



VIIRS Land Surface Temperature and Emissivity Continuity

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Outline

1. Algorithm and product status
2. Validation
3. VIIRS-MODIS Continuity
4. New Science

Proposed development/refinement	Product(s)	Status
Implement new L2 and L3 gridded LST&E algorithms (2014-2018)	MxD21 VNP21	<u>Complete</u> In processing at MODAPS/LSIPS
Produce L3 Climate Modeling Grid (CMG) products	MxD21C1-C3 VNP21C1-C3	On schedule for MODIS C6.1
Improve atmospheric correction <ul style="list-style-type: none"> • Replace MERRA2 with GEOS5 • Higher resolution and latency 	MxD21 VNP21	On schedule for MODIS C6.1
Produce emissivity product for midwave IR bands <ul style="list-style-type: none"> • Critical for sounding community (e.g. CLIMCAPS) • Continuity of MEaSURES LST&E 	MxD21 VNP21	?
Reduce overall number of MODIS LST products (currently 10) <ul style="list-style-type: none"> • Retire MxD11 suite • Complete analysis study on differences between MxD21/MxD11 products 	MxD21 MxD11	?

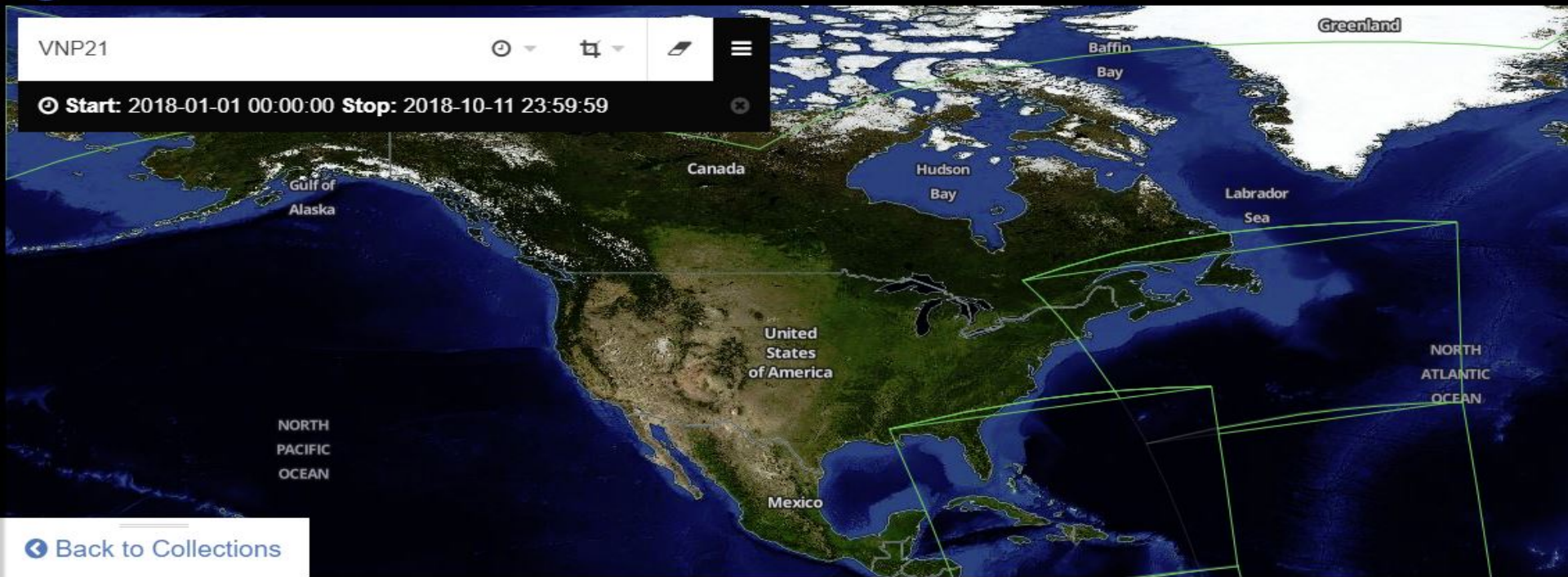
VNP21 Product Suite

Earth Science Data Type (ESDT)	Product Level	Data Dimension	Spatial Resolution	Temporal Resolution	Map Projection
VNP21	L2	3232 lines by 3200 pixels	750m at nadir	Swath, Twice-daily	None, (lat, lon tagged)
VNP21A1D/ VNP21A1N	L3	1200 rows by 1200 columns	1 km	Day and Night	Sinusoidal
VNP21A2	L3	1200 rows by 1200 columns	1 km	Eight day	Sinusoidal
VNP21C1	L3	3600 by 7200 global	0.05 deg	Daily	Climate Modeling Grid
VNP21C2	L3	3600 by 7200 global	0.05 deg	Eight day	Climate Modeling Grid
VNP21C3	L3	3600 by 7200 global	0.05 deg	Monthly	Climate Modeling Grid

VNP21



Start: 2018-01-01 00:00:00 Stop: 2018-10-11 23:59:59



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VIIRS/NPP Land Surface Temperature and Emissivity 6-Min L2 Swath 750m V001 [View details](#)

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Granule Search:

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Showing 20 of 24633 matching granules

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END 2018-08-31 18:00:00

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2.nc

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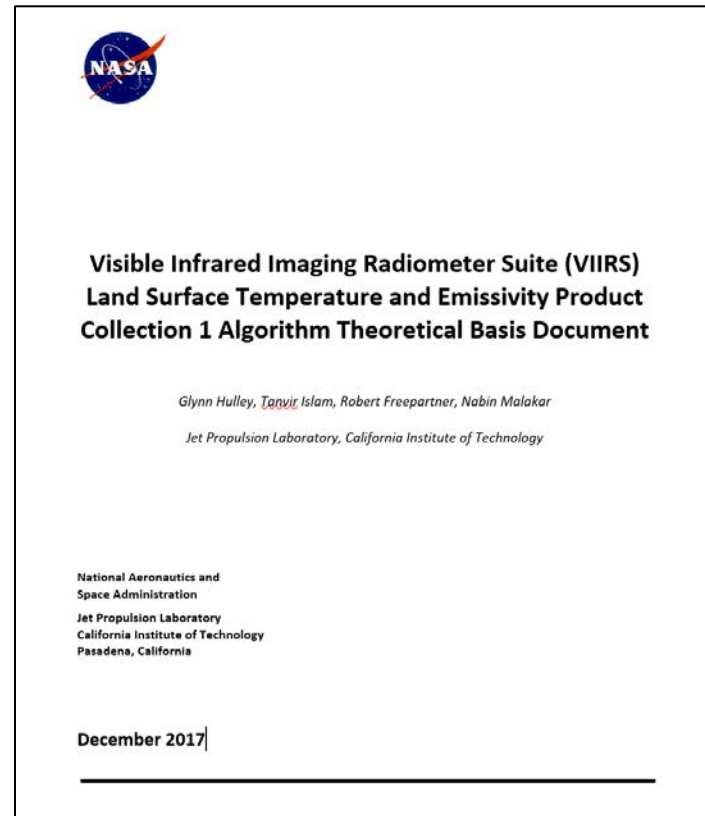
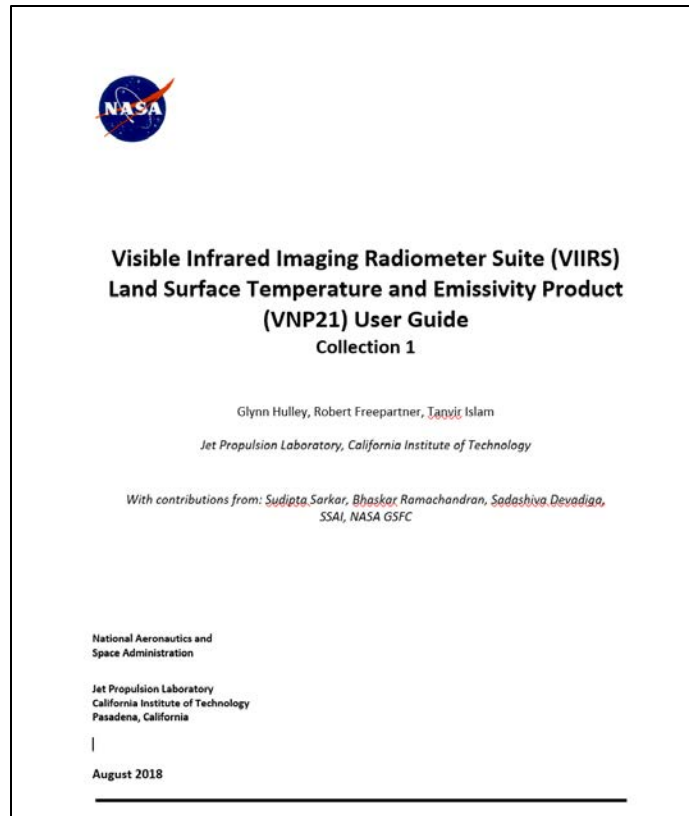
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YEAR



