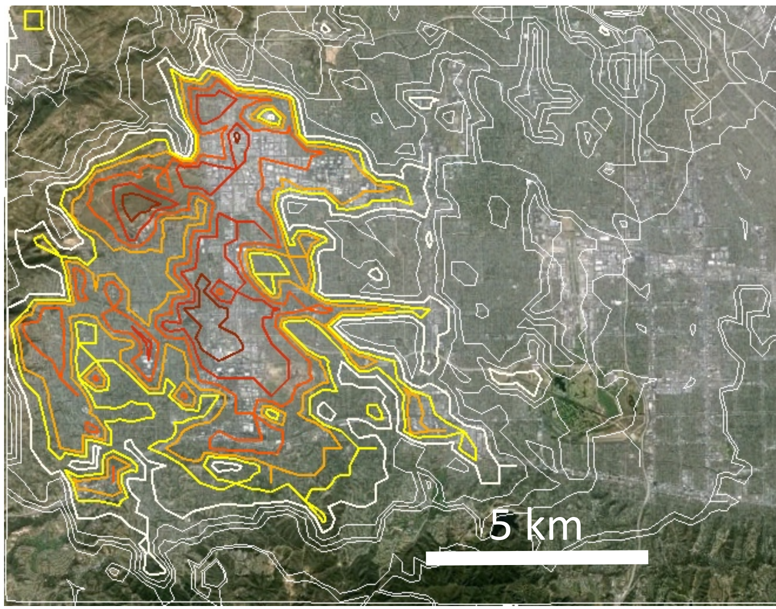
Source: Central Roofing

Source: Chandler's Roofing

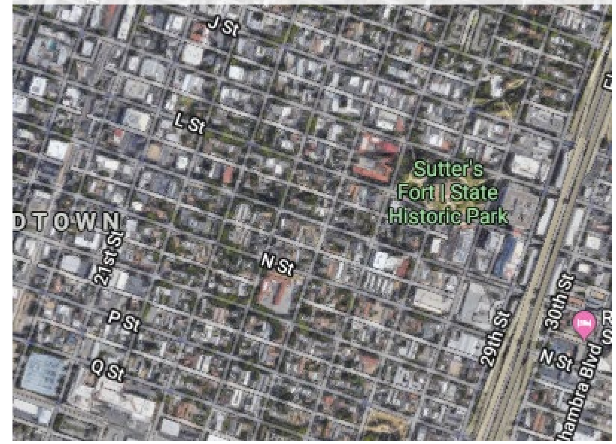
- Evidence in study from existing roof albedo & urban greening values which have room for improvement
- Cool roof & greening programs and policies can mitigate urban heat
- These programs can be tailored to be more effective

The calibrated model can be used in other communities in CA to find local UHIs

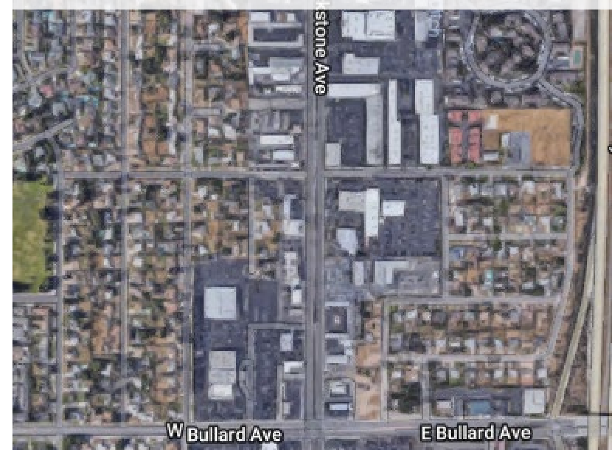
Model validation for Los Angeles



EXAMPLE: Sacramento, CA



EXAMPLE: Fresno, CA

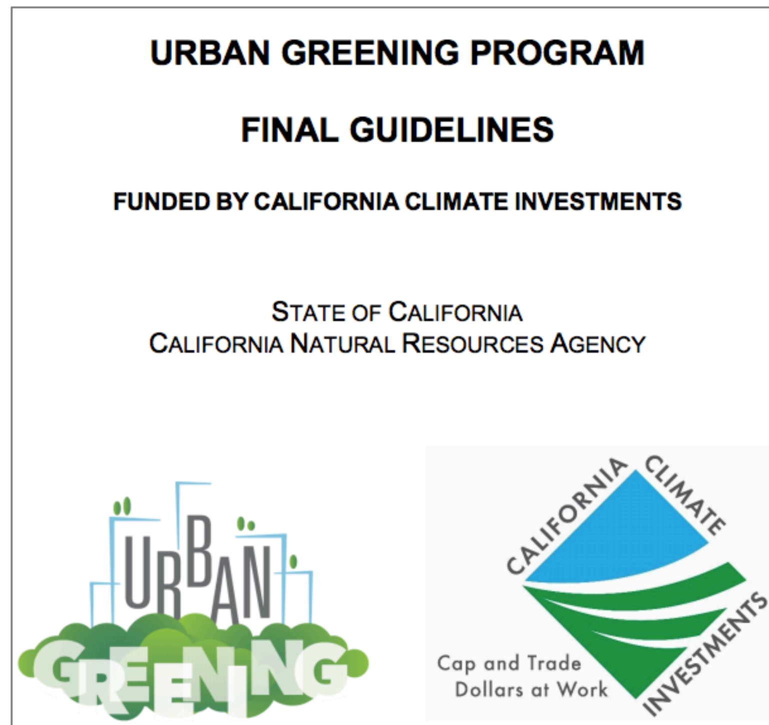


But same model and methodology can be applied to other CA communities

Local and state government programs could utilize project results

- City of Los Angeles Department of Water and Power's Cool Roof rebate program
- California Natural Resource Agency's Urban Greening program

Source: MCA Tile



URBAN GREENING PROGRAM

FINAL GUIDELINES

FUNDED BY CALIFORNIA CLIMATE INVESTMENTS

STATE OF CALIFORNIA
CALIFORNIA NATURAL RESOURCES AGENCY

Related publications

- Mohegh A, Levinson R, Taha H, Gilbert H, Zhang J, Li T, Tang T, Ban-Weiss G. 2018. Observational evidence of neighborhood scale reductions in air temperature associated with increases in roof albedo. *Climate* 6, 98 (19 pp). https://doi.org/10.3390/cli6040098

- Taha H, Ban-Weiss G, Chen S, Gilbert H, Goudey H, Ko J, Mohegh A, Rodriguez A, Slack J, Tang T, and Levinson RM. 2018. Modeling and observations to detect neighborhood-scale heat islands and inform effective countermeasures in Los Angeles. A report for California's Fourth Climate Change Assessment, report # CCCA4-CEC-2018-007. http://www.climateassessment.ca.gov/techreports/docs/20180827-Energy_CCCA4-CEC-2018-007.pdf

- Taha H, Levinson R, Mohegh A, Gilbert H, Ban-Weiss G, Chen S. 2018. Air-temperature response to neighborhood-scale variations in albedo and canopy cover in the real world: Fine-resolution meteorological modeling and mobile temperature observations in the Los Angeles climate archipelago. *Climate* 6, 53 (25pp). https://doi.org/10.3390/cli6020053

Thank you!