

NOAA-20 VIIRS Land Surface Temperature Provisional Maturity Review

Presented by Yunyue Yu

Contributed by Yuling Liu and Heshun Wang

Feb. 21, 2019

- Overview
 - LST Cal/Val Team Members
 - Product Requirements
 - NOAA 20 VIIRS LST Status
- Evaluation of the NOAA 20 VIIRS LST
 - Visual Analysis and Beta Correction
 - Theoretical evaluation of the NOAA 20 LST LUT
 - Validation against the ground LST data
 - Cross comparison with other satellite LST products
- Documentation (Science Maturity Check List)
- Provisional Maturity Summary
 - Evaluation Summary
 - Provisional Maturity Check list
- Path Forward to Validated Maturity

LST Cal/Val Team Members

	Name	Institute	Function
JPSS-STAR	Ivan Csiszar	NOAA/NESDIS/SATR	Land Lead, Project Management
	Yunyue Yu	NOAA/NESDIS/SATR	EDR Lead, algorithm development/improvement, calibration/validation, team management
	Yuling Liu	NOAA Affiliate, UMD/ESSIC	product monitoring and validation ; algorithm development/improvement
	Heshun Wang	NOAA Affiliate, UMD/ESSIC	algorithm improvement, product calibration/validation
	Peng Yu	NOAA Affiliate, UMD/ESSIC	product validation tool, monitoring, applications
	Yuhan Rao	NOAA Affiliate, UMD/ESSIC	Product assessment analysis
	Walter Walf	NOAA/NESDIS/SATR	STAR ASSIST Lead
	Christopher Selman	NOAA Affiliate, SciTech/IMSG	STAR ASSIST, Algorithm System integration
	Arthur Russakoff	NOAA Affiliate, SciTech/IMSG	STAR ASSIST, Algorithm System integration
NOAA/EMC	Daryl Kleist	NOAA/EMC/NCEP	user readiness
	Yihua Wu	NOAA Affiliate	user readiness
	Weizhong Zheng	NOAA Affiliate	user readiness
	Xiaoyan Zhang	NOAA Affiliate	user readiness

LST Product Requirements

Product Requirements from JPSS L1RD

	JPSS VIIRS LST	
Products	Threshold	Objective
LST applicable condition: Clear only		
Measurement Accuracy(bias)	1.4 K	0.8 K
Measurement Precision(1 sigma)	2.5 K	1.5 K
Measurement Range	213 – 343 K	183 – 343 K
Refresh	At least 90% coverage of globe every 12 hours(monthly average)	3 hours
Horizontal Cell Size	0.8 km	0.5 km
Mapping uncertainty	1 km at Nadir	1 km at Edge of Scan

JPSS/GOES-R Data Product Validation Maturity Stages – COMMON DEFINITIONS (Nominal Mission)

2. Provisional

- Product performance has been demonstrated through analysis of a large, but still limited (i.e., not necessarily globally or seasonally representative) number of independent measurements obtained from selected locations, time periods, or field campaign efforts.
- Product analyses are sufficient for qualitative, and limited quantitative, determination of product fitness-for-purpose.
- Documentation of product performance, testing involving product fixes, identified product performance anomalies, including recommended remediation strategies, exists.
- Product is recommended for potential operational use (user decision) and in scientific publications after consulting

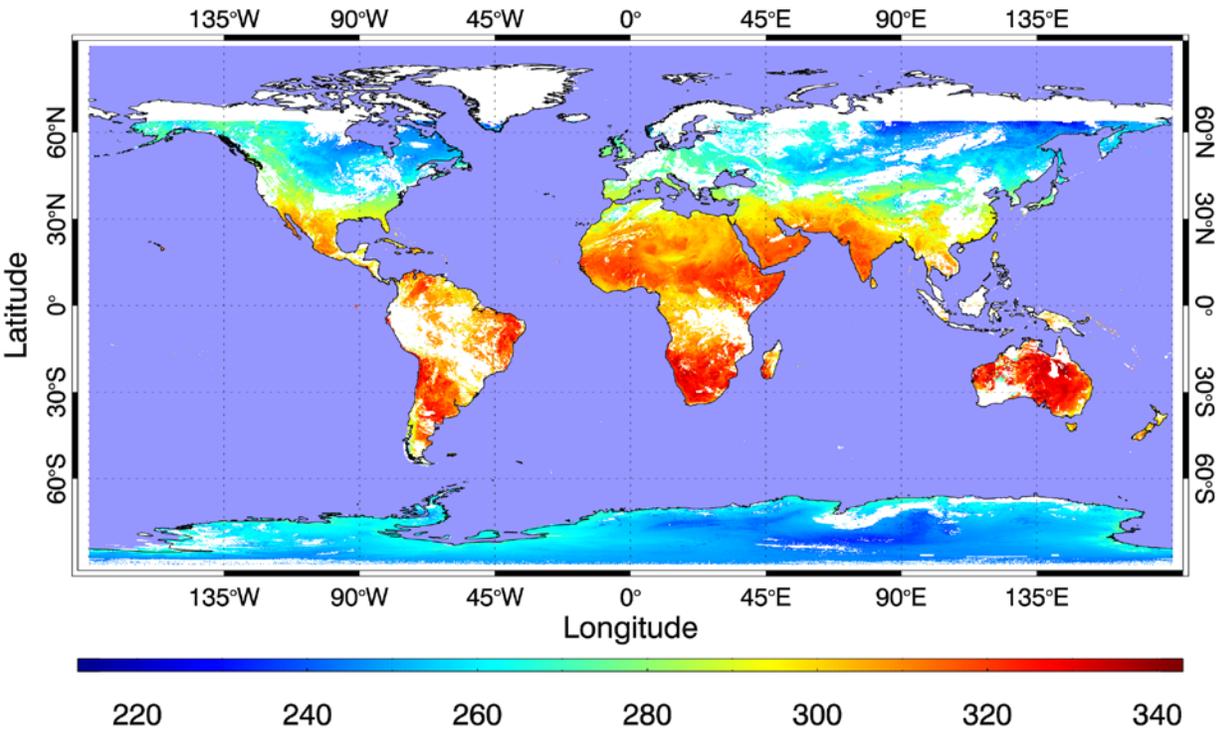
Algorithm update

- Enterprise VIIRS LST algorithm has been developed and integrated into the framework. DAP to NDE was delivered at the end of March, 2018.
- The enterprise LST algorithm has been applied over NOAA-20 data. NRT data of NOAA 20 LST has been generated in the ASSIST framework
- Issues observed during beta stage were fixed. The science code was updated since the beta review
- The LUT for NOAA 20 LST product has been updated and included in this Jan DAP.

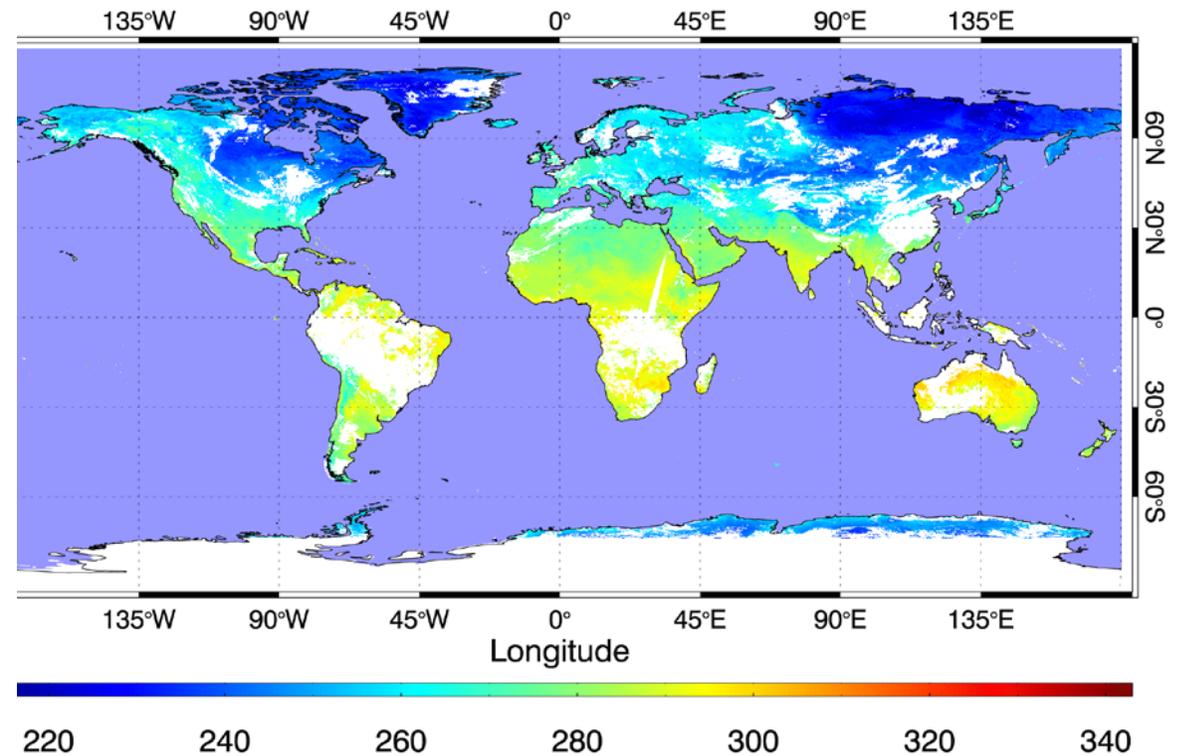
- Visual Analysis and Beta Correction
- Theoretical evaluation of the NOAA 20 LST LUT
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Global LST Map

**NOAA20 Enterprise LST
20180115 Day UTC**

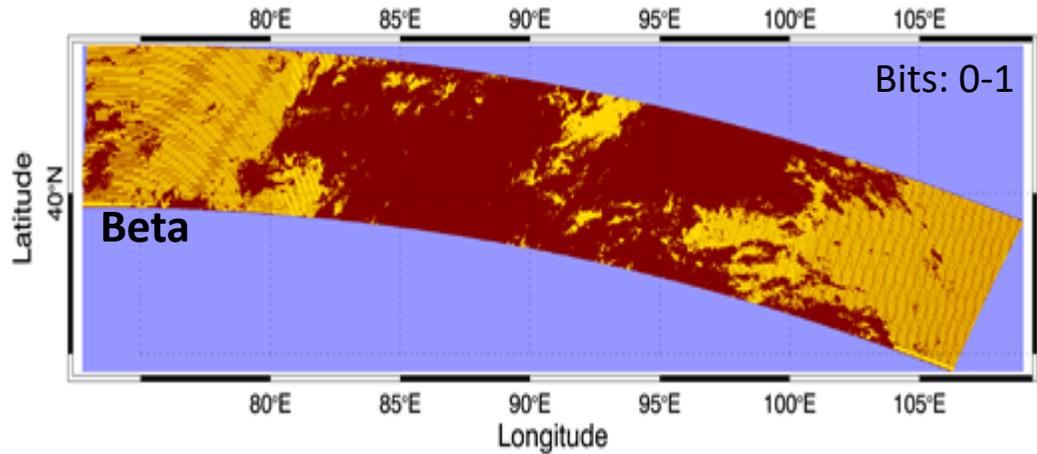


**NOAA20 Enterprise LST
20180115 Night UTC**

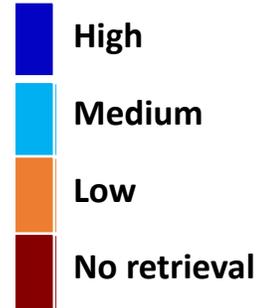
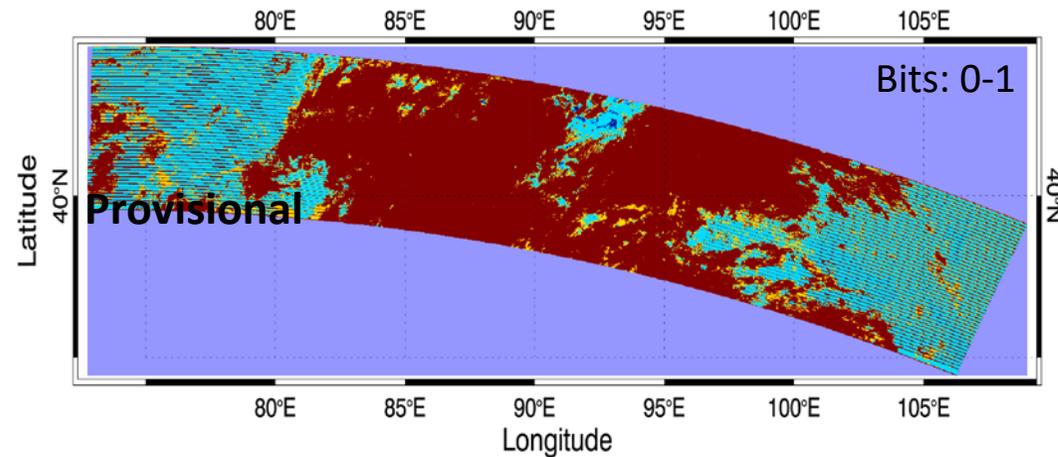


Issue I : Nighttime Quality flag Issue-fixed

LST quality bits(product)
20180621_1949 UTC



LST quality bits(product)
2018172_1949 UTC



LST >= 0	Degraded - Sensor Zenith Angle > 40	Active fire	AOD Range	Thin Cirrus	Cloud Confidence Indicator		
					Confident Clear	Probably Clear	Probably Cloudy
T	x	X	x	yes	Low	Low	Low
T	x	X	out	x	Low	Low	Low
T	x	X	x	x	Low	Low	Low
T	x	fire	x	x	Low	Low	Low
T	Out	no	in	no	Medium	Medium	Low
T	In	no	in	no	High	Medium	Low
F	X	x	x	x	No Retrieval	No Retrieval	No Retrieval

Issue:
LST quality bit (bit 0-1) was not correctly set. For nighttime, the AOD will be missing value, which results in the LST quality as low for all pixels according to the criteria

Solution:

- AOD criteria is added in the quality matrix if available, or, it is not counted in the LST quality
- Above case shows the difference before and after the fix.

