

***Beta Maturity Science Review
For NOAA-21 VIIRS LST Algorithm***



***Prepared by Yuling Liu
and Yunyue Yu
Date:08/02/2023***

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

1. Beta

- 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.



BETA MATURITY REVIEW MATERIAL

- Algorithm Cal/Val Team Members
- Product Overview/Requirements
- Evaluation of algorithm performance to specification requirements
 - Algorithm version, processing environment
 - Evaluation of the effect of required algorithm inputs
 - Quality flag analysis/validation
 - Error Budget
- User Feedback
- Downstream Product Feedback
- Risks, Actions, and Mitigations
- Documentation (Science Maturity Check List)
- Conclusion
- Path Forward

	Name	Organization	Major Task
JSTAR Science	Land Lead: Ivan Csiszar	NOAA/NESDIS/STAR	Project Management
	EDR Lead: Yunyue Yu	NOAA/NESDIS/STAR	Team management, algorithm development, validation advises
	Yuling Liu	NOAA Affiliate, UMD/CISESS	product monitoring and validation ; algorithm development/improvement
	Heshun Wang	NOAA Affiliate, UMD/CISESS	algorithm improvement, product calibration/validation
	Peng Yu	NOAA Affiliate, UMD/CISESS	product validation tool, monitoring, applications
JSTAR ASSIST	Michael Butler	NOAA/NESDIS/STAR	STAR ASSIST Lead
	Mingming Yao	NOAA Affiliate, ProTech/IMSG	STAR ASSIST, Algorithm System integration
	Eric Buzan	NOAA Affiliate, ProTech/IMSG	STAR ASSIST, Algorithm System integration
	Wilson, Michael	NOAA Affiliate, ProTech/IMSG	STAR ASSIST, Framework DAP delivery
NOAA/EMC	Michael Barlage	NOAA/EMC/NCEP	user readiness
	Fanglin Yang	NOAA/EMC/NCEP	user readiness
	Weizhong Zheng	NOAA Affiliate	user readiness
	Helin Wei	NOAA Affiliate	user readiness
NOAA/OSPO	Hanjun Ding	NOAA/NESDIS/OSPO	NDE operational Land Lead
	Yufeng Zhu	NOAA Affiliate	NDE operational

VIIRS LST Requirements

Product Requirements from JPSS L1RD

Attribute	L2 Granule LST	L3 Gridded LST
Geographic coverage <i>Daily global Gridded Product required recently</i>	At least 90% coverage of the globe every 24 hours (monthly average)	Global coverage
Vertical Coverage		
Vertical Cell Size		
Horizontal Cell Size	0.8 km	0.009 degree
Mapping Uncertainty, 3 Sigma	1 Km at Nadir	
Measurement Range	213 – 343 K	213 – 343 K
Measurement Accuracy(bias)	1.4 K	1.4 K
Measurement Precision(1 sigma)	2.5 K	2.5 K
Refresh rate	Granule	Daily
Latency	96 minutes	30 hours

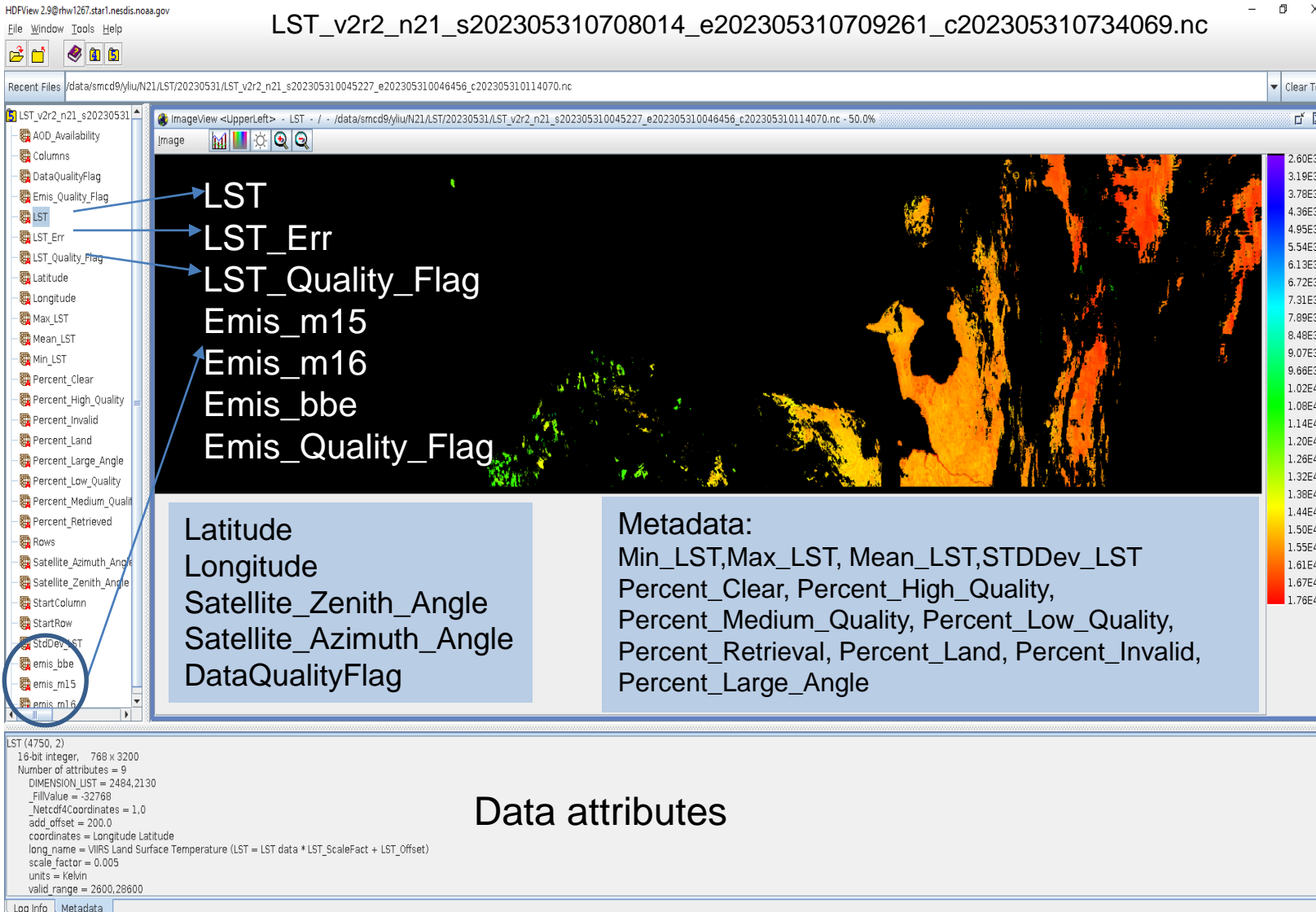
No JSTAR DPS Recommended Update

- Processing environment and algorithms used to achieve the maturity stage
 - Both L2 and L3 NOAA-21 VIIRS LST is included in the beta review.
 - The Enterprise Algorithm version:
 - L2 LST ---- version # v2r2
 - L3 LST ---- version # v1r1.
 - The algorithm LUT is developed based on the NOAA-21 spectral response function released in 2019.
 - Effective date:
 - L2 LST data stream started from May 29th, 2023
 - L3 LST data stream started from June 8, 2023
 - Note:** SNPP and NOAA20 still has the old version of v1r4 and v1r0 in its operational run for L2 and L3, respectively, which results in some differences in the inter-comparison.
 - Evaluation period: from the beginning of the data stream to present

- Algorithm performance evaluation
 - Visual analysis
 - Temperature based validation through the comparison with ground measurements from SURFRAD and ARM network.
 - It covers a month worth of data since the beginning of the data stream. It has global spatial coverage.
 - Long term monitoring tool is available and ready for the test with the ingest of operational NOAA-21 LST.
- Inter-sensor comparison
 - Compare with S-NPP and NOAA-20 LSTs

Visual analysis

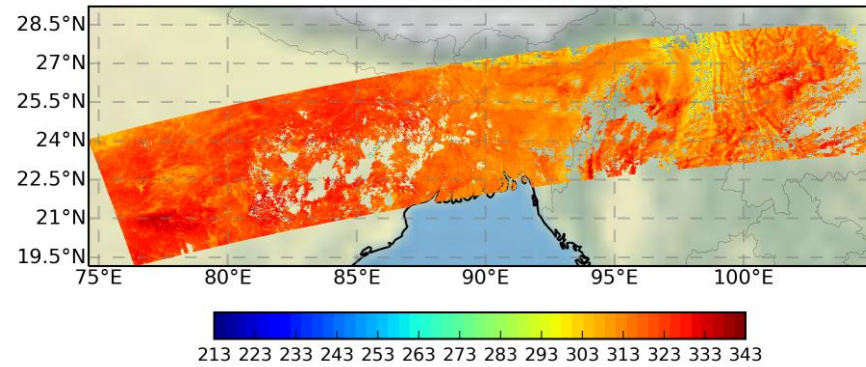
L2 NOAA-21 LST Data Verification



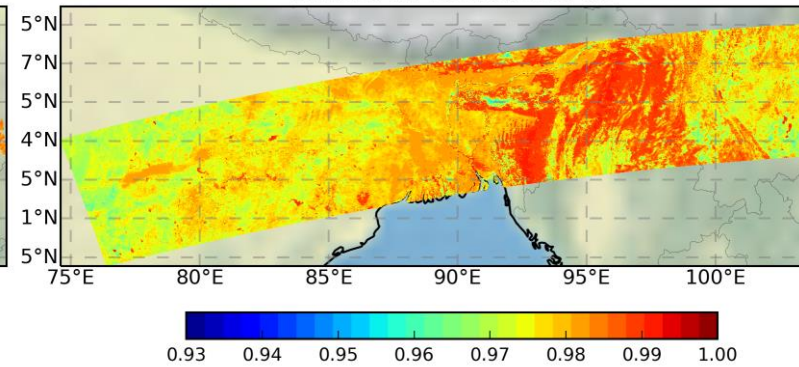
- The output layers as shown in the left figure are complete with valid data range and correct data attributes set. Next slide shows the sample image of the L2 dataset. No issues are observed from the visual verification.
- Global metadata shows some updates with the correct information provided
- In the next slide, the granule LST product data layers were inspected with issues found.

