A High Spatio-temporal Resolution Land Surface Temperature (LST) Product for Urban Environments

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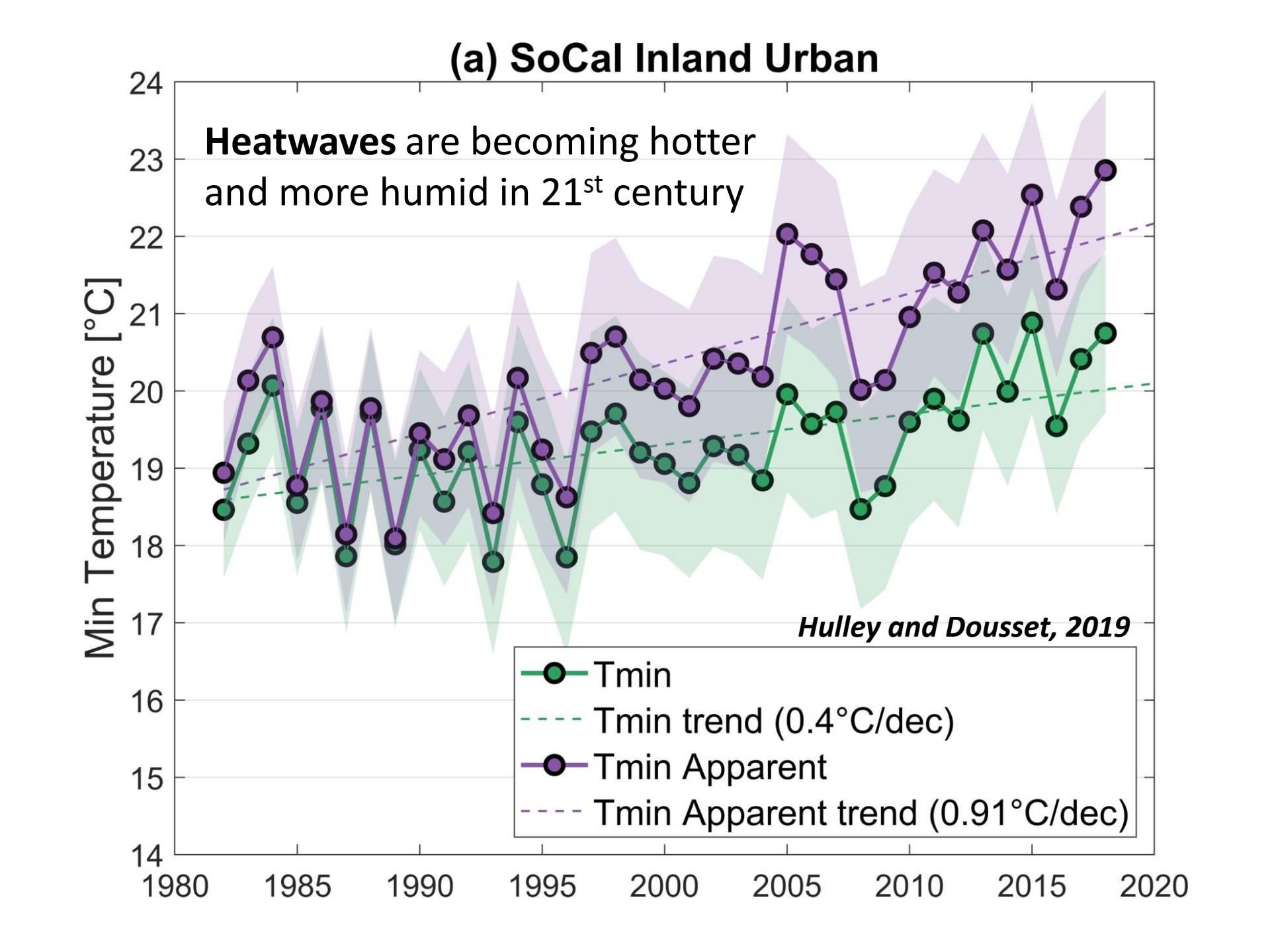
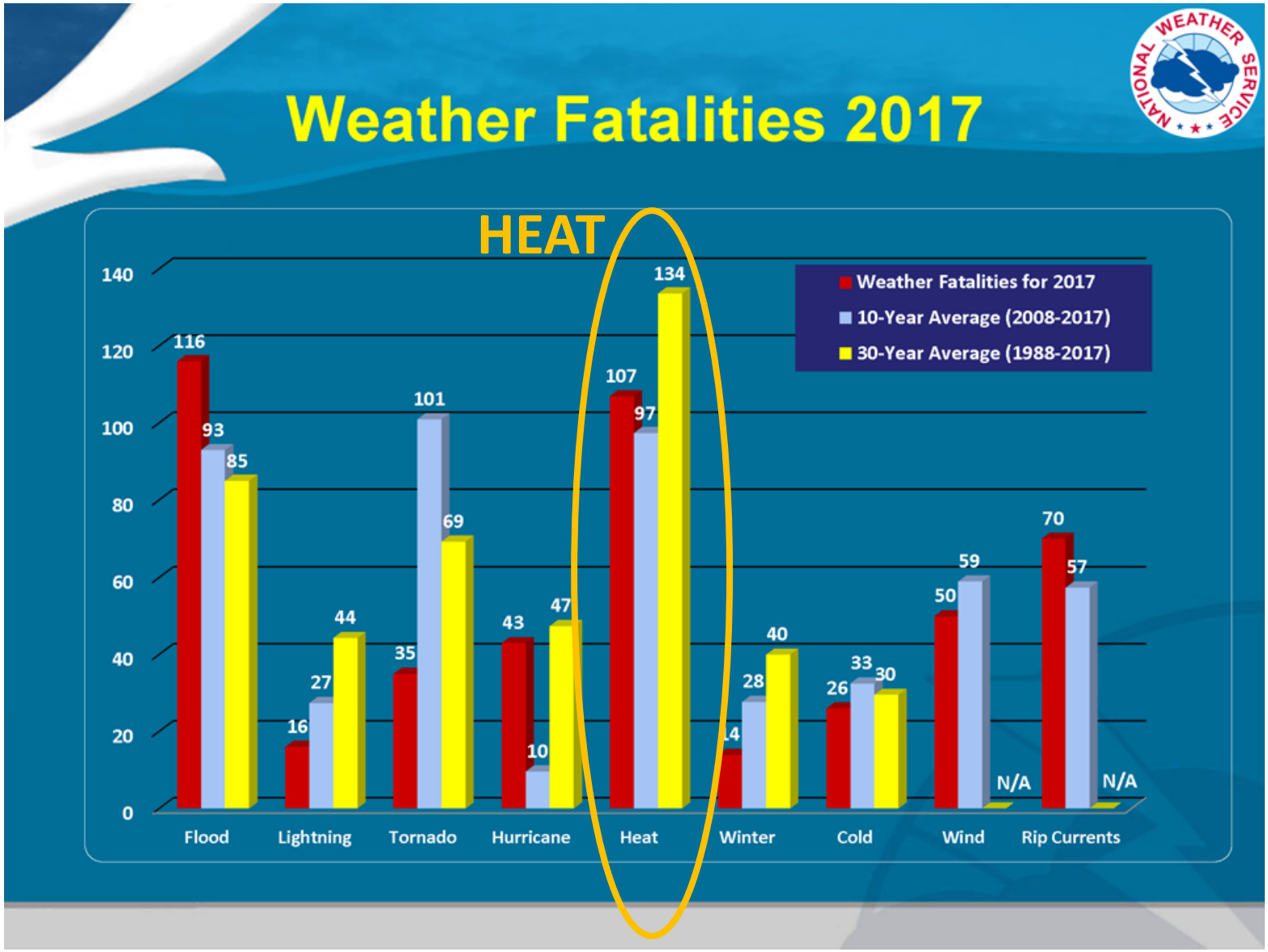
MuSLI Type 2 Prototype Product:

	Data	Spatial	Temporal
Urban Land Surface Temperature (LST)	TIR: GOES 16, ECOSTRESS VSWIR: Landsat 8, Sentinel 2, HLS	30 – 100m	30 minute

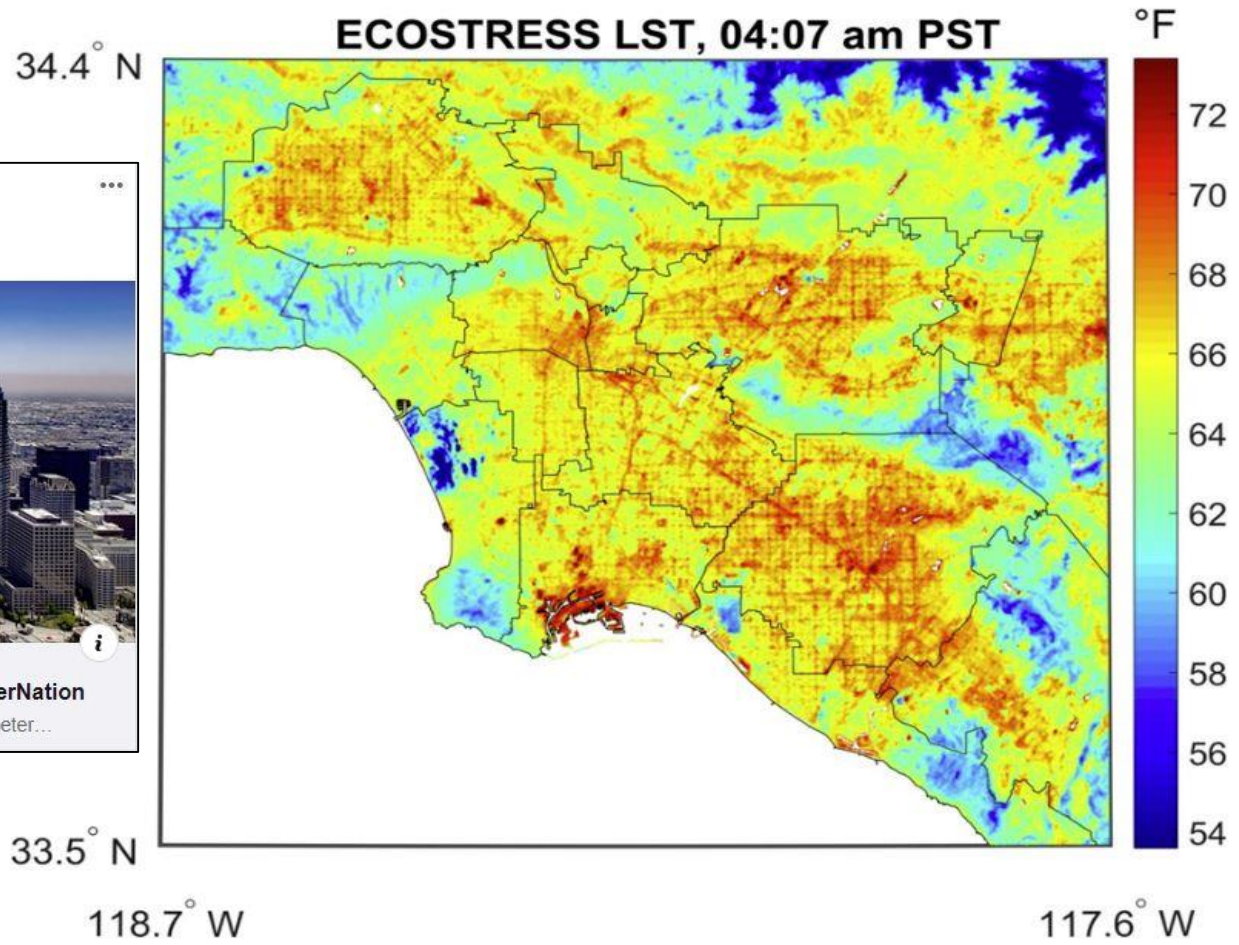

(a) SoCal Inland Urban
Heatwaves are becoming hotter and more humid in 21st century
Min Temperature [°C]
24
23
22
21
20
19
18
17
16
15
14
1980
1985
1990
1995
2000
2005
2010
2015
2020
Hulley and Dousset, 2019
Tmin
Tmin trend (0.4°C/dec)
Tmin Apparent
Tmin Apparent trend (0.91°C/dec)

