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Radiance Based VIIRS LST Product Validation

***Heshun Wang*[1,2], *Yunyue Yu*[2], *Yuling Liu*[1,2], *Peng Yu*[1,2]**

1. Cooperative Institute for Climate and Satellites, University of Maryland
2. Center for Satellite Applications and Research, NOAA NESDIS

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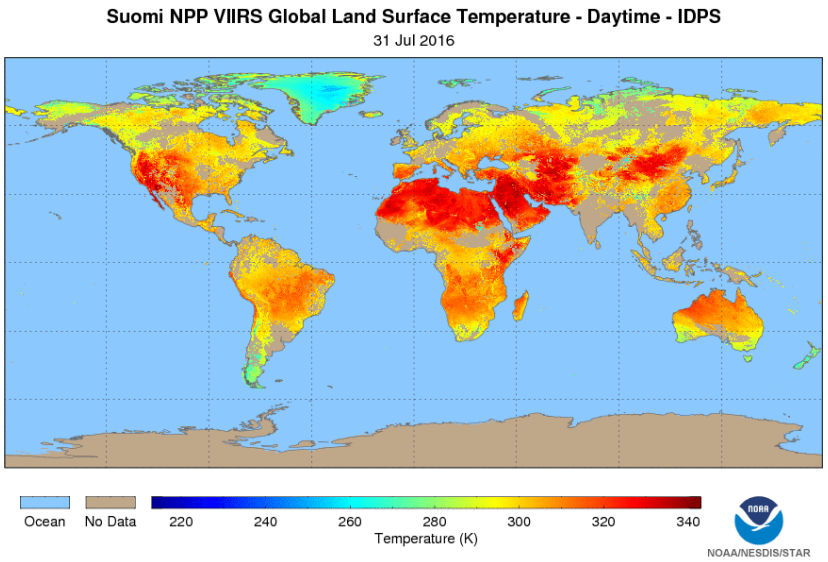
Content

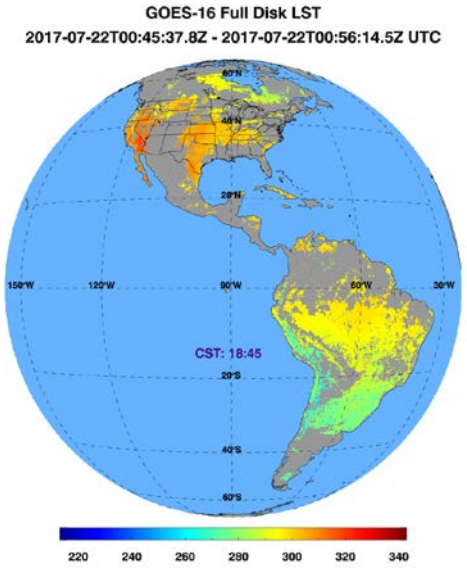
- Introduction
- Atmospheric Profile Evaluation.
- VIIRS LST Radiance based validation
- Summary and ongoing work

Background

- JPSS and GOES-R Operational LST Product



- LEO: JPSS/VIIRS LST (Left)
- GEO: GOES-R/ABI LST (Right)



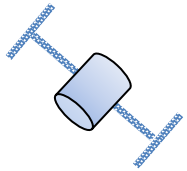
- Temperature Based LST Validation
  - **Convincing & Straightforward**
  - Representative: Point (1-100m) → Pixel (1-2km)
  - Limited at global scale

Radiance Based LST Introduction

At-Sensor Radiance | 1.Surface Emission | 2.Surface Reflection | 3. Atmospheric Emission

$$R_\lambda = \underbrace{\tau_\lambda \varepsilon_\lambda B_\lambda (T_s)}_{1} + \underbrace{\tau_\lambda (1-\varepsilon_\lambda) L_\lambda^{\downarrow}}_{2} + \underbrace{L_\lambda^{\uparrow}}_{3}$$

- LST Retrieval: R + ε + TPW → Ts

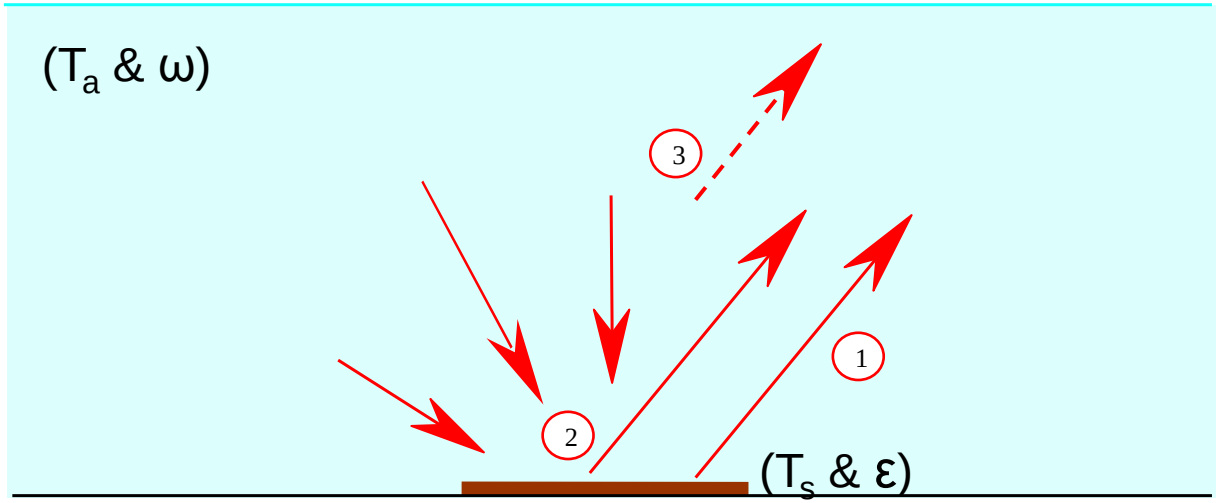


Take advantage of absorption difference, Don't need atmospheric details.

Radiance Based LST:

R+ε+(Ta,w)(p)→ T_{RB}

Need atmospheric details and RT models simulation to get T_{RB} (e.g. MODTRAN, CRTM)

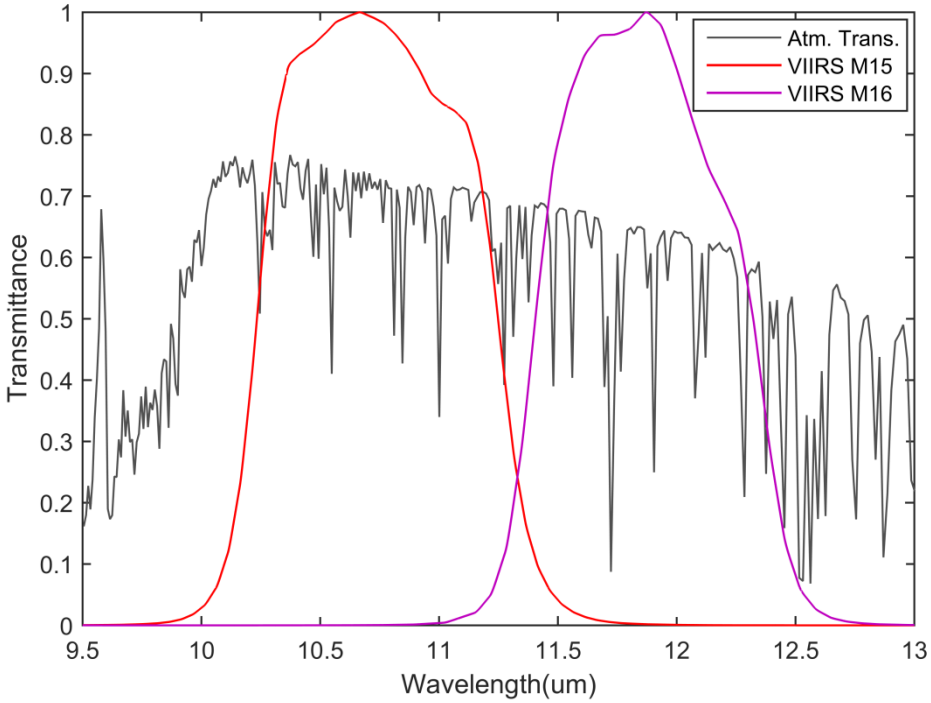


VIIRS TIR Bands for R Based LST

■ M15 (11 μm) used for R-Based LST determination for its higher transmittance than 12 μm

■ Brightness Temperature (BT) difference (BT11-BT12) is adopted for profile check.