L2 NOAA-21 LST Granule data layers visual analysis

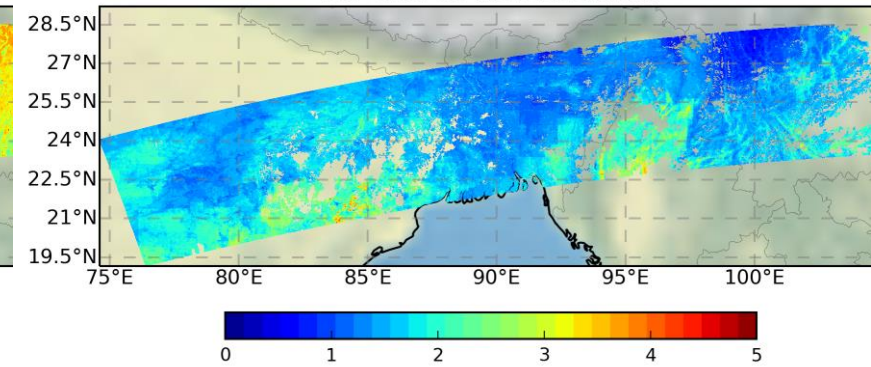
LST on 202305310708



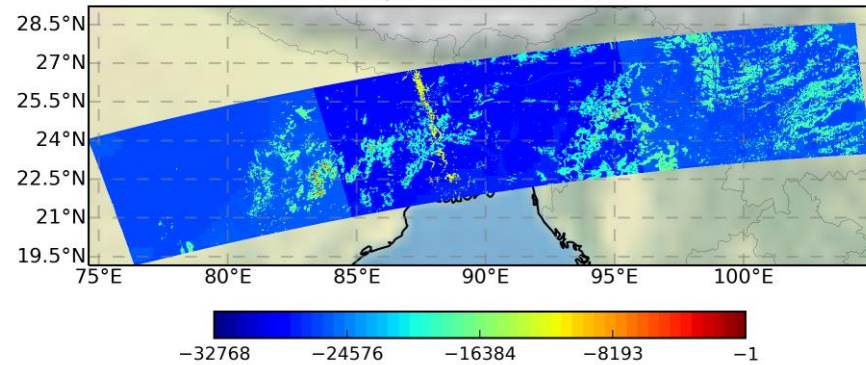
Emis15 on 202305310708



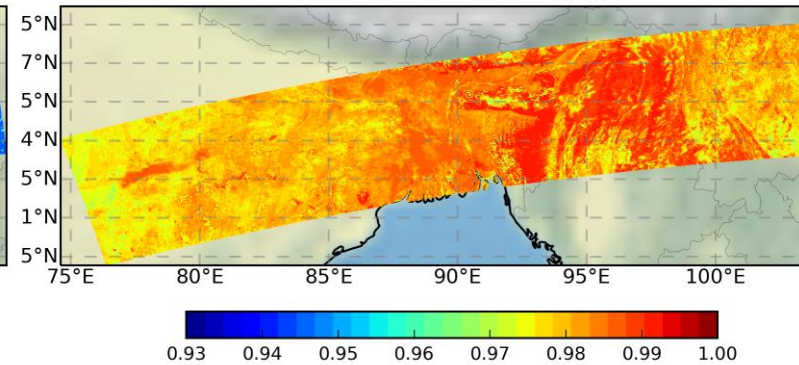
LST Error on 202305310708



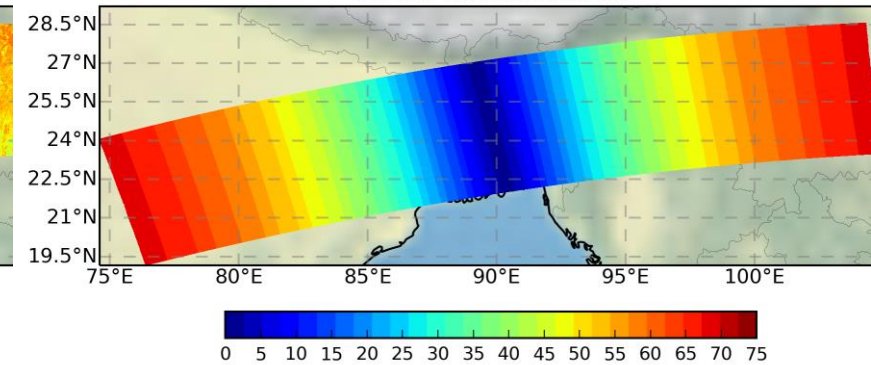
LST QC on 202305310708



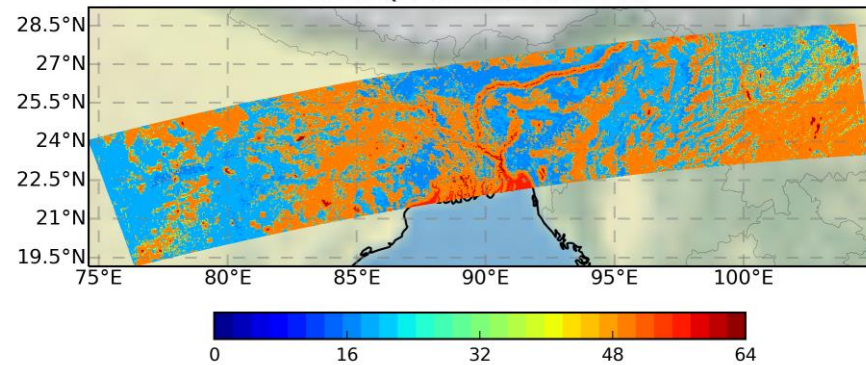
Emis16 on 202305310708



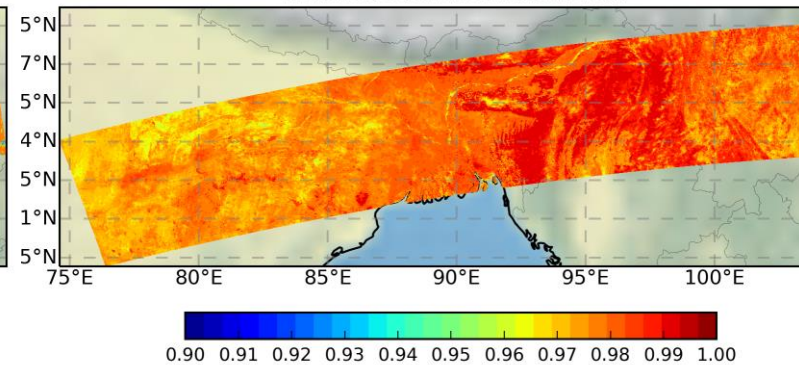
STZ on 202305310708



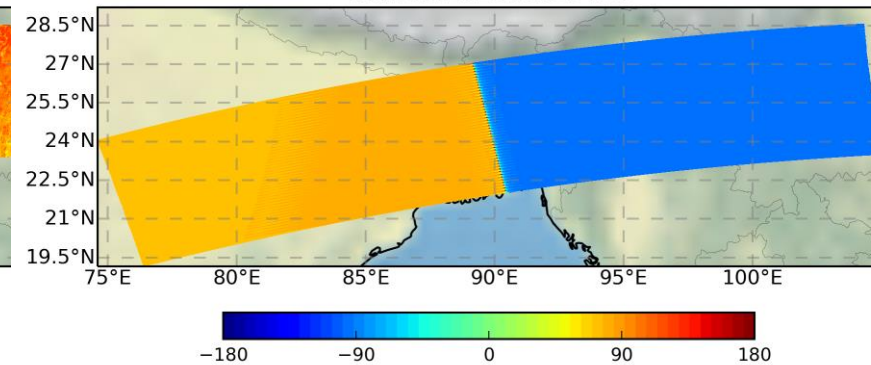
Emis QC on 202305310708



Emis BBE on 202305310708



Staz on 202305310708



L3 NOAA-21 LST Data Verification

Daytime

HDFView 2.9@rhw1267.star1.nesdis.noaa.gov

File Window Tools Help

GRIDDED-VIIRS-LST-D_v1r1_n21_s20230608_e20230608_c202306090250360.nc

Recent Files /data/smcd9/yliu/N21/L3_LST/GRIDDED-VIIRS-LST-D_v1r1_n21_s20230608_e20230608_c202306090250360.nc Clear Text

GRIDDED-VIIRS-LST-D_v1r1

Columns

DQF

LST_Day

QC_Day

Rows

View_Angle_Day

View_Time_Day

	0	1	2	3	4	5	6	7
0	-32767	-32767	-32767	-32767	-32767	-32767	-32767	-32767
1	-32767	-32767	-32767	-32767	-32767	-32767	-32767	-32767
2	-32767	-32767	-32767	-32767	-32767	-32767	-32767	-32767
3	-32767	-32767	-32767	-32767	-32767	-32767	-32767	-32767
4	-32767	-32767	-32767	-32767	-32767	-32767	-32767	-32767
5	-32767	-32767	-32767	-32767	-32767	-32767	-32767	-32767
6	-32767	-32767	-32767	-32767	-32767	-32767	-32767	-32767
7	-32767	-32767	-32767	-32767	-32767	-32767	-32767	-32767
8	-32767	-32767	-32767	-32767	-32767	-32767	-32767	-32767
9	-32767	-32767	-32767	-32767	-32767	-32767	-32767	-32767
10	-32767	-32767	-32767	-32767	-32767	-32767	-32767	-32767
11	-32767	-32767	-32767	-32767	-32767	-32767	-32767	-32767
12	-32767	-32767	-32767	-32767	-32767	-32767	-32767	-32767
13	-32767	-32767	-32767	-32767	-32767	-32767	-32767	-32767
14	-32767	-32767	-32767	-32767	-32767	-32767	-32767	-32767
15	-32767	-32767	-32767	-32767	-32767	-32767	-32767	-32767
16	-32767	-32767	-32767	-32767	-32767	-32767	-32767	-32767

LST_Day (1039, 2)
16-bit integer, 21600 x 43200
Number of attributes = 9
DIMENSION_LIST = 685,331
_FillValue = -32768
_Netcdf4Coordinates = 1,0
add_offset = 200.0
long_name = Daily Daytime Land Surface Temperature
scale_factor = 0.005
type = int16
units = K
valid_range = 2600,28600

Log Info Metadata

Nighttime

HDFView 2.9@rhw1267.star1.nesdis.noaa.gov

File Window Tools Help

GRIDDED-VIIRS-LST-N_v1r1_n21_s20230608_e20230608_c202306090250360.nc

Recent Files /data/smcd9/yliu/L3_LST/N21/2023/06/GRIDDED-VIIRS-LST-N_v1r1_n21_s20230608_e20230608_c202306090250360.nc Clear Text

GRIDDED-VIIRS-LST-N_v1r1_n21

Columns

DQF

LST_Night

QC_Night

Rows

View_Angle_Night

View_Time_Night

	0	1	2	3	4	5	6	7
0	-32767	-32767	-32767	-32767	-32767	-32767	-32767	-32767
1	-32767	-32767	-32767	-32767	-32767	-32767	-32767	-32767
2	-32767	-32767	-32767	-32767	-32767	-32767	-32767	-32767
3	-32767	-32767	-32767	-32767	-32767	-32767	-32767	-32767
4	-32767	-32767	-32767	-32767	-32767	-32767	-32767	-32767
5	-32767	-32767	-32767	-32767	-32767	-32767	-32767	-32767
6	-32767	-32767	-32767	-32767	-32767	-32767	-32767	-32767
7	-32767	-32767	-32767	-32767	-32767	-32767	-32767	-32767
8	-32767	-32767	-32767	-32767	-32767	-32767	-32767	-32767
9	-32767	-32767	-32767	-32767	-32767	-32767	-32767	-32767
10	-32767	-32767	-32767	-32767	-32767	-32767	-32767	-32767
11	-32767	-32767	-32767	-32767	-32767	-32767	-32767	-32767
12	-32767	-32767	-32767	-32767	-32767	-32767	-32767	-32767
13	-32767	-32767	-32767	-32767	-32767	-32767	-32767	-32767
14	-32767	-32767	-32767	-32767	-32767	-32767	-32767	-32767

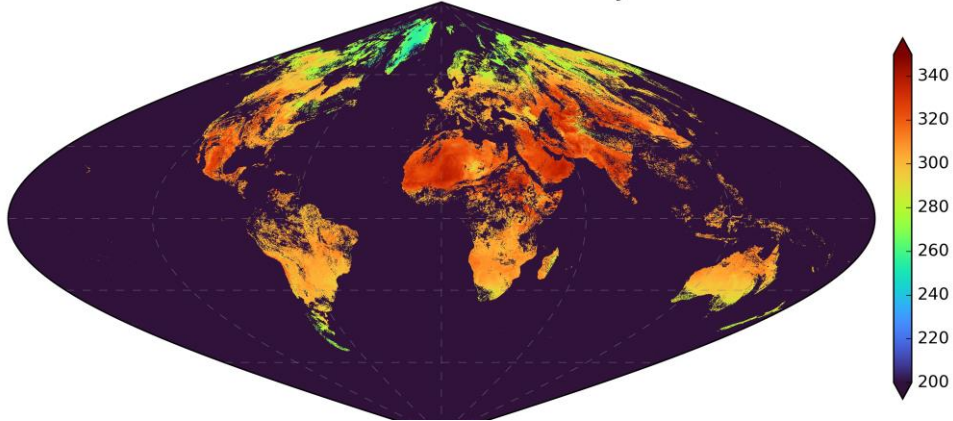
LST_Night (1039, 2)
16-bit integer, 21600 x 43200
Number of attributes = 9
DIMENSION_LIST = 685,331
_FillValue = -32768
_Netcdf4Coordinates = 1,0
add_offset = 200.0
long_name = Daily Nighttime Land Surface Temperature
scale_factor = 0.005
type = int16
units = K
valid_range = 2600,28600

Log Info Metadata

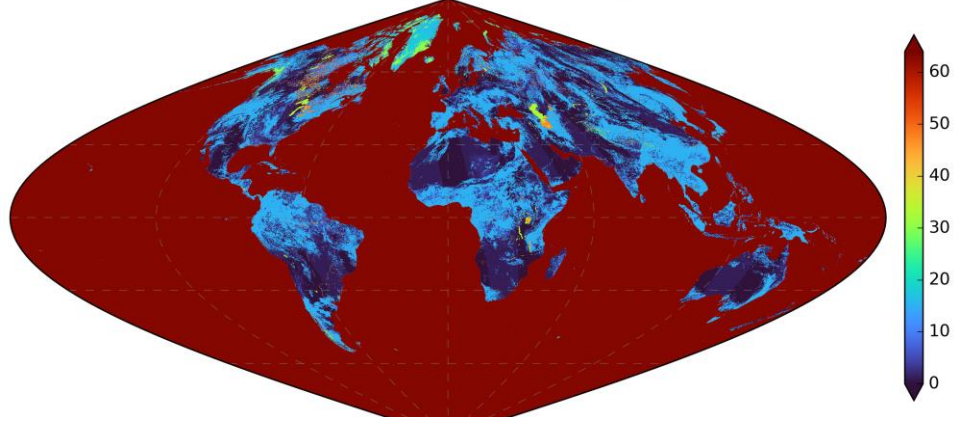
- The data stream began on June 8th, 2023.
- The L3 LST product consists of two LST datasets for daytime and nighttime, respectively, with one file each in v1r1 version while the current operational SNPP and NOAA20 LST are in v1r0 version.
- The data layers include LST, QC, View time, DQF, and View Angle, all with correct data attributes and valid ranges.
- Product specific metadata is provided together with the global metadata. No issues were observed.

