Beta Maturity Science Review
For
NOAA-20 VIIRS Land Surface Temperature EDR

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July 19, 2018

Outline

- LST Cal/Val Team Members
- Product Requirements
- NOAA 20 VIIRS LST Status
- Preliminary Evaluation of the LST
- Documentation (Science Maturity Check List)
- Beta Maturity Conclusions
- Path Forward to Provisional

LST Cal/Val Team Members

	Name	Organization	Major Task
STAR/EMB	Ivan Csiszar	NOAA/NESDIS/STAR	Land Lead
	Yunyue Yu	NOAA/NESDIS/STAR	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
STAR/OPDB	Walter Walf	NOAA/NESDIS/STAR	STAR ASSIST Lead
	Rachel Hatteberg	NOAA Affiliate, SciTech/IMSG	STAR ASSIST, Algorithm System integration
	Arthur Russakoff	NOAA Affiliate, SciTech/IMSG	STAR ASSIST, Algorithm System integration

LST Product Requirements

Product Requirements from JPSS L1RD*

	JPSS VIIRS LST	
Attribute	**Threshold**	**Objective**
LST applicable condition: Clear only		
Horizontal Cell Size	0.8 km	0.5 km
Mapping uncertainty	1 km at Nadir	1 km at Edge of Scan
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

*http://www.jpss.noaa.gov/assets/pdfs/technical_documents/level_1_requirements_supplement.pdf

JPSS Data Products Maturity Definition

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

1.<u>Beta</u>

- Product is minimally validated, and may still contain significant identified and unidentified errors.
- Information/data from validation efforts can be used to make initial qualitative or very limited quantitative assessments regarding product fitness-for-purpose.
- Documentation of product performance and identified product performance anomalies, including recommended remediation strategies, exists.

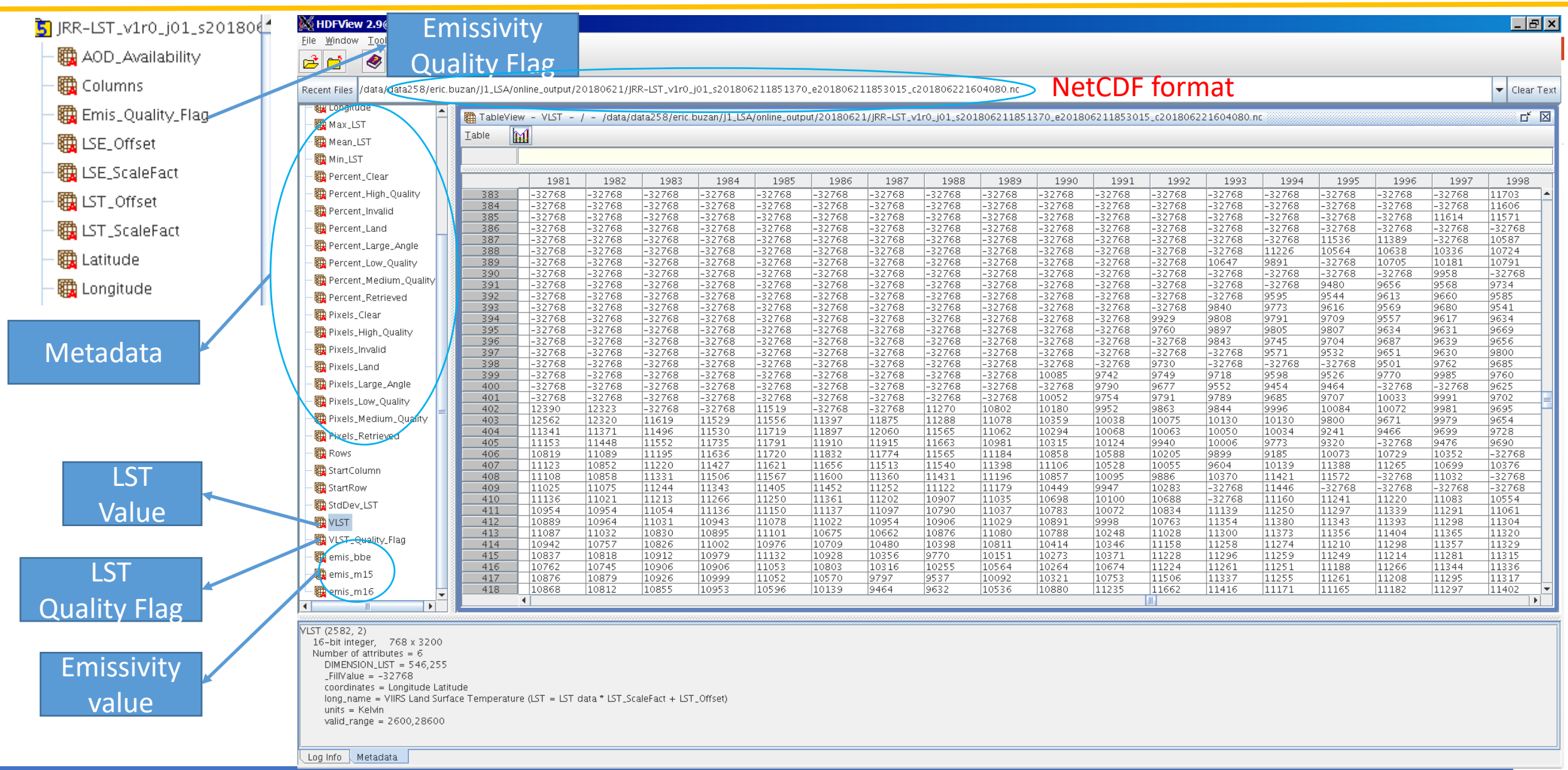
NOAA-20 VIIRS LST Status

- The enterprise VIIRS LST algorithm has been developed and integrated into the framework. The final DAP (originally for SNPP) was delivered to NDE at the end of March, 2018.
- The enterprise LST algorithm is applied in NDE for NOAA-20 data, with the LUTs developed for S-NPP VIIRS sensor.
- The LUT for NOAA-20 LST production has been developing, and will be applied for the LST provisional release.
- Evaluation of the NDE NOAA-20 LST data by the science team (following slides) is limited.

Evaluation Method

- Visual inspection of the global and regional NOAA-20 LST image
- Verification of quality flags and metadata
- Algorithm performance validation
  - ✓ In-situ validation against the SURFRAD LST estimates
  - ✓ Cross comparison with other satellite LST products
    - o MODIS AQUA LST
    - o GOES 16 LST

NOAA 20 VIIRS LST Status



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410	11136	11021	11213	11266	11250	11361	11202	10907	11035	10698	10100	10688	-32768	11160	11241	11220	11083	10554
411	10954	10954	11054	11136	11150	11137	11097	10790	11037	10783	10072	10834	11139	11250	11297	11339	11291	11061
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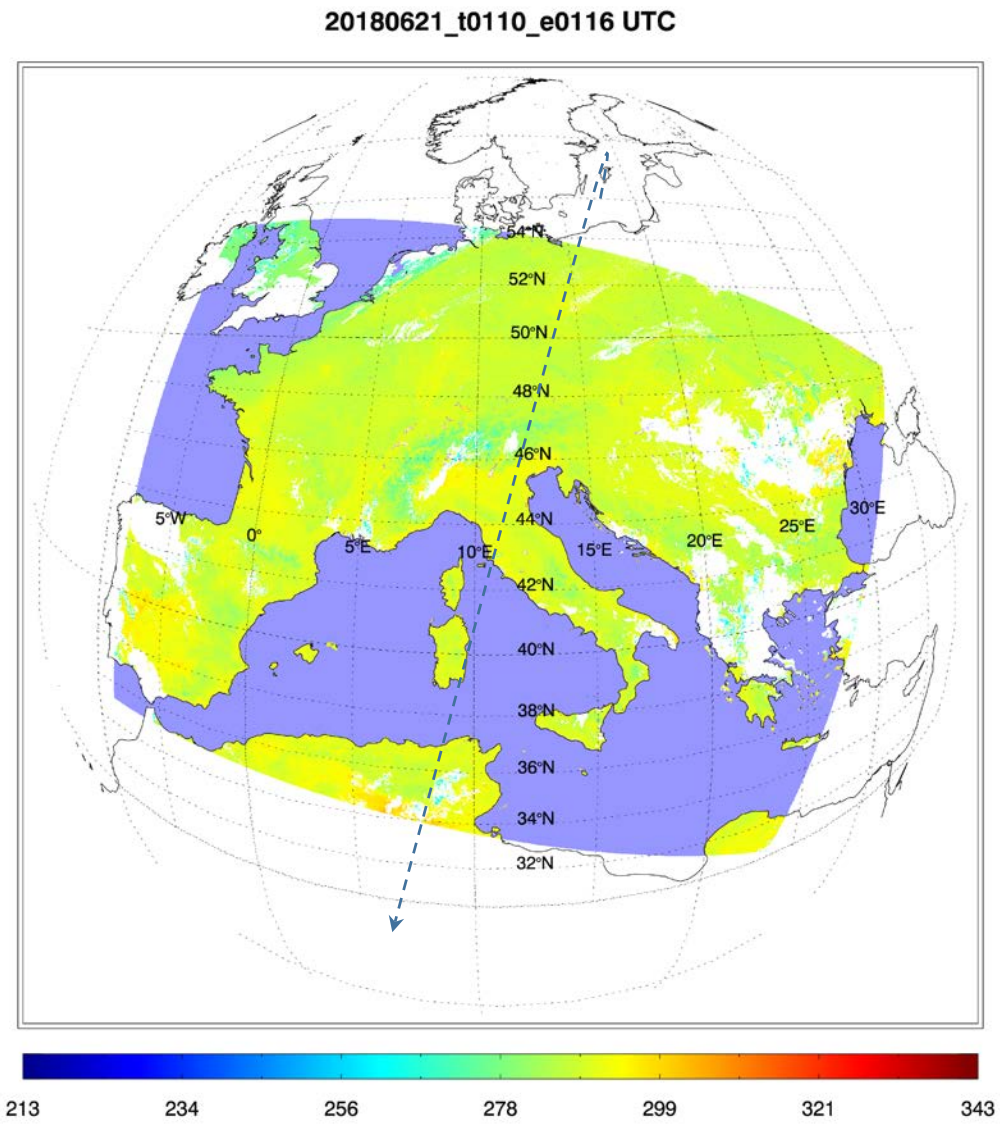
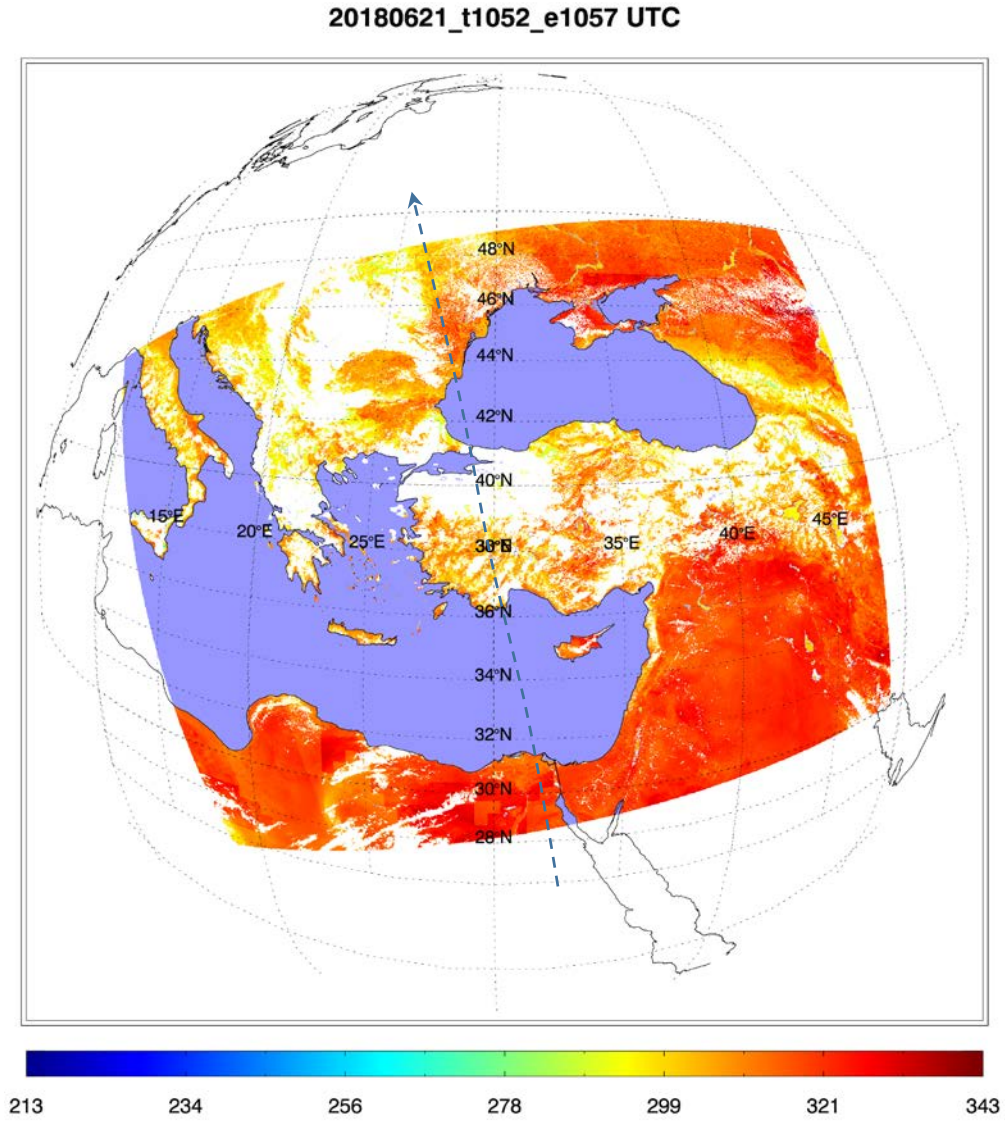
417	10876	10879	10926	10999	11052	10570	9797	9537	10092	10321	10753	11506	11337	11255	11261	11208	11295	11317
418	10868	10812	10855	10953	10596	10139	9464	9632	10536	10880	11235	11662	11416	11171	11165	11182	11297	11402