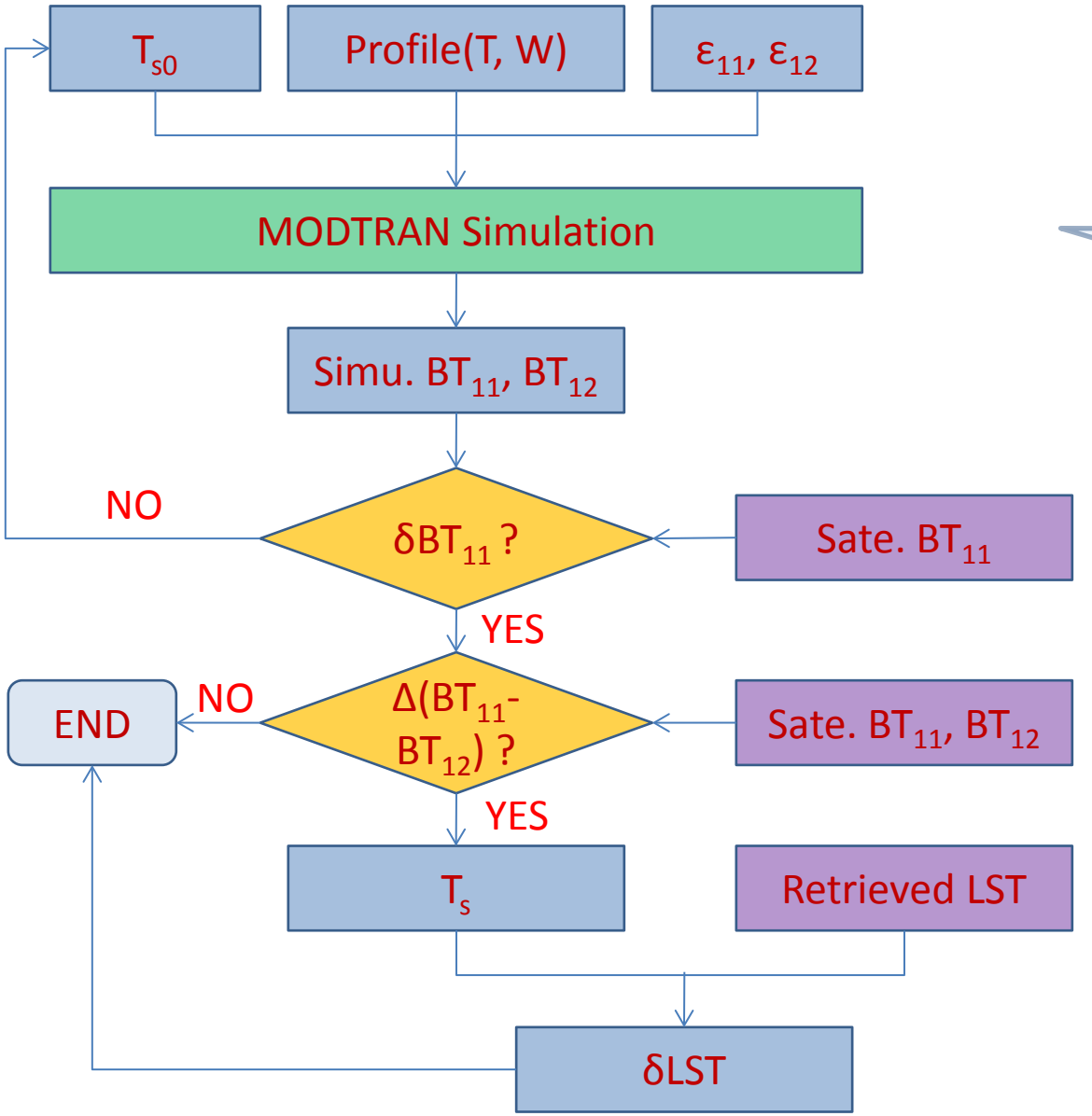
➢ Assumed Emissivity difference is accurate.
➢ More clear → smaller BT Diff.
➢ Profile accurate → simulated BT Diff close to Satellite BT Diff



VIIRS M15, M16 and the transmittance

$$\delta(dBT) = \left(BT_{11}^{Simu} - BT_{12}^{Simu}\right) - \left(BT_{11}^{Sate} - BT_{12}^{Sate}\right)$$