VIIRS/NPP Land Surface Temperature and Emissivity 6-Min L2 Swath 750m V001

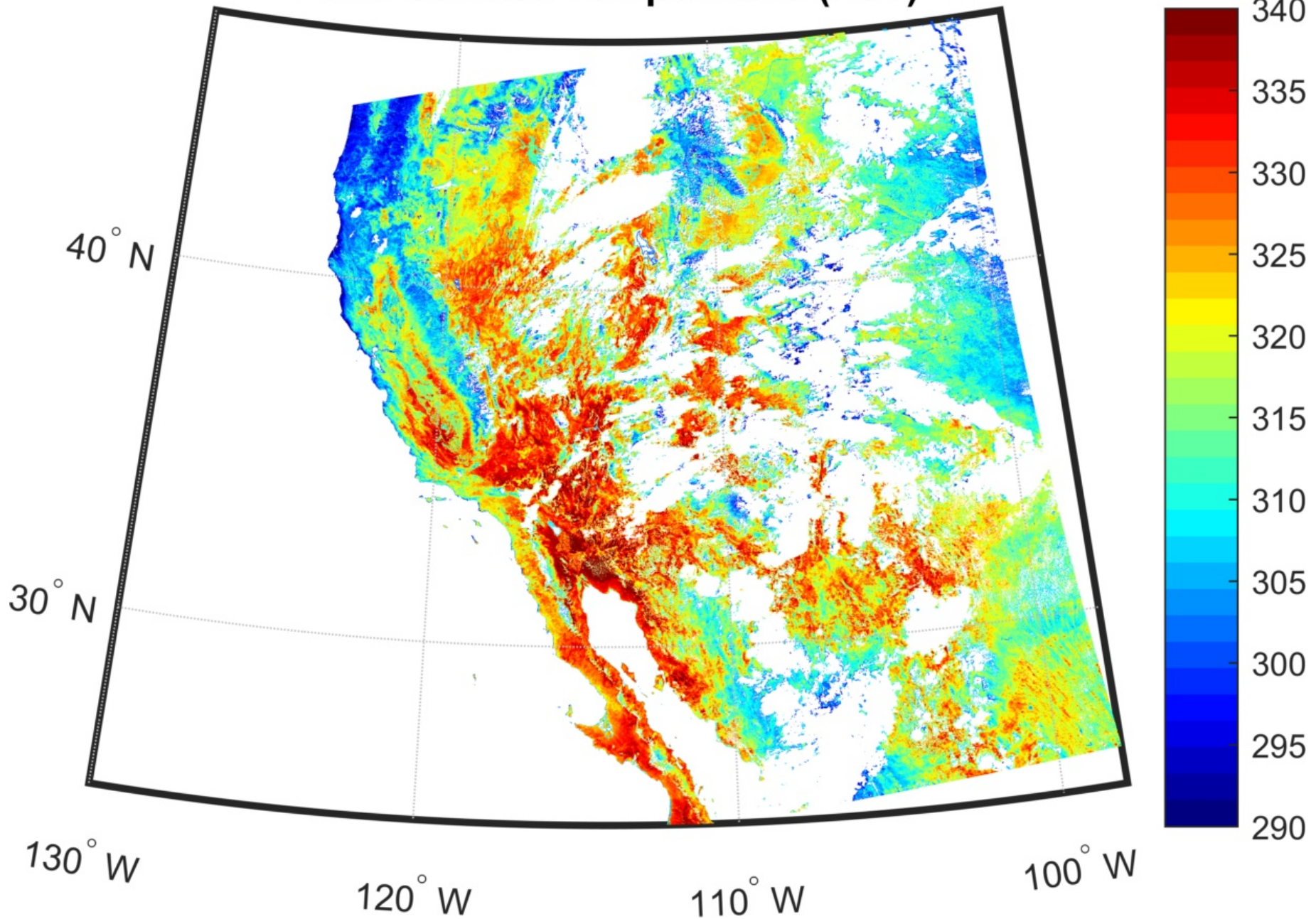
2010 2020



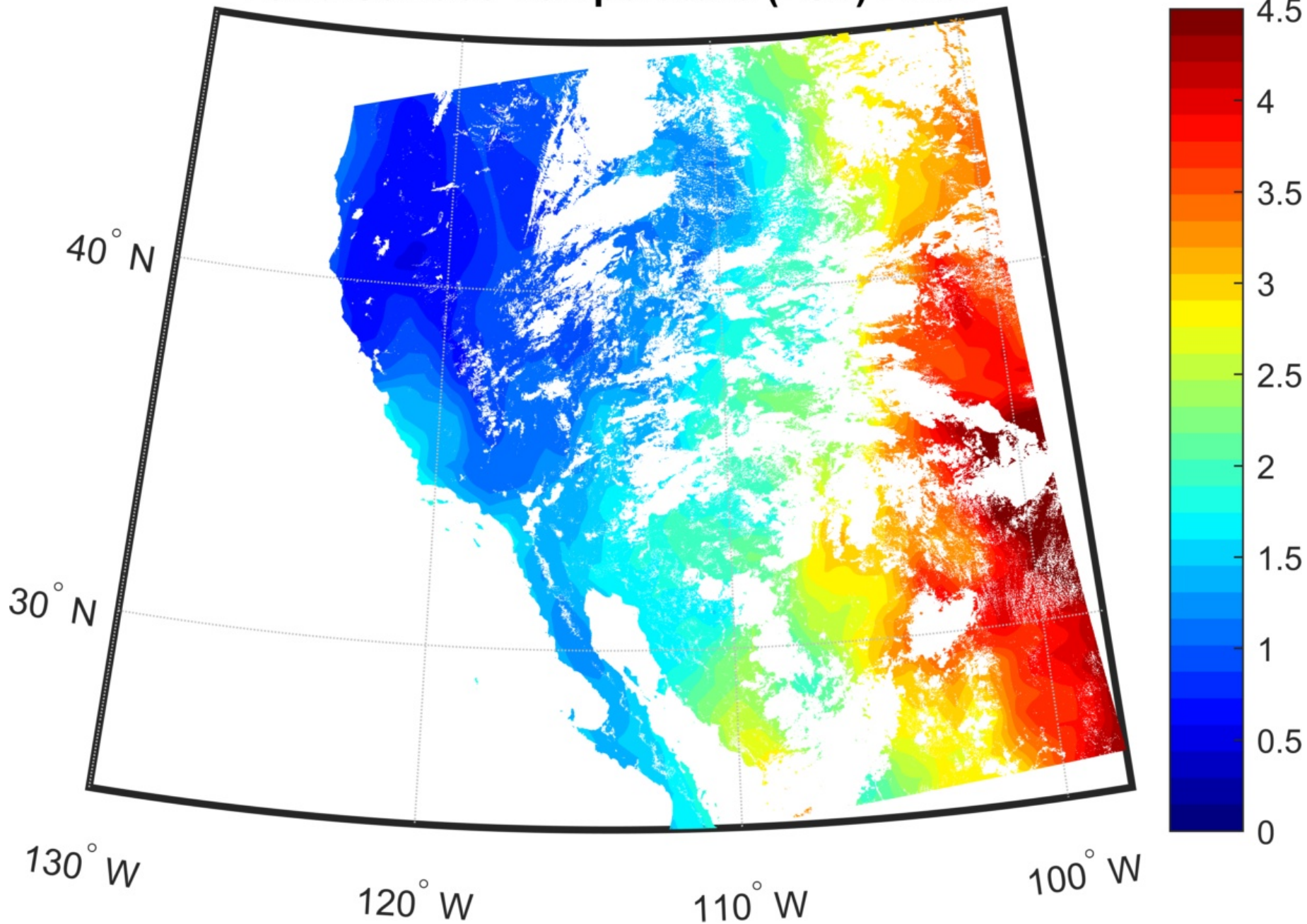
Hulley, G. C., Malakar, N., Islam, T., Freepartner, R., (2018), NASA's MODIS and VIIRS Land Surface Temperature and Emissivity Products: A Consistent and High Quality Earth System Data Record, IEEE TGRS, DOI: 10.1109/JSTARS.2017.2779330.

Islam, T. G. C. Hulley, N. Malakar, R. Radocinski, S. Hook, P. Guillevic (2017), A physics-based algorithm for the simultaneous retrieval of land surface temperature and emissivity from VIIRS thermal infrared data, IEEE Transactions on Geoscience and Remote Sensing, 55, 563-576

Land Surface Temperature (LST)

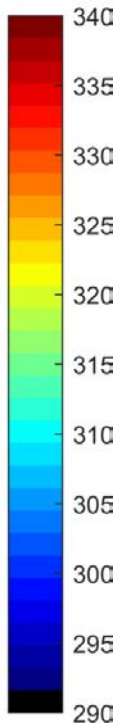
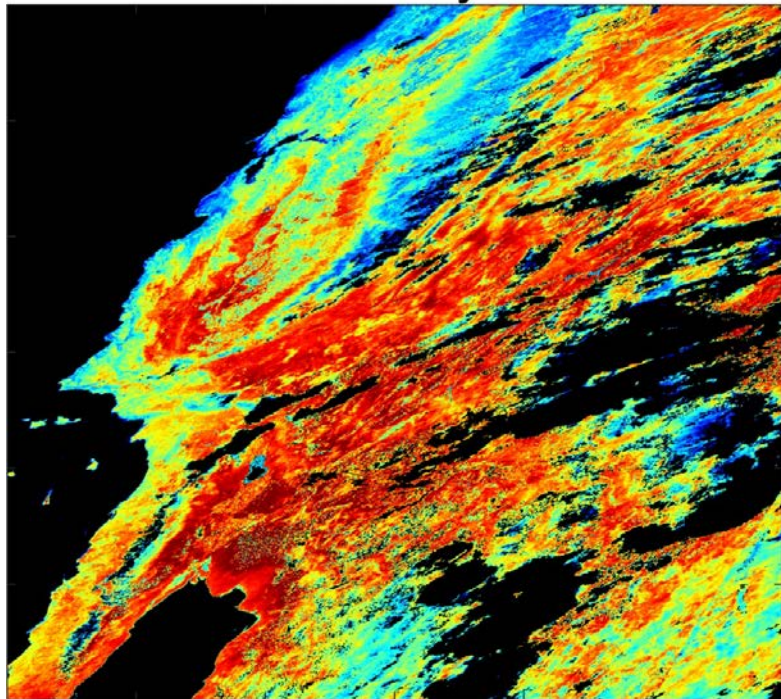


Land Surface Temperature (LST) Error

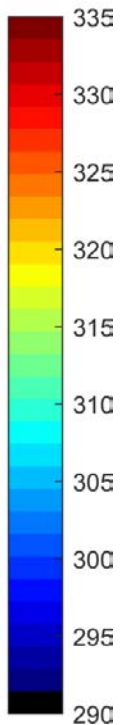
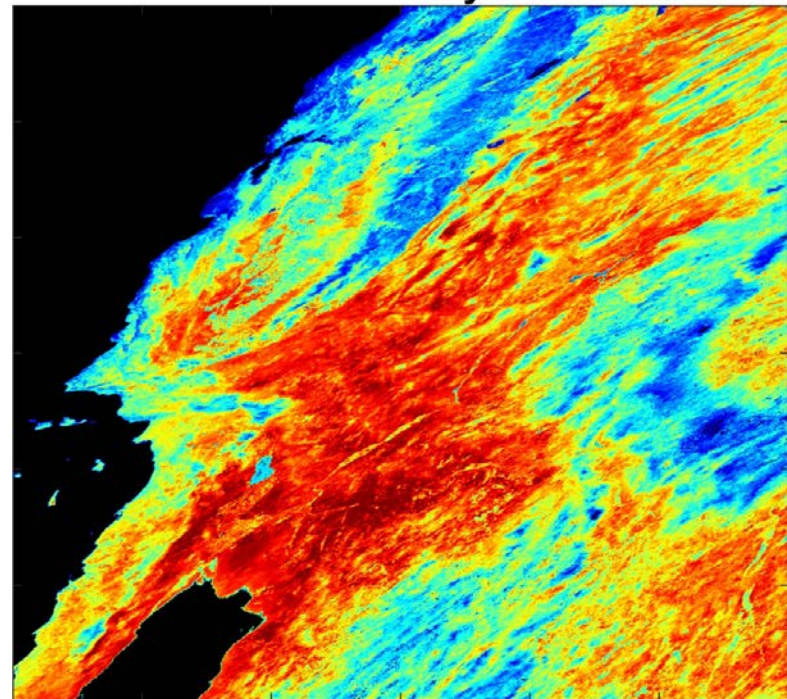


VNP21A1/A2 Daily (left) and 8-day (right) Daytime Land Surface Temperature (LST) h08v05

VNP21A1 Day LST

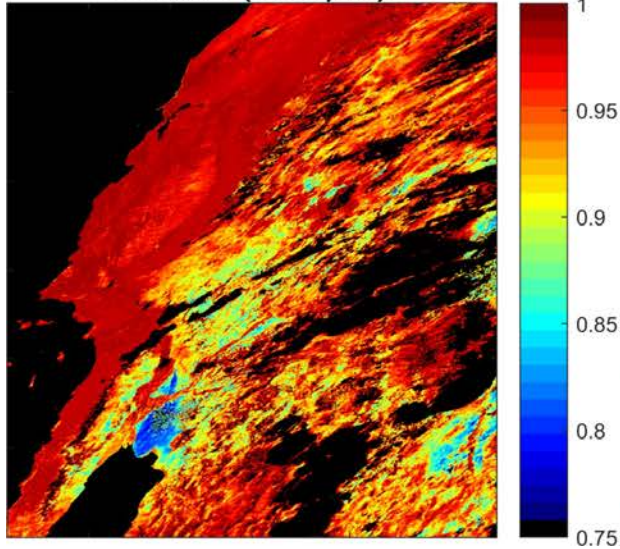


VNP21A2 Day LST

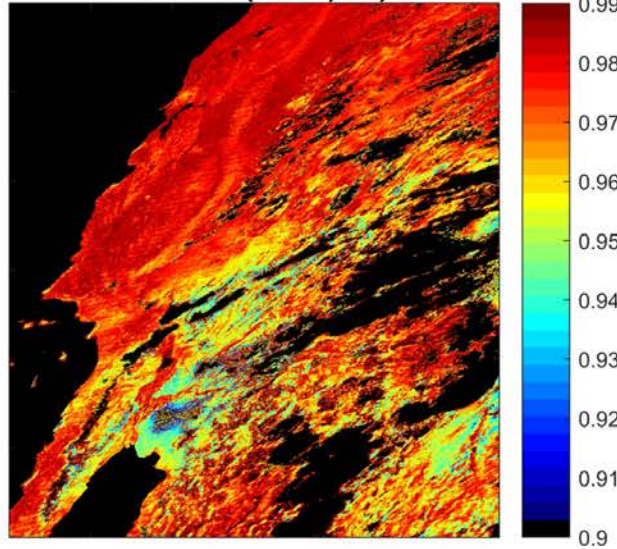


VNP21A1 Daily Emissivity (h08v05)

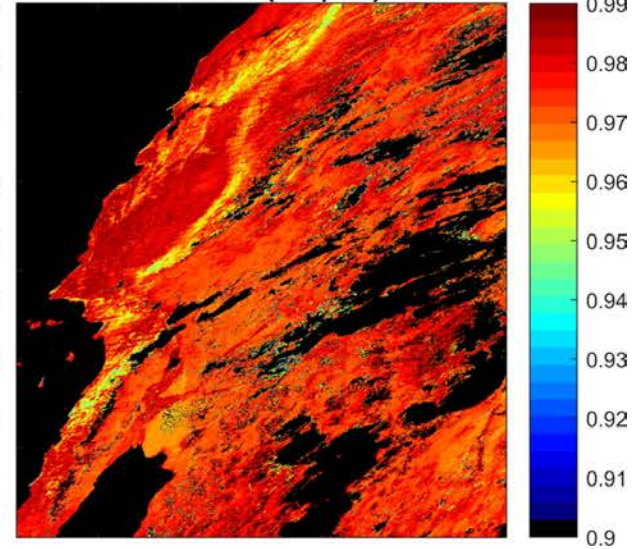
Emis14 (8.55 μm)



Emis15 (10.8 μm)