Regional LST Image

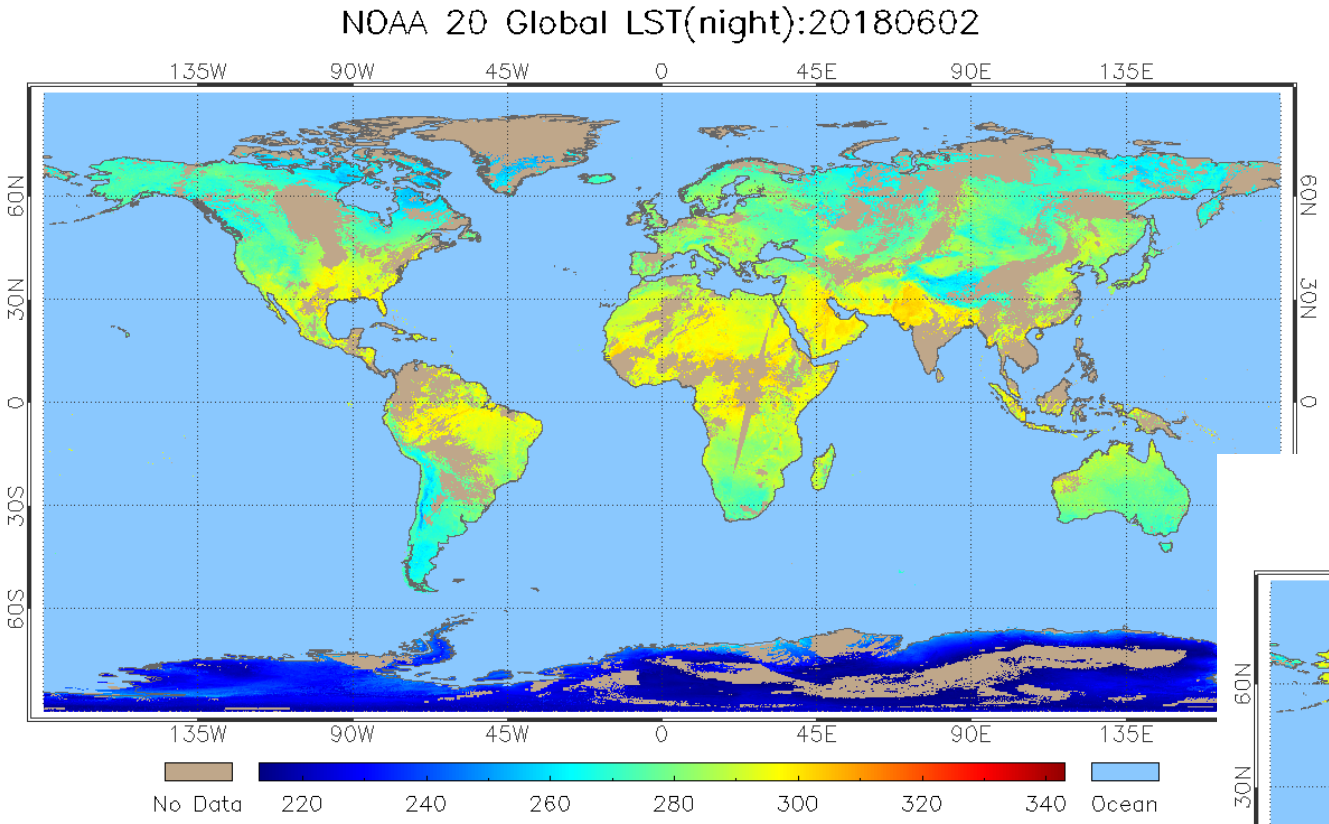


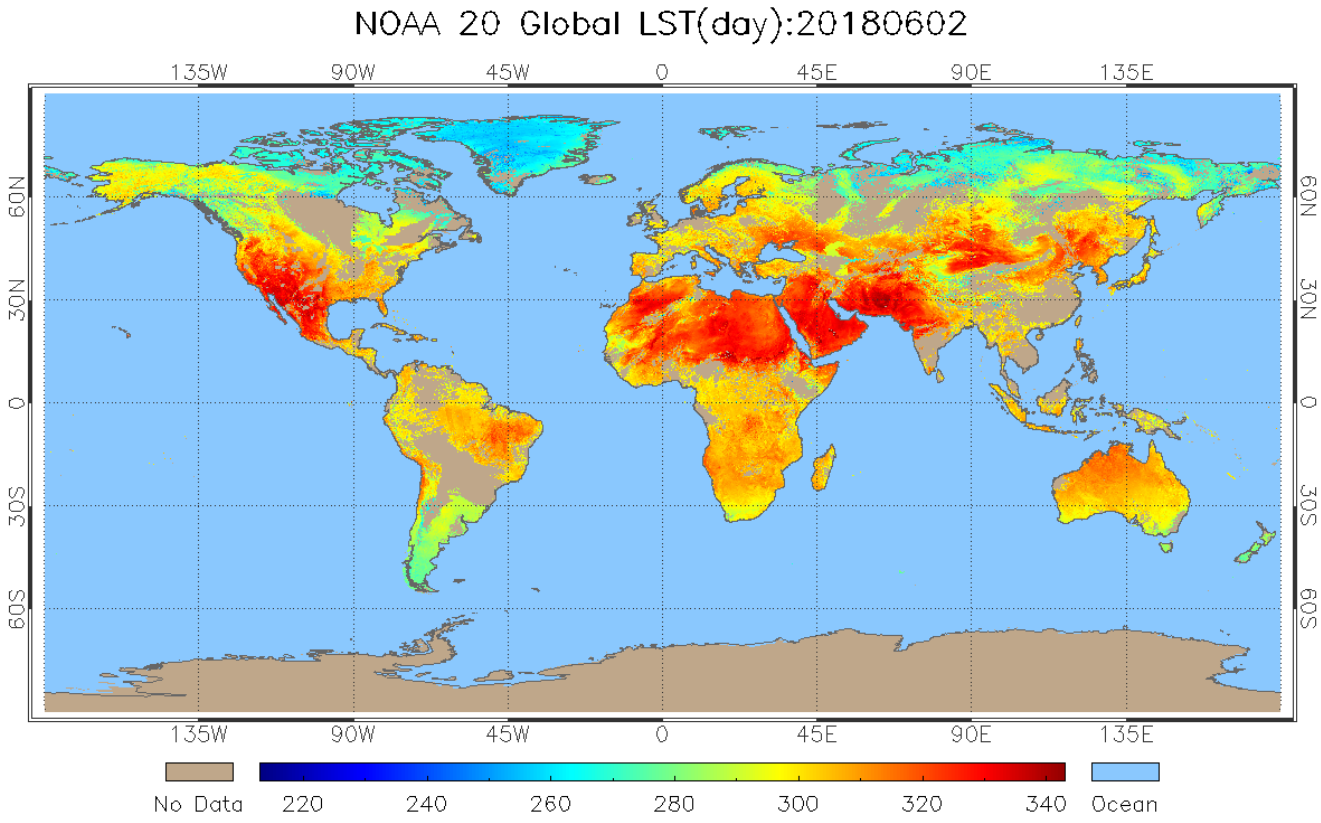
Granule over Europe at nighttime



Granule over Europe, North Africa and West Asia at daytime

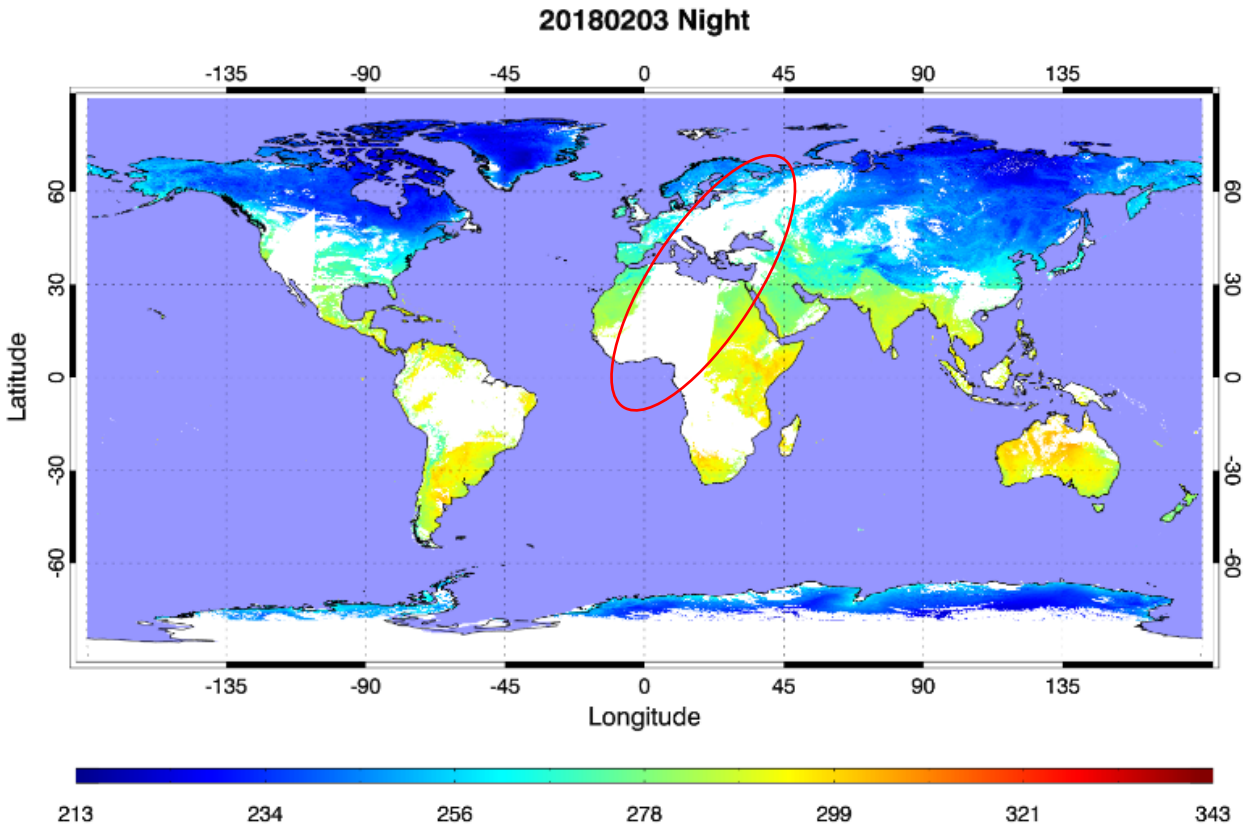
Global LST Map

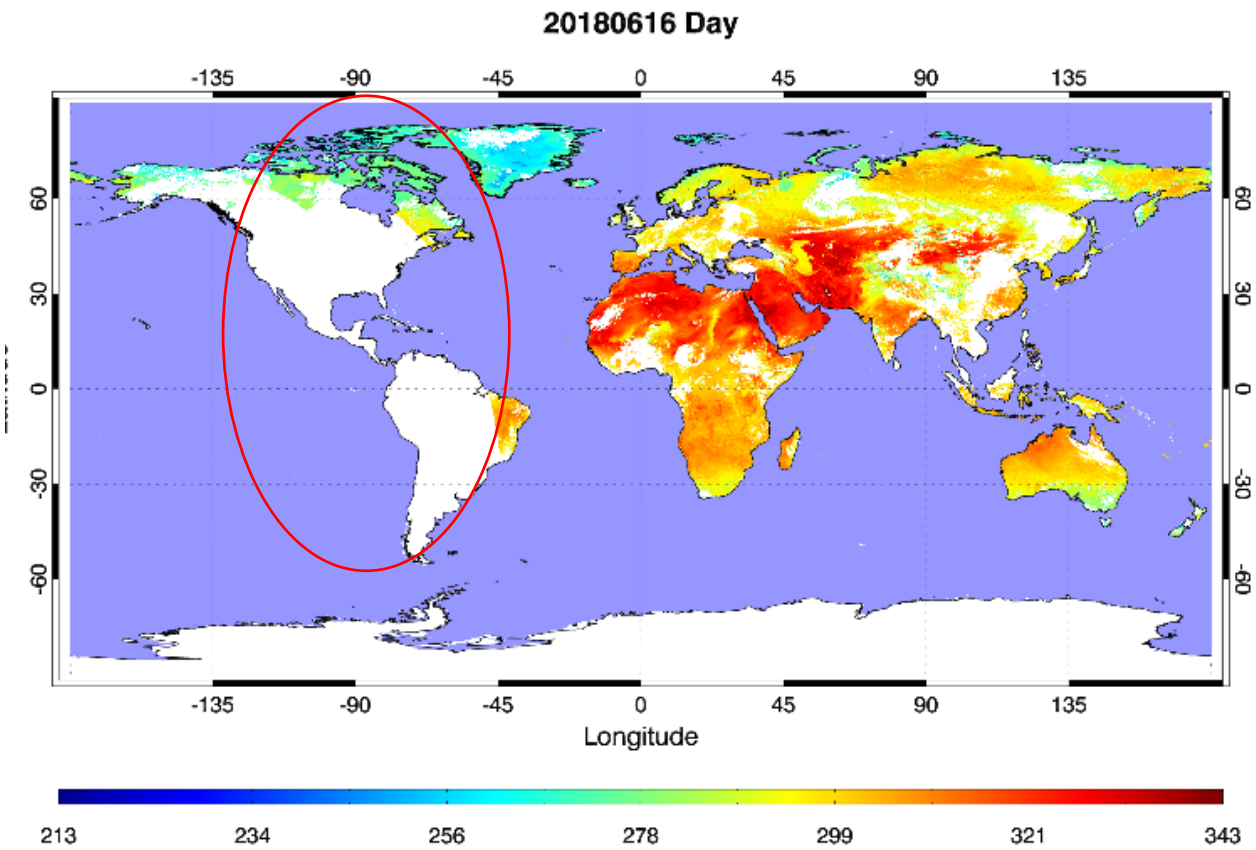




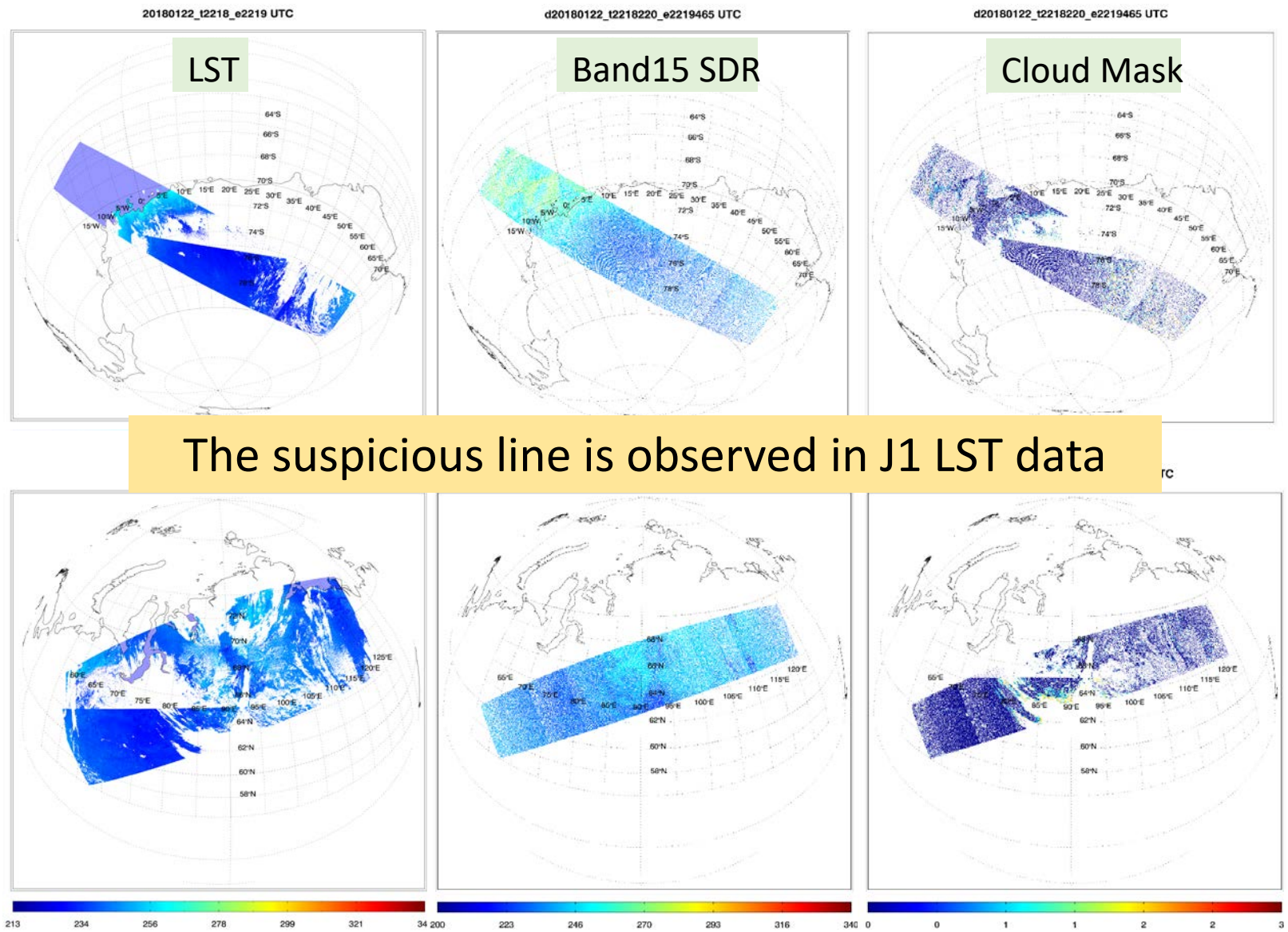
Issues/Findings

- Data missing

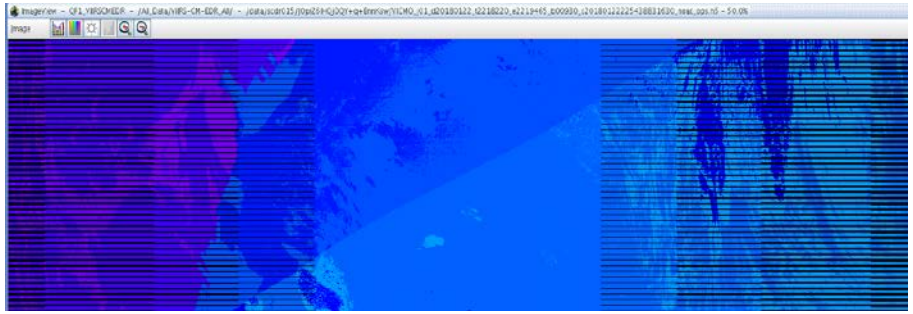




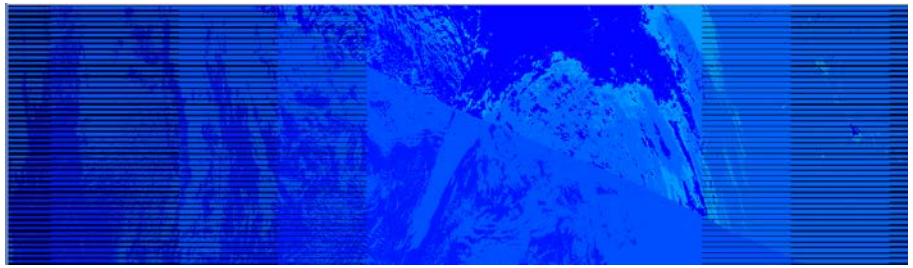
Issues/Findings



The suspicious line is observed in J1 LST data



Left figures show the LST, Band 15 brightness temperature and associated cloud mask confidence indicator map and the right figure shows the corresponding QF1_VIIRSCMEDR in the cloud mask map (VICMO). Cloud confidence indicator is derived from QF1).

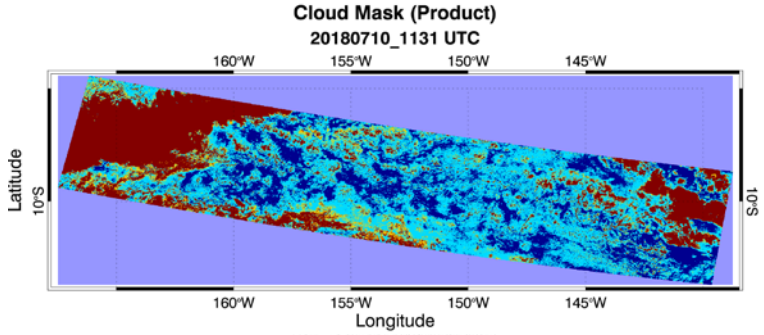


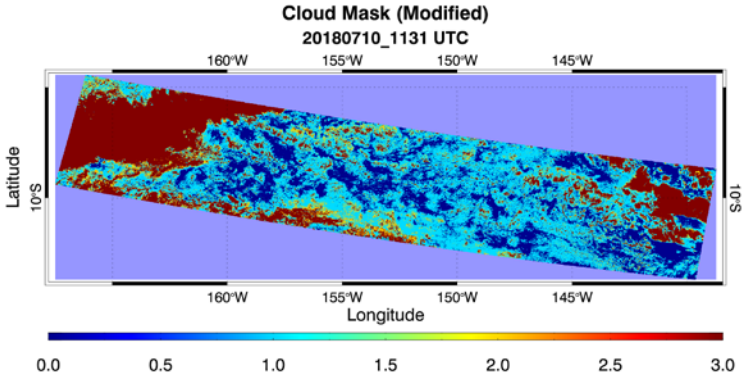
Issues/Findings

Cloud mask: the criteria for probably clear is set wrong in V1 ECM cloud mask product

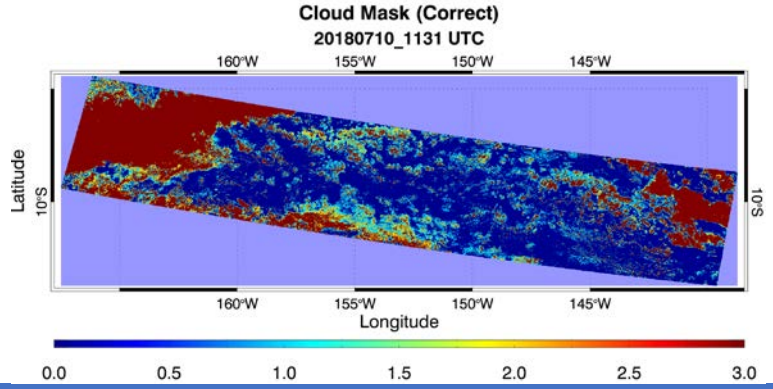
- Impact on LST

It will not affect the LST value in the product. However, the quality flag indicating the cloud status is affected. In addition, LST validation and user applications are affected where confidently clear pixel is usually used for data selection.





0—Confidently clear
1– probably clear
2– probably cloudy
3– confidently cloudy



Top right figure is generated using the cloud probability in the range of [0.01,0.5) for probably clear classification. And it is found that it is identical with the current product(top left). Therefore the problem is that the cloud probability of 0.01 instead of 0.1 is used for probably clear classifications in the cloud mask product. The bottom left is the figure using the corrected criteria.

Quality flag and metadata inspection

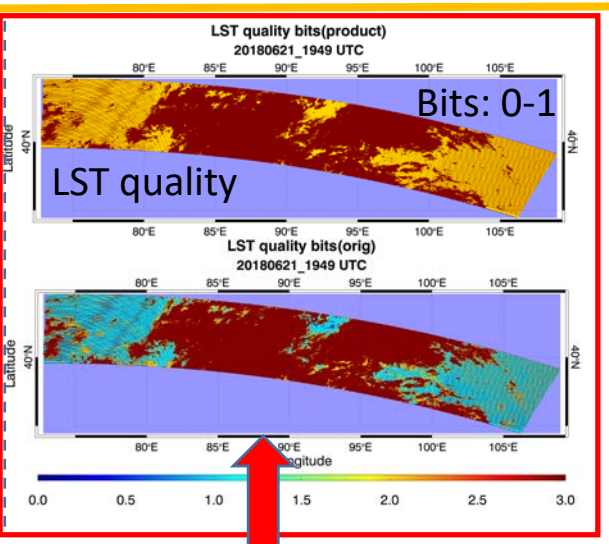
byte	bit	Flag	Source	description
1	0-1	LST quality	LST	00=high, 01=medium, 10=low, 11=no retrieval
	2-3	Cloud condition	Cloud mask	00=confidently clear, 01=probably clear,10=probably cloudy,11=confidently cloudy
	4	SDR quality	SDR	0=normal, 1=bad data
	5	AOD at 550 nm (slant path)	AOT	0=within range(AOT<=1.0);1=outside range (AOT >1)
	6-7	Land surface cover	land/sea mask snow/ice mask	00=land;01=snow/ice;10=in land water;11=coastal
2	8-9	Water vapor condition	Tpw input	00=very dry atmosphere(wv<1.5g/cm^2) ; 01= dry [1.5,3); 10=moist atmosphere(3,4.5]; 11= very moist[4.5+)
	10	Emissivity availability	Emissivity	0=normal, 1=historical emissivity
	11	Degradation by large viewing angle	SDR	0=no degradation, 1=large view degradation (VIIRS: 40 degree, GOES-R: 55 degree)
	12	Day/night flag	SDR	0=night(solar zenith angle > 85degree), 1=day
	13	Thin cirrus	Cloud Mask	0= no thin cirrus, 1= thin cirrus
	14	Active fire	Cloud mask	0= no active fire, 1= active fire
	15	Reserved		Reserved for future use

2-byte pixel-level quality flags are available:

- Each bit is recomputed, and compared with the value from the original input/out files.
  - *The quality flag for nighttime has an issue that the LST quality bit is not correctly set due to AOD input missing at nighttime*.
  - The quality flag and metadata evaluation for daytime granule reveals no issues with upstream SDRs and EDRs.
- Granule level metadata is checked and the result shows that they are correctly generated

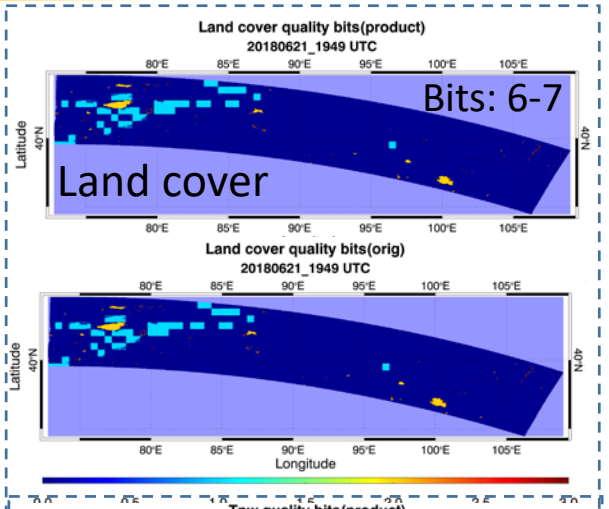
Quality flag Inspection

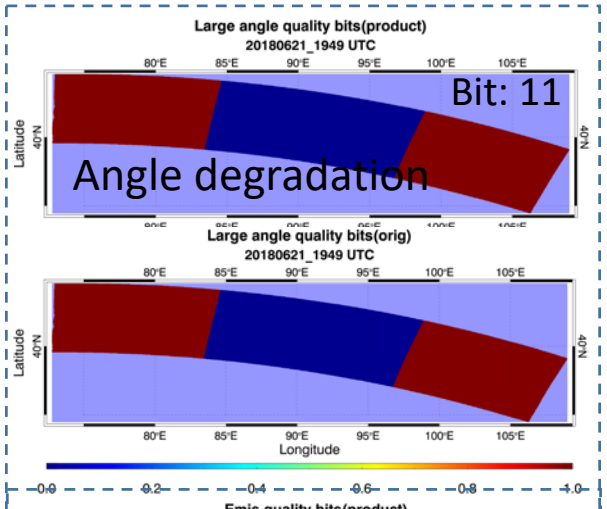
Nighttime quality flag inspection

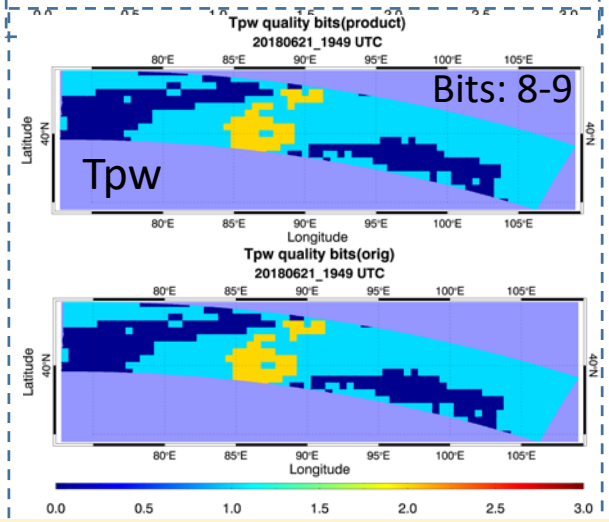


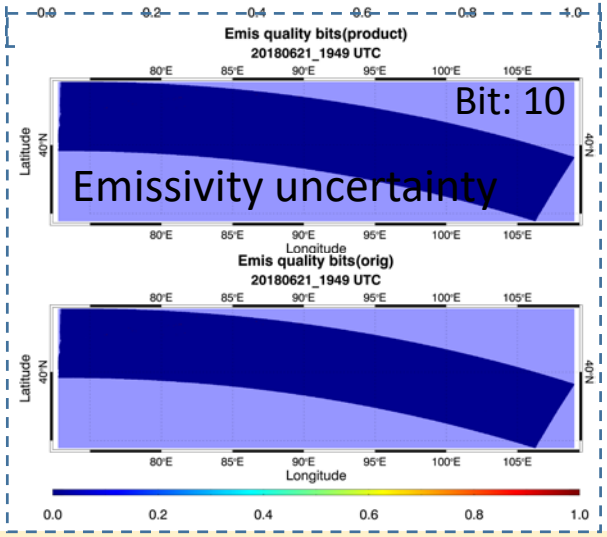
Bits: 2-3

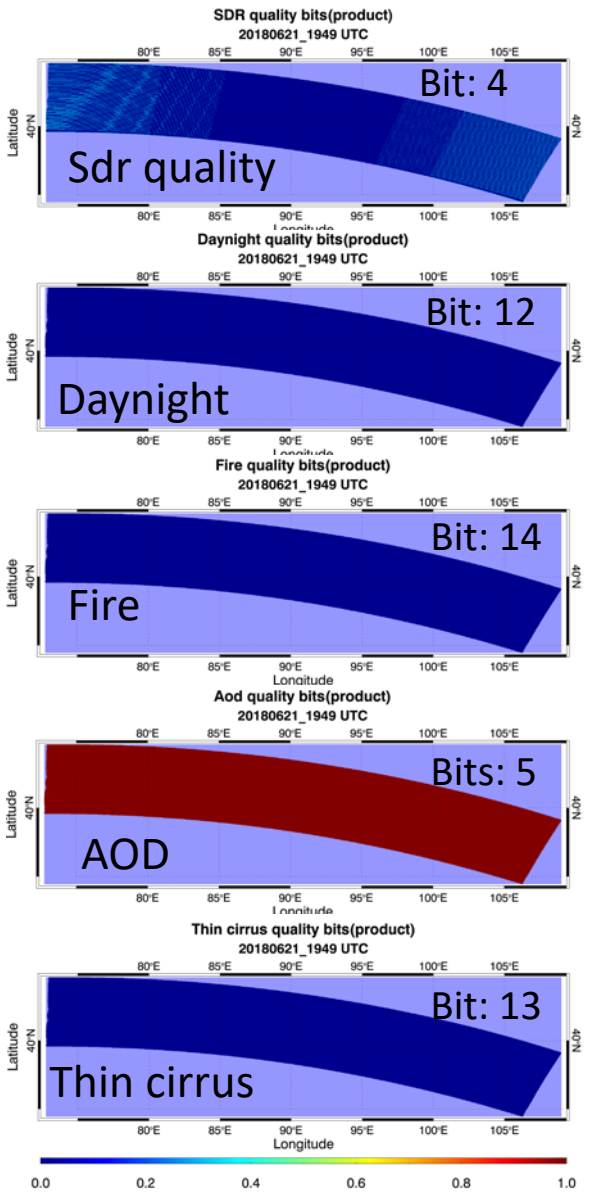
The flag of LST quality is not right due to AOD input error at nighttime.





