A Spatiotemporal investigation of heat wave characteristics and trends in Los Angeles

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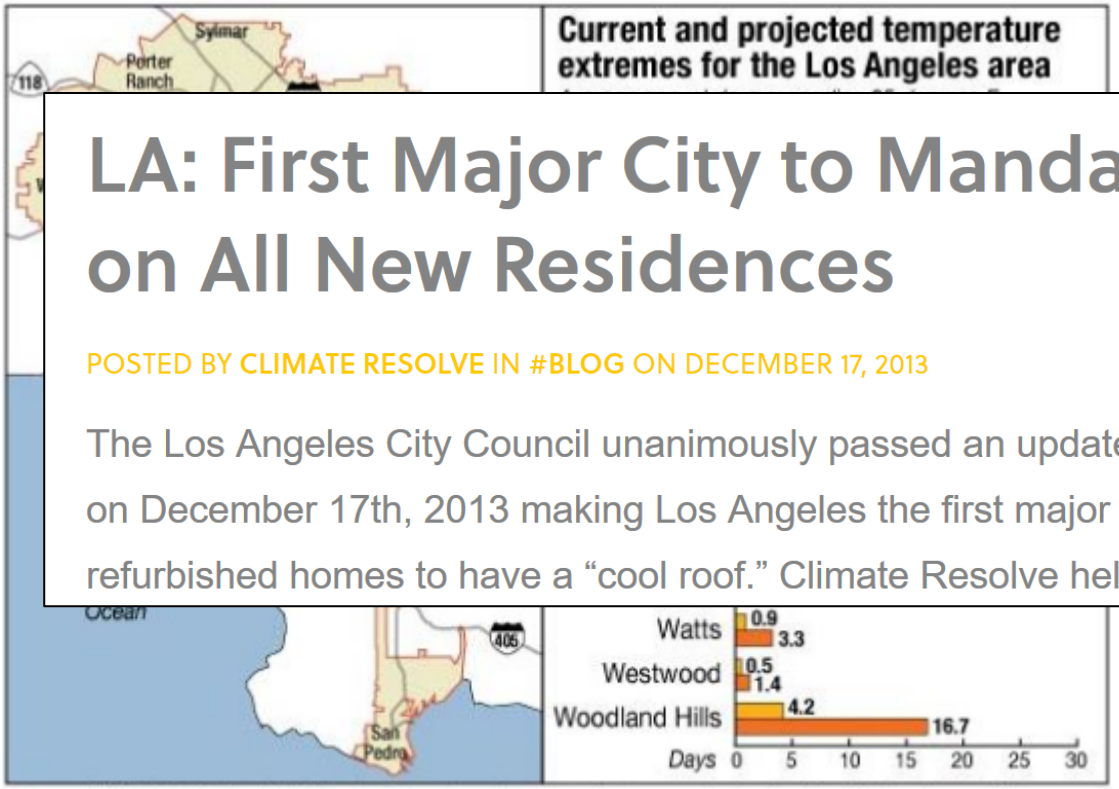
Outline

- Background and Motivation
- Heat waves
  - Definition
  - Detection
  - Trends
- Thermal remote sensing
  - Spatiotemporal LST patterns
  - Extreme heat day trends
  - Heat wave vulnerability maps

ENVIRONMENT + CLIMATE

Mercury rising: Greater L.A. to heat up an average 4 to 5 degrees by mid-century



Source: UCLA LARC study, 2012; chart based on the mean/average projected by the 19 climate models

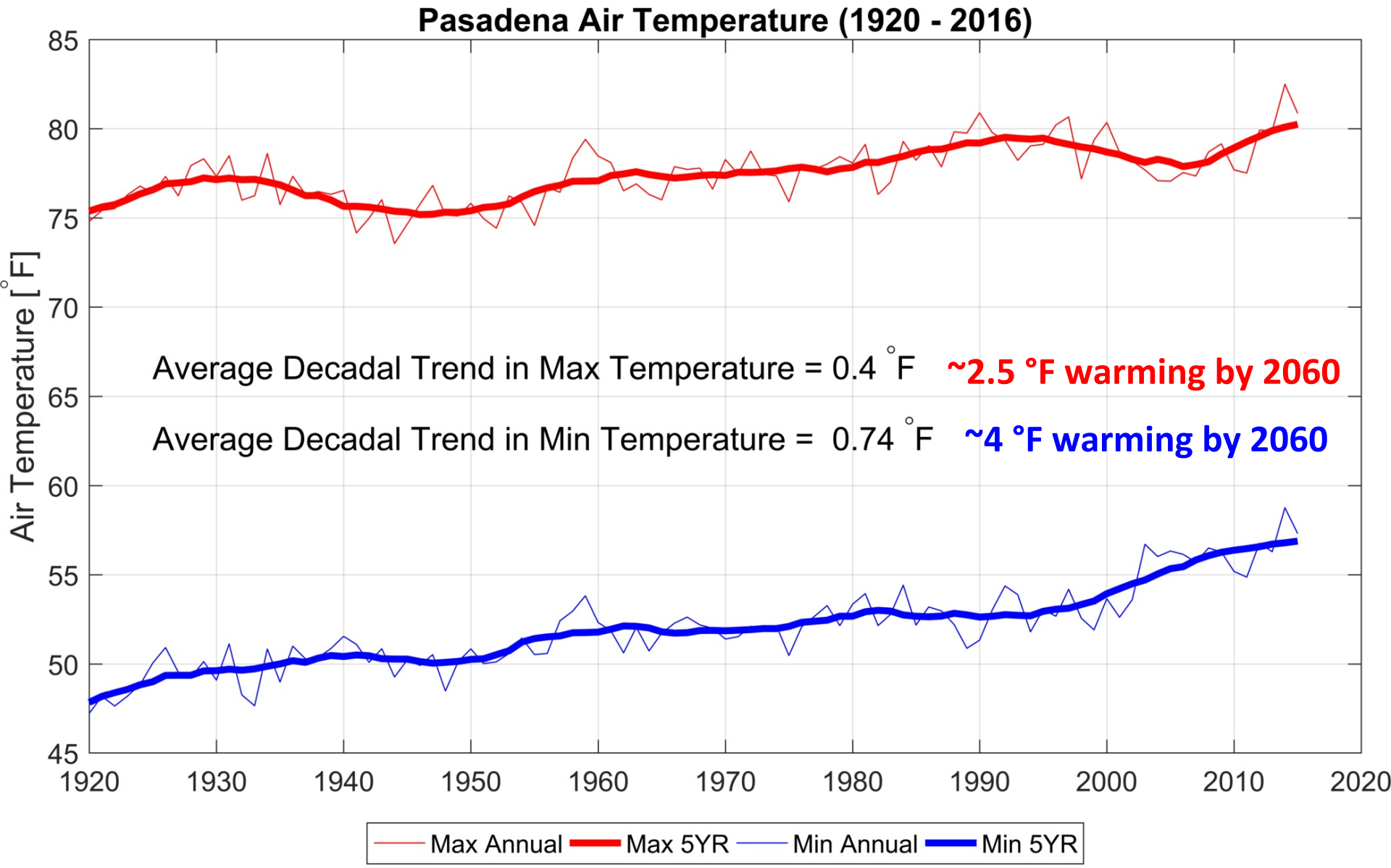
LA: First Major City to Mandate Cool Roofs on All New Residences

POSTED BY **CLIMATE RESOLVE** IN **#BLOG** ON DECEMBER 17, 2013

The Los Angeles City Council unanimously passed an update to the Municipal Building Code on December 17th, 2013 making Los Angeles the first major city to require all new and refurbished homes to have a "cool roof." Climate Resolve held the "Hot City, Cool Roofs"

Before and after: Current and projected temperature extremes in the L.A. area.

UCLA LARC Study (Hall et al. 2012) – ensemble climate model projection



Data Source: NCDC COOP

..On a global scale

NATURE CLIMATE CHANGE | LETTER

Global risk of deadly heat

Camilo Mora, Bénédicte Dousset, Iain R. Caldwell, Farrah E. Powell, Rollan C. Geronimo, Coral R. Bielecki, Chelsie W. W. Counsell, Bonnie S. Dietrich, Emily T. Johnston, Leo V. Louis, Matthew P. Lucas, Marie M. McKenzie, Alessandra G. Shea, Han Tseng, Thomas W. Giambelluca, Lisa R. Leon, Ed Hawkins & Clay Trauernicht

Nature Climate Change **7**, 501–506 (2017) | doi:10.1038/nclimate3322

Currently, about 30% of the world's population experiences at least 20 days per year of potentially deadly heat.

By 2100, this percentage jumps to 74% of the population if emissions continue unchecked.

Heat Waves

Most common cause of weather-related deaths in the United States!

They cause more deaths each year (~1,500) than hurricanes, lightning, tornadoes, floods, and earthquakes combined (~200).

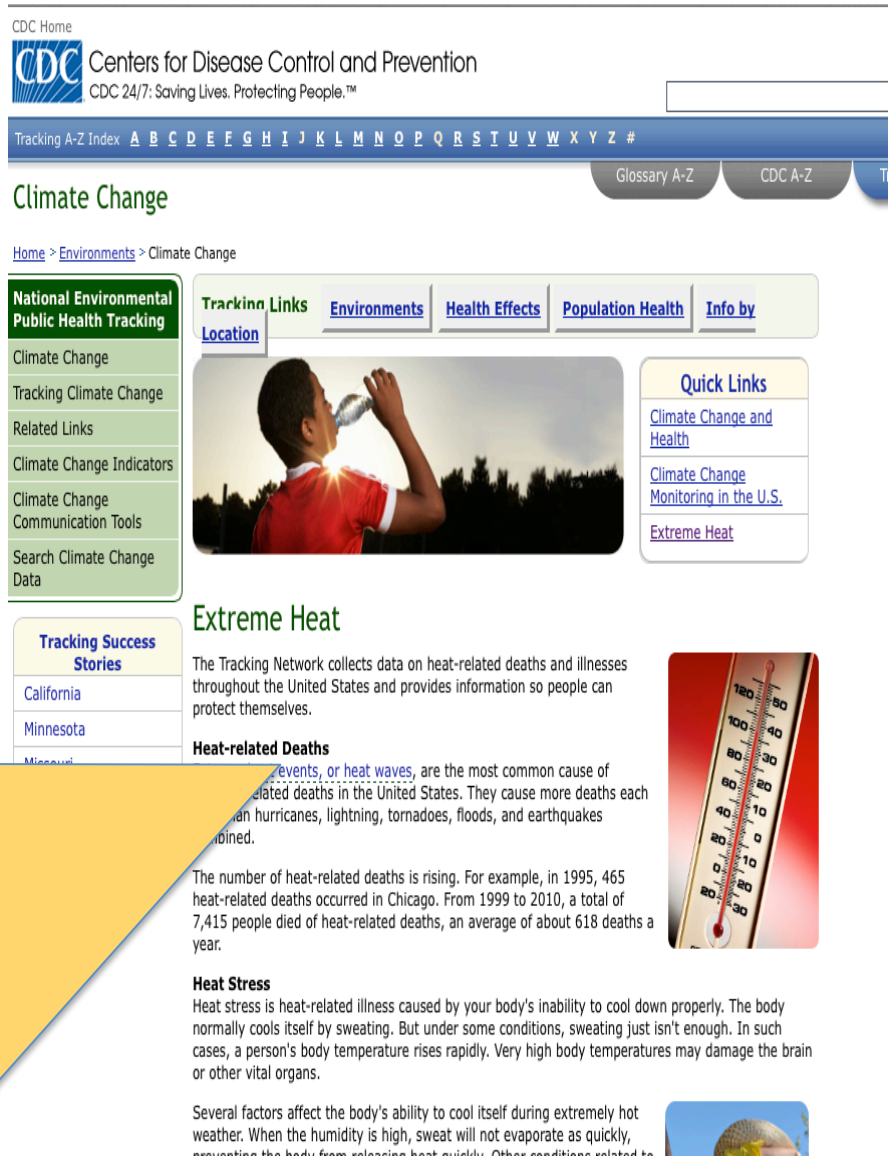
The number of heat-related deaths is rising.