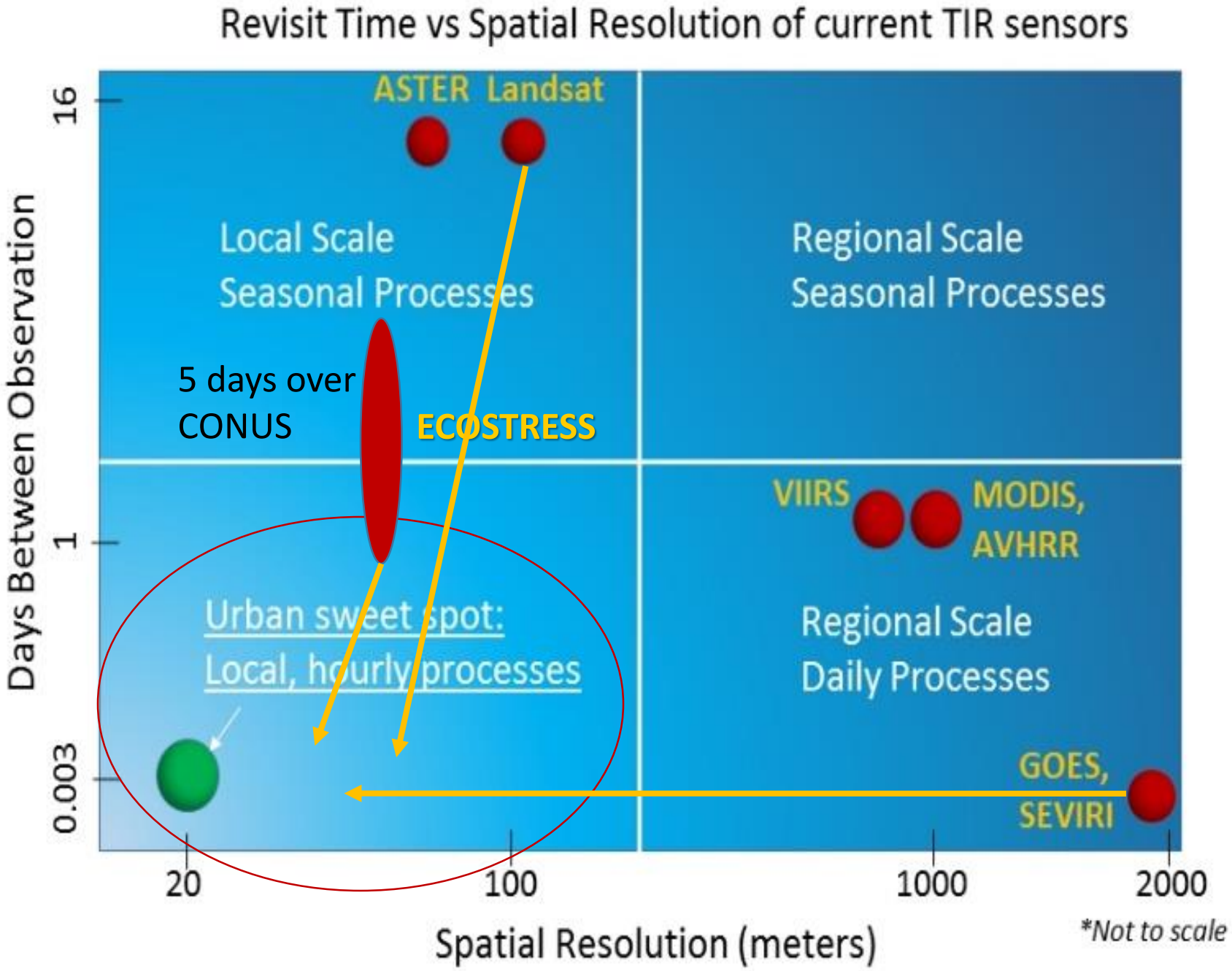


Source: http://www.nws.noaa.gov/om/hazstats.shtml

NEWS | SEPTEMBER 18, 2018

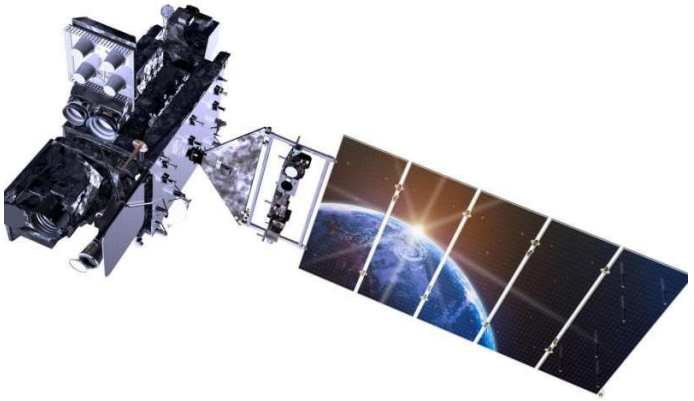
ECOSTRESS Maps LA's Hot Spots



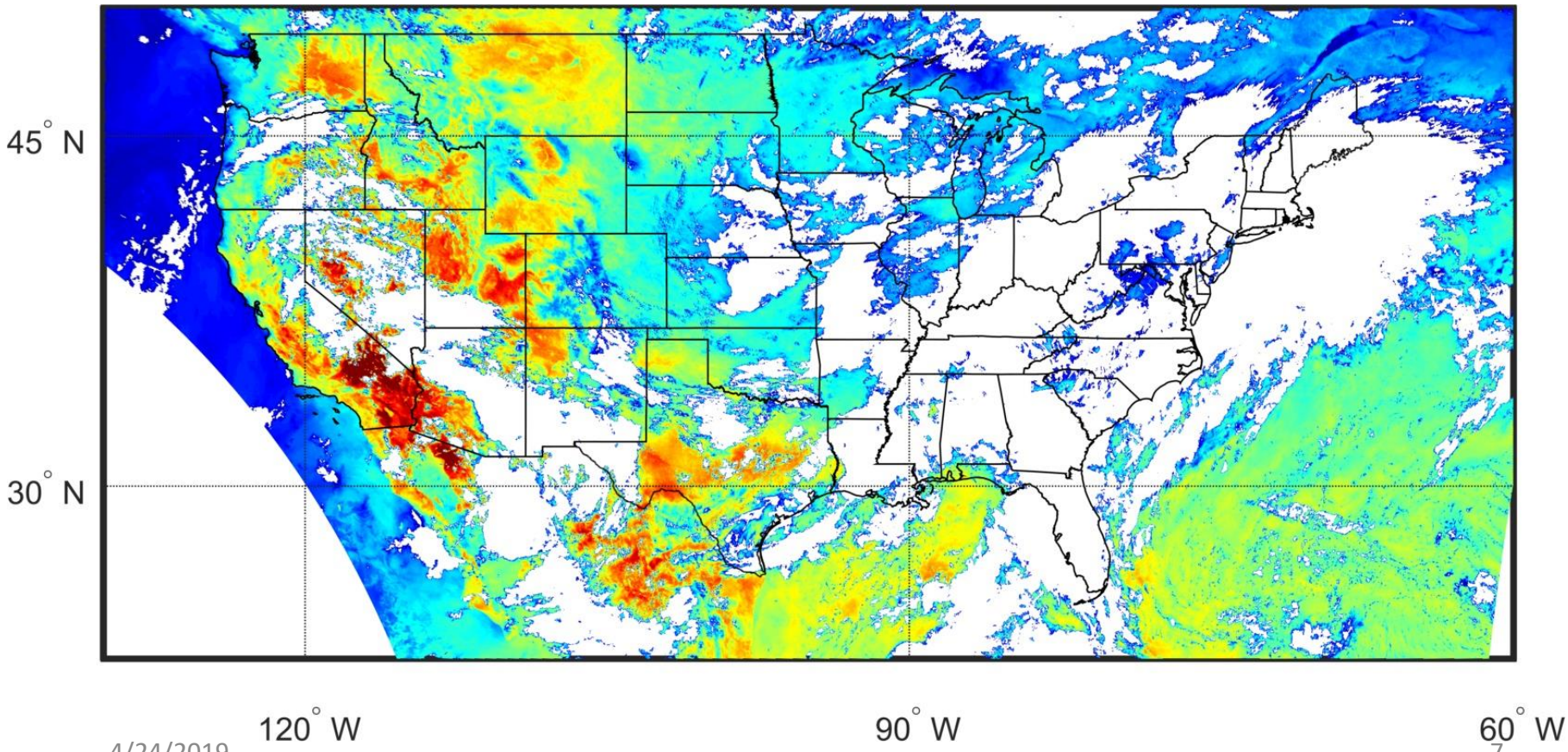

Revisit Time vs Spatial Resolution of current TIR sensors
ASTER
Landsat
Local Scale
Seasonal Processes
Regional Scale
Seasonal Processes
5 days over
CONUS
ECOSTRESS
VIIRS
MODIS,
AVHRR
Urban sweet spot:
Local, hourly processes
Regional Scale
Daily Processes
GOES,
SEVIRI
Days Between Observation
16
1
0.003
20
100
1000
2000
Spatial Resolution (meters)
*Not to scale

GOES-16 ABI:

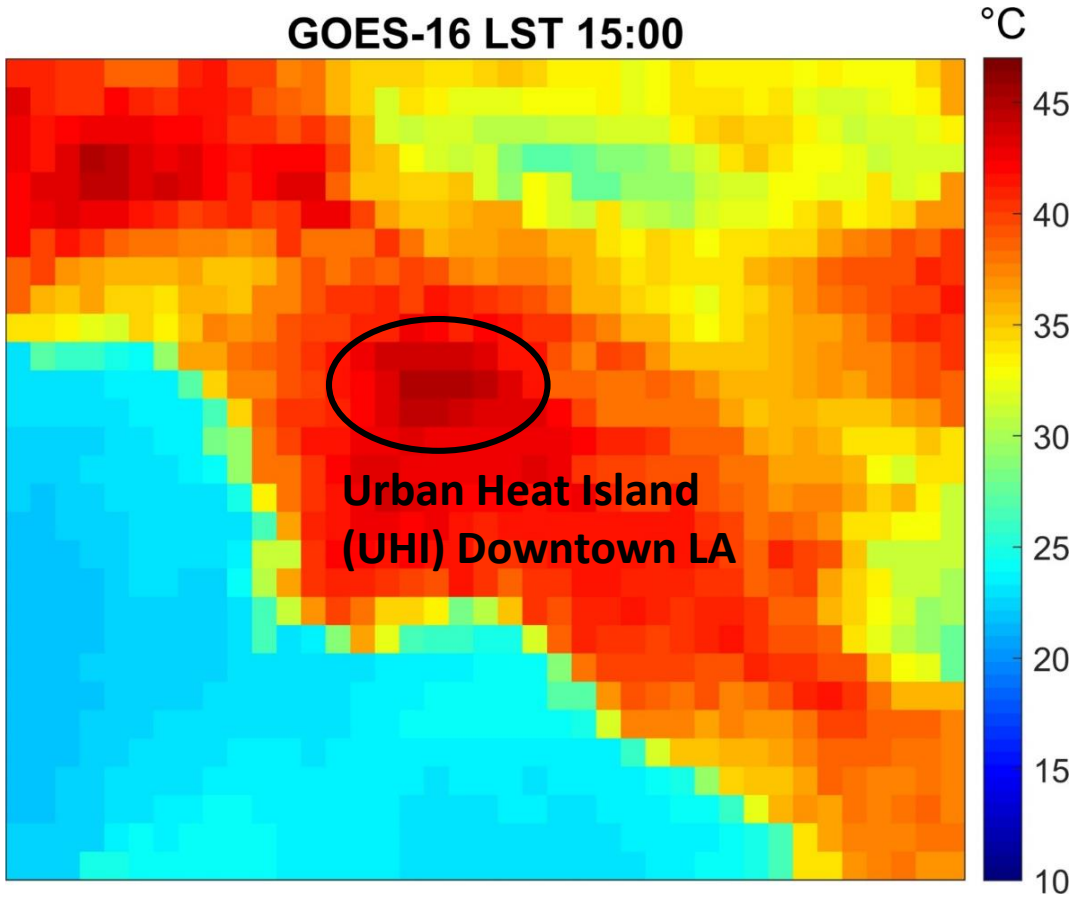
- 3 thermal bands
- Spatial: **2.5km**
- Temporal: **5 minutes**
- LST produced at JPL through NASA MEaSUREs



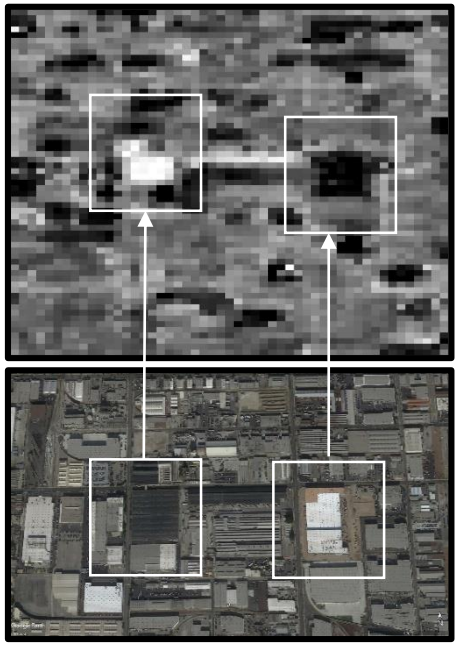
GOES-16 LST, 31 July, 2018, 9:27 pm



GOES-16 images hotspots at the neighborhood km-scale, but roof-level scale (30m – 100m) are <u>required for more precise and targeted heat mitigation strategies in cities</u>