Daytime L3 NOAA-21 LST

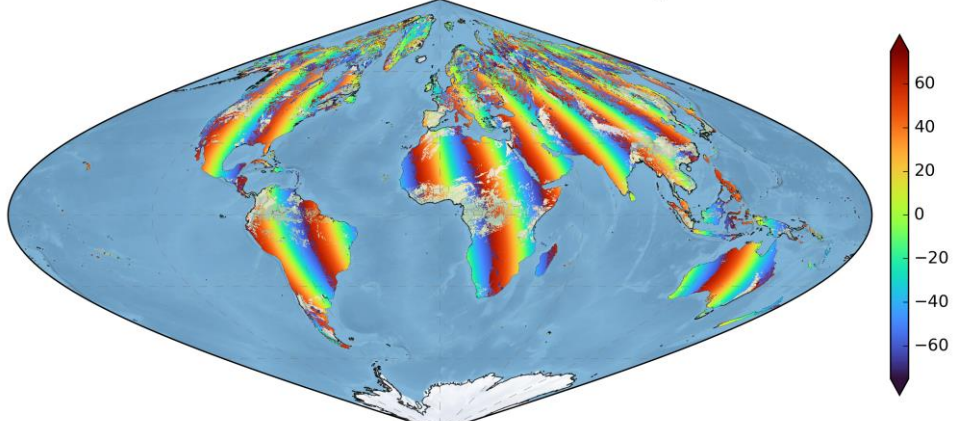
N21 VIIRS LST: 20230608 Day



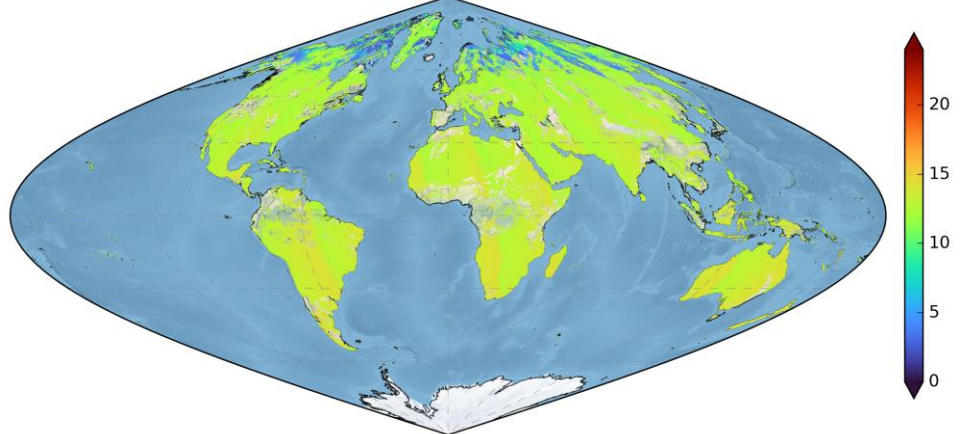
N21 VIIRS QC: 20230608 Day



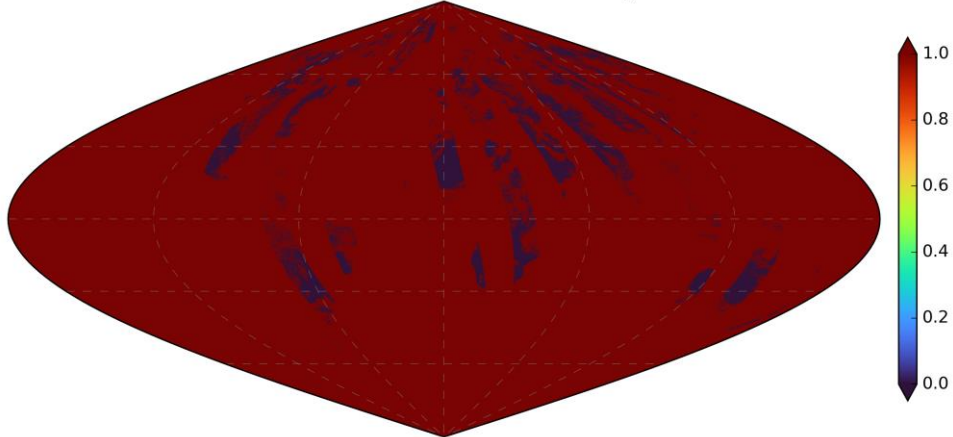
N21 VIIRS ViewAngle: 20230608 Day



N21 VIIRS Viewtime: 20230608 Day



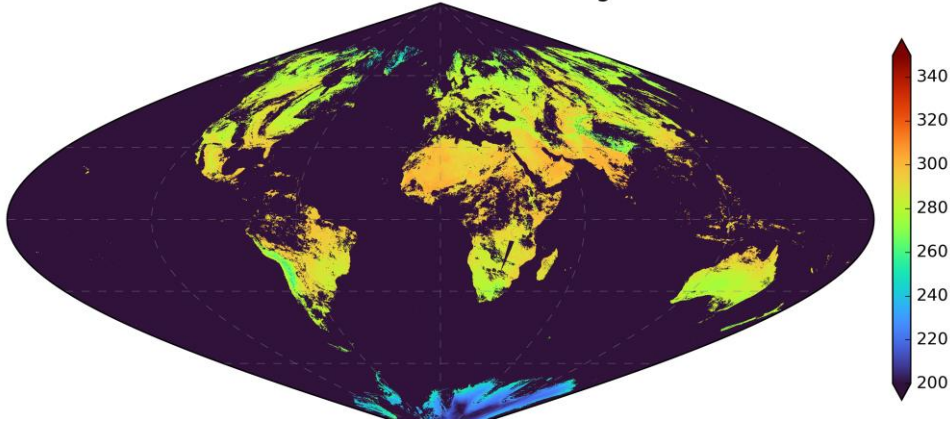
N21 VIIRS DQF: 20230608 Day



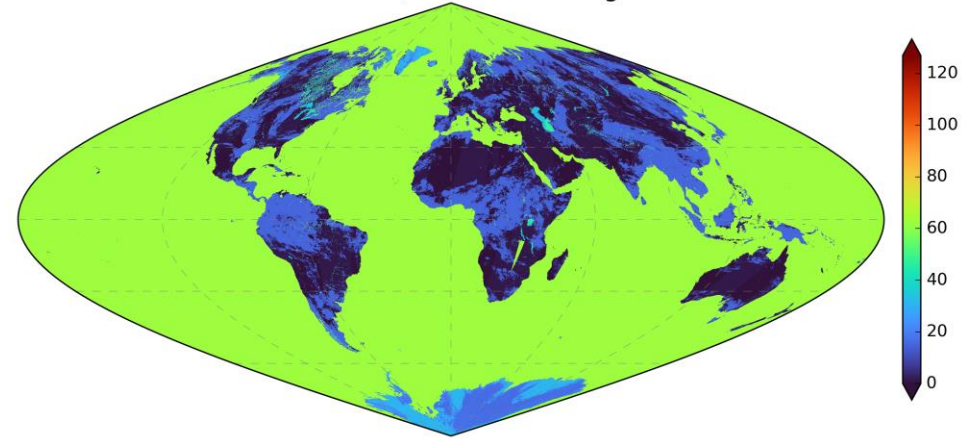
- Sample L3 LST dataset for daytime (LST, QC, View angle, View time and DQF) on June 8, 2023
- The LST is in valid range and its global distribution pattern looks reasonable
- All other dataset in valid range and reasonable distribution

Nighttime L3 NOAA-21 LST

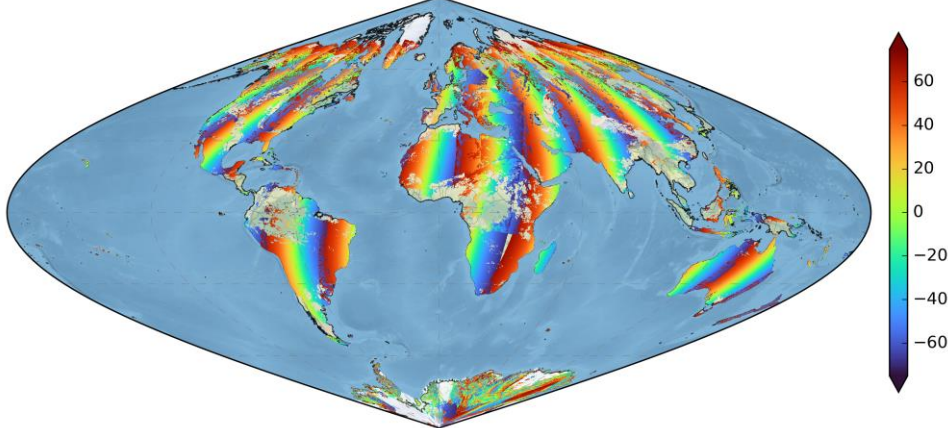
N21 VIIRS LST: 20230608 Night



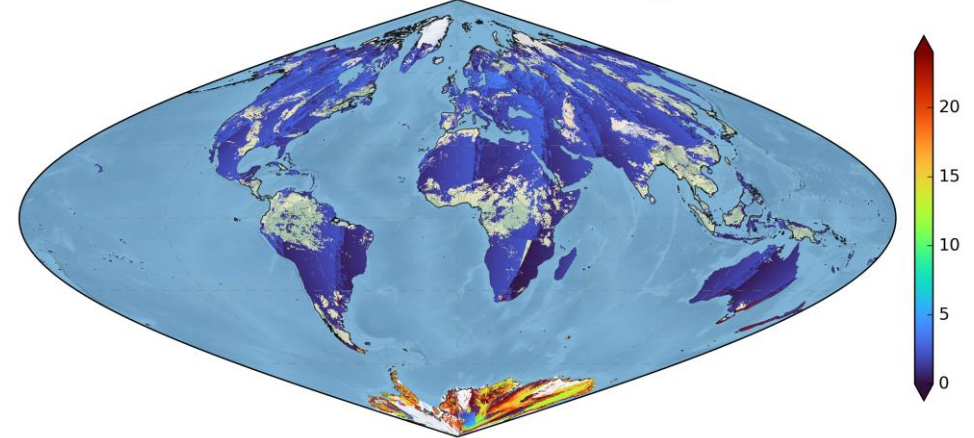
N21 VIIRS QC: 20230608 Night



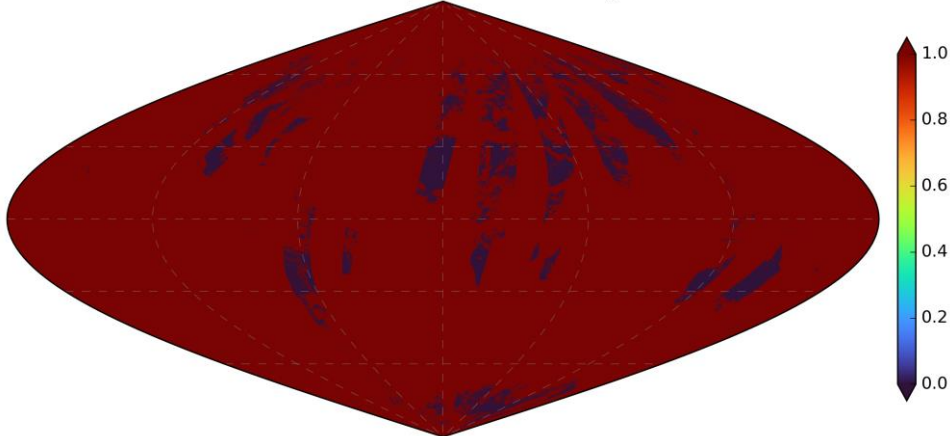
N21 VIIRS ViewAngle: 20230608 Night



N21 VIIRS Viewtime: 20230608 Night



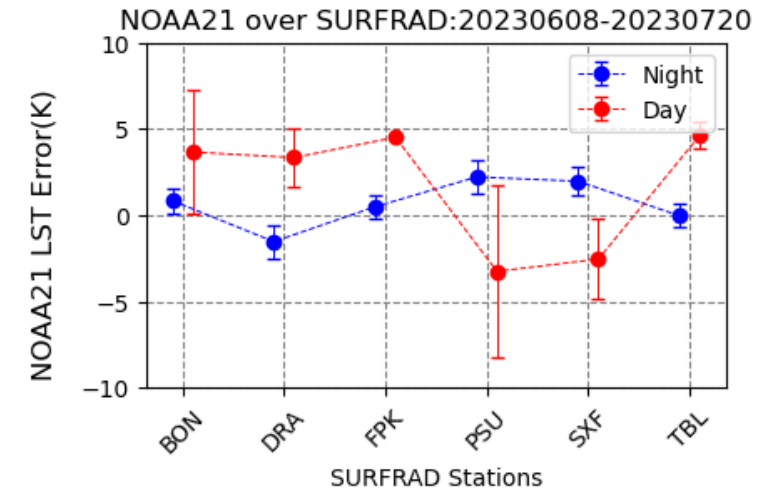
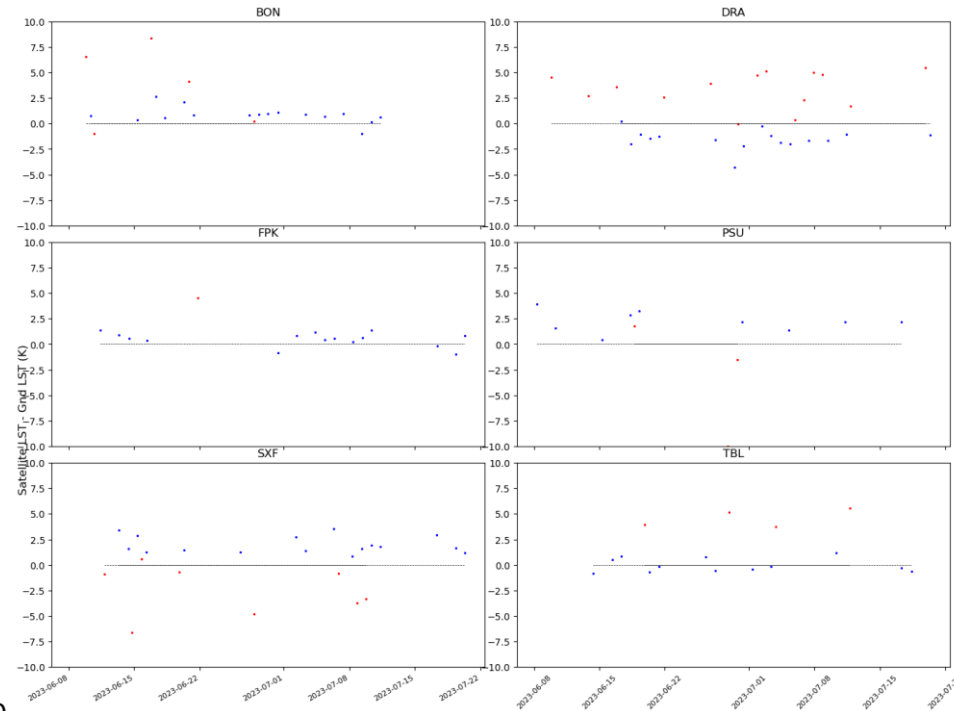
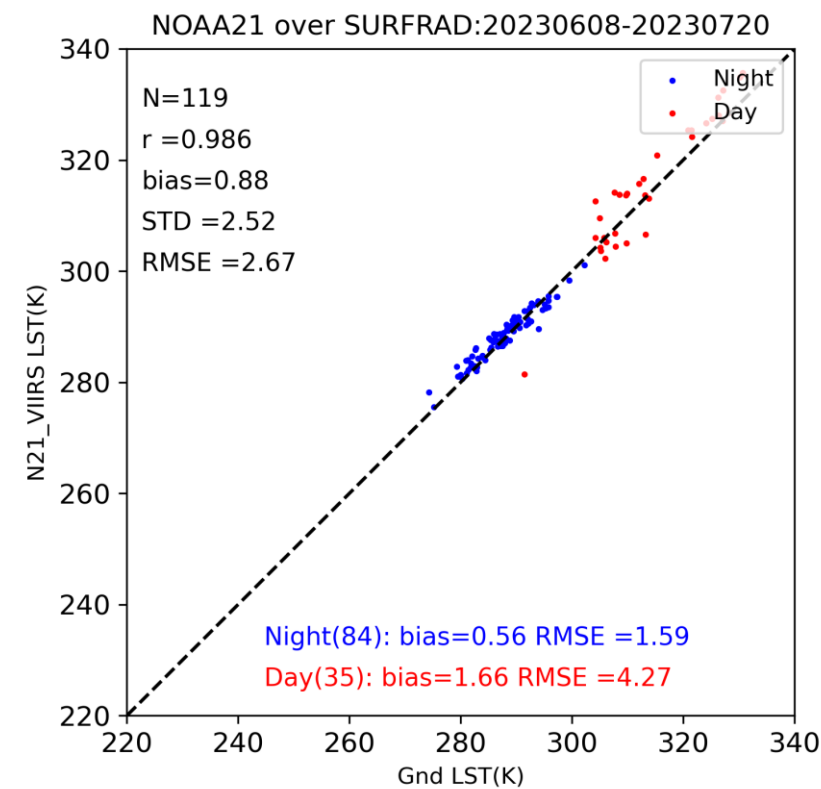
N21 VIIRS DQF: 20230608 Night