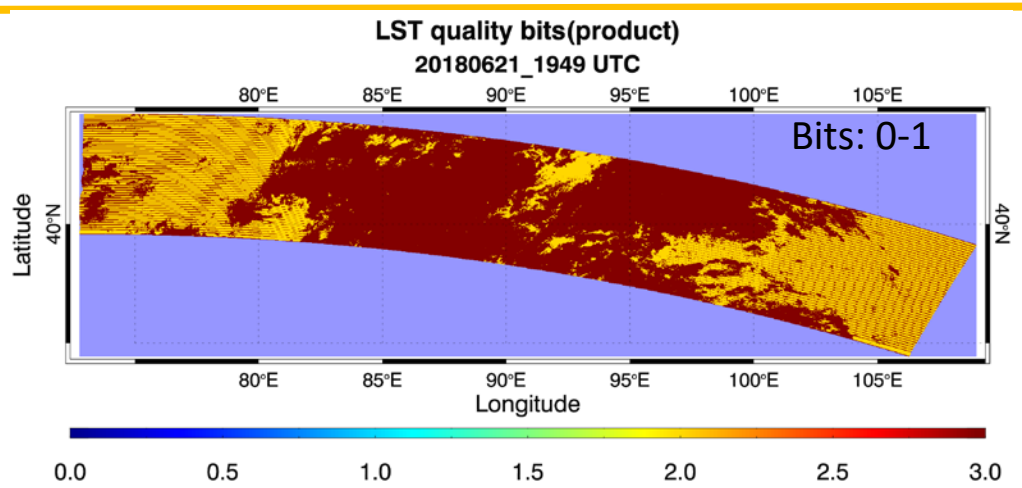


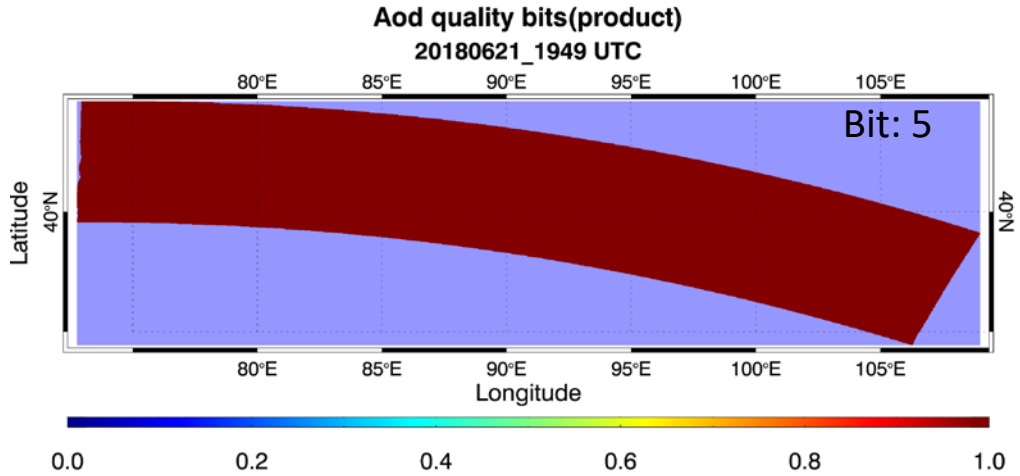




Statistics(Mean, standard deviation, minimum and maximum difference) was checked between the product and the original value, and results show that all items are identical except the LST quality flag.

Nighttime Quality flag Issue





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

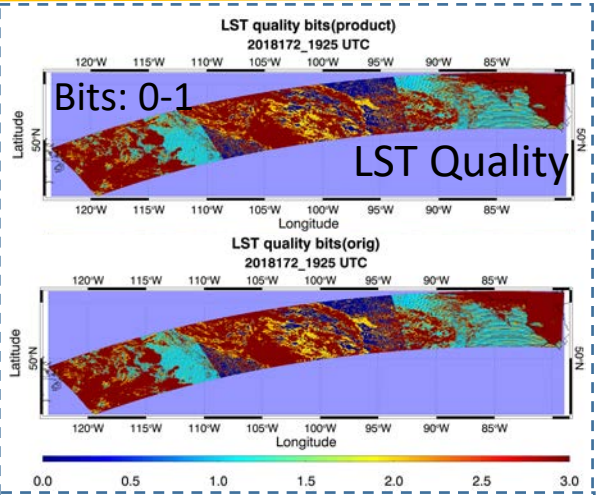
- Aerosol Optical Thickness (bit 5) is set correctly as 1 also represents the missing value condition
- LST quality bit (bit 0-1) is not correctly set. For nighttime, the AOD will be missing value, which results in the LST quality as low for all pixels according to the criteria

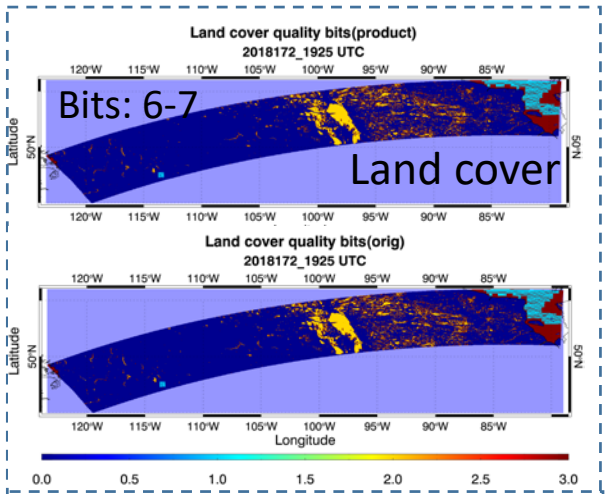
Solution:

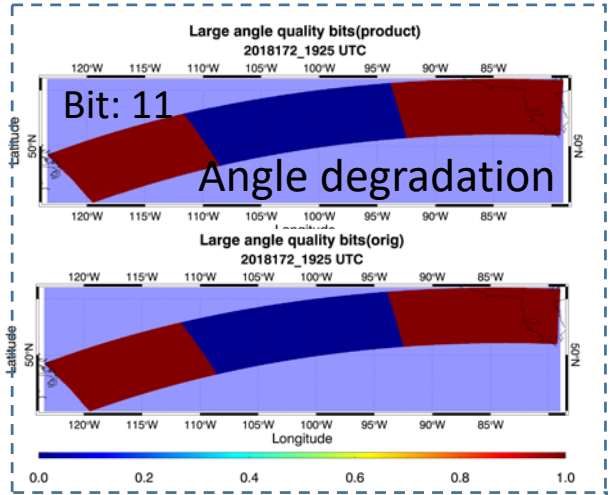
LST quality bit set is separated for day/night condition. For nighttime, the AOD related criteria should be removed in the code. This will be fixed toward the provisional maturity

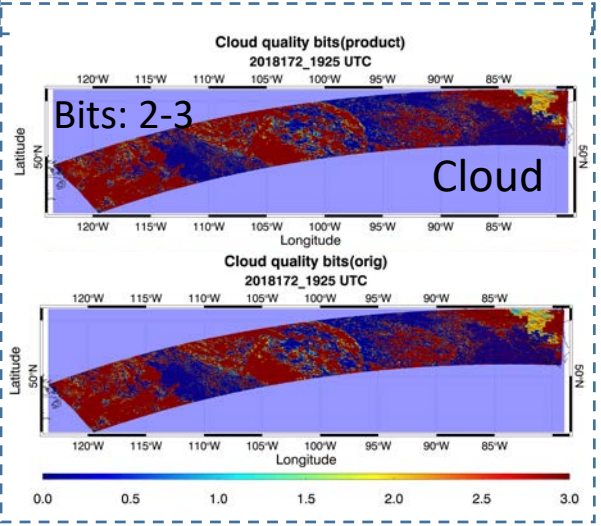
Quality flag Inspection

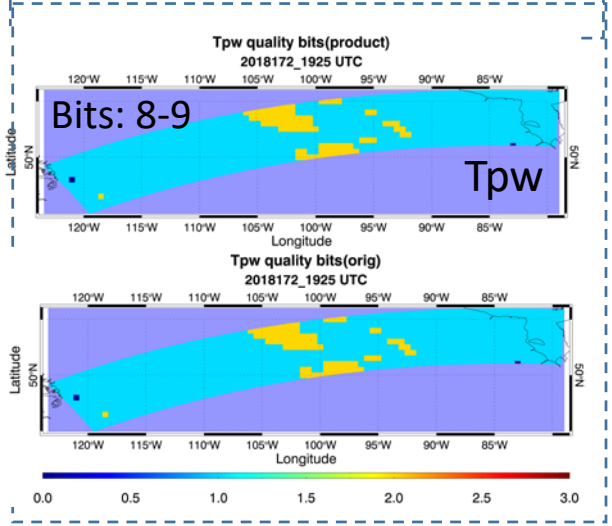
Daytime quality flag inspection

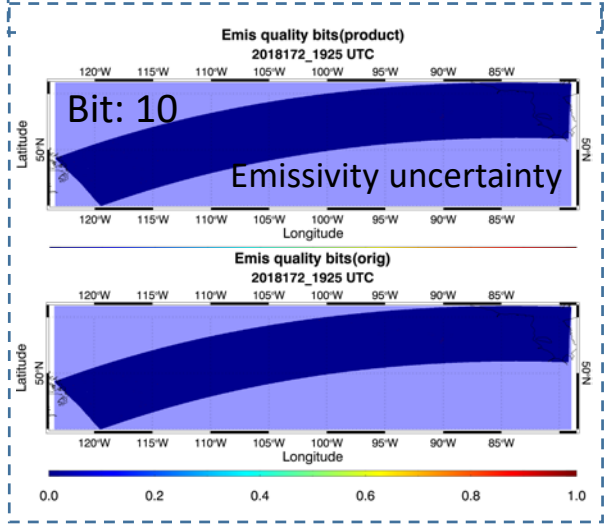


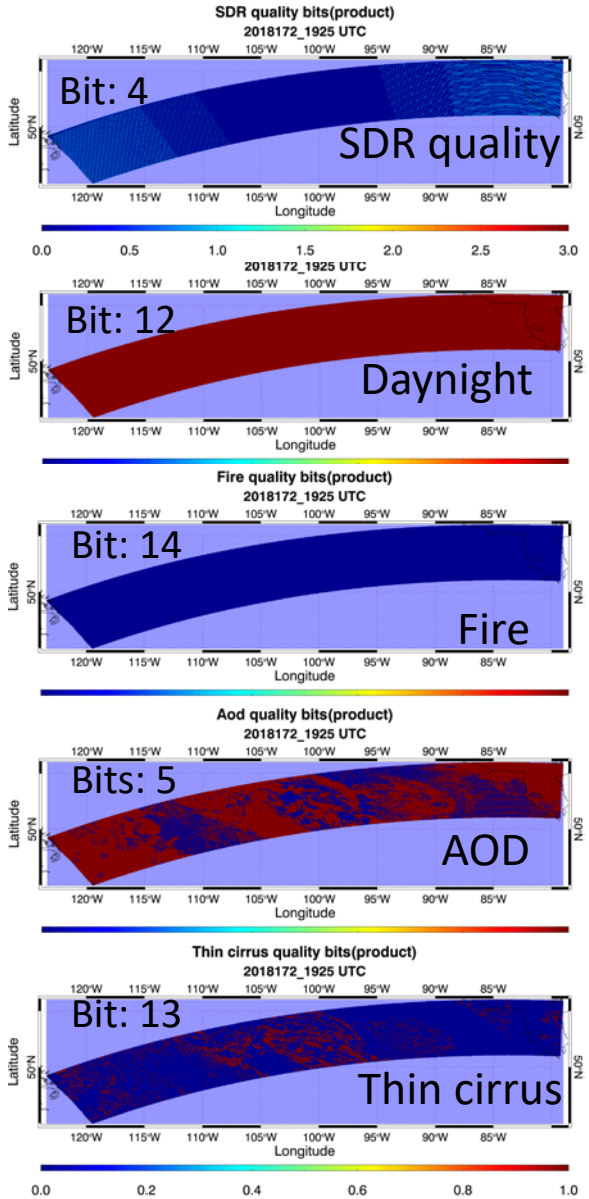










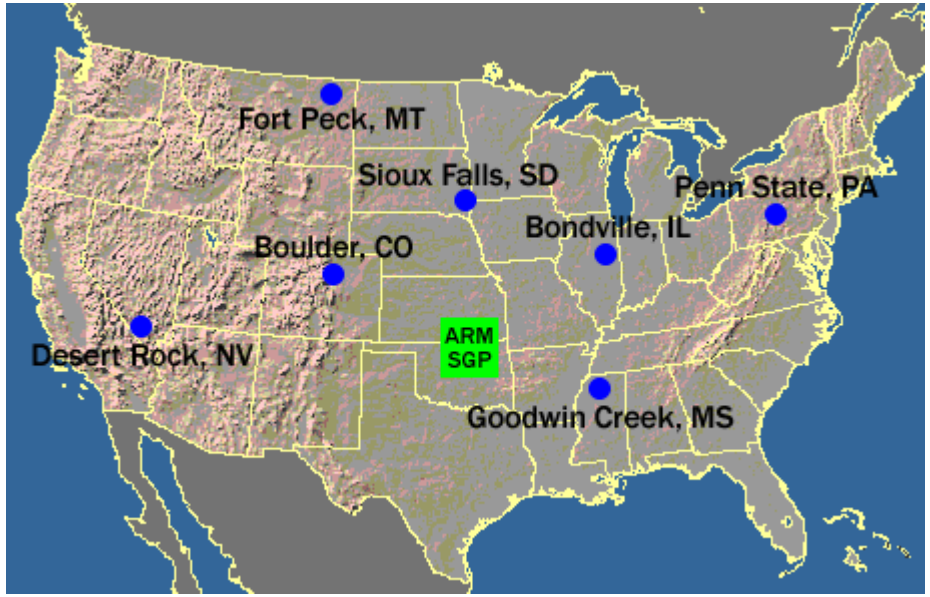


Statistics(Mean, standard deviation, minimum and maximum difference) was checked between the product and the original value, and results show that they are identical.

NOAA-20 VIIRS LST against ground data

Seven sites ground LST observations were used in the validation.

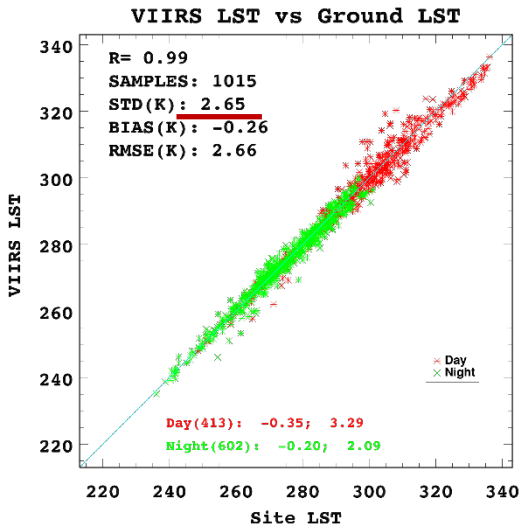
Site No.	Site Location	Lat(N)/Lon(W)	Surface Type(IGBP)
1	Pennsylvania State University, PA	40.72/77.93	Crop Land
2	Bondville, IL	40.05/88.37	Crop Land
3	Goodwin Creek, MS	34.25/89.87	Grass Land
4	Fort Peck, MT	48.31/105.10	Grass Land
5	Boulder, CO	40.13/105.24	Crop Land
6	Desert Rock, NV	36.63/116.02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

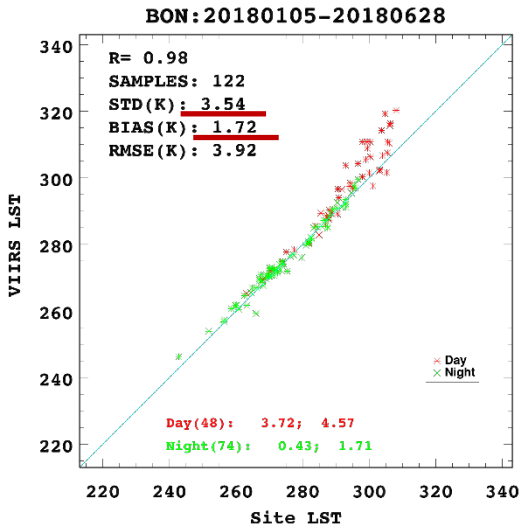


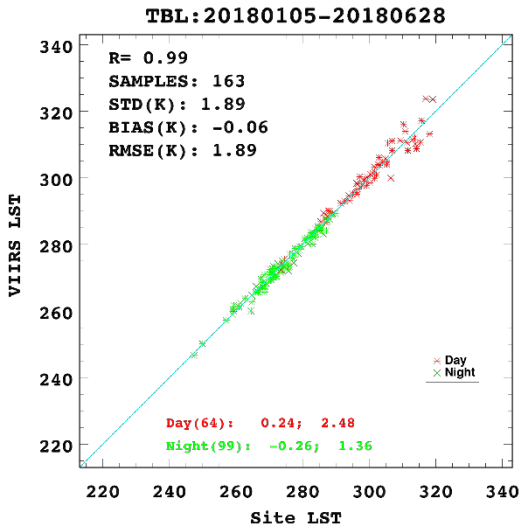
Match up procedures:

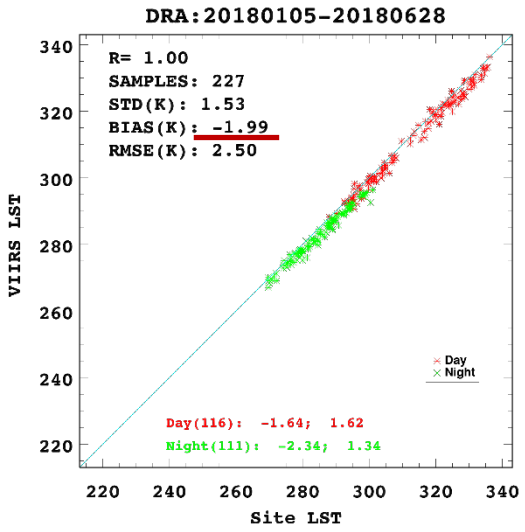
- Spatially closest pixel
- Only confidently clear pixel is used
- The ground observation at the same time as the granule observation starting time is used
- No any additional cloud filtering applied

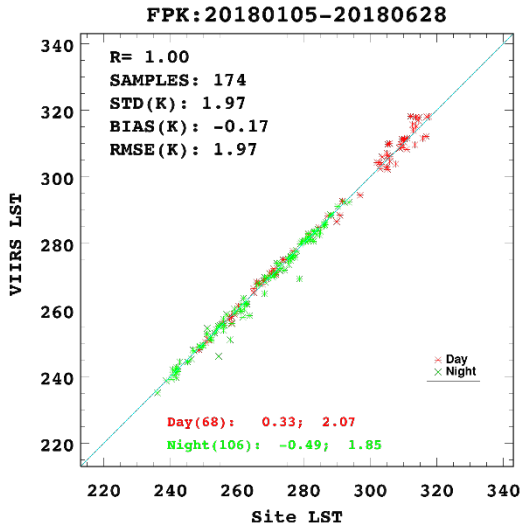
NOAA-20 VIIRS LST against ground data

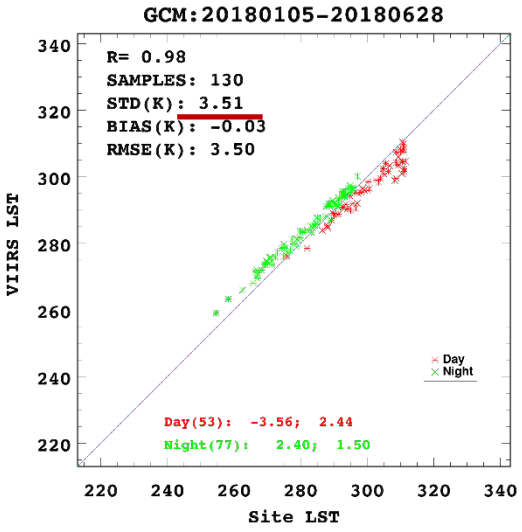


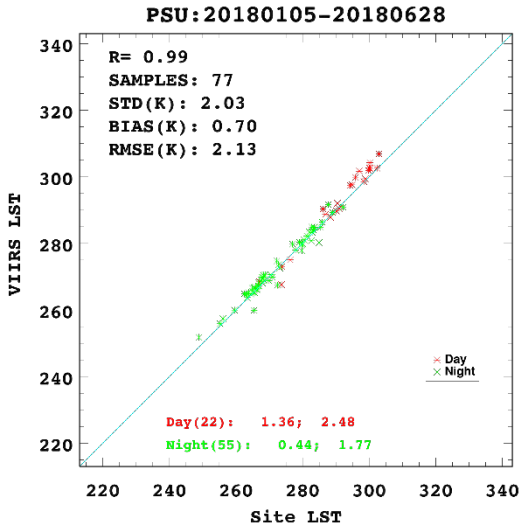


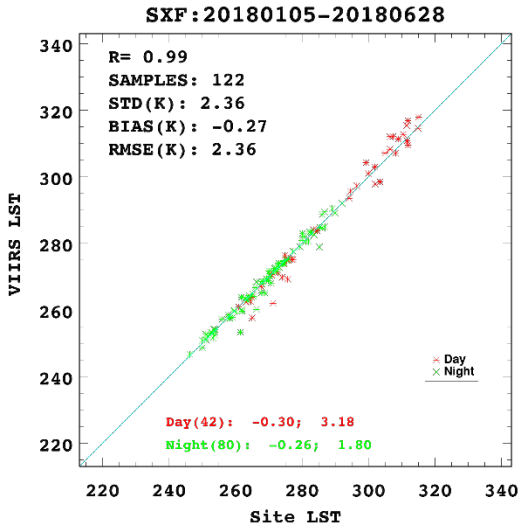












NOAA-20 VIIRS LST against ground data

Site wide statistics

Site Name	count	bias	std	cnt(d)	bias(d)	std(d)	cnt(n)	bias(n)	std(n)
Bondville_IL	194	1.723	3.536	120	3.722	4.571	74	0.426	1.715
Boulder_CO	163	-0.063	1.892	64	0.238	2.483	99	-0.257	1.362
Desert_Rock_NV	227	-1.986	1.528	116	-1.645	1.624	111	- 2.342	1.337
Fort_Peck_MT	174	-0.171	1.973	68	0.326	2.069	106	-0.490	1.849
Goodwin_Creek_MS	130	-0.030	3.514	53	-3.559	2.436	77	2.400	1.495
Penn_State_PA	77	0.701	2.028	22	1.363	2.480	55	0.436	1.773
Sioux_Falls_SD	122	-0.270	2.355	42	-0.299	3.184	80	-0.256	1.799

Note: the L1RD albedo requirement for Accuracy and Precision are 1.4K and 2.5K, respectively.