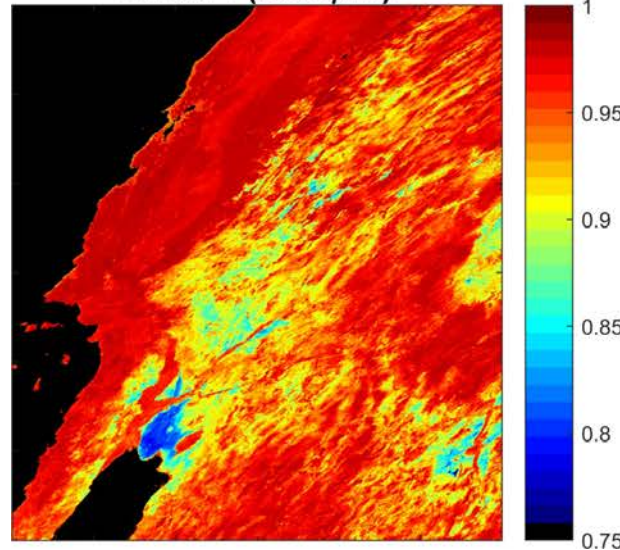


Emis16 (12 μm)

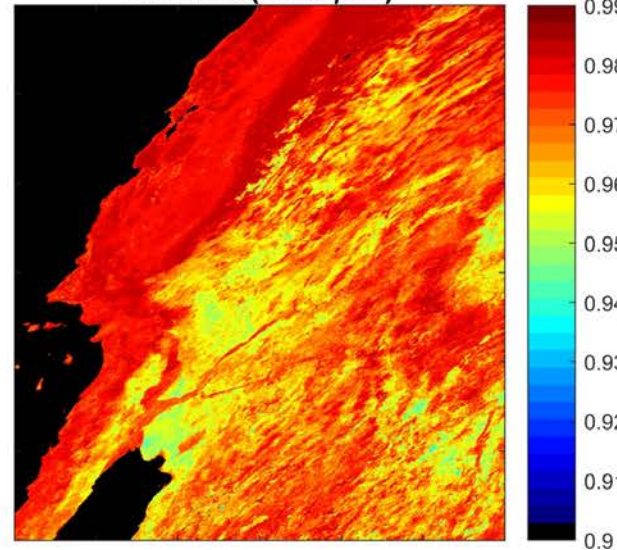


VNP21A2 8-day Emissivity (h08v05)

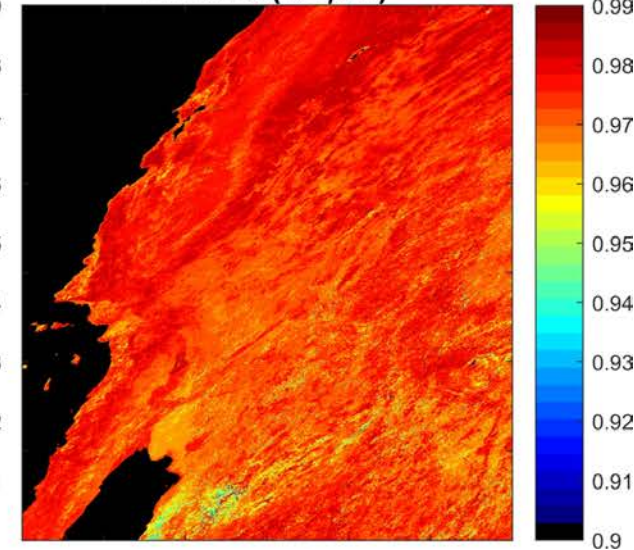
Emis14 (8.55 μm)



Emis15 (10.8 μm)

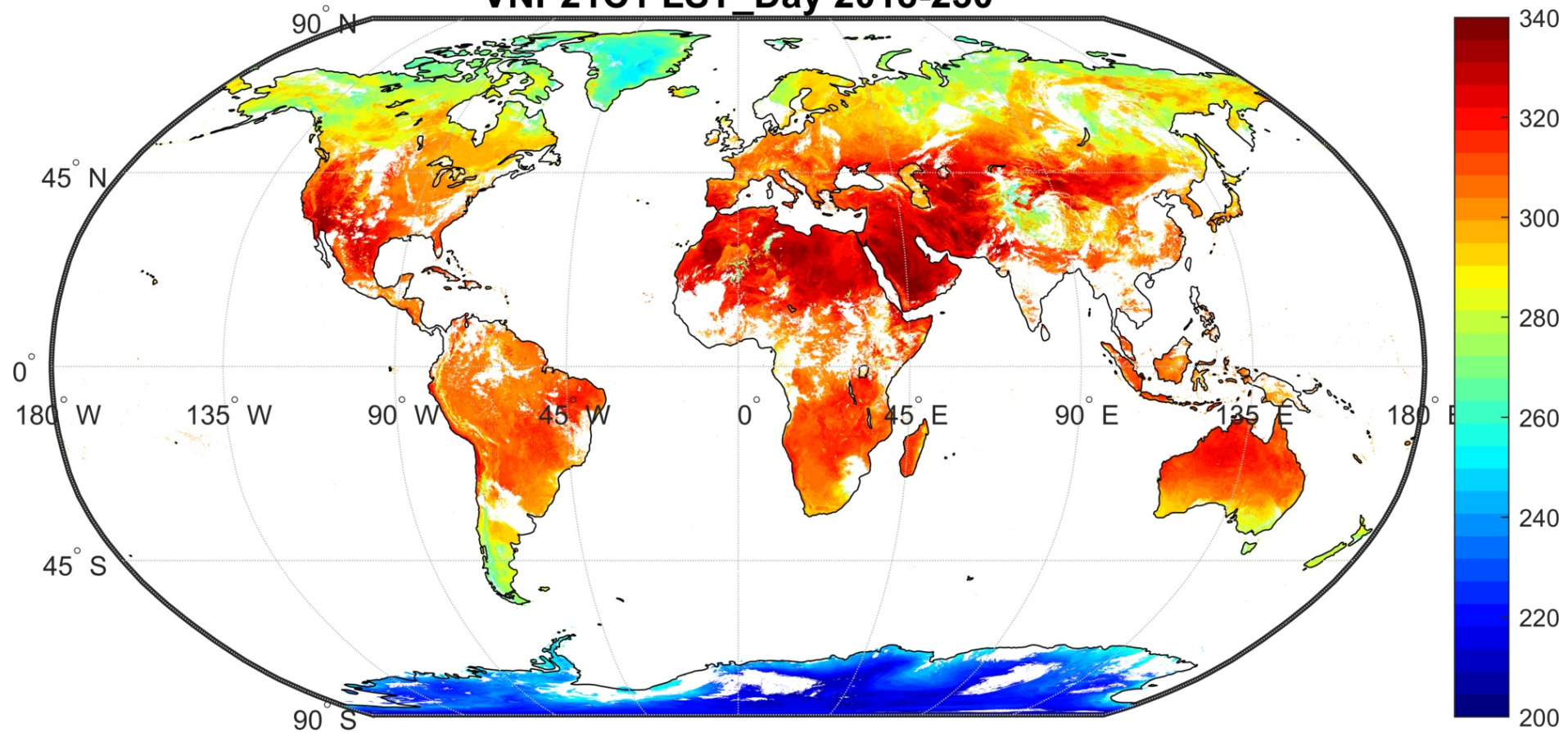


Emis16 (12 μm)



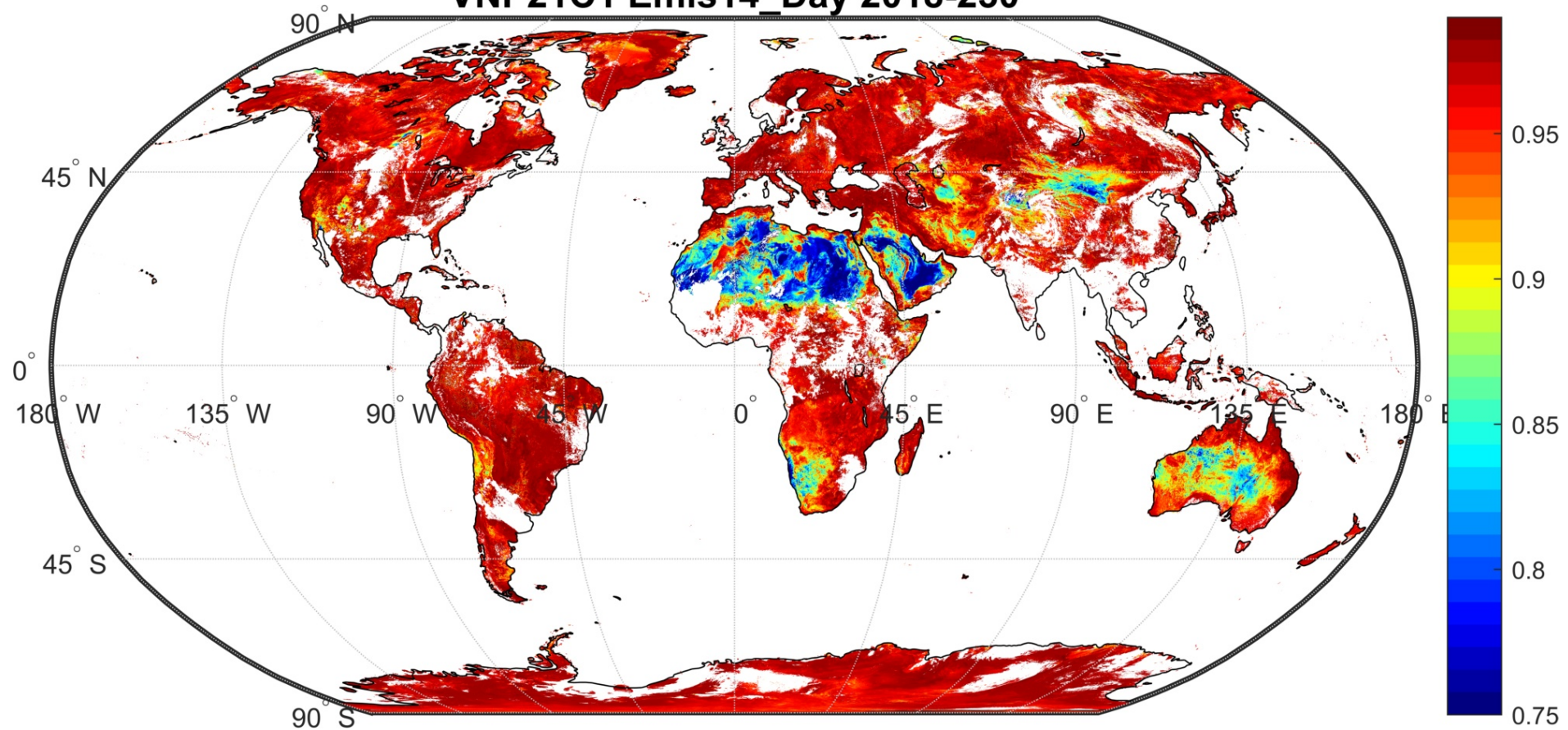
Climate Modeling Grid (CMG) Products

VNP21C1 LST_Day 2018-230



Climate Modeling Grid (CMG) Products

VNP21C1 Emis14_Day 2018-230



8.55 micron

Outline

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3. VIIRS-MODIS Continuity
4. New Science