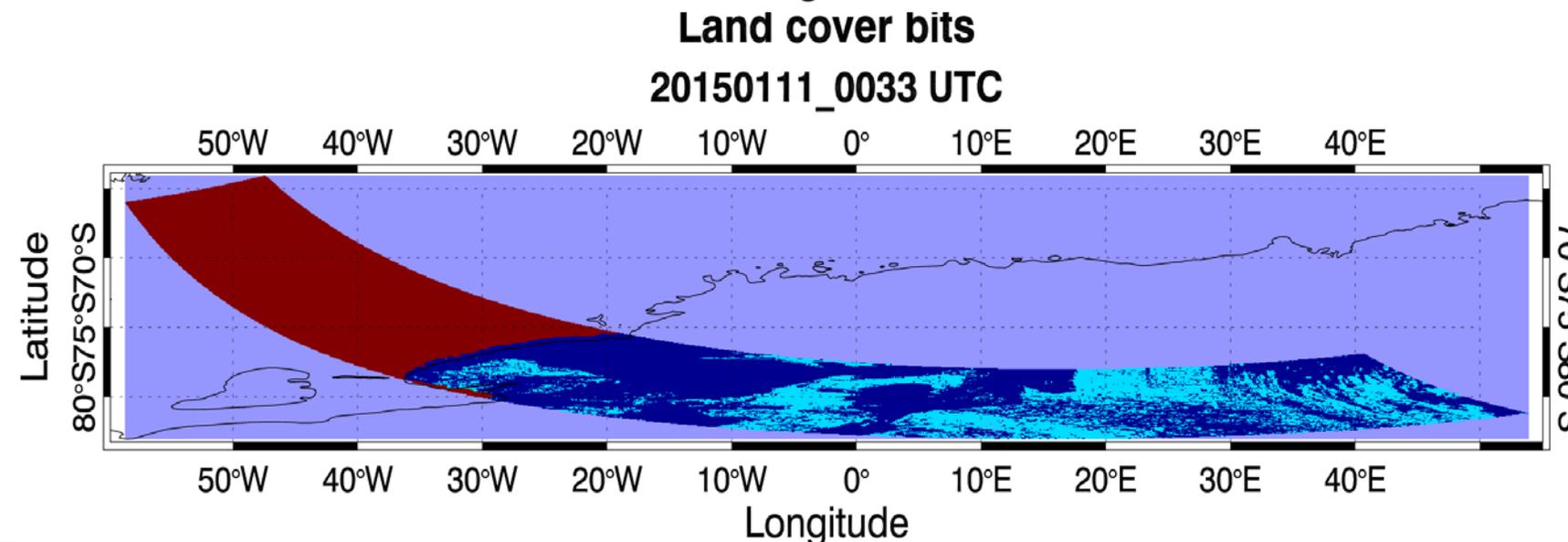
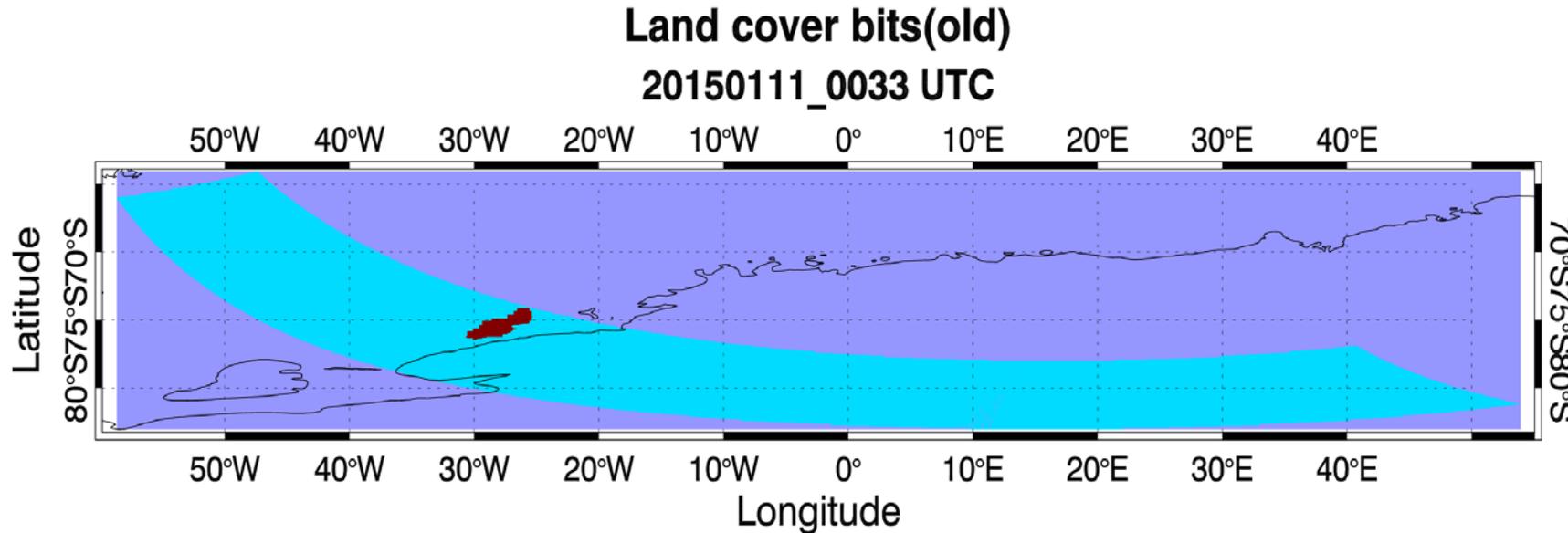
Issue II: Snow cover input change

Input

NWP
snow
cover



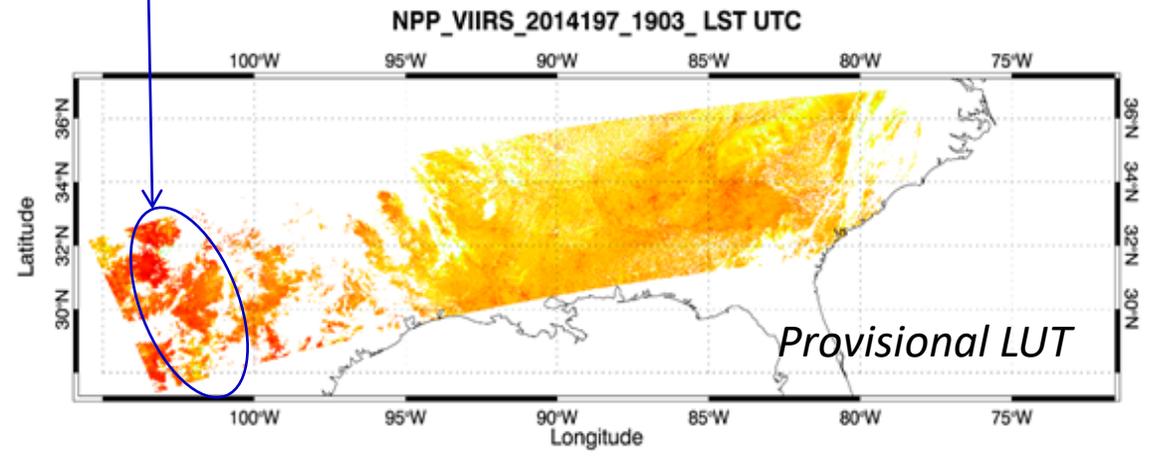
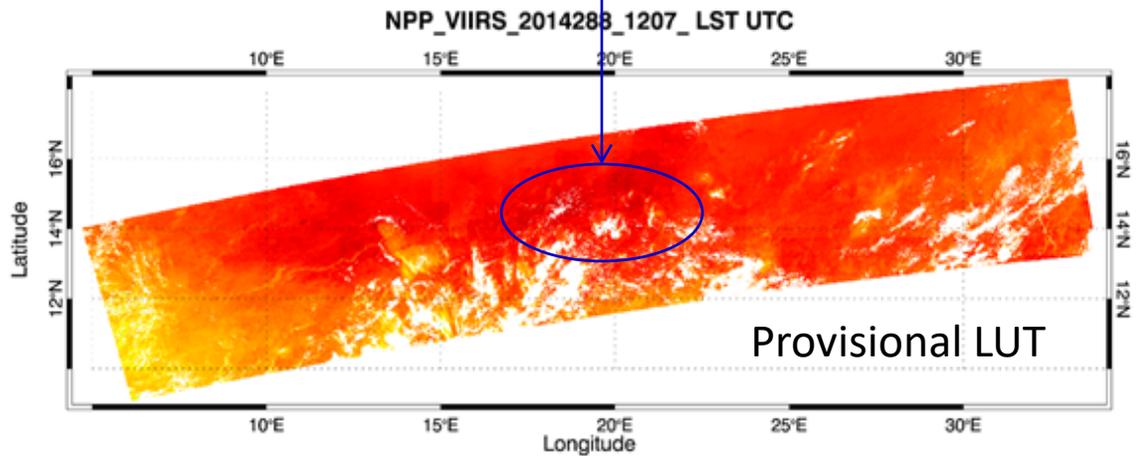
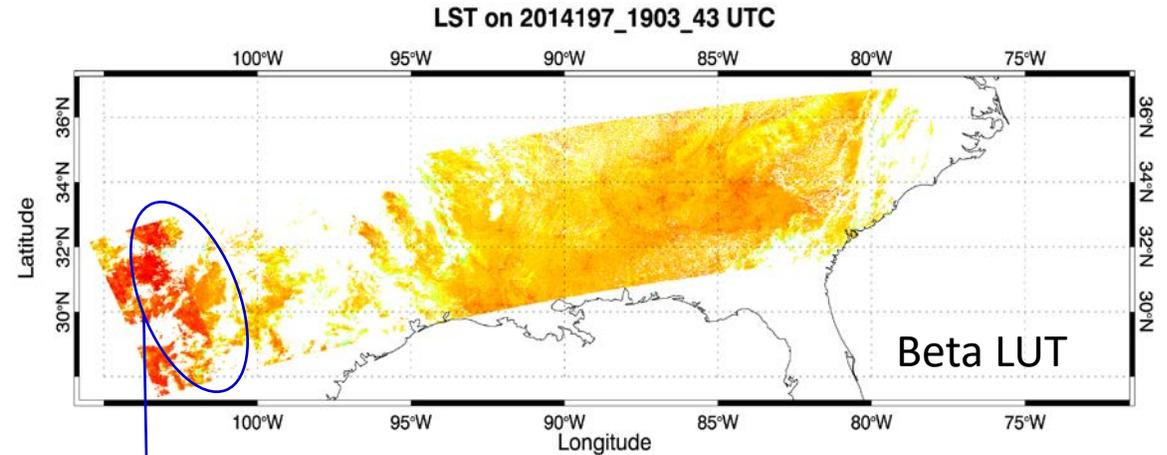
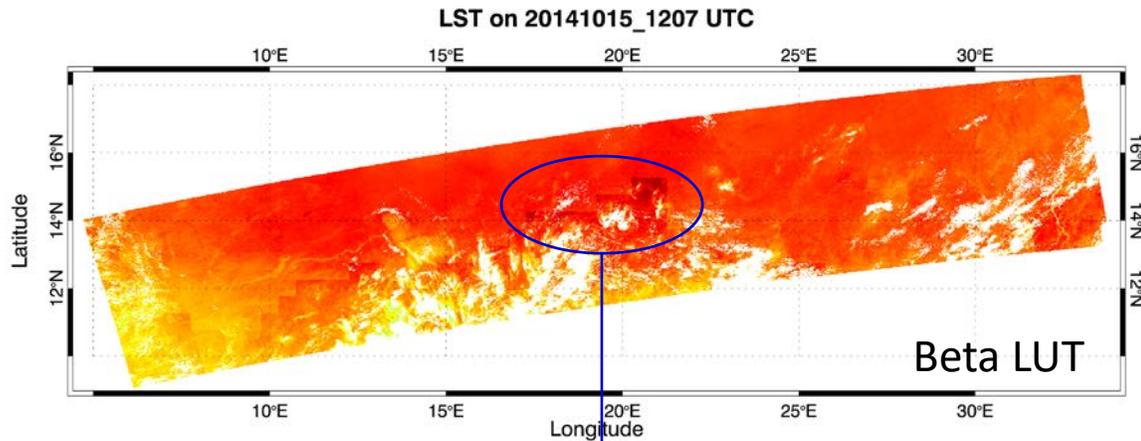
VIIRS
snow
cover
EDR



- ✓ Significant Snow Cover difference between NWP and VIIRS
- ✓ The accuracy of the quality flag of surface cover is improved.

* More details are presented in the VIIRS snow cover EDR compared to the NWP snow cover data.

Issue III: LST LUT Discontinuity improved



Output update : geometric data added

HDFView 2.9.6
 File Window Tool

Recent Files: /data/data258/eric.buzan/j1_LSA/online_output/20180621/JRR-LST_v1r0_j01_s201806211851370_e201806211853015_c201806221604080.nc **NetCDF format**

Table: TableView - VLST - / / - /data/data258/eric.buzan/j1_LSA/online_output/20180621/JRR-LST_v1r0_j01_s201806211851370_e201806211853015_c201806221604080.nc

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415	10837	10818	10912	10979	11132	10928	10356	9770	10151	10273	10371	11228	11296	11259	11249	11214	11281	11315	11315
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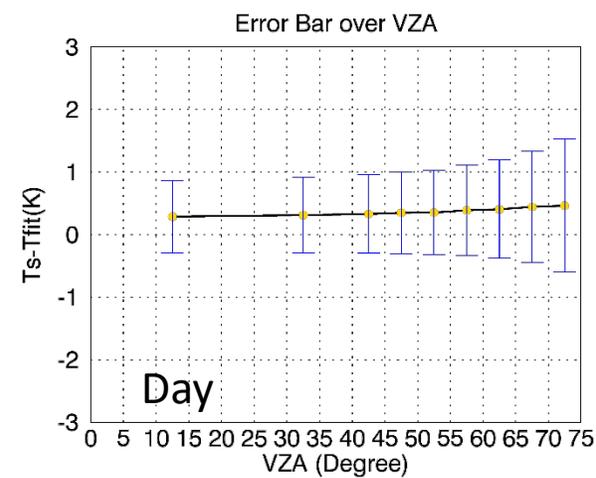
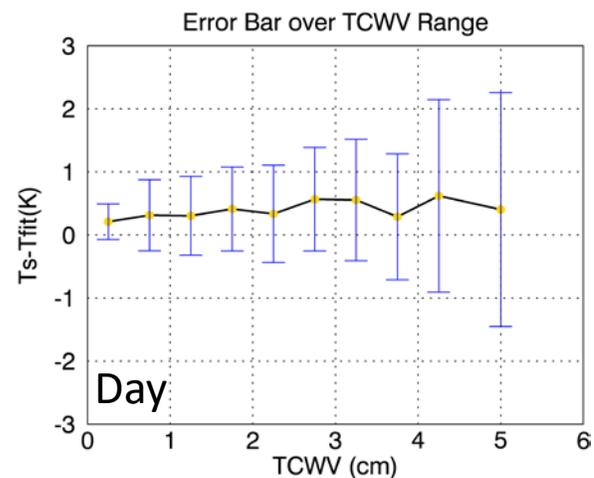
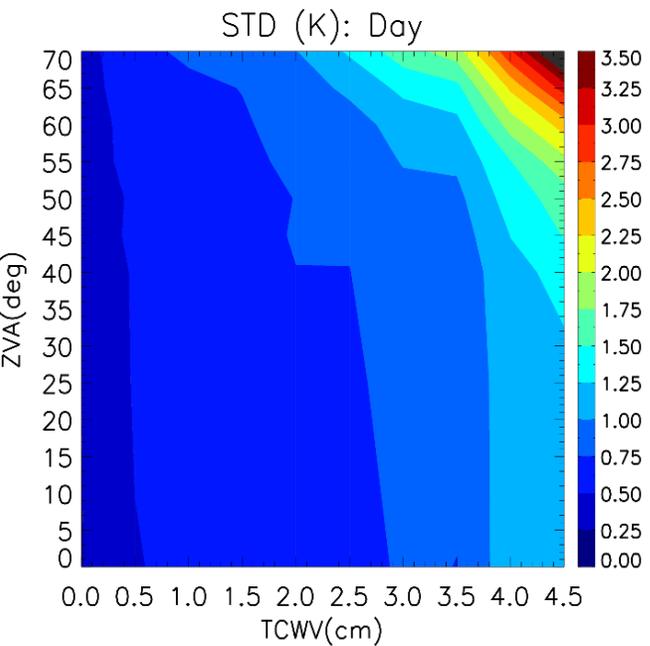
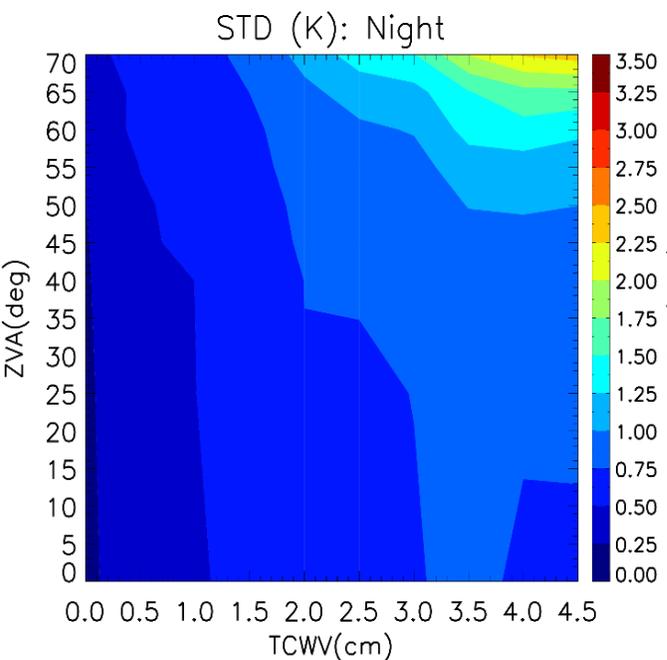
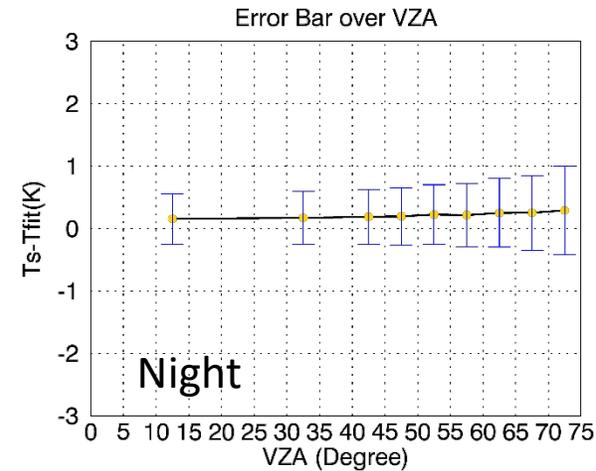
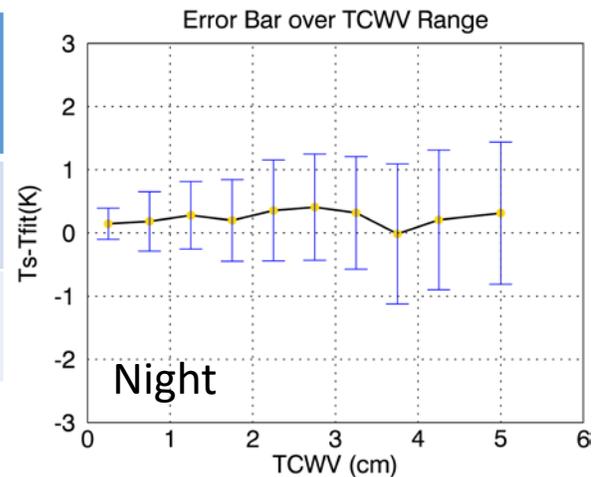
- Metadata
- Viewing Geometry
- LST Value
- LST Quality Flag
- Emissivity value