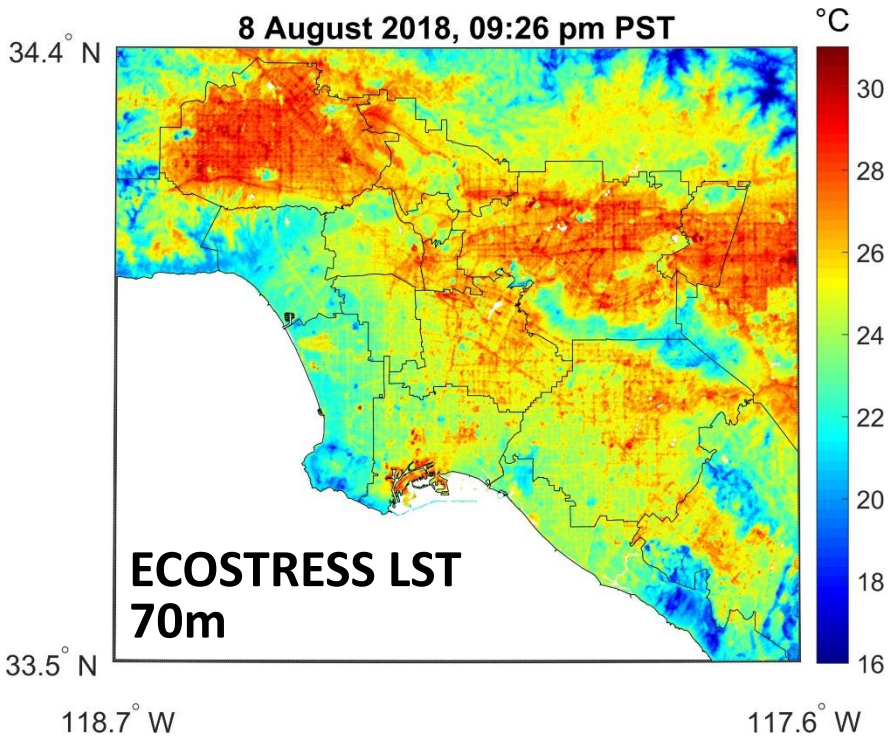


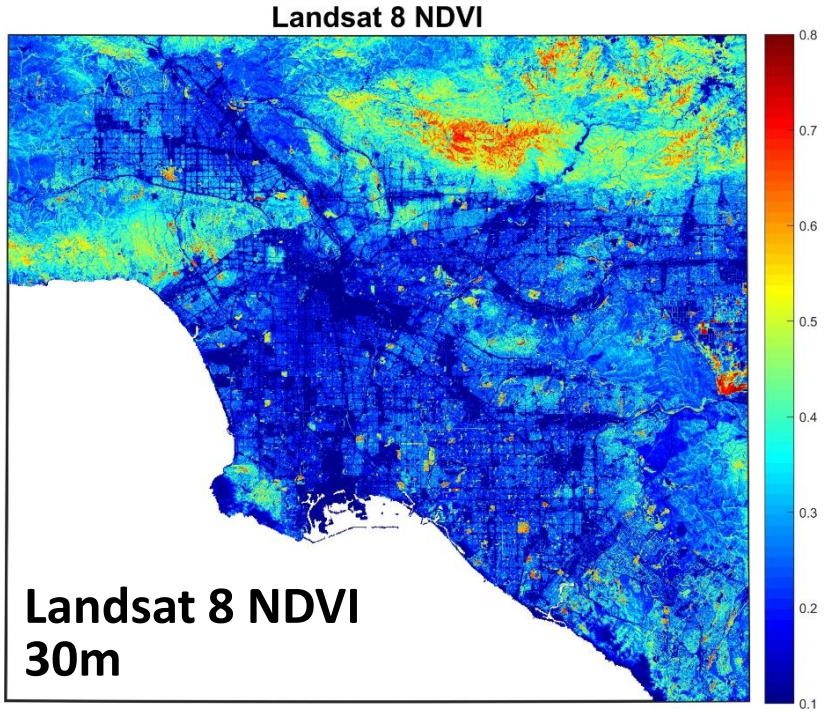
ECOSTRESS

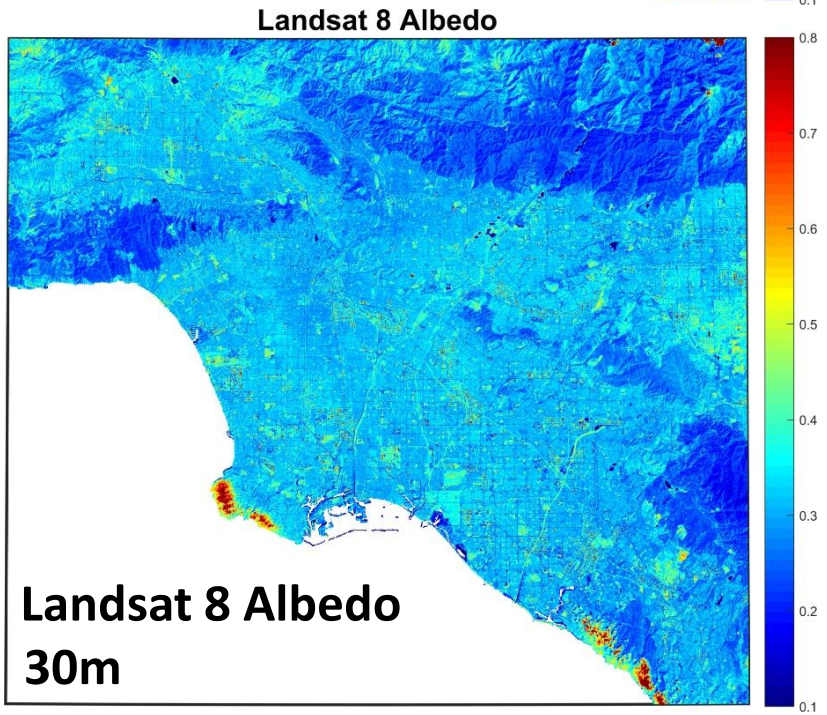


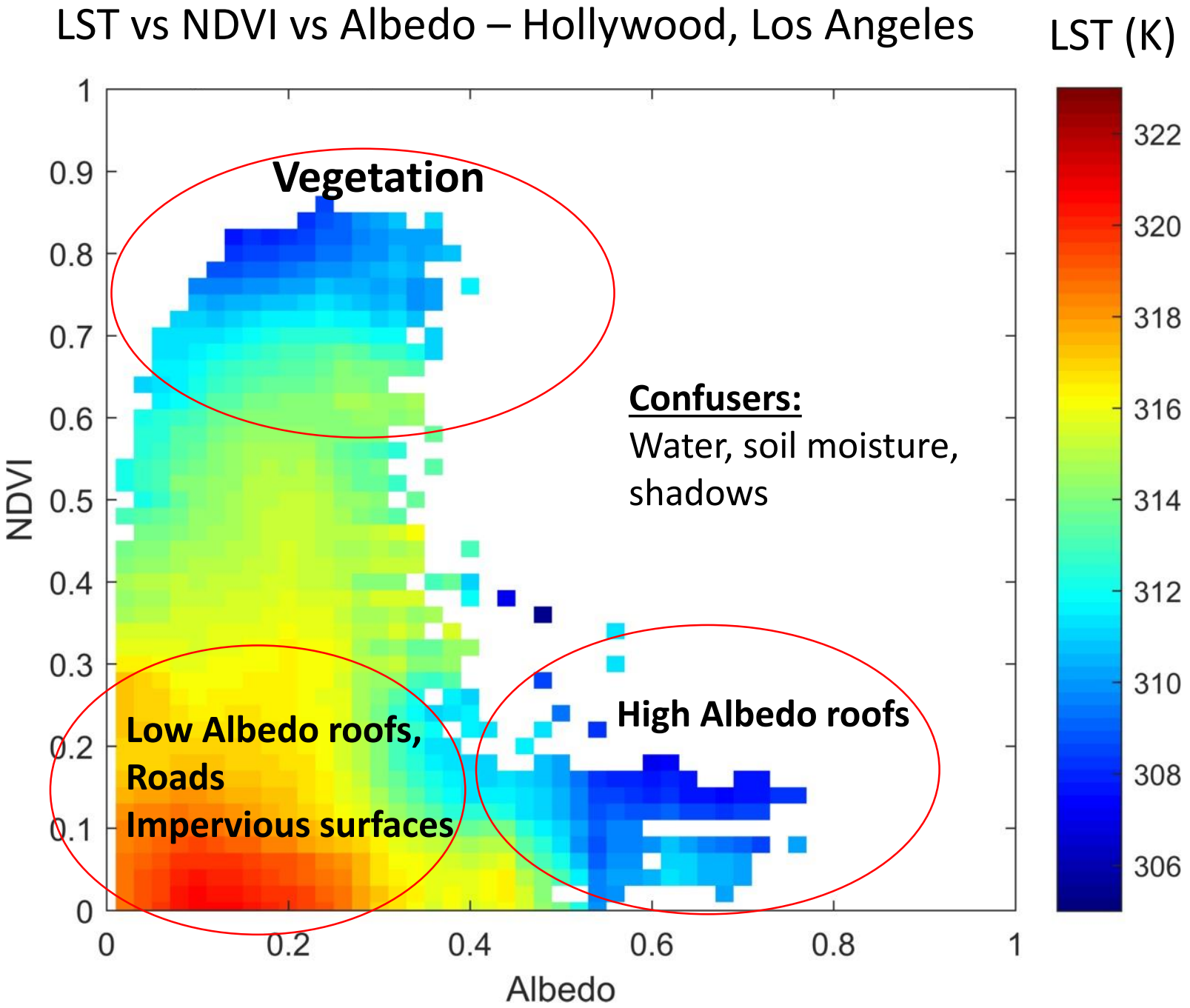
Industrial zone: Black roof with low albedo in Google Earth image is significantly hotter (white) than lighter colored roof with lower temperatures (black)

Are there physical relationships between LST, NDVI and Albedo over the urban environment?





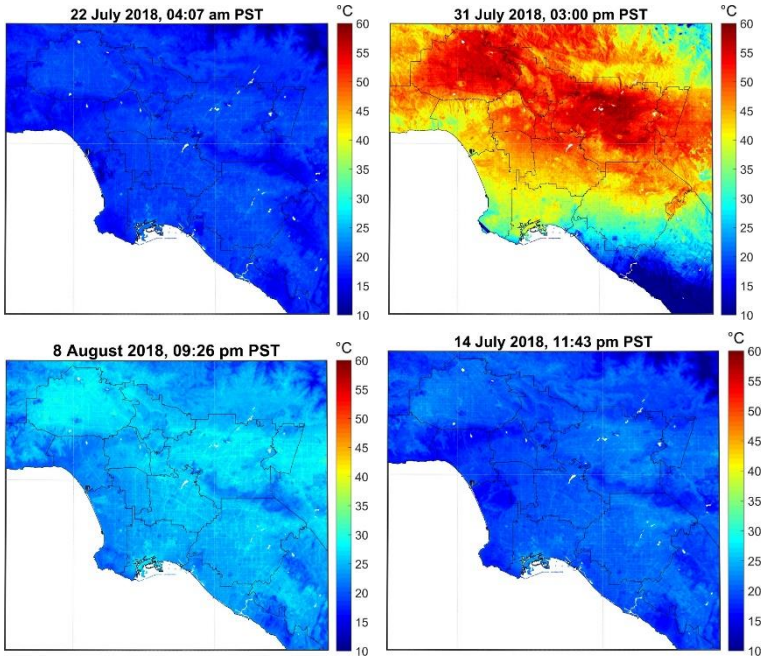



LST vs NDVI vs Albedo – Hollywood, Los Angeles
LST (K)
322
320
318
316
314
312
310
308
306
NDVI
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Albedo
0
0.2
0.4
0.6
0.8
1
Vegetation
Confusers:
Water, soil moisture, shadows
Low Albedo roofs,
Roads
Impervious surfaces
High Albedo roofs