Stage-1 Validation Sites: California



Redwood NP

Tahoe

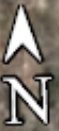
Algodones Dunes

Google Earth

Data LDEO-Columbia, NSF, NOAA

Image Landsat / Copernicus

Data SIO, NOAA, U.S. Navy, NGA, GEBCO



300 mi

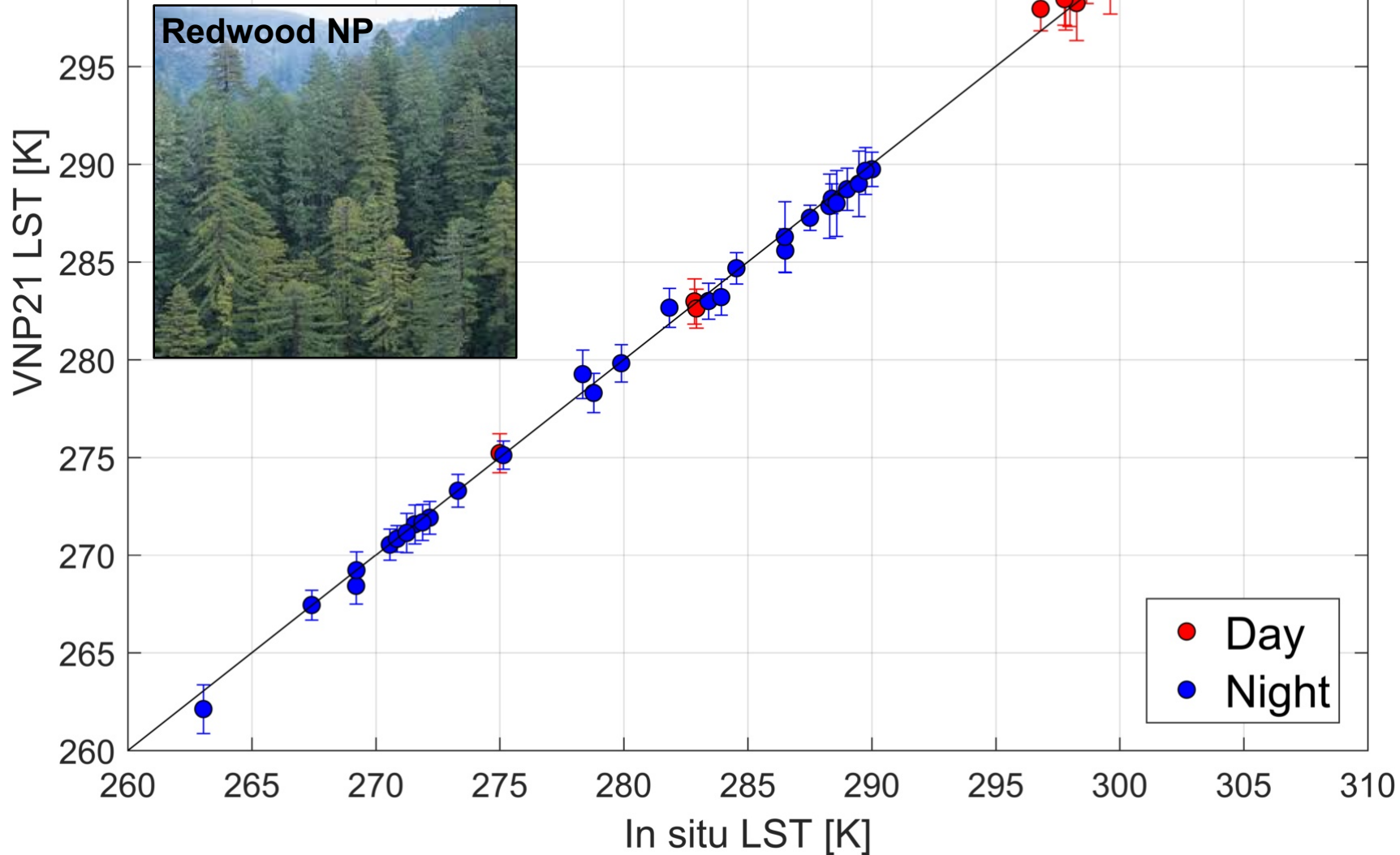
LST Validation Jan/Aug 2018

Bias = 0.1 K

RMSE = 0.6 K

N = 47

Redwood NP



LST Validation Jan/Aug 2018

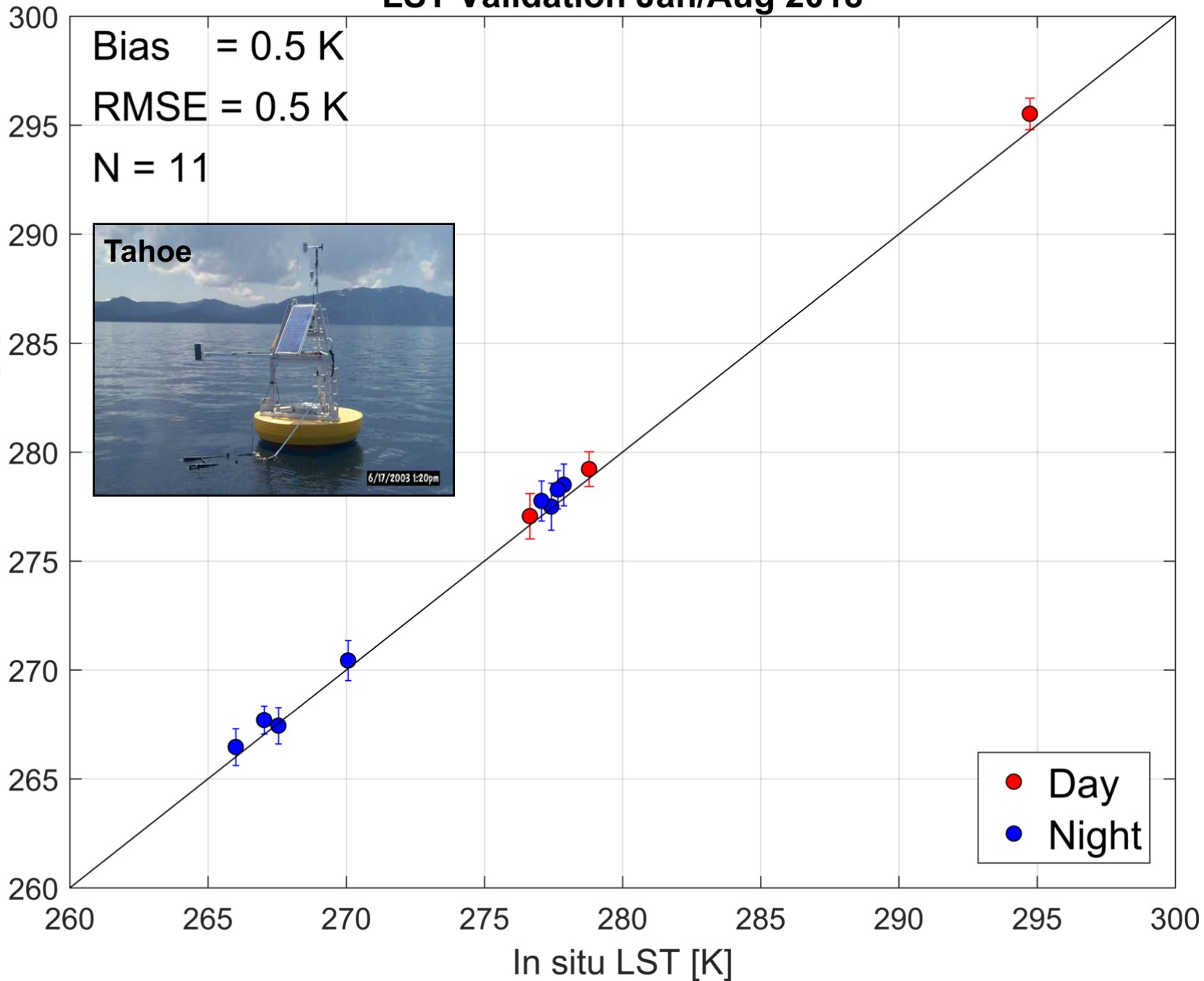
Bias = 0.5 K

RMSE = 0.5 K

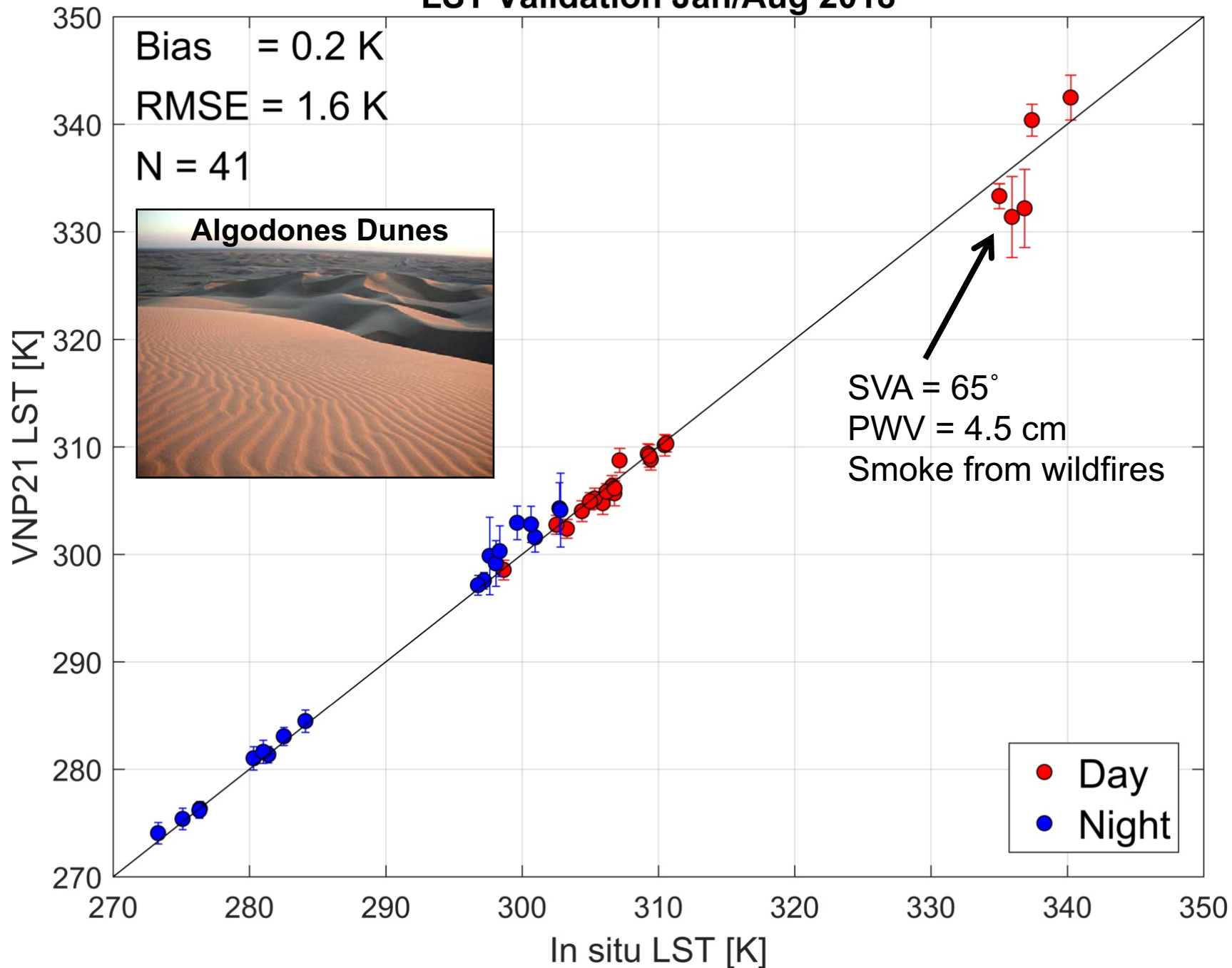
N = 11



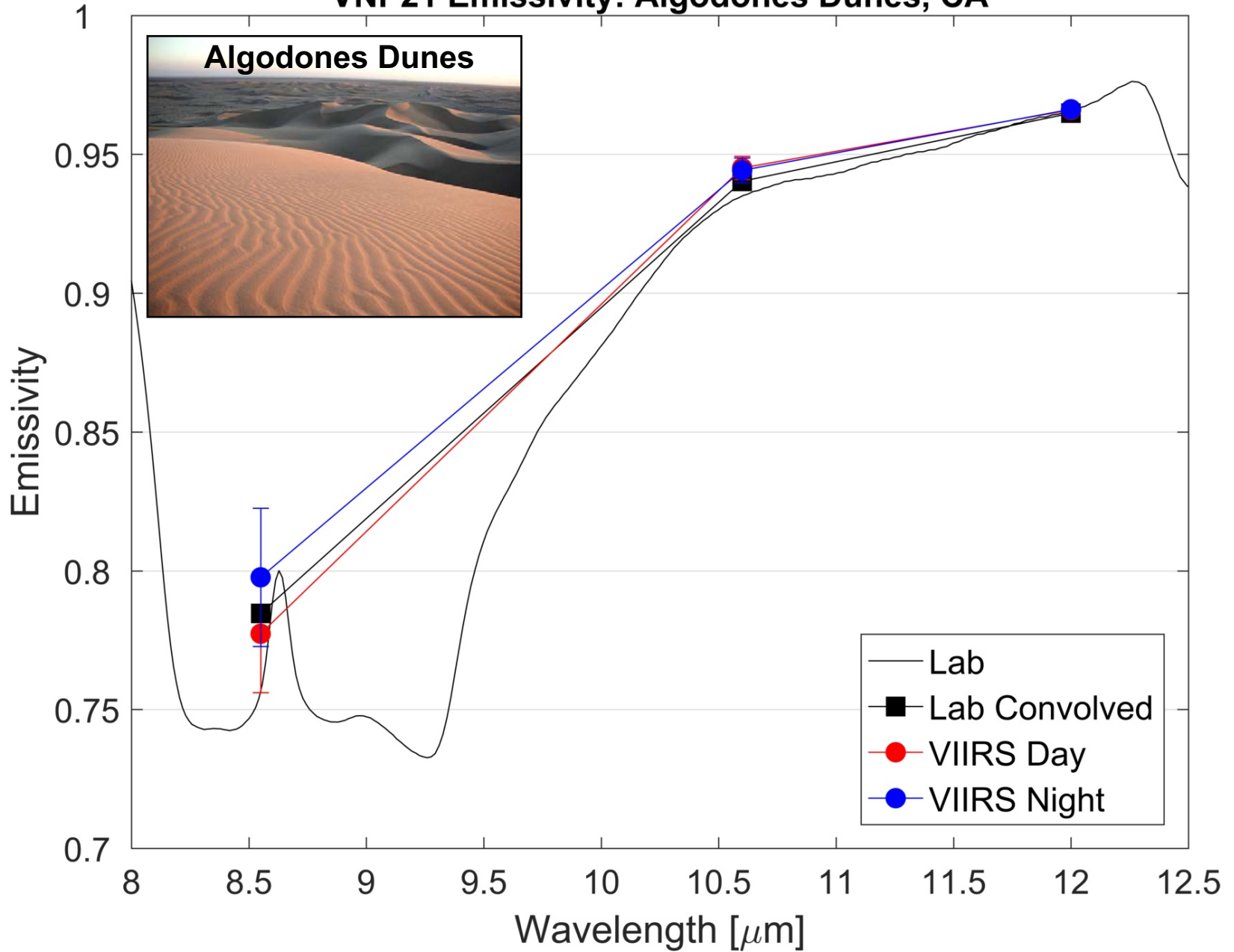
VNP21 LST [K]



