National Aeronautics and Space Administration

Level-2 Land Surface Temperature and Emissivity

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Glynn Hulley, JPL; Eric Wood, Princeton Univ.
Collaborators:
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ECOSTRESS Science Team meeting, Pasadena, CA, 21 March 2019

Outline

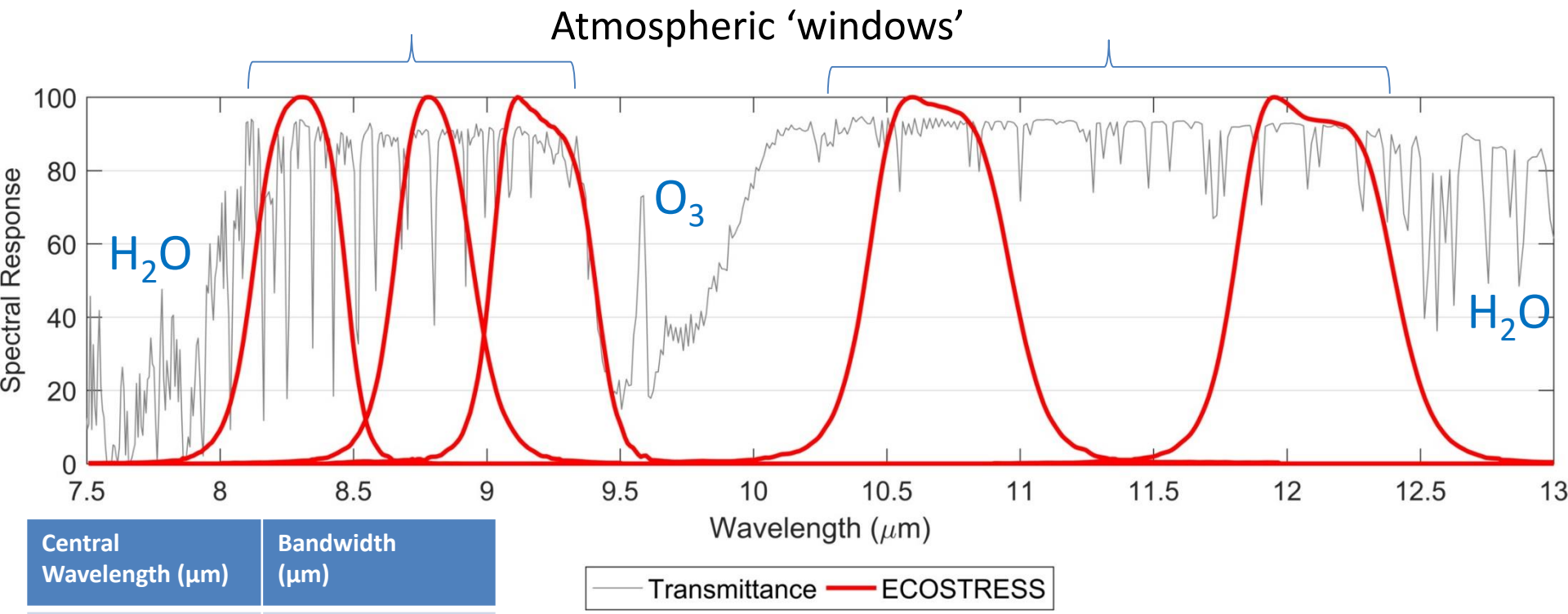
1. L2 products
2. Examples and Highlights
3. Validation

Credit: NASA/SpaceX

ECOSTRESS Level-2 Science Data Sets (SDS)

SDS	Long Name	Units
LST	Land Surface Temperature	K
Emissivity	Emissivity (bands 1 -5)	n/a
PWV	Precipitable Water Vapor	cm
QC	Quality Control (16-bit)	n/a
LST_err	LST Uncertainty	K
Emis_err	Emissivity Uncertainty (bands 1 – 5)	n/a
EmisWB	Wideband Emissivity (8 – 12.5 micron)	n/a