R Based Validation Flowchart

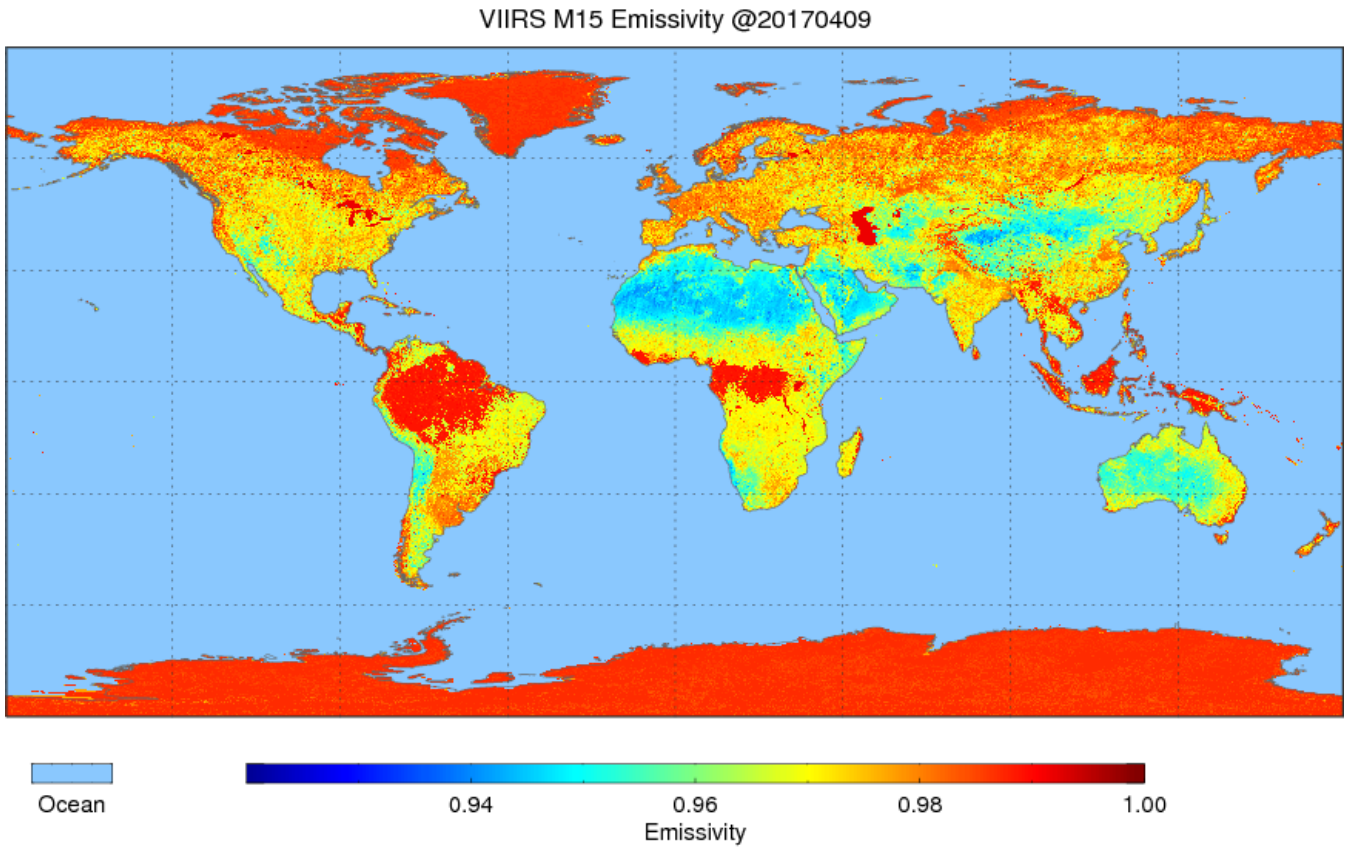


1. Forward Simulation to get R-Based LST

2. Profiles Screening

3. LST Validation

R Based LST Input - Emissivity



- Based on modified vegetation cover method
- Daily product
- Global coverage
- Resolution: 1km (0.009 Degree)
- 4 narrow bands (VIIRS & ABI SW) + 1 broadband.
- Accuracy < 0.015

R Based LST Input - Profile

	NOAA NCEP GDAS	NOAA NCEP GDAS	ECMWF ERA-Interim	NASA MERRA-2
Range	1979-present	201507-present	1979-present	1980-present
Spatial Resolution	1*1	0.25*0.25	0.75*0.75	0.625*0.5
Temporal Resolution	6 hour	6 hour	6 hour	3 hour
Vertical Resolution	26 pressure levels	31 pressure levels	37 pressure levels	42 pressure levels
Latency	Daily	Daily	2 Months	1 Month

Reference Profile: Upper Air Sounding Data (0:00, 12:00 UTC, Regular)