LST Validation Jan/Aug 2018



VNP21 Emissivity: Algodones Dunes, CA

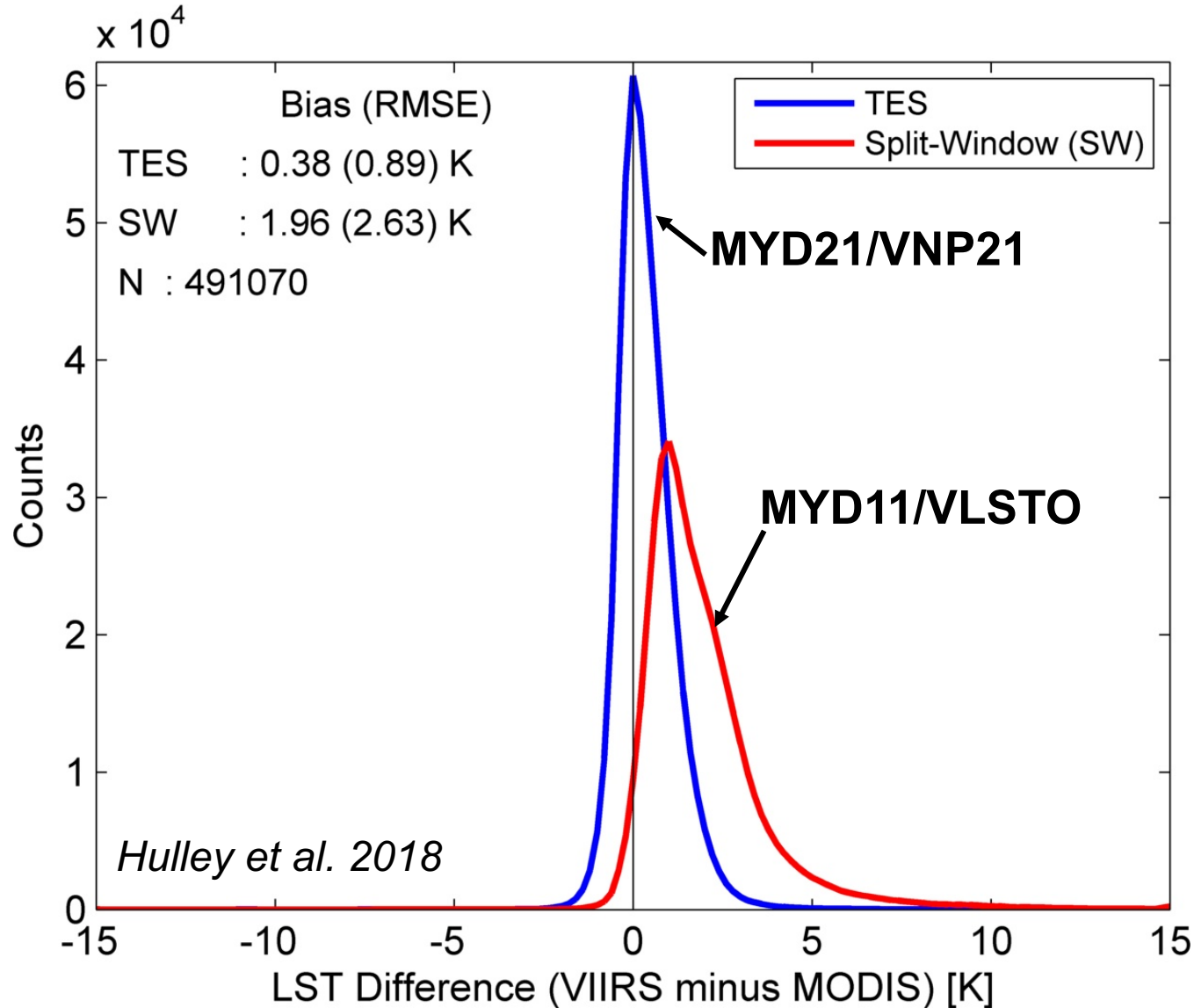


Outline

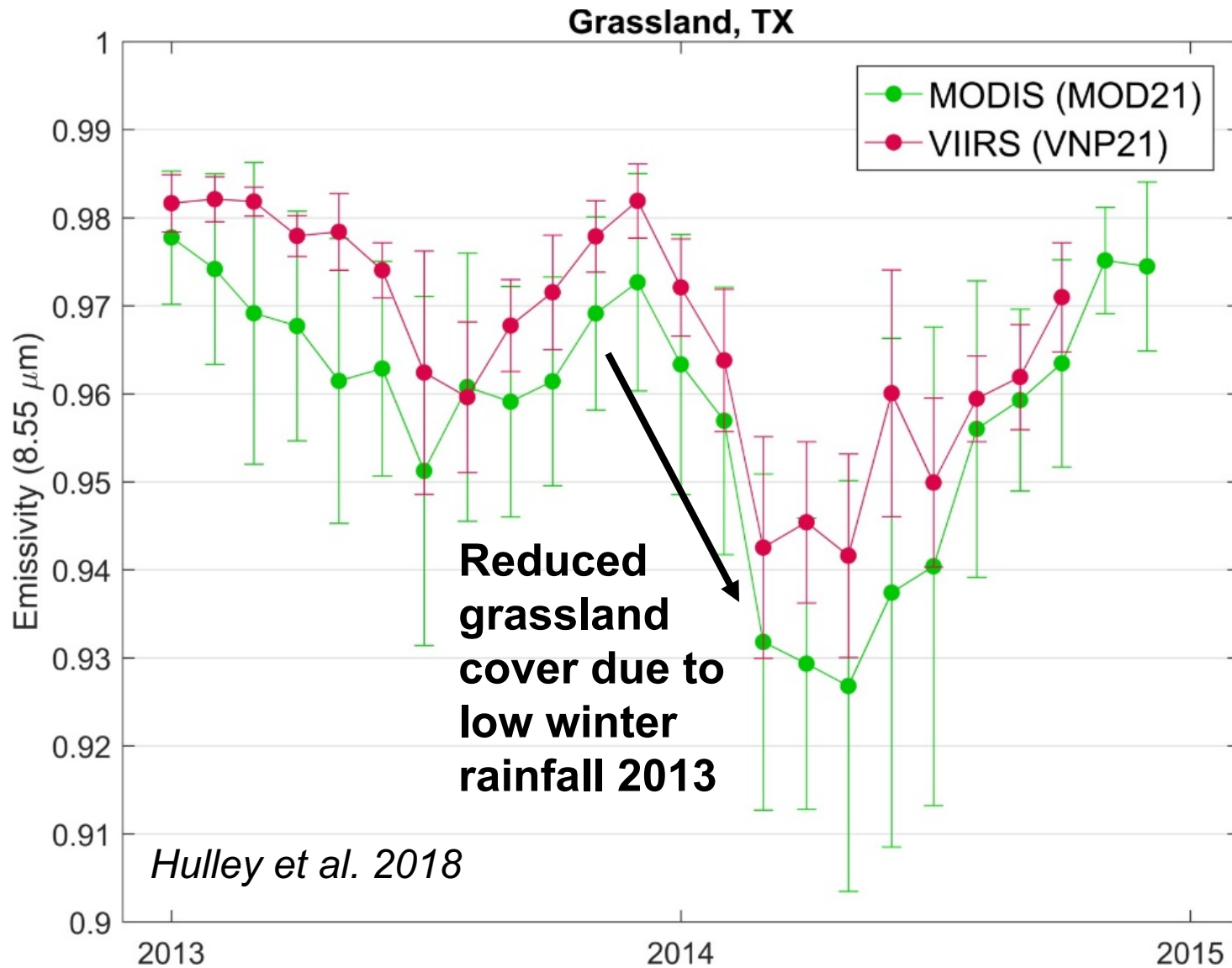
1. Algorithm and product status
2. Validation
- 3. VIIRS-MODIS Continuity**
4. New Science