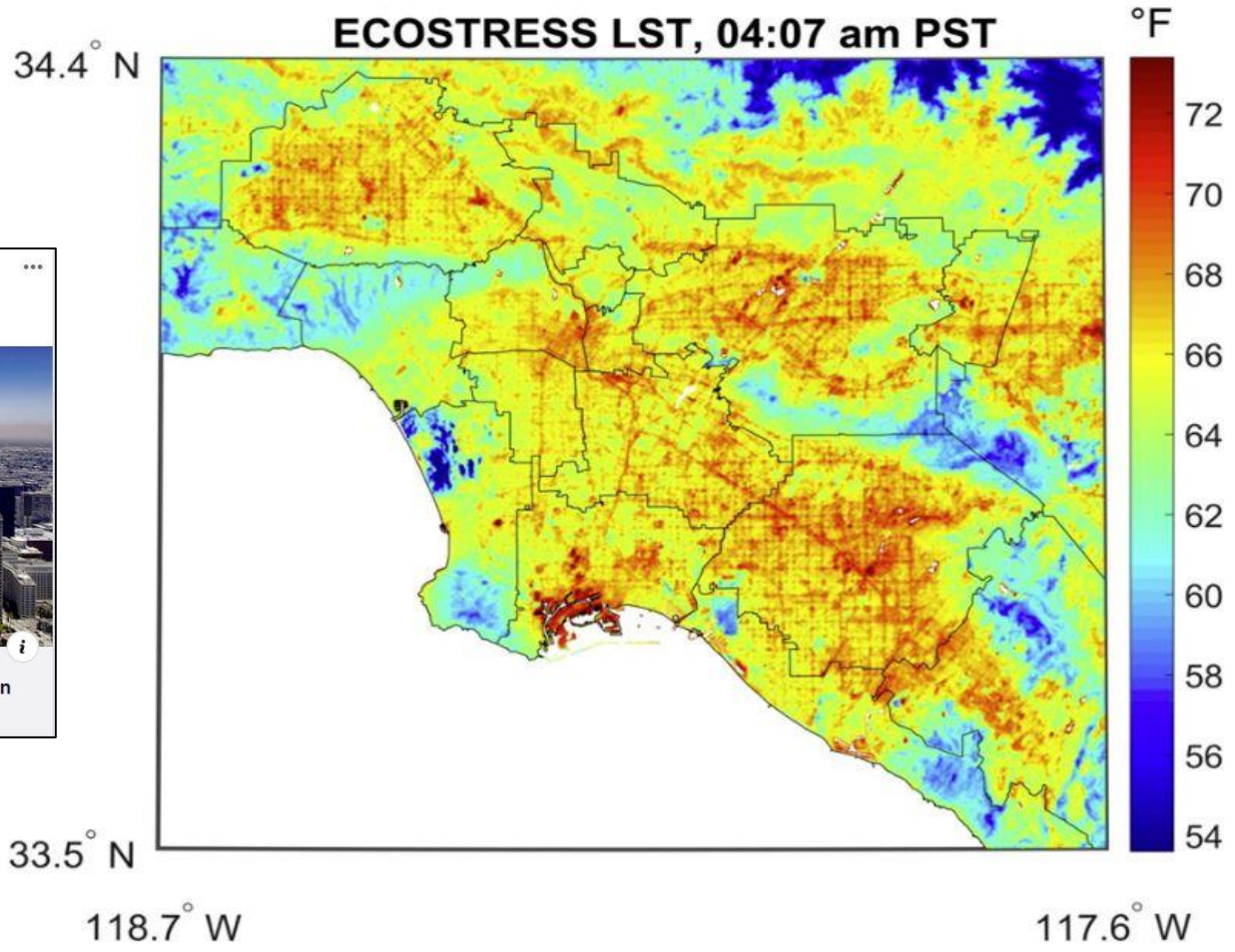
Multispectral information – Emissivity

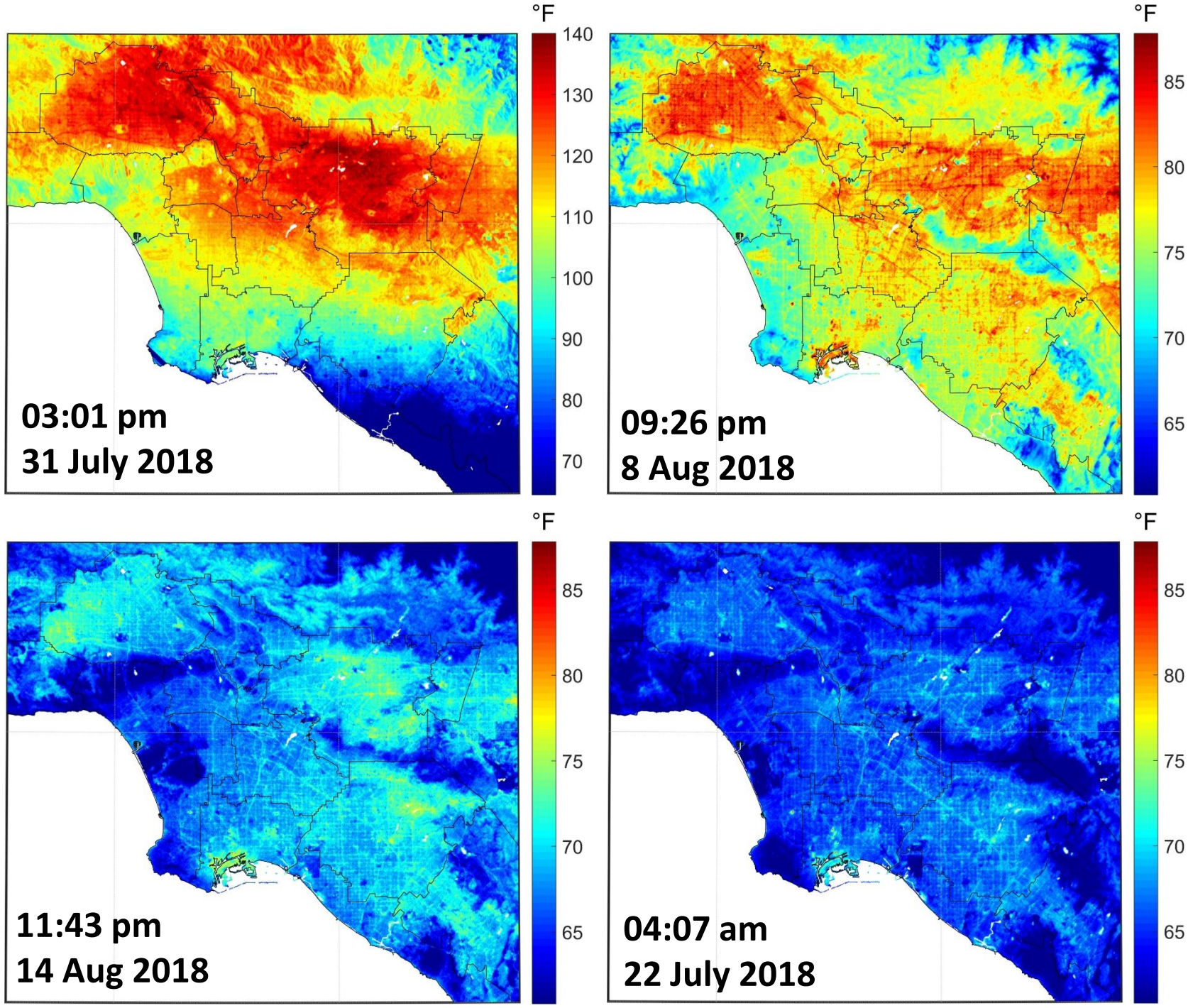


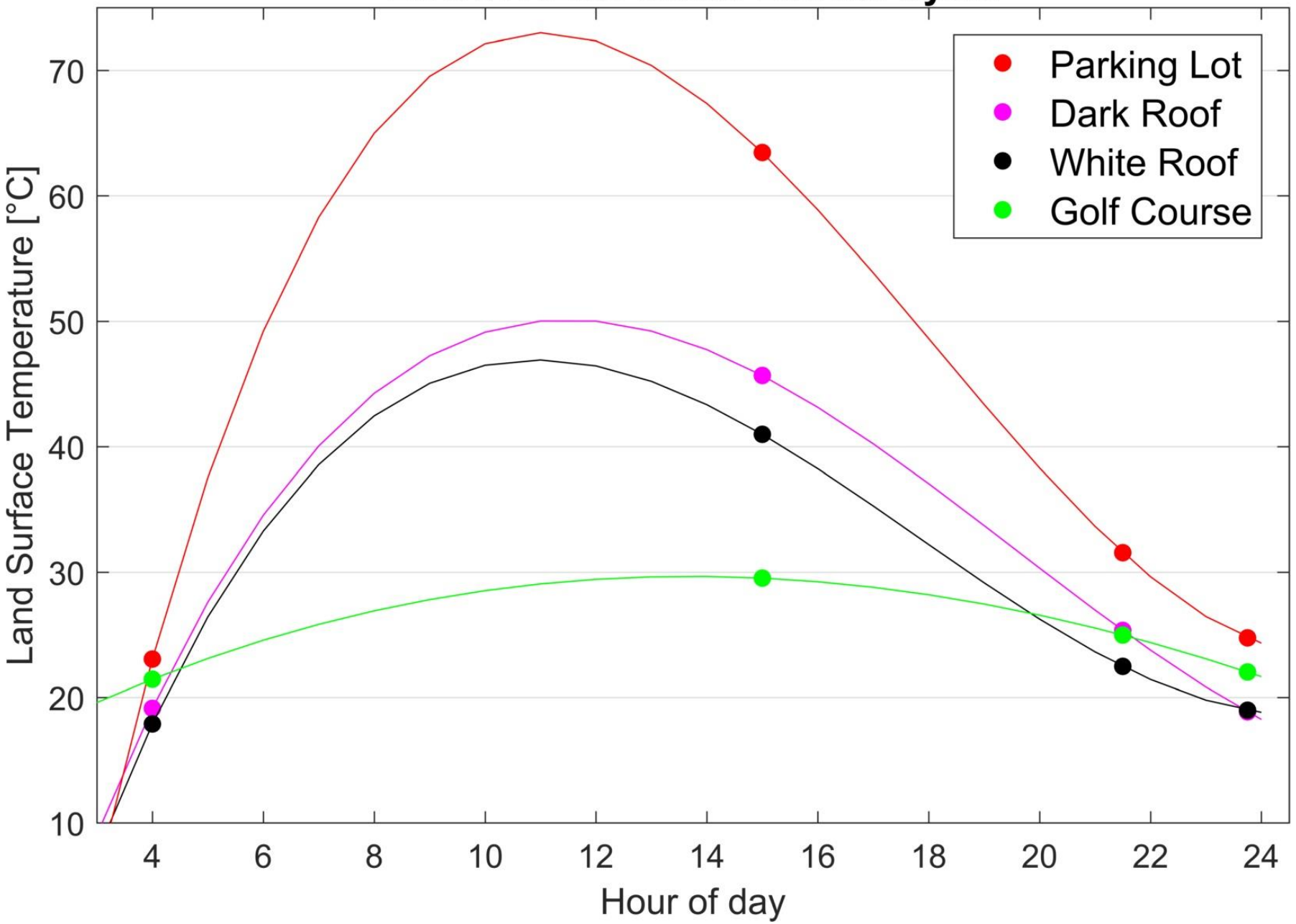
Central Wavelength (µm)	Bandwidth (µm)
8.29	0.355
8.80	0.309
9.20	0.395
10.6	0.553
12.09	0.610

NEWS | SEPTEMBER 18, 2018

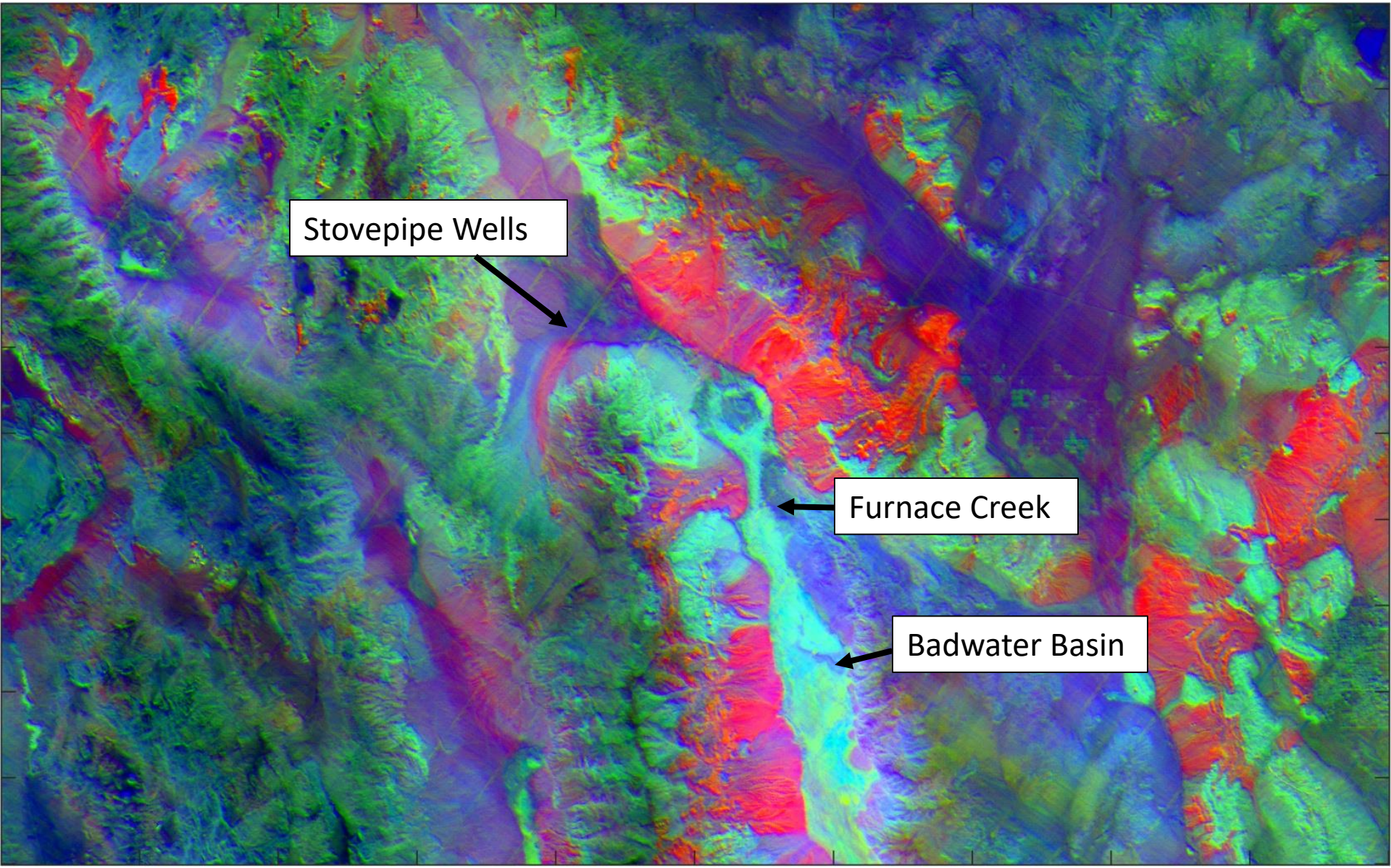
ECOSTRESS Maps LA's Hot Spots



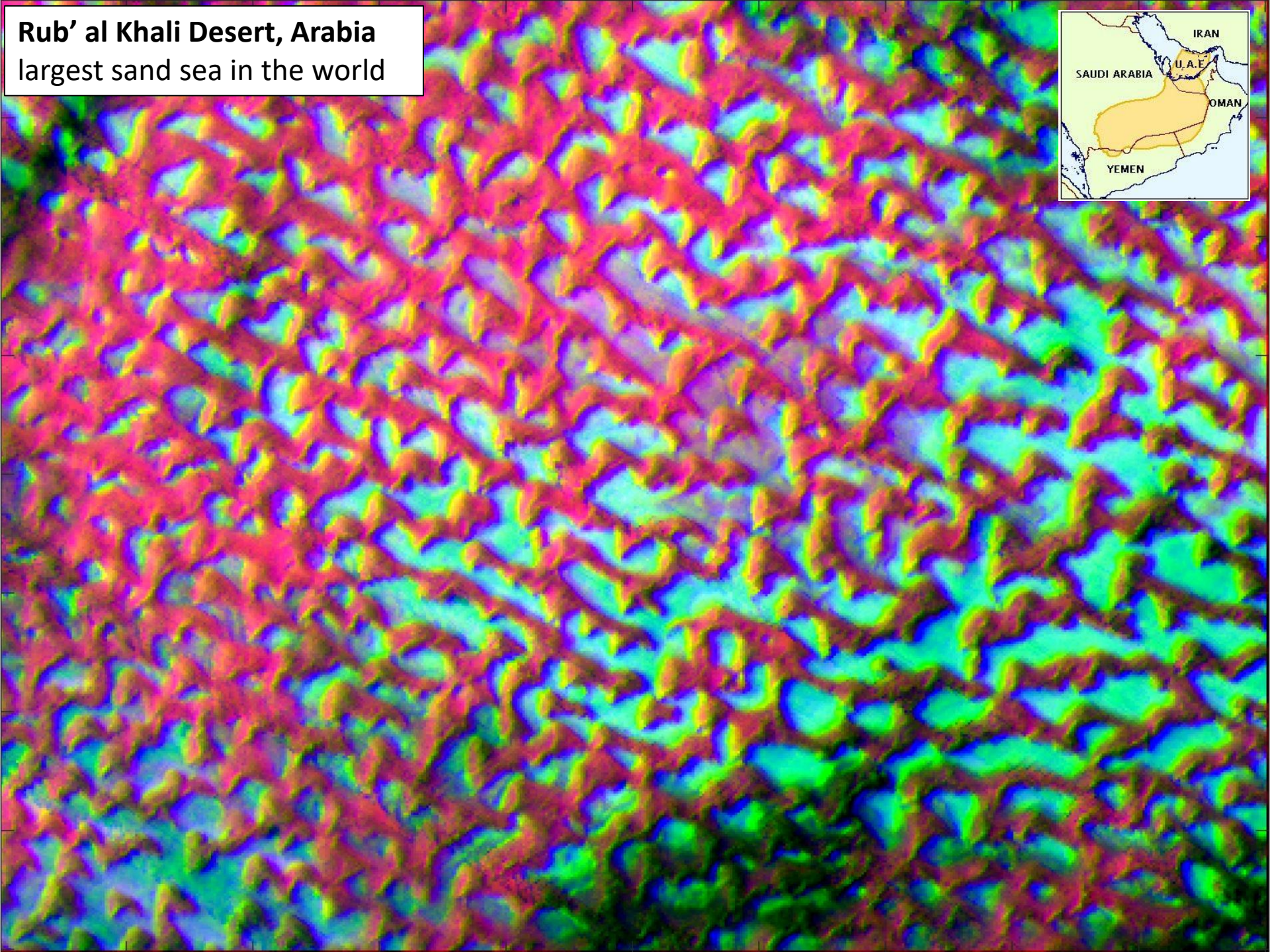

°F
140
130
120
110
100
90
80
70
03:01 pm
31 July 2018
°F
85
80
75
70
65
09:26 pm
8 Aug 2018
°F
85
80
75
70
65
11:43 pm
14 Aug 2018
°F
85
80
75
70
65
04:07 am
22 July 2018


ECOSTRESS Urban Diurnal Cycle
Parking Lot
Dark Roof
White Roof
Golf Course
Land Surface Temperature [°C]
Hour of day
10
20
30
40
50
60
70
4
6
8
10
12
14
16
18
20
22
24

Death Valley, California, 17 September at 12:13 UTC. Decorrelation stretch of bands 5, 3, 2 in RGB



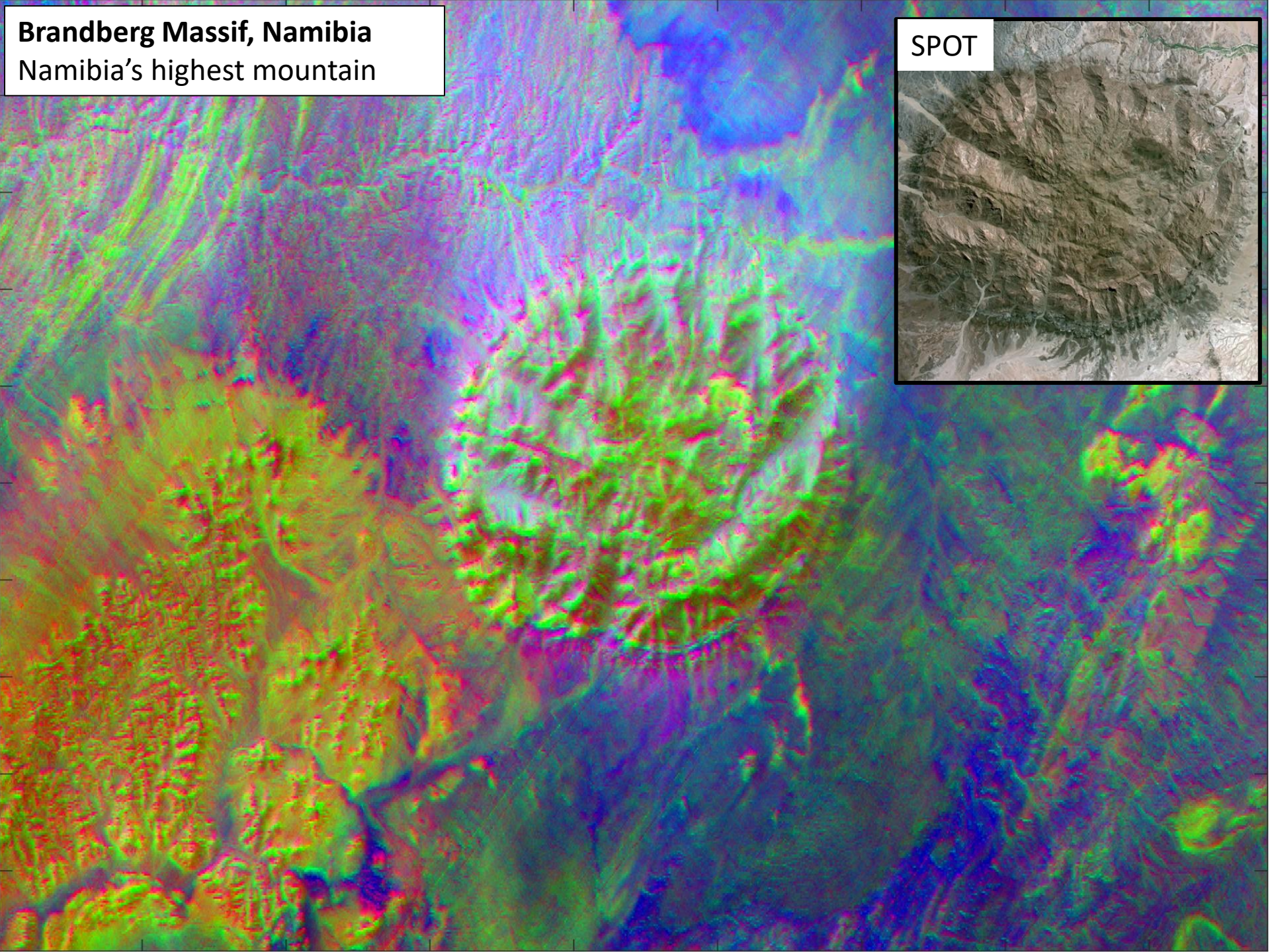
Rub’ al Khali Desert, Arabia
largest sand sea in the world