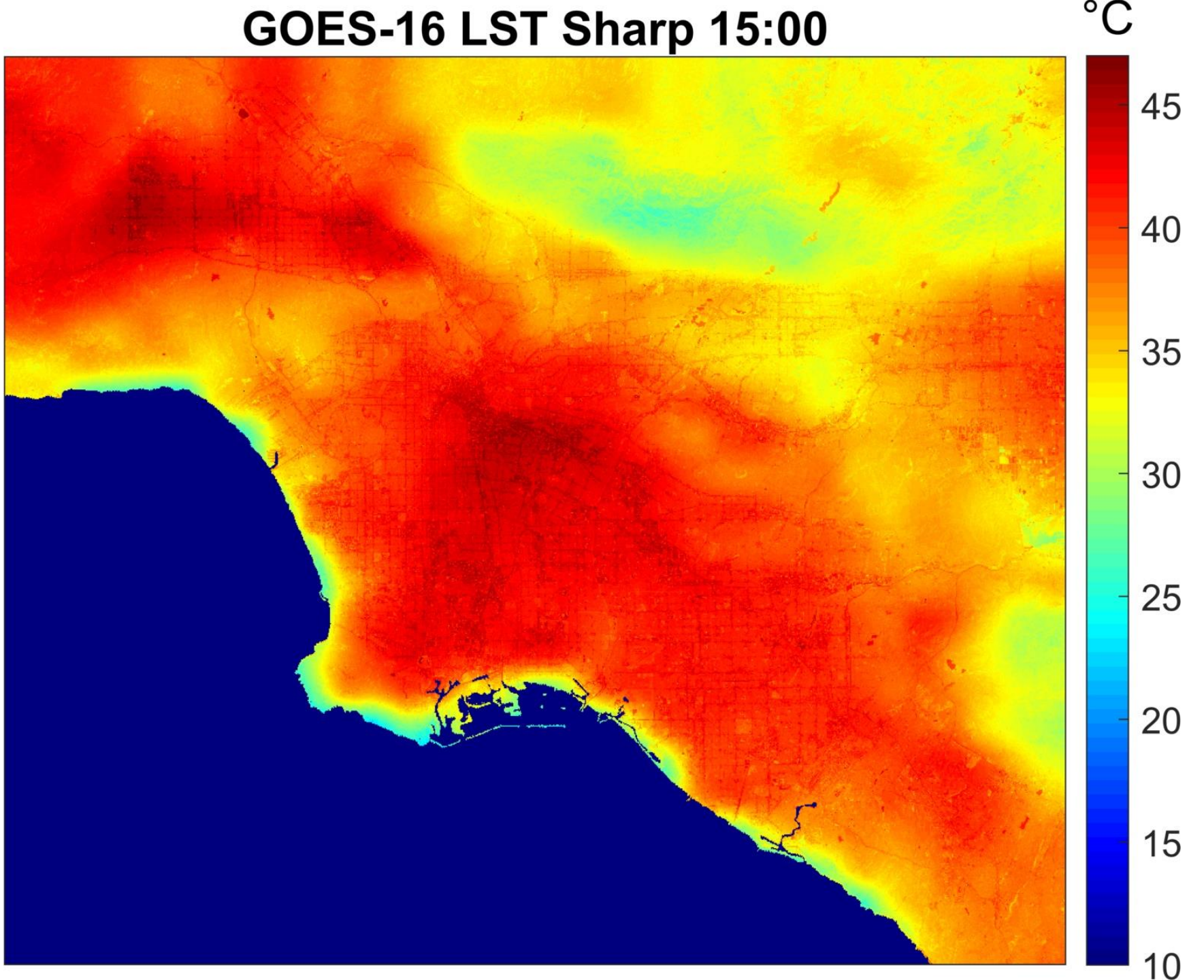
High resolution Urban Thermal Sharpener (HUTS) Multivariate Regression Model:

$$LST_{sharp} = p_1 NDVI^4 + p_2 NDVI^3 \cdot \alpha + p_3 NDVI^2 \cdot \alpha^2 + p_4 NDVI \cdot \alpha^3 + p_5 \alpha^4 + p_6 NDVI^3 + p_7 NDVI^2 \cdot \alpha + p_8 NDVI \cdot \alpha^2 + p_9 \alpha^3 + p_{10} NDVI^2 + p_{11} NDVI \cdot \alpha + p_{12} \alpha^2 + p_{13} NDVI + p_{14} \alpha + p_{15} + \text{dLST}$$

dLST = Energy balance conservation

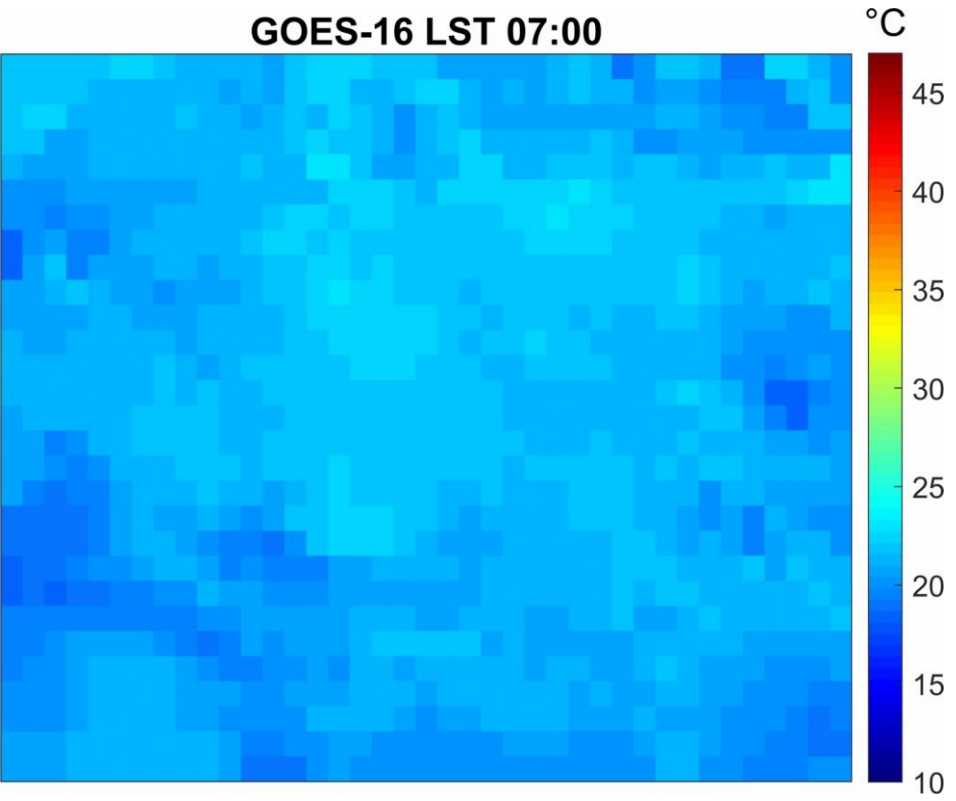


LST (09:30) = f1(NDVI, α)
LST (12:30) = f2(NDVI, α)
LST (14:30) = f3(NDVI, α)
....
....
LST (21:00) = f4(NDVI, α)
LST (04:00) = f5(NDVI, α)