- Sample L3 LST dataset for nighttime (LST, QC, View angle, View time and DQF) on June 8, 2023
- The LST is in valid range and its global distribution pattern looks reasonable
- All other dataset in valid range and reasonable distribution

LST Validation with ground observations

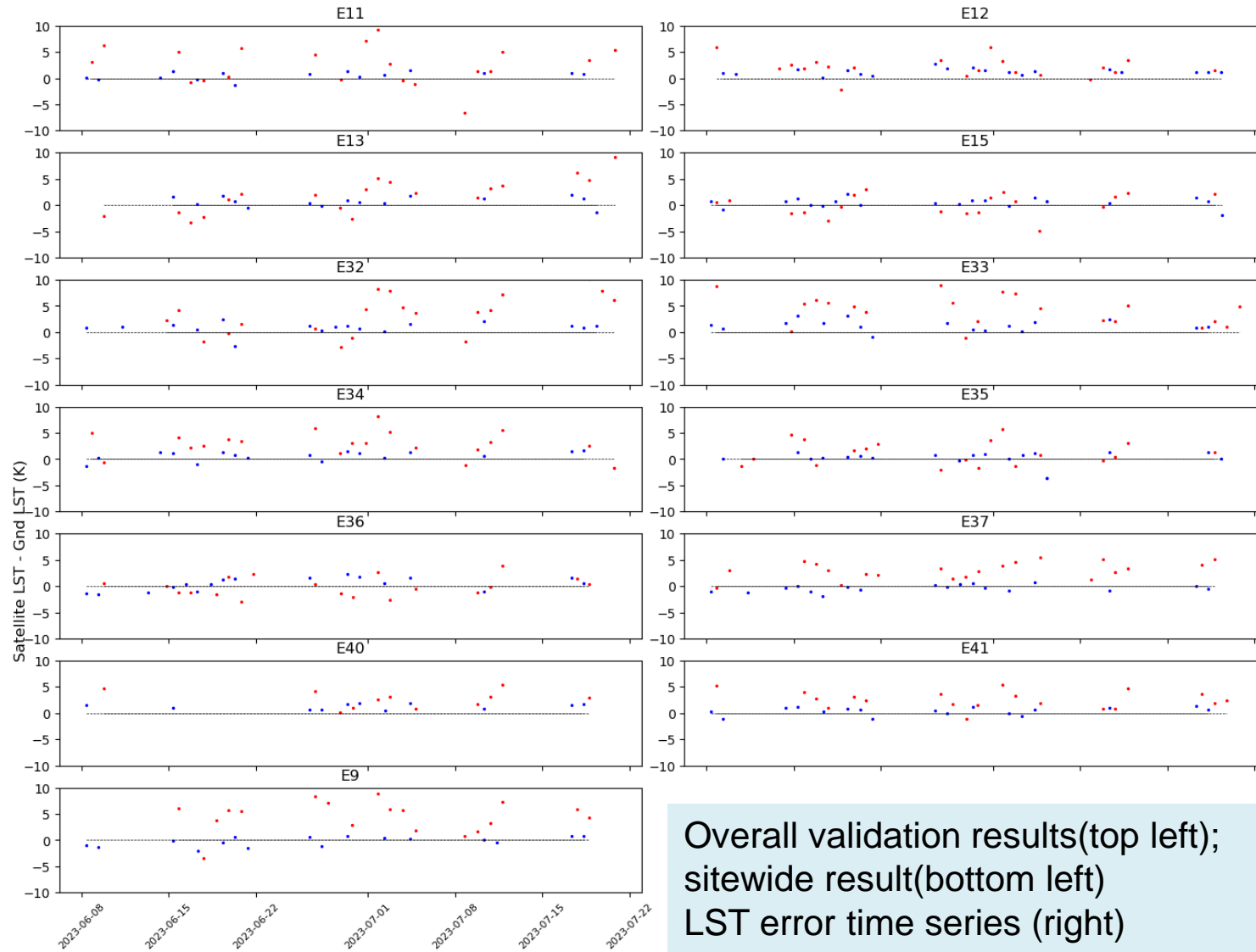
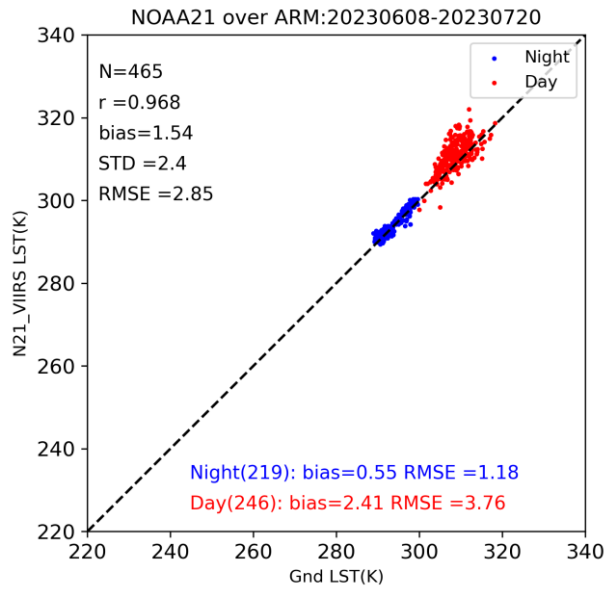
L3 NOAA-21 LST validation-SURFRAD



Left figure shows the scatter plot with statistics results for overall, and day/night separated situations; middle figure is sitewide LST error time series and the right figure displays the sitewide validation performance, separated for day/night.

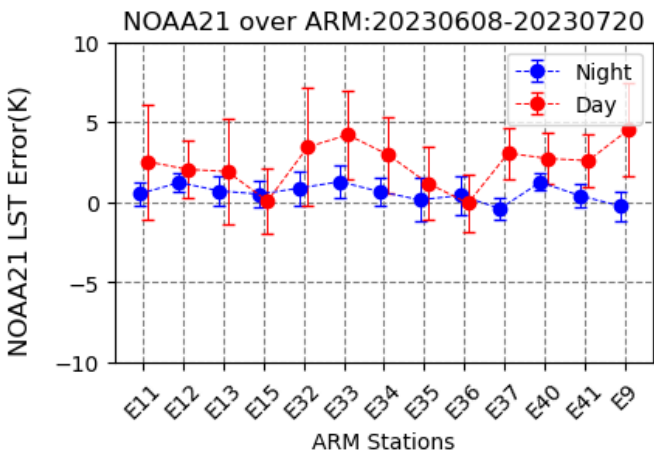
- The data for the time period from June 8th 2023 to July 20th, 2023 is used to validate against ground observations in SURFRAD.
- A significant positive bias is observed at daytime possibly due to the seasonal representativeness of the ground site. The sitewide performance varies significantly over site with positive bias over BON, DRA, FPK and TBL, and negative bias over PSU and SXF station.
- The bias and STD is fine for nighttime LST.

L3 NOAA-21 LST validation-ARM

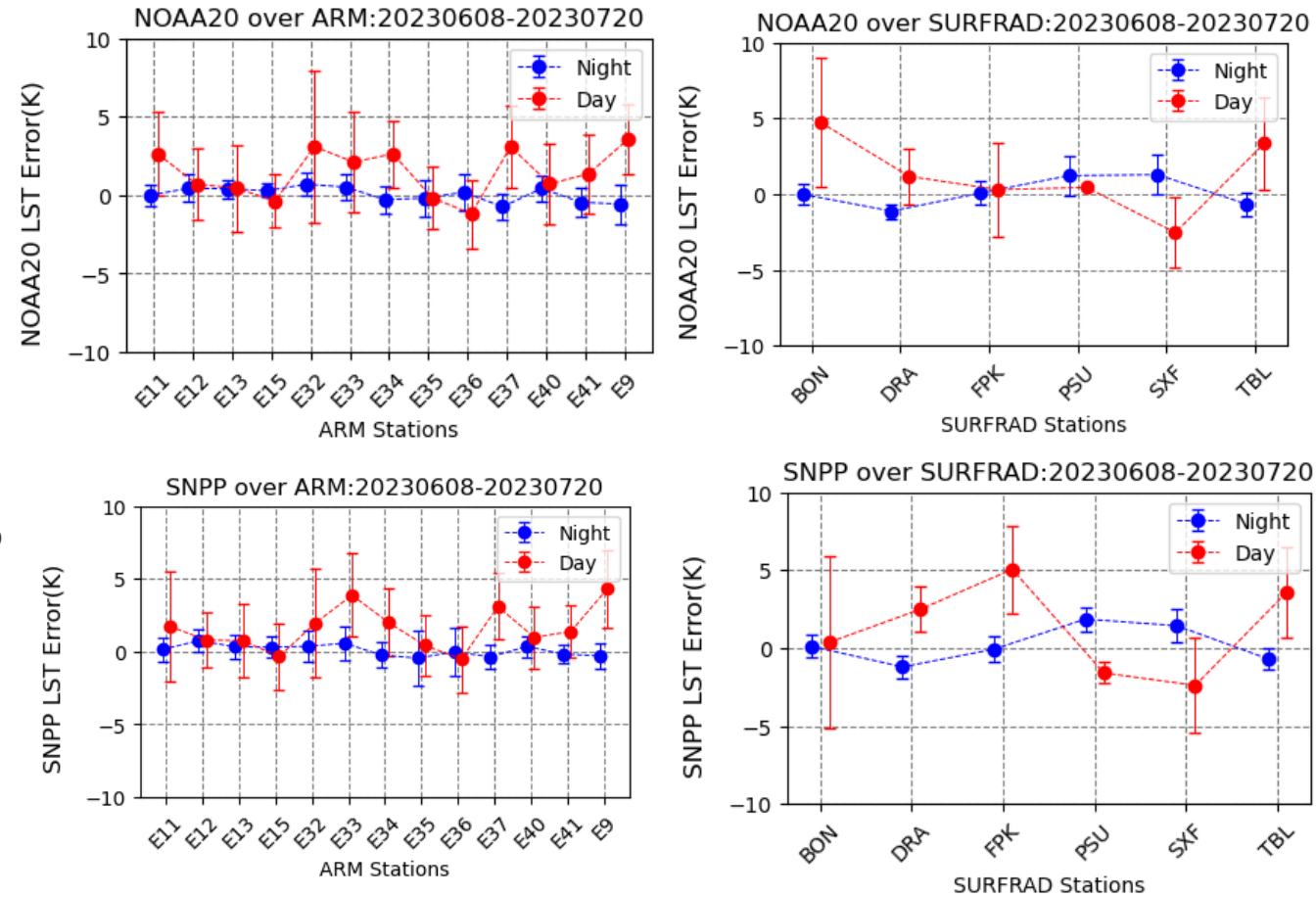
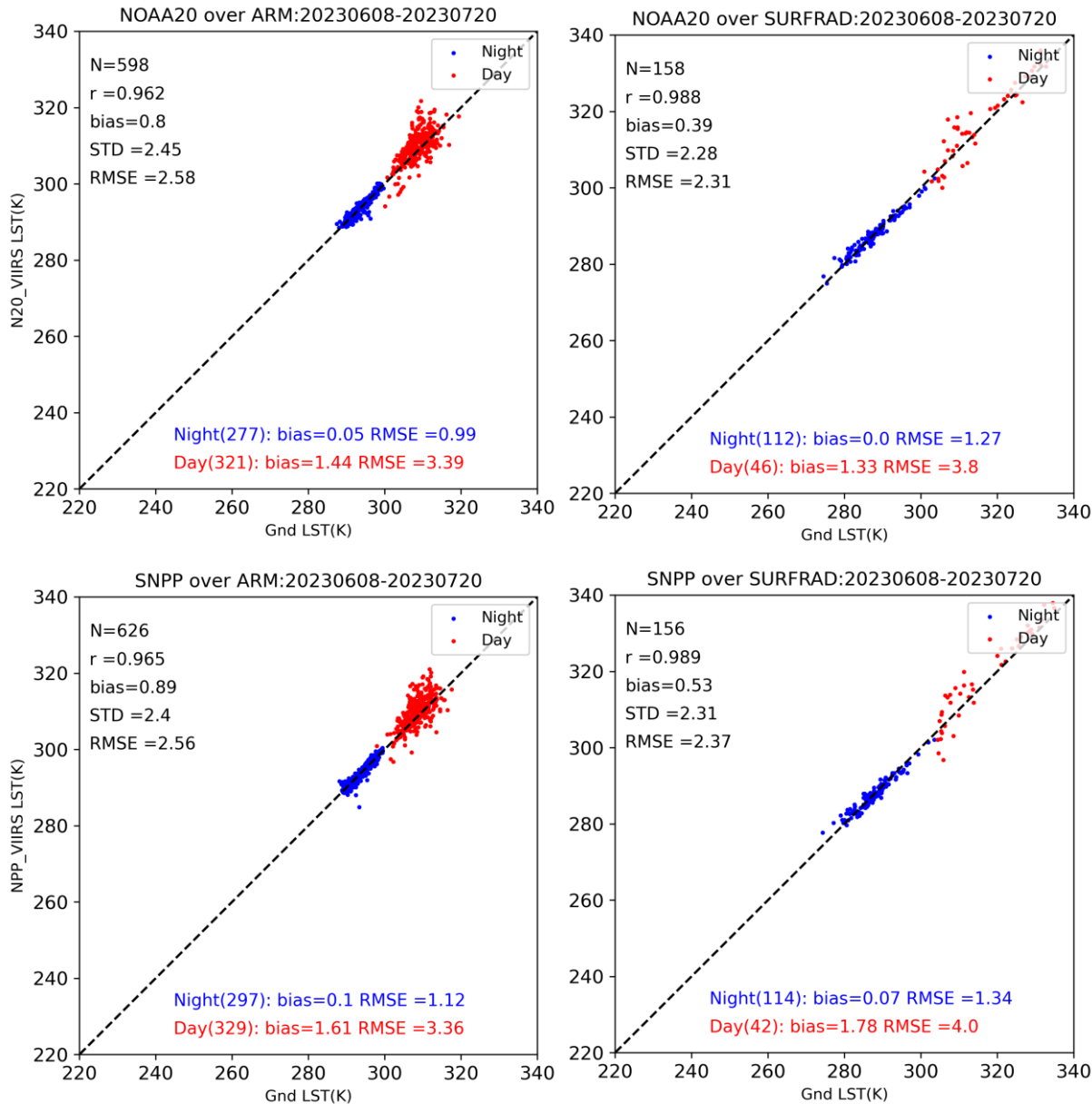


Overall validation results(top left);
 sitewide result(bottom left)
 LST error time series (right)

- The data for the time period from June 8th 2023 to July 20th, 2023 is used to validate against ground observations in ARM.
- A significant positive bias is observed at daytime possibly due to the seasonal representativeness of the ground site
- The bias and STD is fine for nighttime LST.