1995: 465 deaths in Chicago.

2003: 15,000 deaths in Paris

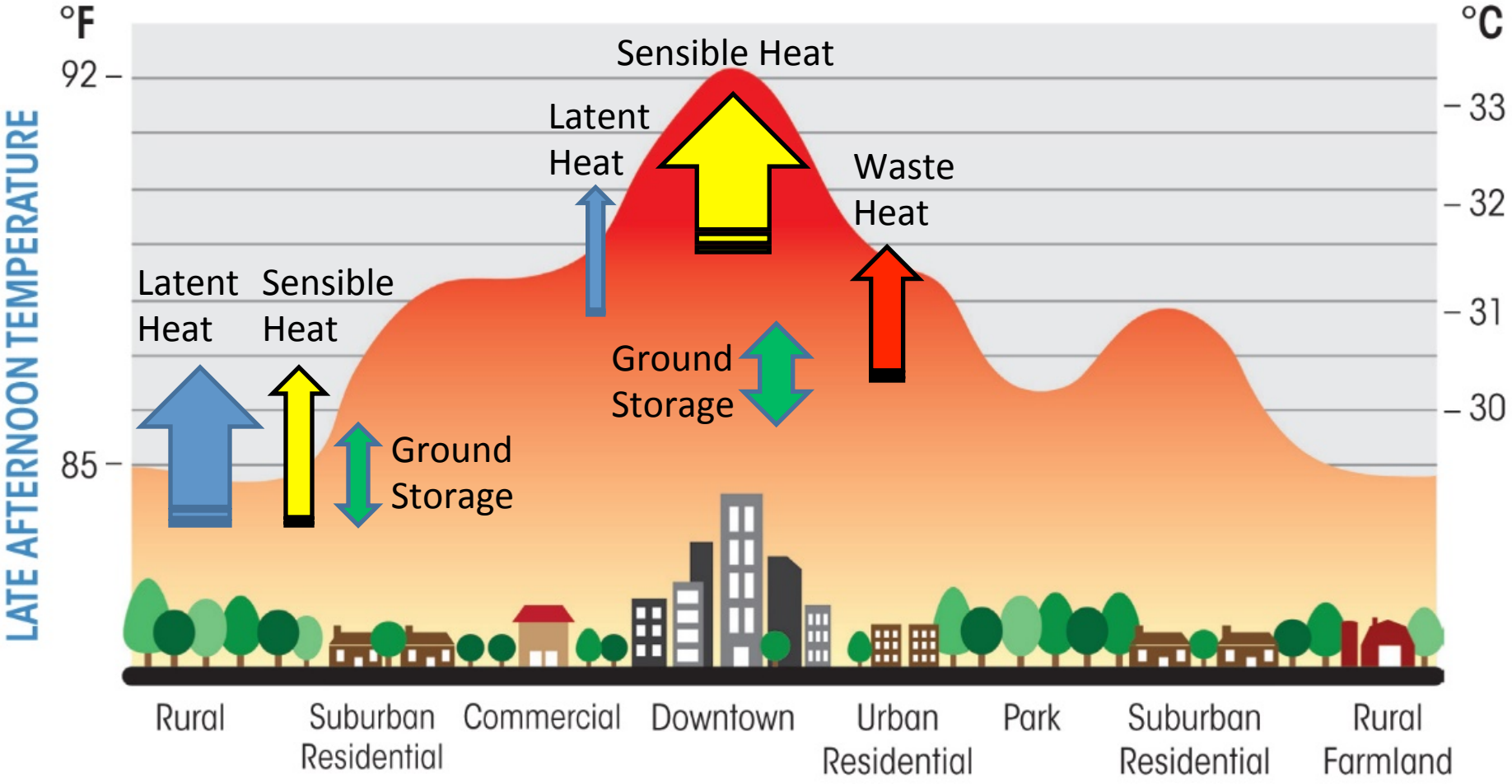
2010: 10,000 deaths in Russia

2013: 760 deaths in UK

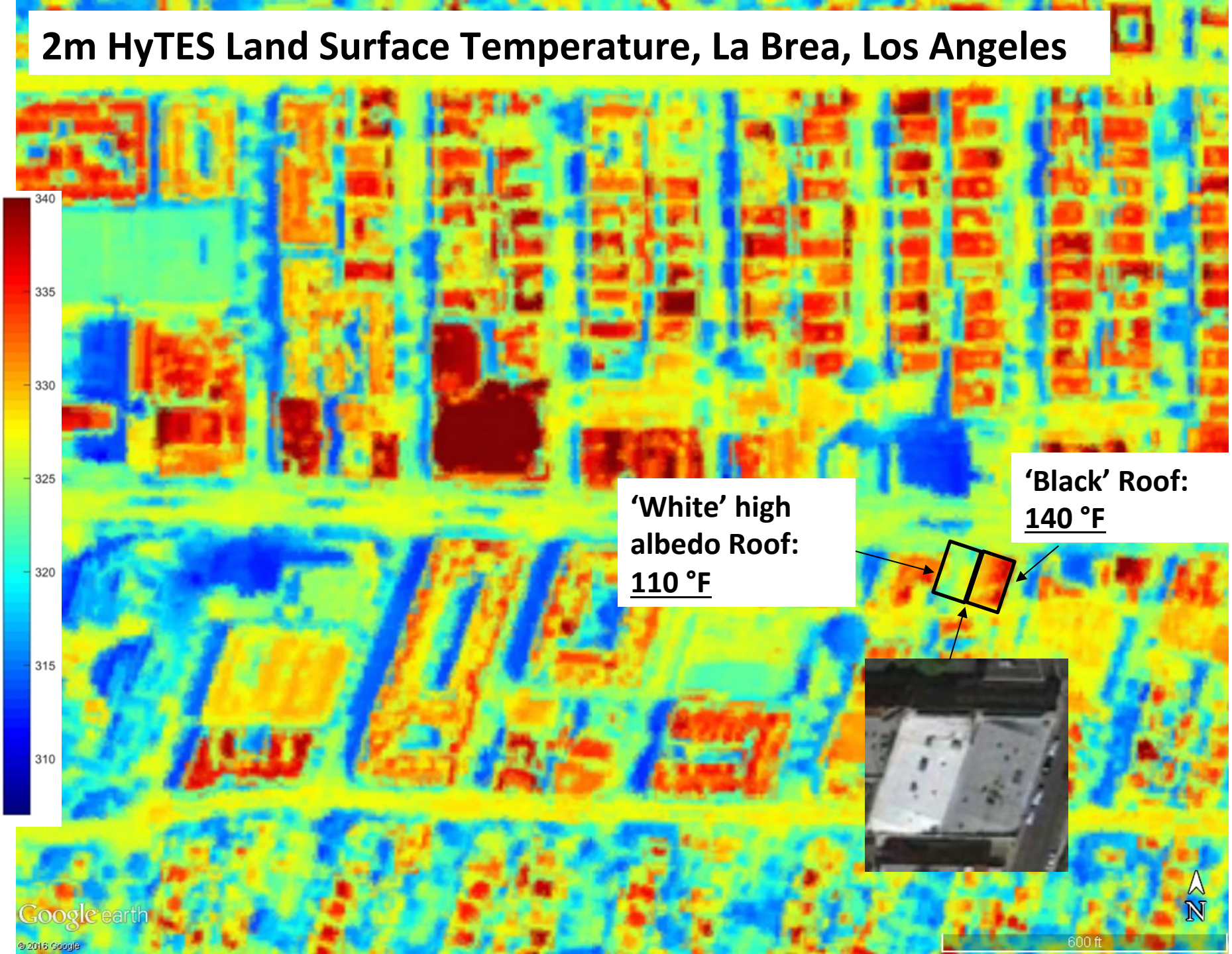


Urban Heat Island (UHI) Effect

Energy absorbed by man-made materials during day is released slowly at night resulting in heating of air



2m HyTES Land Surface Temperature, La Brea, Los Angeles



Heat wave definition

- *Excess Heat Index (EHI)*
  - Unusually high heat arising from daytime temperatures that is not discharged overnight due to combined overnight high temperature