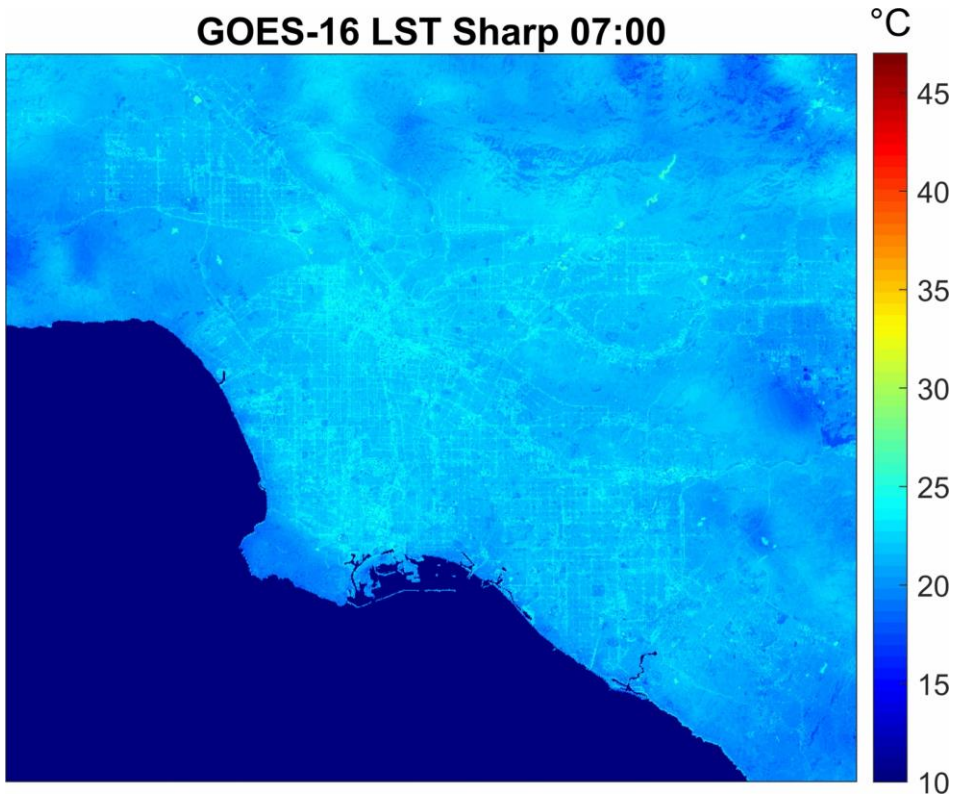

GOES-16 LST Sharp 15:00
°C
45
40
35
30
25
20
15
10

GOES-16 Thermal Sharpening

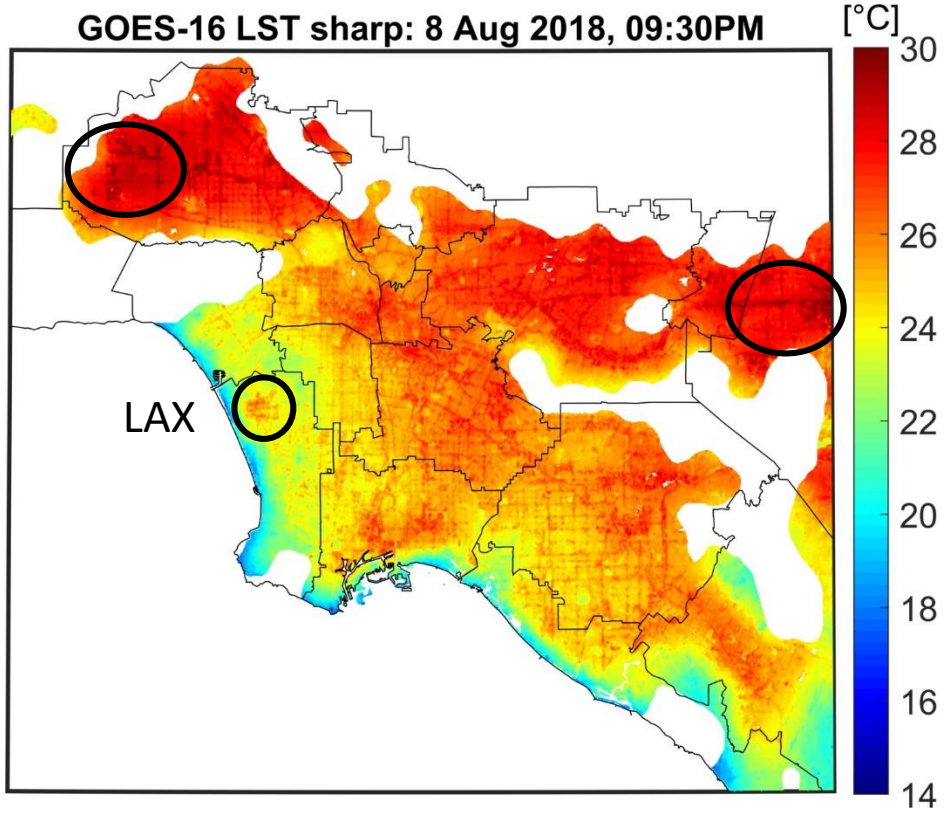
3 km

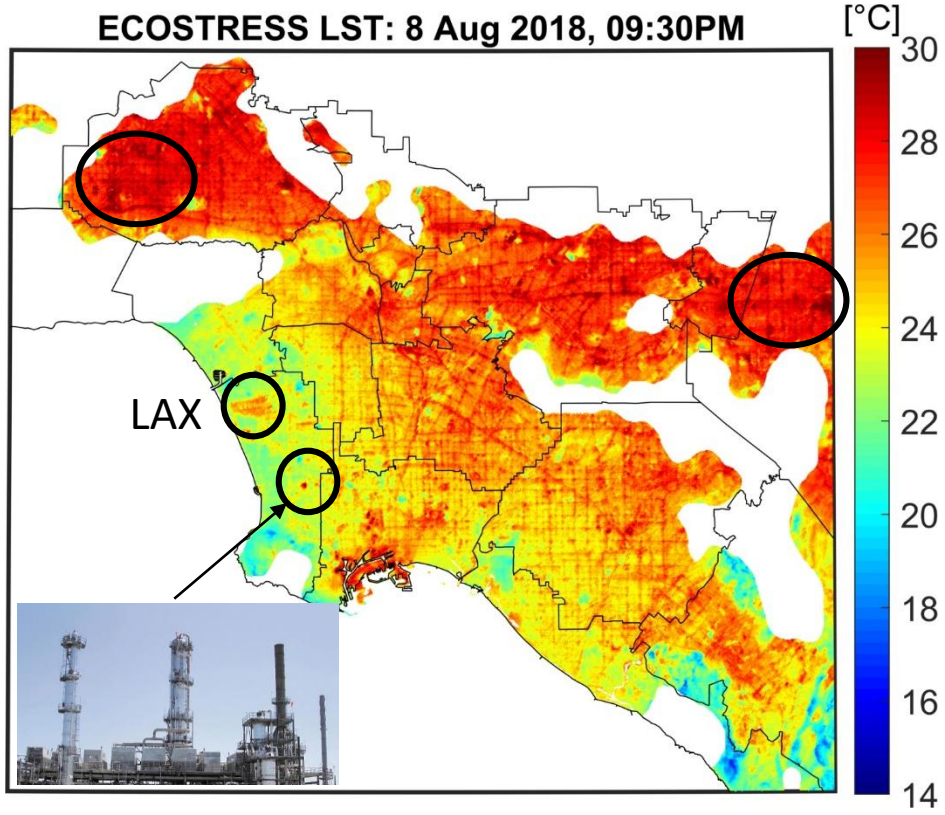


100m

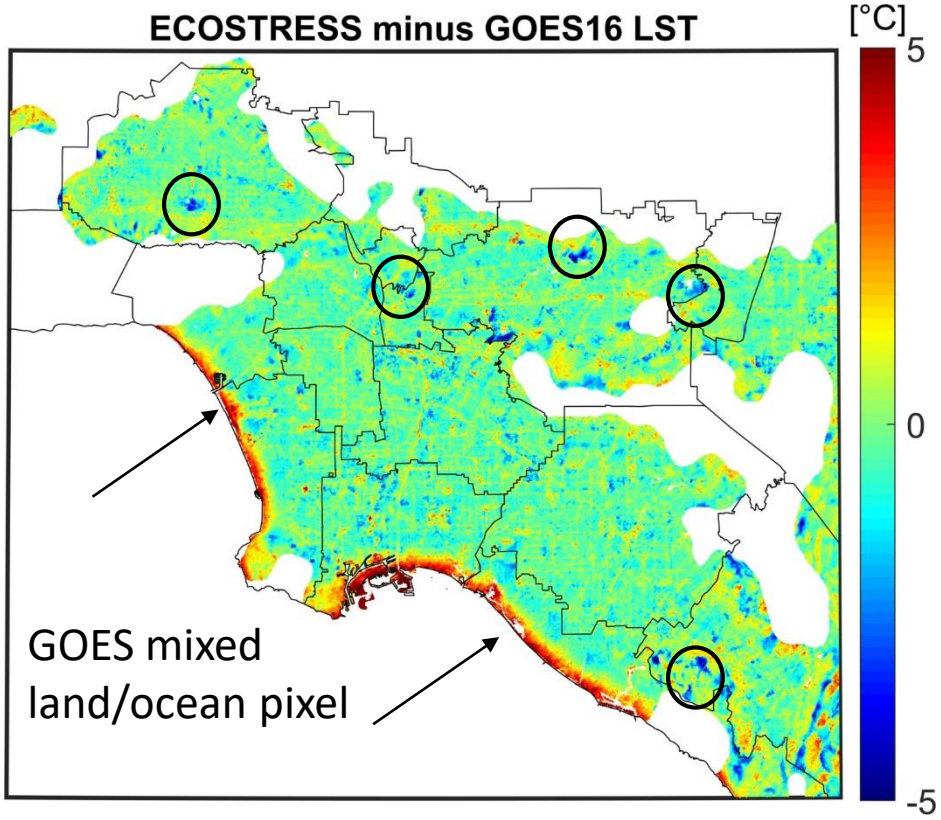


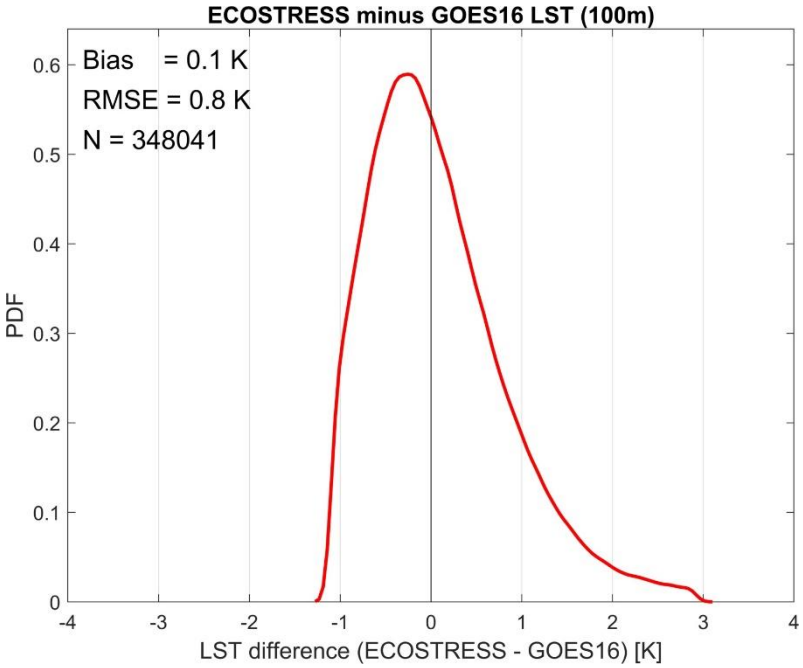
GOES-16 Sharpening validation with ECOSTRESS at 100m resolution – **9:30 pm**





GOES-16 Sharpening validation with ECOSTRESS at 100m resolution – **9:30 pm**

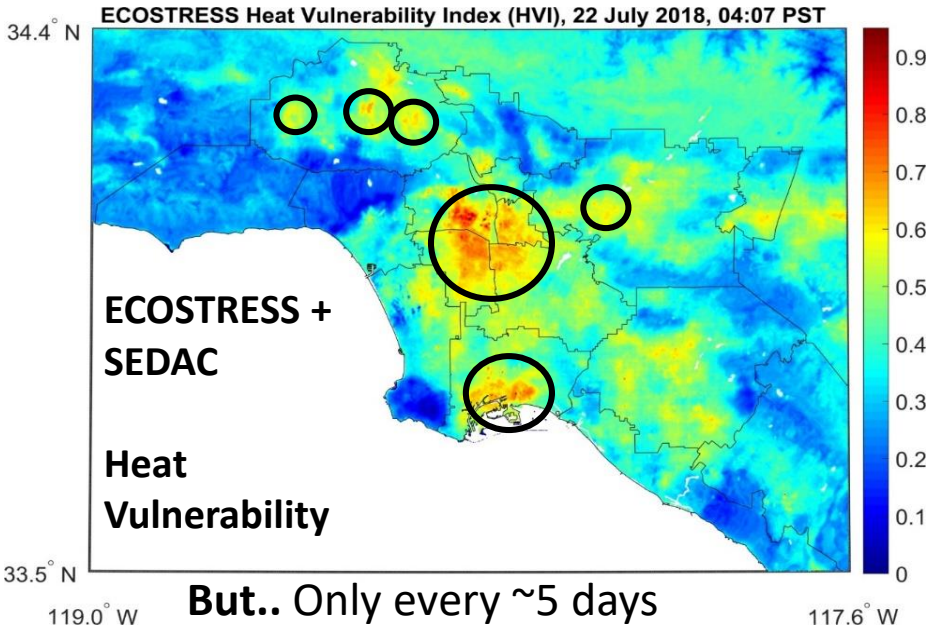




Temperatures of green spaces (e.g. parks) overestimated

Heat advisories and public health:

Provide HVI to issue near real-time heat advisories targeted to vulnerable regions in Los Angeles



But.. Only every ~5 days

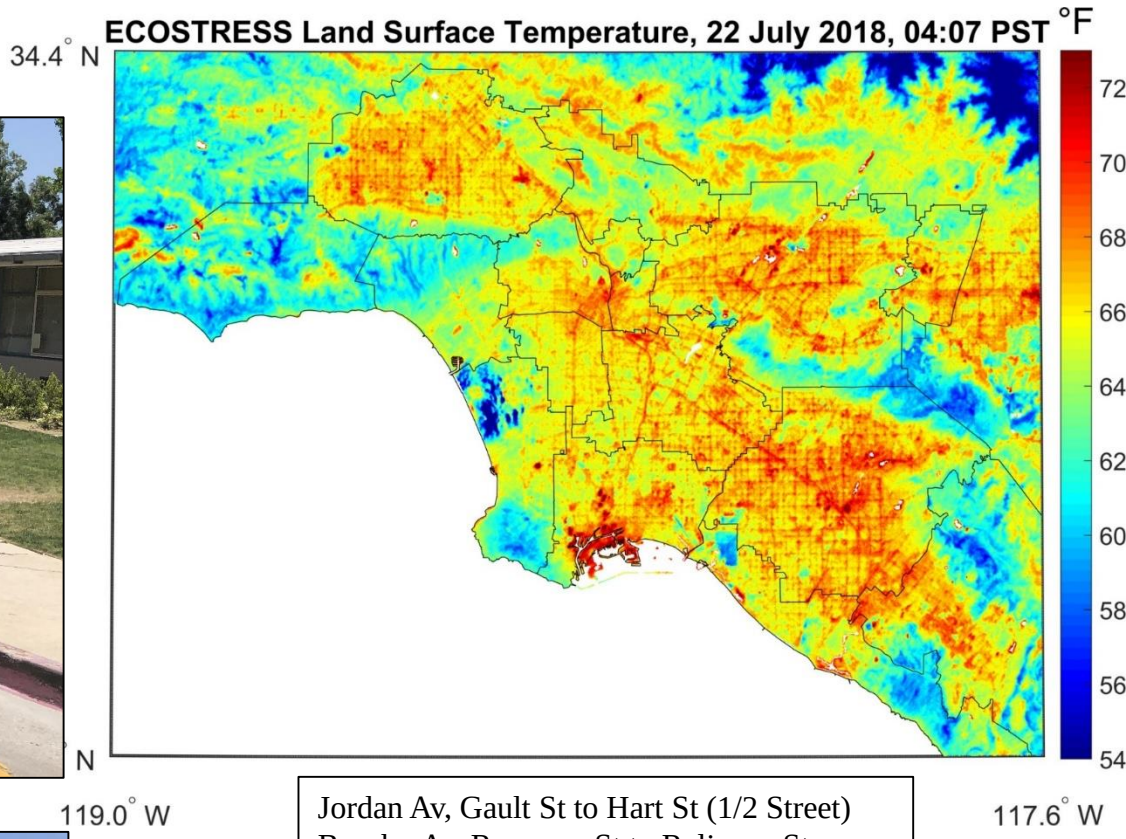
Identify optimal locations for cooling centers

Heat Alerts

2018 Health Advisories

Date of Release	Title	
August 01	Air Quality Advisory: Air is unhealthy in Santa Clarita Valley	View
July 30	Air Quality Advisory: Air is unhealthy in Antelope Valley and Santa Clarita Valley	View
July 30	Heat Alert: High temperatures forecast for Pomona area and San Fernando Valley	View
July 29	Air Quality Advisory: Air is unhealthy in parts of LA County	View
July 28	Air Quality Advisory: Air Quality is unhealthy in parts of LA County	View
July 27	Air Quality Advisory: Air is unhealthy in parts of LA County	View
July 26	Air Quality Advisory: Air is unhealthy in parts of LA County	View

Cool Roads



Jordan Av, Gault St to Hart St (1/2 Street)
Beachy Av, Rangoon St to Reliance St
Etiwanda Av, Napa St to Malden St
70th St, 2nd Av to 3rd Av
Woodbine St, Jasmine Av to Vinton Av
Carmona St, Clemson St to Bowsfield St
Orchard Av, 28th St to 29th St
77th St, Cowan Av to Beland Av
Coronado St, Berkeley Av to Mayberry St
Lord St, 90' S/O Marengo St to Pomeroy Av
President Av, 255th St to 255th St
Bonnie Brae St, 12th St to 12th Pl
Selma Av, Laurel Av to Laurel Canyon Bl
Atoll Av, Barbara Ann St to Gault St
Superior St, Noble to Lemona