Validation comparison –SNPP and NOAA20



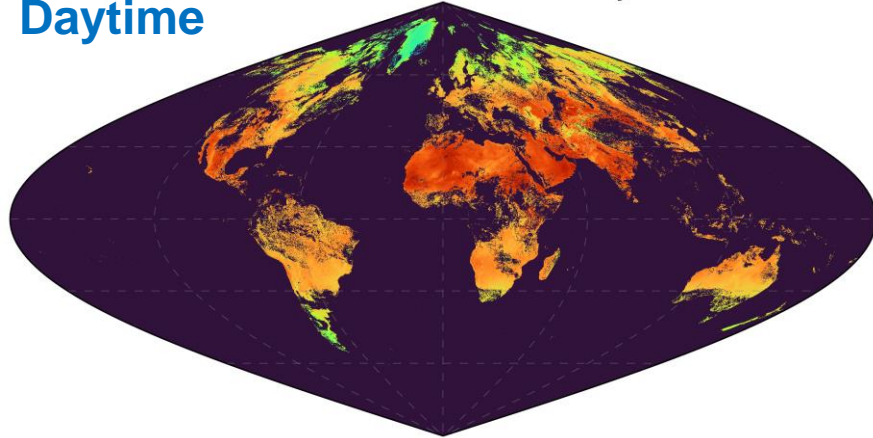
- The SNPP and NOAA-20 VIIRS LST are validated against SURFRAD and ARM observations for the same time period as a reference.
- The validation results indicate a positive bias at daytime, ranging from 1.33 K to 1.78 K, nearly no bias at nighttime.
- NOAA-21 LST exhibits a higher LST estimation than both SNPP and NOAA-20 LST particularly during daytime.

Inter-sensor comparison

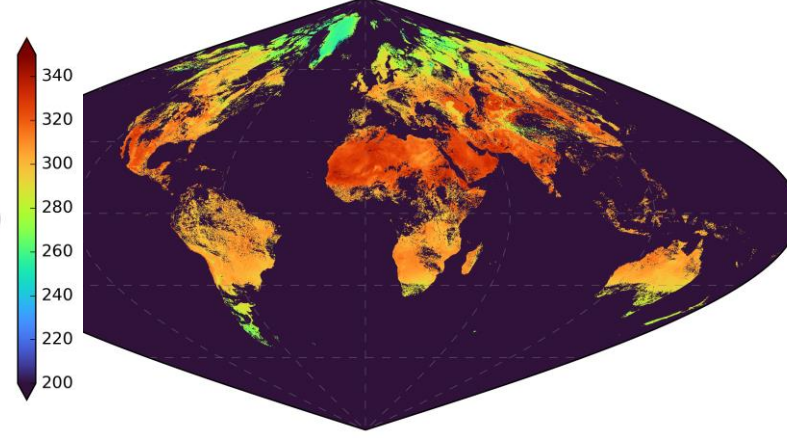
Inter-sensor comparison with SNPP and NOAA-20

Daytime

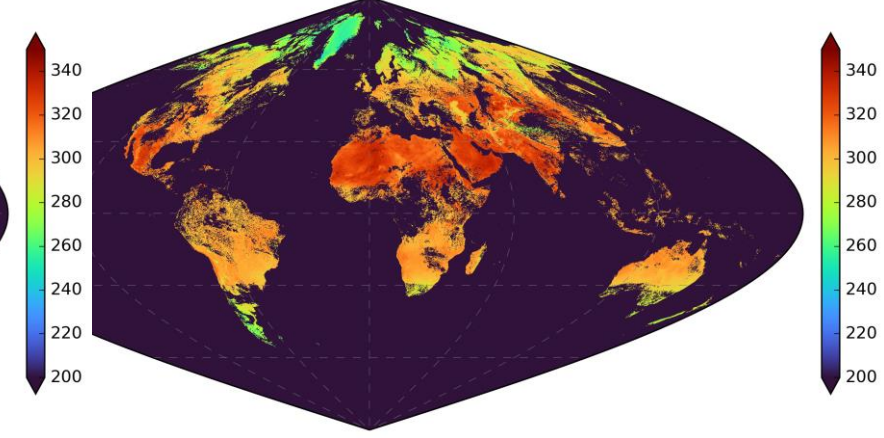
N21 VIIRS LST: 20230609 Day



N20 VIIRS LST: 20230609 Day

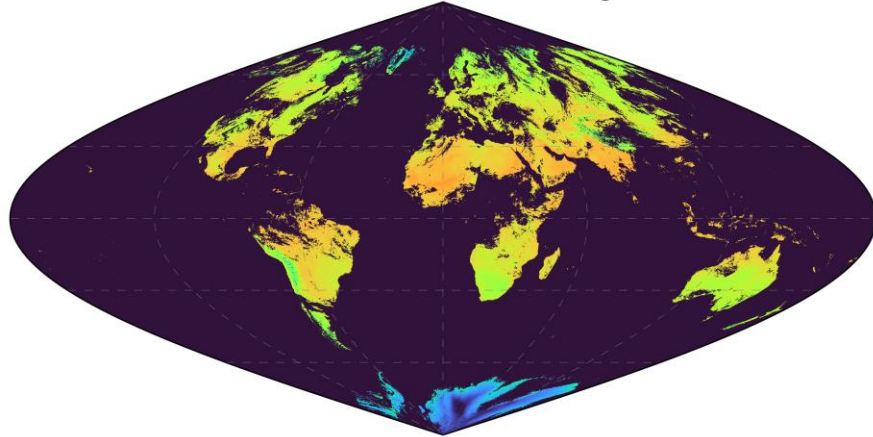


NPP VIIRS LST: 20230609 Day

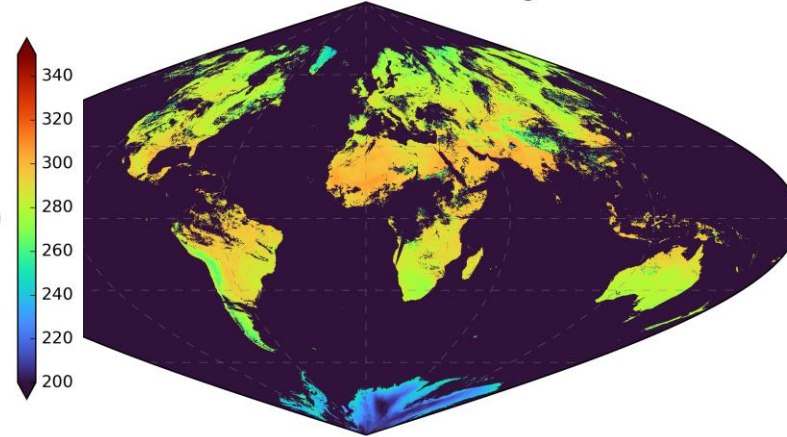


Nighttime

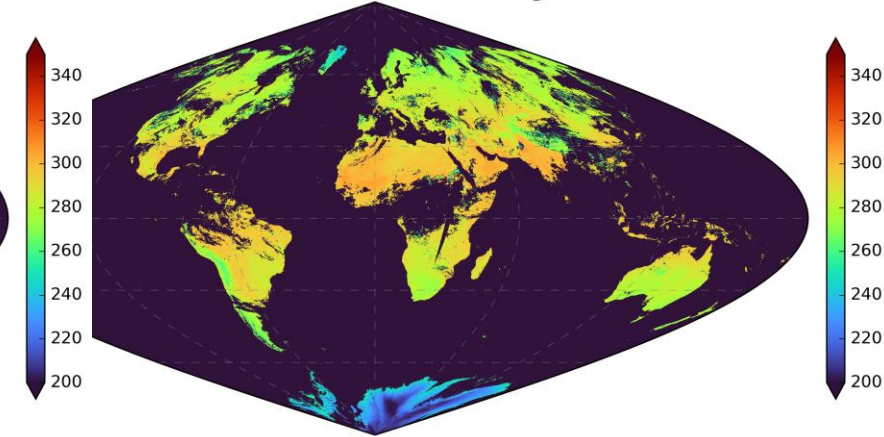
N21 VIIRS LST: 20230609 Night



N20 VIIRS LST: 20230609 Night

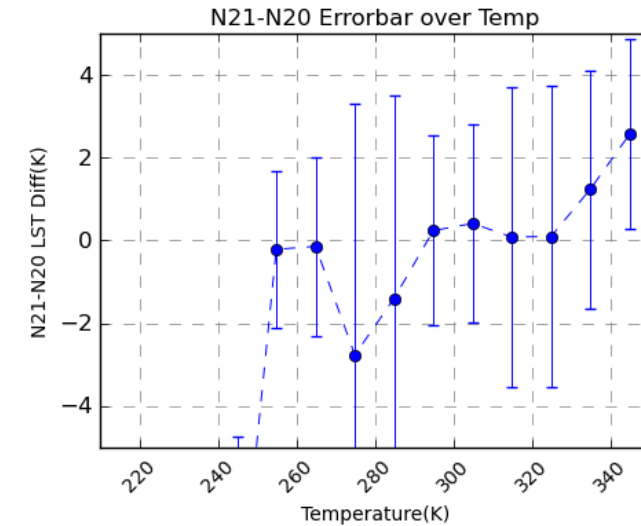
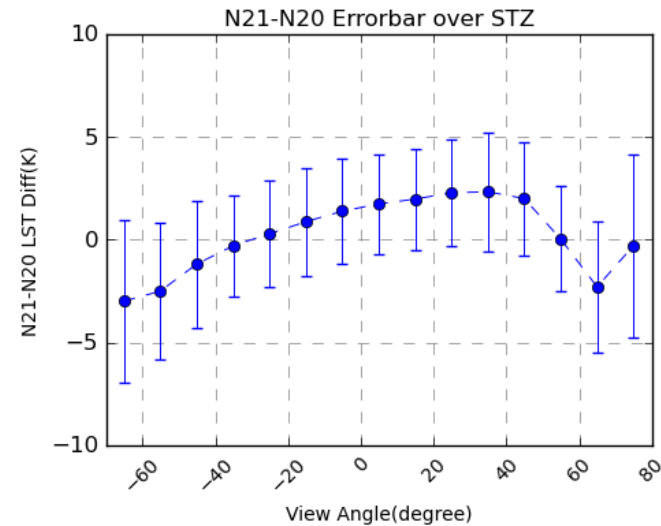
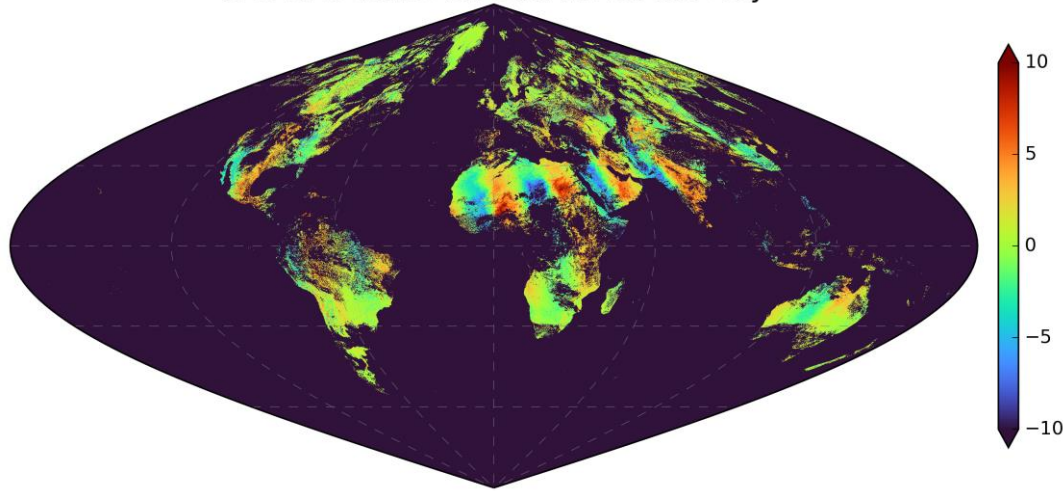