Evaluation method

- Visual Analysis and Beta Correction
- Theoretical evaluation of the NOAA 20 LST LUT
- Validation against the ground LST data
- Cross comparison with other satellite LST products

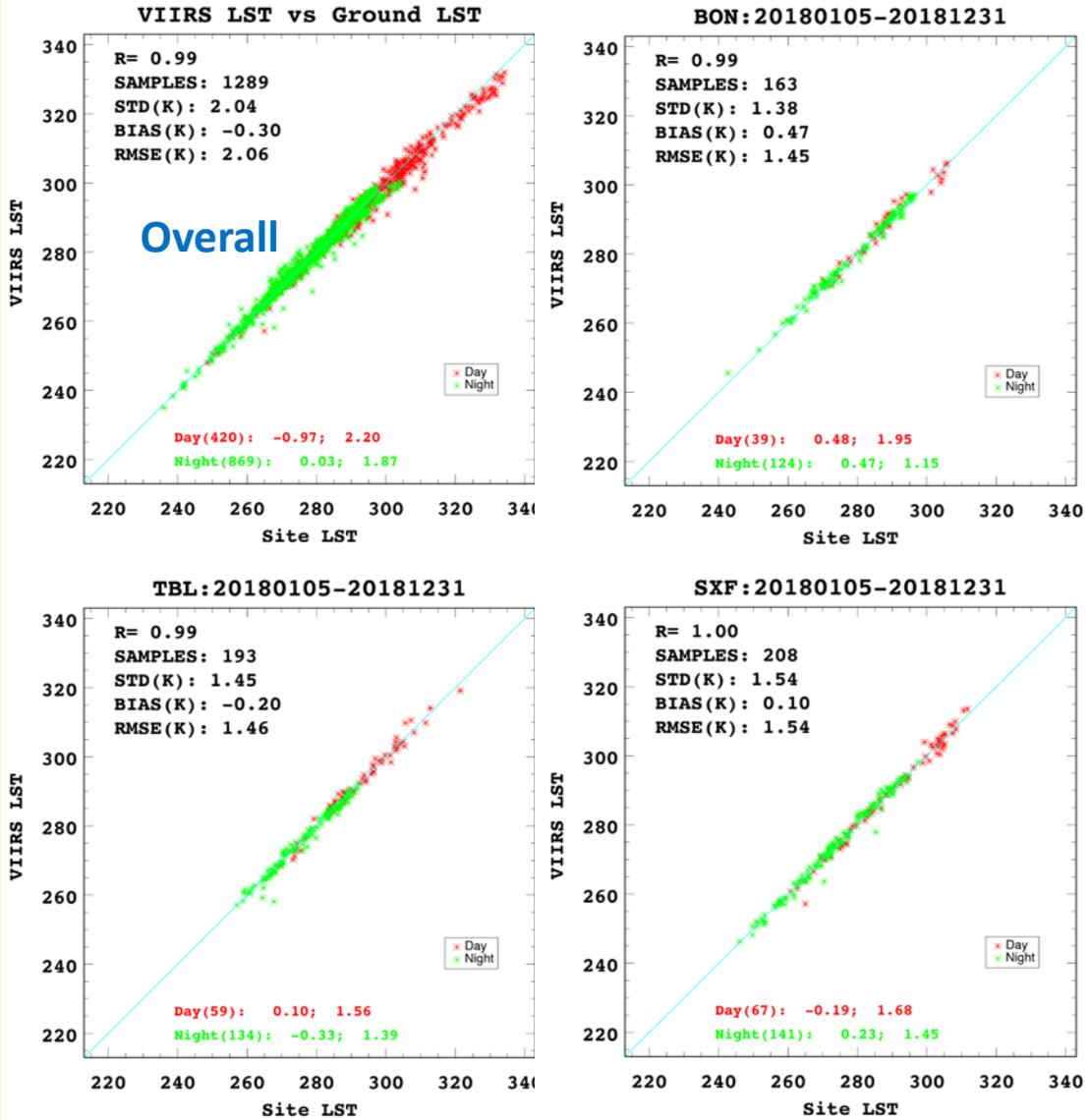
NOAA-20 VIIRS LST LUT Theoretical Evaluation

Day/night	Bias	STD	samples	Profiles Amount
Night	0.19	0.48	21921900	2044
Day	0.34	0.69	19562400	1824



- Visual Analysis and Beta Correction
- Theoretical evaluation of the NOAA 20 LST LUT
- Validation against the ground LST data
 - *SURFRAD*
 - BSRN
- Cross comparison with other satellite LST products

NOAA 20 VIIRS LST against ground data



Site No.	Site Location	Lat(N)/Lon(W)	Surface Type(IGBP)
1	Bondville, IL	40.05/88.37	Crop Land
2	Boulder, CO	40.13/105.24	Crop Land
3	Desert Rock, NV	36.63/116.02	Open Shrub Land
4	Fort Peck, MT	48.31/105.10	Grass Land
5	Goodwin Creek, MS	34.25/89.87	Grass Land
6	Pennsylvania State University, PA	40.72/77.93	Crop Land
7	Sioux Falls, SD	43.73/96.62	Crop Land

Site Name	count	bias	std	Count (day)	Bias (day)	Std (day)	Count (night)	Bias (night)	Std (night)
BON	163	0.47	1.38	39	0.48	1.95	124	0.47	1.15
TBL	193	-0.20	1.45	59	0.10	1.56	134	-0.33	1.39
DRA	245	-2.08	1.55	103	-2.06	1.89	142	-2.09	1.25
FPK	200	-0.41	1.47	69	-0.72	1.75	131	-0.24	1.28
GWN	200	0.52	3.01	66	-2.75	2.30	134	2.14	1.73
PSU	80	0.55	1.71	17	1.30	1.46	63	0.35	1.73
SXF	208	0.10	1.54	67	-0.19	1.68	141	0.23	1.45

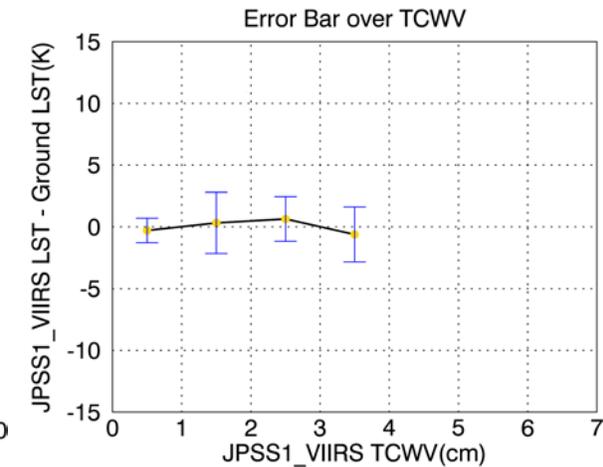
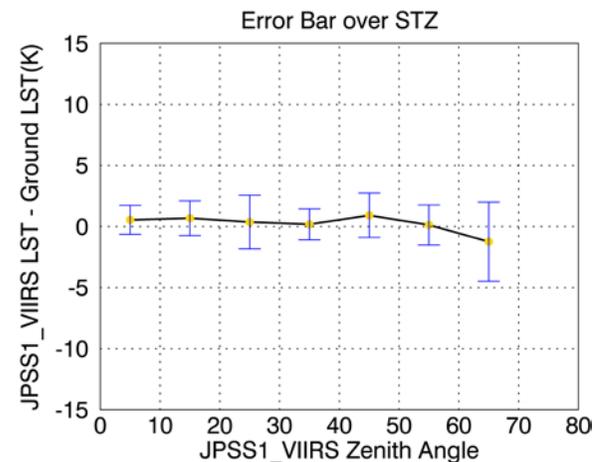
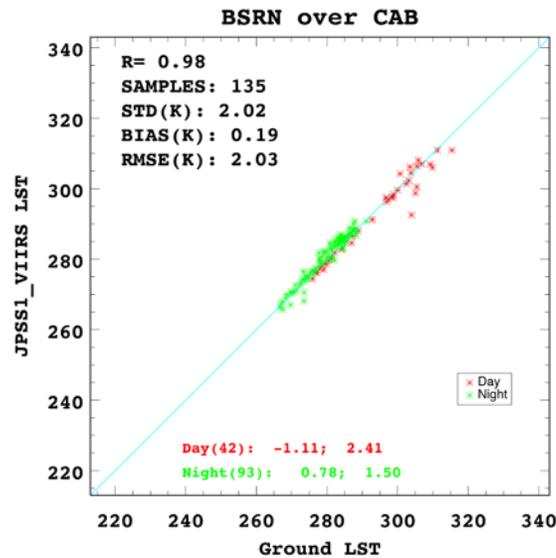
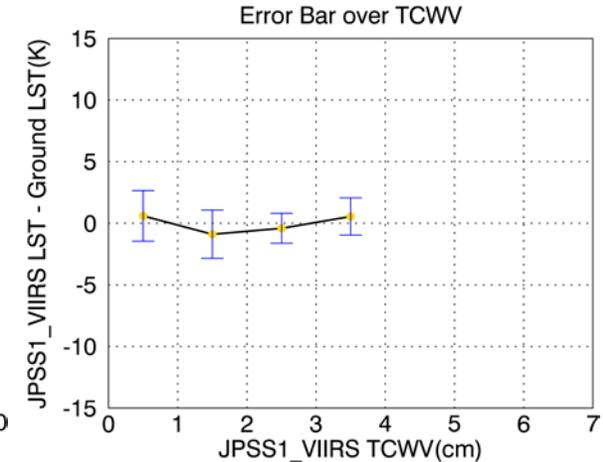
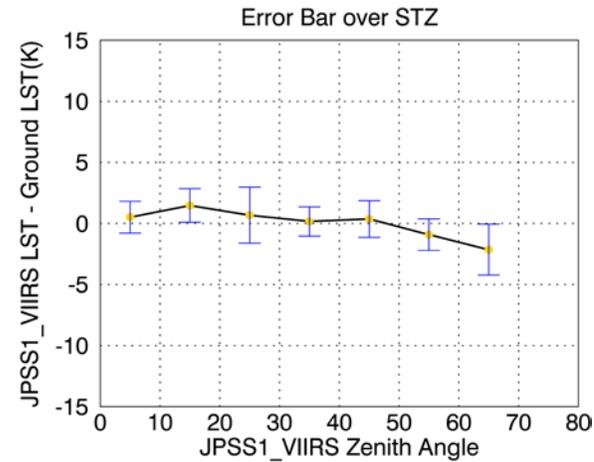
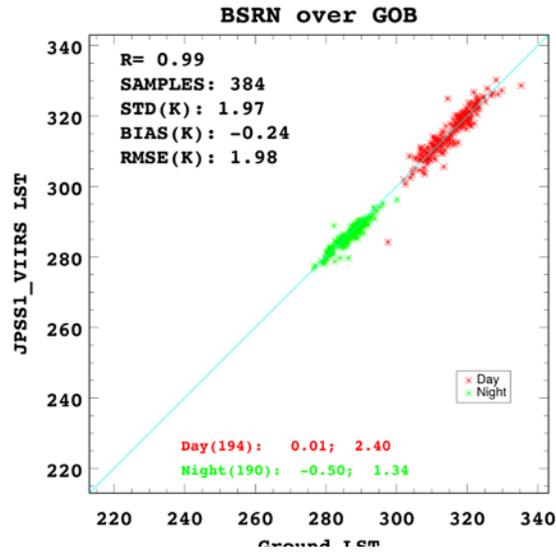
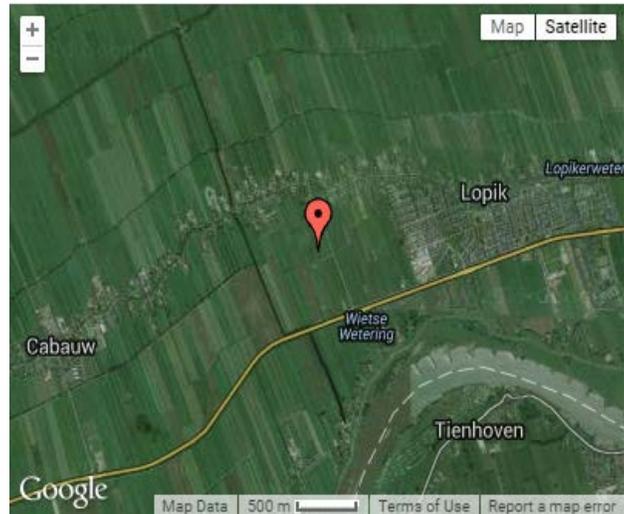
- Visual Analysis and Beta Correction
- Theoretical evaluation of the NOAA 20 LST LUT
- Validation against the ground LST data
 - SURFRAD
 - *BSRN*
- Cross comparison with other satellite LST products

NOAA 20 VIIRS LST against ground data

BSRN



Temporal Range: 20180105-20181130

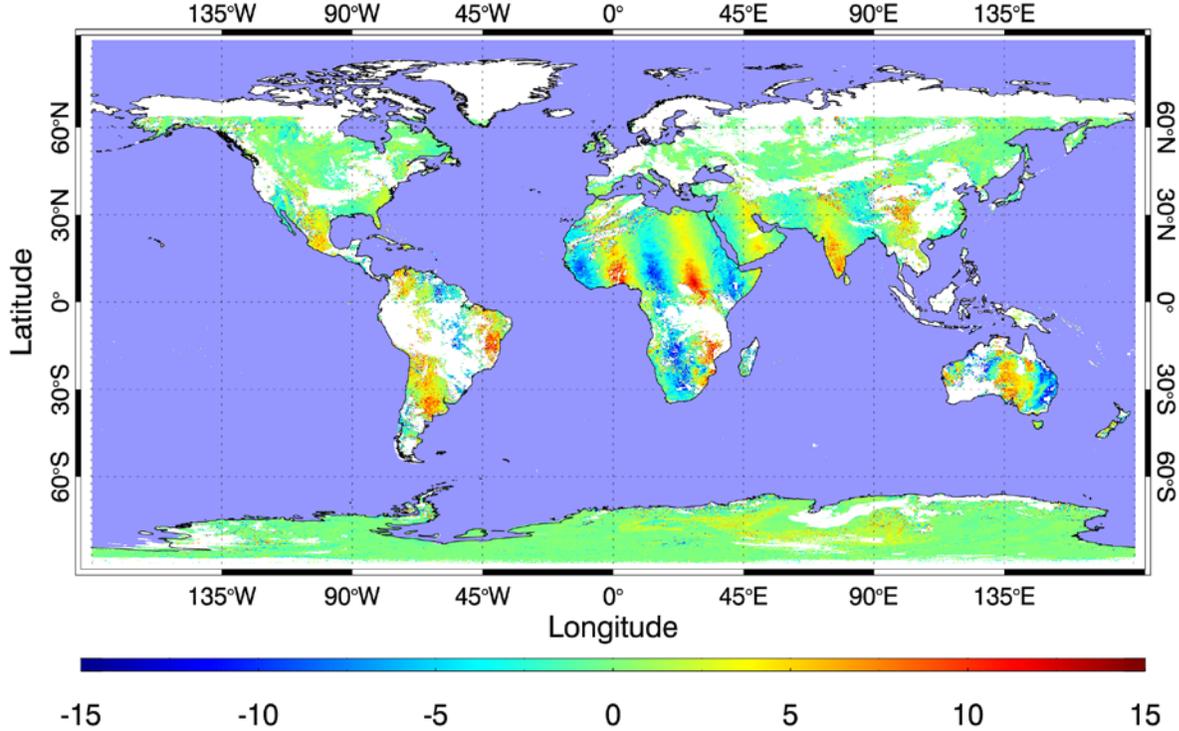


- Visual Analysis and Beta Correction
- Theoretical evaluation of the NOAA 20 LST LUT
- Validation against the ground LST data
- Cross comparison with other satellite LST products
 - *Enterprise SNPP LST*
 - MODIS AQUA LST
 - GOES 16 LST