$$\boldsymbol{EHI = T_i - T_{97.5}}$$

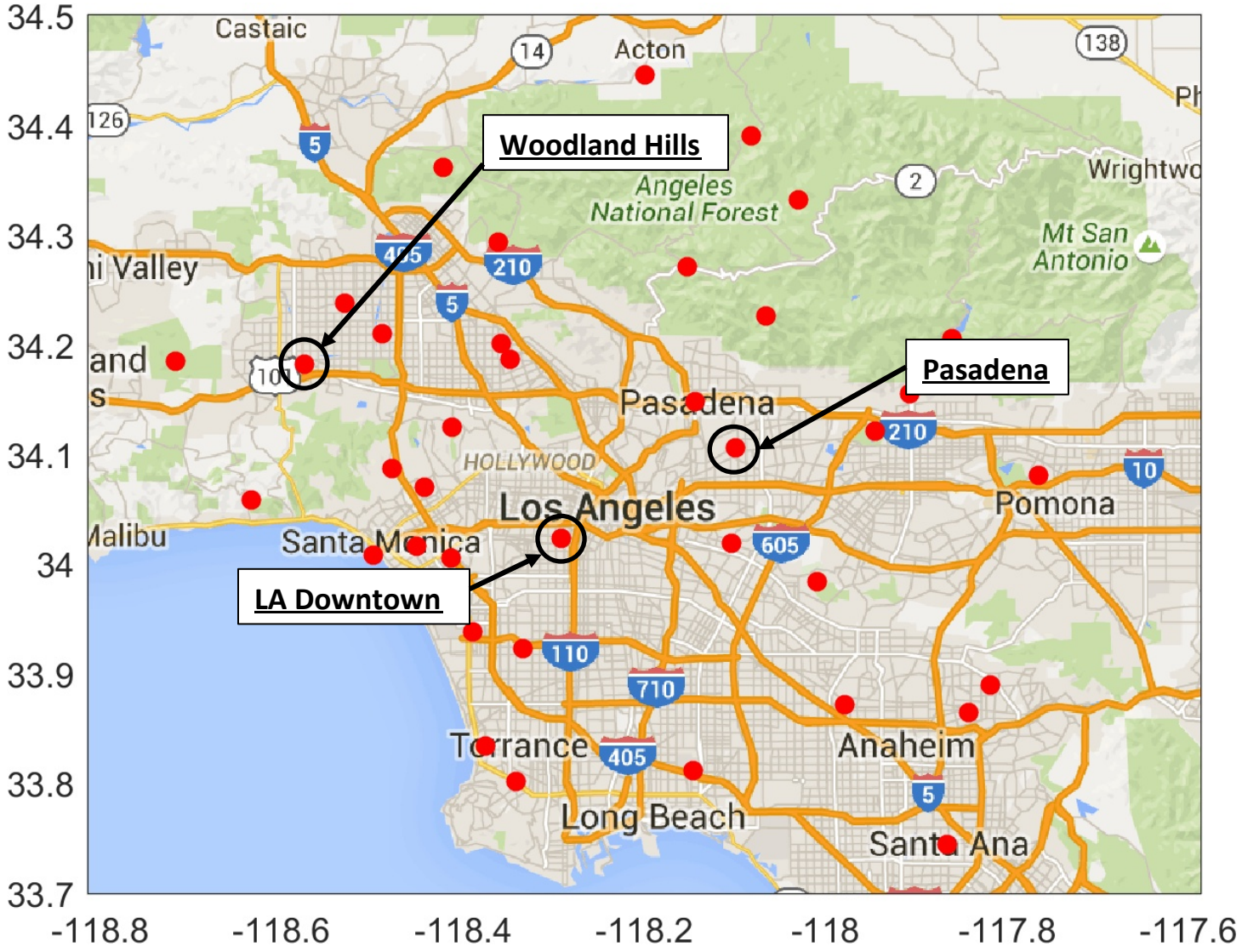
Where, $T_i = (T_{max} + T_{min})/2$

$T_{97.5} = 98^{th}\ percentile\ of\ daily\ T_i\ climatology$

*T_i = apparent temperature = -2.7 + 1.04*T + 2.0*RH -0.65*Vs*
Temperature equivalent as 'felt' by humans

Heat wave = 3 or more consecutive days where EHI values exceed a threshold

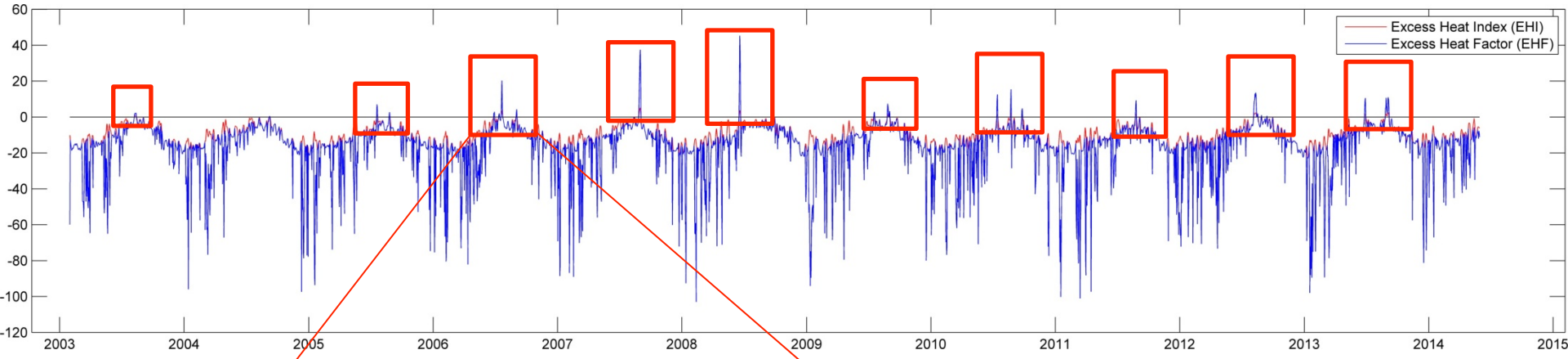
Heat wave trend statistics using NOAA COOP air temperature data (1920 – 2017)

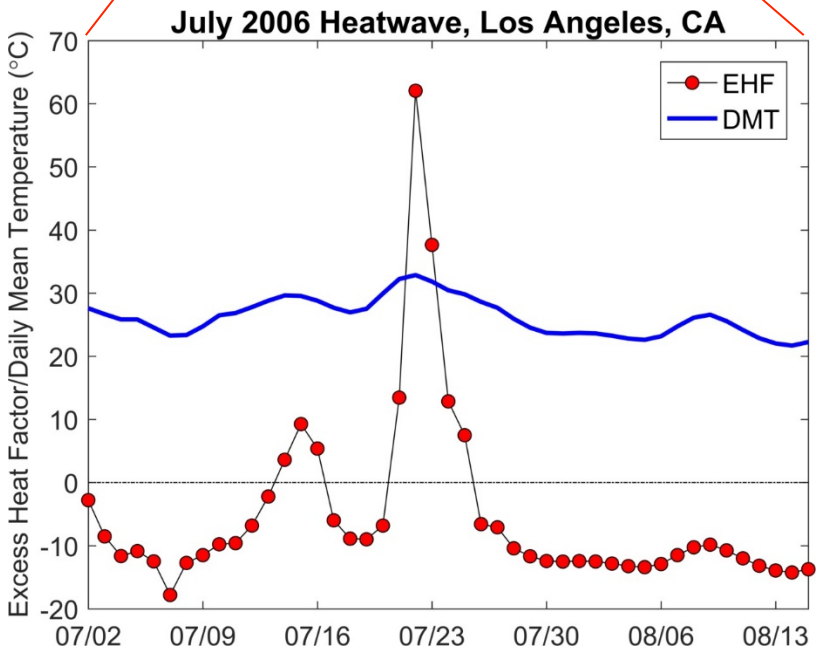


Heat Wave Detection

NCDC 2m Air Temperature – Downtown LA

heatwave: 3 or more consecutive days where EHI values exceed a certain threshold (0, or 20 for extreme)



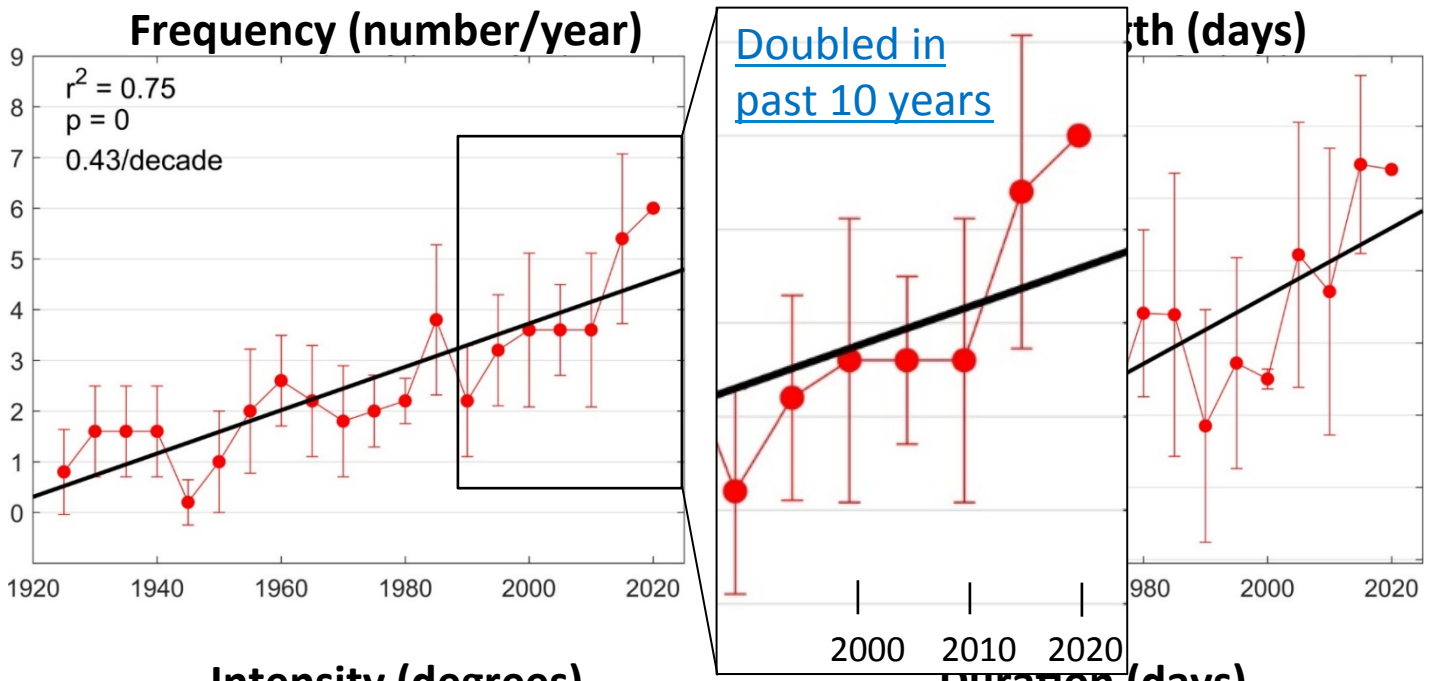


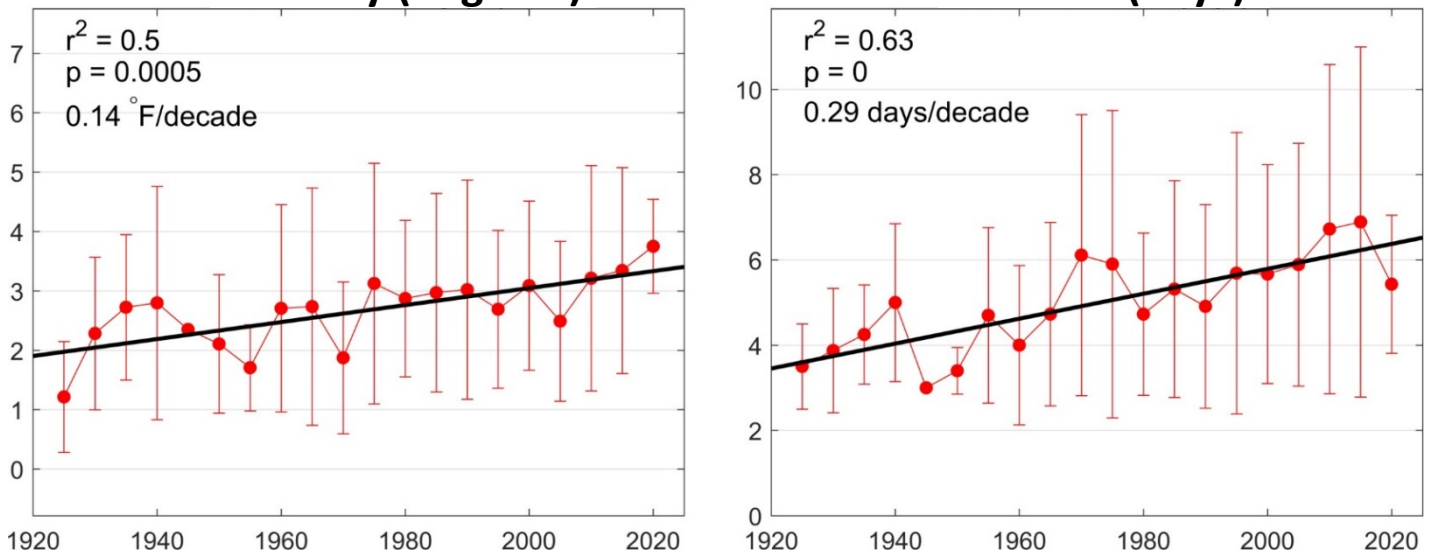
LA July 2006 Heat wave:

- Valley temperatures peaked at 119 °F (all time record)
- Combination of high heat/humidity
- 30 deaths across CA state

Heat Wave Trends

(Each point represents 5-year average)



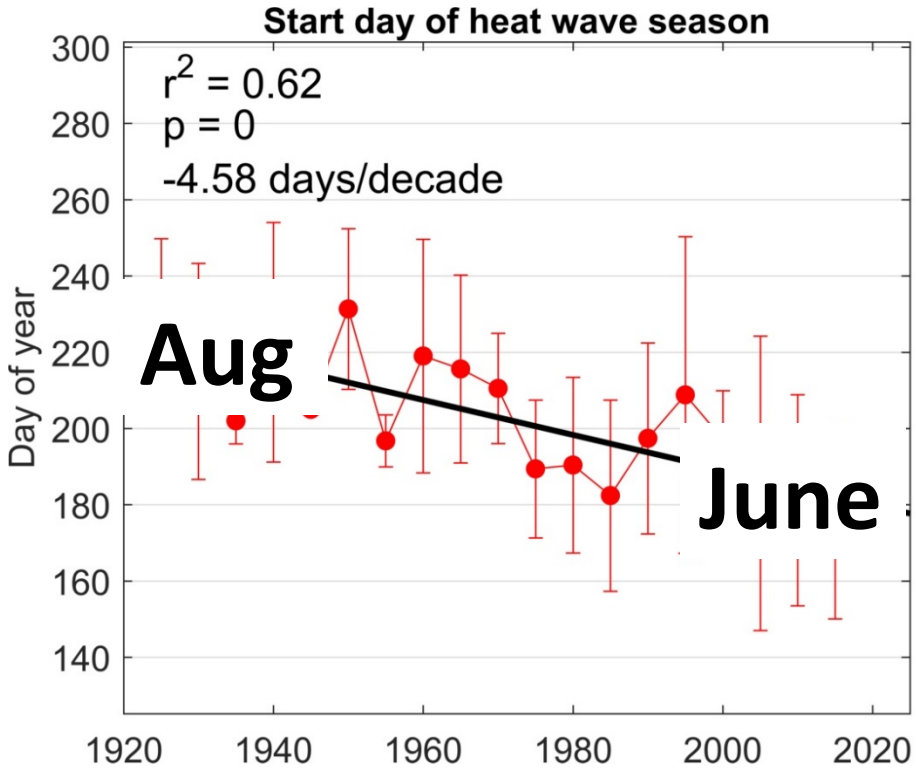


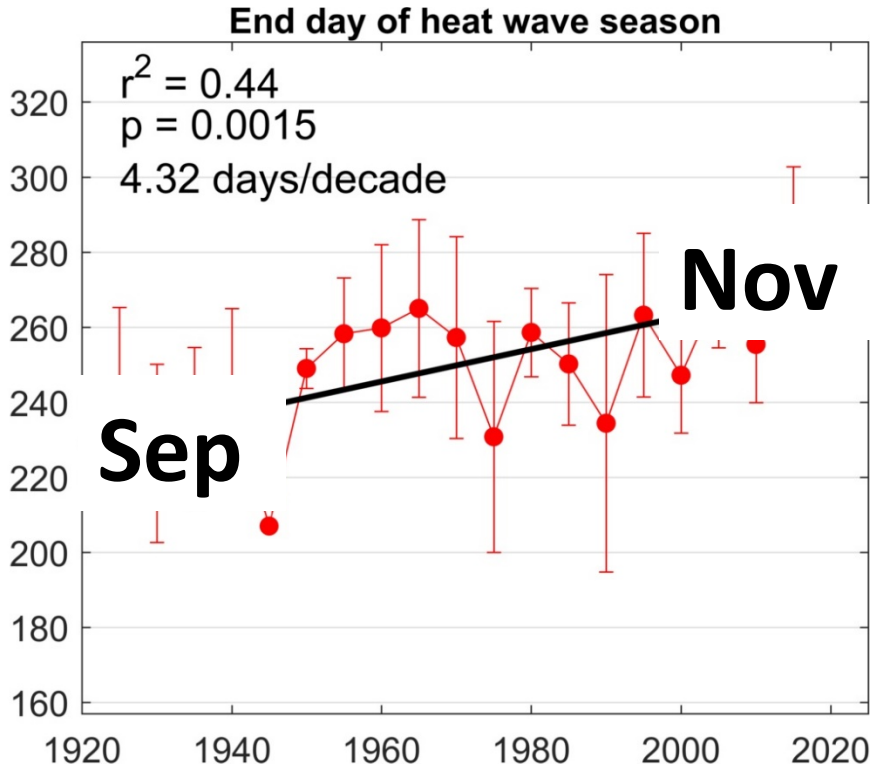
Increases Fire risk!

Human health/ comfort impacts

Pasadena heat wave seasonality

Heat waves are starting earlier in the year and ending later = increased fire risk