LST continuity VIIRS/MODIS Aqua

- 54 scenes CONUS
- JFM, ASO 2012
- SNO's



Emissivity Continuity

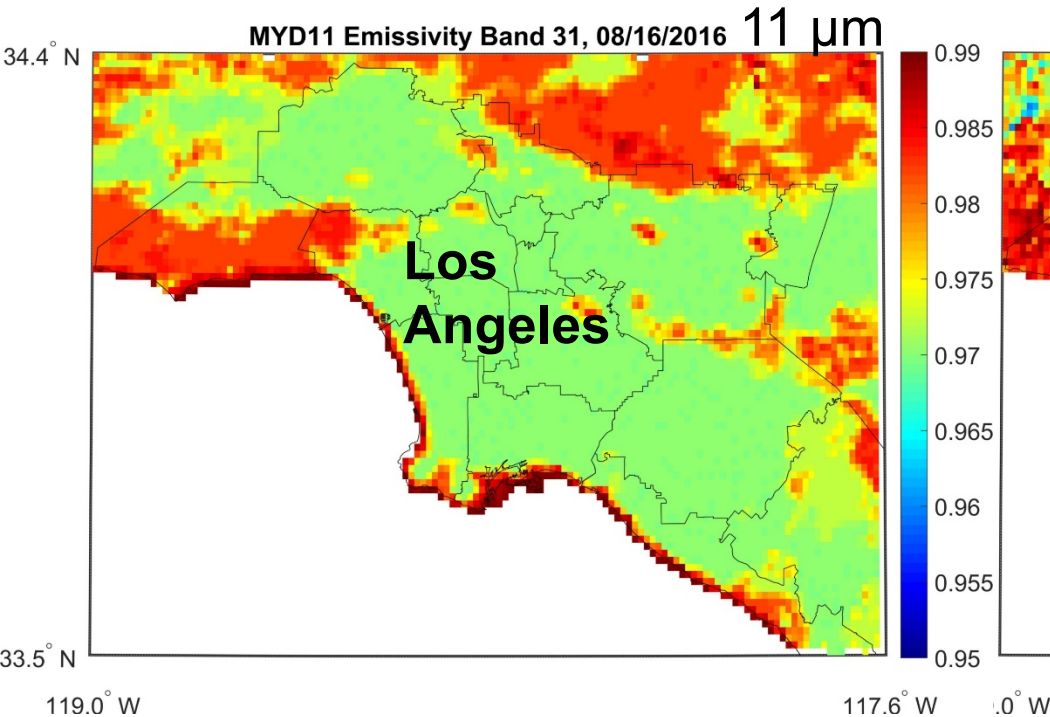


Outline

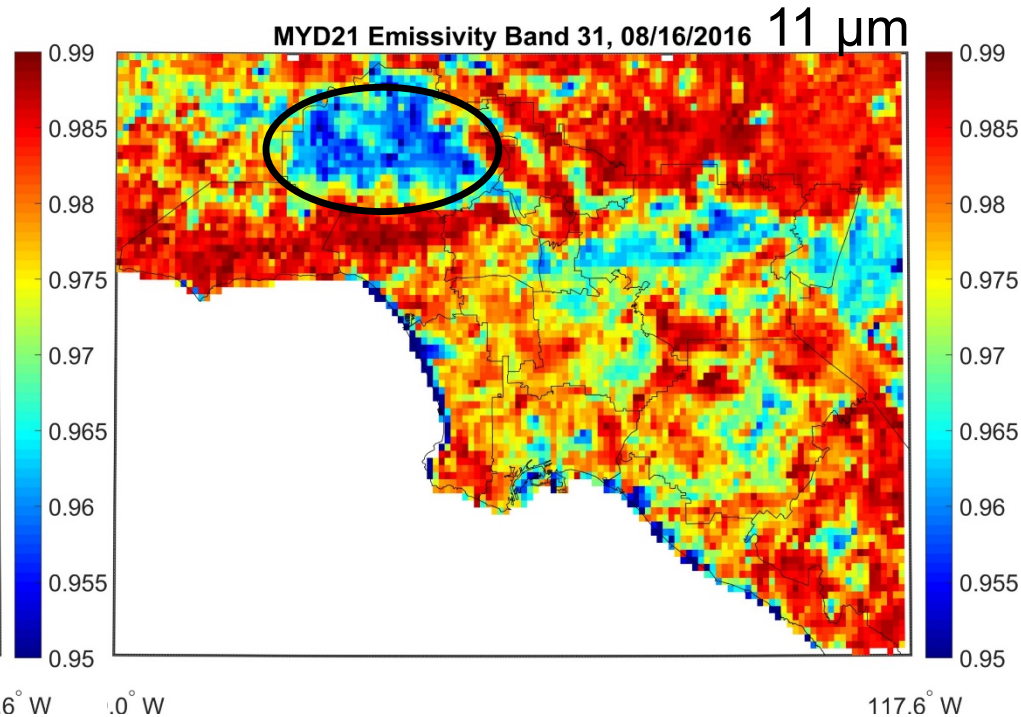
1. Algorithm and product status
2. Validation
3. VIIRS-MODIS Continuity
4. **New Science**

Urban Emissivity Variation

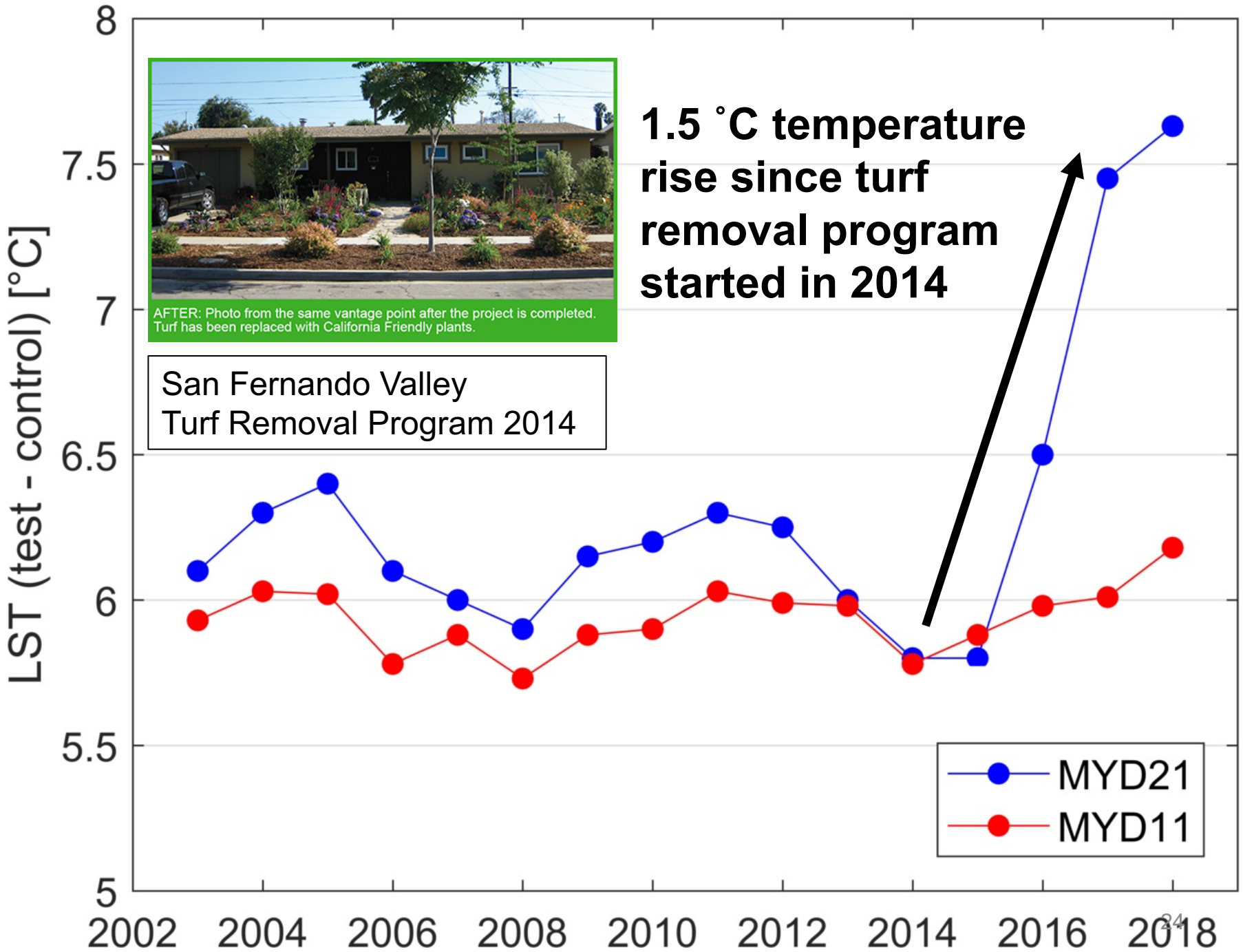
MxD11 Classification



MxD21 TES



- Split-window approaches, e.g. MYD11 assume fixed emissivity over different land classes, e.g. Urban emissivity = 0.97 (green)
- MYD21 physically retrieves the emissivity state of land surface

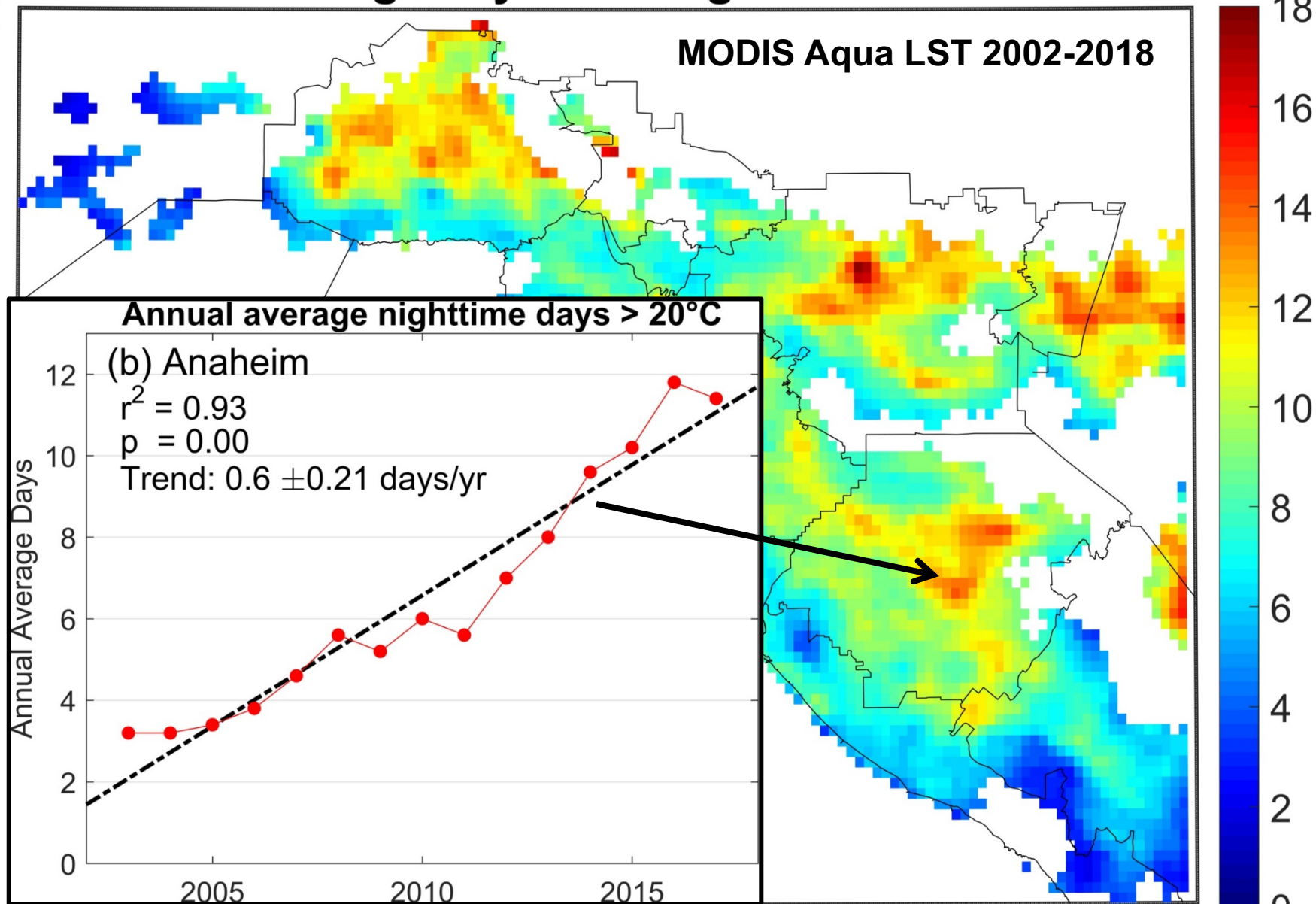


Annual average days with nighttime LST > 20°C

Days

34.4° N

MODIS Aqua LST 2002-2018



33.5° N

119.0° W

Hulley et al. 2018

117.6° W

Summary

1. MxD21 and VNP21 algorithms implemented at MODAPS and Land-SIPS and in reprocessing
2. MxD21/VNP21 uncertainties at ~ 1 K level for LST and $\sim 1.5\%$ for emissivity
3. MXD21/VNP21 continuity demonstrated at the ~ 0.5 K level
4. Urgent user need to reduce overall number of MODIS LST products (currently 10 product types including MxD11 and MxD21)

VNP21

Land Surface Temperature and Emissivity (LST&E) Product Status

Status

- Undergoing final science test at LSIPS.
 - Once complete, review by LDOPE, science team, and LPDAAC
 - Reprocessing to begin after review.
 - Note: VNP21 LST&E algorithm is identical to MxD21 LST&E algorithm.
- Hulley et al. 2017, NASA's MODIS and VIIRS Land Surface Temperature and Emissivity Products: A Long-Term and Consistent Earth System Data Record*

Documentation

Complete; ATBD and User Guide
<https://viirsland.gsfc.nasa.gov/Products/NASA/LSTESDR.html>