The results above is based on SNPP LUT allied for NOAA-20
Improvement is expected after LUT update for NOAA-20

NOAA-20 VIIRS LST against AQUA MODIS LST

SNO Date	VIIRS	MODIS	Region	Samples	Bias (K)	STD (K)	RMSE (K)
20180211	02:00-02:04	02:05	Africa	75241	1.74	1.36	2.20
	04:25-04:32	04:30	Australia	408443	-0.66	2.84	2.92
20180304	08:45-08:50	08:55	US	614860	0.67	1.83	1.95
	20:05	19:55	US	67967	0.42	2.28	2.32
20180320	08:45-08:50	08:55	US	716572	0.93	1.90	2.12
	11:30-11:40	11:40	Africa	386330	-1.3	1.66	2.11
	15:50-15:55	15:50	Australia	25063	0.66	1.46	1.60
	18:05-18:10	18:00	South Africa	48256	0.27	3.17	3.18
	20:00-20:10	19:55	US	131768	10.5	2.95	3.13
20180512	22:15-22:19	22:15	Mid-north Asia	221460	0.44	1.32	1.39
20180611	07:34-07:38	07:35	Greenland	210017	0.45	0.70	0.84

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

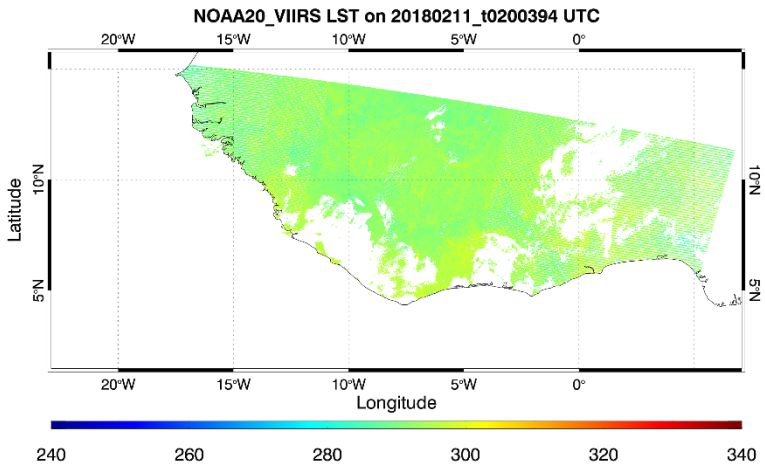
- The comparison is at regional scale not global scale due to SNO limitations. It only represents the LST difference over Africa, Australia, US, mid-north Asia and Greenland area.
- Due to the data availability, it has limited temporal coverage.

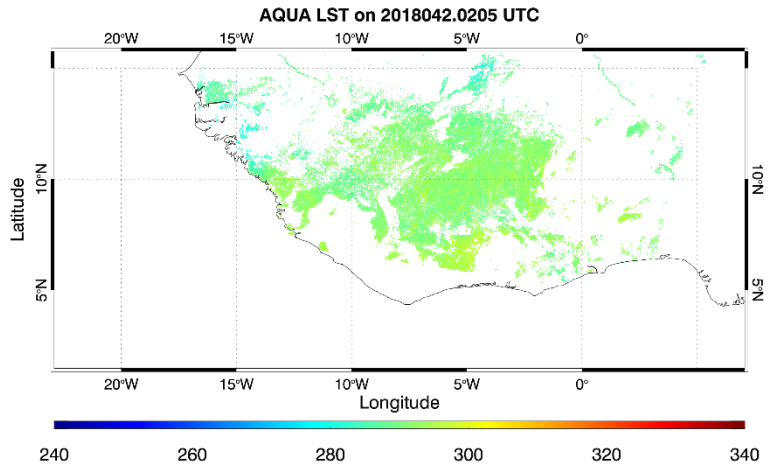
Matchup criteria

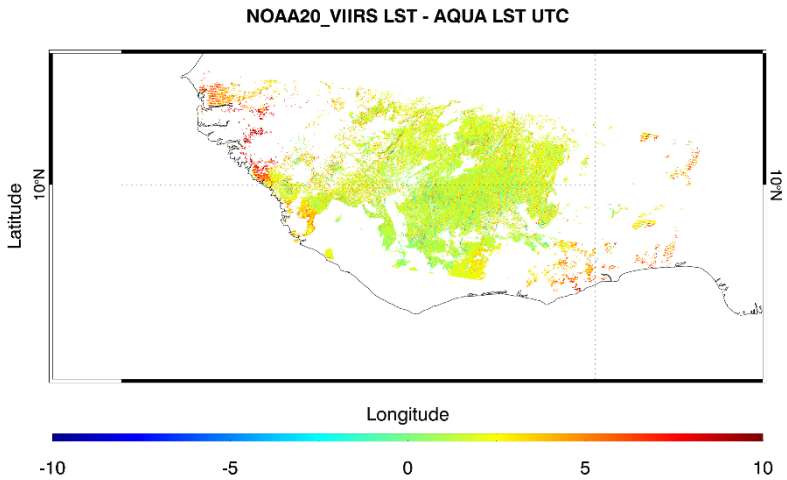
Limitation

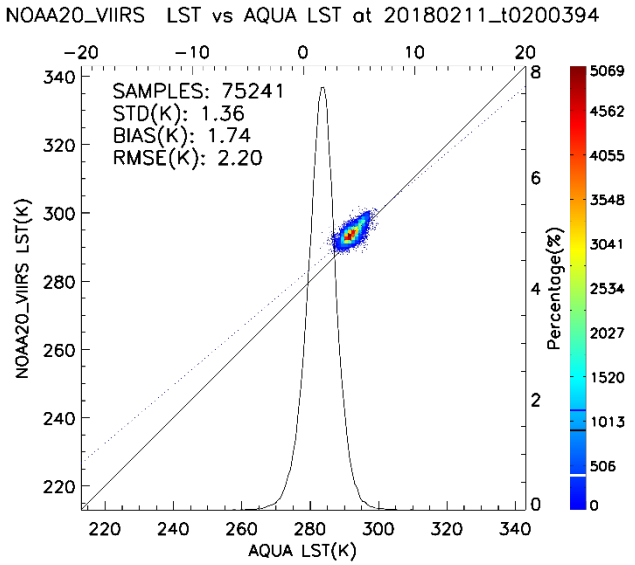
NOAA 20 VIIRS LST against AQUA MODIS LST

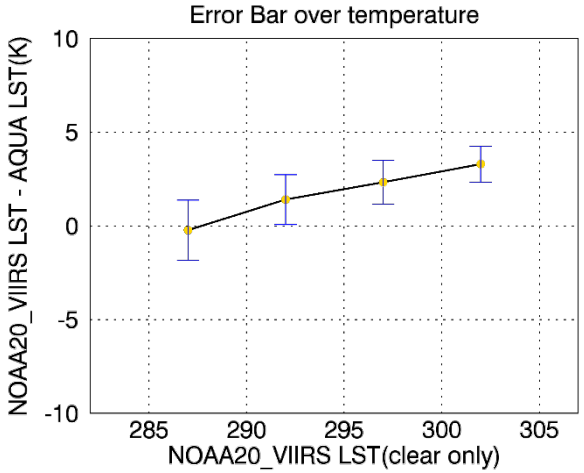
Africa

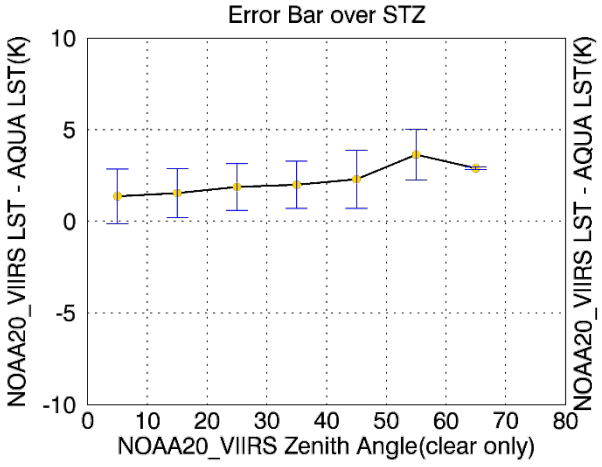


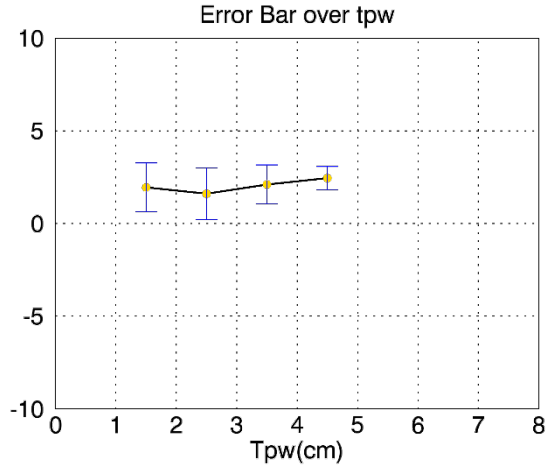






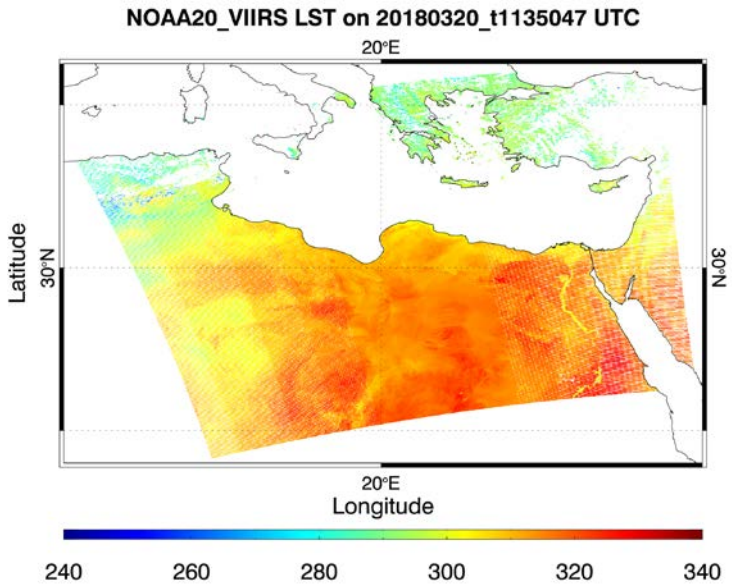


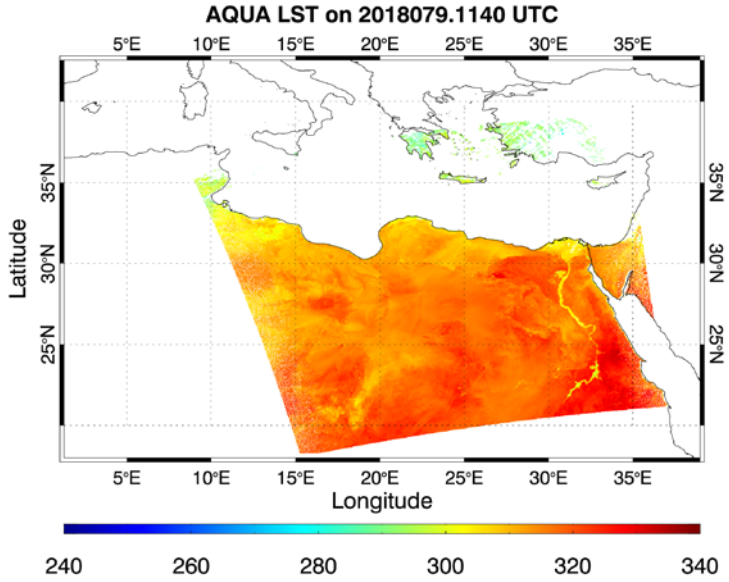


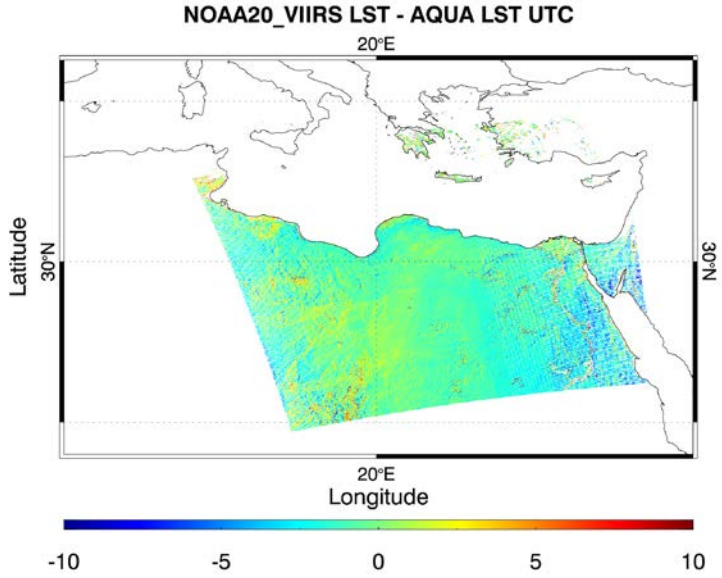


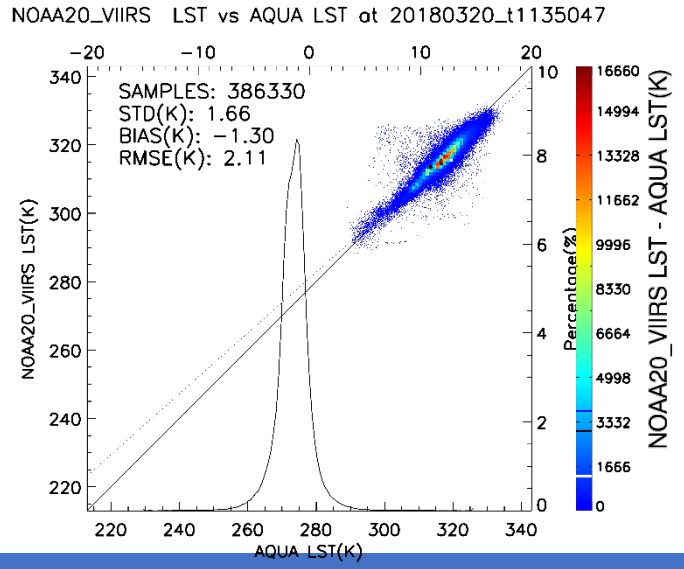
NOAA 20 VIIRS LST against AQUA MODIS LST

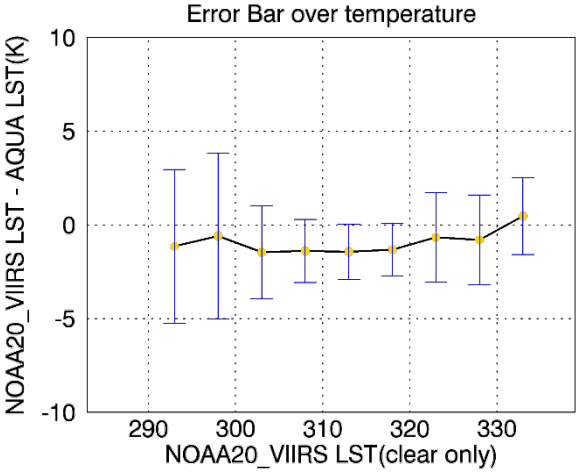
Africa

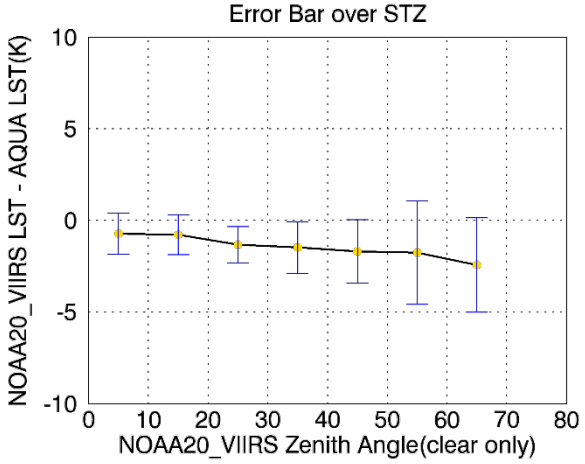


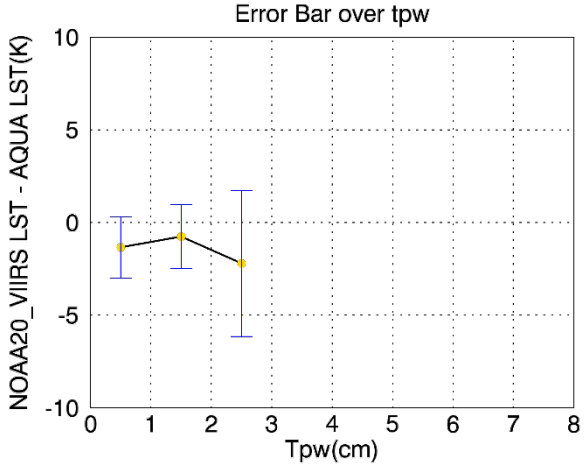






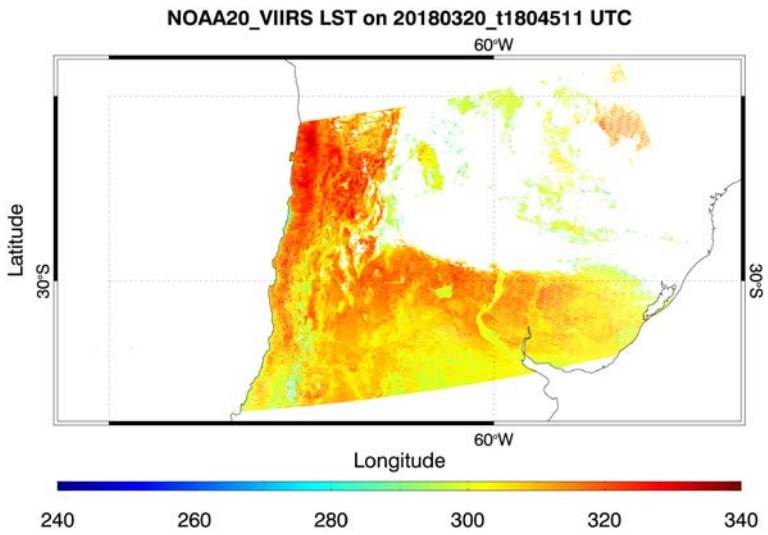


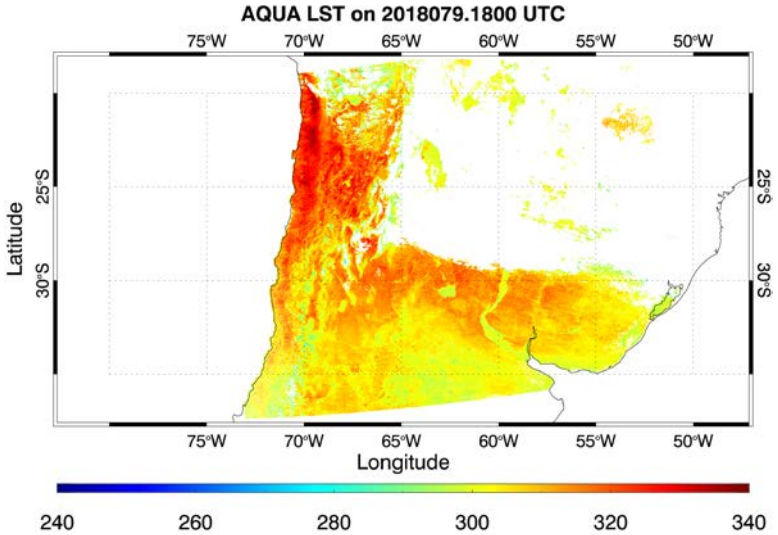


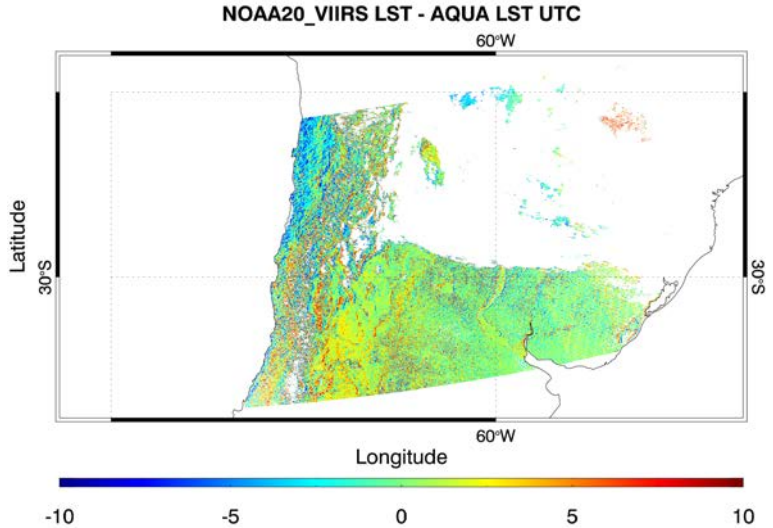


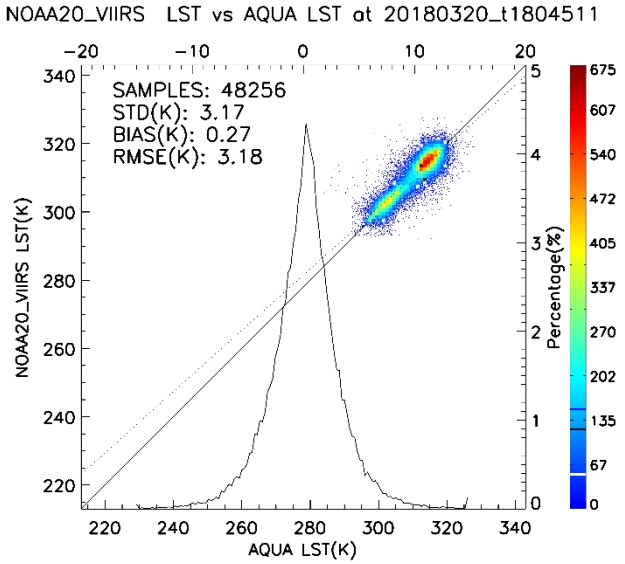
NOAA 20 VIIRS LST against AQUA MODIS LST