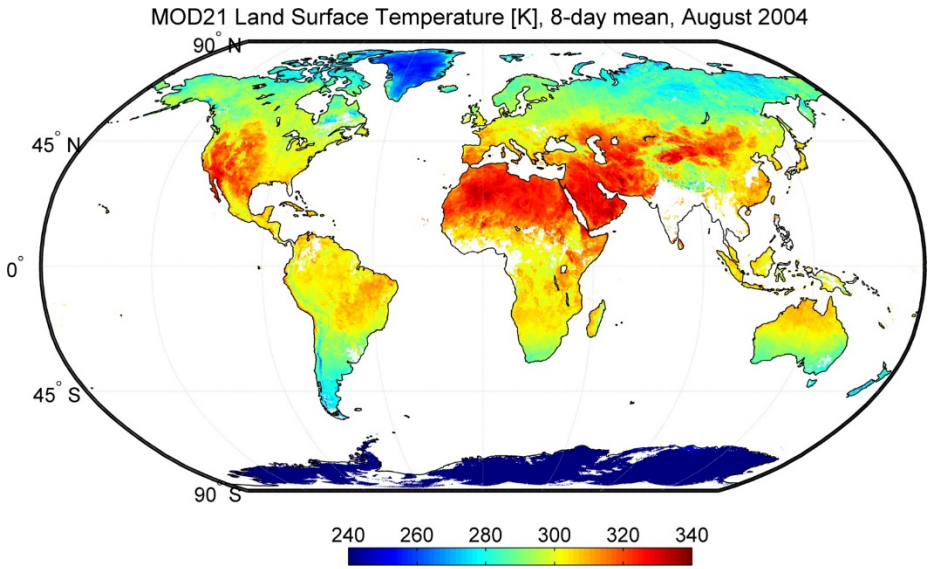


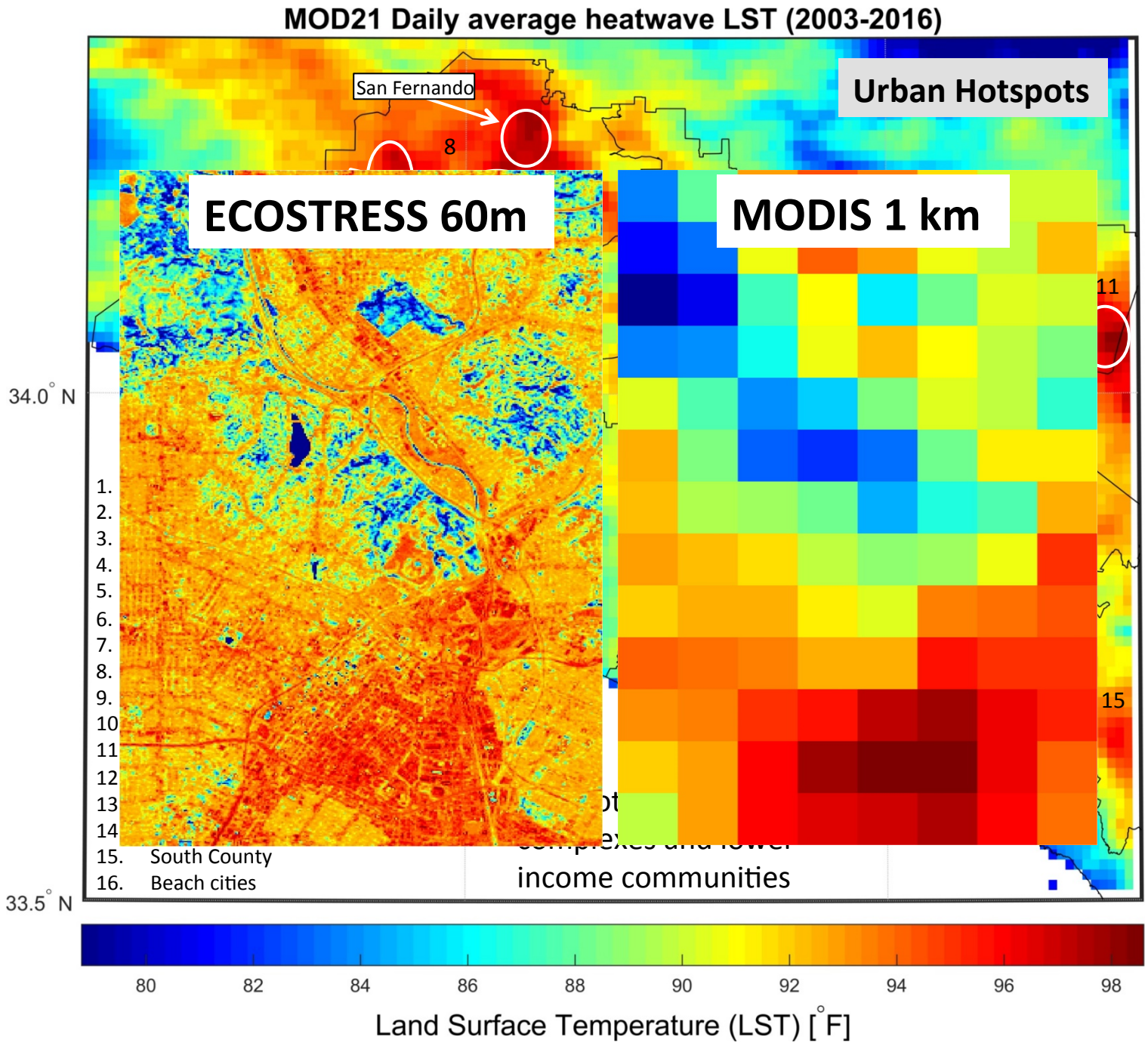


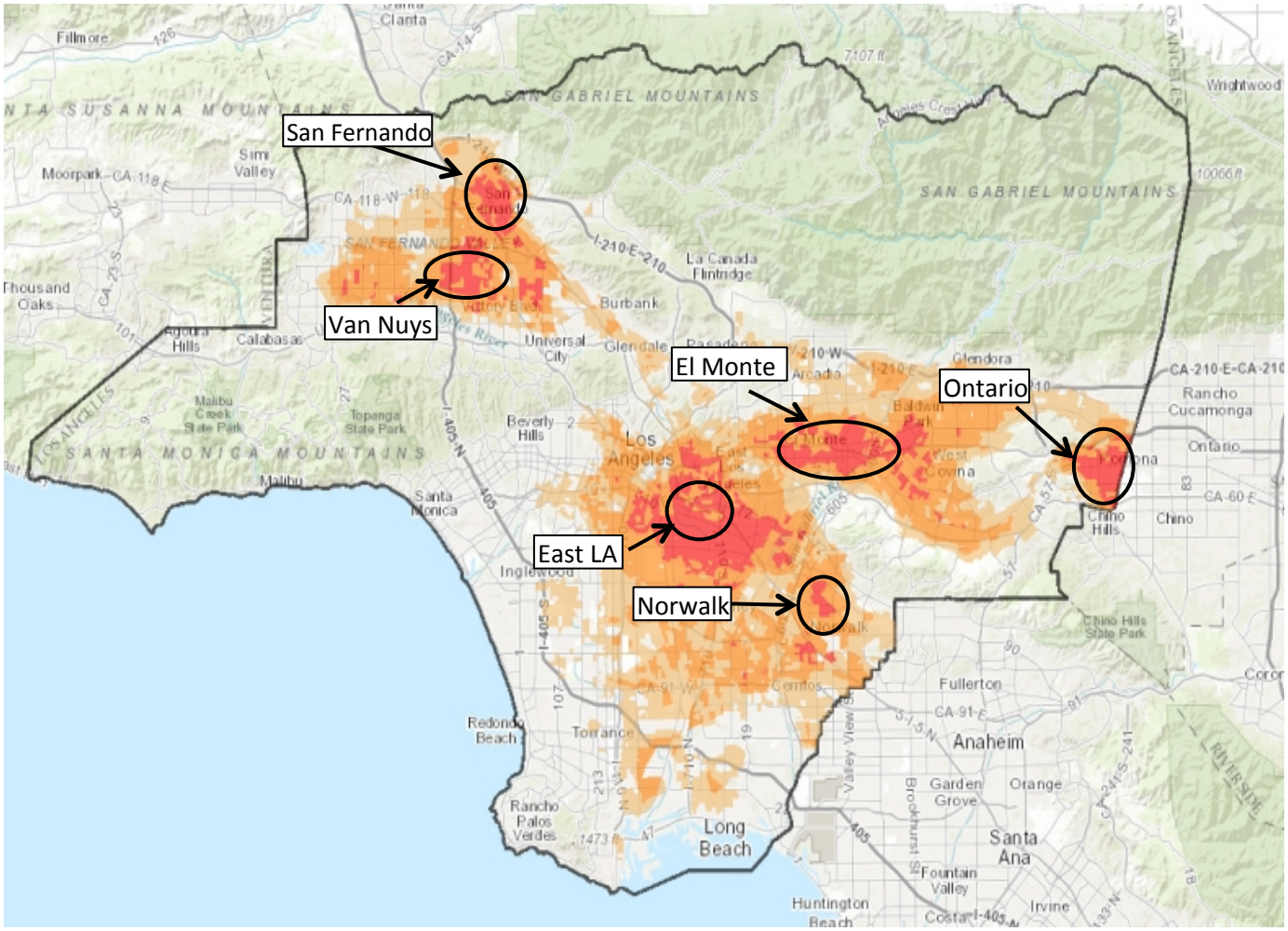
New MODIS LST Product (JPL) – Collection 6

New Products	PI	Status	Spatial	Formats	Algorithm	SDS
MOD21	**Hulley (JPL)**	Released with Tier-2 Collection 6 (Fall 2017)	1-km	L2 Swath, L2 8 day 2X Daily	Temperature Emissivity Separation (TES)	- LST - Emissivity bands 29, 31, 32

LST and Emissivity physically retrieved (ECOSTRESS, HyspIRI, MASTER)




MOD21 Daily average heatwave LST (2003-2016)
San Fernando
8
Urban Hotspots
ECOSTRESS 60m
MODIS 1 km
11
15
34.0° N
33.5° N
1.
2.
3.
4.
5.
6.
7.
8.
9.
10
11
12
13
14
15. South County
16. Beach cities
income communities
80
82
84
86
88
90
92
94
96
98
Land Surface Temperature (LST) [°F]

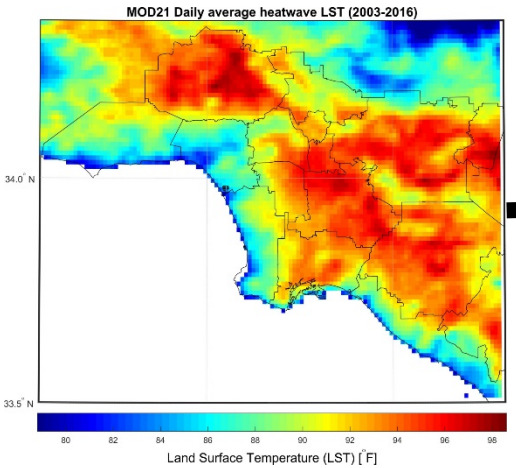


Heat Vulnerability map based on demographic information (income, education, age), identifies communities most vulnerable to rising temperatures.

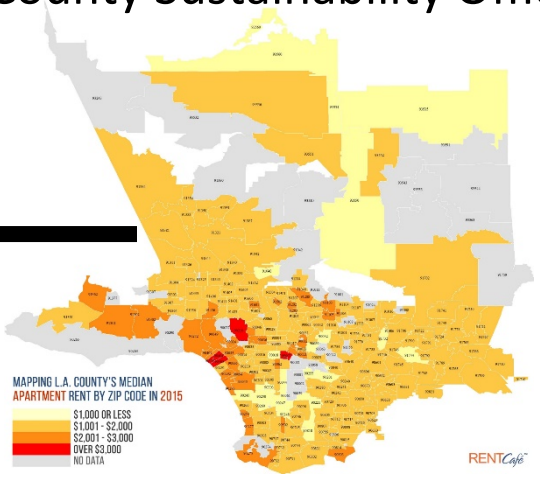
Good correlation with LST data from MODIS. But some areas missed!

Source: Climate Smart Cities program, Fernando Cazares.

LST Data
(MODIS, ECOSTRESS, HyspIRI)



Demographic Data
(LA County Sustainability Office)



Human-Comfort Model (COMFA)
Brown et al. 1995

Urban Heat Stress Index (UHSI)

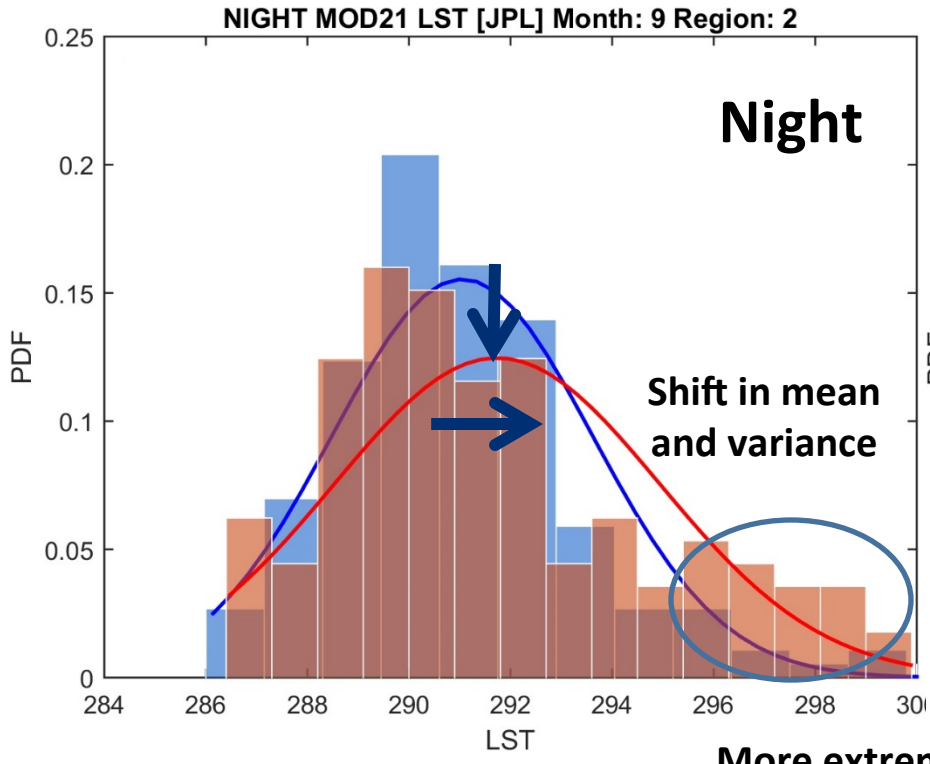
- Near real-time
- Communicated to local officials
- Heat warnings
- Used in mitigation efforts
- Extend to other major cities