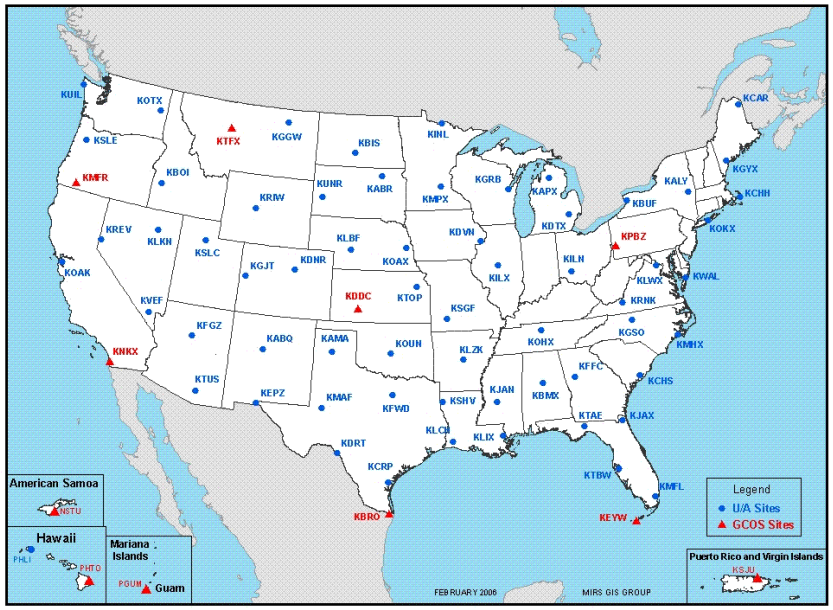
Time Range: 20160101 – 20161231

Stations: 7 stations near SURFRAD

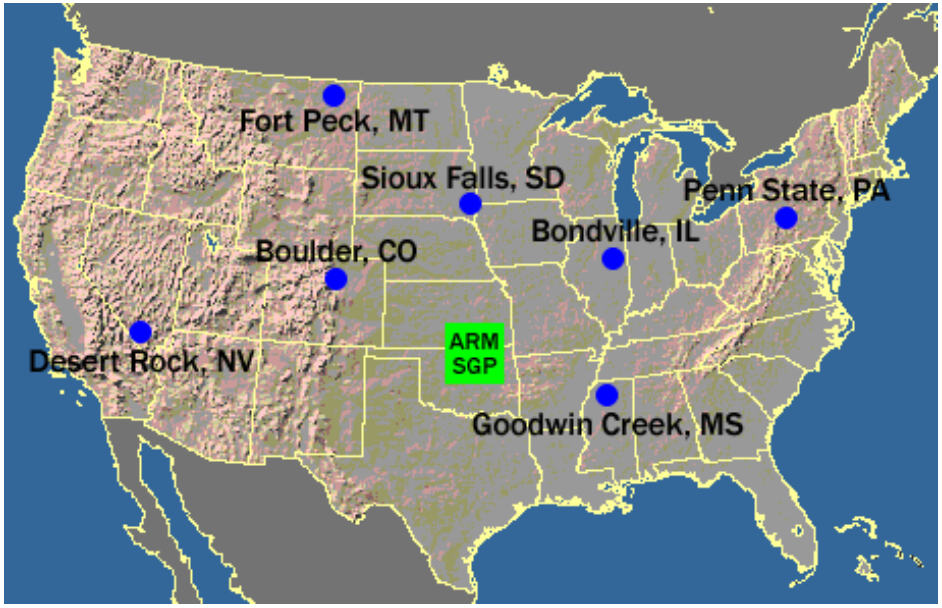
Criteria : TPW, BT11 & BT12

Sounding & SURFRAD Stations

NWS Rawinsonde Network



SURFRAD Station

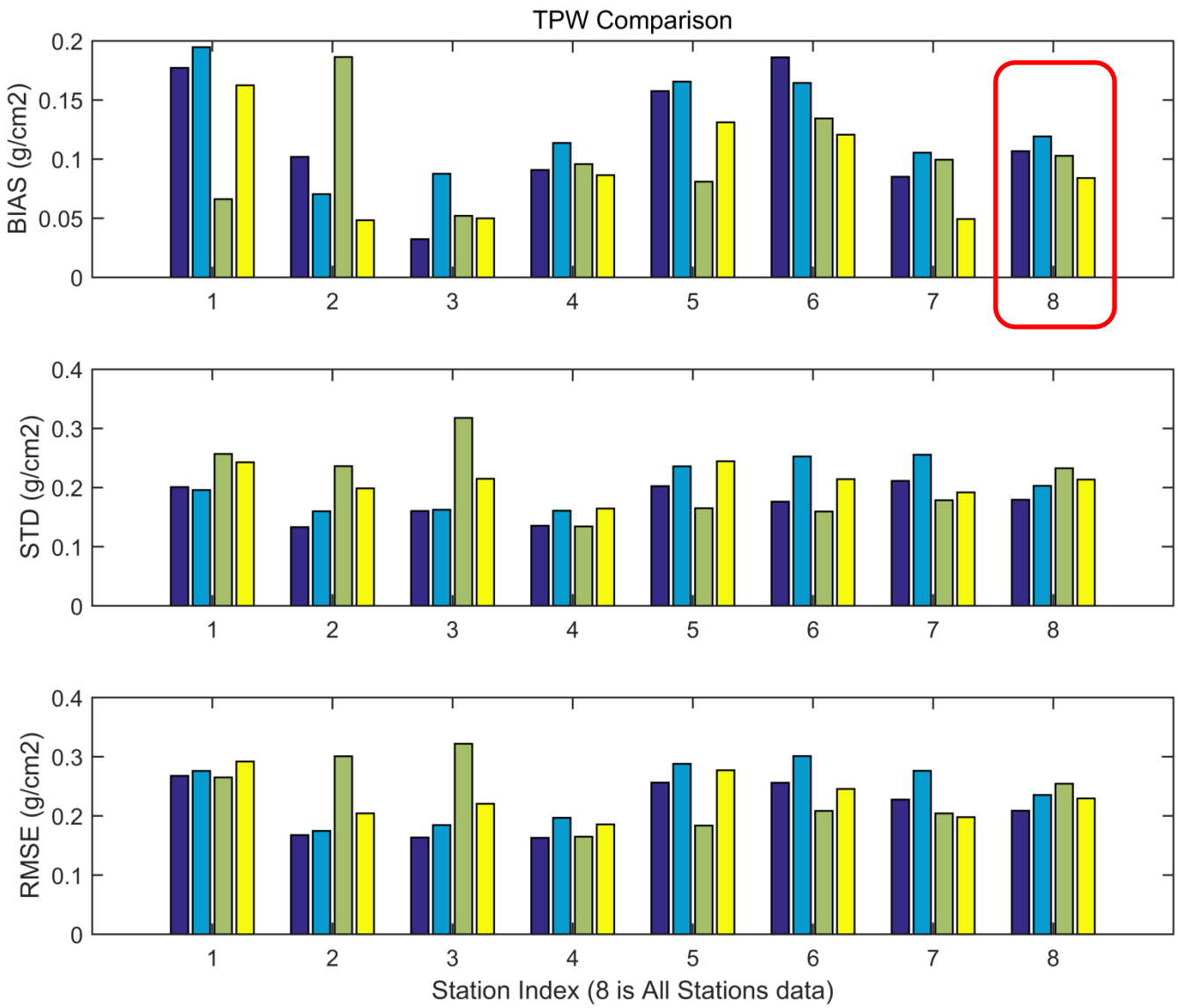


Index	SURFRAD	Lon	Lat	Rawinsonde	Lon	Lat
1	BON	-88.37	40.053	ILX	-89.33	40.15
2	TBL	-105.235	40.124	DNR	-104.87	39.77
3	DRA	-116.014	36.624	VEF	-115.18	36.05
4	FPK	-105.098	48.308	GGW	-106.61	48.21
5	GWN	-89.873	34.253	JAN	-90.08	32.32
6	PSU	-77.93	40.722	PIT	-80.22	40.53
7	FSX	-96.623	43.727	ABR	-98.43	45.45

Method

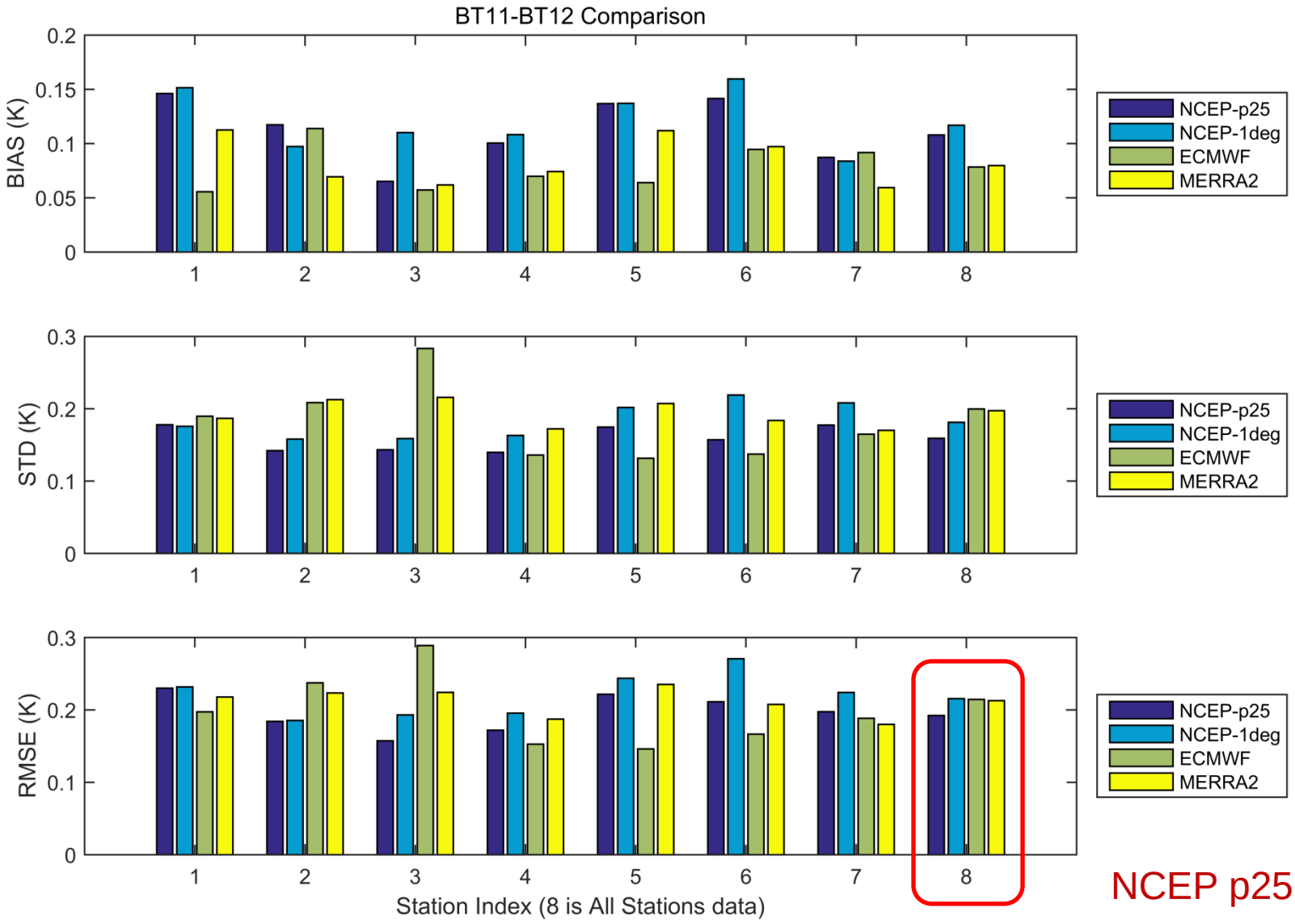
- Profiles Data
  - 7 Sounding Stations near SURFRAD
  - Time range: 20160101 – 20161231 (2993 matchup data pairs)
  - 4 analysis products (NCEP p25, NCEP 1deg, ECMWF & MERRA2)
- Comparison Items
  - Simulating VIIRS BT11 & BT12 using MODTRAN
  - Surface temperature is bottom air temperature + 5
  - Surface emissivity is 0.97 & 0.98 for M15 & 16, respectively
  - Satellite zenith angle set to 25 degree.
  - Evaluating the profiles by TPW, BT11 and BT12.