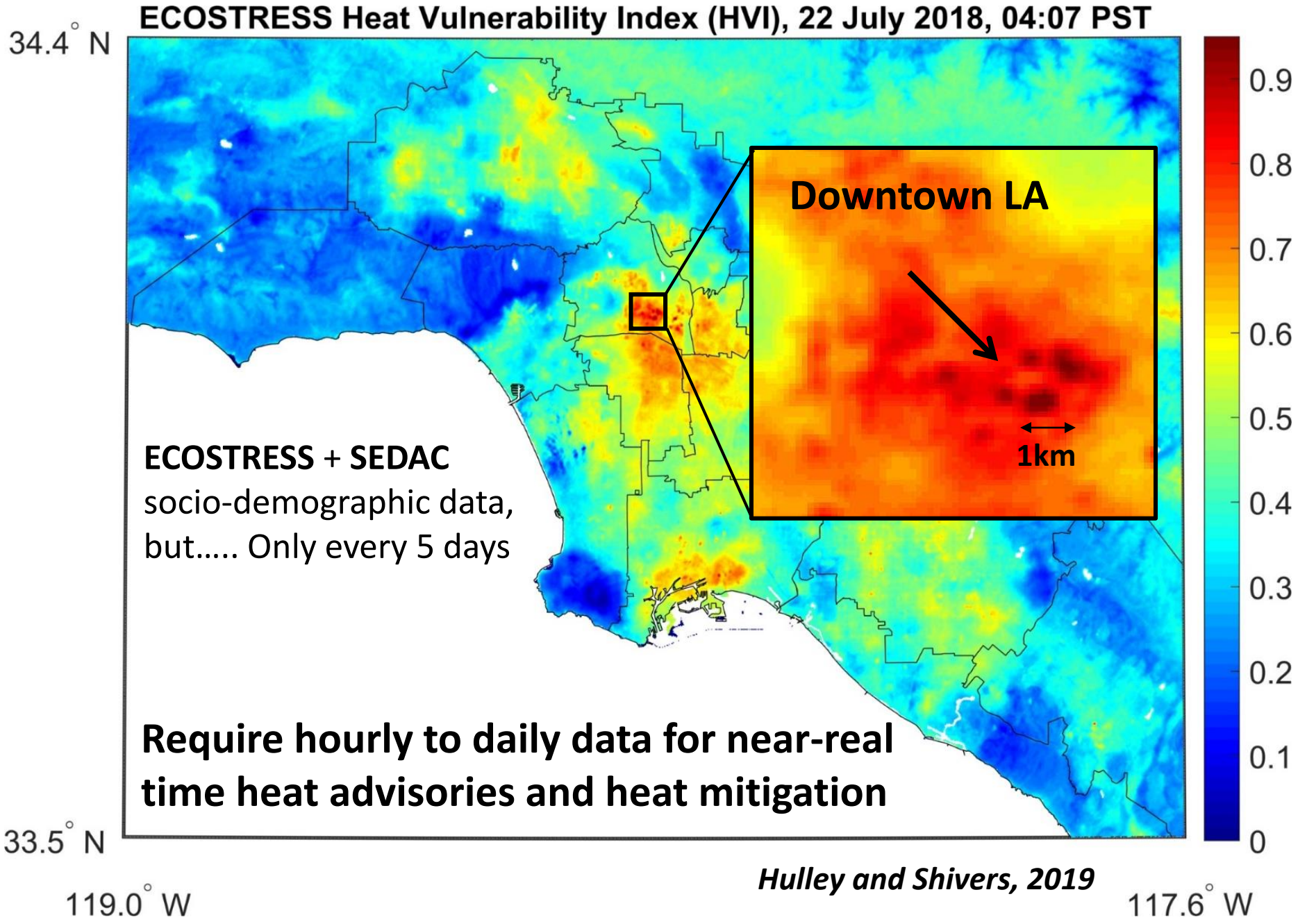
Prototype Urban Products - 2020

Product	Data sources	Spatial	Temporal	Cities
Urban LST	GOES 16/17 Landsat 8 Sentinel 2 HLS ECOSTRESS	30-100m	30 minute	• **Los Angeles** • Atlanta • Chicago • Phoenix • Minneapolis • Washington DC • Seattle
Urban Heat Vulnerability	Urban LST + SEDAC demographic	30-100m	30 minute	

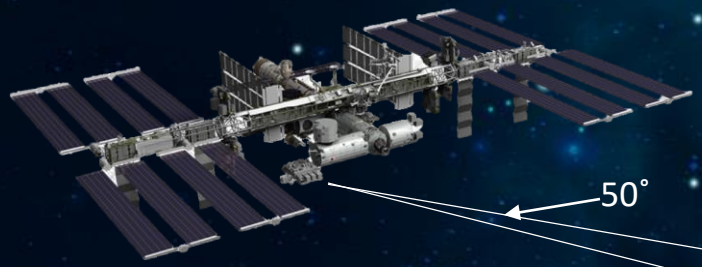

Questions?
glynn.hulley@jpl.nasa.gov

Future work: 2019-2020

- Sharpening model refinement and validation
  - Fix bias along coastlines
  - Continue validation matchups with ECOSTRESS
  - In situ validation – thermal camera within city
- Test sharpening model in other cities, e.g. Atlanta
- Start producing prototype products
  - Geotiff
  - Quality and error estimates

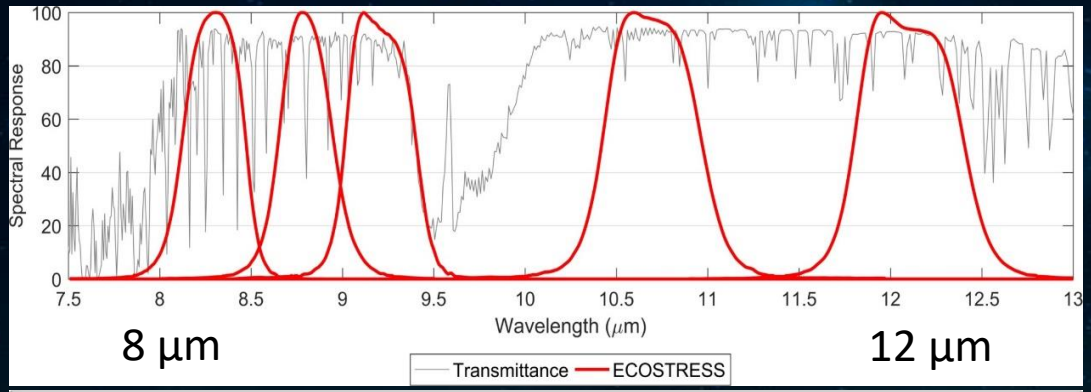

ECOSTRESS Heat Vulnerability Index (HVI), 22 July 2018, 04:07 PST
34.4° N
33.5° N
119.0° W
117.6° W
Downtown LA
1km
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
ECOSTRESS + SEDAC
socio-demographic data,
but….. Only every 5 days
Require hourly to daily data for near-real time heat advisories and heat mitigation
Hulley and Shivers, 2019

ECOSTRESS



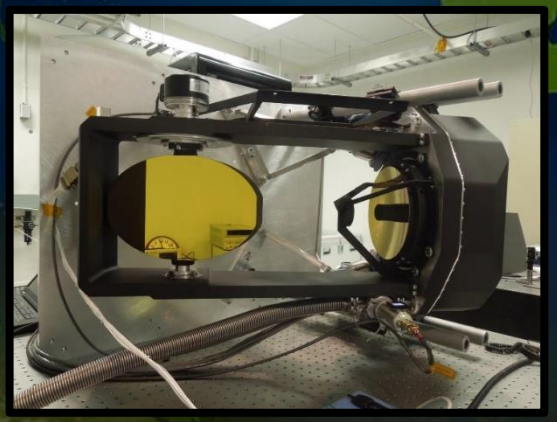
50˚

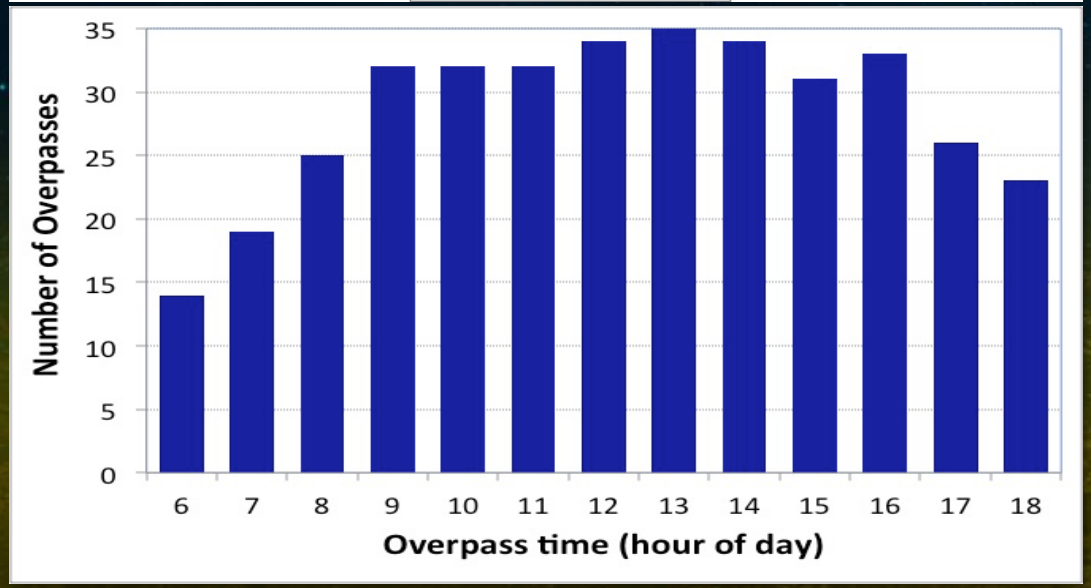
400 km
(70 m)