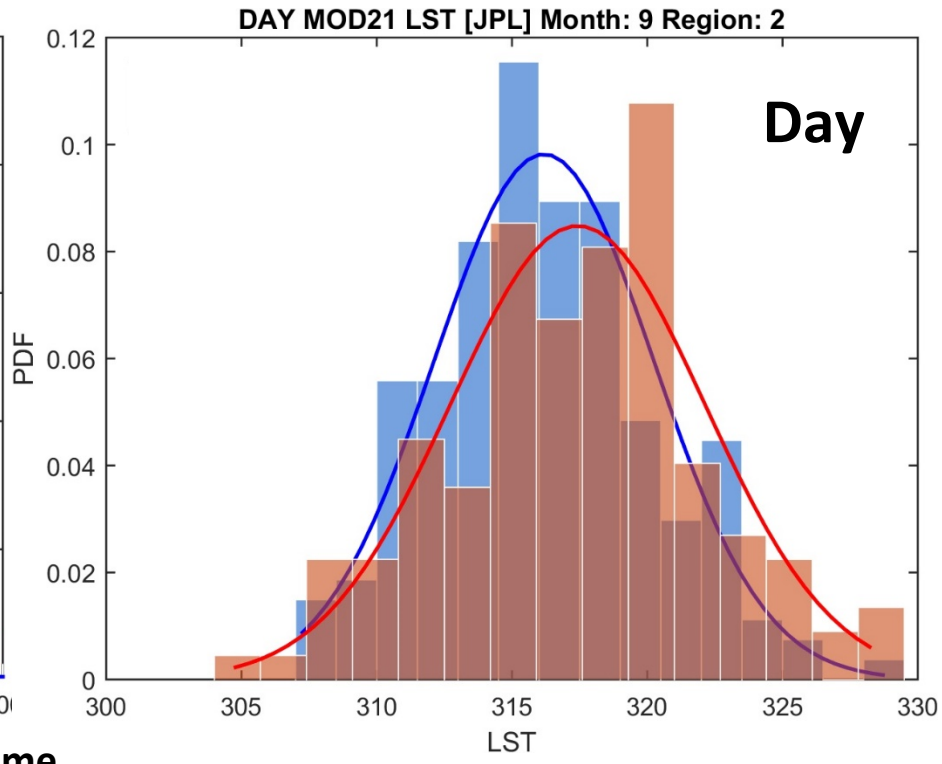
MOD21 day/night LST PDF

2003-2009

2009-2016

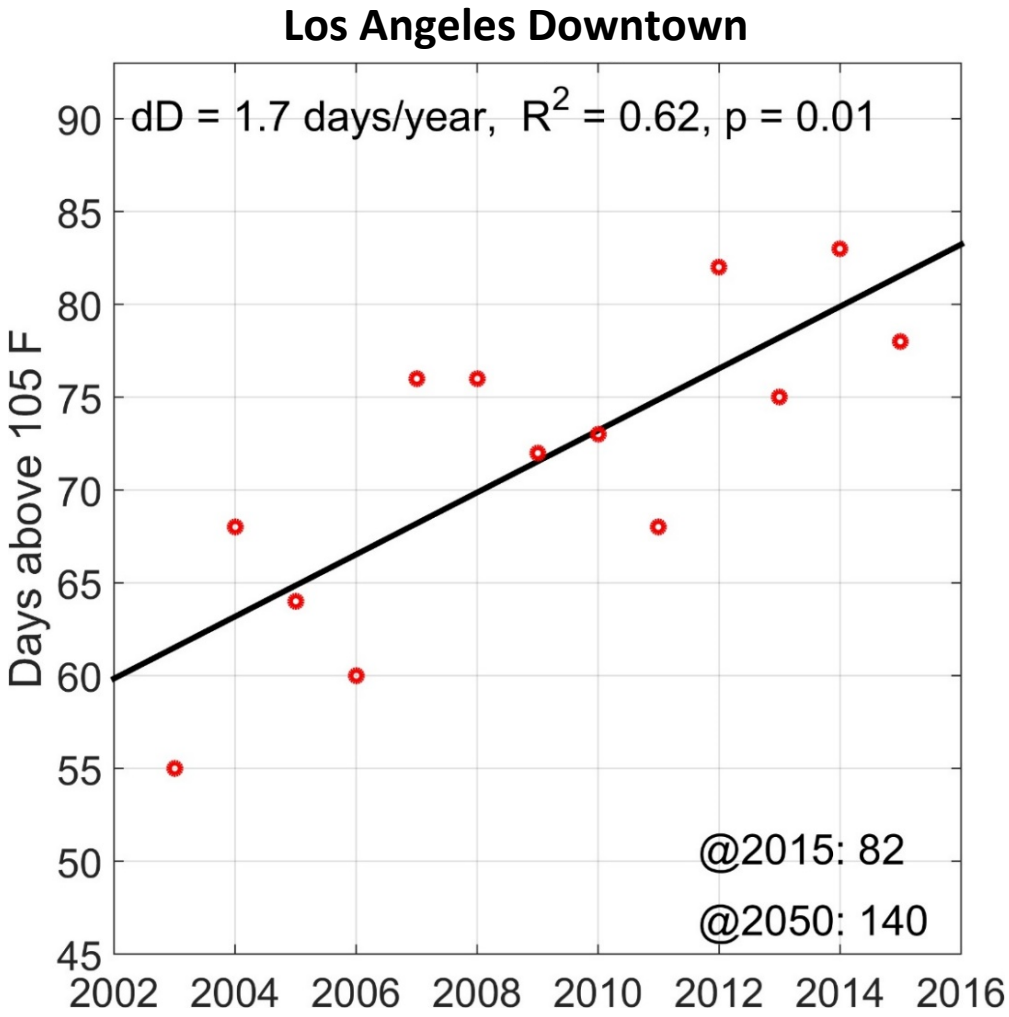
East LA, September



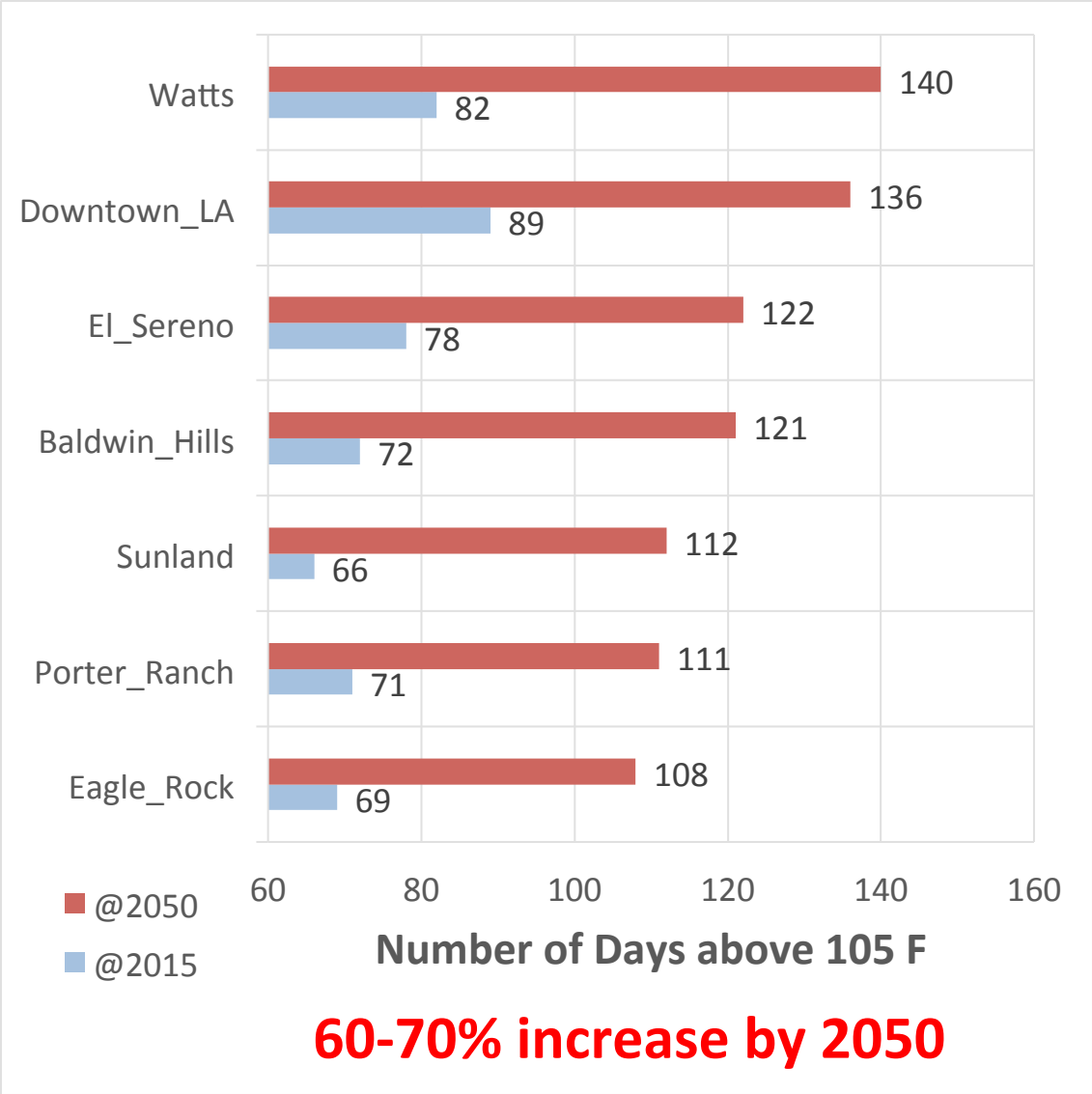


More extreme
temperatures

Days with MODIS LST > 105 °F

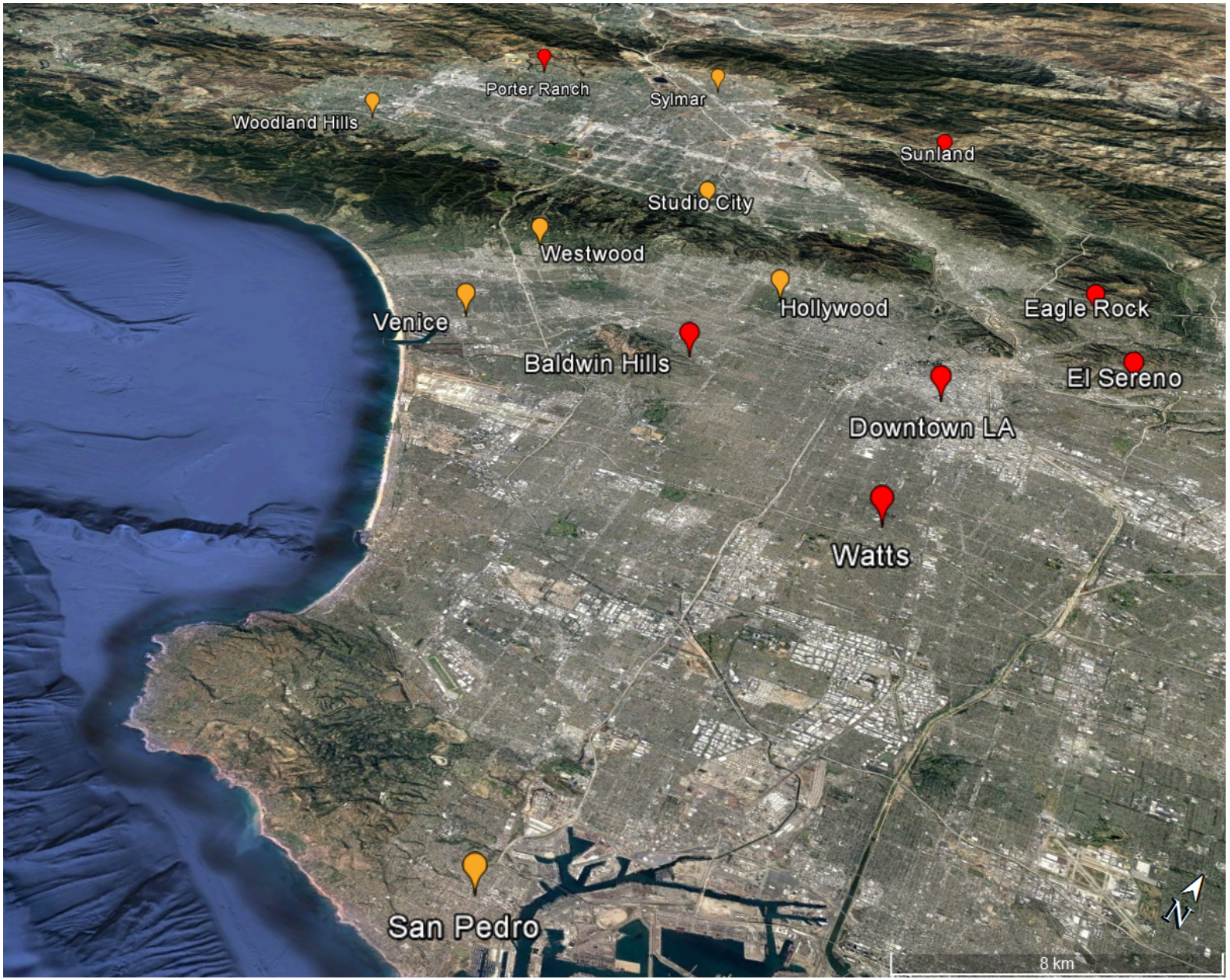


Areas with significant trends (2003-2017)



60-70% increase by 2050

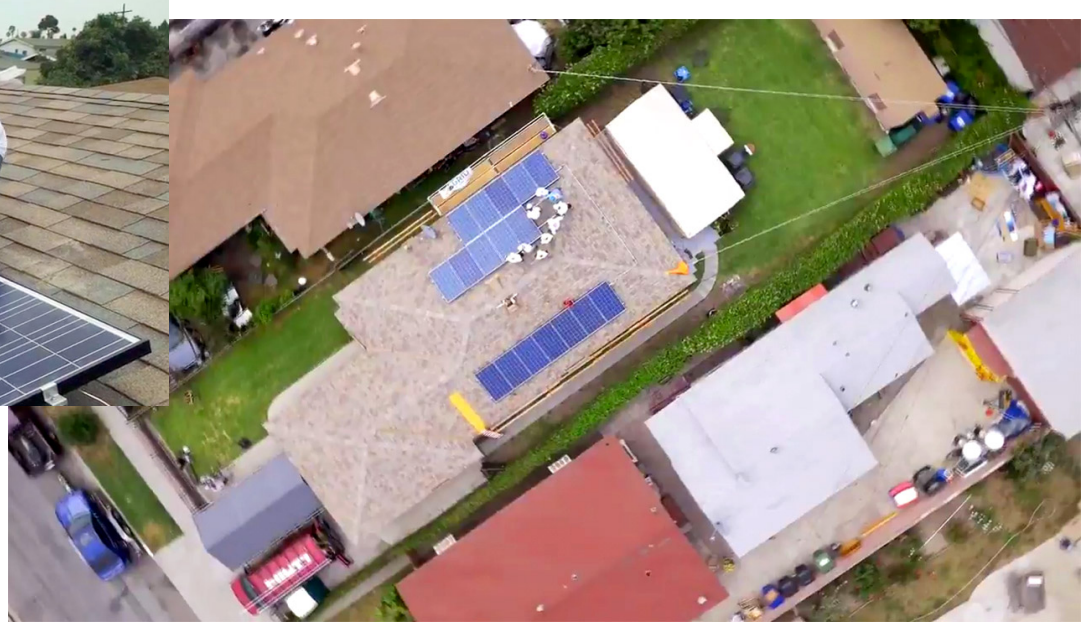