TPW Comparison



All are more humid than Sounding

BT Difference Comparison



NCEP p25 Best

R Based for Different Algorithm

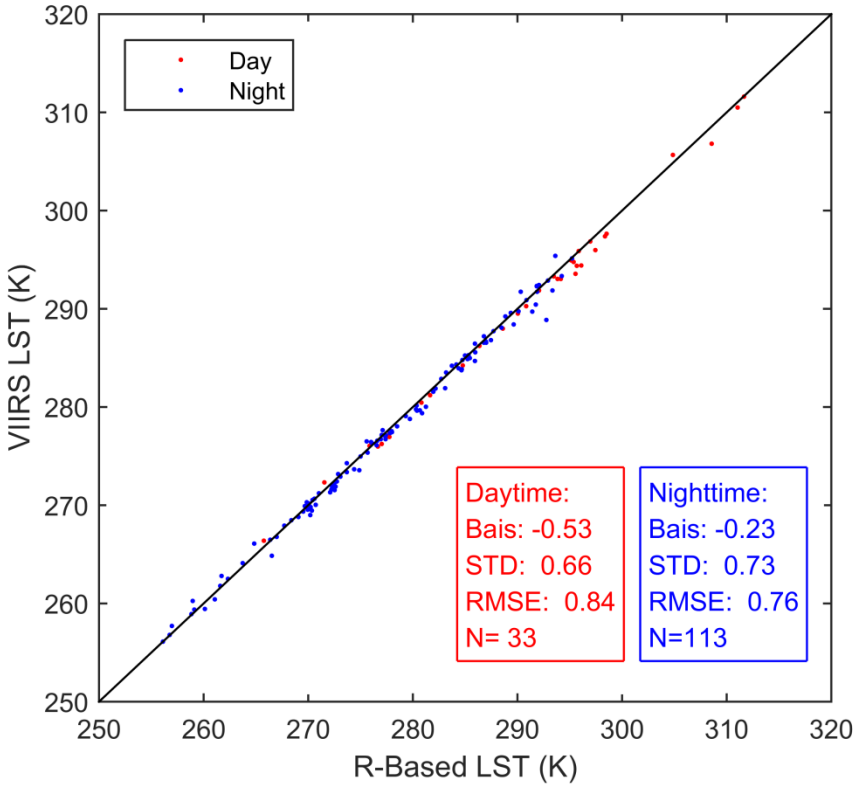
LST algorithm for VIIRS

- IDPS Split Window Algorithm (Surface type dependant)
- Enterprise Split Window Algorithm (Emissivity explicit)

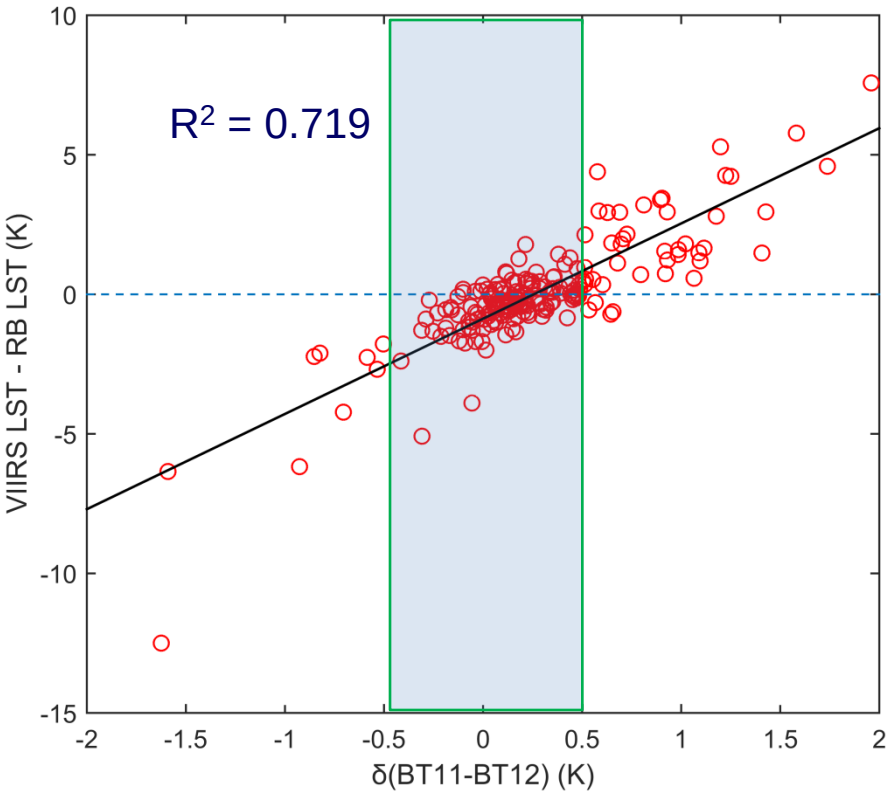
Validation Sites

- 7 Sites of SURFRAD
- 20160101-20161231
- Only clear sky condition.

Profile Screening



Enterprise VIIRS LST R-Based Validation @ Bondville (2016)



Δ(BT11-BT12) and R-Based LST Validation result

R-Based validation result significantly improve after profile screening using δBT Difference, (-0.5K, 0.5K).

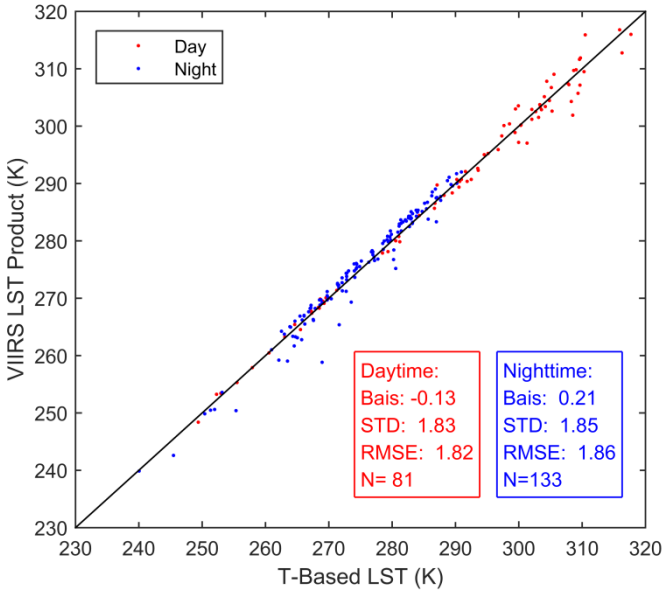
R-Based Validation over SURFRAD

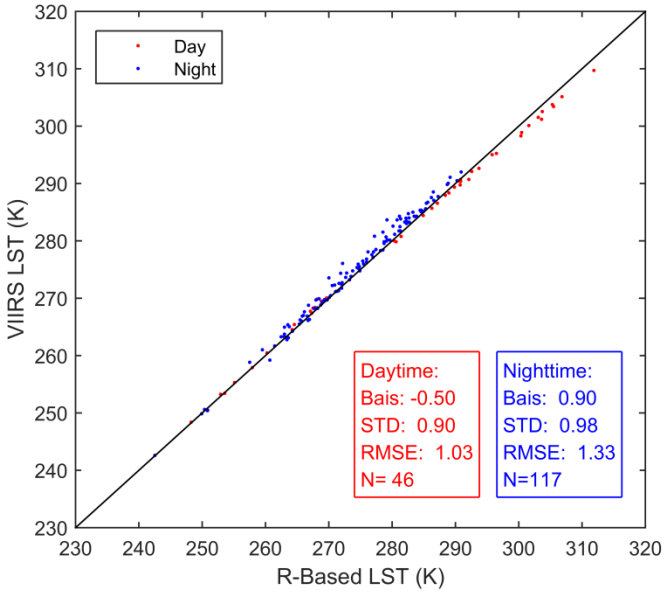
IDPS	Bias(D)	STD(D)	RMSE(D)	Num(D)	Bias(N)	STD(N)	RMSE(N)	Num(N)
BON	-1.25	0.63	1.40	33	-0.03	0.77	0.77	113
TBL	-0.79	0.64	1.00	32	0.32	0.96	1.00	113
DRA	-1.14	0.50	1.25	80	1.32	0.49	1.40	78
FPK	-0.50	0.90	1.03	46	0.90	0.98	1.33	117
GWN	-0.90	0.34	0.96	37	-0.12	0.68	0.68	125
PSU	-0.57	0.52	0.76	17	0.45	0.58	0.73	61
SXF	-0.72	1.15	1.34	43	0.08	0.74	0.75	131