Namib dunes, Namibia
Tallest dunes in the world

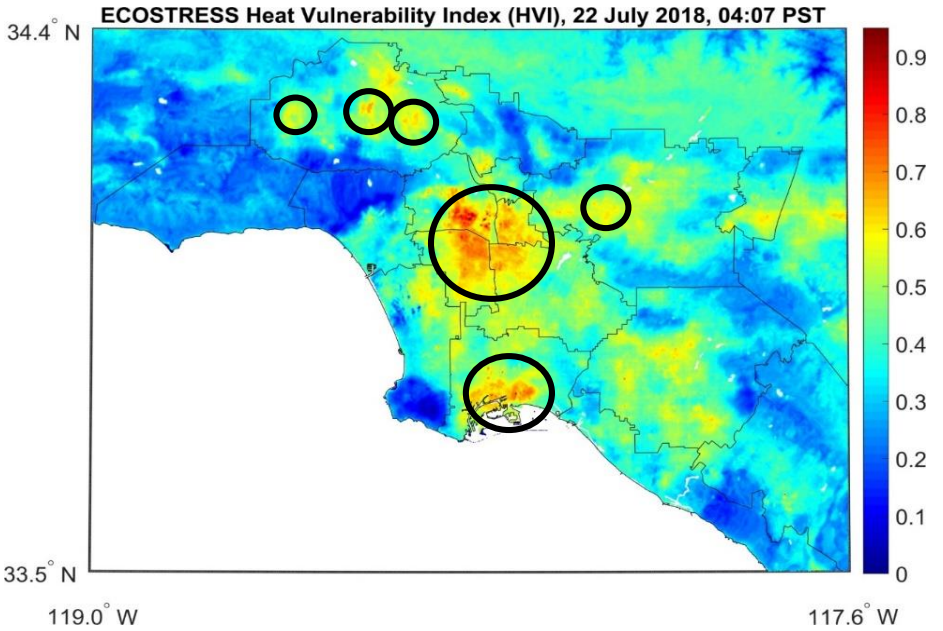
Image credit: 2017 Siyabona Africa (Pty)Ltd

Brandberg Massif, Namibia
Namibia's highest mountain



Heat advisories and public health:

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



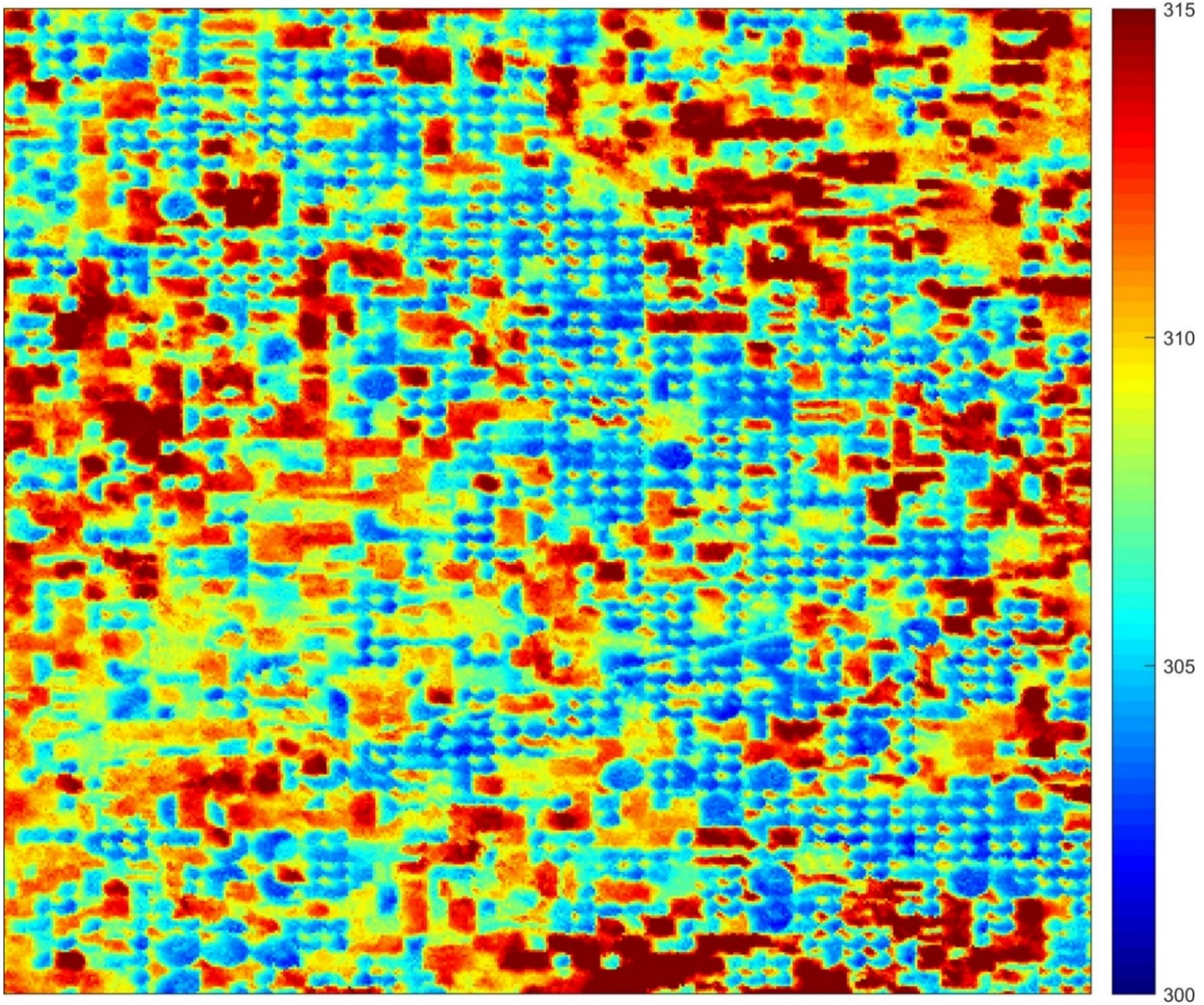
Identify optimal locations for cooling centers

Use HVI to advise on realistic health advisories (currently use Heat Index from NWS)

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

ECOSTRESS LST, Garden city, Kansas, 2018-08-04, 22:05 UTC



National Aeronautics and Space Administration
Goddard Space Flight Center

Keywords

CEOS Working Group on Calibration and Validation

Land Product Validation Subgroup

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LPV Focus Areas

- LAI
- fAPAR
- Fire/Burn Area
- Phenology
- Vegetation Index
- Land Cover
- Snow Cover
- BRDF/Albedo
- Soil Moisture
- LST and Emissivity
- Biomass

LPV Supersites

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The mission of the CEOS Land Product Validation (LPV) subgroup is to coordinate the quantitative validation of satellite-derived products. The focus lies on standardized intercomparison and validation across products from different satellite, algorithms, and agency sources.

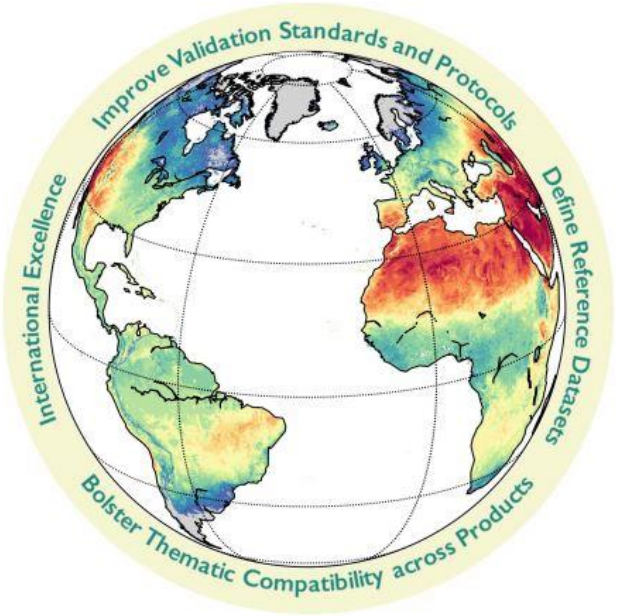
The sub-group consists of 11 Focus Areas, with 2 co-leads responsible for each land surface variable (essential climate and biodiversity variables).

CEOS VALIDATION HIERARCHY

	Validation Stage - Definition and Current State	Variable
0	No validation. Product accuracy has not been assessed. Product considered beta.	
1	Product accuracy is assessed from a small (typically < 30) set of locations and time periods by comparison with in-situ or other suitable reference data.	Snow Fire Radiative Power
2	Product accuracy is estimated over a significant set of locations and time periods by comparison with reference in situ or other suitable reference data. Spatial and temporal consistency of the product and consistency with similar products has been evaluated over globally representative locations and time periods. Results are published in the peer-reviewed literature.	fAPAR Phenology Burned Area Land Cover LAI
3	Uncertainties in the product and its associated structure are well quantified from comparison with reference in situ or other suitable reference data. Uncertainties are characterized in a statistically rigorous way over multiple locations and time periods representing global conditions. Spatial and temporal consistency of the product and with similar products has been evaluated over globally representative locations and periods. Results are published in the peer-reviewed literature.	Vegetation Indicies Albedo Soil Moisture LST & EmissiSvity Phenology
4	Validation results for stage 3 are systematically updated when new product versions are released and as the time-series expands.	Active Fire

Committee on Earth Observation Satellites
Working Group on Calibration and Validation
Land Product Validation Subgroup

Land Surface Temperature Product Validation Best Practice Protocol



Version 1.1 - January, 2018

Editors: Pierre Guillevic, Frank Göttsche, Jaime Nickeson, Miguel Román

Authors: Pierre Guillevic, Frank Göttsche, Jaime Nickeson, Glynn Hulley, Darren Ghent, Yunyue Yu, Isabel Trigo, Simon Hook, José A. Sobrino, John Remedios, Miguel Román and Fernando Camacho

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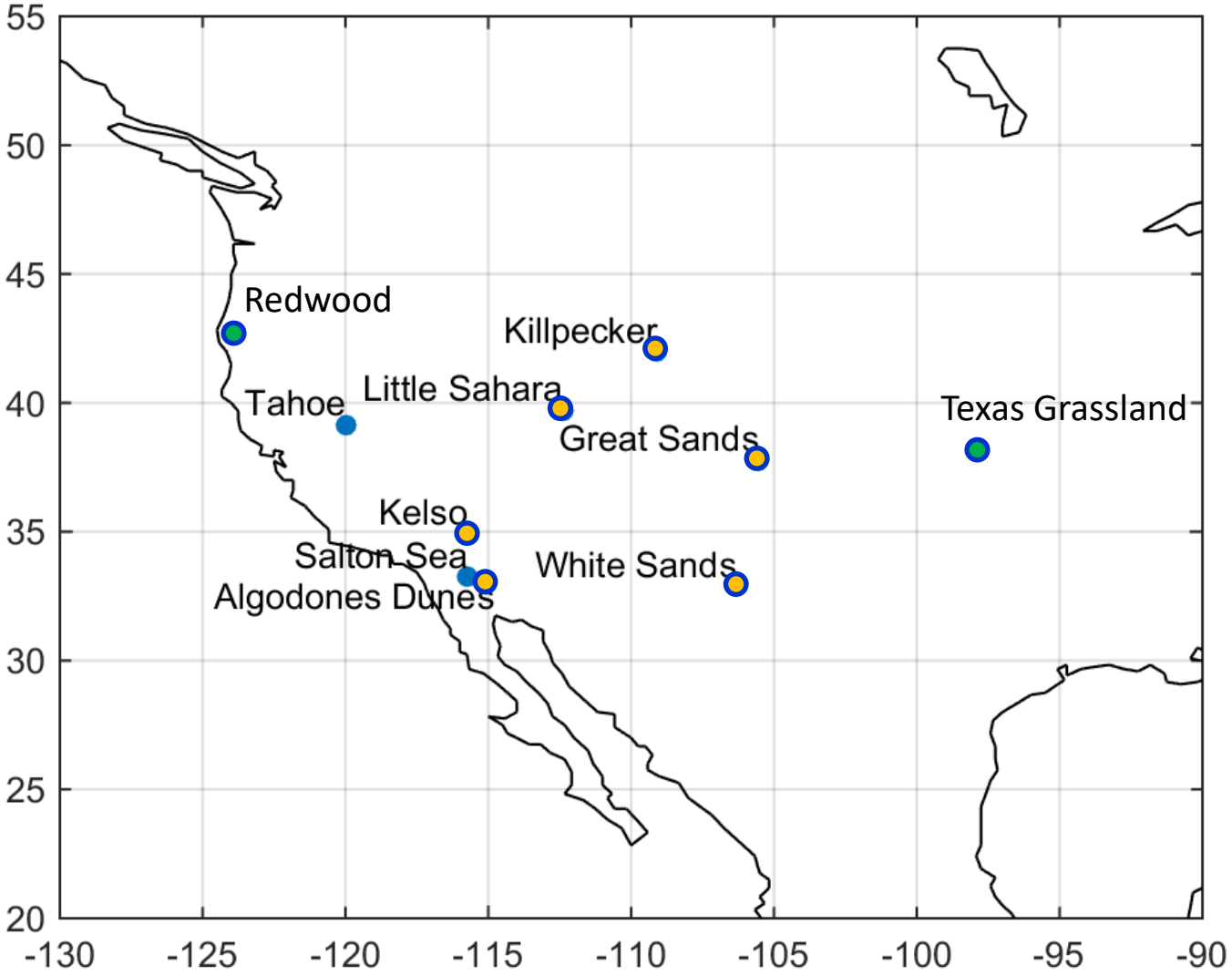
Three Validation Methods:

1. Temperature-based
2. Radiance-based
3. Sensor intercomparison

LST&E Validation Sites (Stage 1)



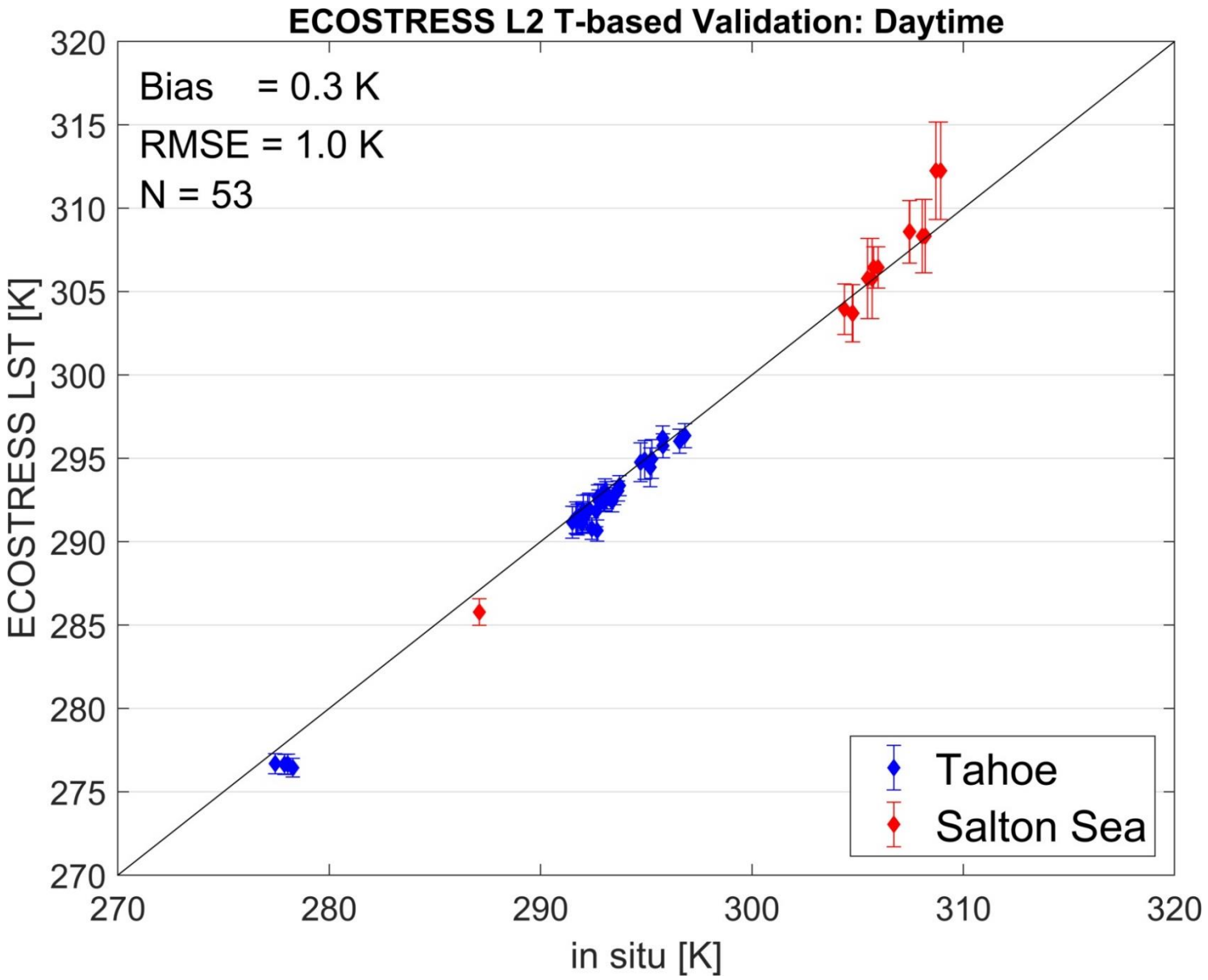
Temperature-based and Radiance-based validation methods

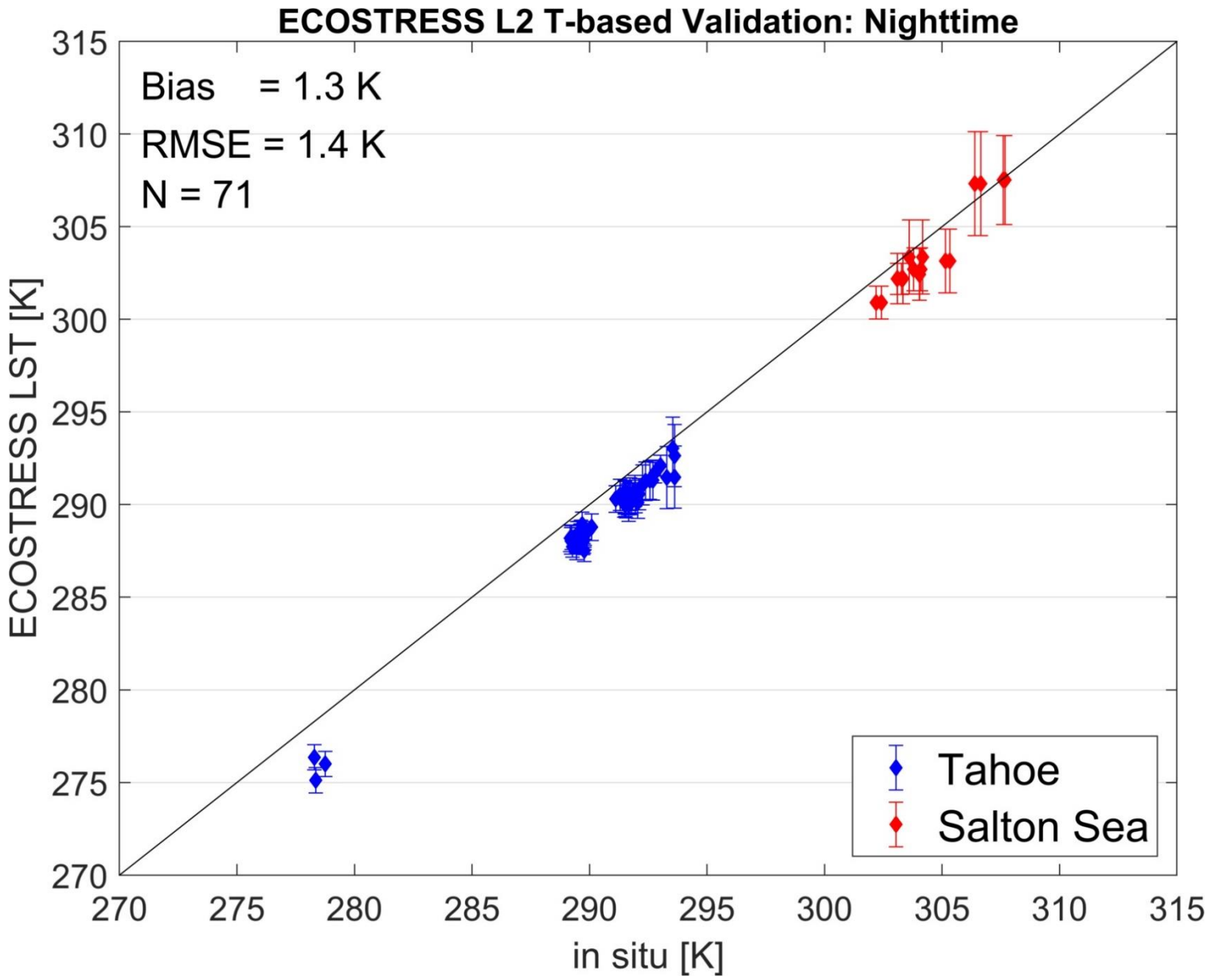
(Wan et al. 2008, Guillevic et al. 2012, Schneider et al. 2013, Hulley et al. 2012, Hook et al. 2007)

Water Validation

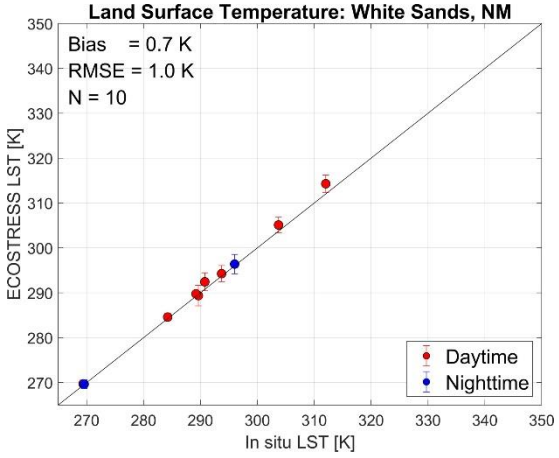
Lake Tahoe operating 24x7 since 1999

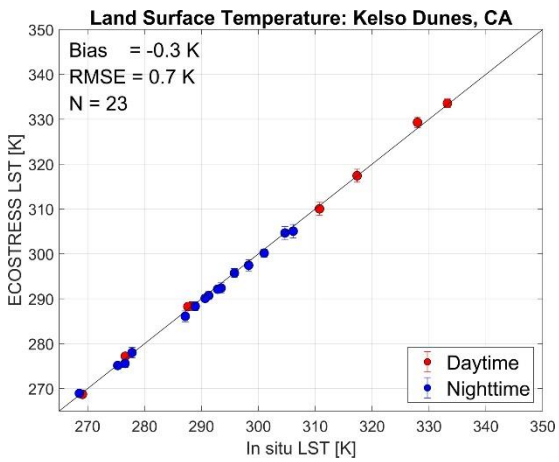
Salton Sea since 2007

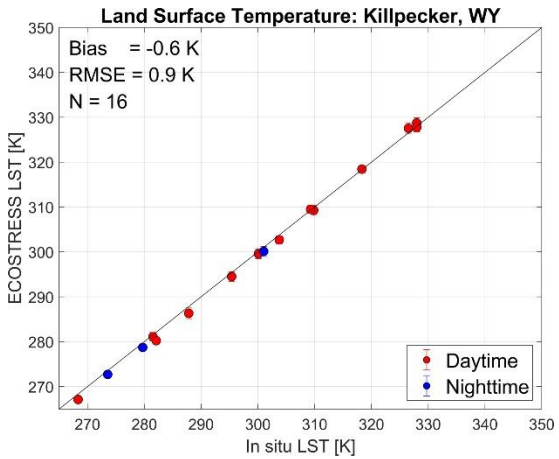

ECOSTRESS L2 T-based Validation: Daytime
Bias = 0.3 K
RMSE = 1.0 K
N = 53
ECOSTRESS LST [K]
in situ [K]
270
275
280
285
290
295
300
305
310
315
320
Tahoe
Salton Sea

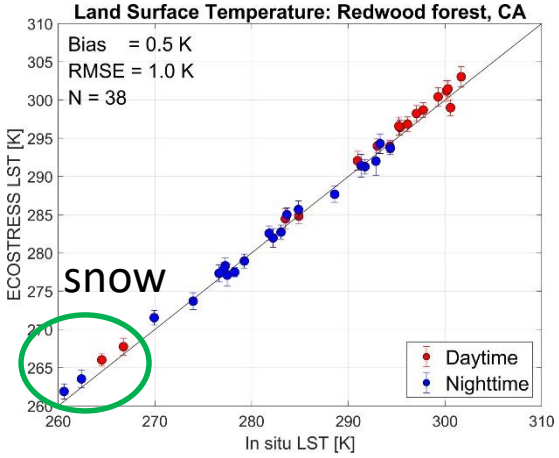

ECOSTRESS L2 T-based Validation: Nighttime
Bias = 1.3 K
RMSE = 1.4 K
N = 71
ECOSTRESS LST [K]
in situ [K]
Tahoe
Salton Sea
270
275
280
285
290
295
300
305
310
315