NOAA 20 VIIRS LST vs SNPP LST

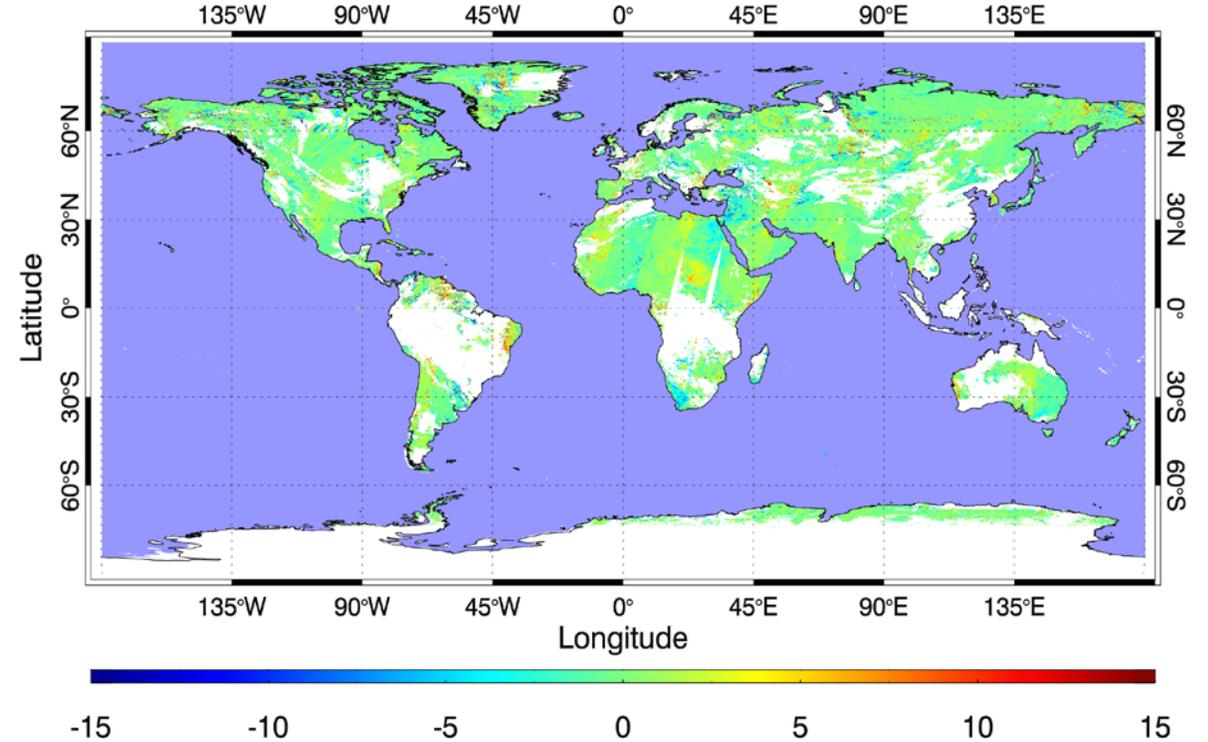
LST Difference

NOAA20-SNPP 20180115 Day UTC



LST Difference

NOAA20-SNPP 20180115 Night UTC



Condition

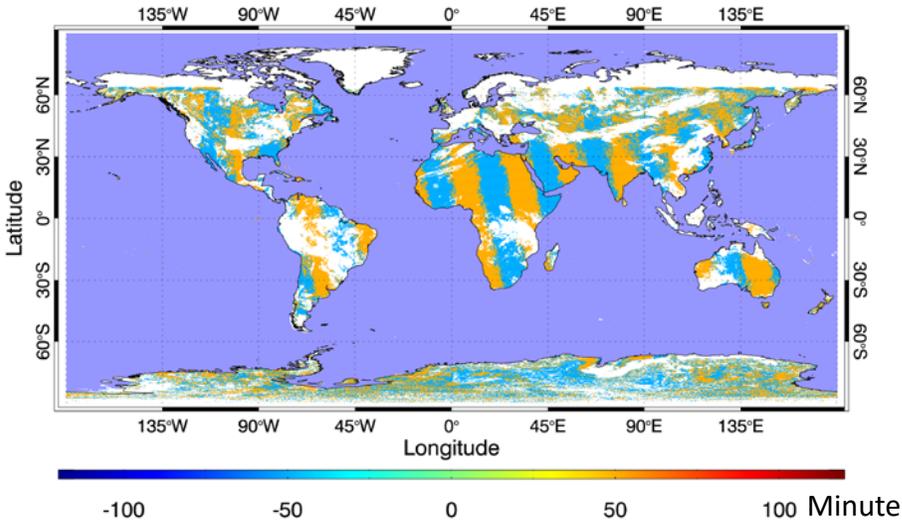
- NOAA20 and SNPP LST were generated using the latest LUT
- Two days in each month of 2018 were selected for comparison
- LST difference for day (Left) and night (Right) were presented

Results

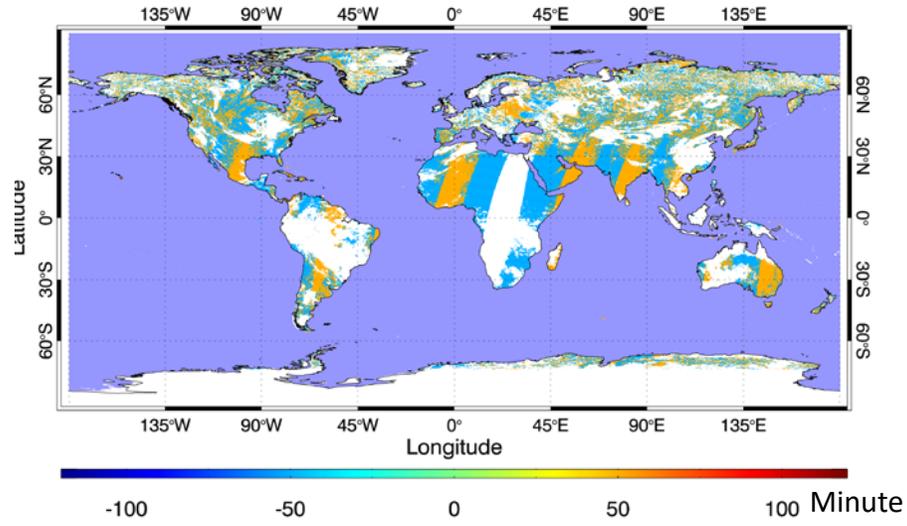
- Daytime LST diff. presents an orbit-related pattern particularly at mid and low latitude
- The LST diff. is small at high latitude area for both daytime and nighttime

NOAA 20 VIIRS LST vs SNPP LST

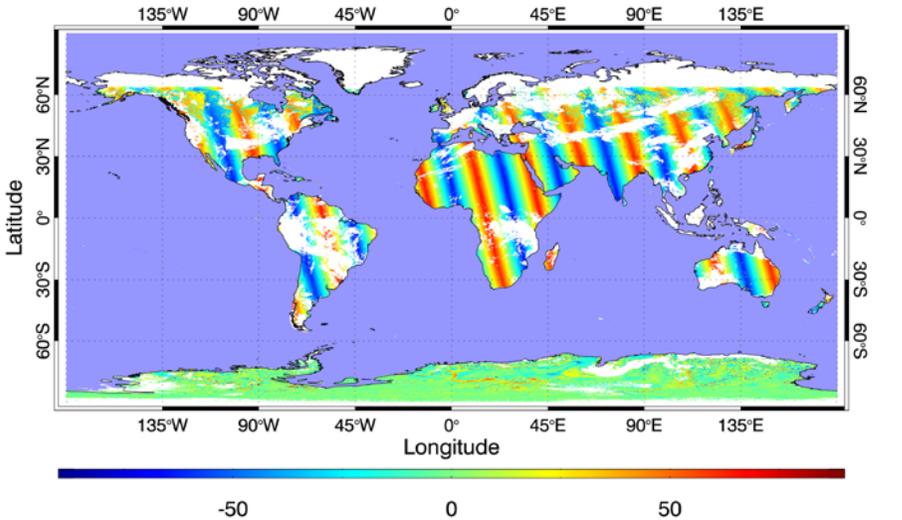
Viewtime Difference
NOAA20-SNPP 20180115 Day UTC



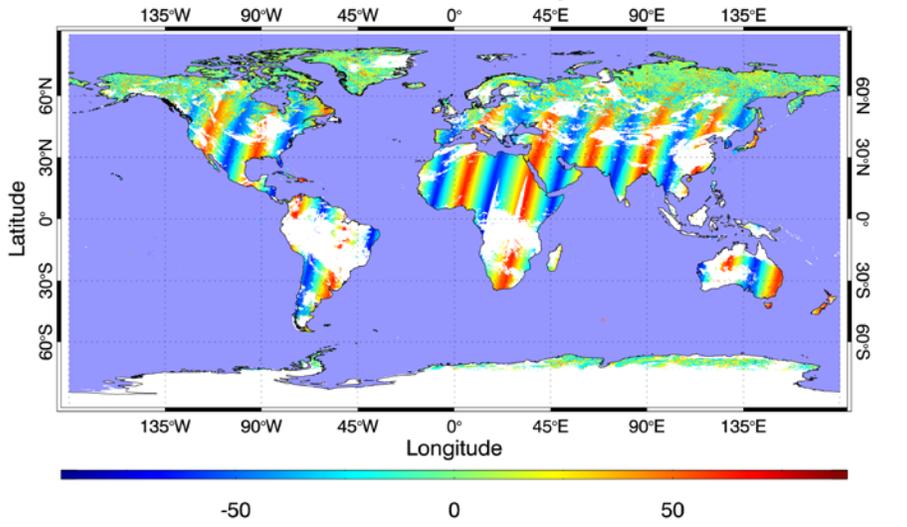
Viewtime Difference
NOAA20-SNPP 20180115 Night UTC



STZ Difference
NOAA20-SNPP 20180115 Day UTC

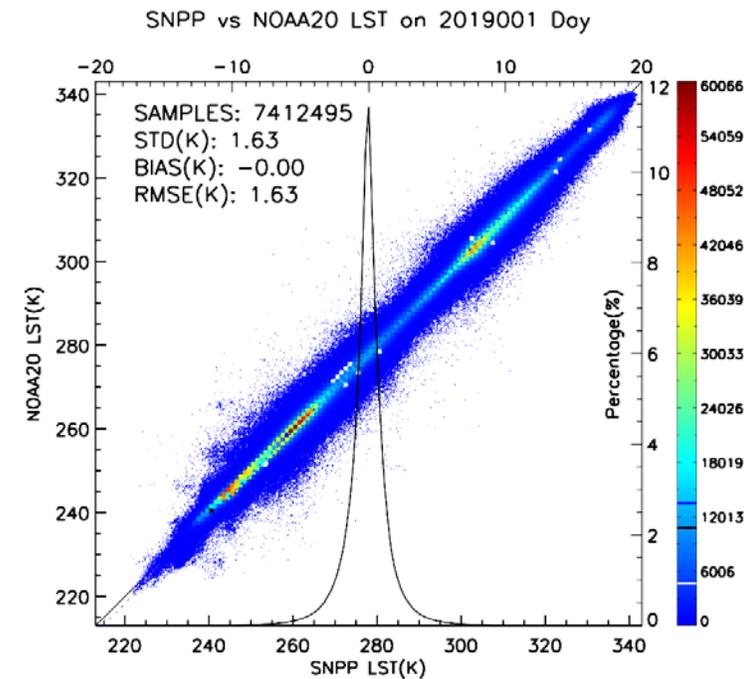
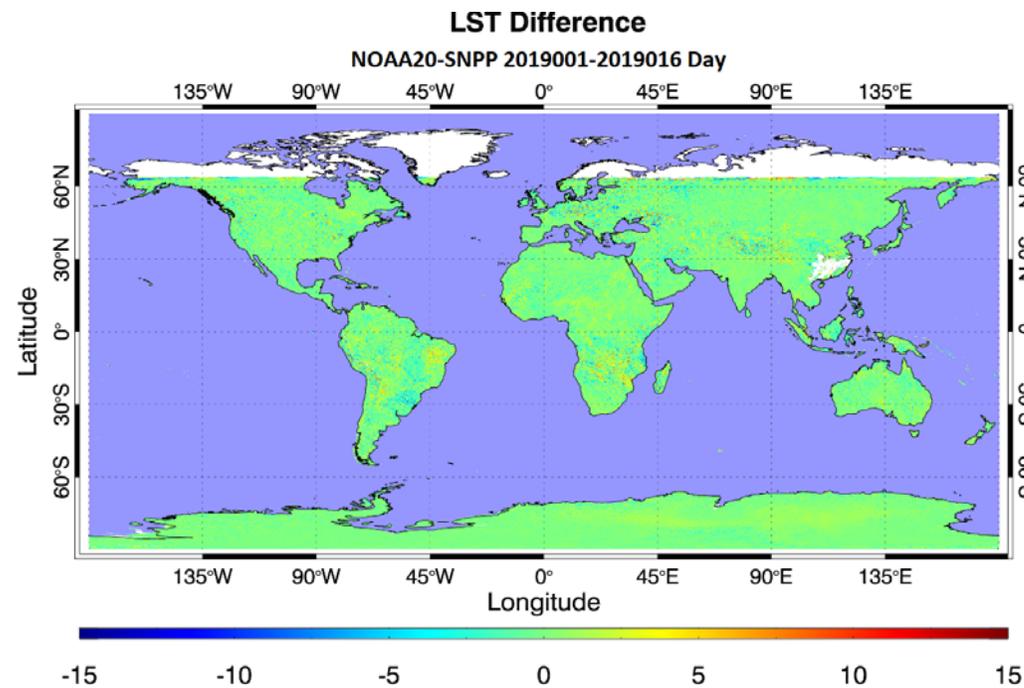
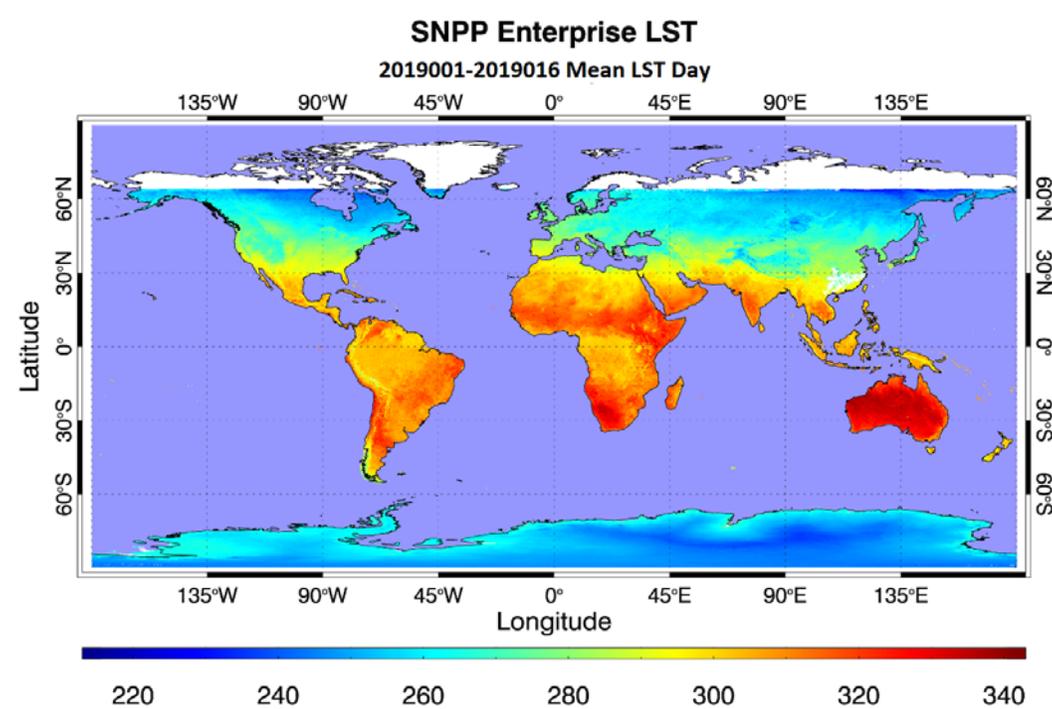
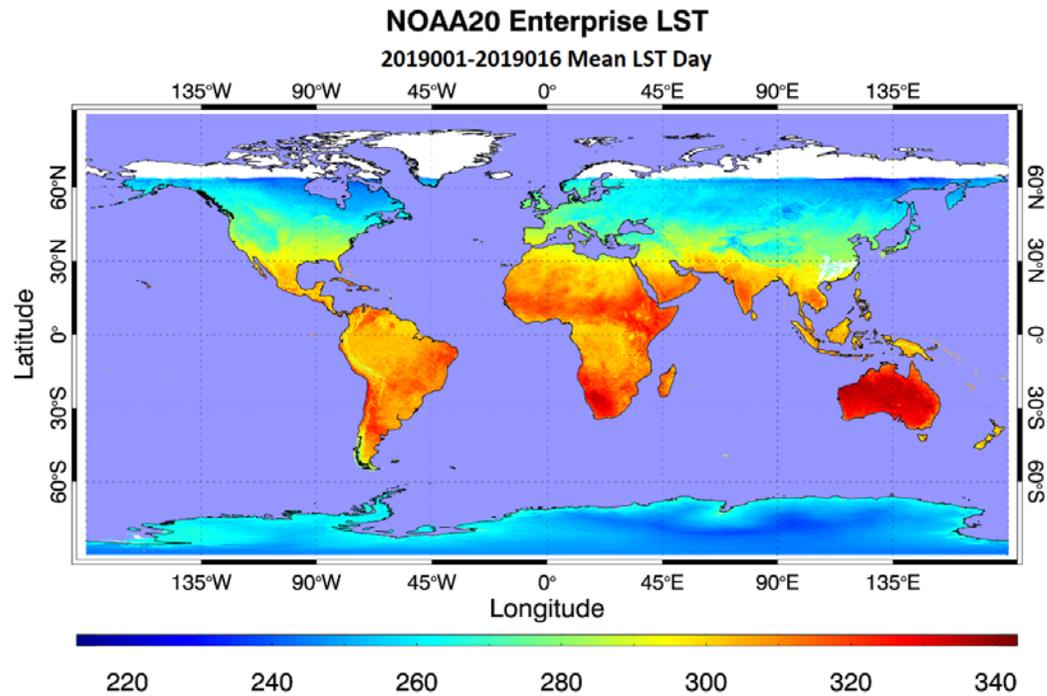