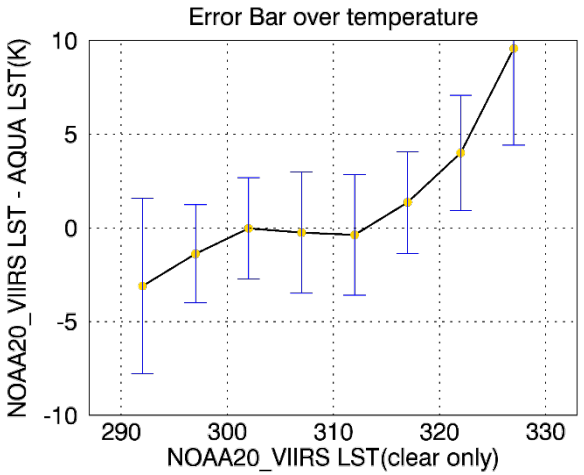
South Africa

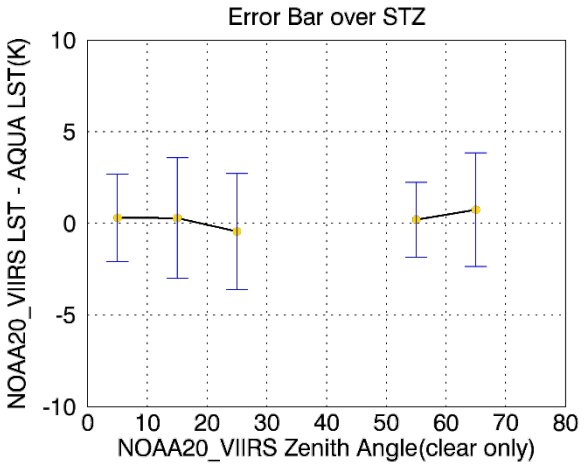


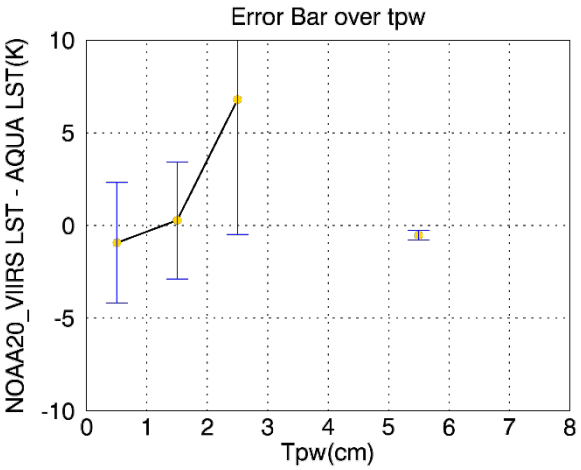






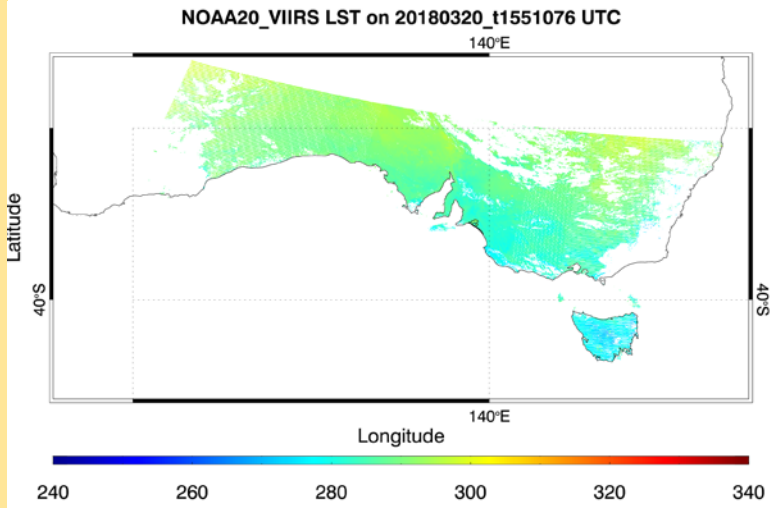


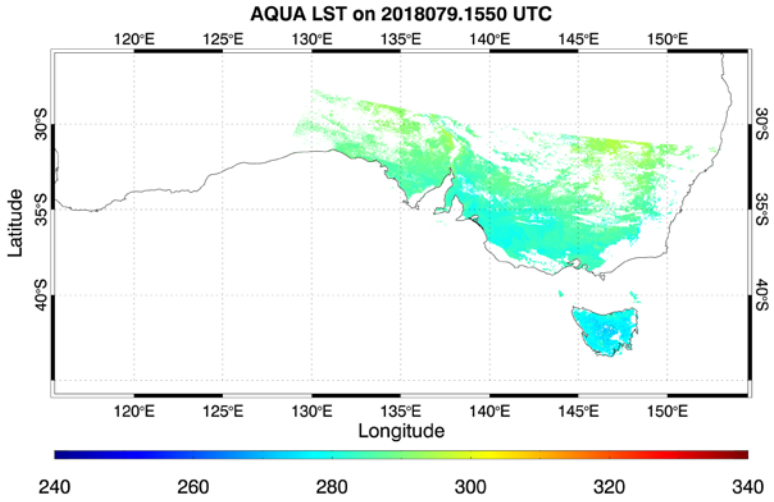


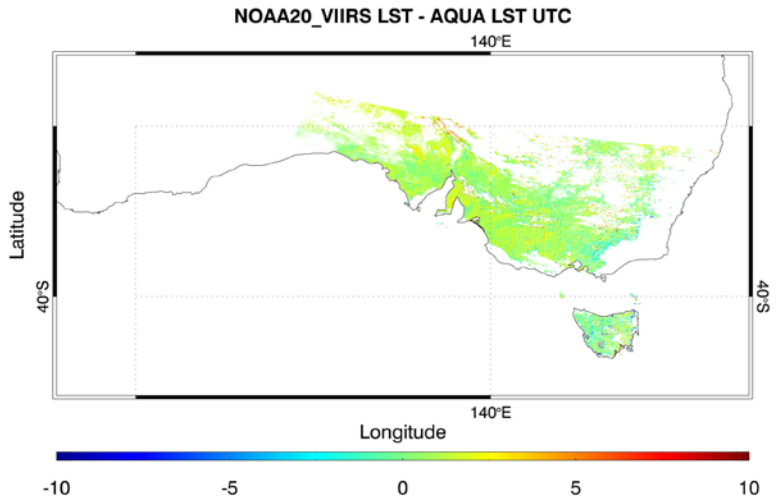


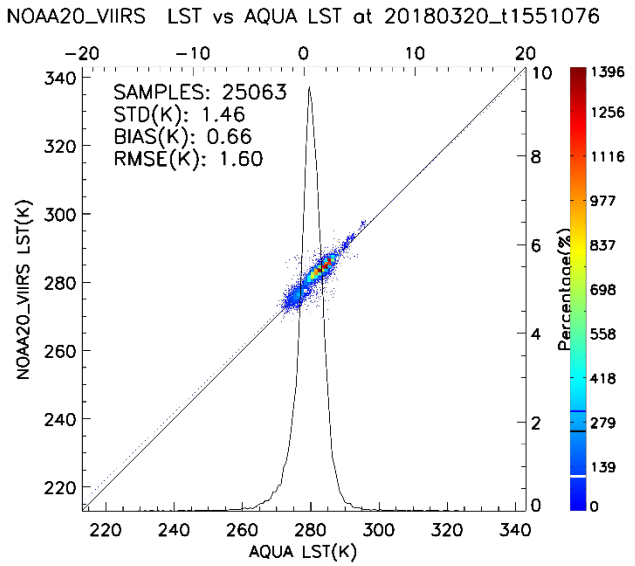
NOAA 20 VIIRS LST against AQUA MODIS LST

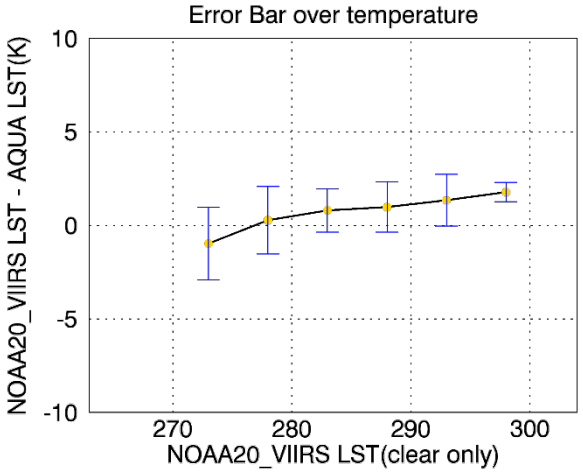
Australia

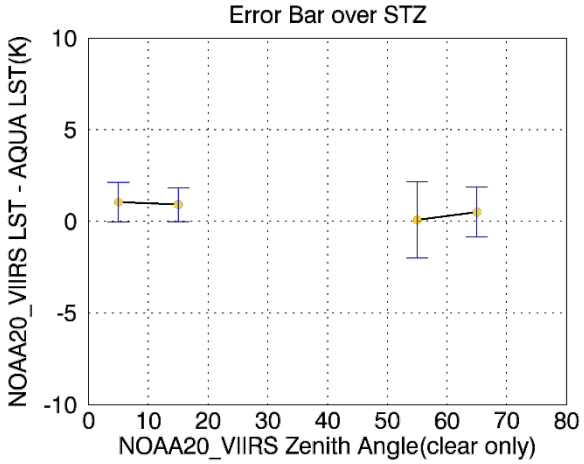


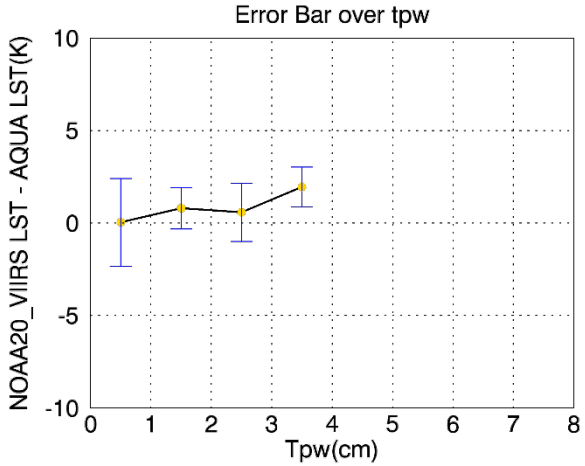






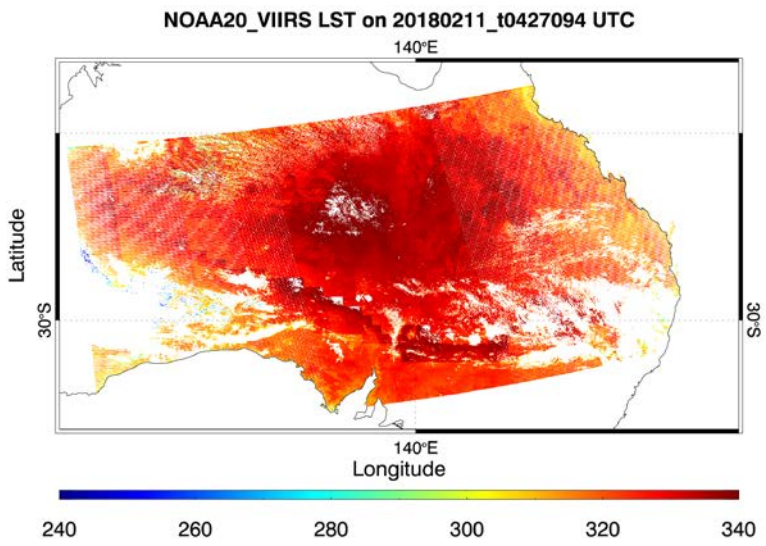


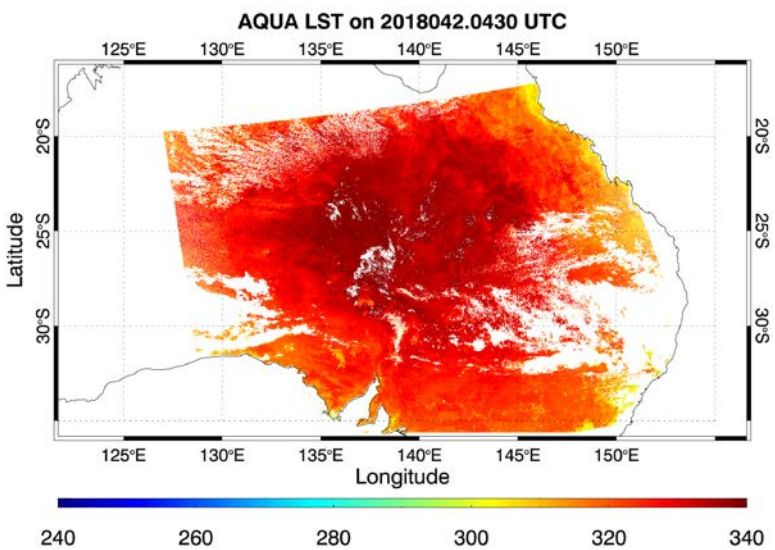


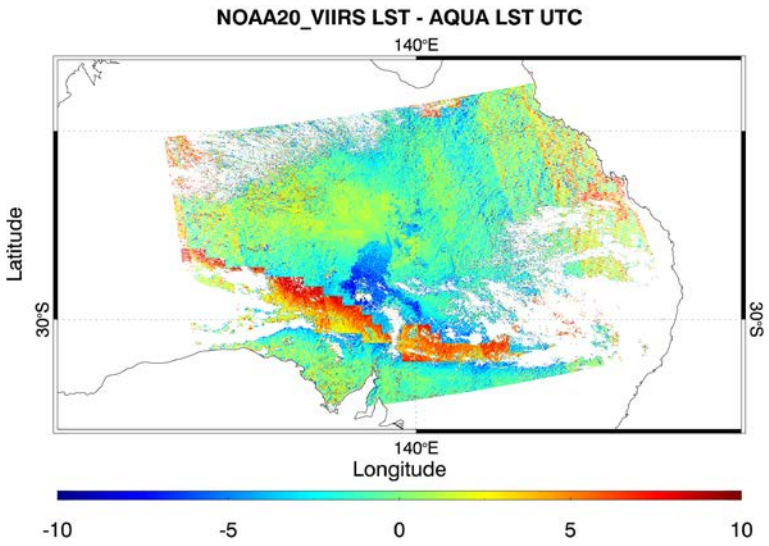


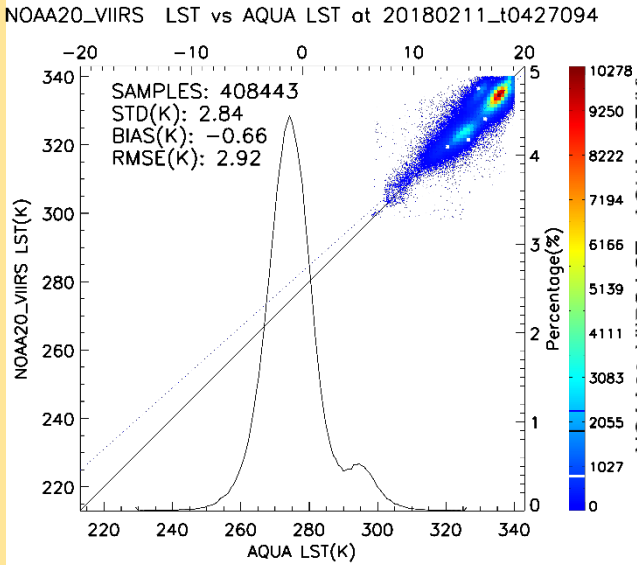
NOAA 20 VIIRS LST against AQUA MODIS LST

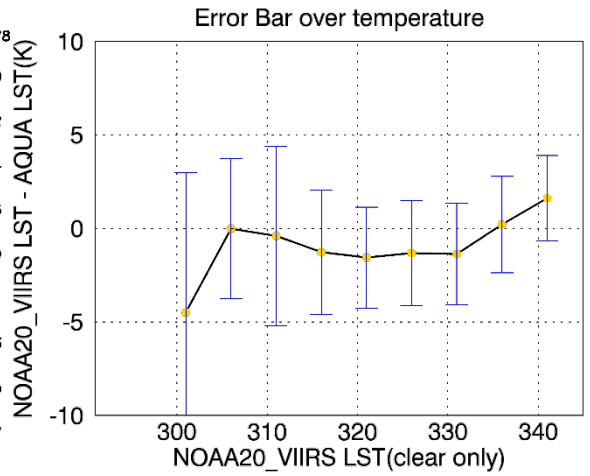
Australia

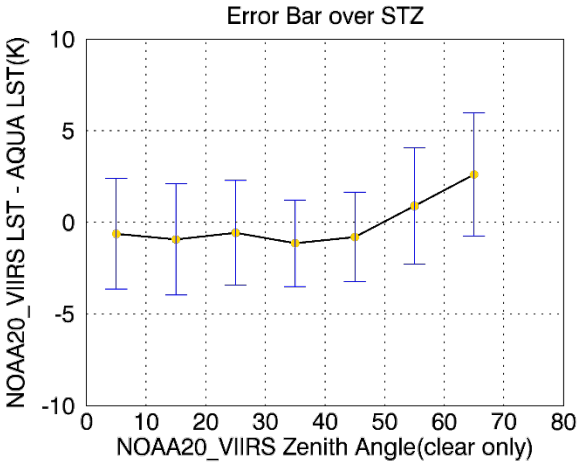


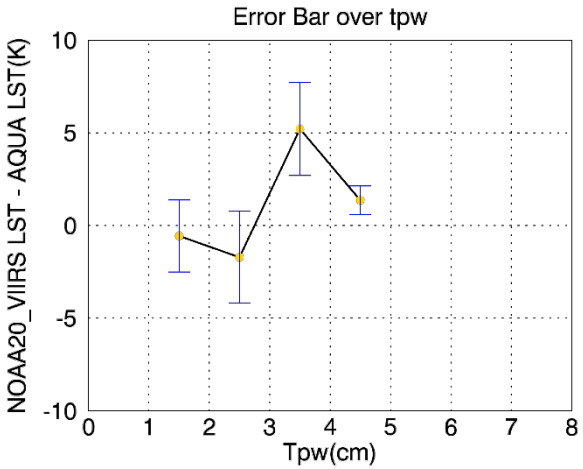






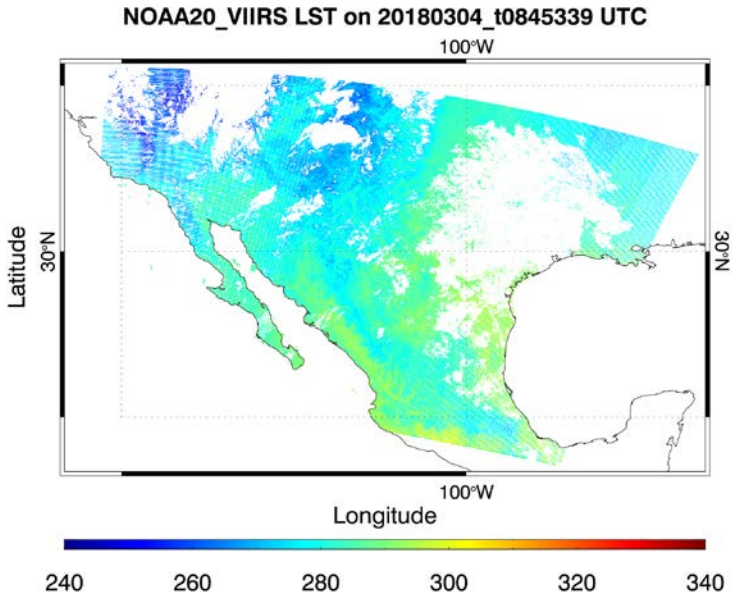


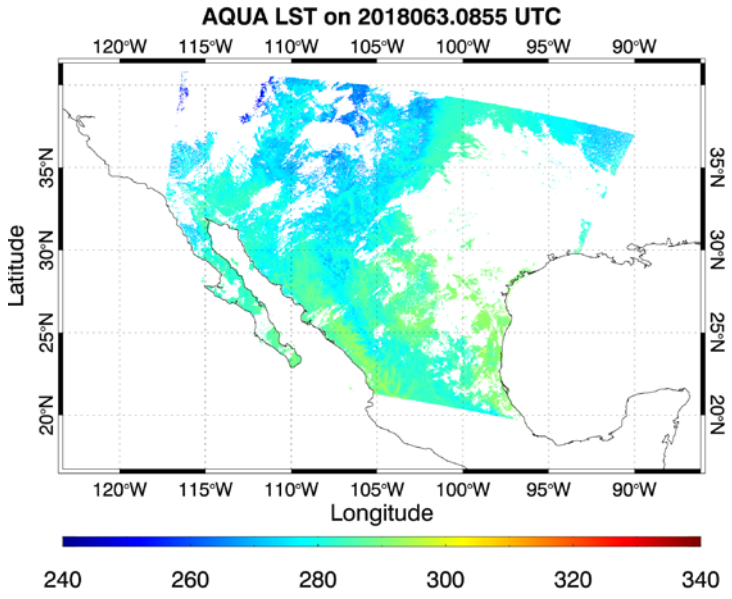


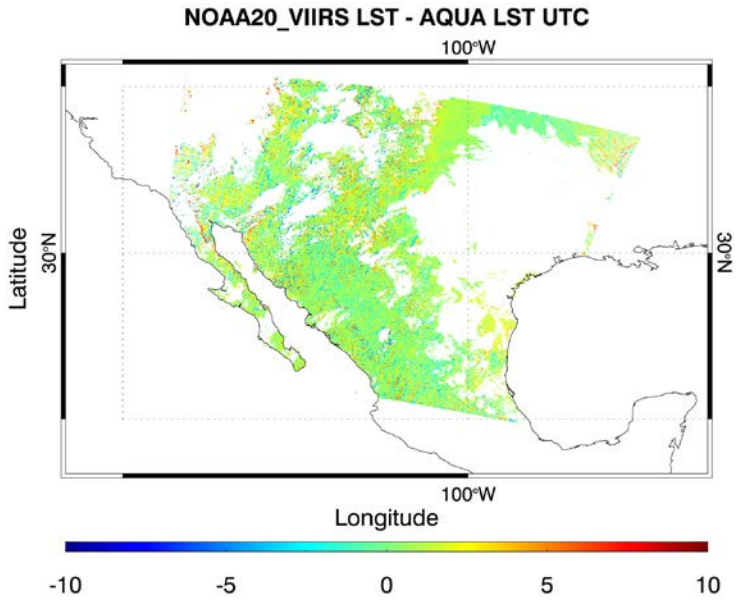


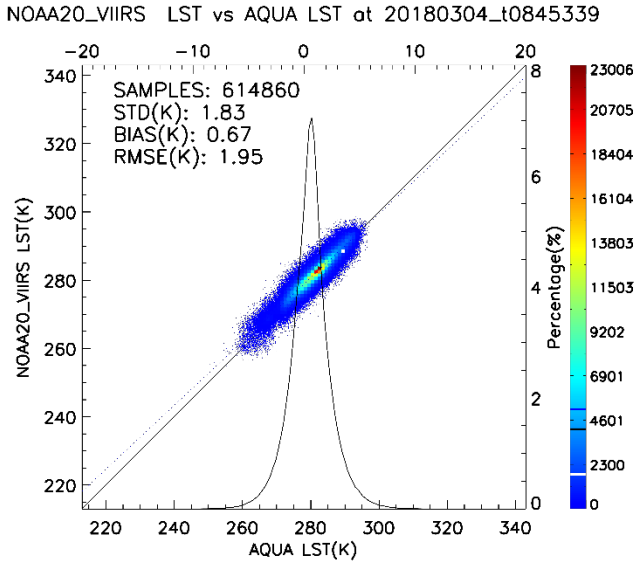
NOAA 20 VIIRS LST against AQUA MODIS LST