Pseudo-invariant sand dune sites

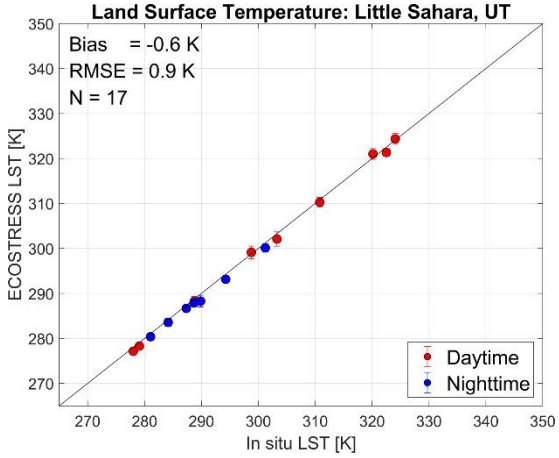


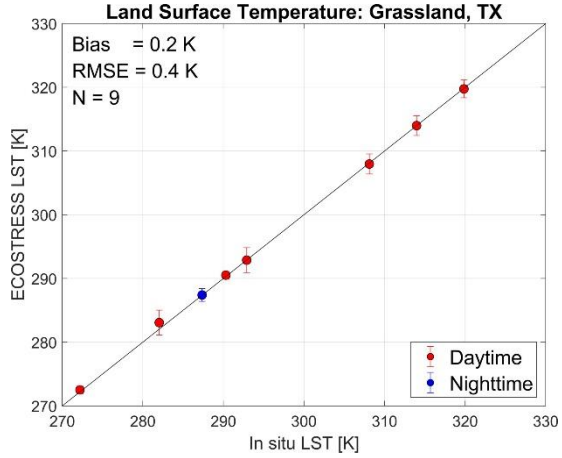


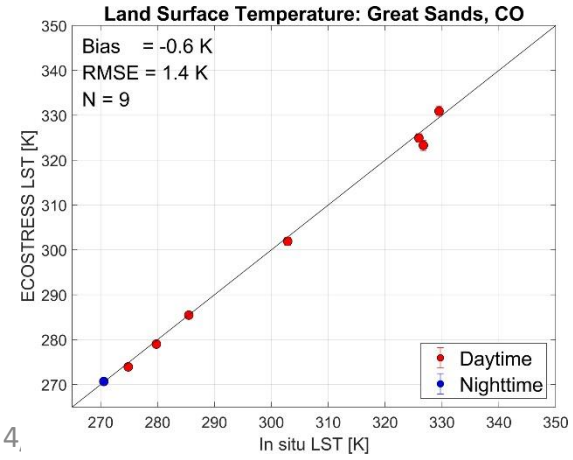


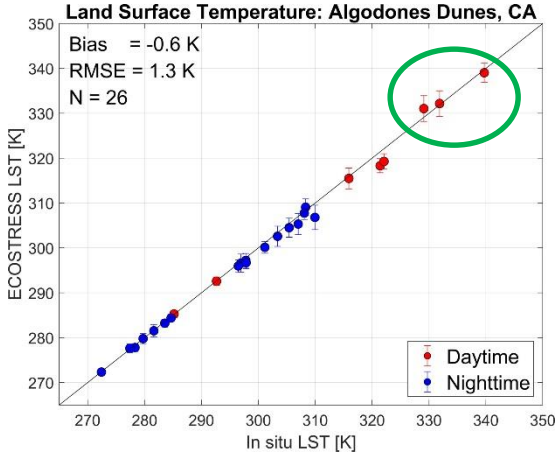


snow



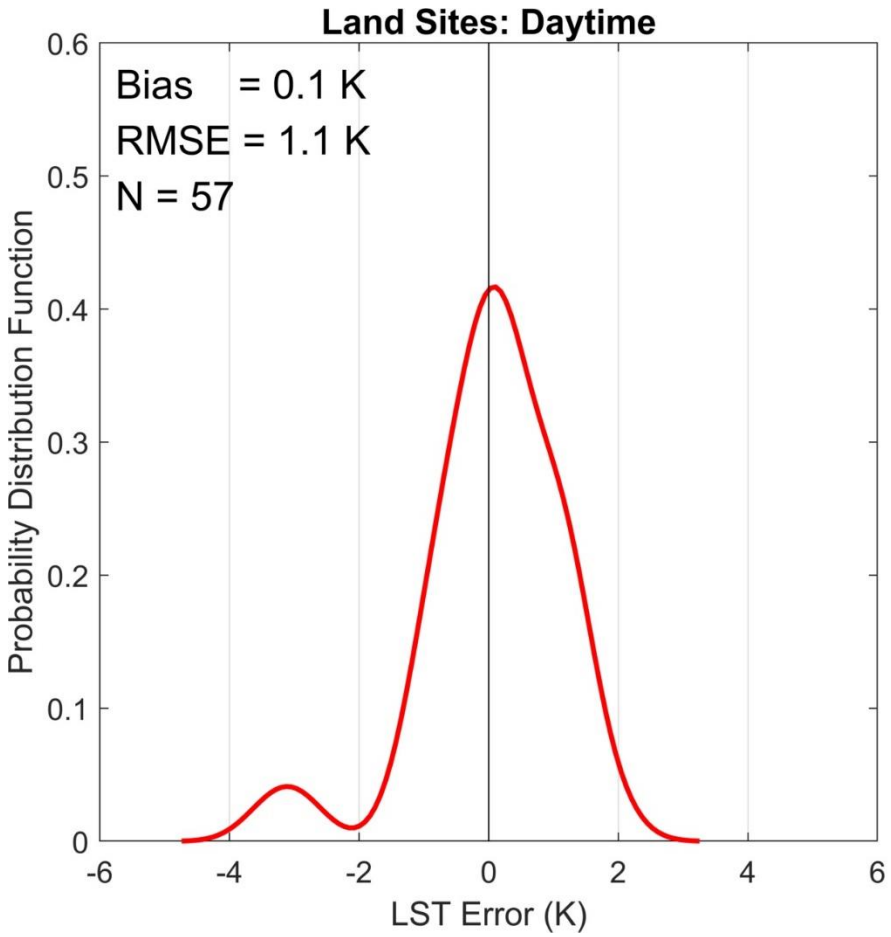


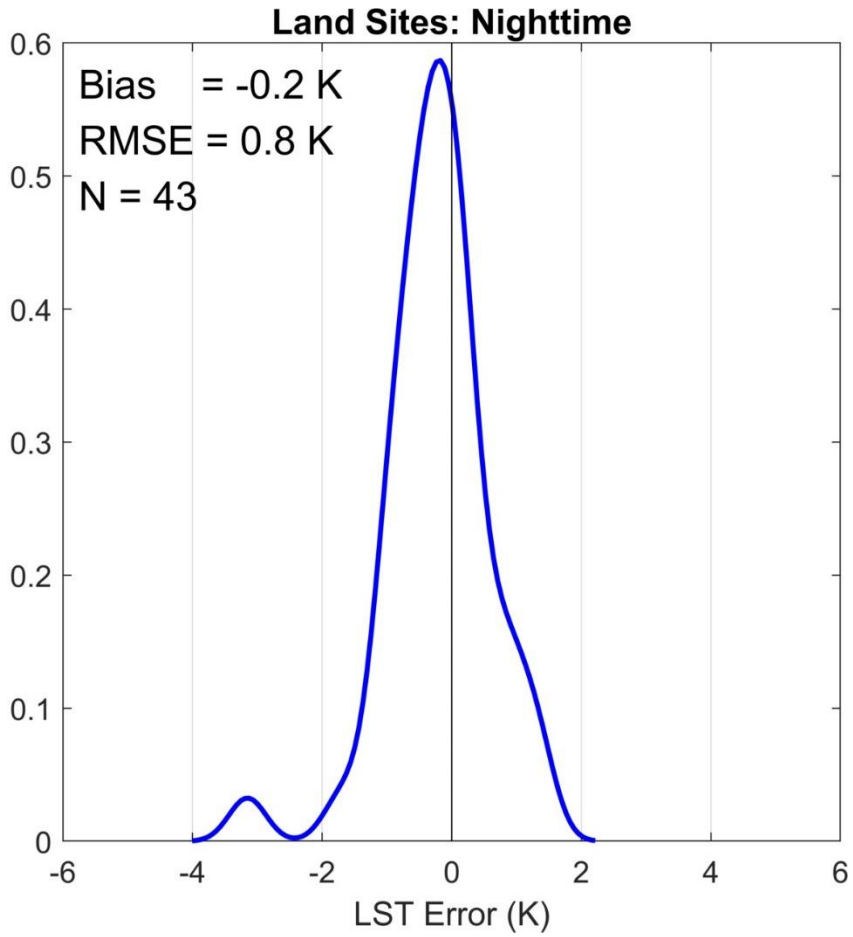




heatwave

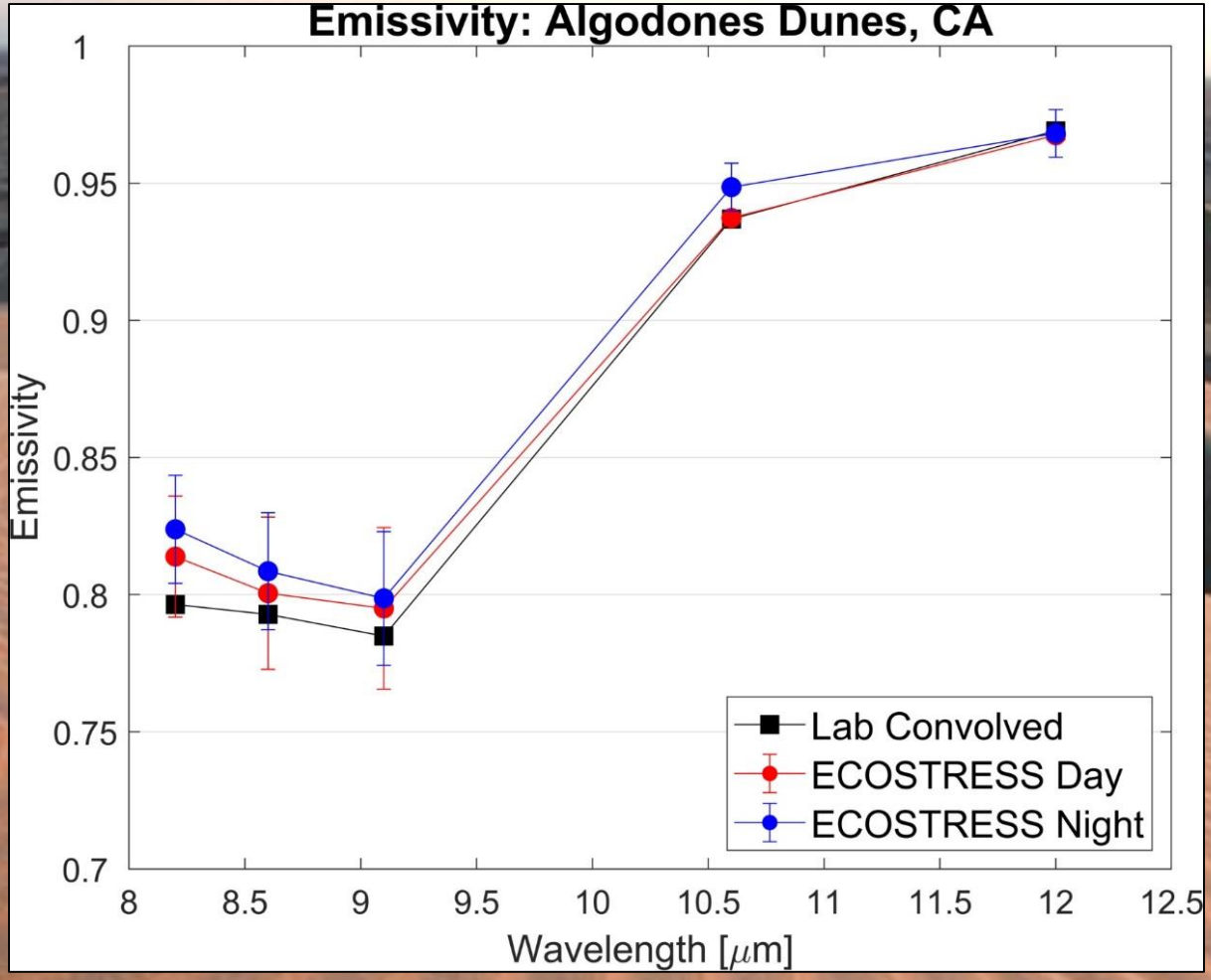
Land sites summary



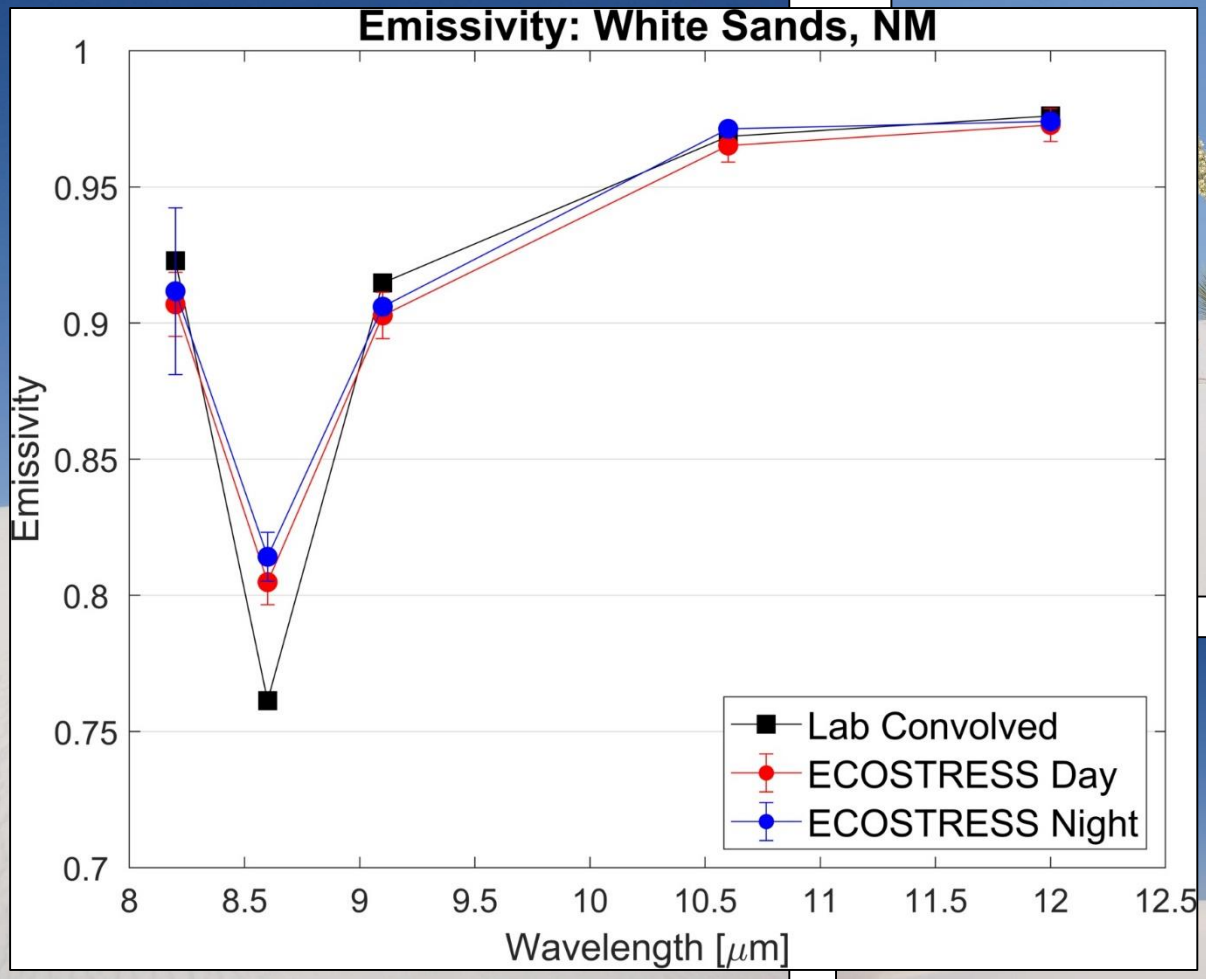


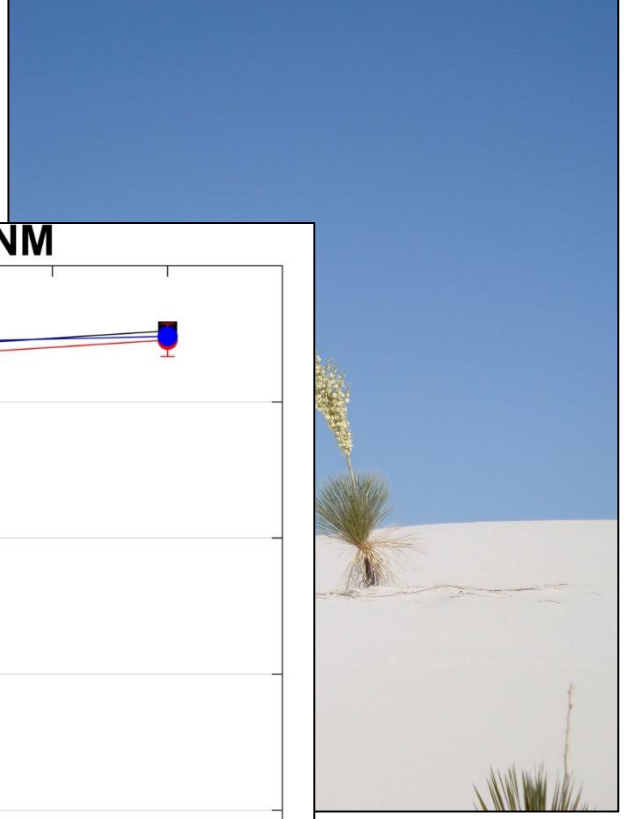
~1 K RMSE meeting accuracy requirements