STZ Difference
NOAA20-SNPP 20180115 Night UTC

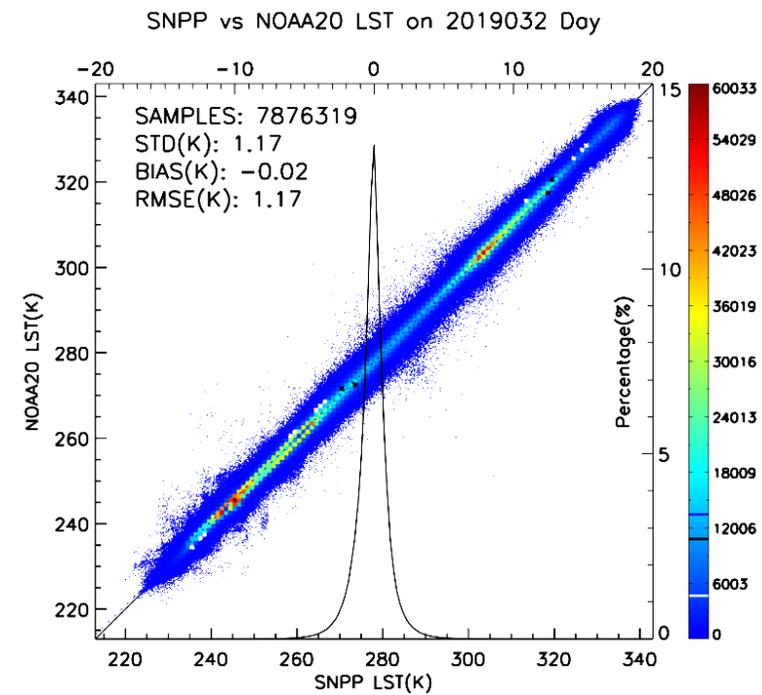
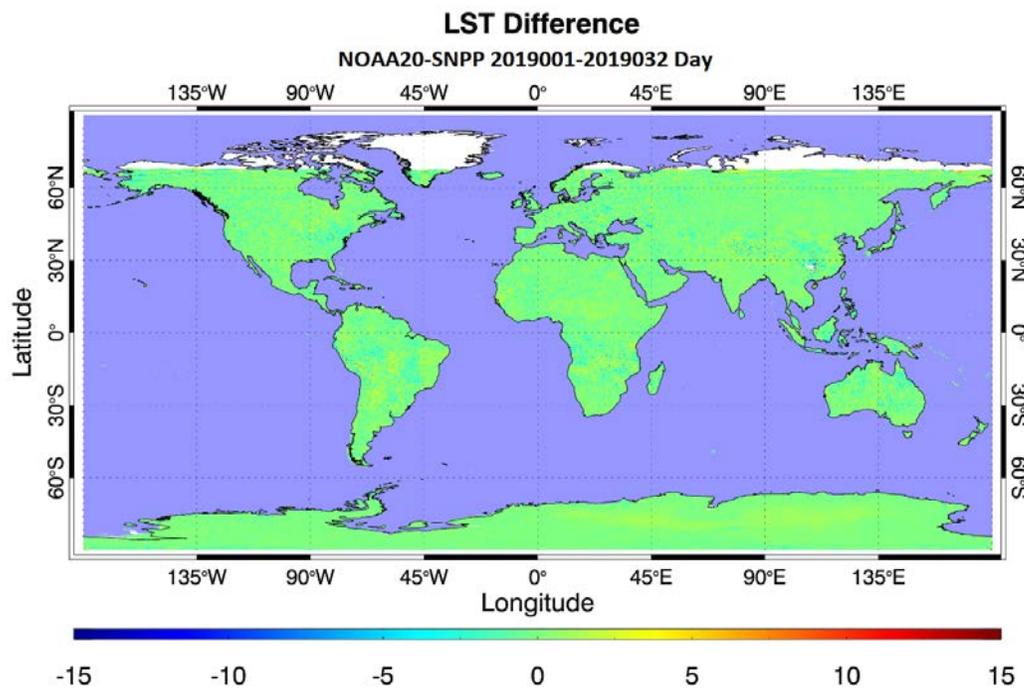
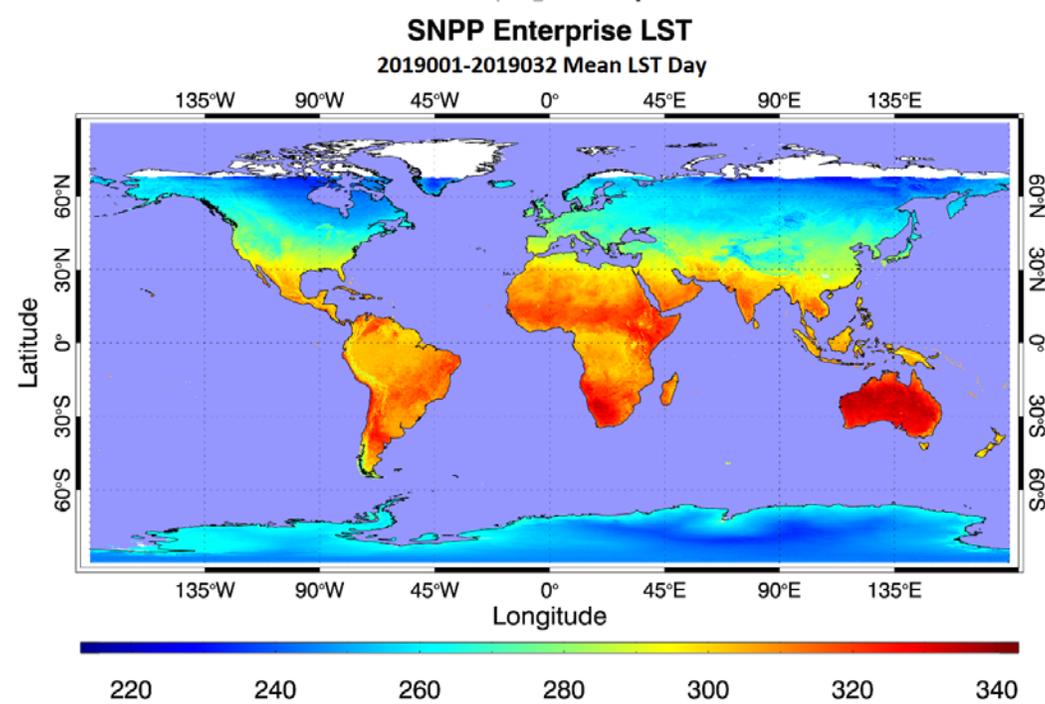
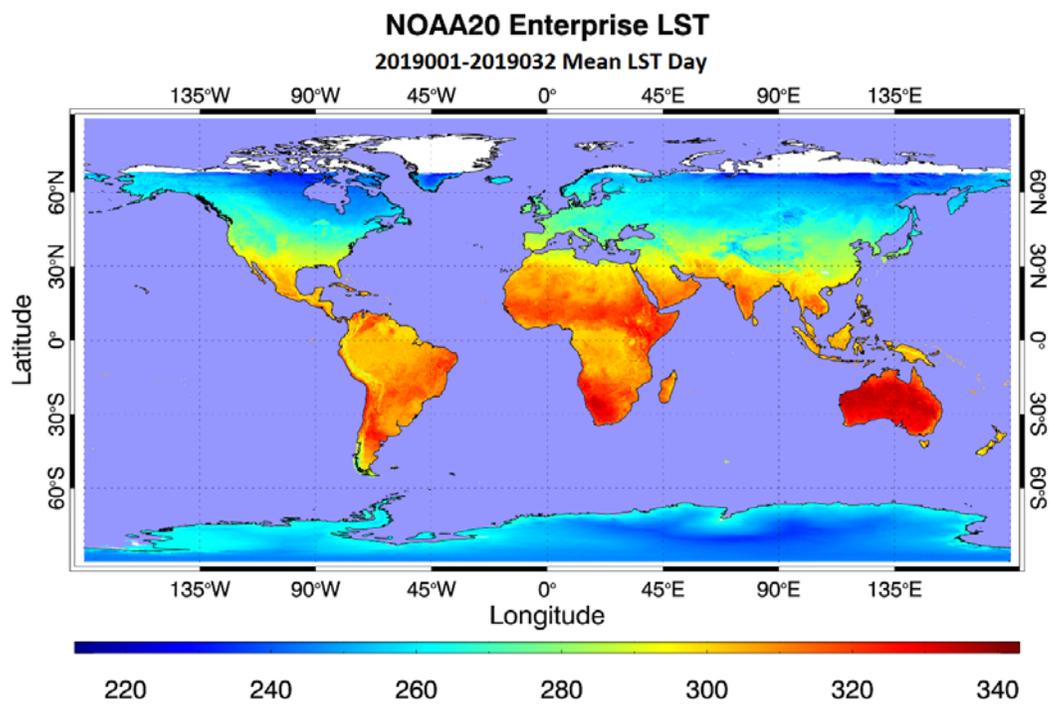


- View time difference presents similar stripe pattern to the LST difference.
- View time difference is generally 50 minutes at low and mid latitude. The time difference is larger at high latitude area
- View angle difference also presents a stripe pattern

16 Day Mean LST: Day



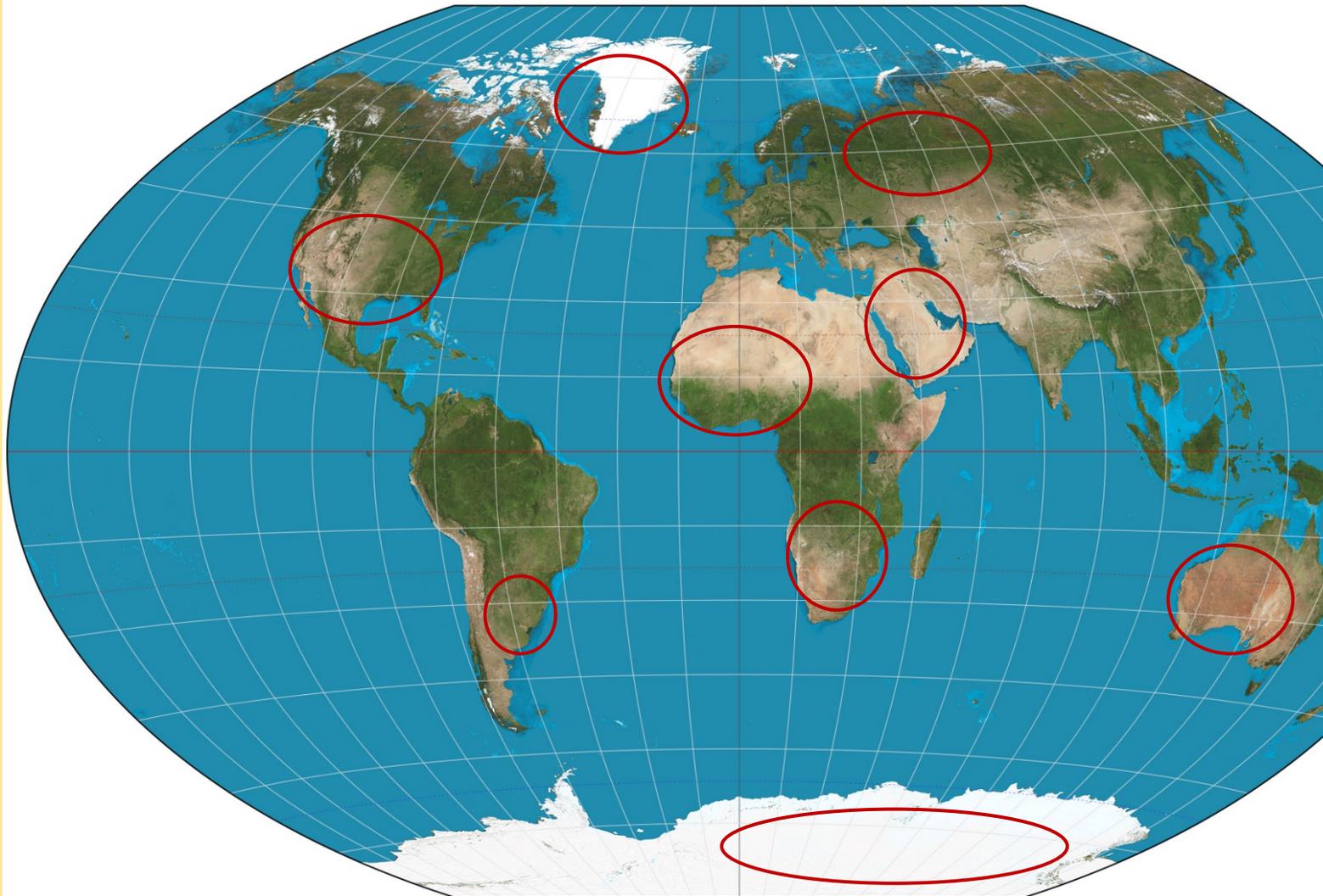
32 Day Mean LST: Day



- Visual Analysis and Beta Correction
- Theoretical evaluation of the NOAA 20 LST LUT
- Validation against the ground LST data
- Cross comparison with other satellite LST products
 - Enterprise SNPP LST
 - *MODIS AQUA LST*
 - GOES 16 LST

NOAA 20 VIIRS LST vs AQUA MODIS LST

N20 VIIRS vs MODIS AQUA



- **Spatial coverage:** as shown in the circled area
- **Temporal coverage :** every month
- **Day/night:** both included
- **MODIS Product selection:** MYD21, latest MODIS LST product in version 6 was selected for the cross comparison.