More extreme temperatures expected inland



$p < 0.05$
$R^2 > 0.3$

Climate Resolve

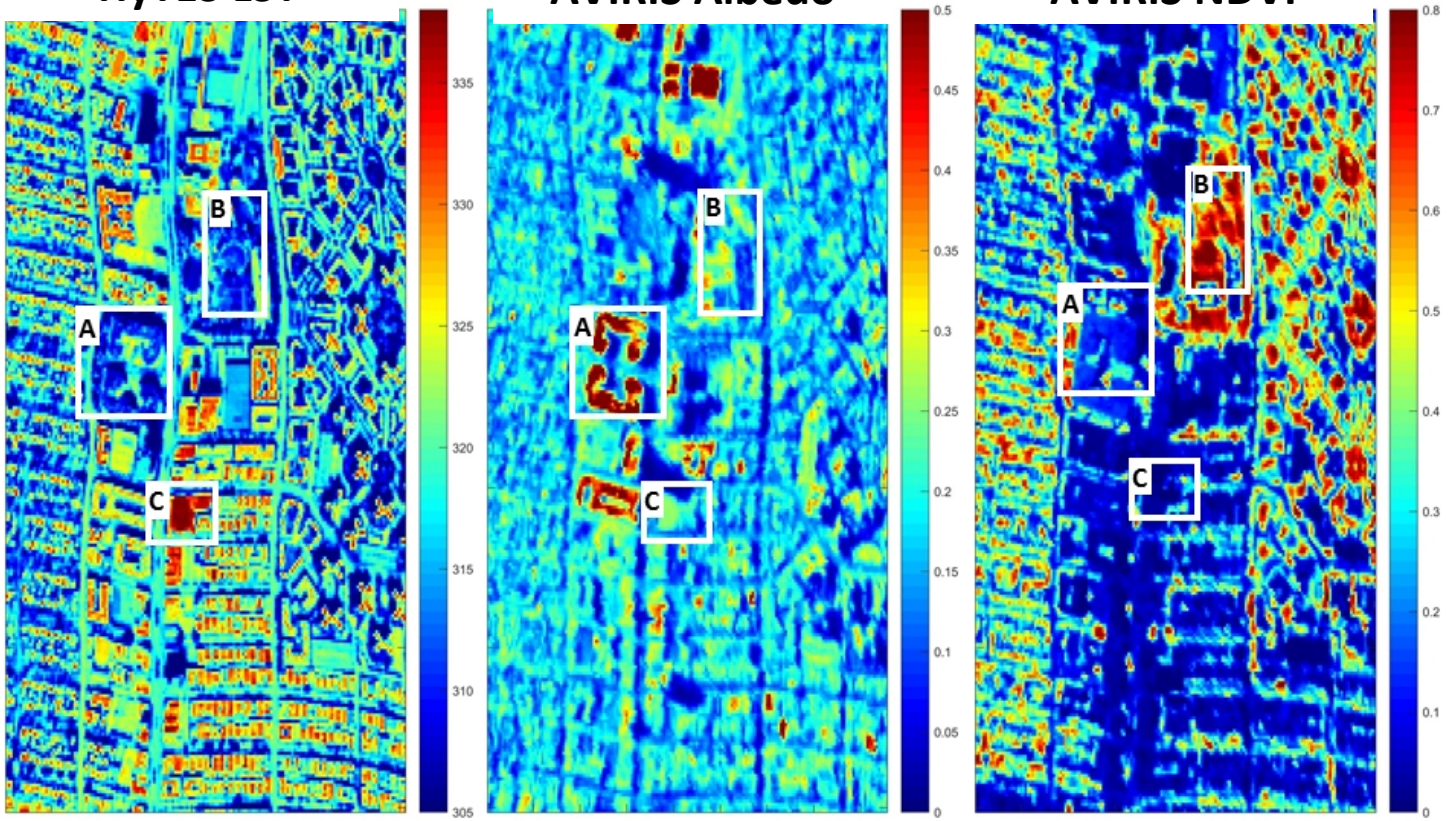
LARC
Los Angeles Regional Collaborative
for Climate Action and Sustainability

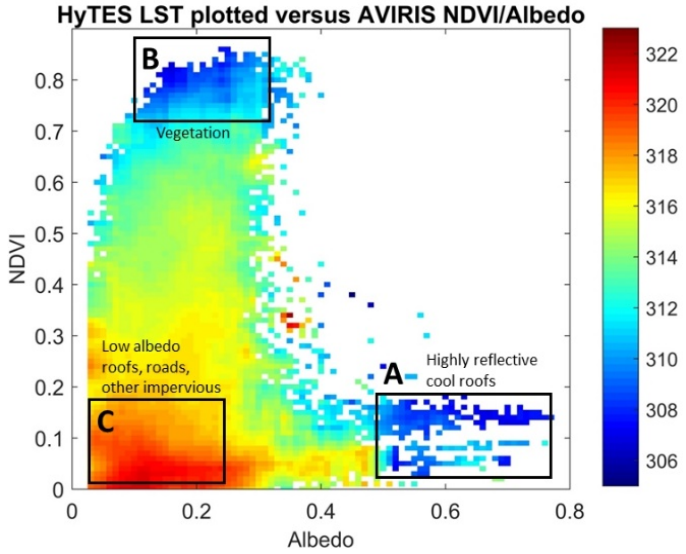


Urban Thermal Sharpening

- Imaging spectroscopy in VSWIR (0.4-2.5 um) can be acquired at higher spatial resolution than TIR (8-12 um)
- TIR wavelengths are longer – larger optics, cooling challenges