Enterp.	Bias(D)	STD(D)	RMSE(D)	Num(D)	Bias(N)	STD(N)	RMSE(N)	Num(N)
BON	-0.53	0.66	0.84	33	-0.23	0.73	0.76	113
TBL	0.15	0.36	0.39	32	0.12	0.43	0.45	113
DRA	-0.74	0.59	0.95	80	-0.41	0.57	0.70	78
FPK	0.42	0.78	0.88	46	0.26	0.58	0.64	117
GWN	-0.14	0.34	0.36	37	0.06	0.91	0.91	125
PSU	0.14	0.50	0.51	17	0.07	0.65	0.64	61
SXF	0.26	0.85	0.88	43	0.29	0.72	0.77	131

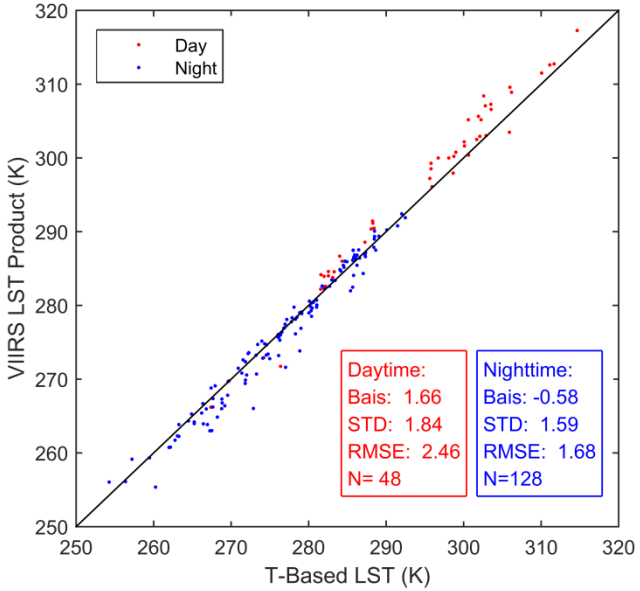
T-Based and R-Based Validation

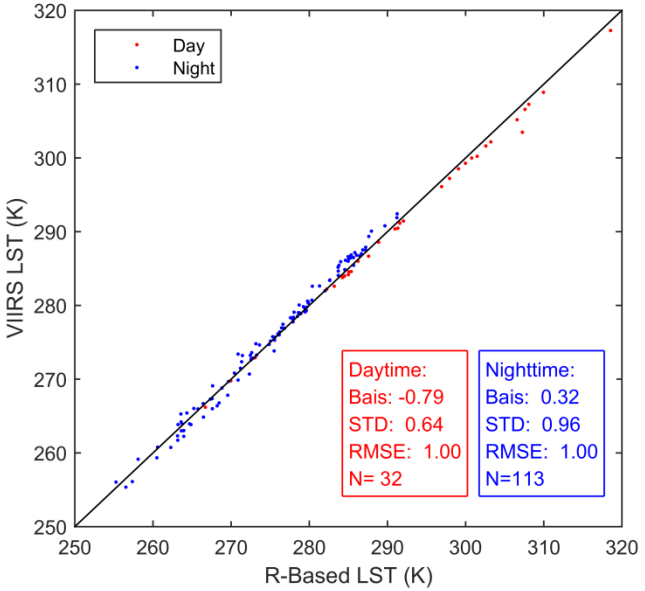
■ SURFRAD
FPK Site
Left: T-Based
Right: R-Based





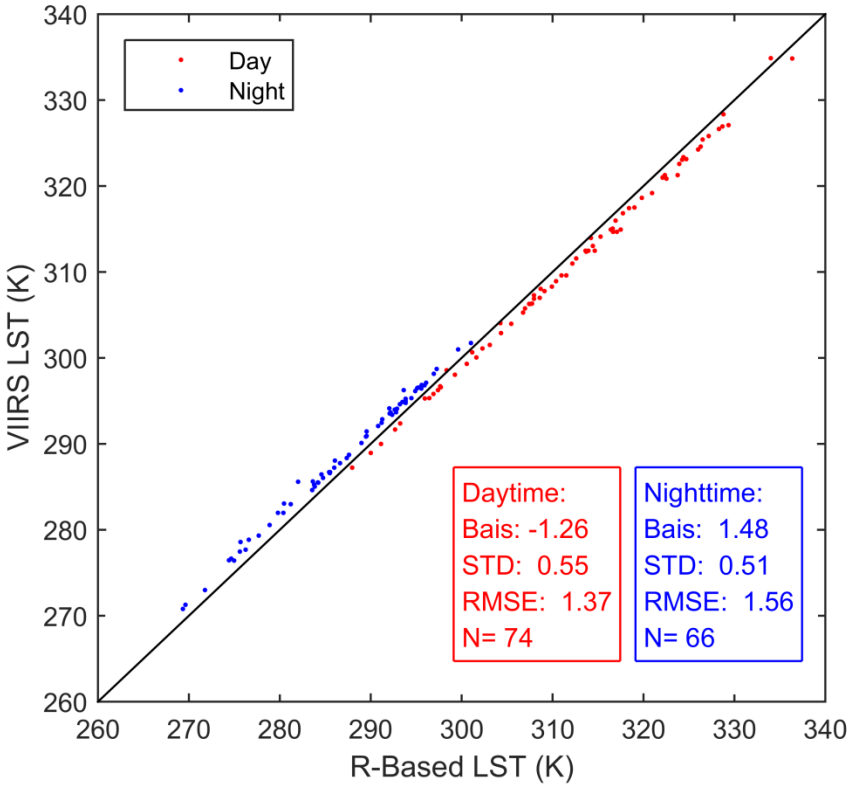
■ SURFRAD
TBL Site
Left: T-Based
Right: R-Based