The regions covered by the cross comparison

NOAA 20 VIIRS LST against AQUA MODIS LST

SNO Date 2-18	VIIRS	MODIS	Region	Samples	Bias (K)	STD (K)	RMSE (K)
20180211 (042)	02:00-02:04	02:05	Africa	115688	-0.29	1.59	1.61
	04:25-04:32	04:30	Australia	370326	-2.17	2.49	3.30
20180304(063)	08:45-08:50	08:55	US	644994	0.53	1.74	1.82
	20:05	19:55	US	74793	-0.49	2.11	2.16
20180320(079)	08:45-08:50	08:55	US	723437	0.58	1.76	1.85
	11:30-11:40	11:40	Africa	387709	-2.12	1.61	2.67
	15:50-15:55	15:50	Australia	30167	0.38	1.31	1.36
	18:05-18:10	18:00	South Africa	48921	-1.15	3.34	3.53
	20:00-20:10	19:55	US	133721	0.14	2.85	2.85
20180408(098)	0735-07:39	07:35	Greenland	44257	0.44	1.69	1.74
20180424(114)	07:35-07:39	07:35	Greenland	102200	0.01	1.22	1.22
20180512(132)	22:15-22:19	22:15	Mid-north Asia	245013	0.27	1.21	1.24
20180526(146)	0644-06:46	06:45	South Pole	116261	-0.14	0.77	0.78
20180611(162)	07:34-07:38	07:35	Greenland	215109	0.06	0.78	0.79
20180822(234)	09:44-09:51	09:40	Arabian Peninsula	60293	-1.91	3.45	3.94
20180824(236)	21:03-21:10	21:05	US	166280	-1.30	4.09	4.29
20180902(245)	00:04-00:12	00:05	North Africa	204908	-1.63	1.37	2.13
20180904(247)	12:10-12:20	12:15	South Africa	756012	-1.14	2.40	2.66
	17:13-17:21	17:10	South America	27405	-1.08	3.17	3.34
20180920(263)	09:34-09:41	09:40	US	574271	0.67	2.16	2.26
	12:21-12:31	12:25	North Africa	235305	-3.03	2.3	3.8
	20:54-21:00	20:45	US	151374	-0.97	3.91	4.02

NOAA 20 VIIRS LST against AQUA MODIS LST

SNO Date 2-18	VIIRS	MODIS	Region	Samples	Bias (K)	STD (K)	RMSE (K)
20181017(290)	05:19-05:26	05:20	Australia	209549	-1.40	2.54	2.90
	01:08-01:13	01:15	North Africa	321086	-1.57	1.78	2.37
	09:24-09:30	09:20	US	135948	0.54	1.36	1.47
20181107(311)	12:10-12:20	12:15	South Africa	284200	-0.63	2.44	2.52
	12:20-12:28	12:25	North Africa	306504	-2.61	2.40	3.54
	16:37-16:42	16:35	Australia	128961	-0.09	1.11	1.11
	20:55-21:01	20::45	US	136666	-0.54	2.96	3.01
20181118(322)	09:24-09:30	09:30	US	13237	0.42	1.99	2.03
	10:34-10:40	10:30	West Asia and North Africa	118871	-1.51	2.4	2.84
20181121(325)	00:08-00:13	00:05	North Africa	93173	0.05	1.86	1.86
20181129(333)	00:58-01:L05	00:55	North Africa	147532	0.14	1.48	1.48
20181017(290)	05:55-05:59	05:55	Greenland	74336	0.26	1.16	1.19
20181014(287)	14:27-14:31	14:25	South Pole	955	-0.77	0.76	1.08
20181110(314)	05:55-05:59	05:55	South Pole	29561	-0.57	1.60	1.70
20181126(330)	06:45-06:49	06:45	Greenland	30959	0.26	2.07	2.09

Matchup Criteria:

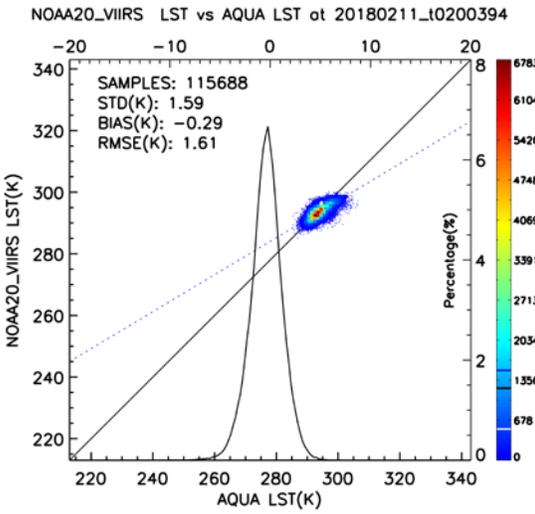
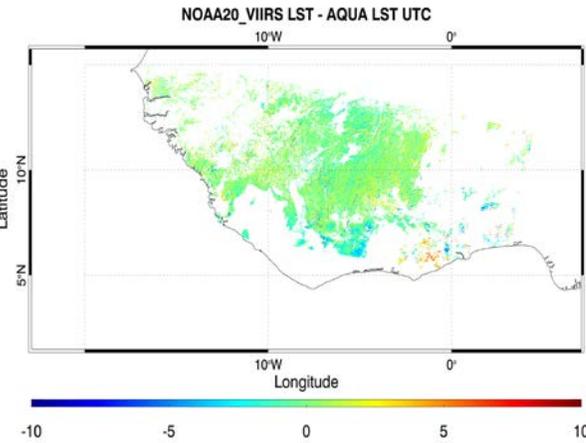
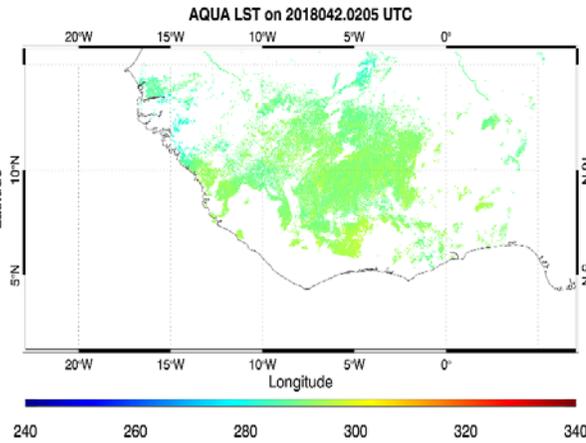
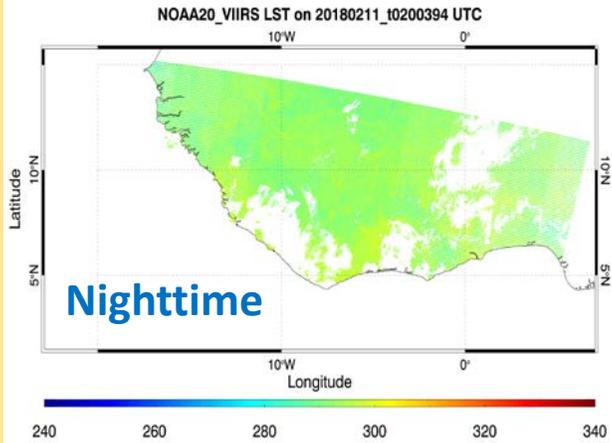
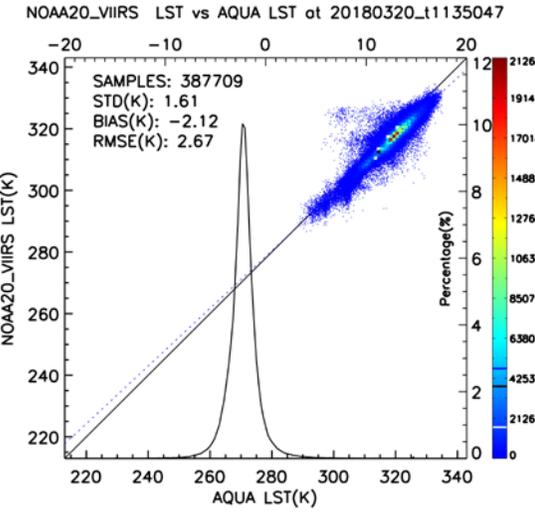
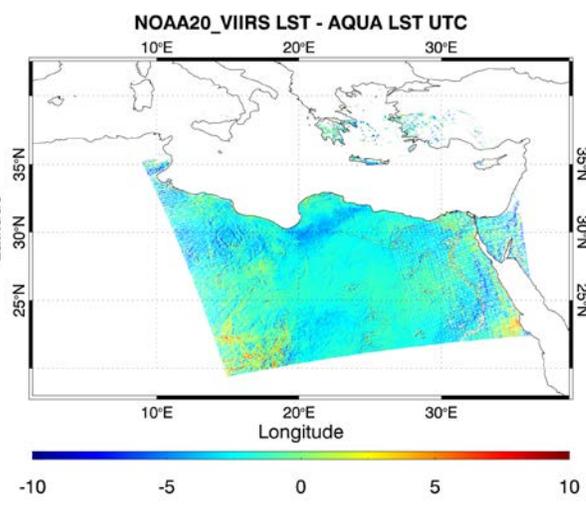
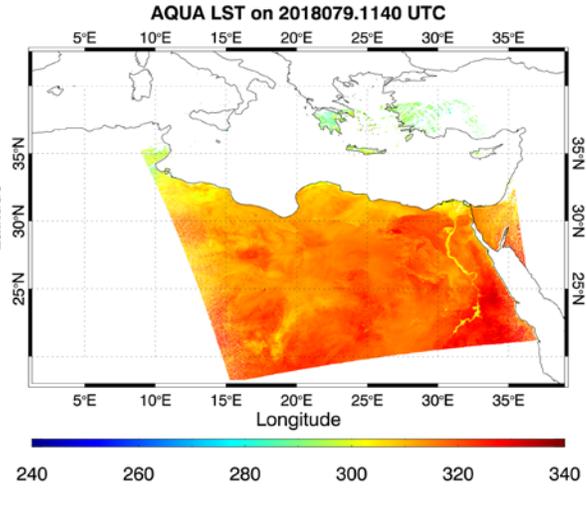
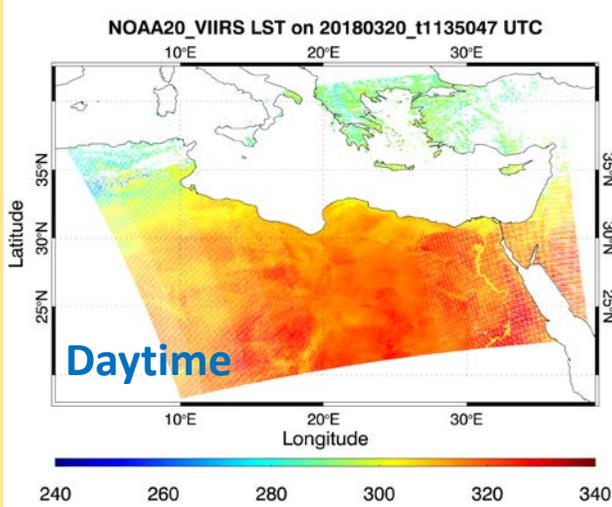
- The temporal difference is mostly within 10 minutes
- The spatially closest pixel
- The angle difference is within 10 degree
- Both are cloud clear

Limitation:

- The comparison is at regional scale not global scale due to SNO limitations. It represents the LST difference over **Africa, Australia, US, mid-north Asia, South America and Greenland** and South pole area.

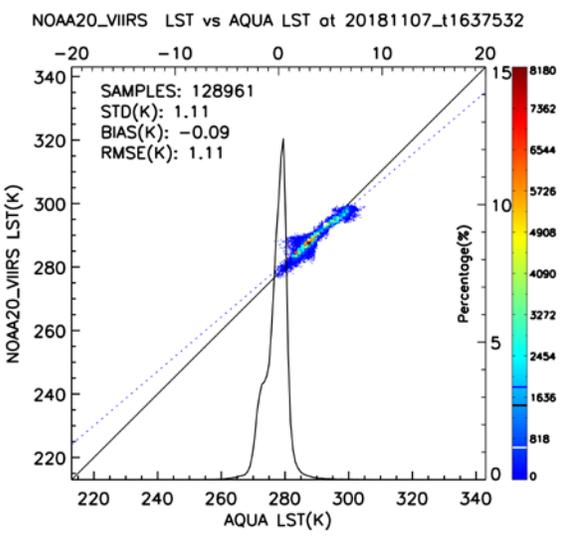
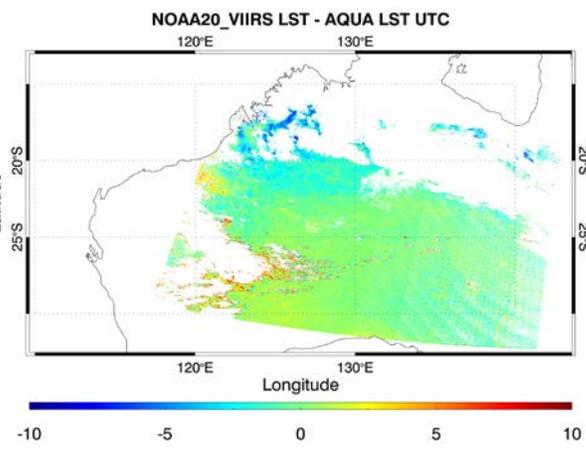
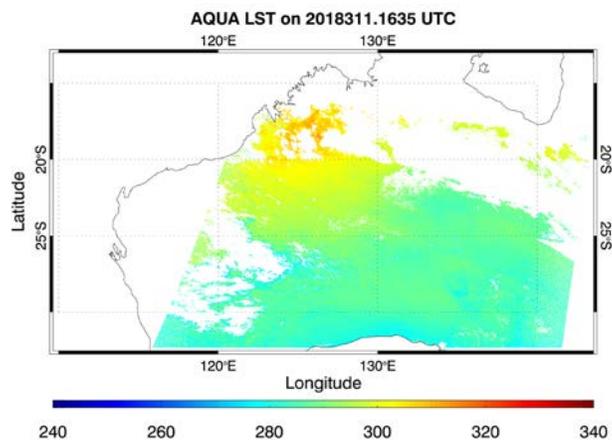
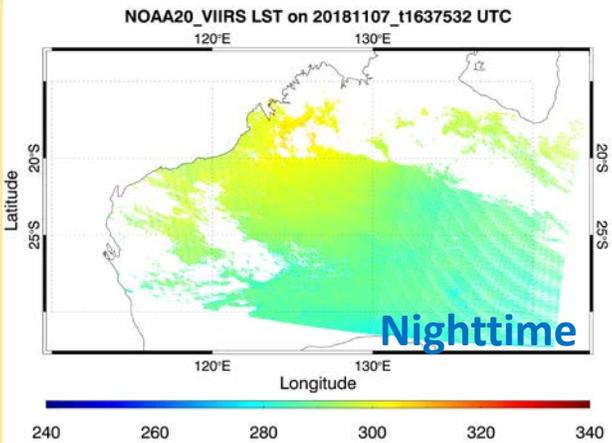
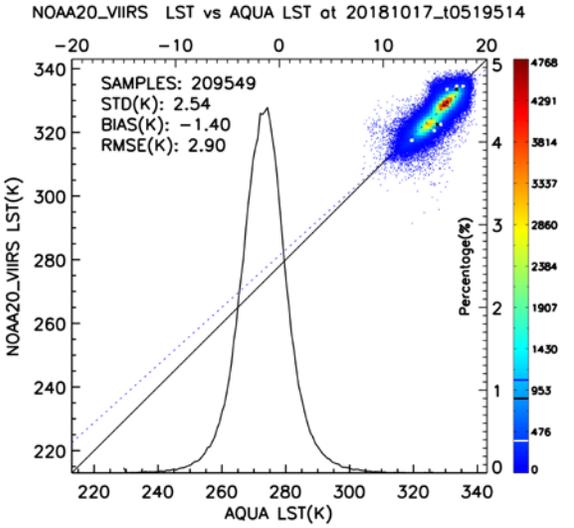
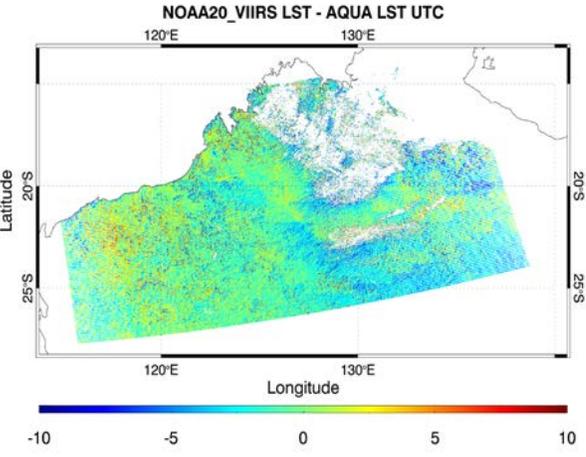
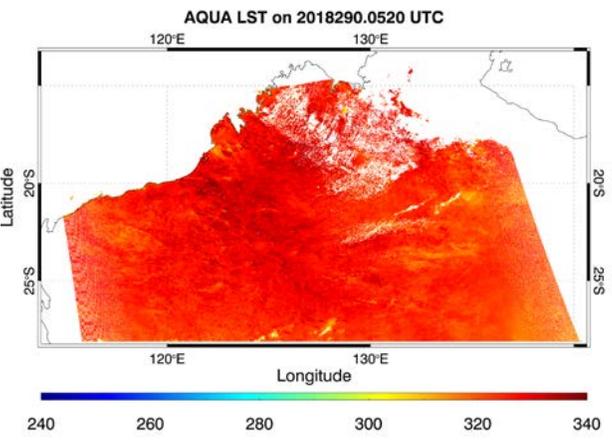
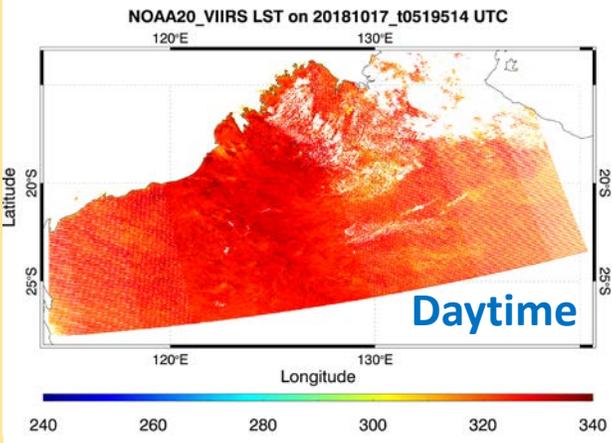
NOAA 20 VIIRS LST against AQUA MODIS LST