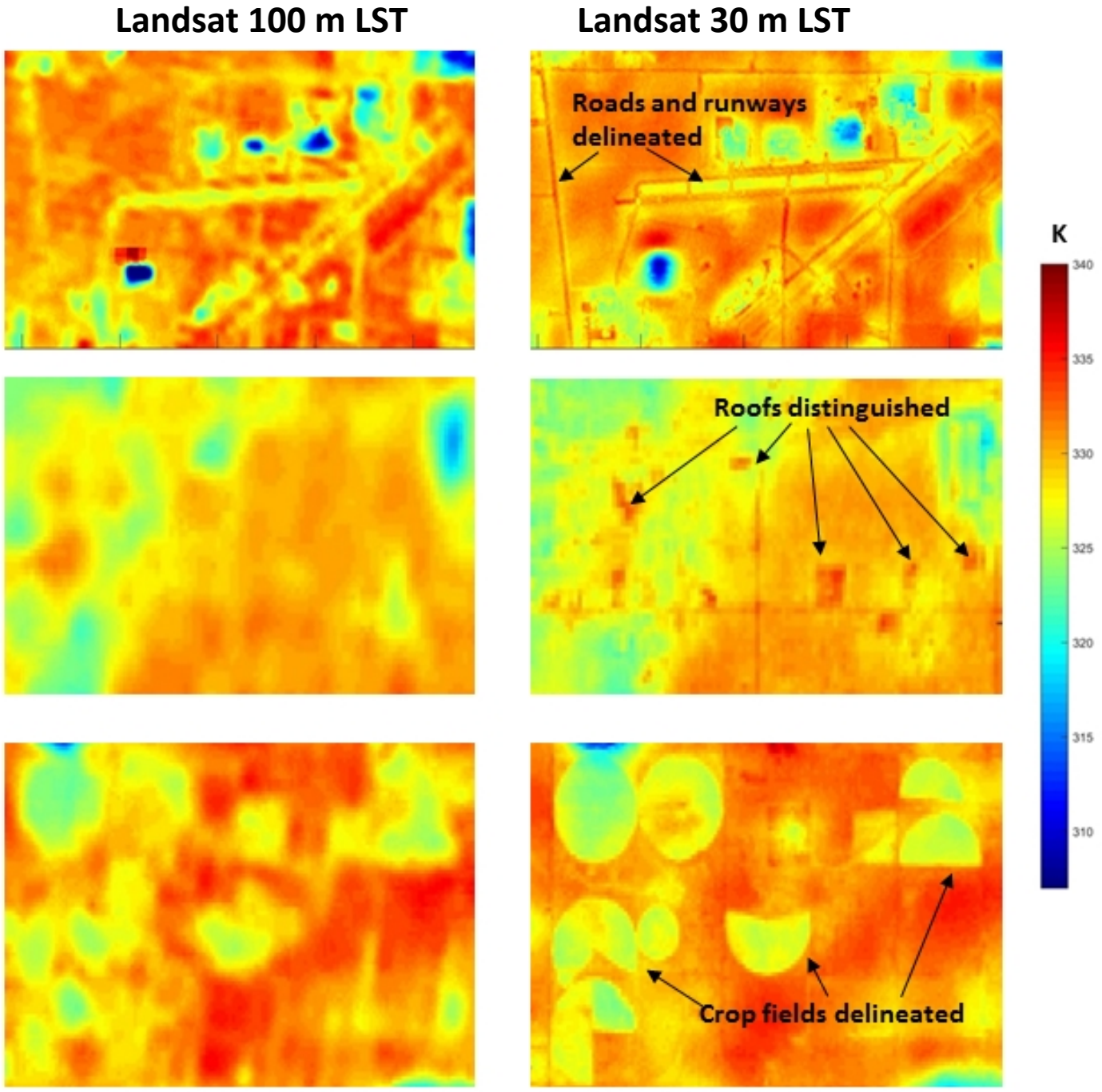
Resolution	SWIR	TIR
MODIS	250-500m	1 km
Landsat	30 m	100 m
HyspIRI	30 m	60 m

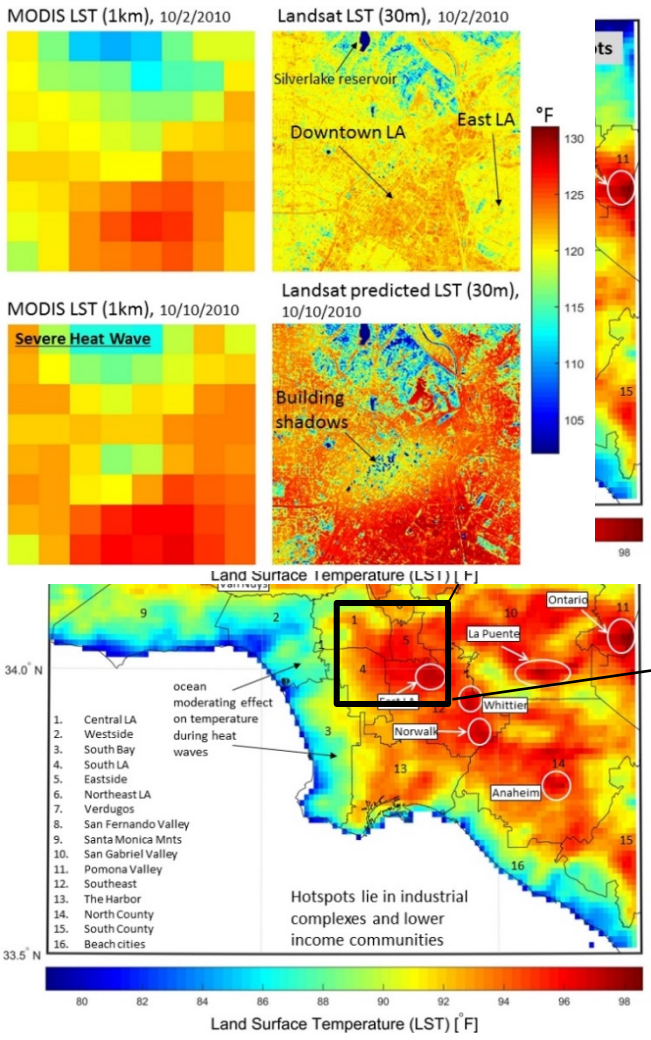


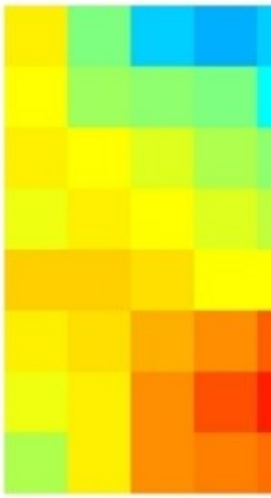


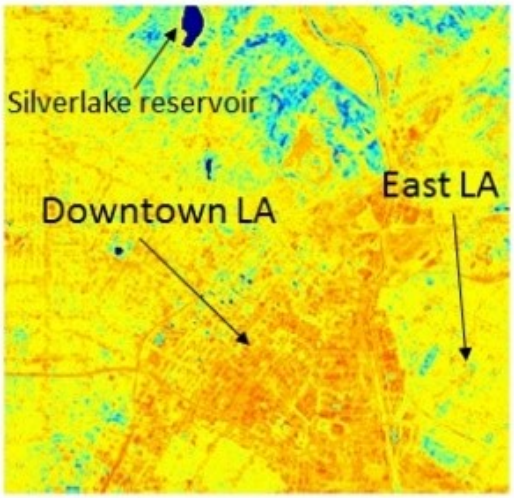
HUTS (High Resolution Urban Thermal Sharpener) *Dominguez et al. 2011*

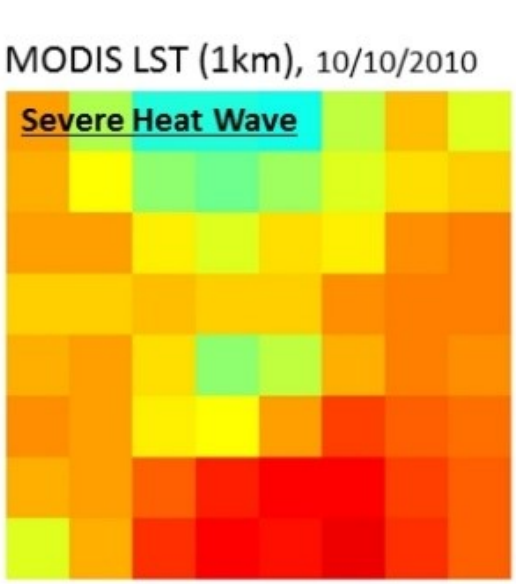
$$LST = f(\text{Albedo, NDVI}) + dLST$$

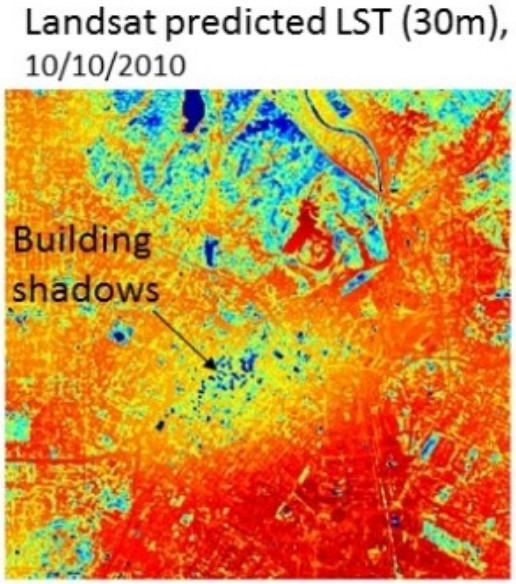

Landsat 100 m LST
Landsat 30 m LST
Roads and runways delineated
Roofs distinguished
Crop fields delineated
K
340
335
330
325
320
315
310

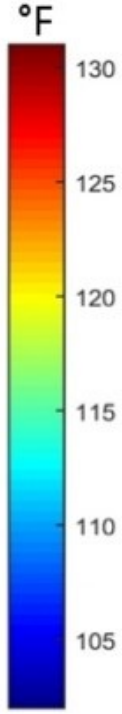

MODIS LST (1km), 10/2/2010
Landsat LST (30m), 10/2/2010
Silverlake reservoir
Downtown LA
East LA
°F
130
125
120
115
110
105
MODIS LST (1km), 10/10/2010
Severe Heat Wave
Landsat predicted LST (30m), 10/10/2010
Building shadows
Land Surface Temperature (LST) [°F]
Ontario
La Puente
Whittier
Norwalk
Anaheim
34.0° N
33.5° N
ocean moderating effect on temperature during heat waves
1. Central LA
2. Westside
3. South Bay
4. South LA
5. Eastside
6. Northeast LA
7. Verdugos
8. San Fernando Valley
9. Santa Monica Mnts
10. San Gabriel Valley
11. Pomona Valley
12. Southeast
13. The Harbor
14. North County
15. South County
16. Beach cities
Hotspots lie in industrial complexes and lower income communities
80 82 84 86 88 90 92 94 96 98
Land Surface Temperature (LST) [°F]


MODIS LST (1km), 10/2/2010


Landsat LST (30m), 10/2/2010
Silverlake reservoir
Downtown LA
East LA


MODIS LST (1km), 10/10/2010
Severe Heat Wave


Landsat predicted LST (30m), 10/10/2010
Building shadows


°F
130
125
120
115
110
105