8 µm

12 µm

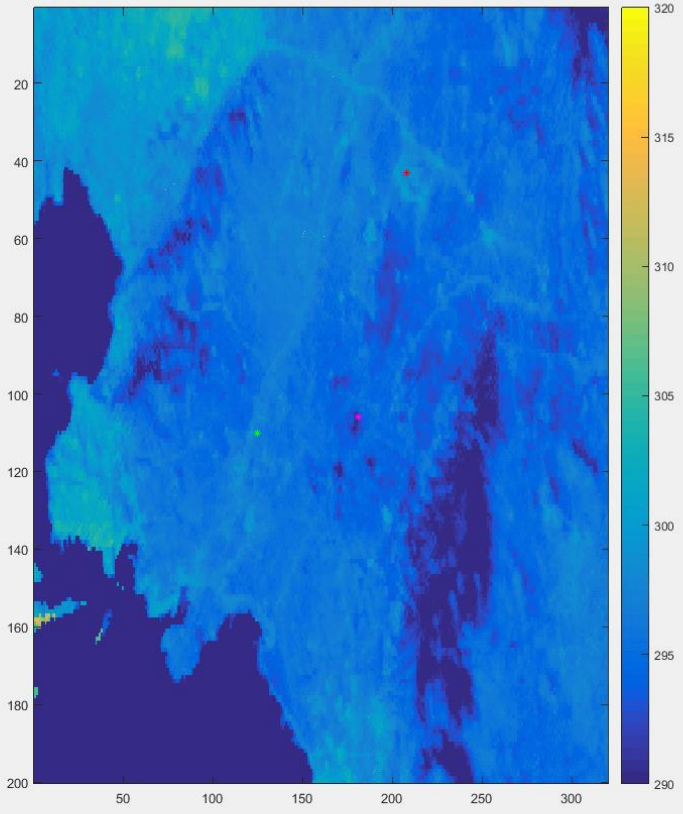


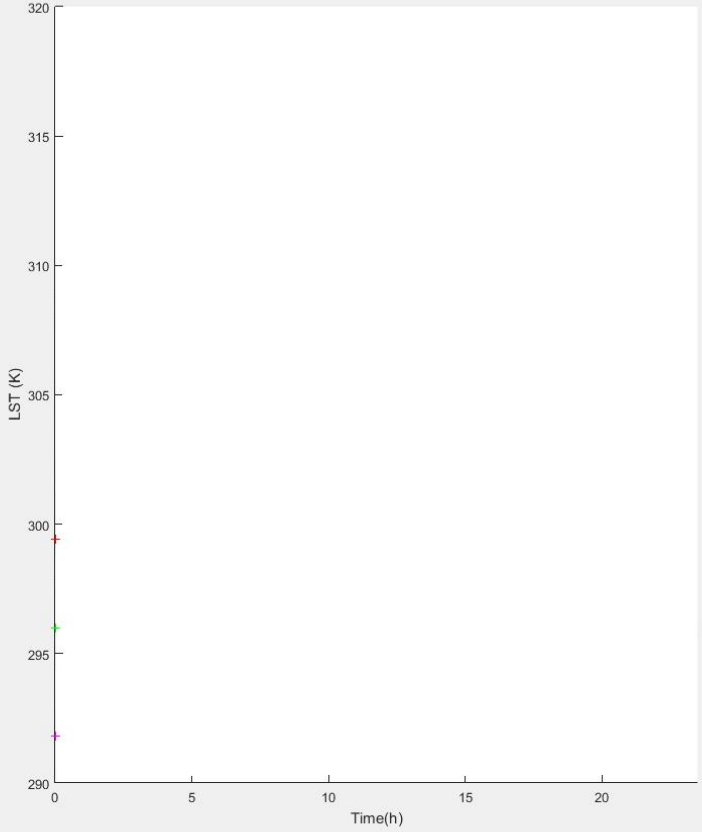


Athens, Greece, 08/21/2018

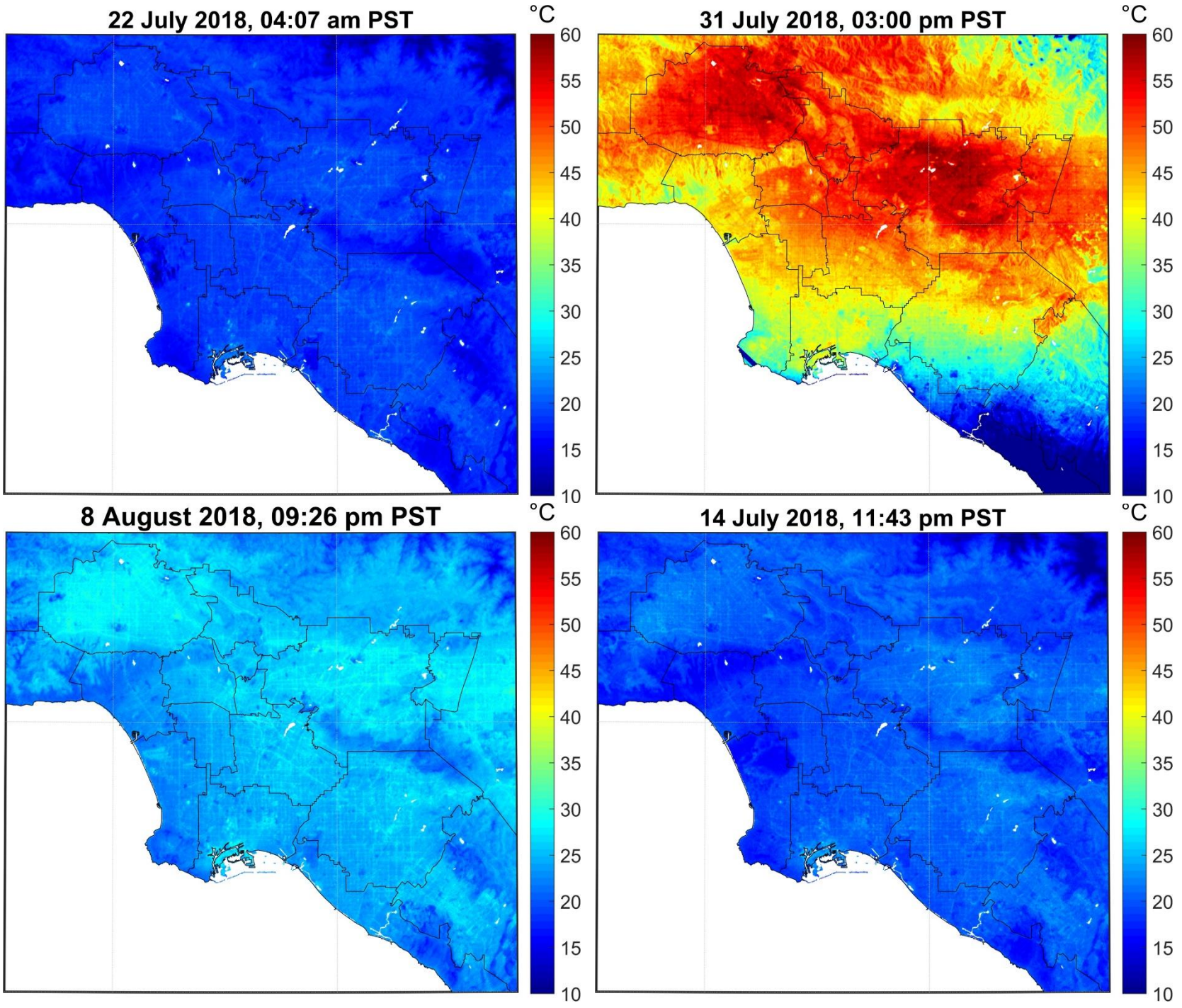
SEVIRI geostationary thermal (4km, 30minute)

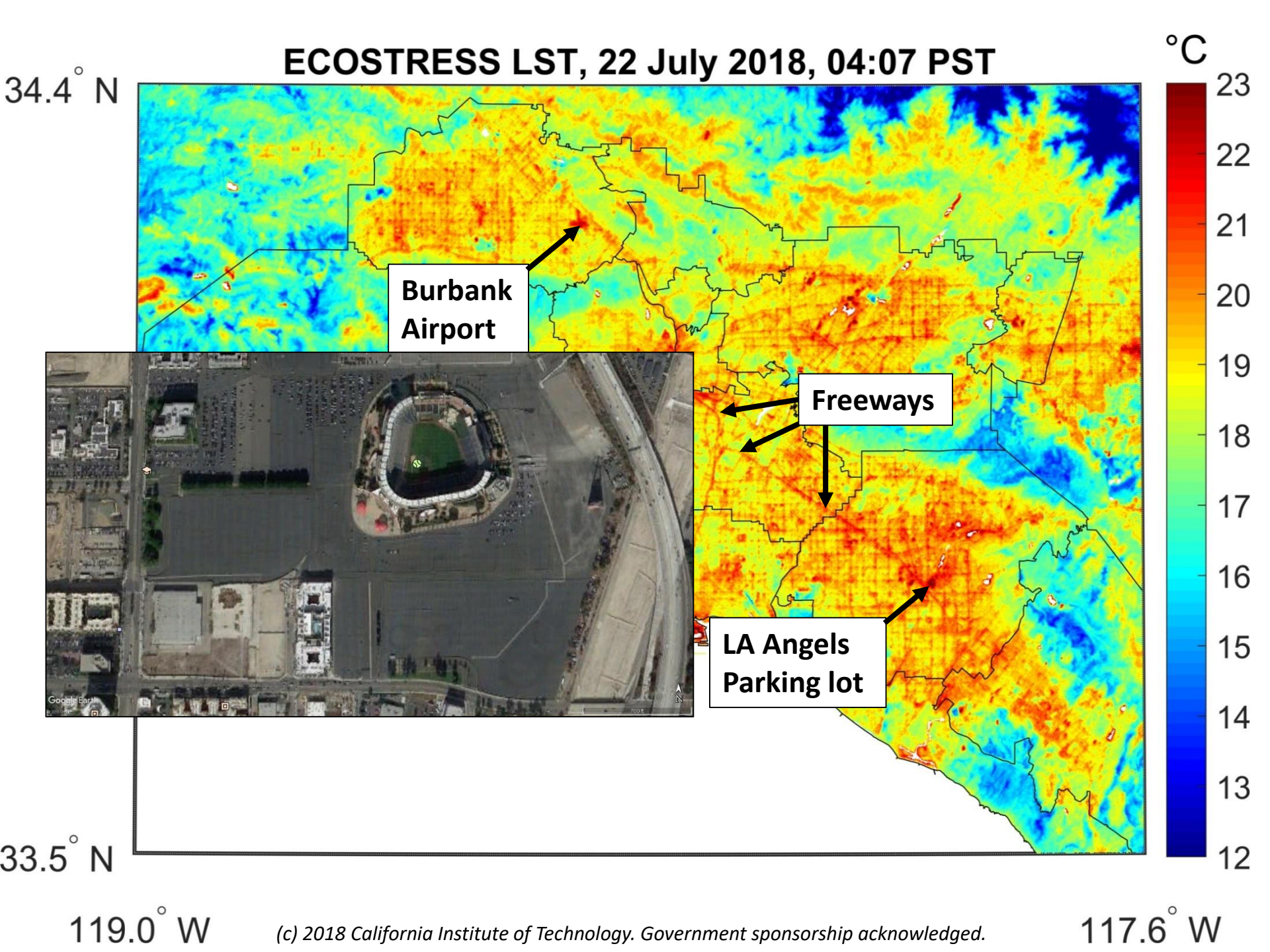
Sentinel-2 + ECOSTRESS sharpening to 100m





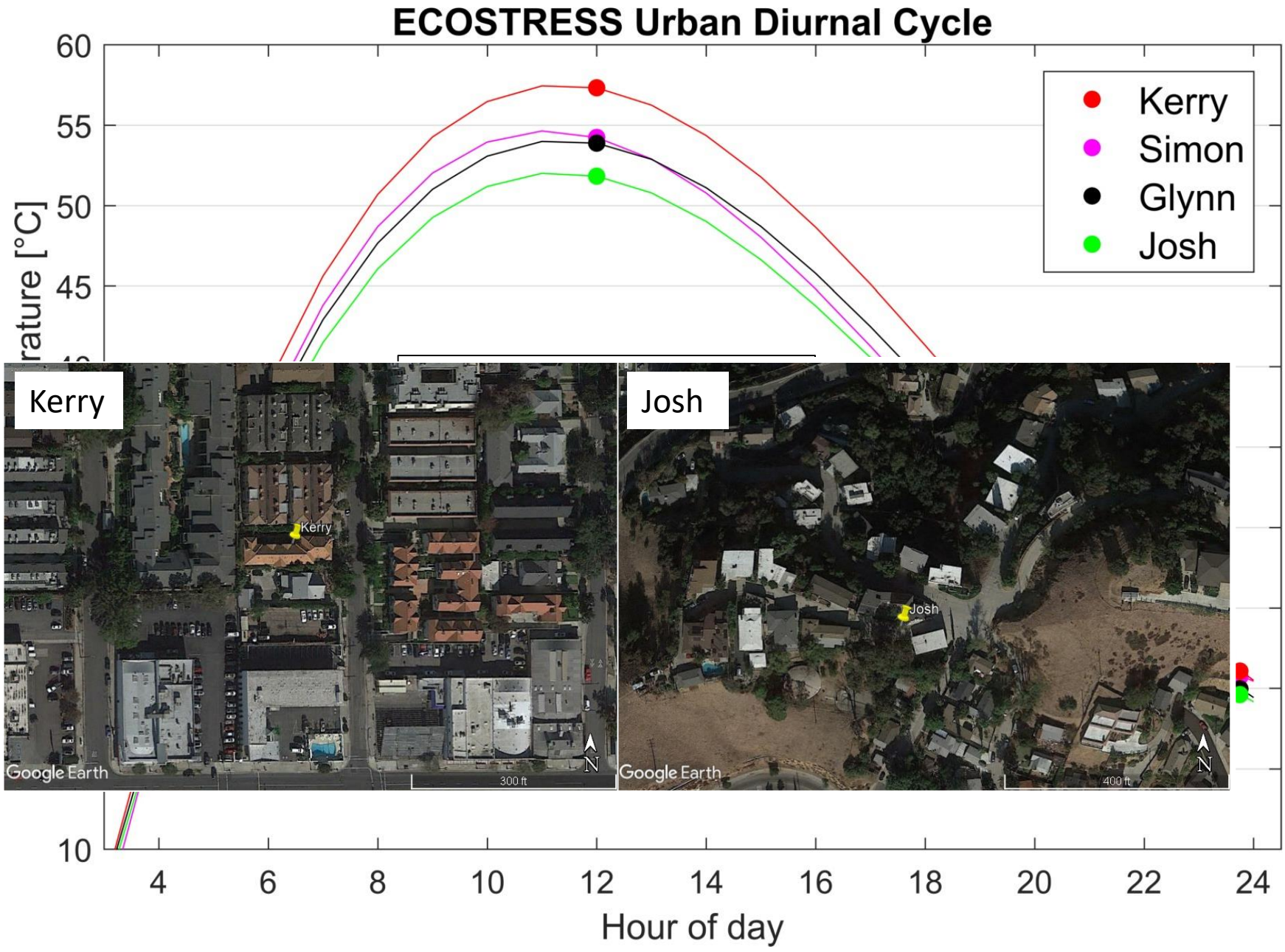
Slide courtesy of Pangiotis Sismanidis, NOA


22 July 2018, 04:07 am PST
31 July 2018, 03:00 pm PST
8 August 2018, 09:26 pm PST
14 July 2018, 11:43 pm PST
°C
60
55
50
45
40
35
30
25
20
15
10



Hottest spot?

150 F


ECOSTRESS Urban Diurnal Cycle
60
55
50
45
10
rature [°C]
4
6
8
10
12
14
16
18
20
22
24
Hour of day
Kerry
Simon
Glynn
Josh
Kerry
Kerry
Google Earth
300 ft
N
Josh
Josh
Google Earth
400 ft
N

Heat Vulnerability Index (HVI) Model

$$HVI = E_i(x) + S_i(y) - R_i(z)$$

$E_i(x)$ ***Exposure***

x = Land Surface Temperature (LST) ⟶ **ECOSTRESS**

$S_i(y)$ ***Sensitivity***

y = Socio-Demographic Data (poverty, elderly etc)