LST&E Products

- Daily 5-min L2 Swath 1km
- Daily L3 Global 1km
- 8-day L3 Global 1km

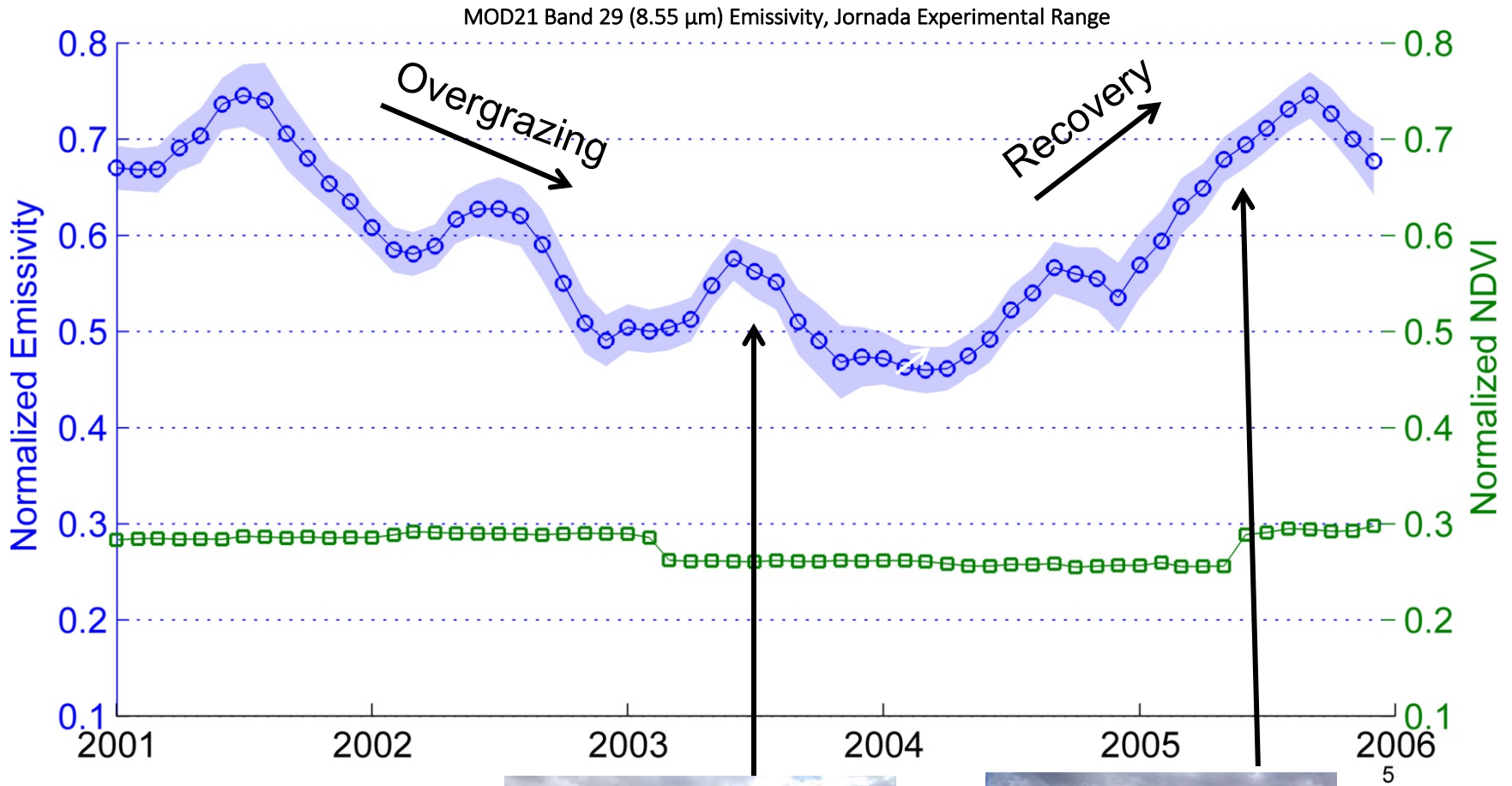
Validation Status

Stage 1: https://lpvs.gsfc.nasa.gov/LSTE/LSTE_home.html
±1 K accuracy demonstrated over U.S. sites (*Islam et al. 2017*)

Future plans

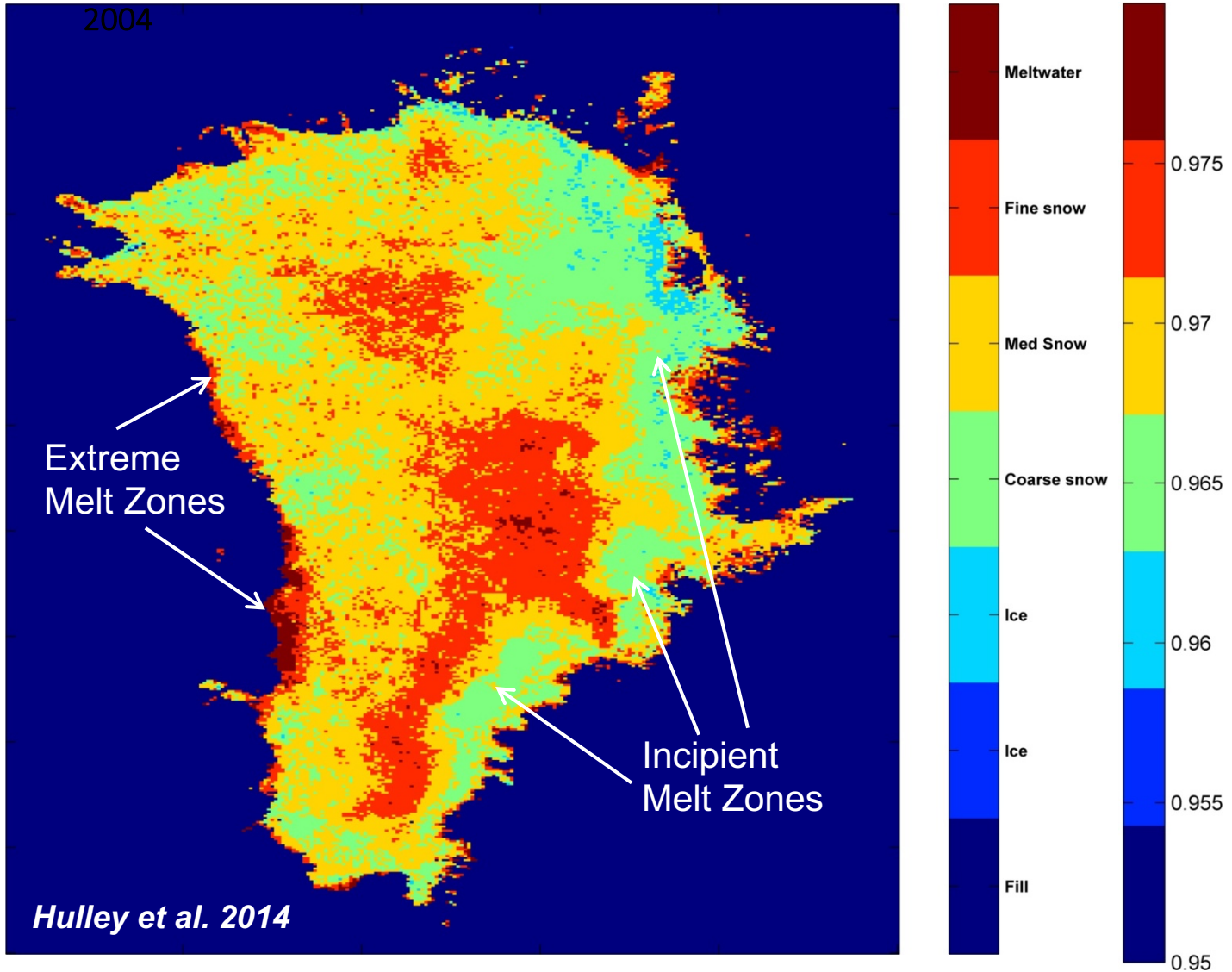
1. Produce Climate Modeling Grid (CMG) products
 - VNP21C1 – Daily 0.05 deg gridded LST&E
 - VNP21C2 – 8-day 0.05 deg gridded LST&E
 - VNP21C3 – Monthly 0.05 deg gridded LST&E
2. Produce Emissivity products for mid-IR bands M12, M13
 - Ensure continuation of LST&E MEaSURES products (JPL)
 - Used by atmospheric sounding community as first guess in air temperature/water vapor retrievals

Land Cover Change Detection



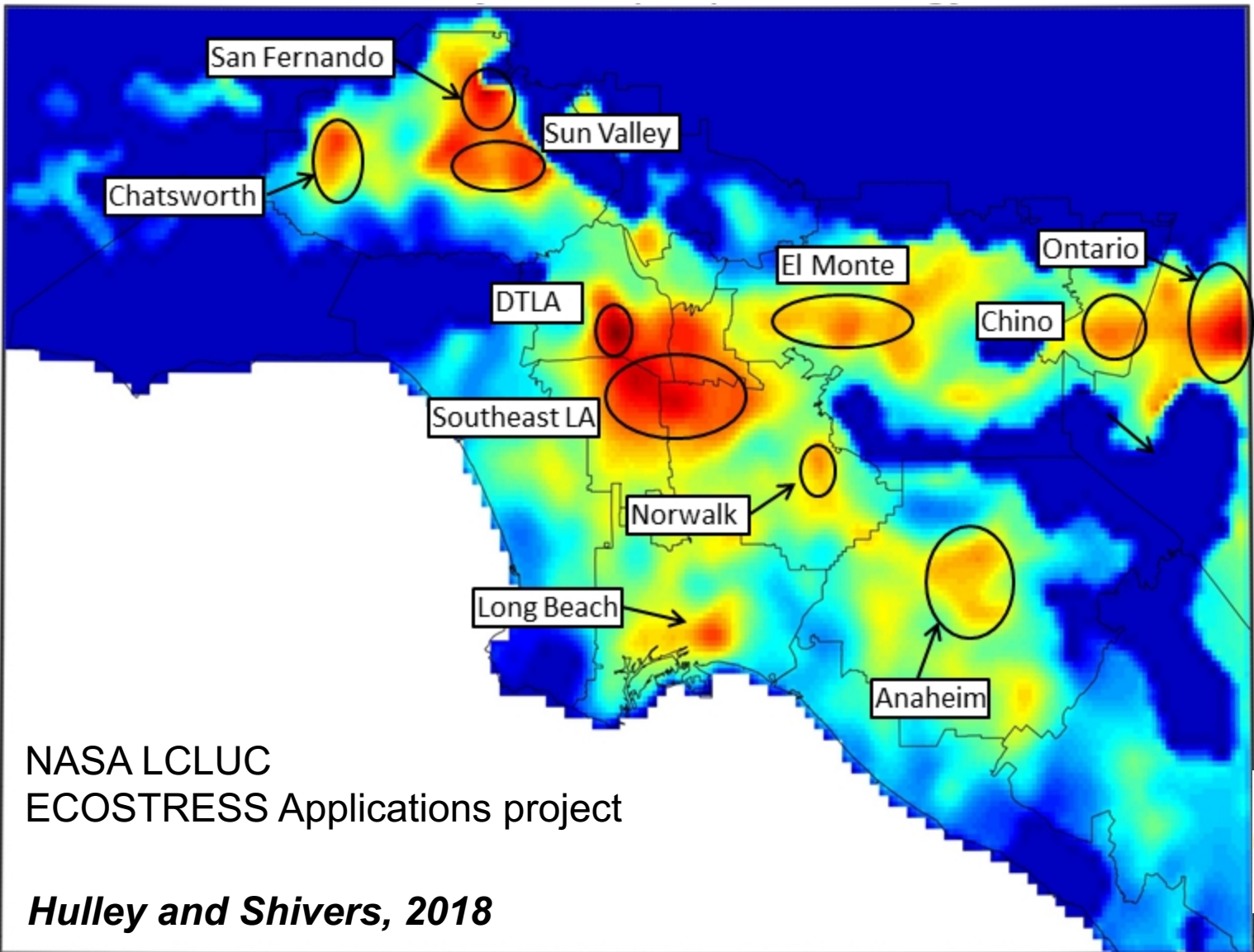
Cryosphere Studies

MOD21 Band 32 (12 μm) Emissivity, Greenland, August 2004



MODIS Heat Vulnerability Index (HVI)

34.4° N



33.5° N

119.0° W

117.6° W

NASA LCLUC
ECOSTRESS Applications project

Hulley and Shivers, 2018



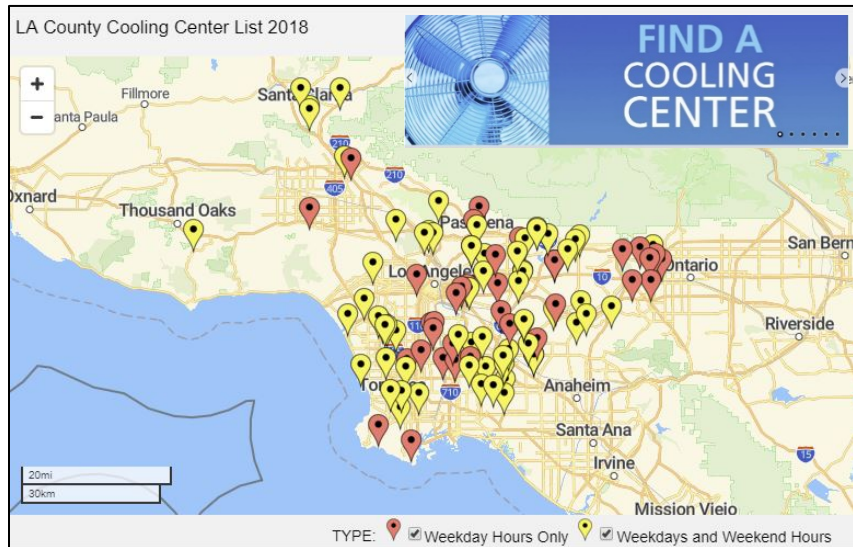


Heat advisories and mitigation



Identify optimal locations for cooling centers

Heat mitigation



Advise on realistic health advisories

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

Outline

1. Algorithm and product updates
2. Validation
- 3. Product unification (MOD11+MOD21)**
4. Continuity

LST Uncertainty Model

Hulley et al. 2012

$$\delta LST_{MODIS} = a_0 + a_1 TCW + a_2 SVA + a_3 TCW \cdot SVA + a_4 TCW^2 + a_5 SVA^2 \quad (10)$$

a_i = Regression coefficients dependent on surface type (gray, bare, transition)