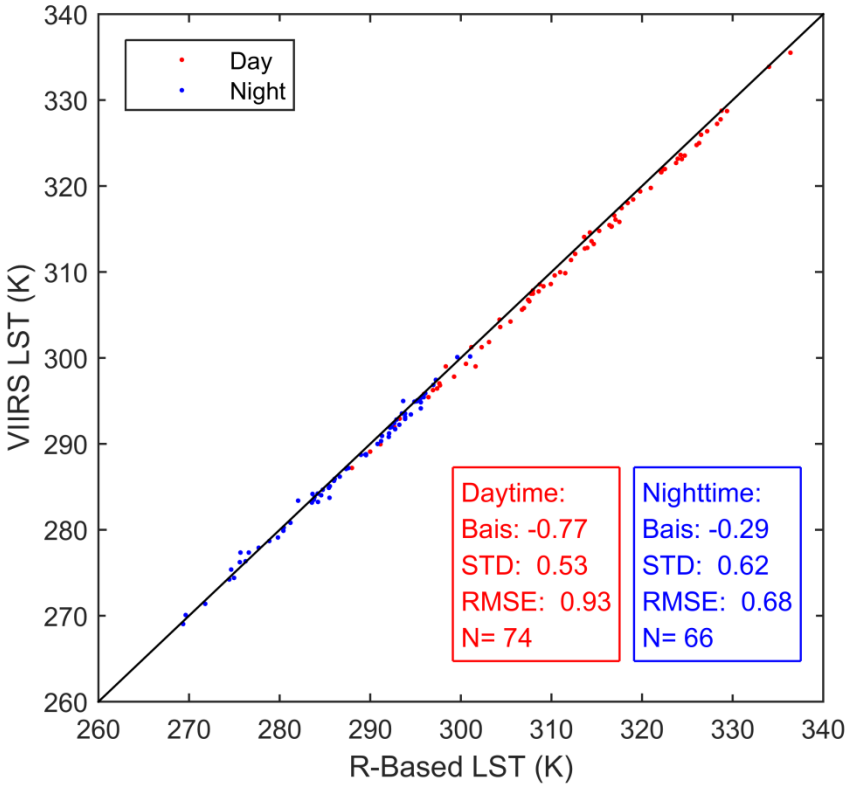


Desert Rock Site

- SURFRAD Desert Rock Site



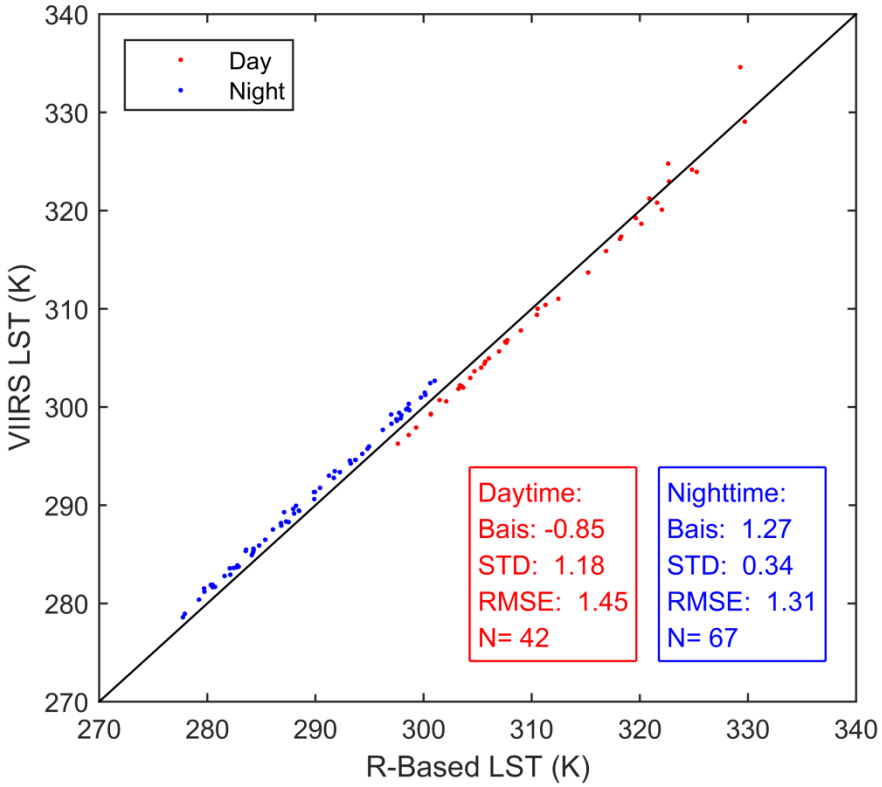
IDPS VIIRS LST R-Based (2016)



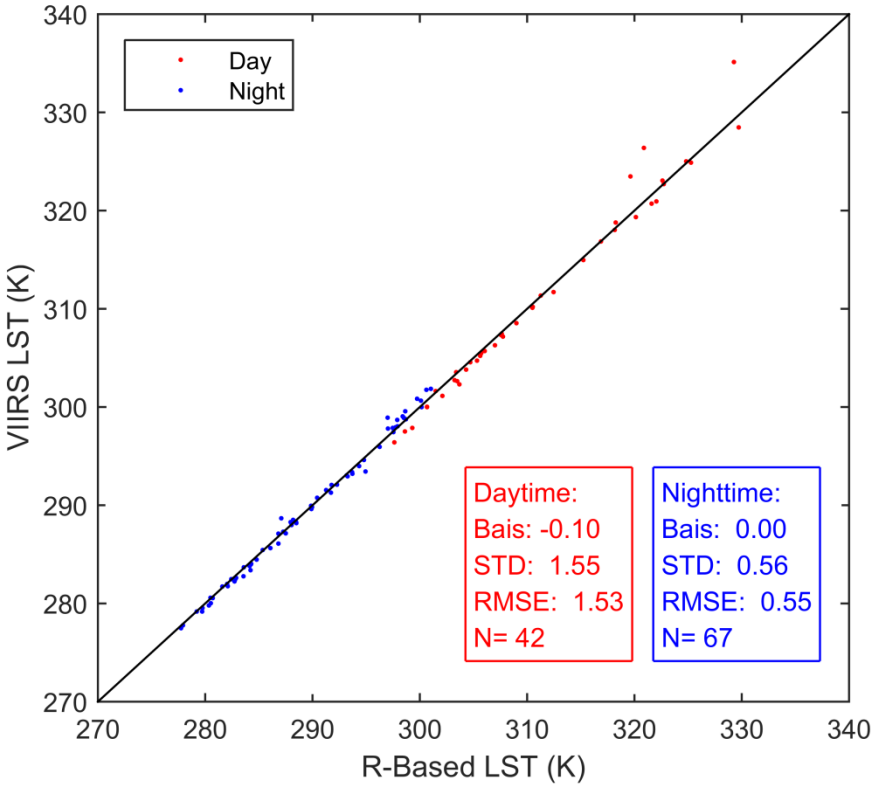
Enterprise VIIRS LST R-Based (2016)

IDPS VIIRS LST has negative bias at daytime and positive bias at nighttime, while Enterprise VIIRS LST has good results!

ASM site in Australia



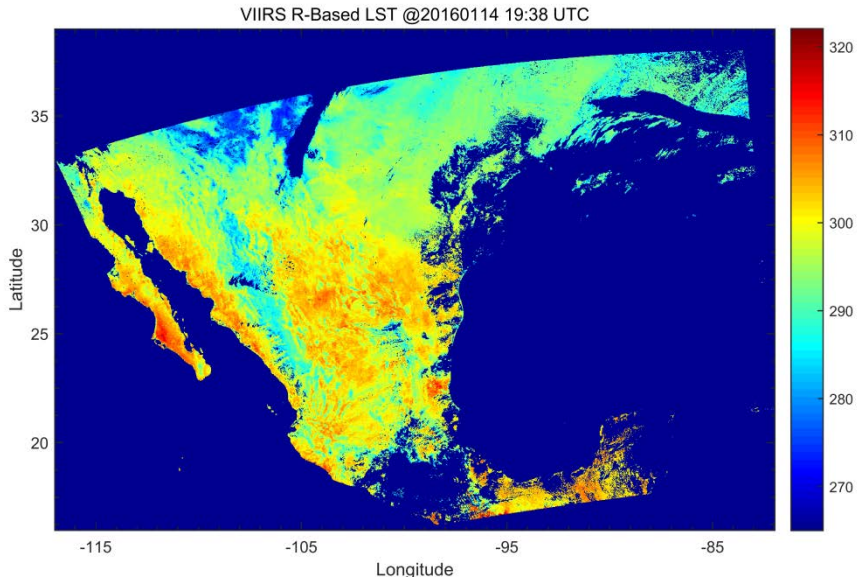
ASM IDPS (201504-201603)