NPP VIIRS LST: 20230609 Night

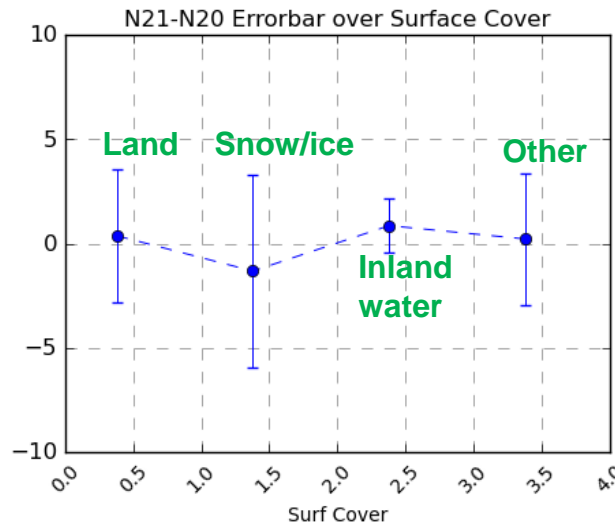
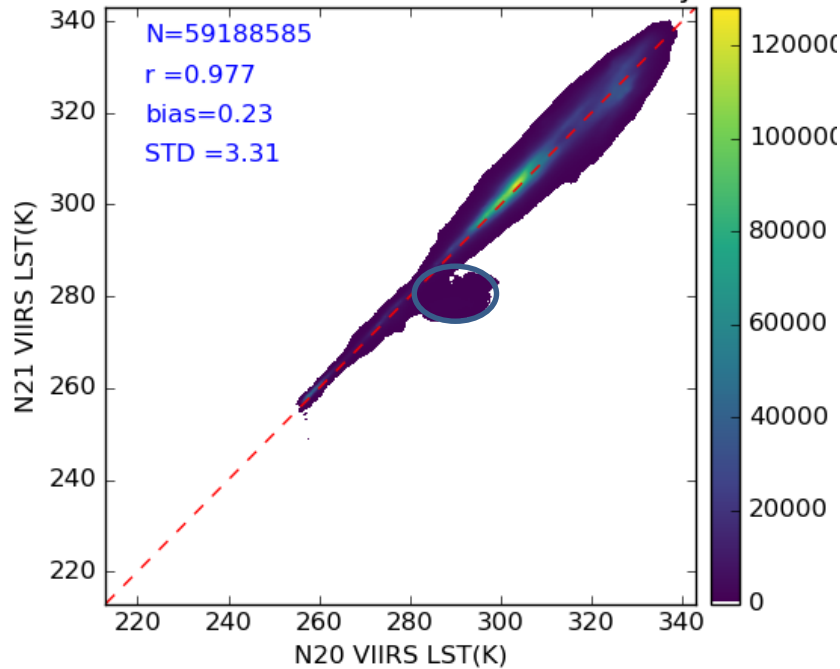


- NOAA-21 LST (left), NOAA-20 LST (middle) and SNPP LST(right) for daytime(top) and nighttime bottom)
- No obvious difference is observed from the visual observation

N21-N20 VIIRS LST Diff: 20230609 Day

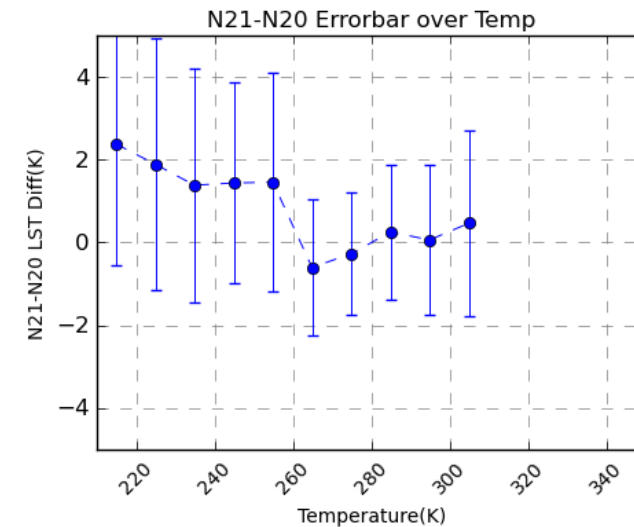
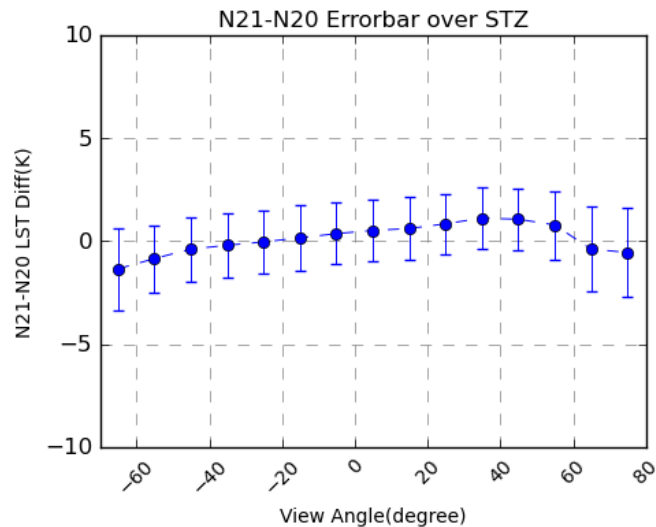
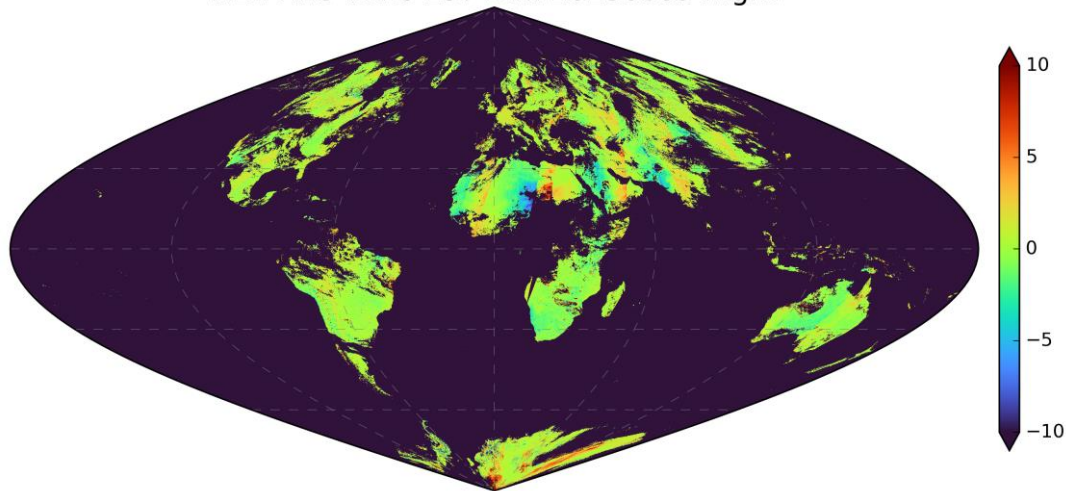


N21-N20 VIIRS LST Diff: 20230609 Day

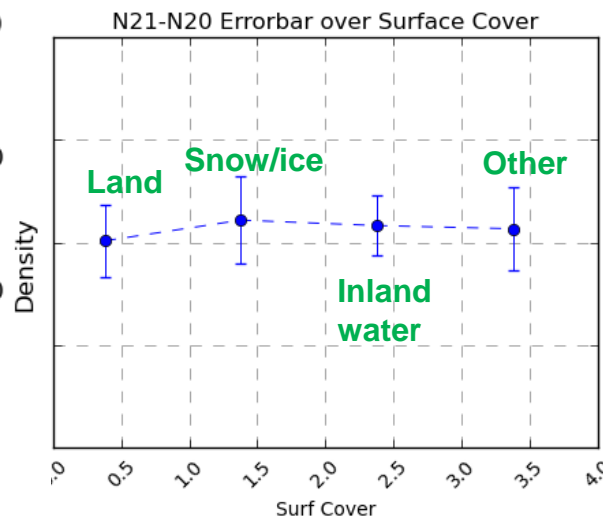
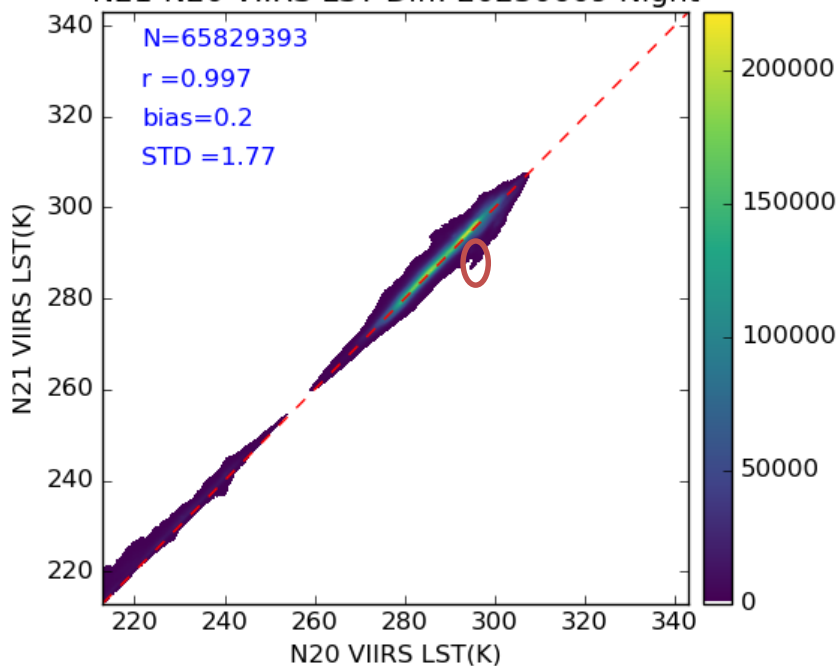


- Daytime LST difference between NOAA-21 and NOAA-20 (top left), difference statistics (bottom left). The difference analysis over sensor zenith angle (top middle), over temperature (top right) and over surface cover (bottom right)
- It is observed that daytime LST difference has generally exhibits a zonal pattern aligned with the orbit and the view angle.
- The scatter plot indicates a bias of 0.2 K and STD of 3.3 K with significant difference under certain situations (circled area), primarily over the temperature range between 280-295K. Further investigation is shown in slides 21-23.

N21-N20 VIIRS LST Diff: 20230609 Night

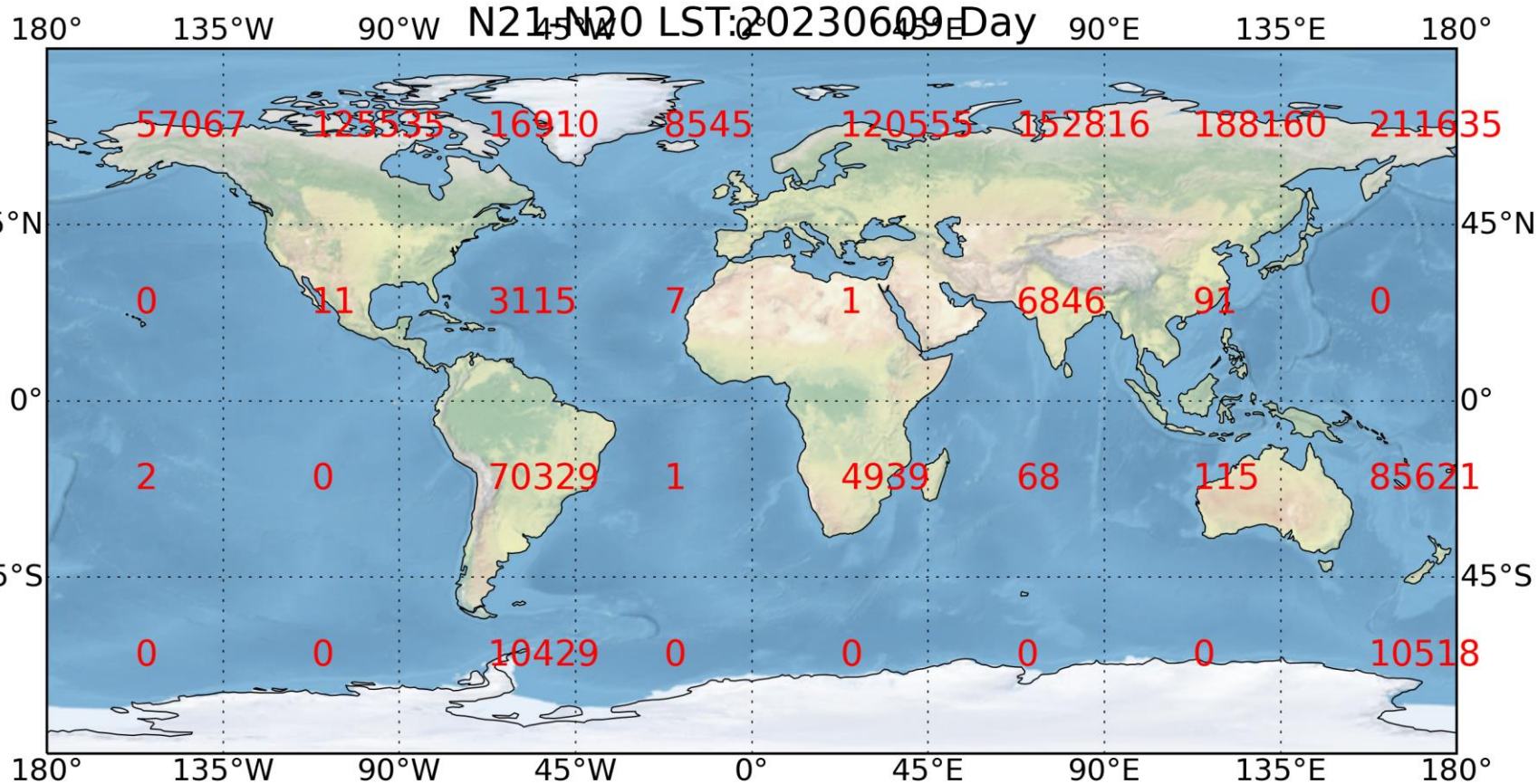


N21-N20 VIIRS LST Diff: 20230609 Night



- Nighttime LST difference between NOAA-21 and NOAA-20 (top left), difference statistics (bottom left). The difference analysis over sensor zenith angle (top middle), over temperature (top right) and over surface cover (bottom right)
- It is observed that nighttime LST difference has generally exhibits a zonal pattern aligned with the orbit, with a less magnitude compared to daytime LST.
- The scatter plot indicates a bias of 0.2 K and a STD of 1.77 K with a positive bias at temperature below 260 K. There is a relatively large difference under certain situations (as shown in the circled area)

Significant inter-sensor LST Difference Investigation

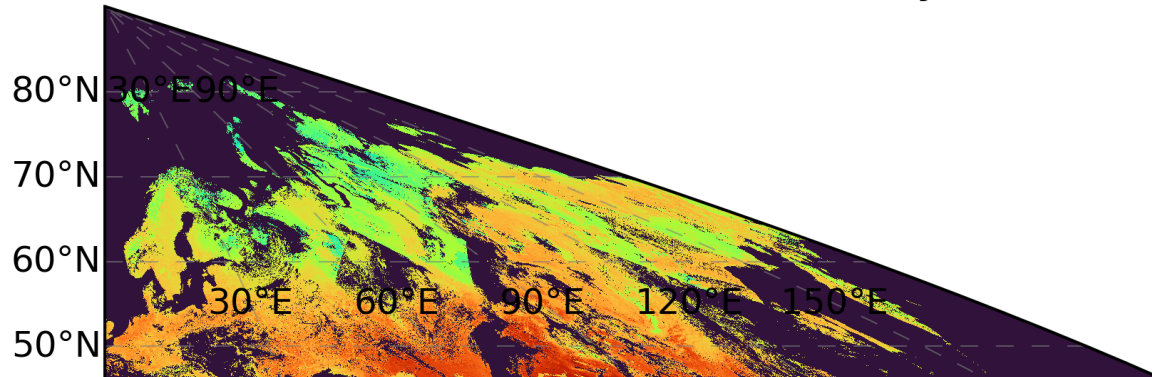


- LST Difference for subarea statistics under following conditions:
 - Both LST not fill
 - Both under cloud clear condition
 - NOAA-20 LST within [280,298] and NOAA-21 LST within [275,285]
- Numbers in red color indicate the total pixels meet above conditions.