North Africa



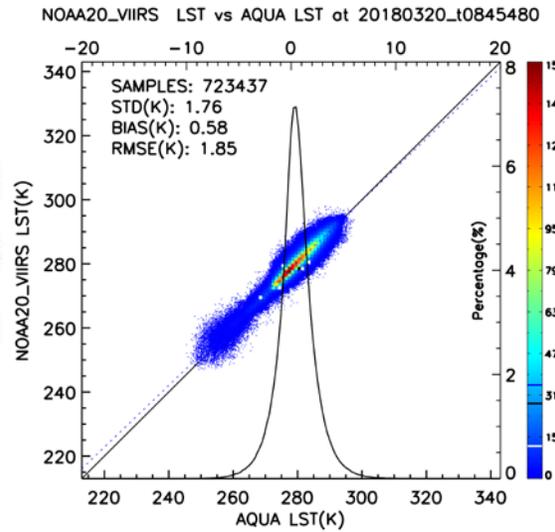
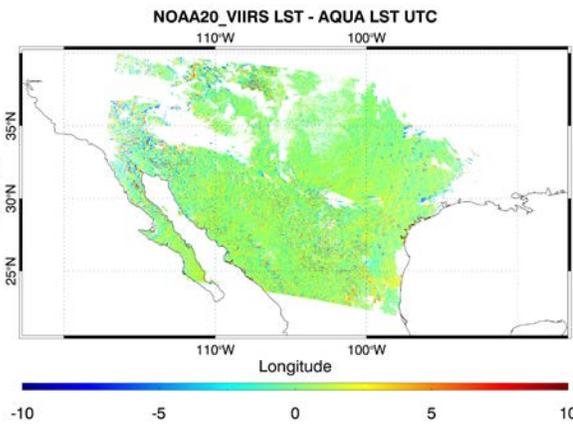
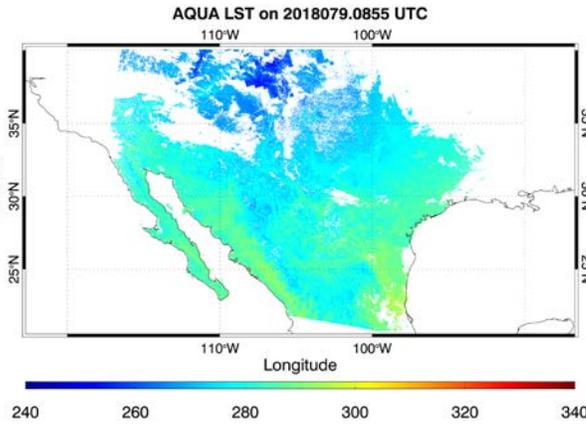
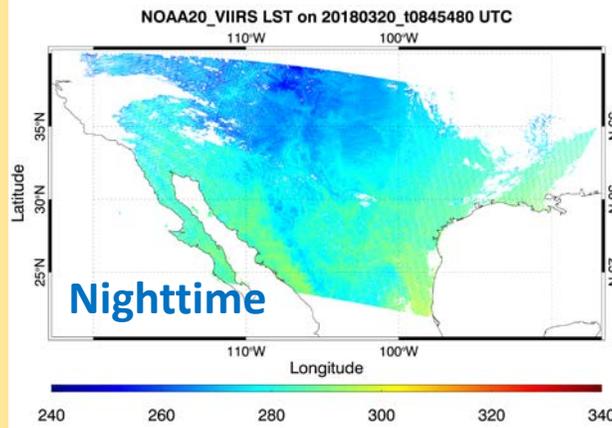
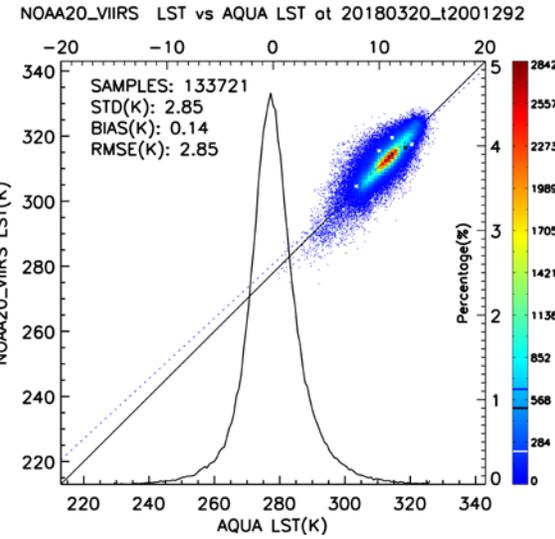
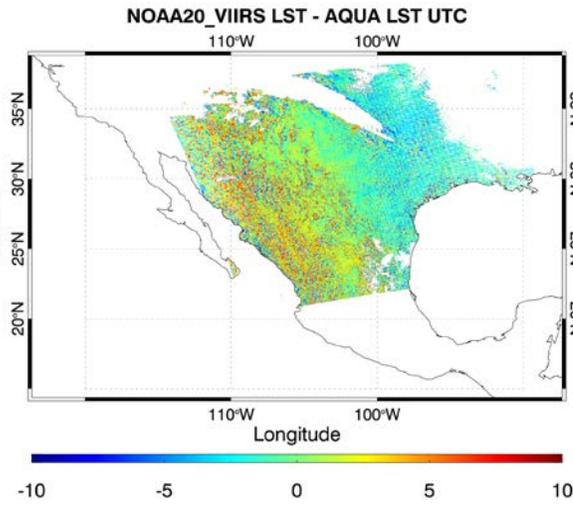
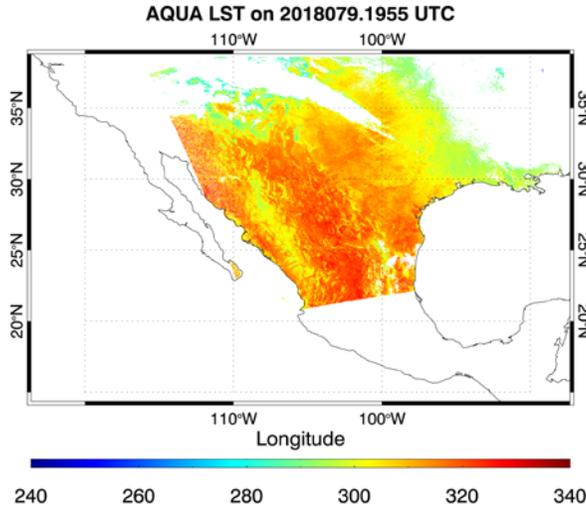
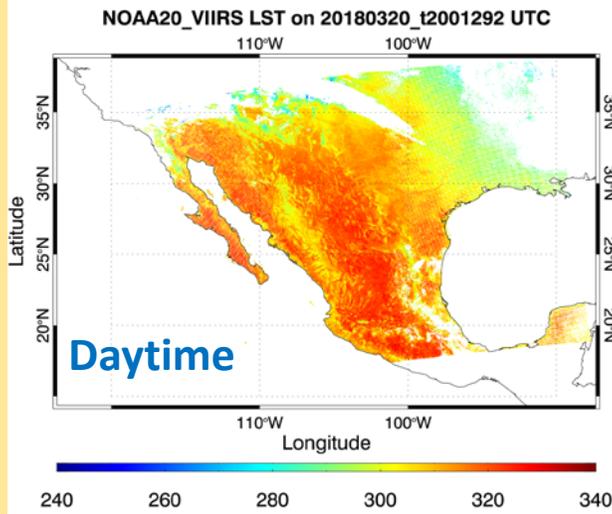
NOAA 20 VIIRS LST against AQUA MODIS LST

Australia



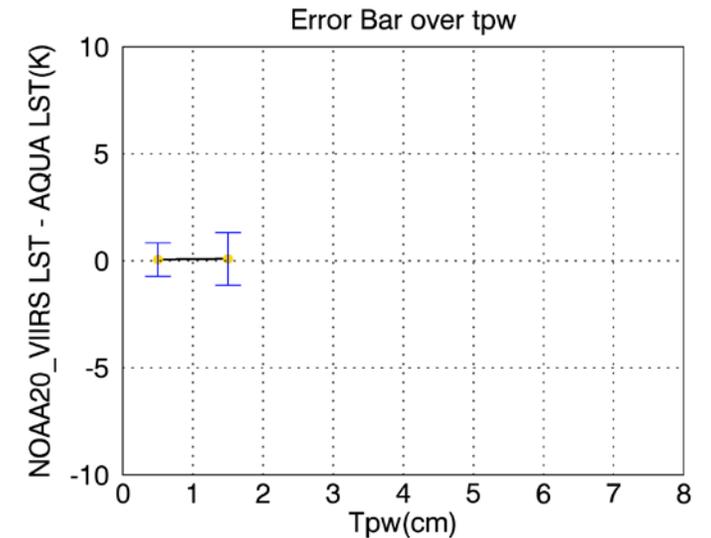
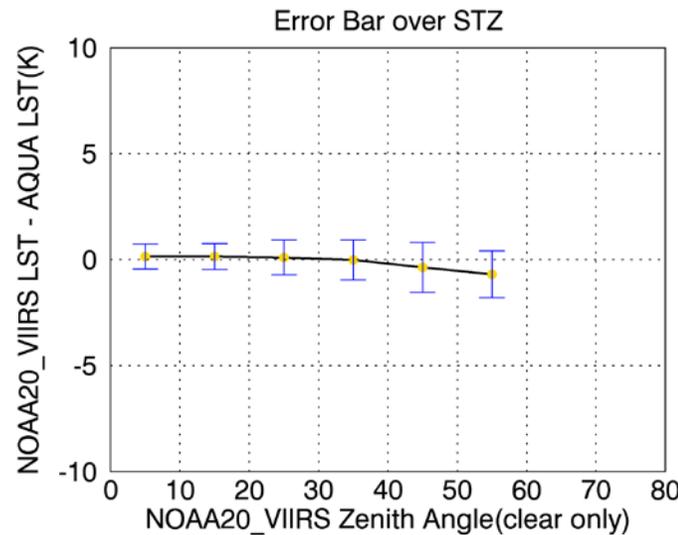
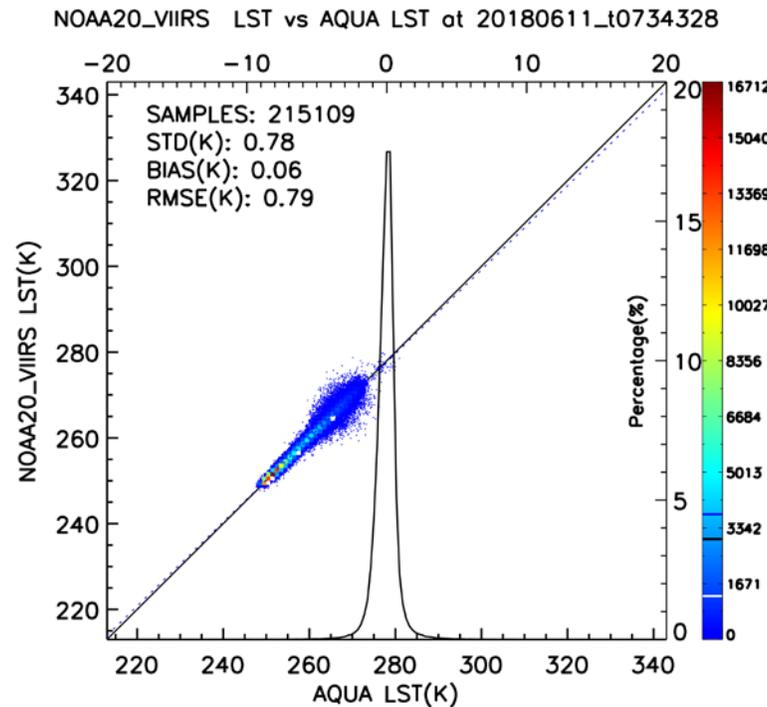
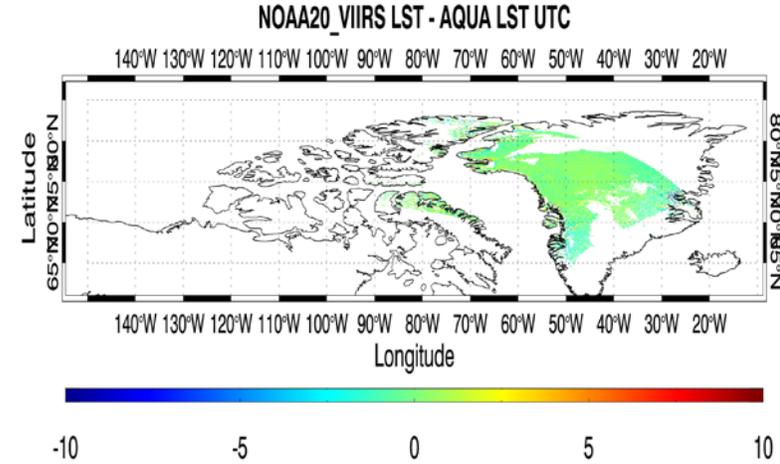
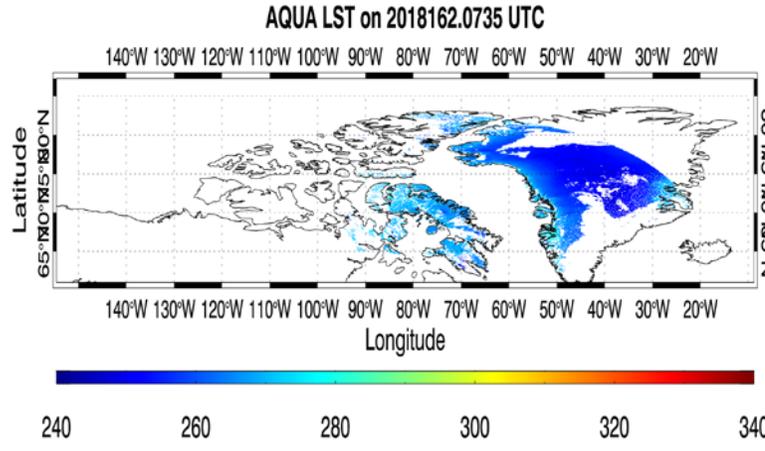
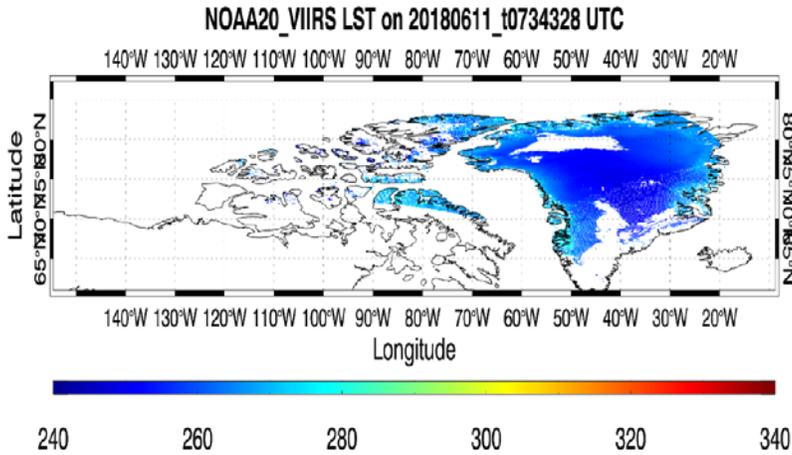
NOAA 20 VIIRS LST against AQUA MODIS LST

U.S.