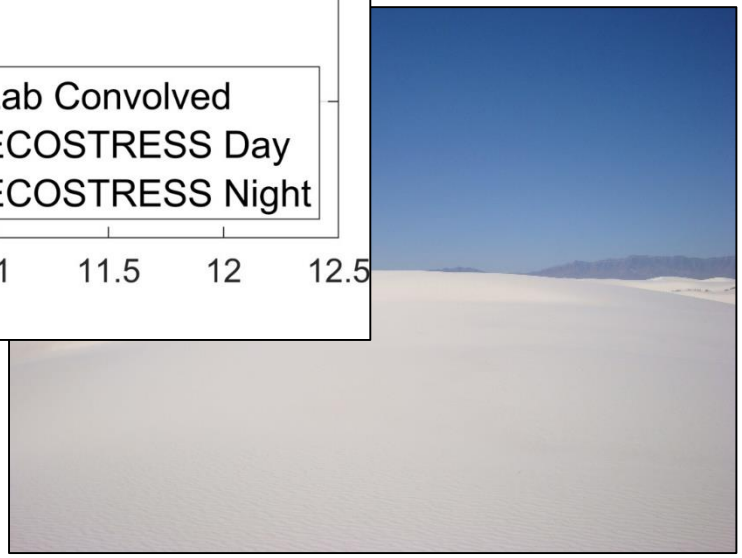
Algodones Dunes, CA



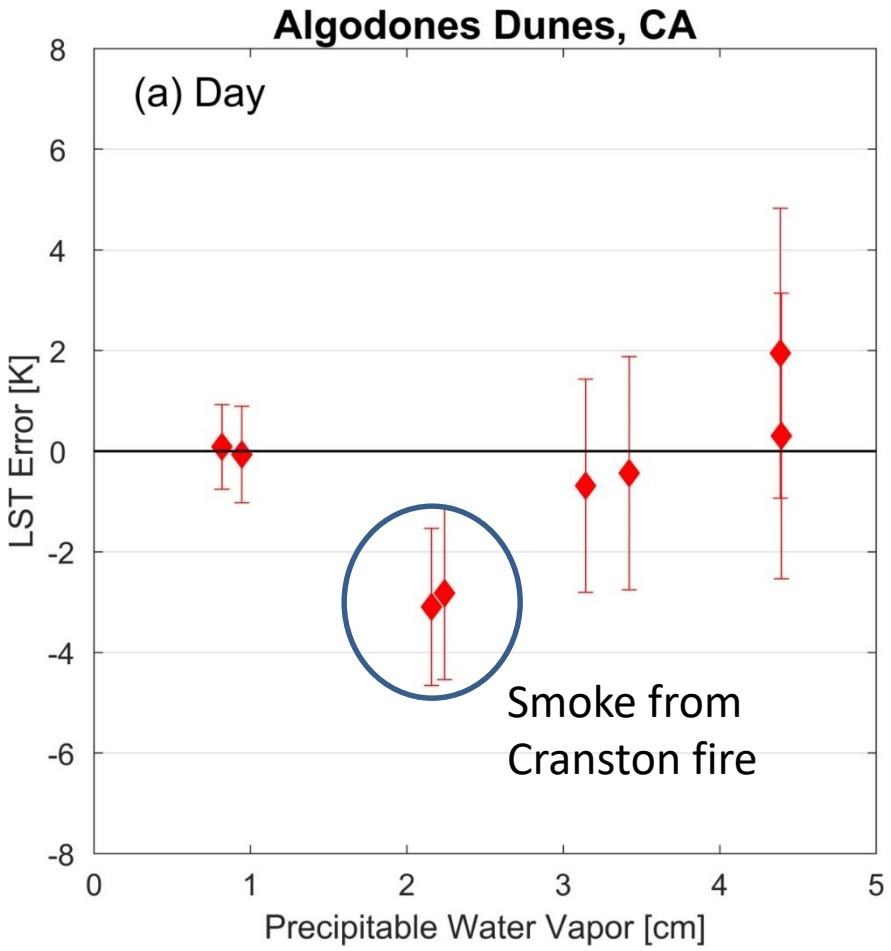
White Sands, NM

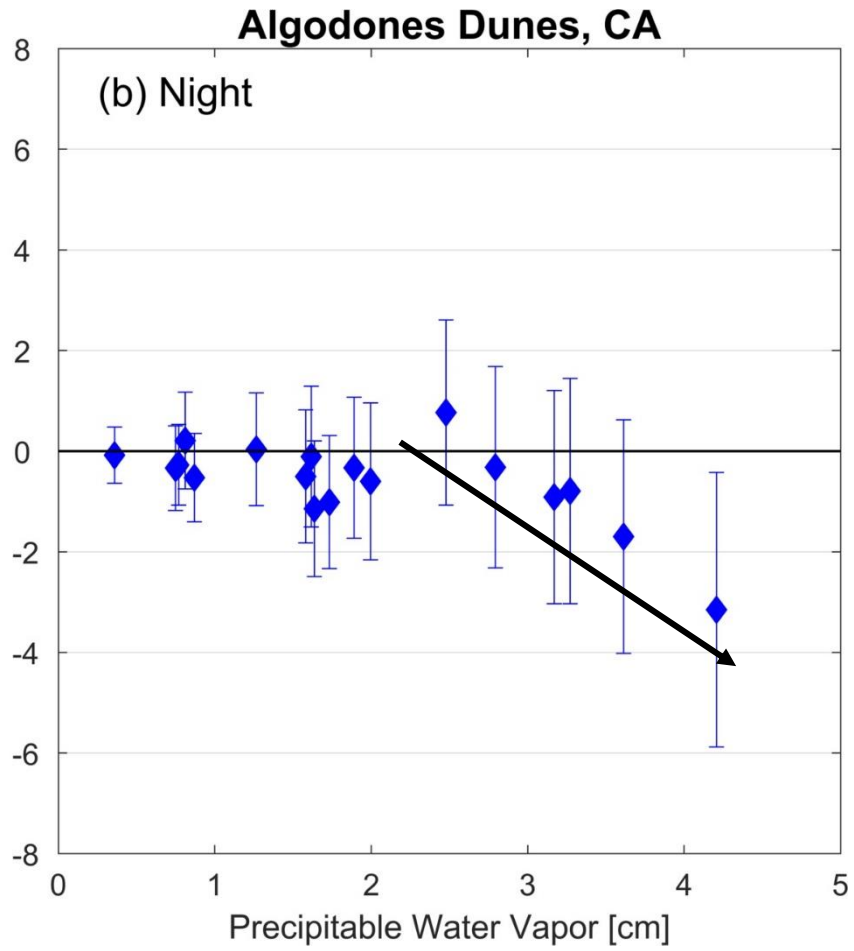






LST error and estimated uncertainty

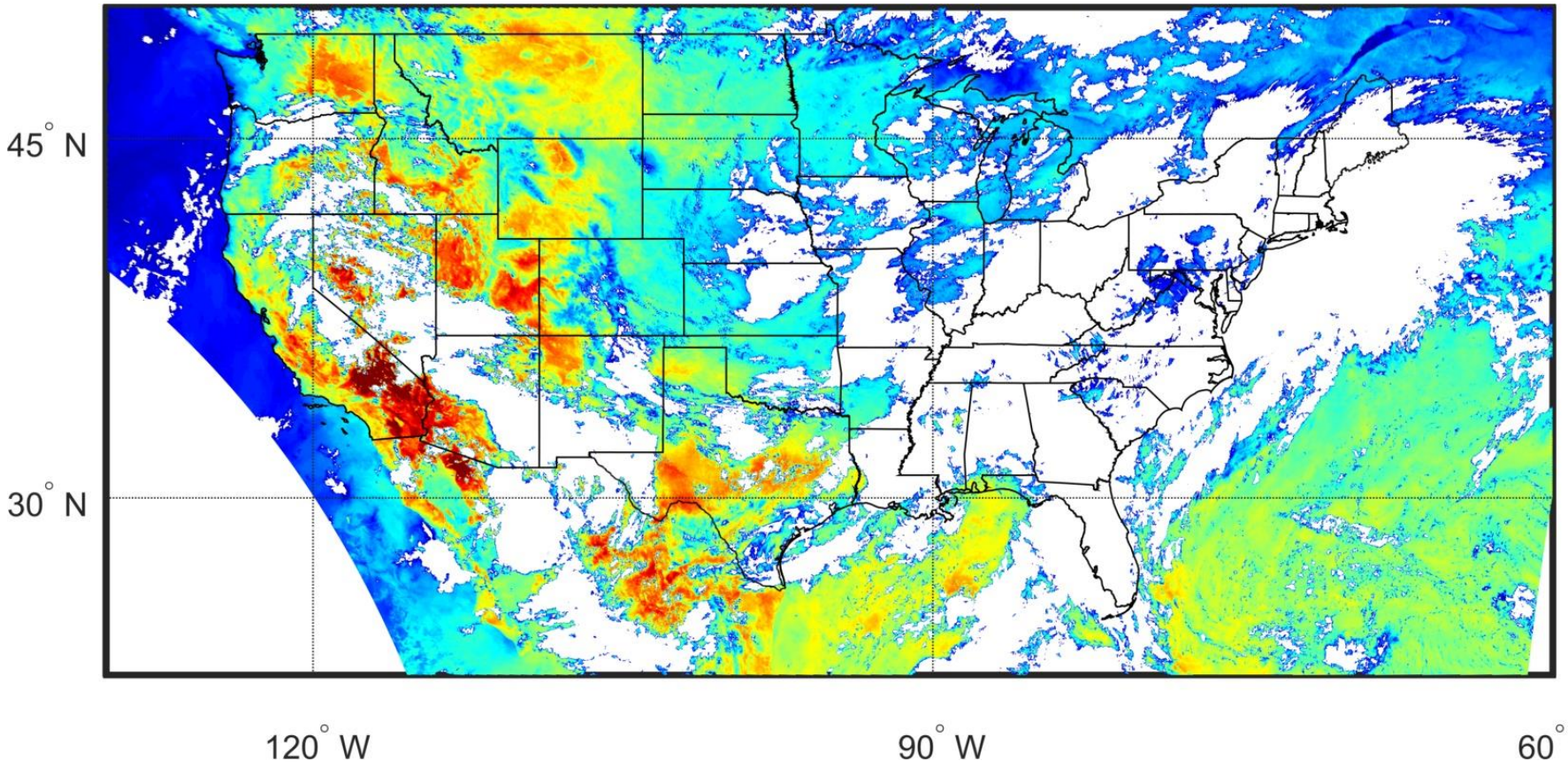


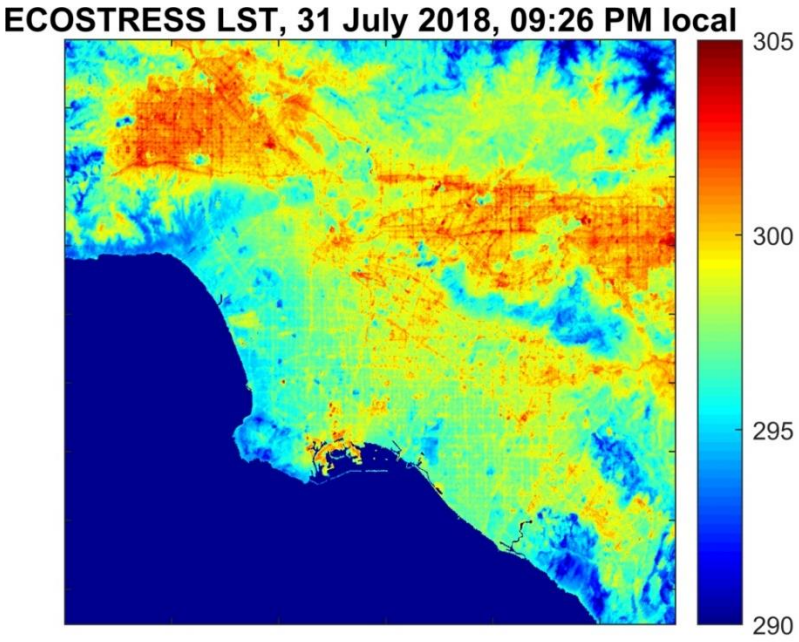


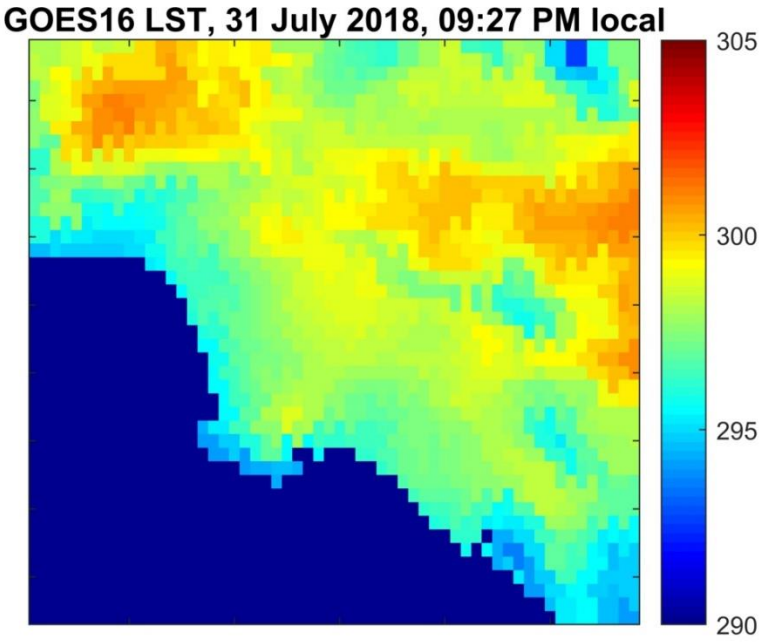
ECOSTRESS LST matchups with GOES-16 ABI:

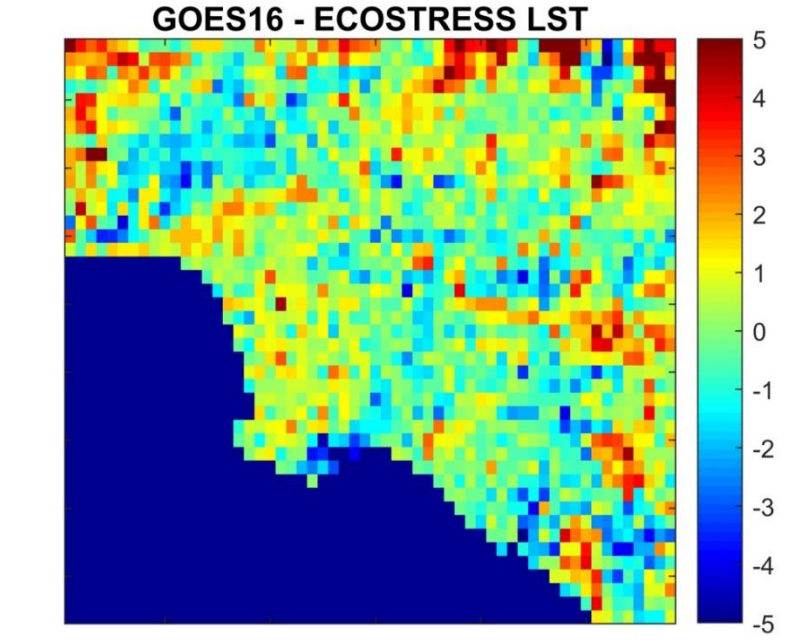
- 3 thermal bands
- Spatial: 2.5 km resolution
- Temporal: 5 minutes
- LST produced at JPL through NASA MEaSUREs