SVA = Sensor view angle

TCW = Total column water estimate (cm), e.g. from MOD07, NCEP

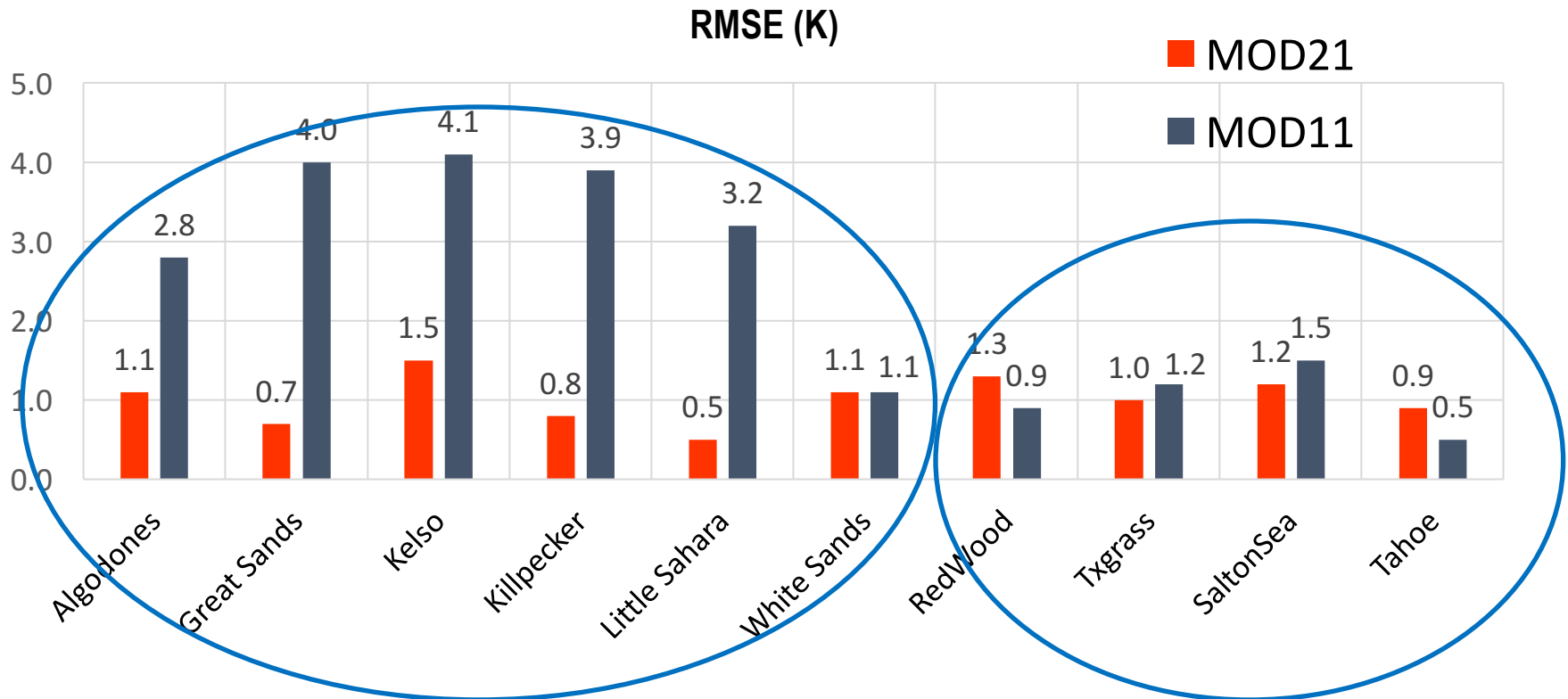
Combined LST is weighted mean:

$$\overline{LST} = \frac{1}{(w1 + w2)} (w1 \cdot LST1 + w2 \cdot LST2) \quad (1)$$

$$w = 1/\delta^2$$

TCW

MODIS LST Validation Summary



MOD11 larger
uncertainty over bare
regions
(3-5 K)

MOD11 more stable
over graybodies
(higher precision)

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NOAA

National Calibration Center

NESDIS / STAR
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION



Ensuring accurate and consistent operational satellite data for weather, climate, and other environmental applications

NOAA National Calibration Center

NPP vs. AQUA

[Return to SNO Predictions >>](#)

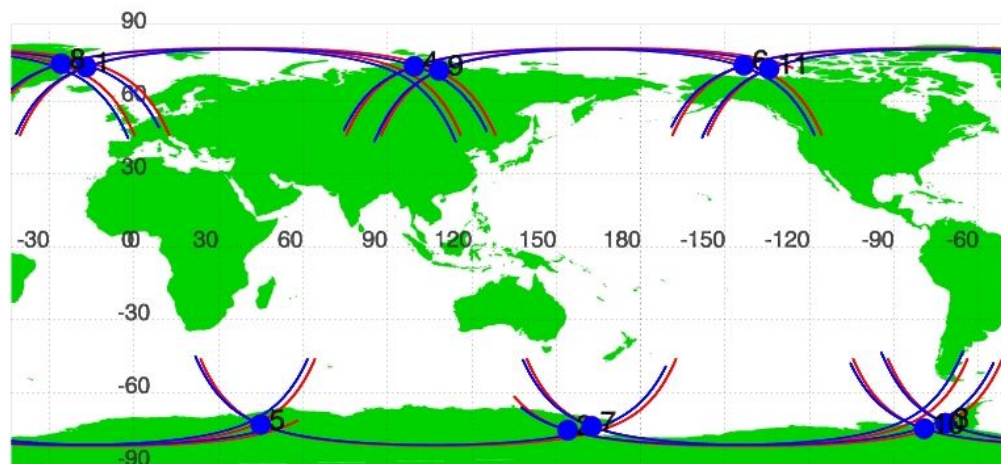
MODIS Aqua/VIIRS Matchups for 2012 over Contiguous US:

Winter (Jan, Feb): 24 granules

Summer (Aug, Sep): 30 granules

Observation Criteria:

1. Time: <10 min
2. Angular separation: <2°
3. View angles < 10°

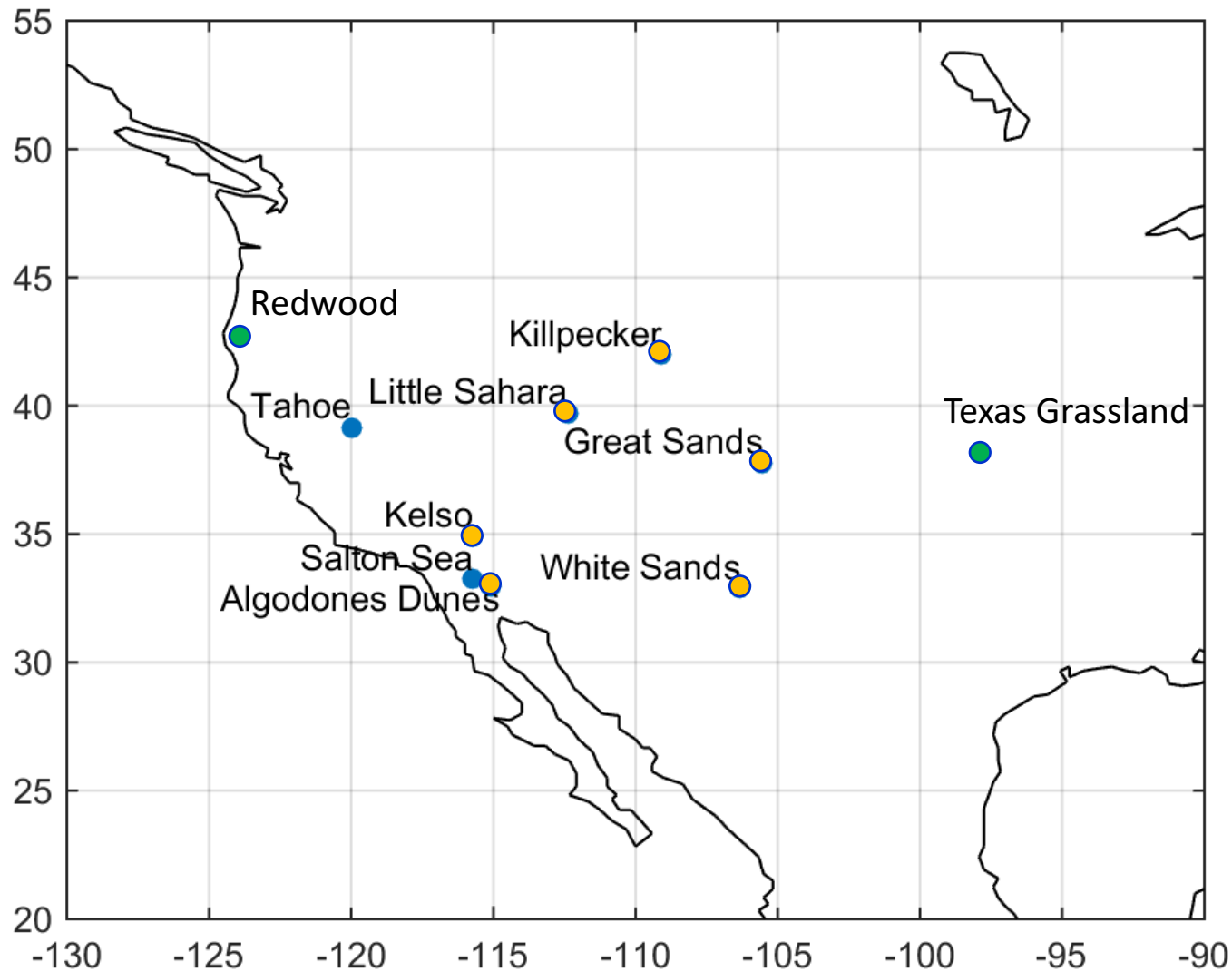


Red line: AQUA

Blue line: NPP

TLE Epoch: 2015/12/7

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)

Uncertainty Analysis

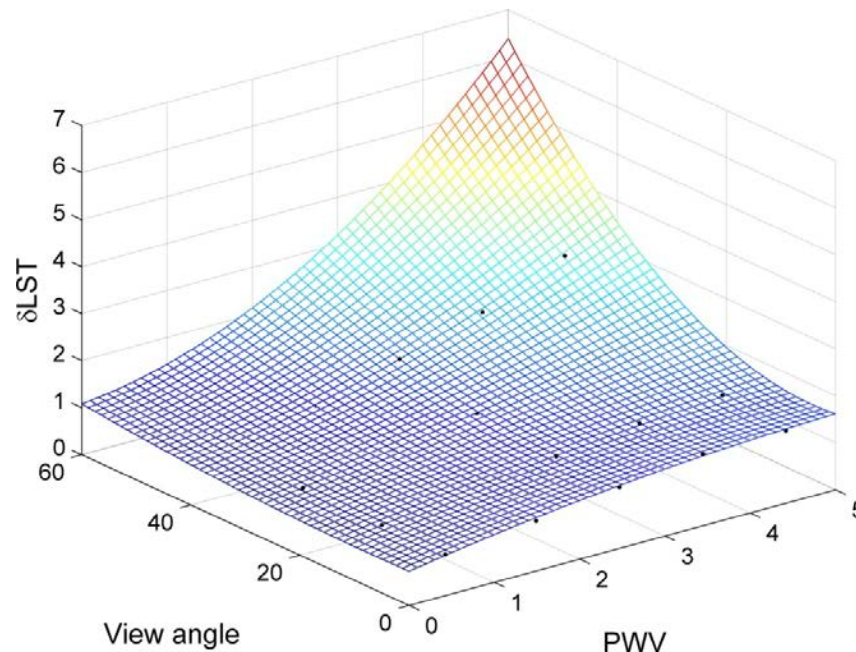
Hulley et al. 2012

$$\delta LST_{MODIS} = a_0 + a_1 TCW + a_2 SVA + a_3 TCW \cdot SVA + a_4 TCW^2 + a_5 SVA^2 \quad (10)$$

a_i = regression coefficients dependent on surface type (gray, bare, transition)

SVA = sensor view angle

TCW = total column water estimate (cm), e.g. from MERRA2, NCEP



Uncertainty Analysis