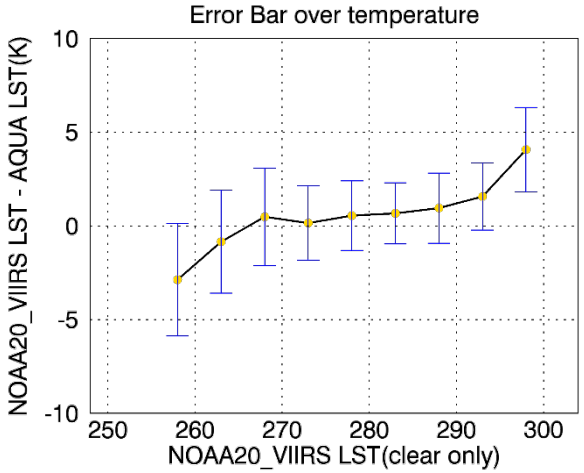
US

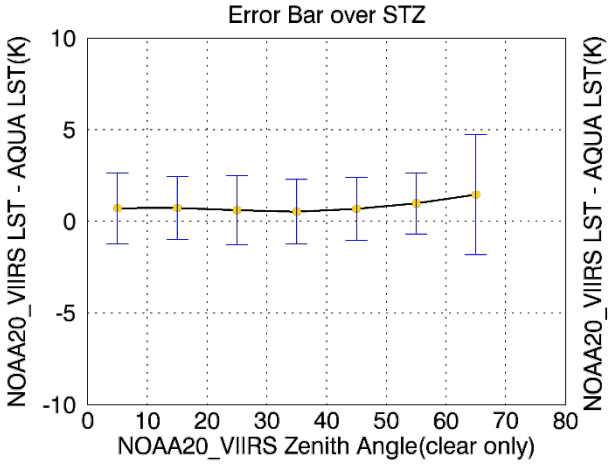


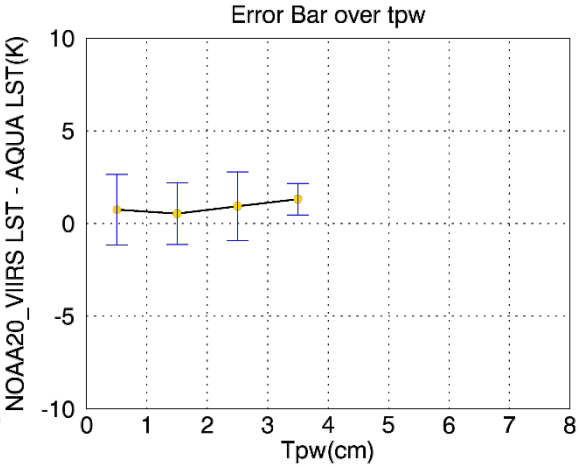






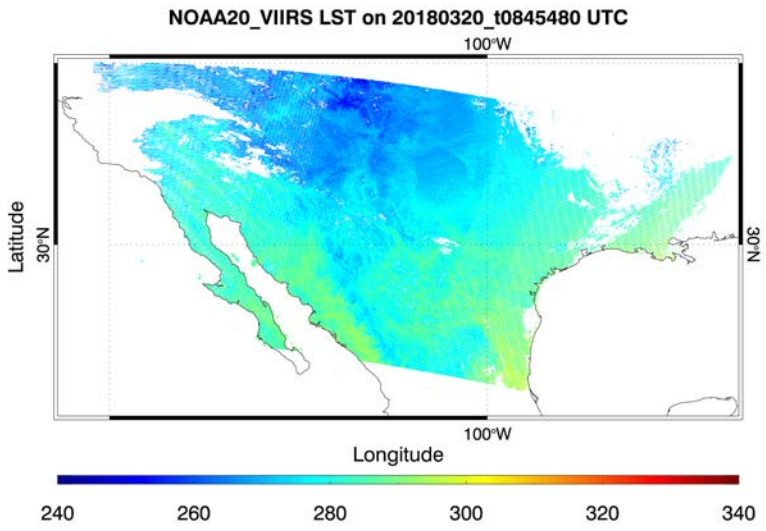


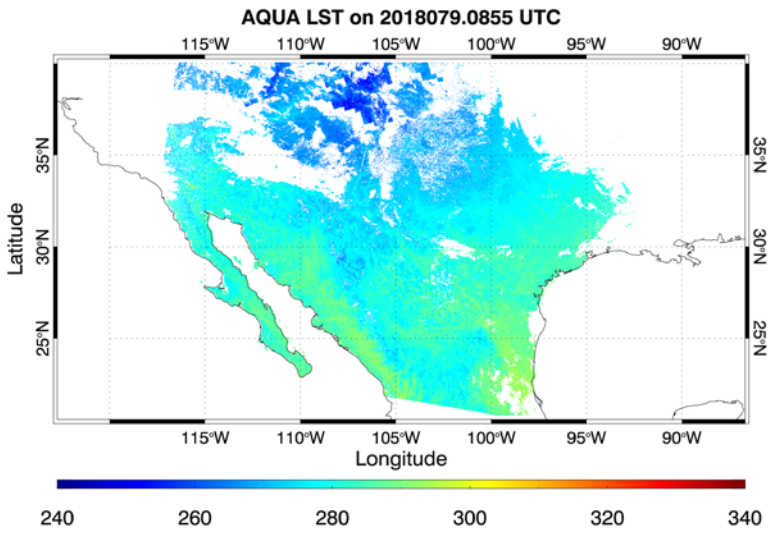


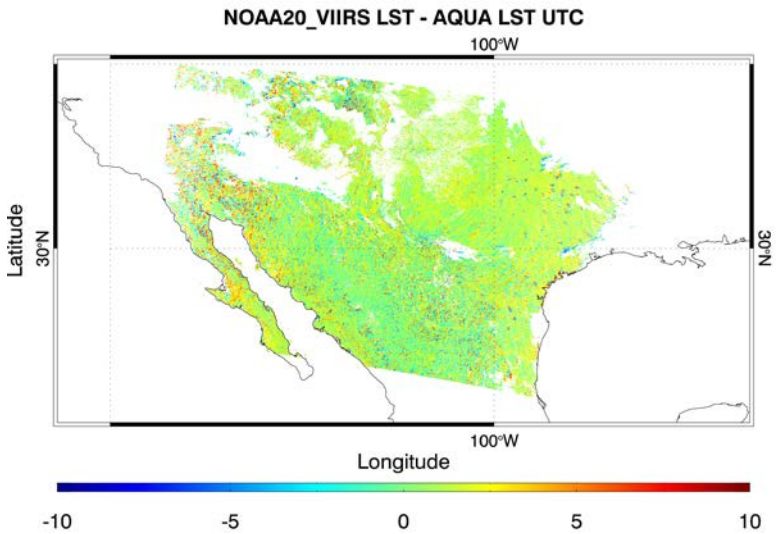


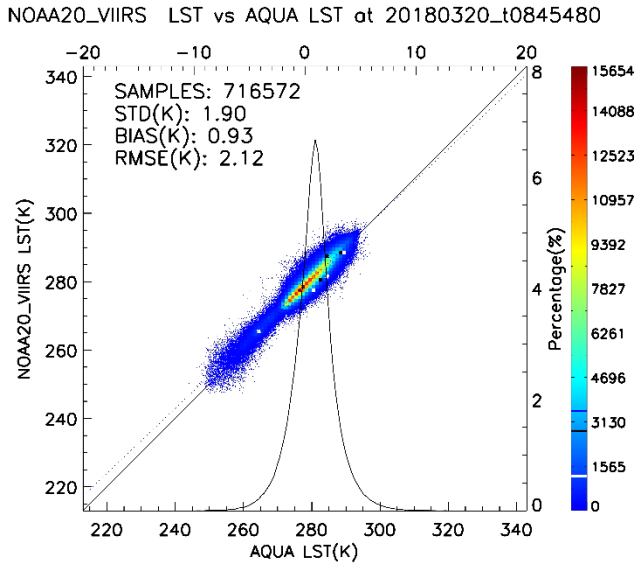
NOAA 20 VIIRS LST against AQUA MODIS LST

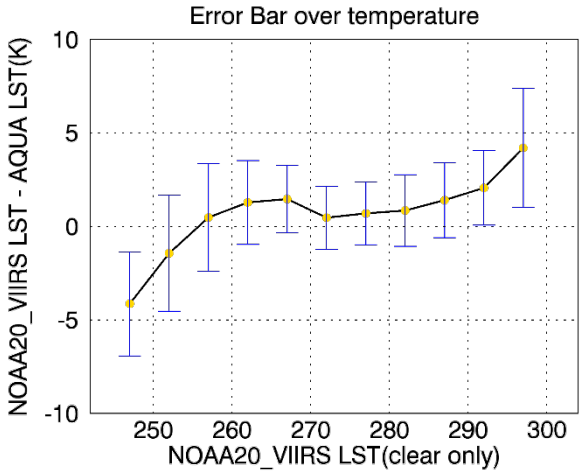
North America

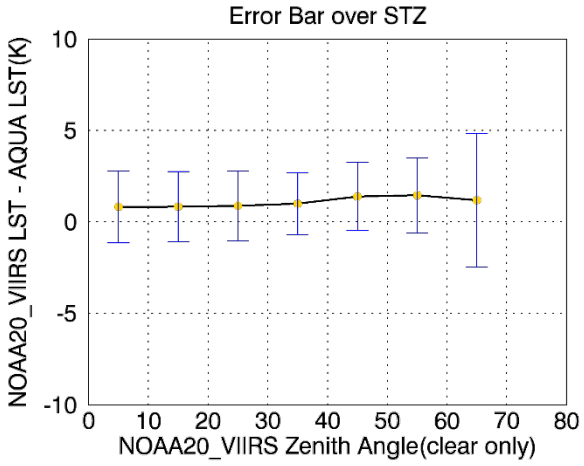


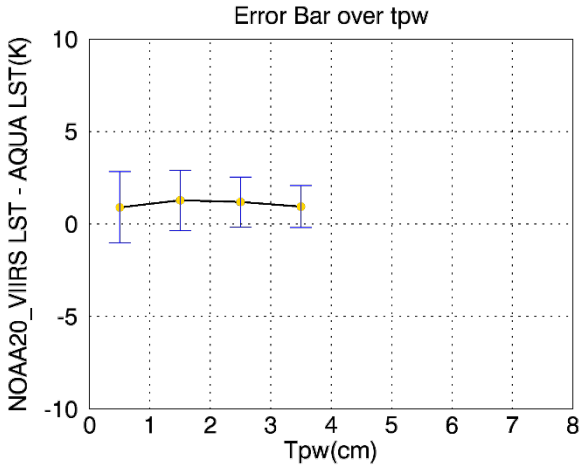






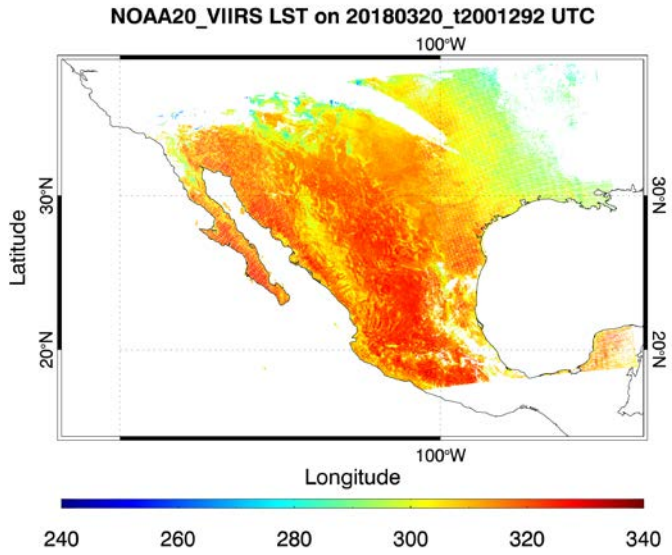


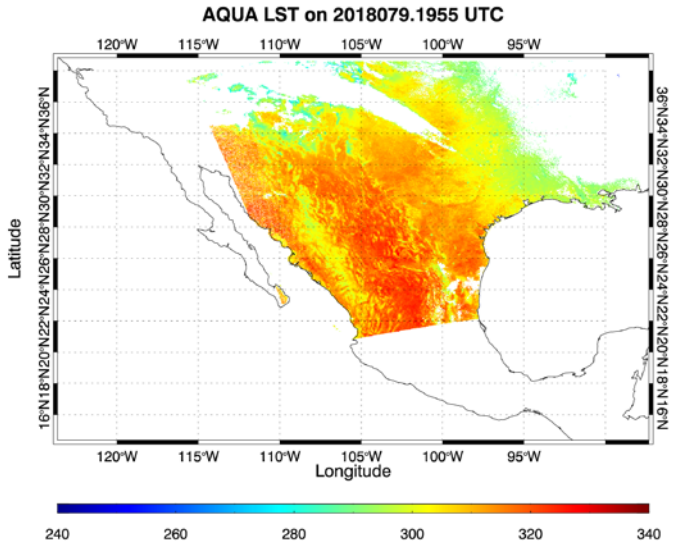


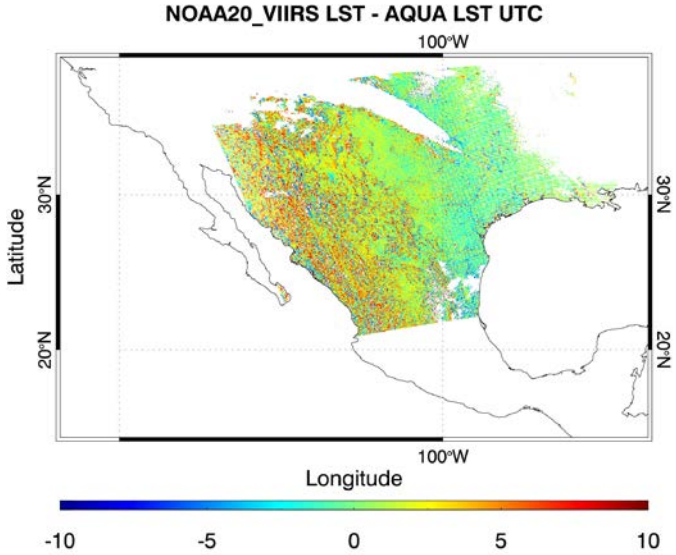


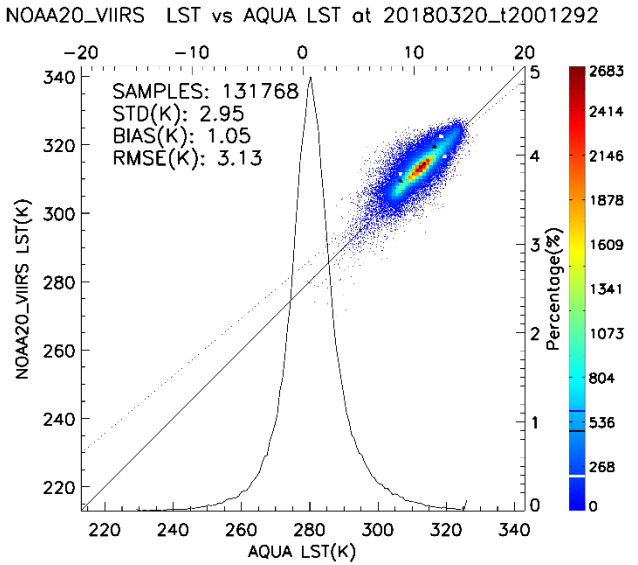
NOAA 20 VIIRS LST against AQUA MODIS LST