- MERRA2 atmospheric correction

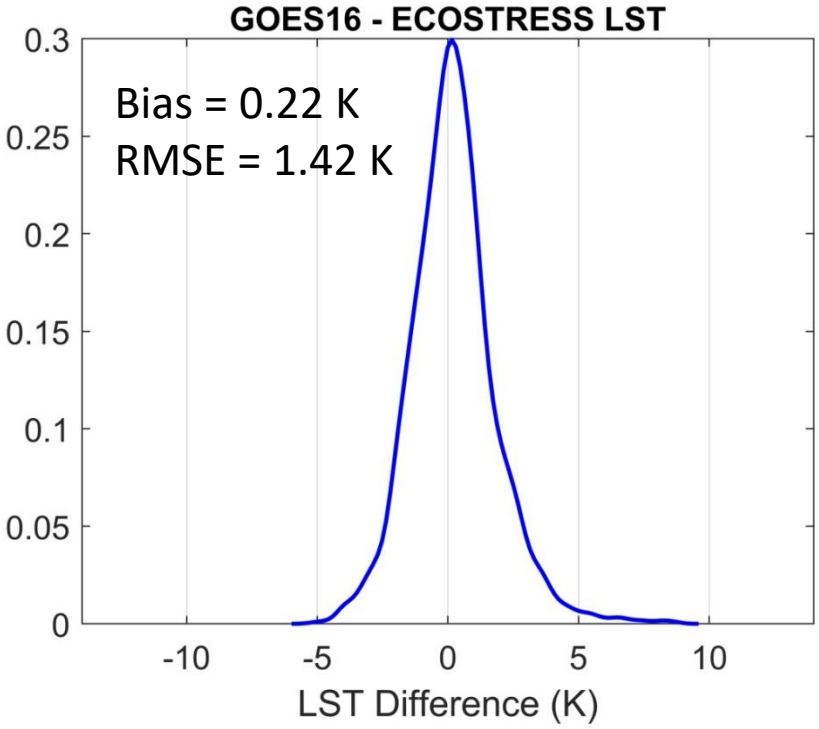
GOES-16 LST, 31 July, 2018, 9:27 pm




ECOSTRESS LST, 31 July 2018, 09:26 PM local
305
300
295
290


GOES16 LST, 31 July 2018, 09:27 PM local
305
300
295
290

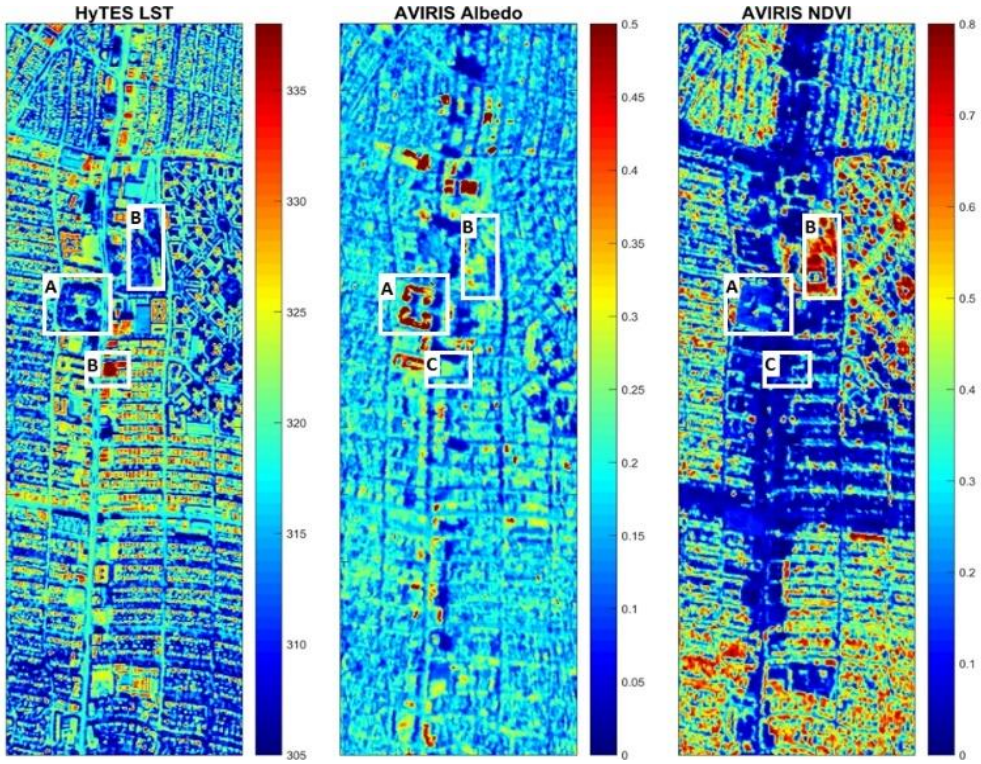

GOES16 - ECOSTRESS LST
5
4
3
2
1
0
-1
-2
-3
-4
-5

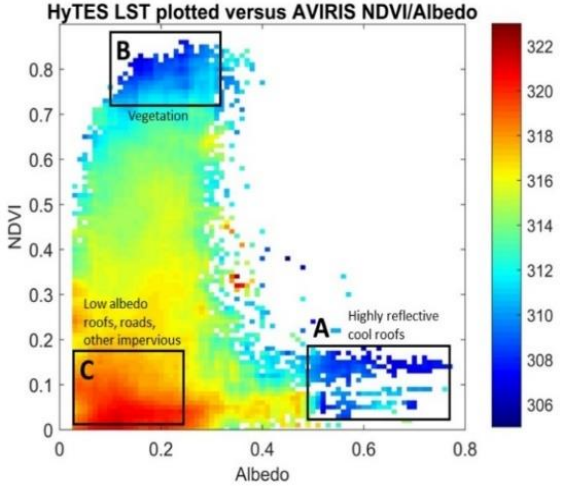

GOES16 - ECOSTRESS LST
Bias = 0.22 K
RMSE = 1.42 K
0.3
0.25
0.2
0.15
0.1
0.05
0
-10
-5
0
5
10
LST Difference (K)