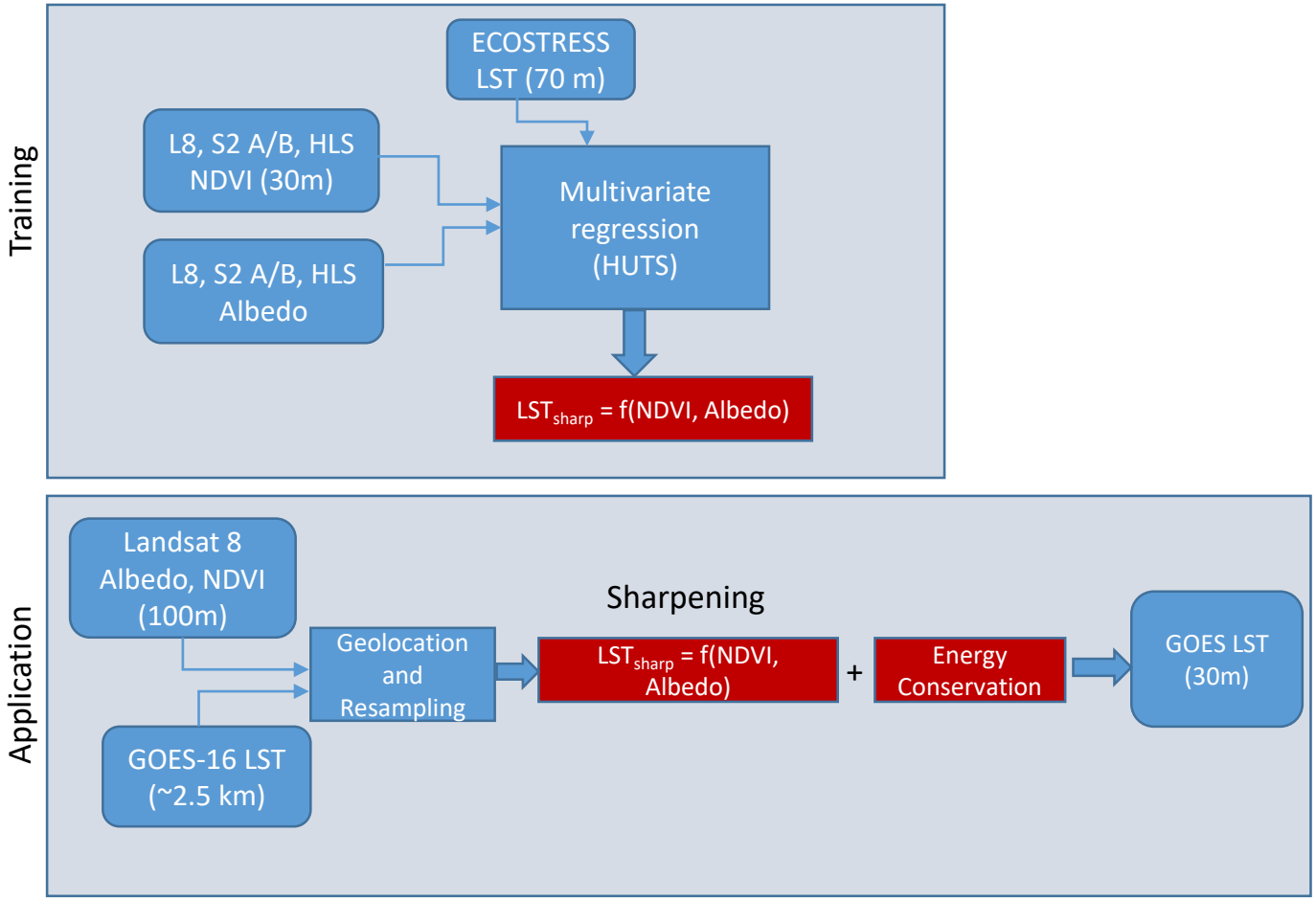
(source: SEDAC, 200m) SOCIOECONOMIC DATA AND APPLICATIONS CENTER (SEDAC)
A Data Center in NASA's Earth Observing System Data and Information System (EOSDIS) — Hosted by CIESIN at Columbia University

$R_i(z)$ ***Resilience***

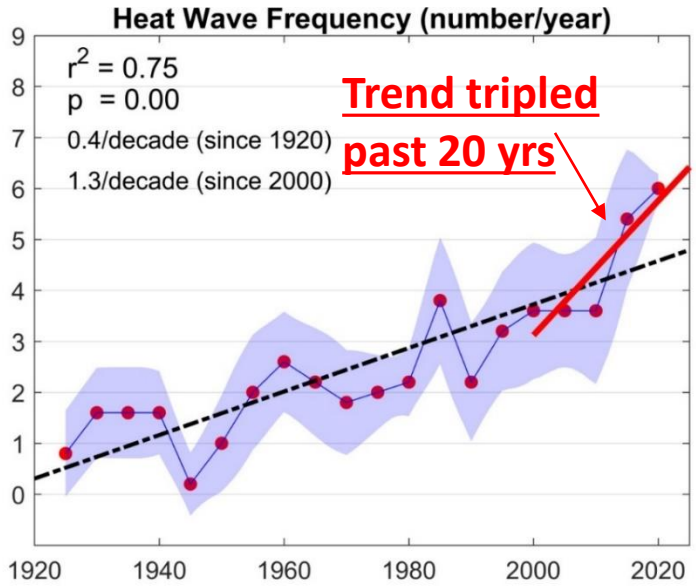
z = Vegetation fraction, Annual Income, Education

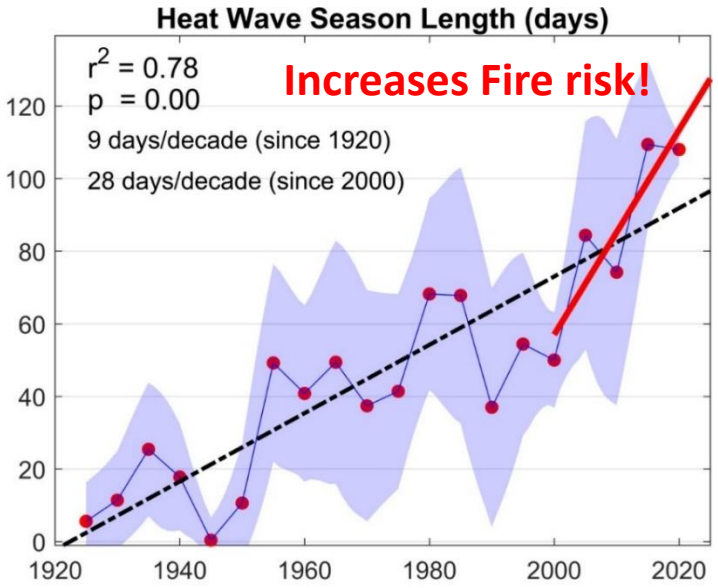
Still to include: Albedo, Building height, ET

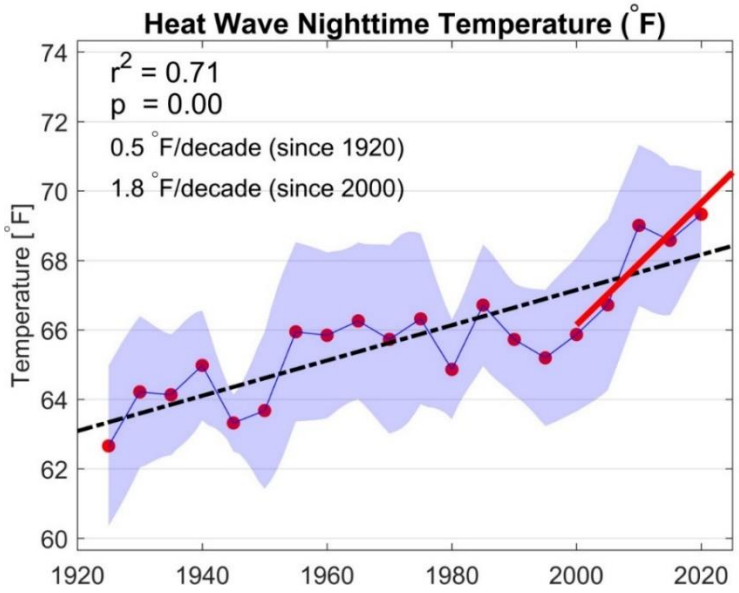
Sharpening Methodology

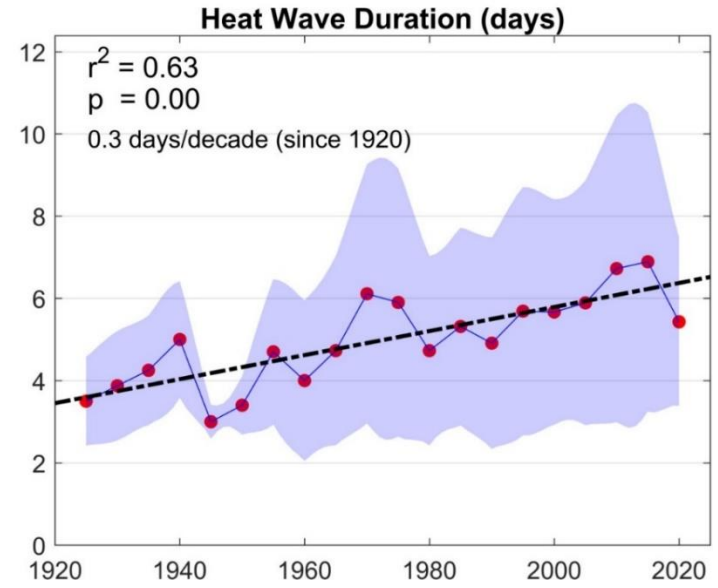


Los Angeles Heat Wave Trends









Human health impacts (Morbidity, Mortality)

Applications

How do we provide tangible benefits to society and cool cities?

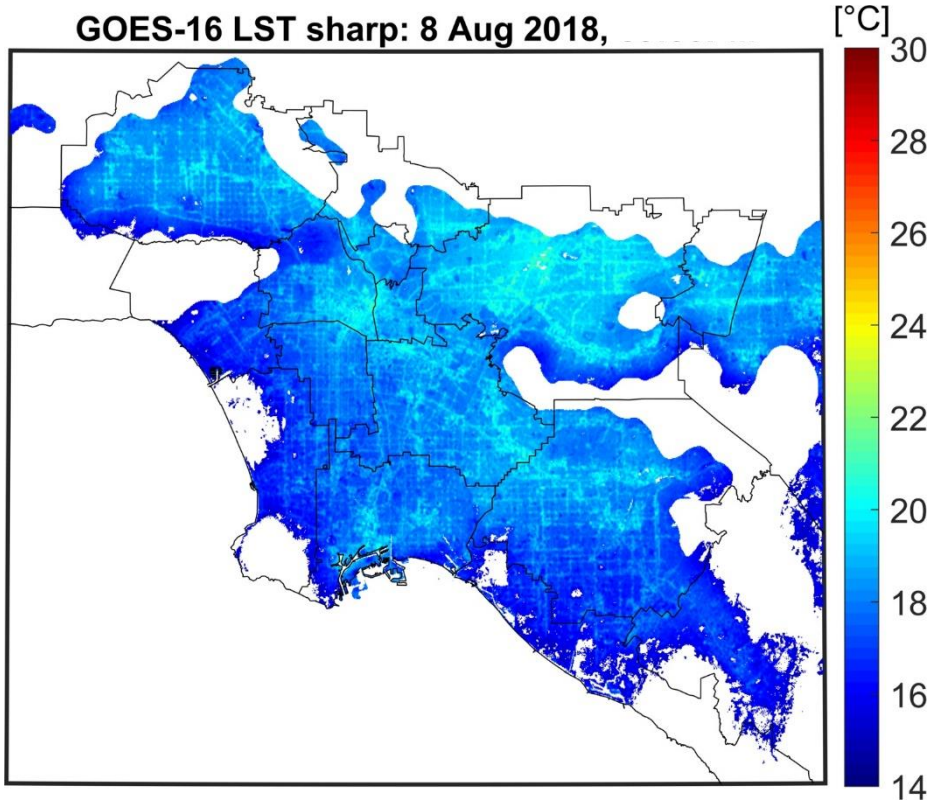
Climate Resolve

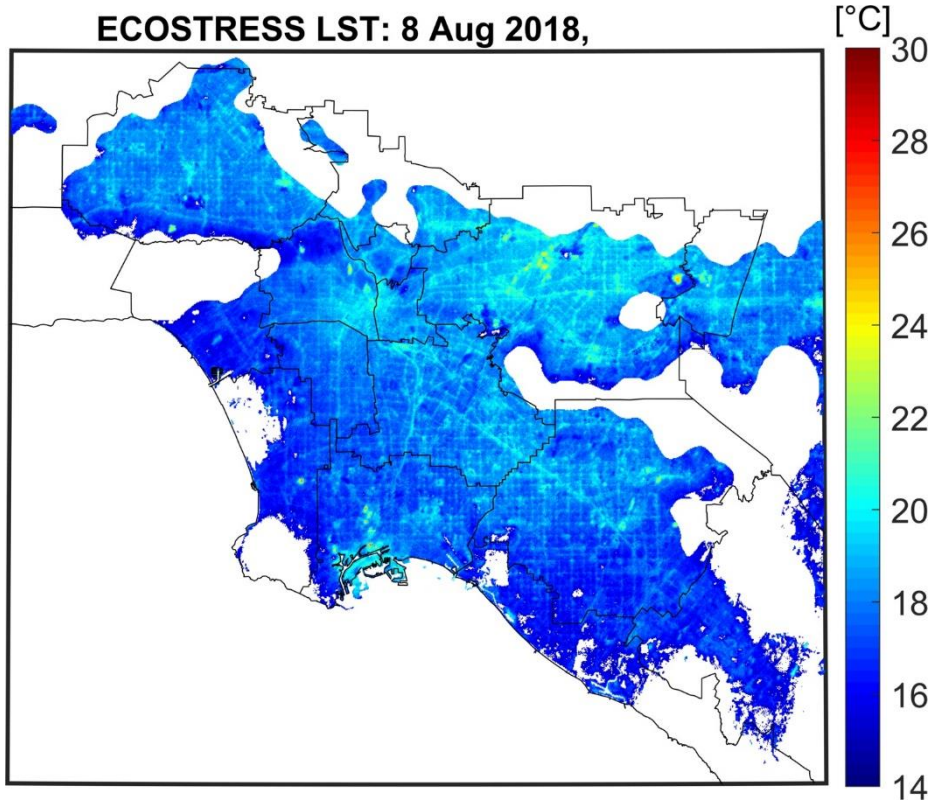
County of Los Angeles Public Health

LARC
Los Angeles Regional Collaborative for Climate Action and Sustainability

LOS ANGELES COUNTY
CHIEF SUSTAINABILITY OFFICE
ENVIRONMENT. EQUITY. ECONOMY.

GOES-16 Sharpening validation with ECOSTRESS at 100m resolution – **4:00 am**





GOES-16 Sharpening validation with ECOSTRESS at 100m resolution – **4:30 am**