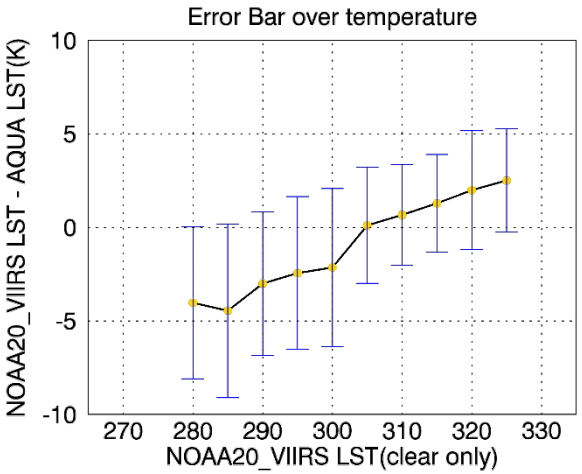
North America

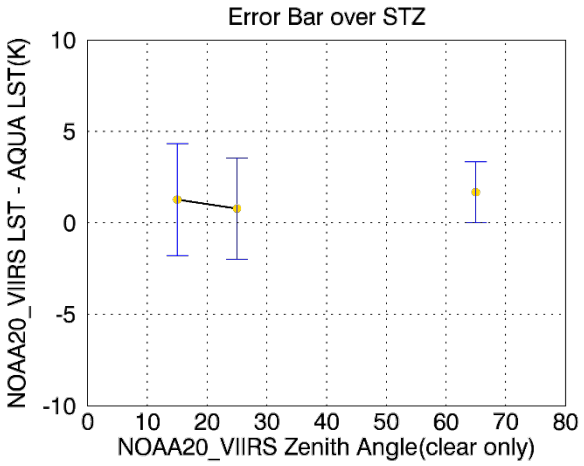


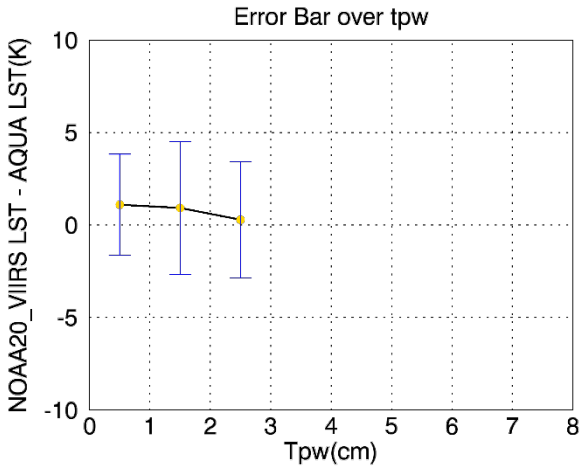






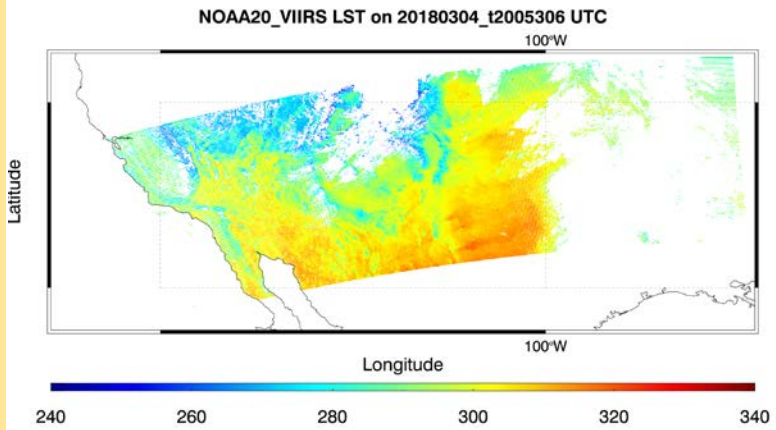


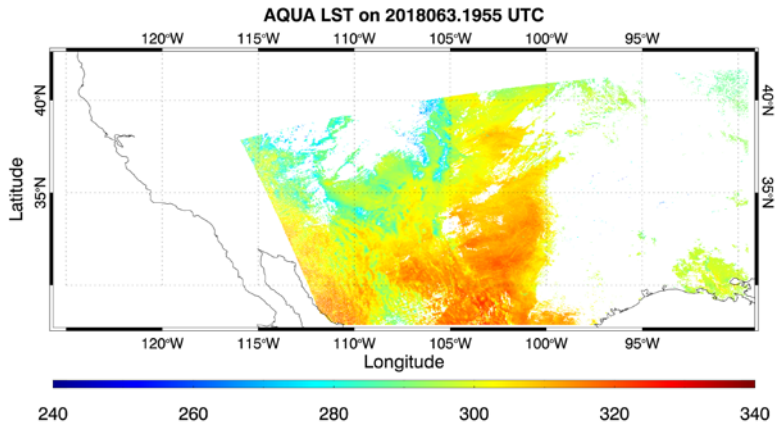


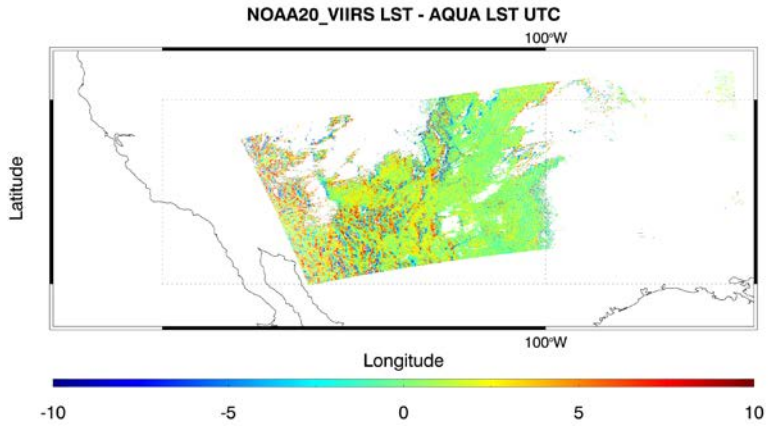


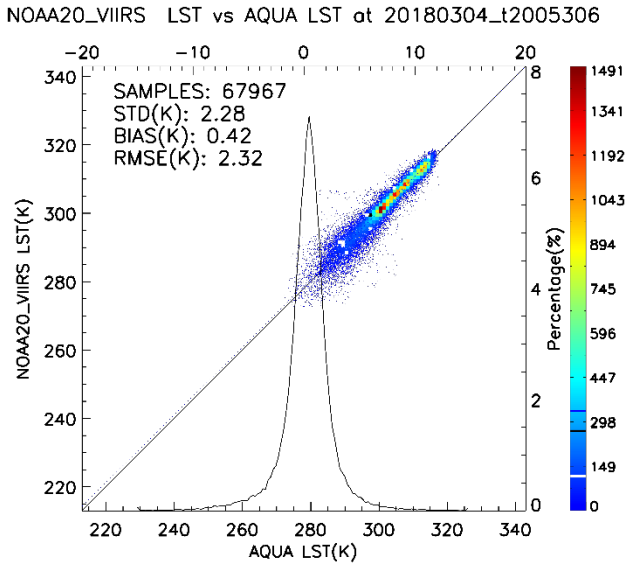
NOAA 20 VIIRS LST against AQUA MODIS LST

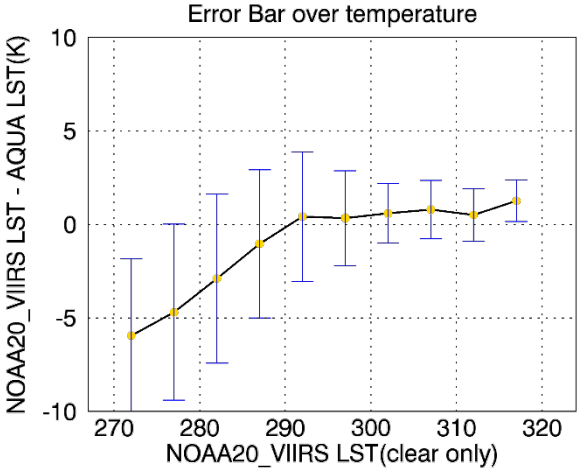
US

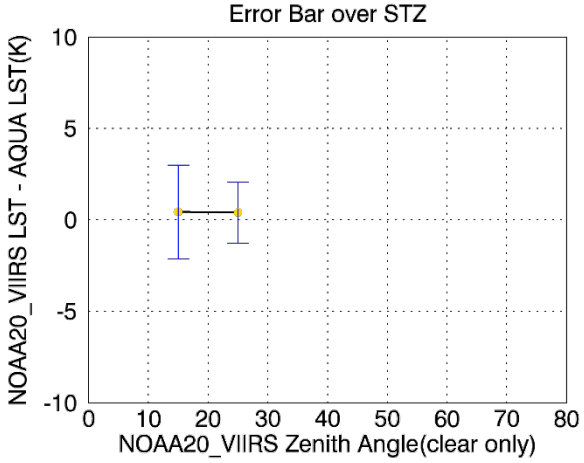


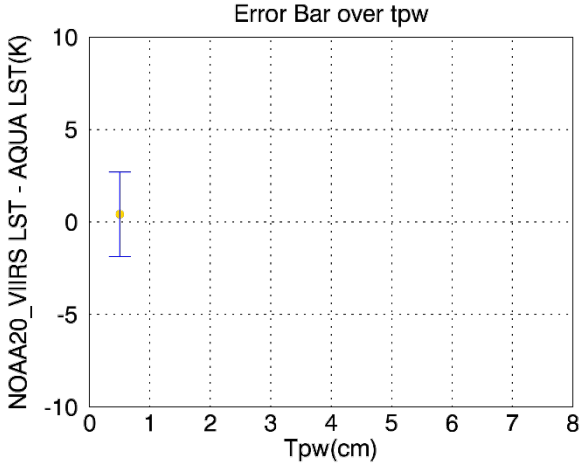






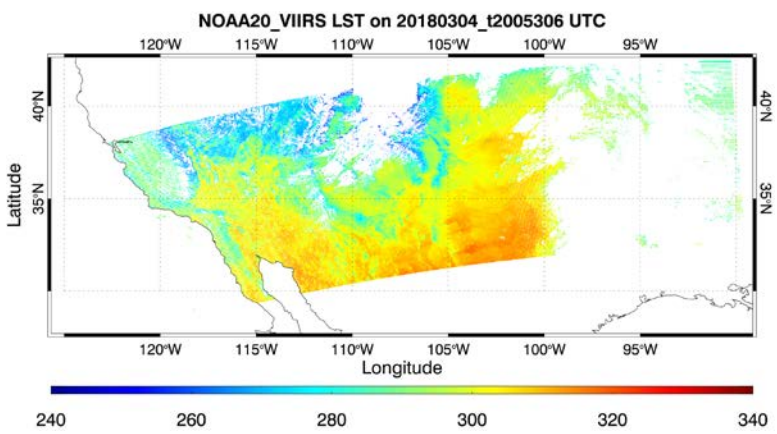


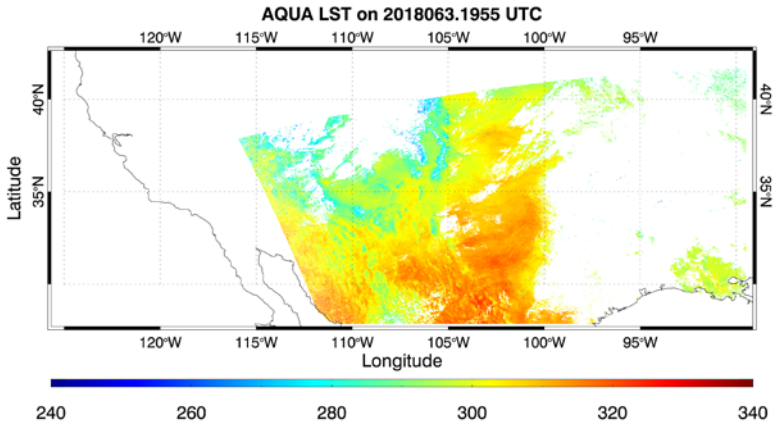


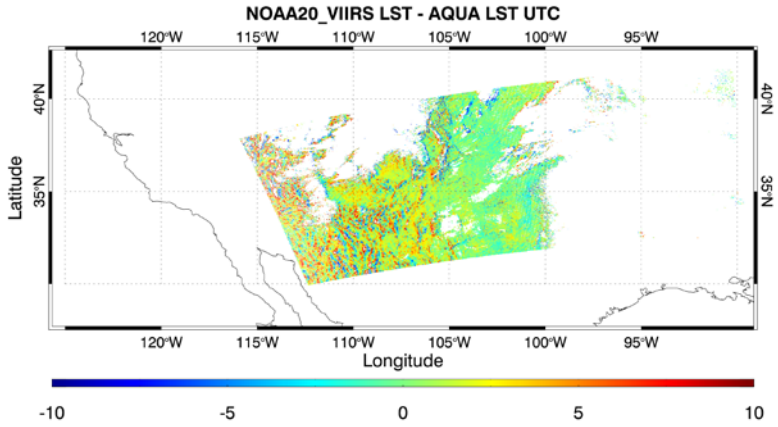


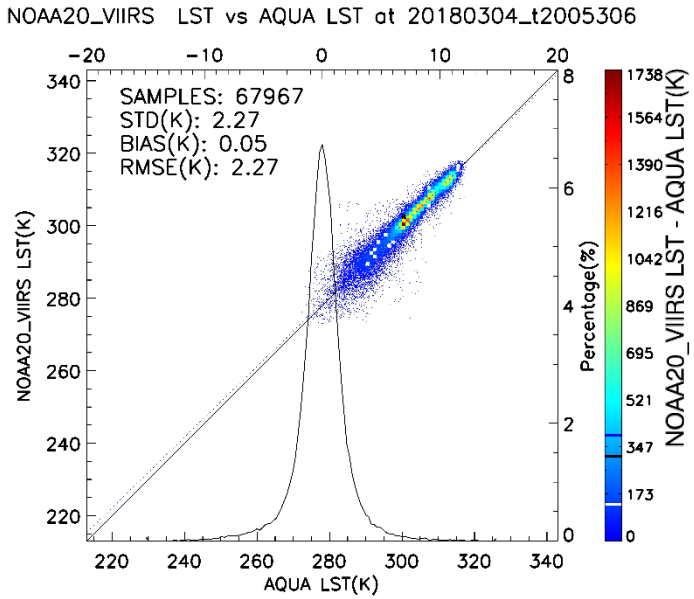
NOAA 20 VIIRS LST against AQUA MODIS LST

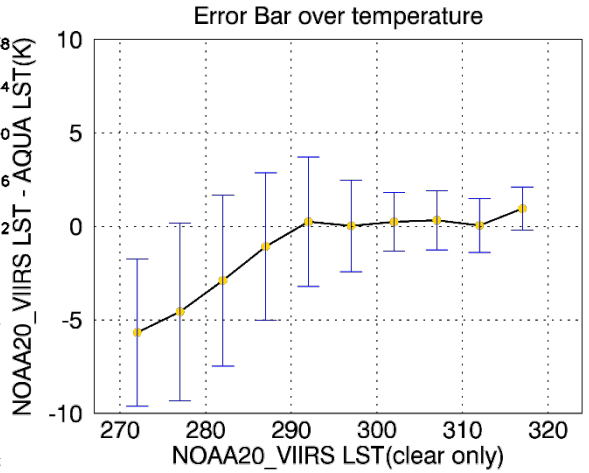
US

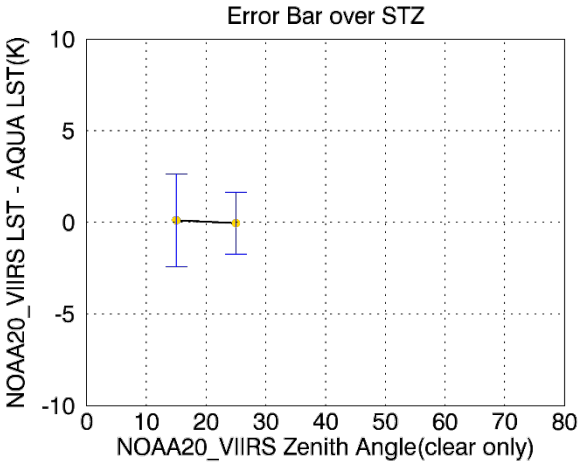


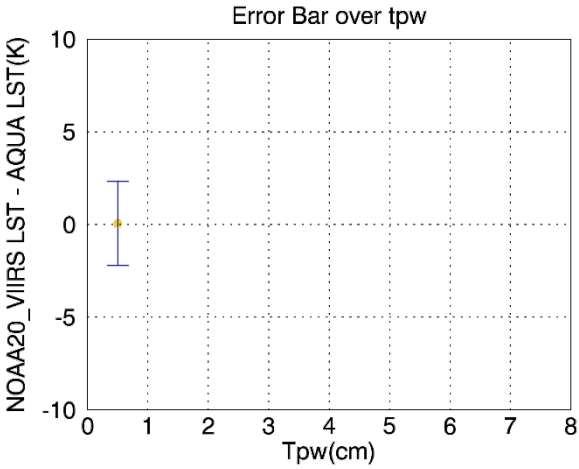






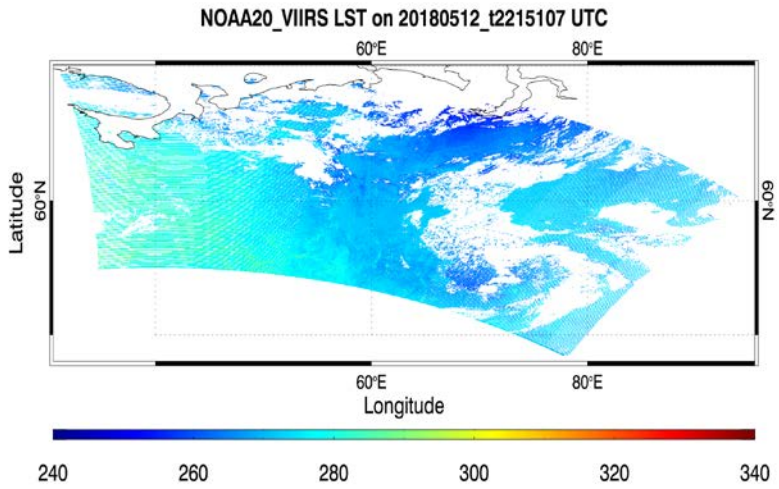


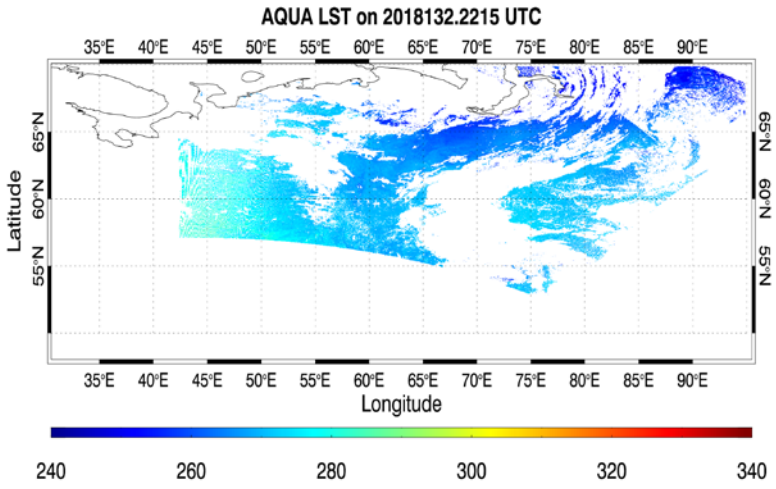


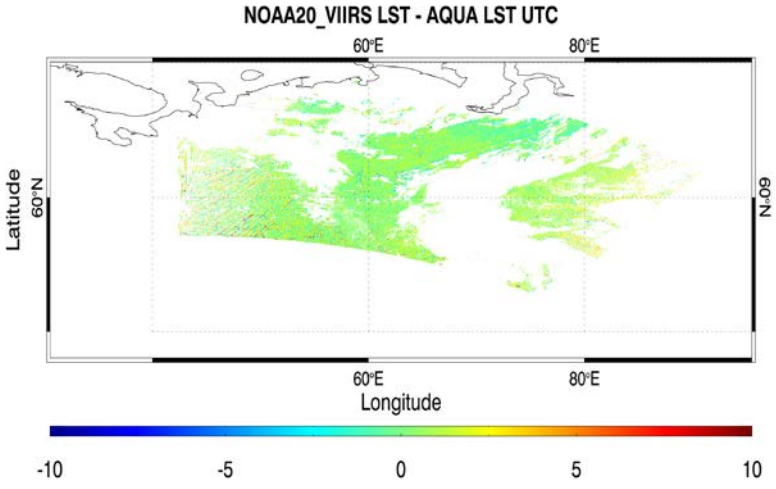


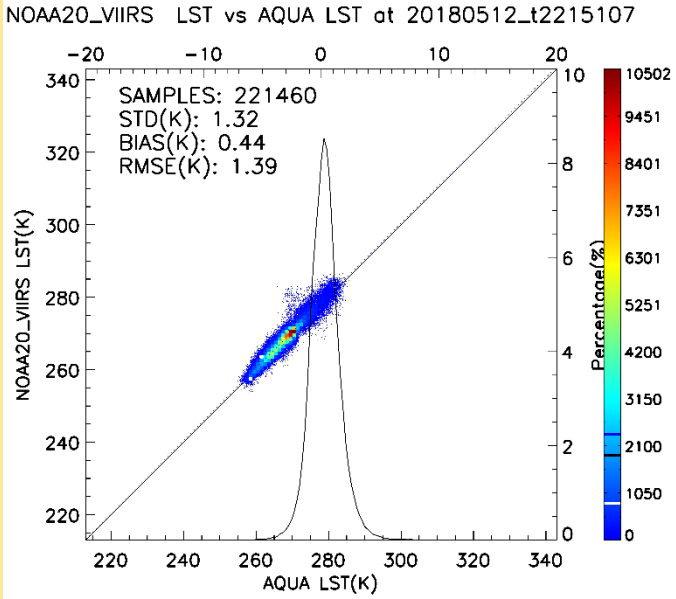
NOAA 20 VIIRS LST against AQUA MODIS LST