LST Uncertainty Analysis vs Validation

Surface types	Samples	MODTRAN Simulations	Uncertainty Simulations	Validation Results
Vegetation water	8	660,096	**1.63 K**	**1.10 K**
Rocks	48	3,960,576	**1.45 K**	**n/a**
Soils	45	3,713,040	**0.91 K**	**n/a**
Sands	10	825,120	**0.99 K**	**0.89 K**
Total	**111**	**9,158,832**	**1.35 K**	**0.98 K**

LST Sharpening model
Training with high resolution airborne data (HyTES, AVIRIS)

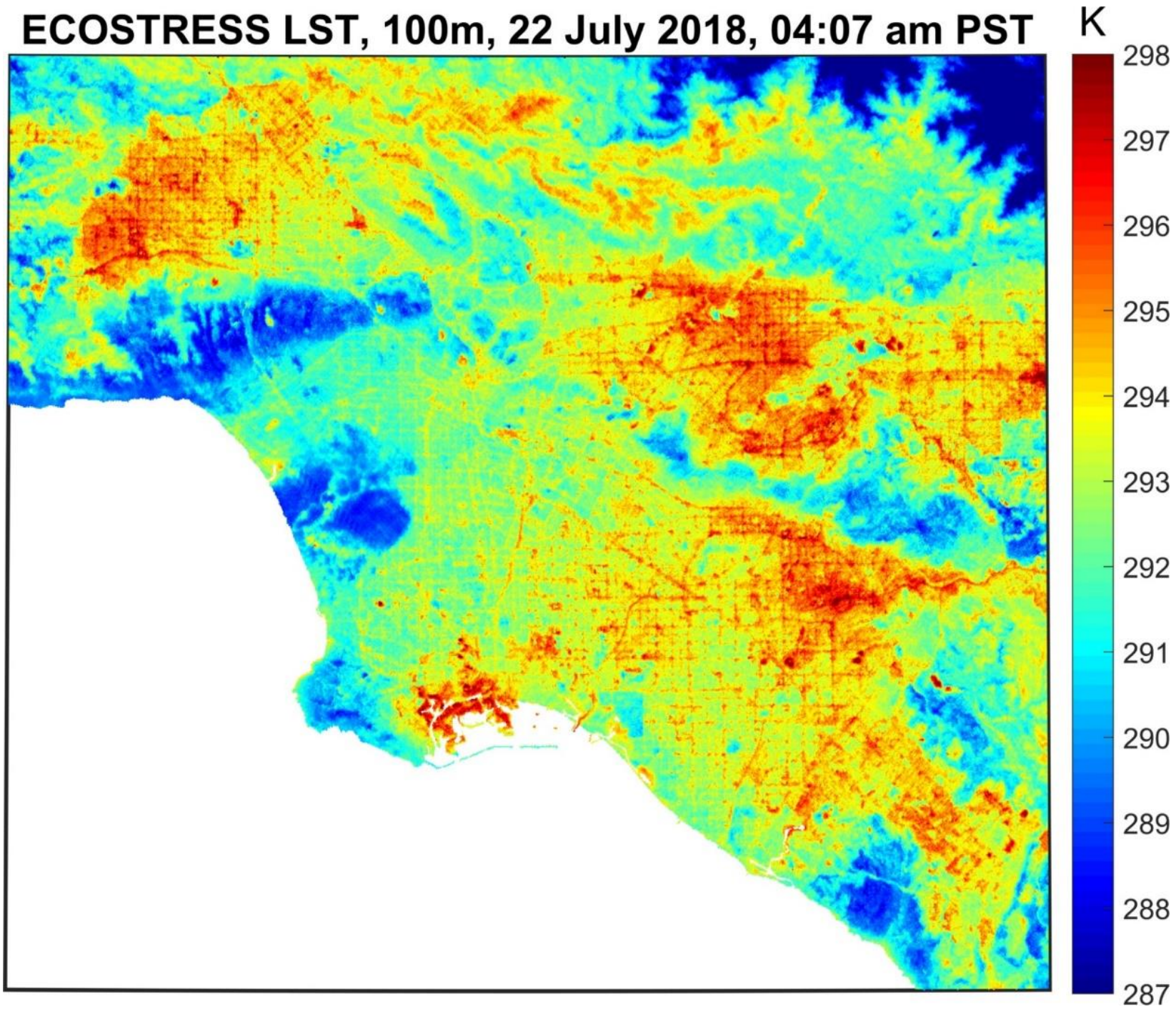


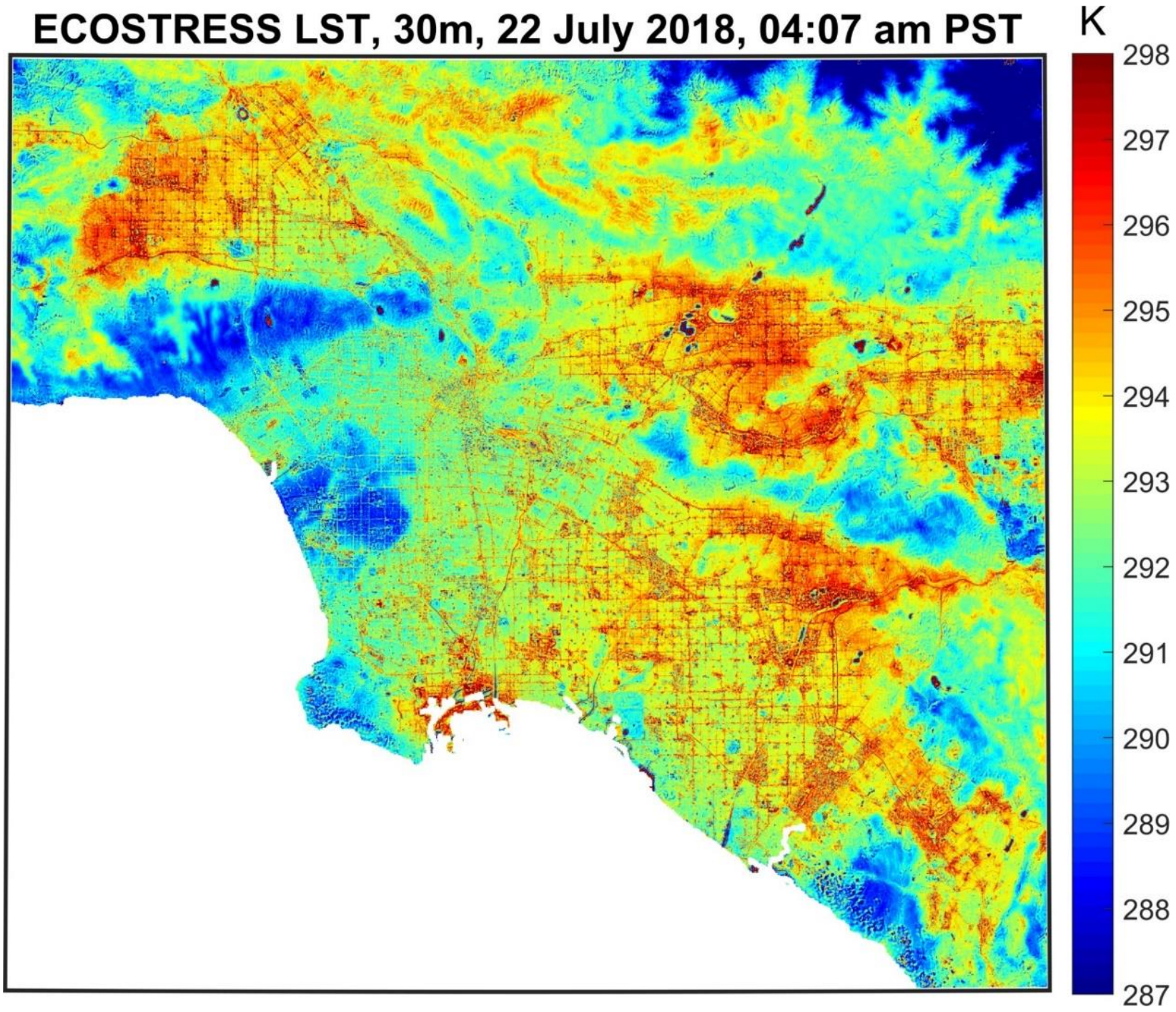


HUTS Multivariate Regression Sharpening Model:

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

Where Energy conservation = dLST = LST(native resolution) – LST_{sharp}(with NDVI and α at native resolution)
Note: this ensures the average LST between native resolution and sharpened resolution remain the same over a given area.


ECOSTRESS LST, 100m, 22 July 2018, 04:07 am PST
K
298
297
296
295
294
293
292
291
290
289
288
287


ECOSTRESS LST, 30m, 22 July 2018, 04:07 am PST
K
298
297
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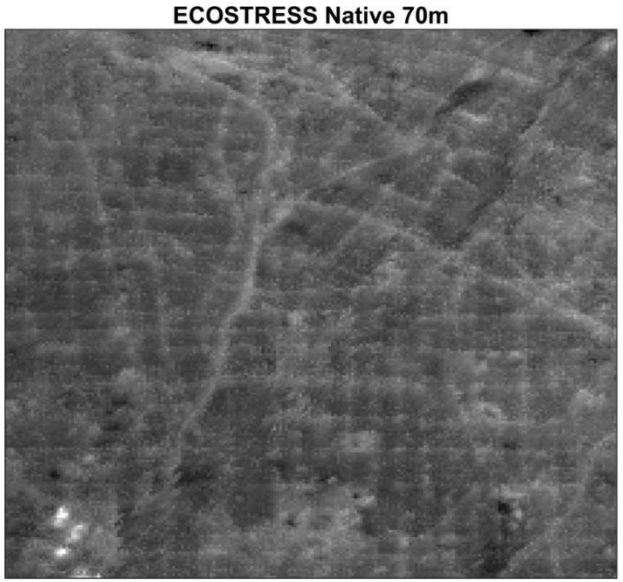
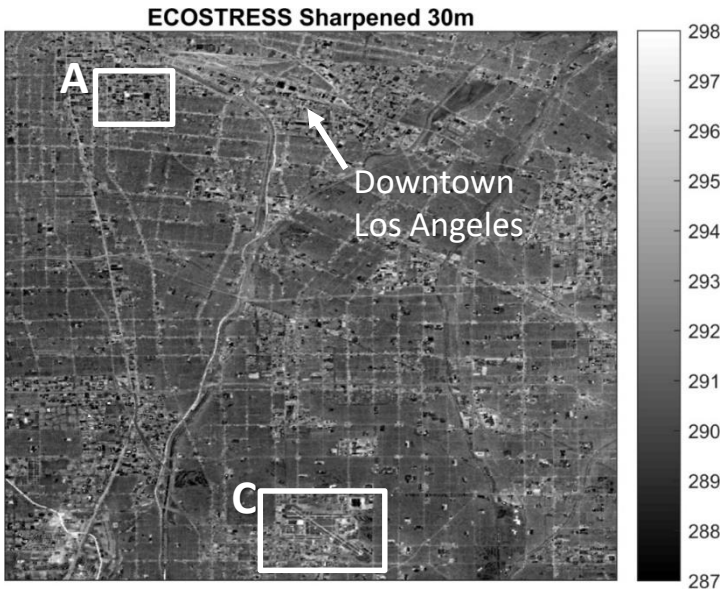
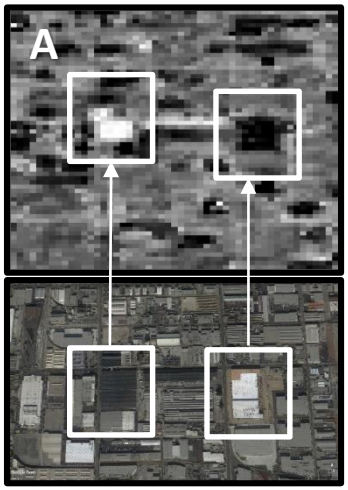
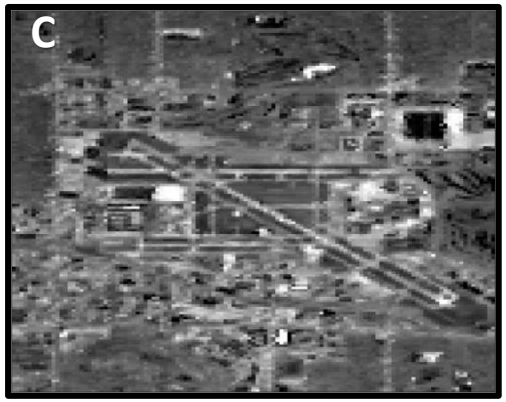
New Urban LST product able to distinguish fine-scale temperatures of individual building roofs and transport network infrastructure (roads, runways) within the city









Questions?