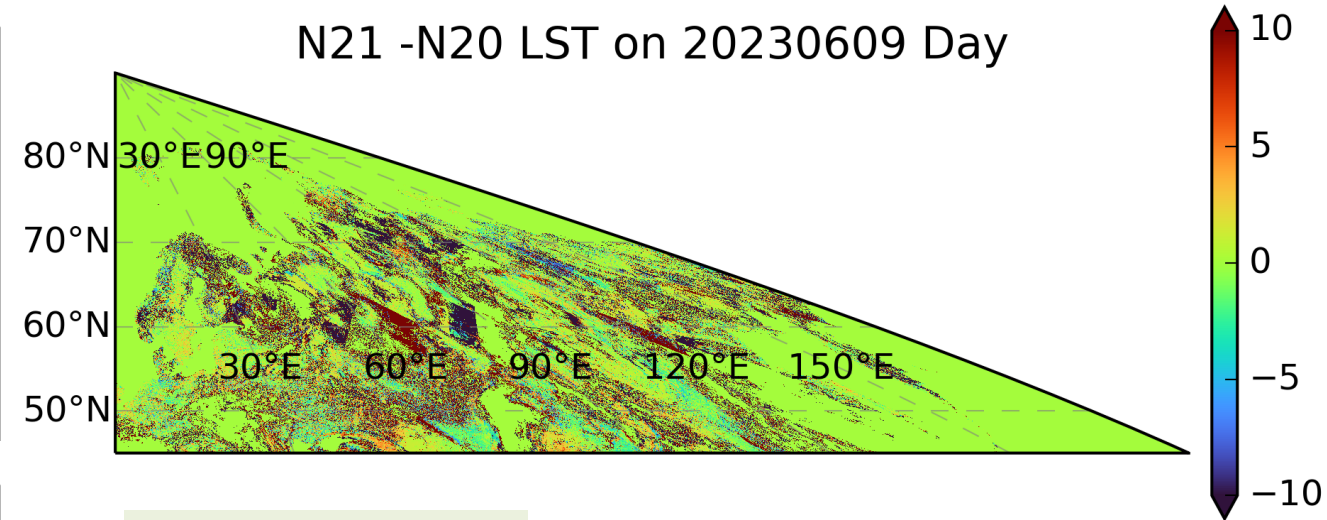
- It is found that more pixels are found in higher latitude areas above 45 degree, particularly in the eastern hemisphere
- The area within latitude range of [45,90] and longitude range of [135,180] with the most pixels is selected for further investigation

LST difference investigation

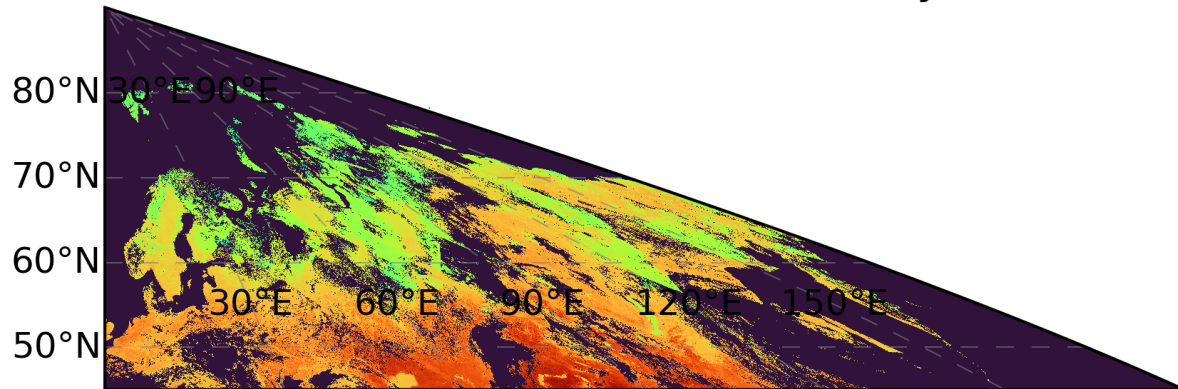
N20 LST on 20230609 Day



N21 - N20 LST on 20230609 Day

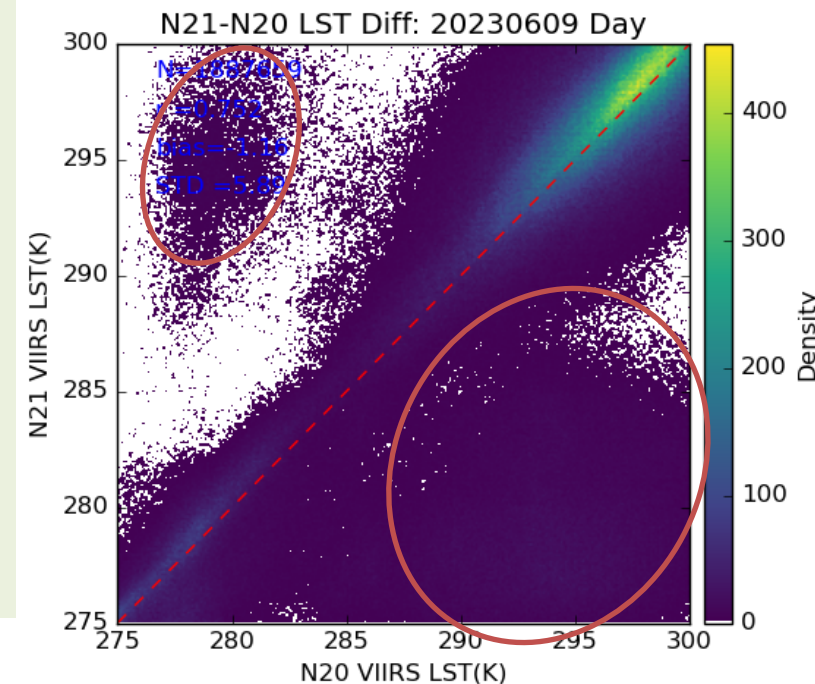


N21 LST on 20230609 Day



- Significant LST differences are found over this area as shown in the scatter plot within the circled area. One is below 1:1 line and the other one is above 1:1 line.

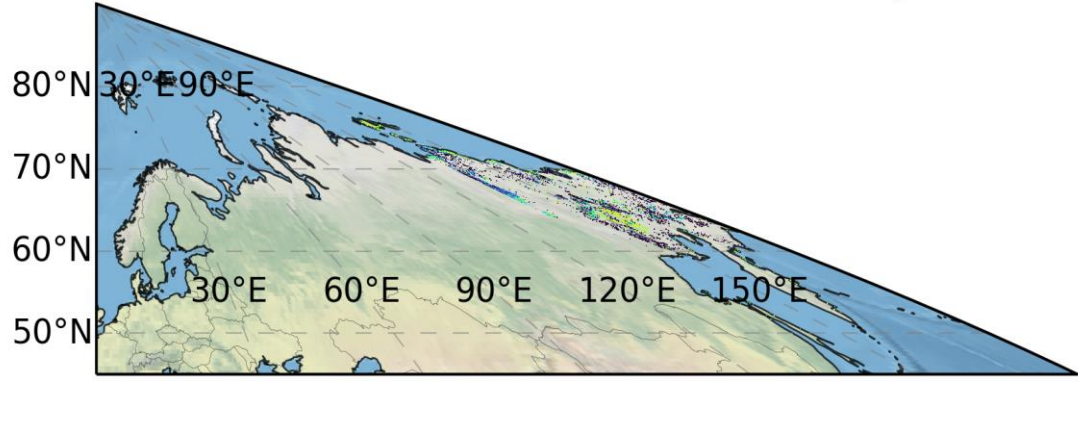
Detailed investigation is conducted for the area of [135, 180, 45, 90], top left is N-20 LST map and bottom is N-21 LST, top right is the LST difference between N-21 and N-20. Bottom right shows the scatter plot of the two LSTs.



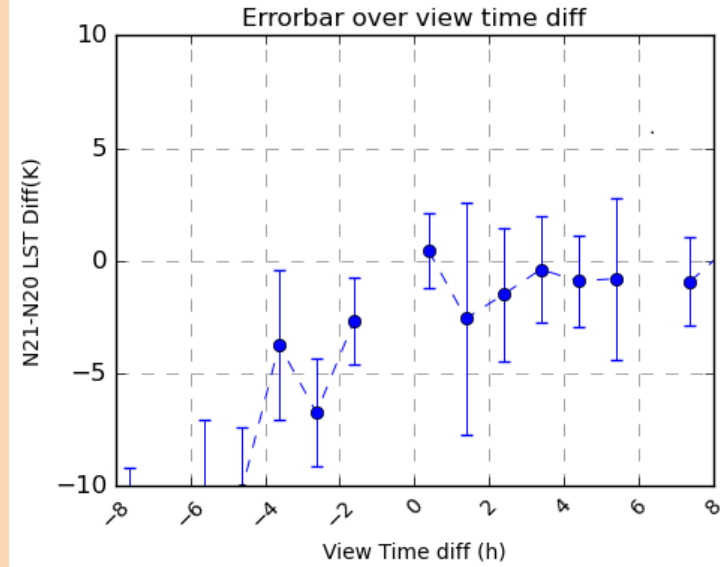
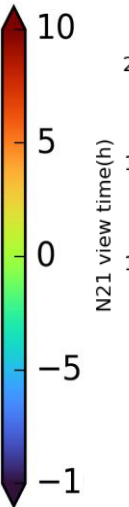
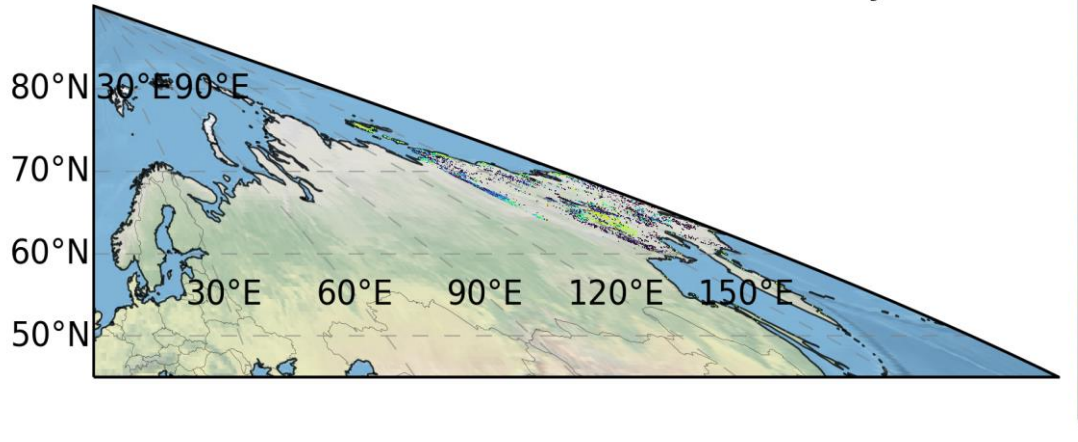
LST difference investigation: related Factors

- Related factors are checked including the view time and sensor view angle.
- It is observed that on average, there is a 4.5 hours difference in view time, with N20 mostly having an earlier view time than N-21. This is mainly attributed to the composition method update in N-21 LST. N20 VIIRS LST still uses the old composition method.
- the LST difference generally increases with view time difference.