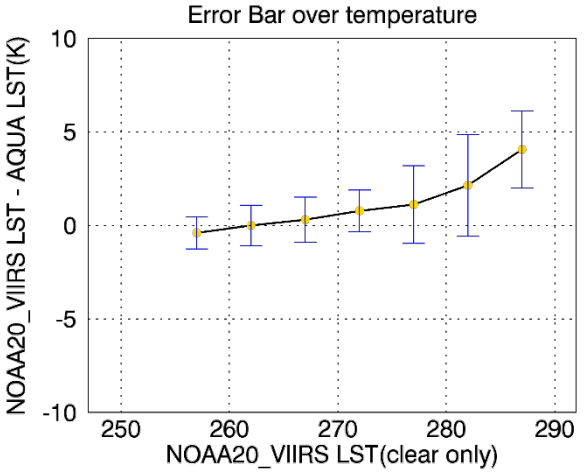
Mid-north Asia

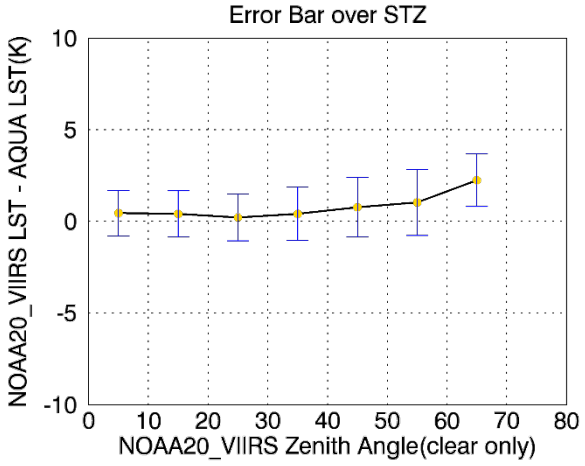


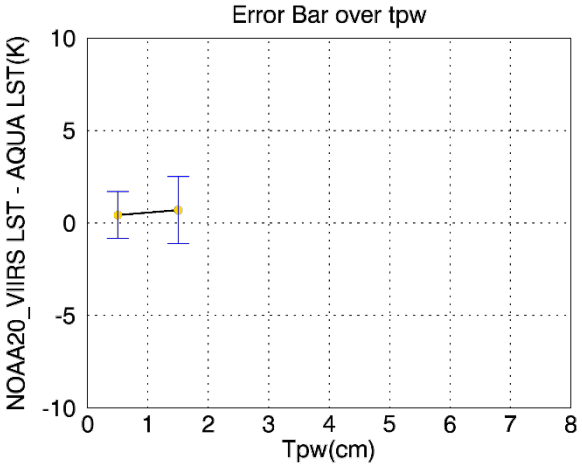






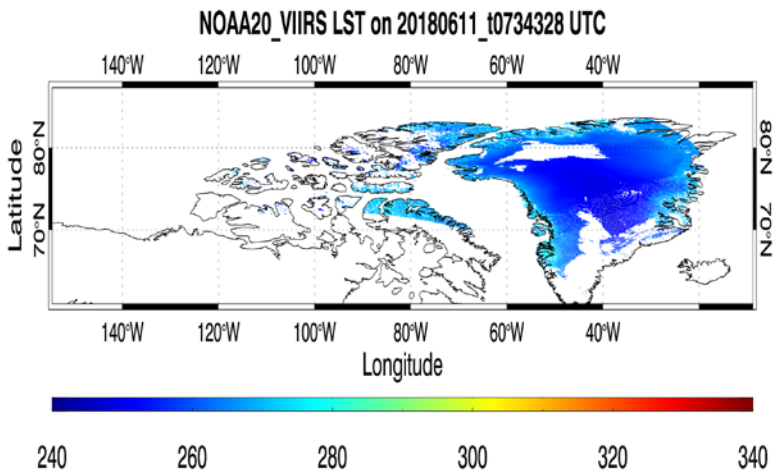


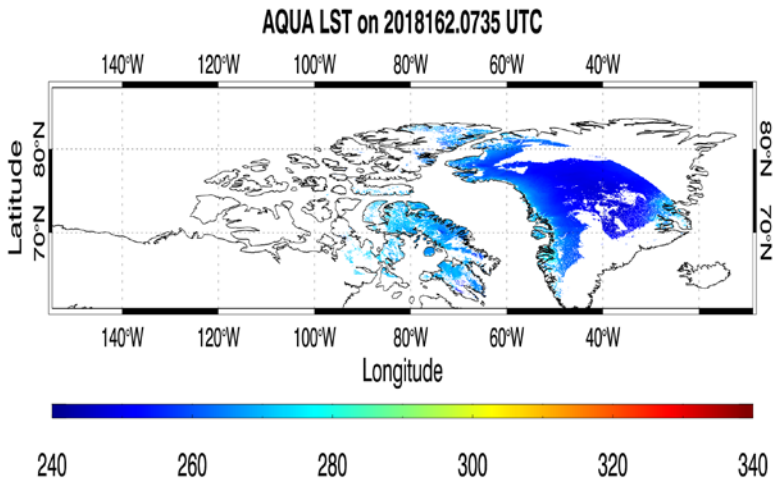


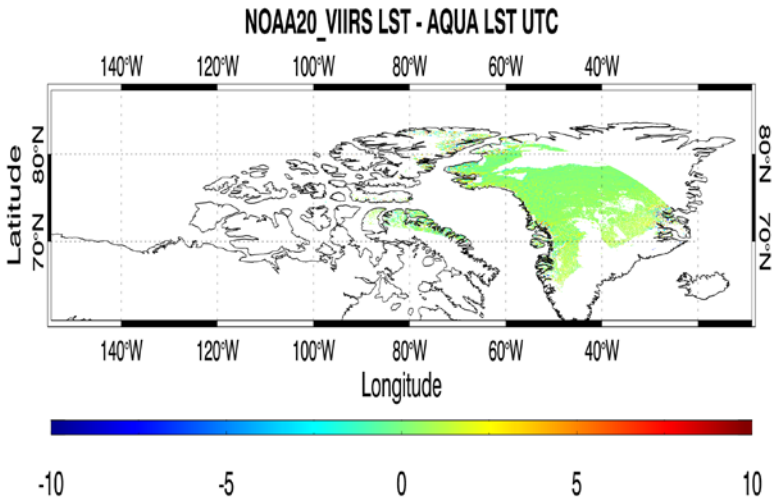


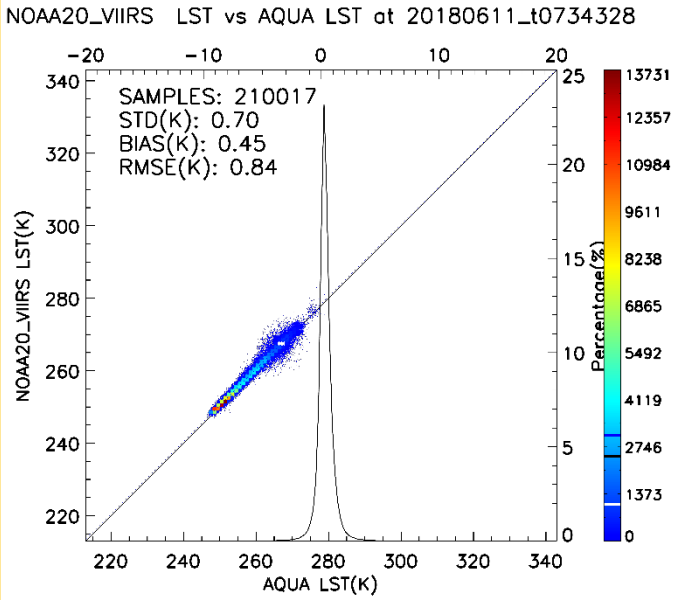
NOAA 20 VIIRS LST against AQUA MODIS LST

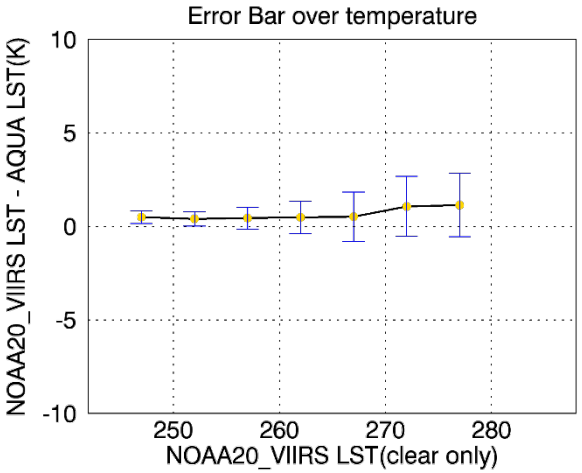
Greenland

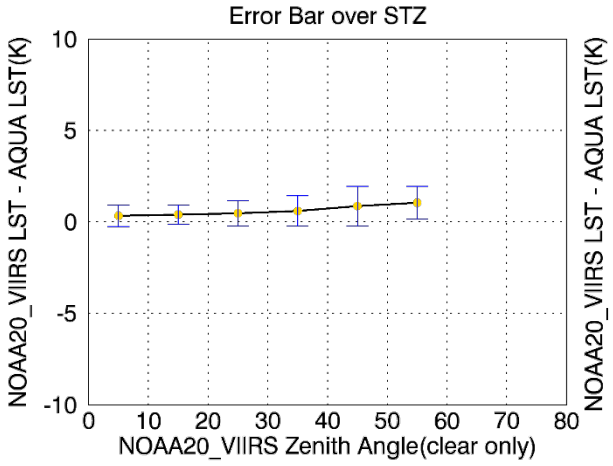


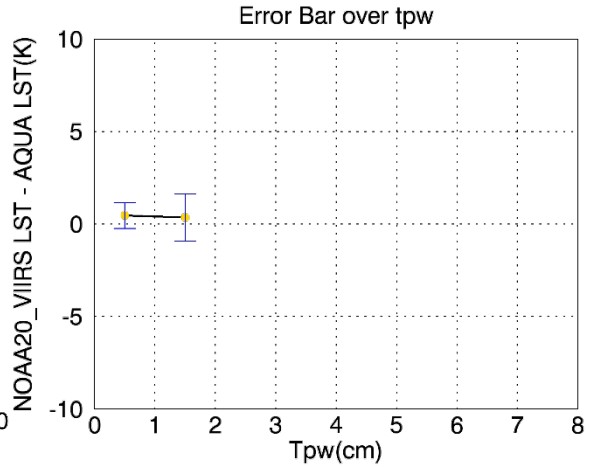






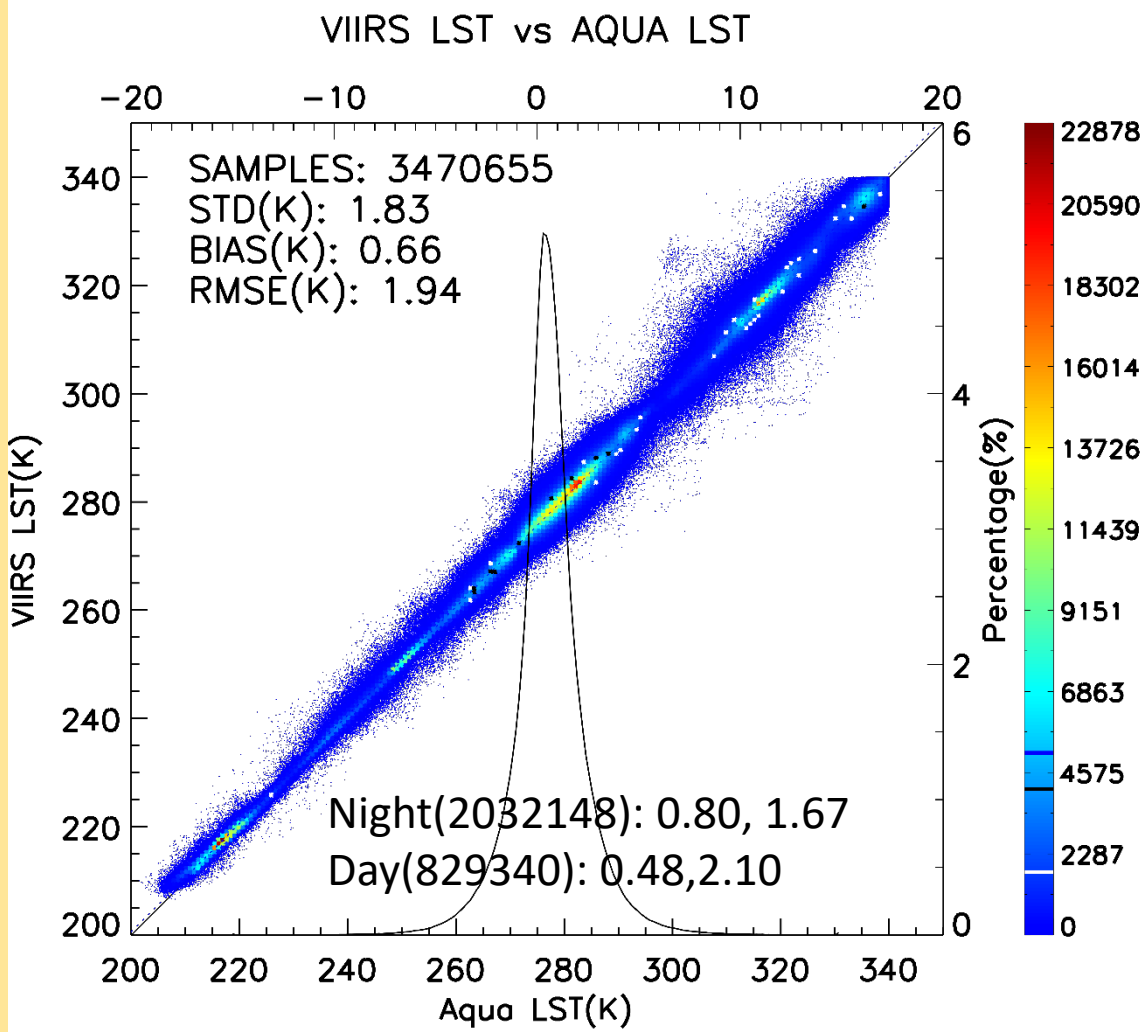


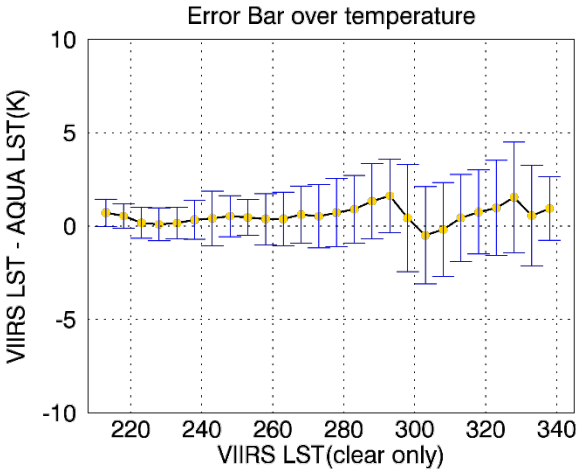


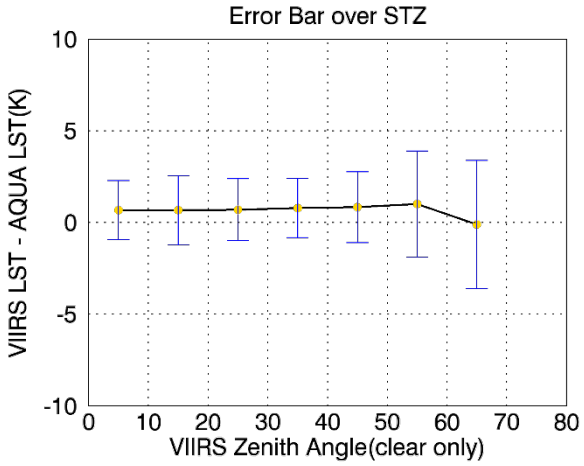


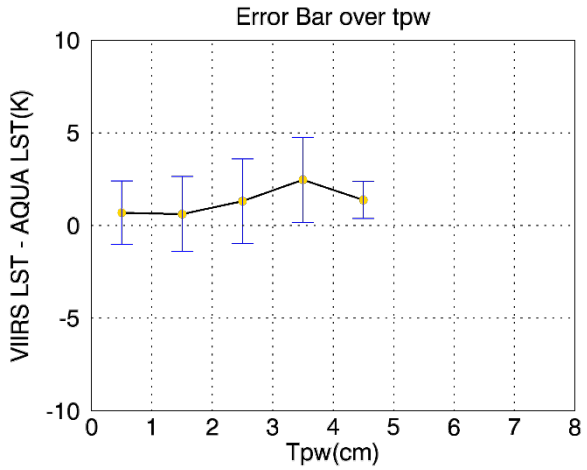
Cross comparison with AQUA MODIS LST

Overall





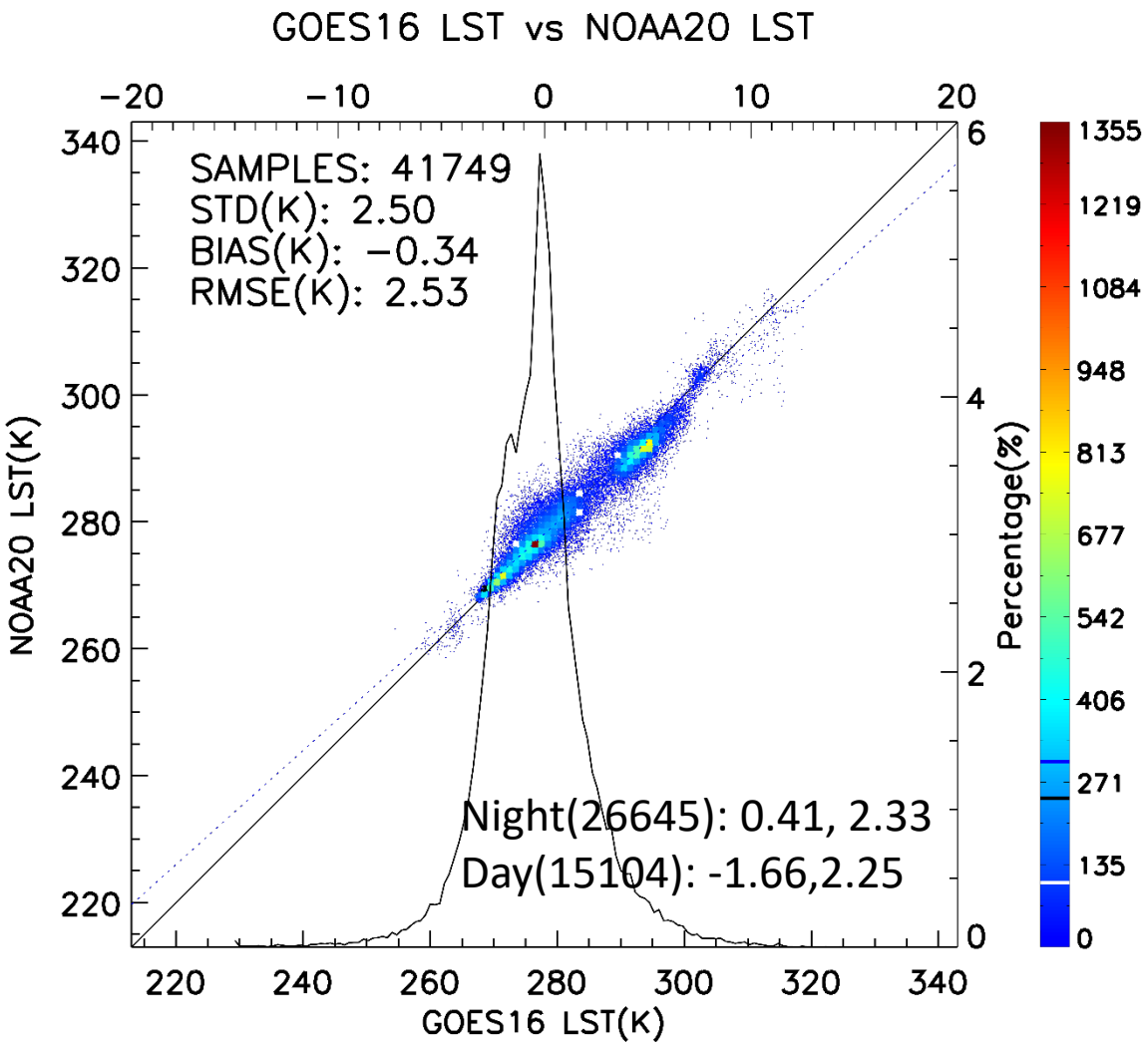




Lat	Samples	Bias	std
-90~-60	389897	0.48	0.77
-60~-30	63110	0.47	2.46
-30~0	149760	0.73	2.61
0-30	1003389	0.78	2.11
30-60	750284	0.92	1.85
60-90	505048	0.43	1.10

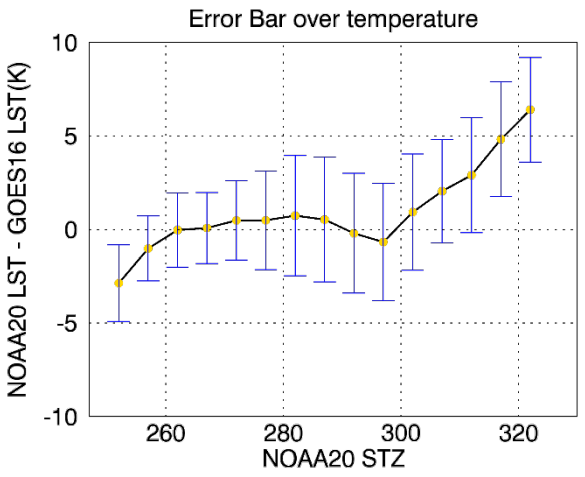
Cross comparison with GOES16 LST

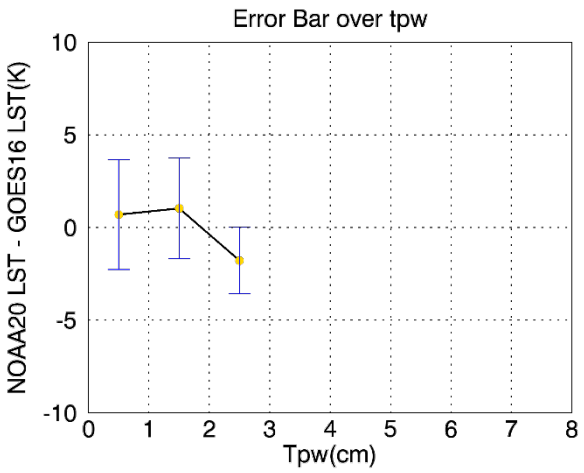
US

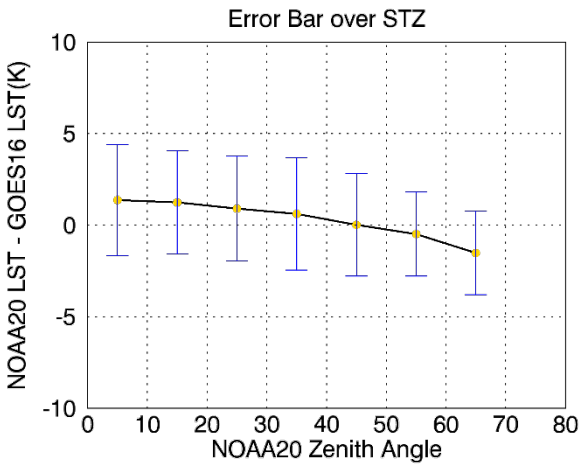


Match up criteria:

- 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: 1.7K (3.5K) TBL: -0.1K (1.9K) DRA:-2K (1.5K) FPK: -0.2K (2.0K) GWN: 0.03 (3.5K) PSU: 0.7K (2.0K) SXF: -0.3K (2.4K)	The error statistics is based on the validation against SURFRAD measurements for the time period from Jan. 05- June 21 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 0.66(1.83) Daytime: 0.48(2.1) Nighttime:0.8,1.7	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 low US, Australia, Africa, and Greenland only. It is also limited by the spatial and temporal difference, sensor difference, angle difference etc.
		GOES-16: -0.3K (2.5K) Daytime: -1.7K (2.3 K) Nighttime: 0.4K (2.3K)	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.

Beta Maturity Conclusions

- NOAA-20 LST Product has been verified and preliminarily validated. The product is suggested being released as beta maturity version.
- Some issues and problems are found that will be solved or improved for the provisional release:
  - Data errors have been observed due to upstream data error: data missing, suspicious line in certain areas, wrong criteria set for probably clear pixels.
  - LST discontinuity is observed over Australia area for daytime case. The mitigation includes the update of the LUT and LUT interpolation.
  - Performance over cropland cover may downgrade in growing season, e.g. May and June due to the exposure of the barren soil in satellite FOV.
  - Results of the cross comparison to AQUA MODIS LST and GOES 16 ABI LST vary over region and day/night; further analysis is needed.

Check List - Beta Maturity

Beta Maturity End State	Assessment
Product is minimally validated, and may still contain significant identified and unidentified errors	Yes. Note that the LST for validation is calculated in the local environment.
Information/data from validation efforts can only be used to make initial qualitative or very limited quantitative assessments regarding product fitness-for-purpose	Yes. The validation is based on a limited data set and limited time period. The statistics is not significant enough for a sound quantitative evaluation yet.
Documentation of product performance and identified product performance anomalies, including recommended remediation strategies, exists	Yes

Documentations

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

Path Forward/ Future Plan

- Track and fix the problems observed
  - Track the upstream data update
  - Fix the problem with the nighttime LST quality flag due to AOD missing at nighttime
  - LST discontinuity investigation and improvement
- Product refinement
  - ➢ The LUT for the enterprise NOAA 20 LST needs further evaluation and calibration with more data available. The current evaluation only shows its performance in winter, spring and early summer. Year round evaluation is necessary.
  - ➢ The current validation of the enterprise LST is based on the VCM. ECM shall be used when the data is available.
  - ➢ The preliminary validation shows that the performance over some sites is beyond the requirement. Further analysis and improvements are needed.
  - ➢ Further studies are needed for the LST retrieval under high temperature and moist conditions
- Global /Comprehensive Validation
  - Monitoring tool
  - Global in situ data collection
  - Extend the cross satellite comparisons. (MODIS, 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 Review !