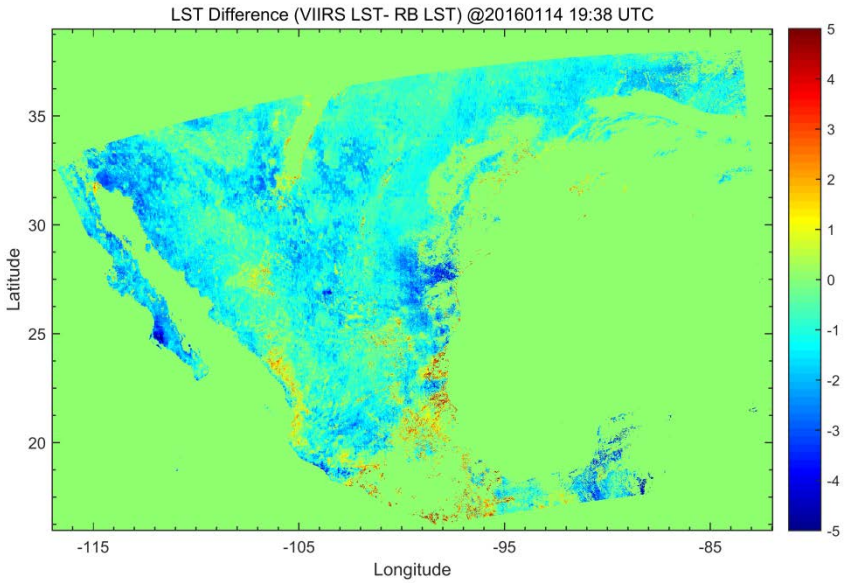


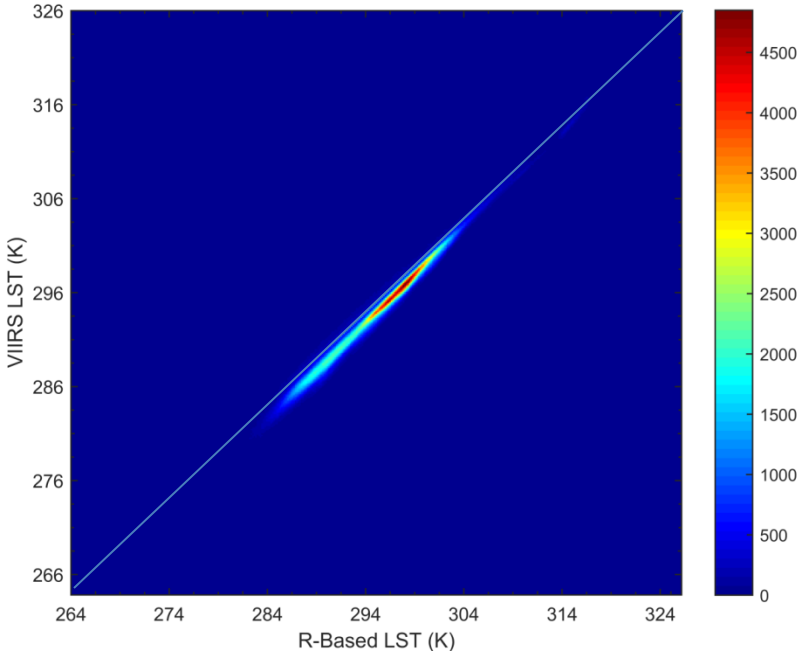
ASM Enterprise (201504-201603)

IDPS has bias at day and night, Enterprise works well.

R-Based LST at Granule Level







- R-Based LST (Upper Left) compared with VIIRS EDR LST (difference: Upper Right)

- Bias = -0.97K; STD = 0.87K; RMSE = 1.30K; N = 3,169,359

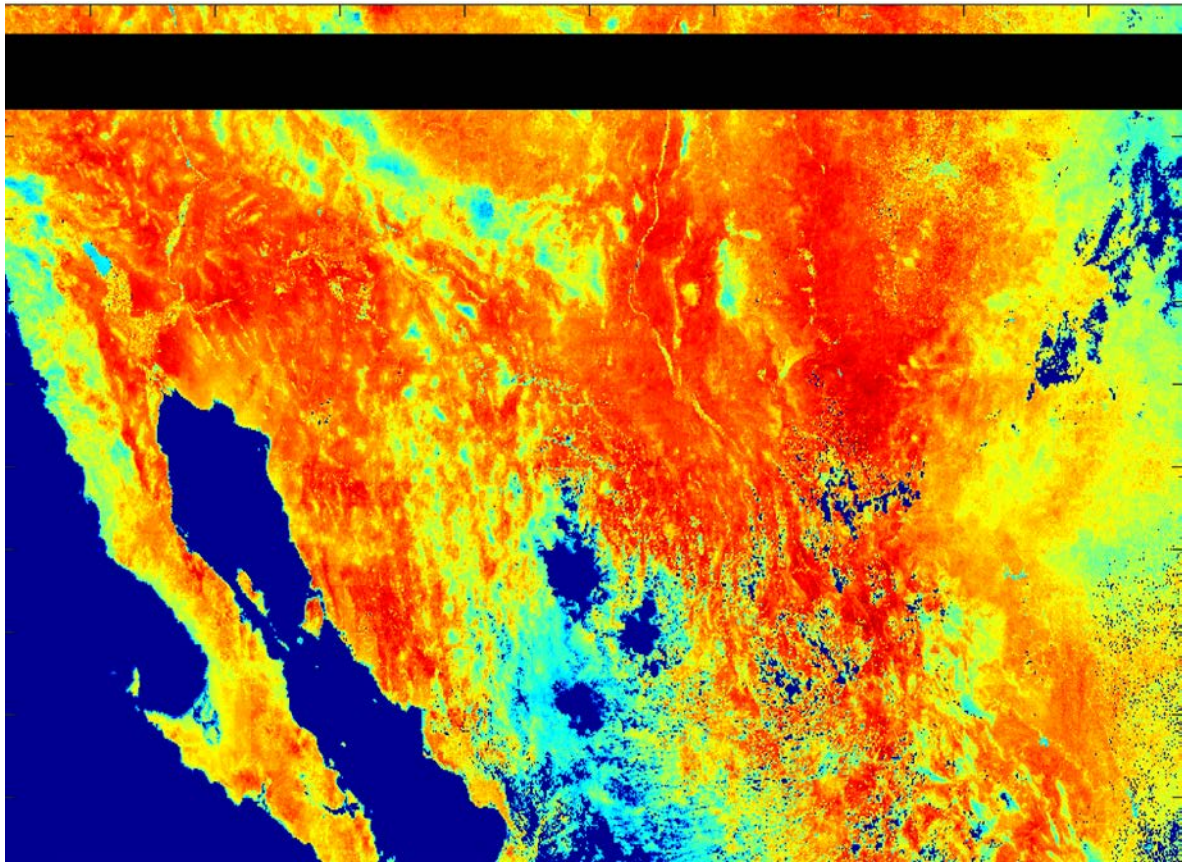
Summary

- NCEP 0.25° reanalysis profile has the best accuracy for R-Based Validation, before July 2015, NCEP 1° will substitute.
- Long time series R-Based Validation indicates VIIRS LST has a good accuracy over SURFRAD sites.
- For the barren sites, R-based validation shows the improvement of Enterprise algorithm over operation algorithm.

Ongoing work

- Since R-Based simulation using MODTRAN is time-consuming, switch to CRTM for granule level validation.
- More global LST validation over various surface types will be performed, not only for VIIRS, but also for GOES-R/ABI.
- A R-based validation package is under developing for LST product monitoring.

Thank You!



Heshun Wang (hswang@umd.edu; heshun.wang@noaa.gov)