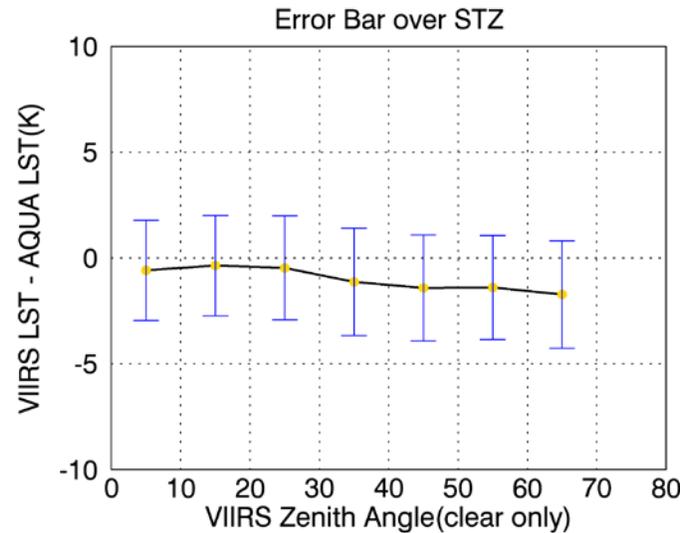
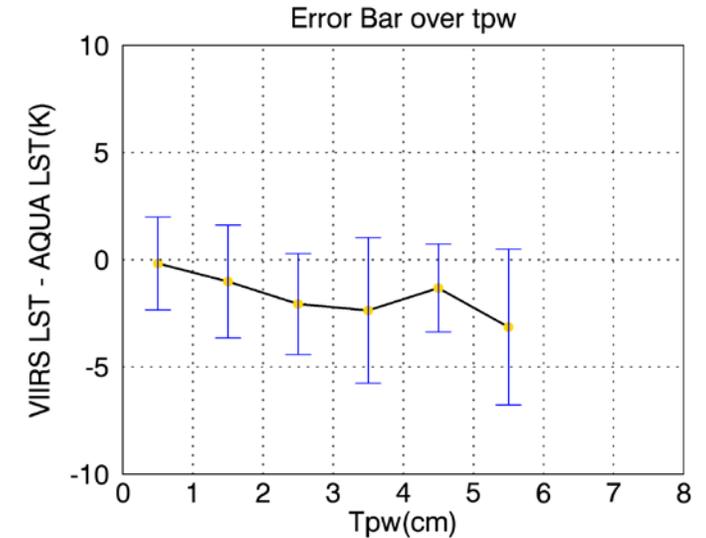
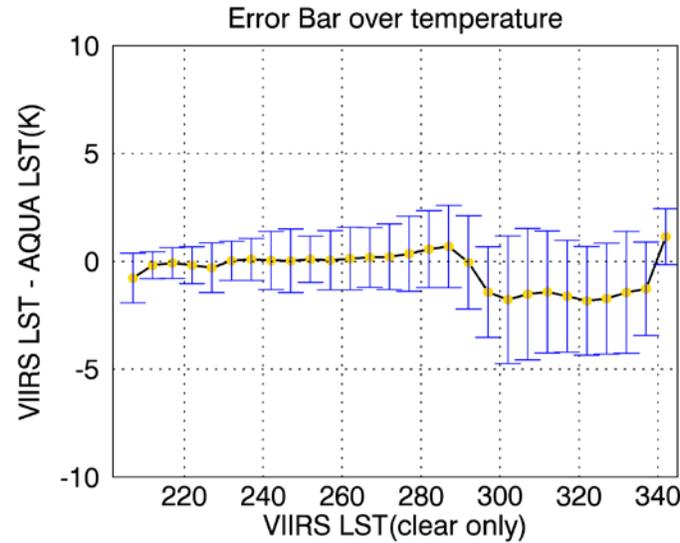
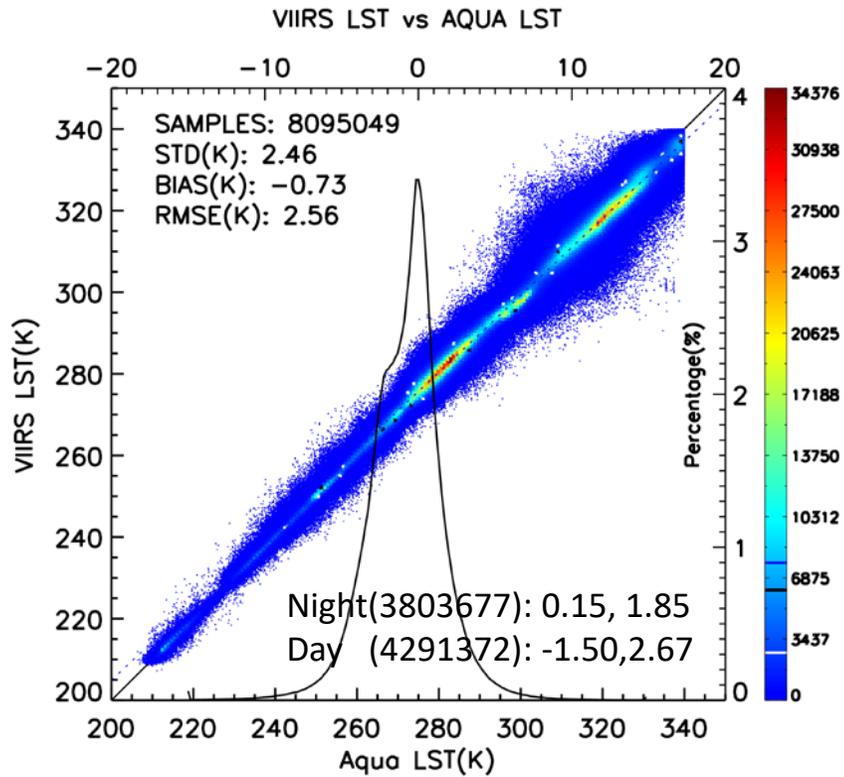
NOAA 20 VIIRS LST against AQUA MODIS LST

Greenland



Cross comparison with AQUA MODIS LST

N20 vs AQUA MODIS Overall

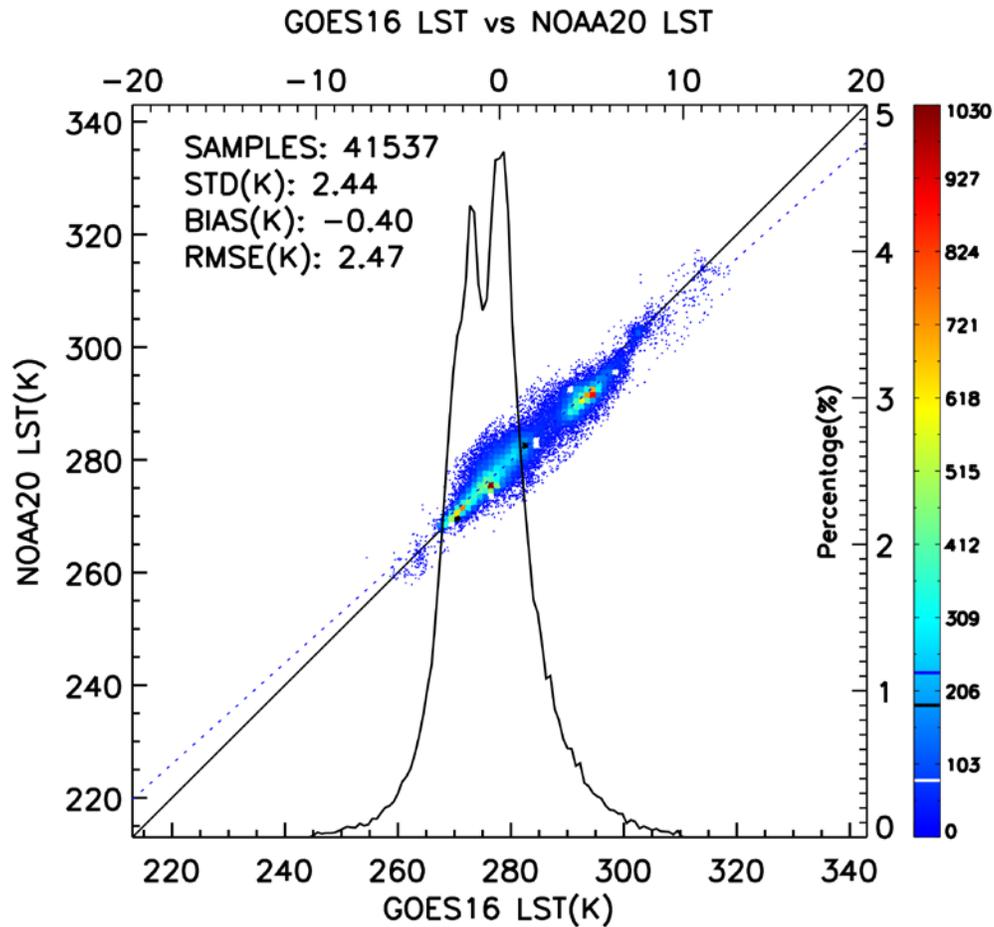


Lat	Samples	Bias	STD
-90~-60	146777	-0.23	1.01
-60~-30	187104	-1.49	2.7
-30~0	2011480	-1.08	2.45
0-30	3022573	-1.22	2.48
30-60	2079506	0.09	2.49
60-90	647609	0.16	1.18

- Visual Analysis and Beta Correction
- Theoretical evaluation of the NOAA 20 LST LUT
- Validation against the ground LST data
- Cross comparison with other satellite LST products
 - MODIS AQUA LST
 - Enterprise SNPP LST
 - *GOES 16 LST*

Cross comparison with GOES16 LST

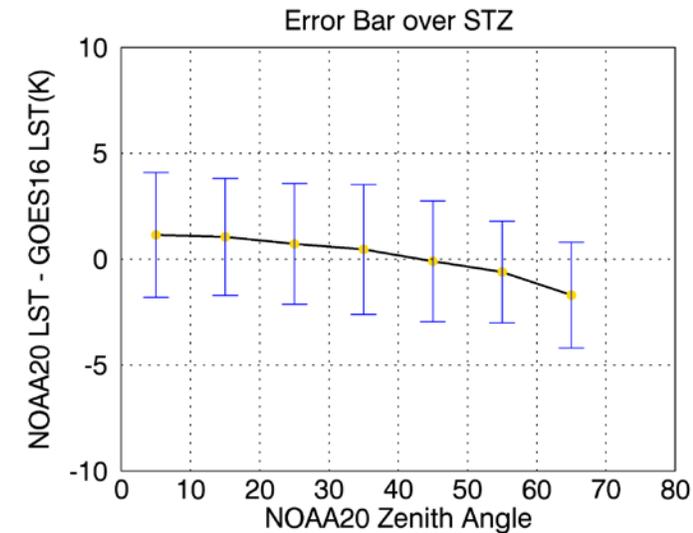
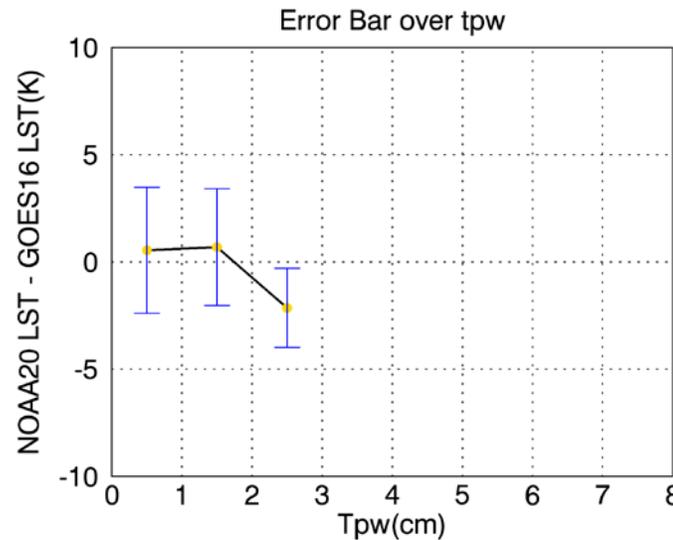
N20 vs GOES R over US



The matchup cases are on 04/15, 04/17, 04/27 and 04/28.

Match up criteria:

- temporal differences less than 7.5 minutes
- Confidently clear for ABI
- Clear VIIRS pixel percentage within a ABI grid greater than 75%
- Cross-sensor match-up data pairs w/ viewing angle differences less than 5 degree



Error Budget Summary

Attribute Analyzed	L1RD Threshold	Analysis/Validation Result	Error Summary
Theoretical evaluation	1.4K(2.5K)	Day: 0.34K (0.69 K) Night: 0.19K (0.48K)	The error statistics is based on the simulation database.
T-based Validation	1.4K(2.5K)	BON: 0.47K (1.38K) TBL: -0.2K (1.45K) DRA:-2.1K (1.55K) FPK: -0.41K (1.47K) GWN: 0.52 (3.01K) PSU: 0.55K (1.71K) SXF: 0.1K (1.54K)	The error statistics is based on the validation against SURFRAD measurements for the time period from Jan. 05- Dec. 2018 of NOAA 20 VIIRS data. The error budget is limited by ground data quality control, cloud filtering procedure and upstream error from the input data particularly surface type.
		GOB:-0.24K(1.97K) CAB:0.19K(2.02K)	The error statistics is based on the validation against BSRN measurements for the time period from Jan. 05- Nov. 2018 of NOAA 20 VIIRS data. The error budget is limited by ground data quality control, cloud filtering procedure and upstream error from the input data particularly surface type.
Cross satellite Comparison		AQUA MODIS LST -0.73(2.46) Daytime: -1.5(2.67) Nighttime:0.15(1.85)	The error is estimated according to cross comparison between NOAA 20 VIIRS LST and MODIS AQUA LST . This error budget has a regional limitation, i.e. over US, Australia, Africa, west Asia, South America, Greenland and South pole. It is also limited by the spatial and temporal difference, sensor difference, angle difference etc.
		GOES-16: -0.40K (2.44K) Daytime: -2.03K (2.21 K) Nighttime: 0.47K (2.33K)	The error is estimated according to cross comparison between NOAA 20 VIIRS LST and GOES 16 LST. This error budget has a regional limitation (over US only) and seasonal limitation(only for April 2018). It is also limited by the spatial and temporal difference, sensor difference, angle difference etc.

Documentations

Science Maturity Check List	Yes ?
ReadMe for Data Product Users	Yes
Algorithm Theoretical Basis Document (ATBD)	Yes
Algorithm Calibration/Validation Plan	Yes
(External/Internal) Users Manual	Yes
System Maintenance Manual	Yes
Peer Reviewed Publications (Demonstrates algorithm is independently reviewed)	In preparation

Evaluation/Validation Summary

NOAA 20 LST has performance well based on our local computation, though the data is still limited and longer period of validation is necessary.

- *Track and fix the problems observed*
- *Theoretical evaluation presents an overall reasonable uncertainty of 0.5 K and 0.7 K for night and day, respectively. The uncertainty increases with angle and total water vapor with ~3K under the very moist condition and large viewing angle.*
- *Ground site observation data (7 from SURFRAD; 2 from BSRN) were used in the validation. Overall good agreement is achieved. Further investigation is needed over certain sites e.g DRA and GWN.*
- *The cross comparison shows : NOAA 20 LST is overall consistent to AQUA MODIS LST and GOES 16 ABI LST; the LST difference between NOAA 20 LST and SNPP LST has an expected orbit-related pattern, and the difference varies over region and day/night.*

Requirement Check List – LST

JERD	Requirement	Performance
	Applicable Conditions: Clear Condition only	
JERD-2438	The algorithm shall produce a land surface temperature product with a horizontal cell size of 0.80 km	Yes
JERD-2516	The algorithm shall produce a land surface temperature product with a mapping uncertainty (3 sigma) of 1 km at Nadir	Yes
JERD-2517	The algorithm shall produce a land surface temperature product with a measurement range of 213 – 343 K	Yes
JERD-2518	The algorithm shall produce a land surface temperature product with a measurement precision (1 sigma) of 2.5 K (Note 1)	Yes, details are given in error budget summary
JERD-2519	The algorithm shall produce a land surface temperature product with a measurement accuracy (bias) of 1.4 K (Note 1)	Yes, details are given in error budget summary

Note 1: Accuracy and precision performance will be verified and validated for an aggregated 4 km horizontal cell to provide for adequate comparability of performance across the scan

Check List - Provisional Maturity

Provisional Maturity End State	Assessment
<p>Product performance has been demonstrated through analysis of a large but still limited (i.e. not necessarily globally or seasonally representative) is minimally validated, number of independent measurements obtained from selected locations, periods, and associated ground truth or field campaign efforts.</p>	<p>Yes. Multiple dataset comparisons are conducted using available independent ground measurements, SNPP LST, AQUA MODIS LST, and GOES 16 LST. Limitations are noted in readme.</p>
<p>Product analysis is sufficient to communicate product performance to users relative to expectations (Performance baseline)</p>	<p>Yes. Evaluation documents are available to users upon request.</p>
<p>Documentation of product performance exists that includes recommended remediation strategies for all anomalies and weaknesses. Any algorithm changes associated with severe anomalies have been documented, implemented, tested and shared with the user community</p>	<p>Yes. The performance analyses are all documented. Monitoring results (weekly) are recorded and shared through ftp site. Weakness and further improvements are filed.</p>
<p>Product is ready for operational use and for use in comprehensive cal/val activities and product optimization</p>	<p>Yes. Limitations are noted in the Readme.</p>

Path Forward/ Future Plan

- Product refinement
 - LUT for the enterprise NOAA 20 LST needs further evaluation and calibration with more data available.
 - The preliminary validation shows that the performance over certain site meet the requirement. Further analysis and improvements are needed.
 - Method to further improve the LST discontinuity is under development.
 - Method to identify outlier and reduce ground measurement noise is under development.
- Global /Comprehensive Validation
 - Monitoring tool
 - Global in situ data collection
 - Extend the cross satellite comparisons. (Sentinel, SEVIRI, AHI, GOES 17 ...)
- Gridded NOAA 20 LST product generation
- Promote VIIRS LST data usage in NOAA climate model application. Continue to support the studies using VIIRS LST in model for air temperature prediction over Alaska area.

Thanks for your attention.