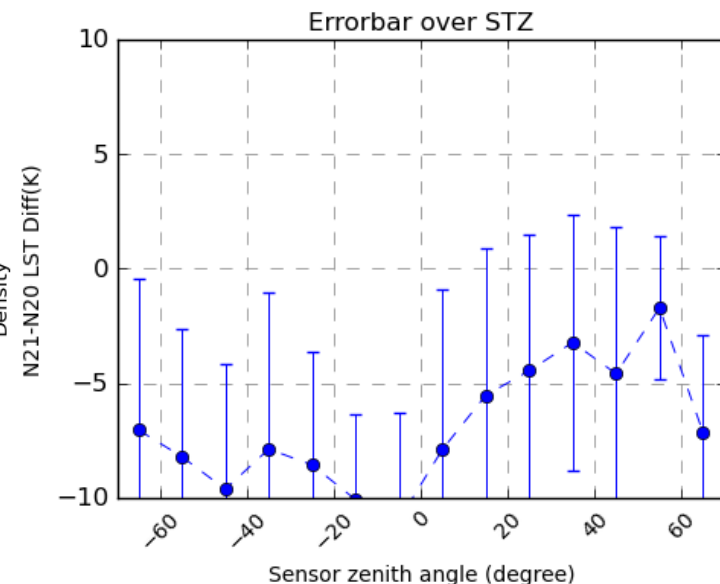
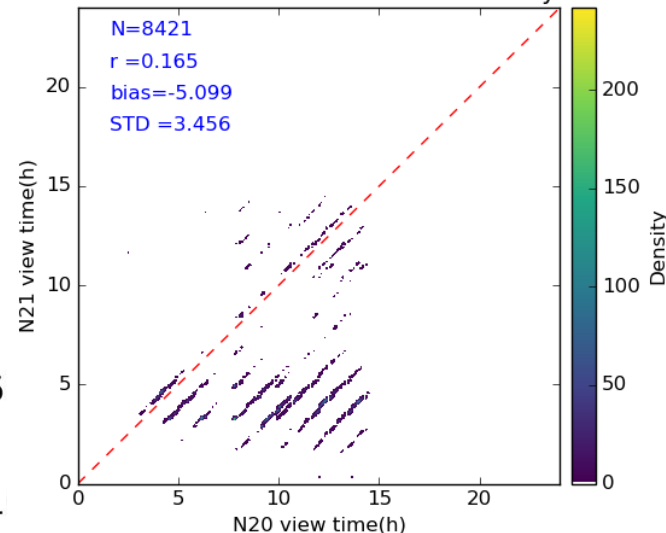
N21 -N20 LST on 20230609 Day



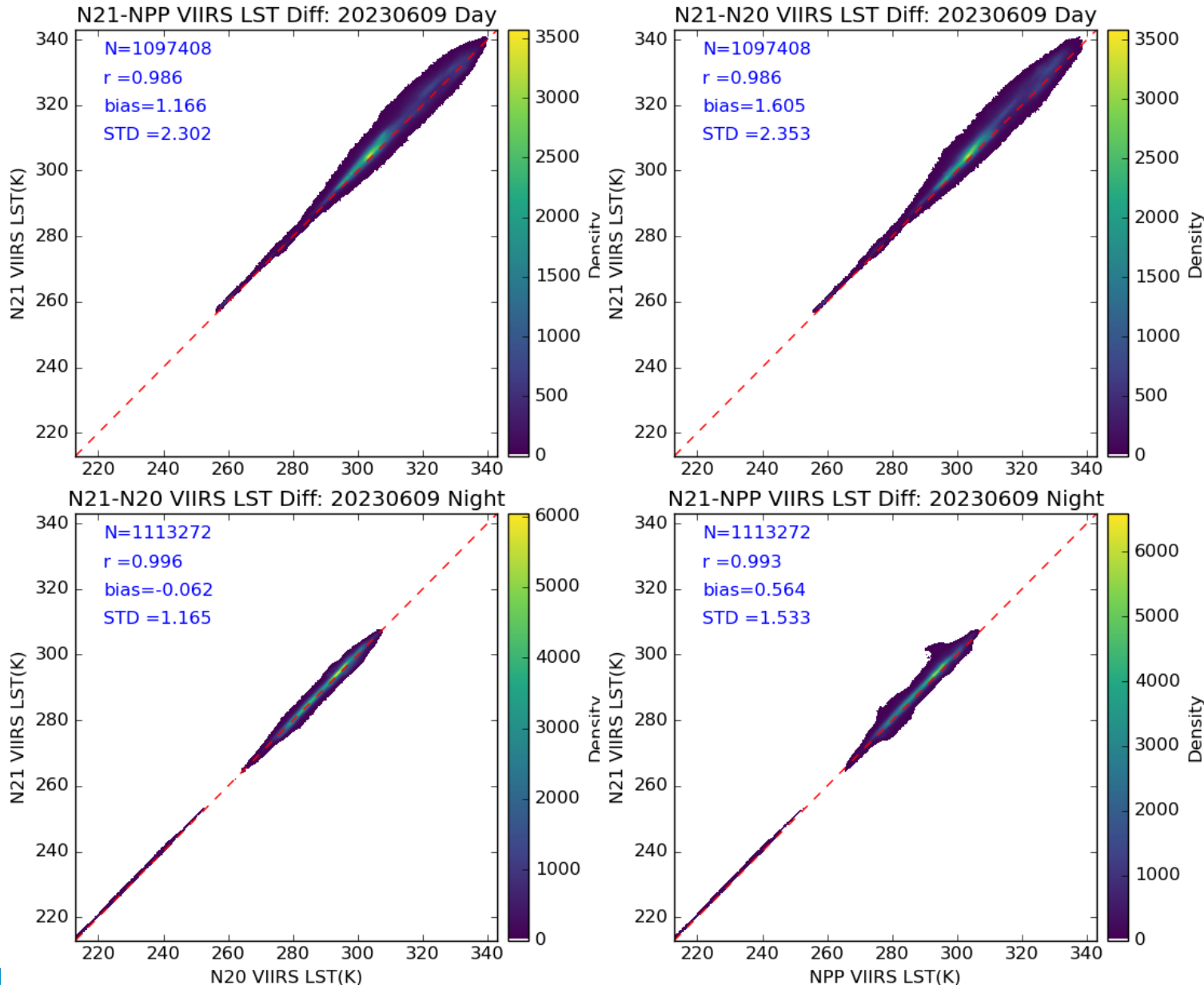
Viewtime diff on 20230609 Day



N21-N20 View time diff: 20230609 Day



Inter-sensor LST Comparison update

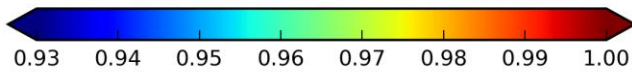
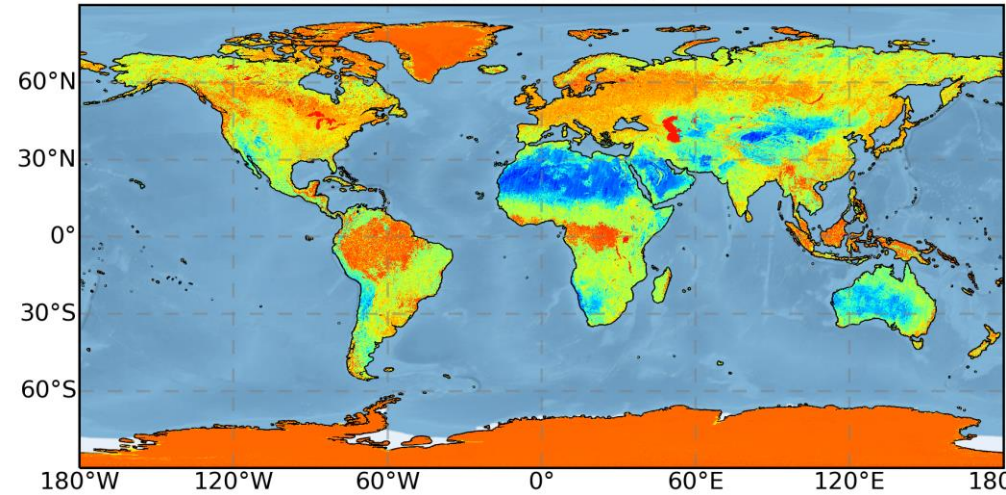


- The global LST comparisons were made under the following conditions: all cloud clear; LST not fill; and a temporal difference less than 60 minutes (a newly added criteria to mitigate the impact of the observation time difference)
- The statistical analysis was performed for the difference between NOAA-21 and SNPP/NOAA-20 LST for both daytime (top) and nighttime (bottom)
- The results indicate no significant LST difference observed. During the daytime, NOAA-21 LST is statistically higher than NOAA-20 LST and SNPP LST with a bias of 1.6 K and 1.1 K, respectively. At nighttime, NOAA-21 LST is close to NOAA-20 LST with a bias close to zero, but it is 0.5 K higher than SNPP LST.

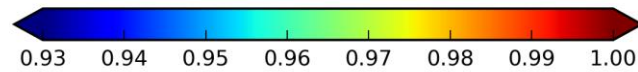
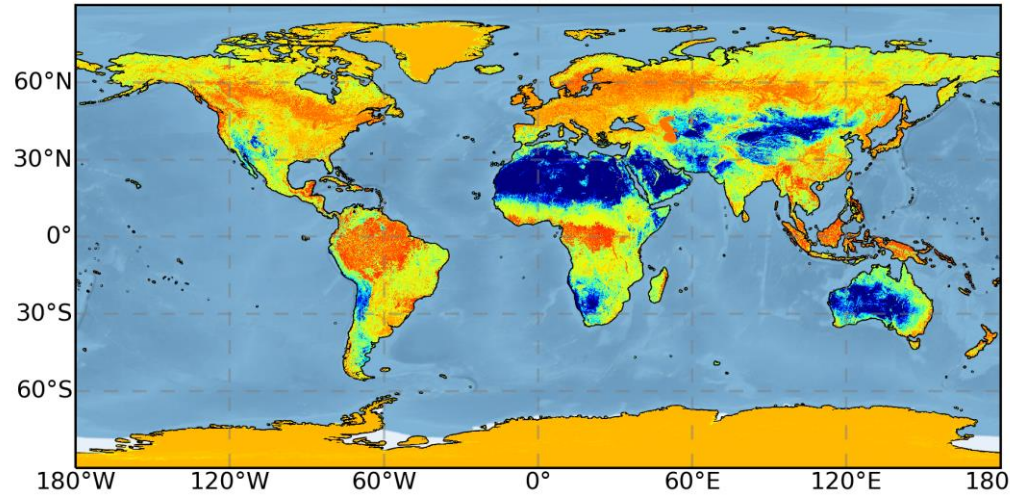
- Required Algorithm Inputs
 - Primary Sensor Data
 - VIIRS M-band SDR(M15 and M16 brightness temperature), geometry and geolocation
 - Ancillary Data
 - Land/sea mask
 - Upstream algorithms
 - LSE, AOD, Cloud mask, snow mask, GFS forecast (total precipitable water vapor)
 - LUTs / PCTs
 - LST LUT, configuration parameters
- Evaluation of the effect of required algorithm inputs
 - NOAA-21 LSE data evaluation
 - Visual analysis
 - Inter-sensor comparison with SNPP LSE data
 - LSE issue due to problematic GVF observed in SNPP and NOAA-20 run

NOAA-21 Emissivity data investigation

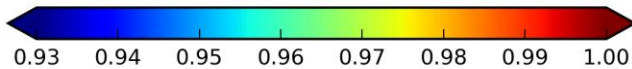
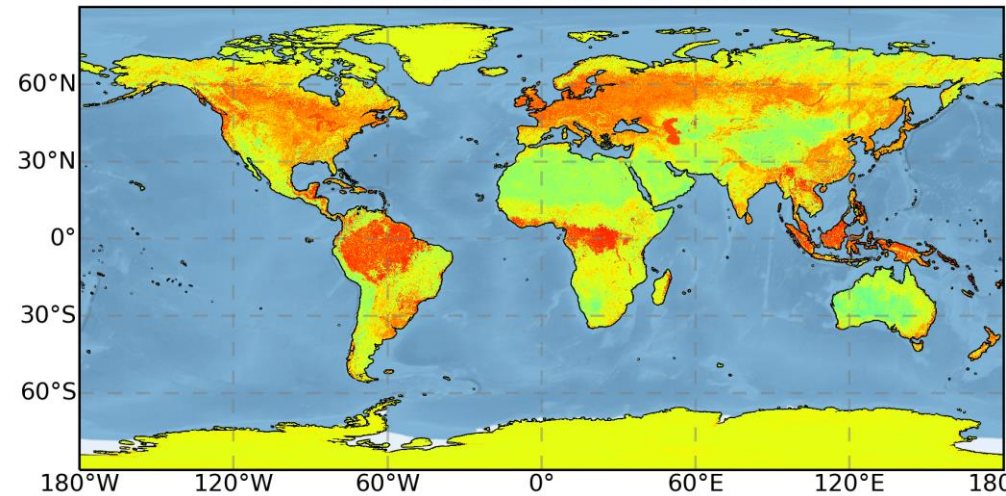
NOAA21 Band15 LSE on 20230609



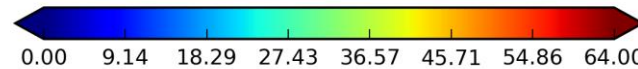
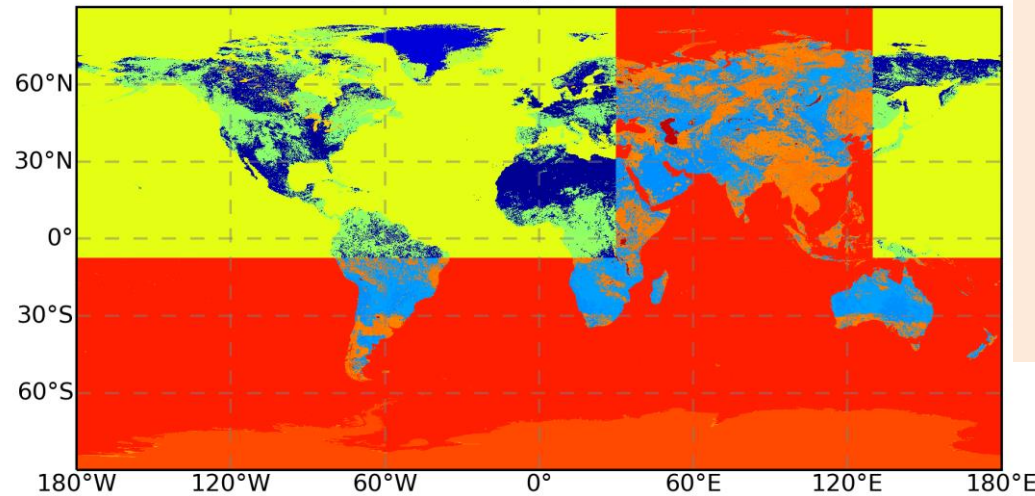
NOAA21 Broadband LSE on 20230609



NOAA21 Band16 LSE on 20230609



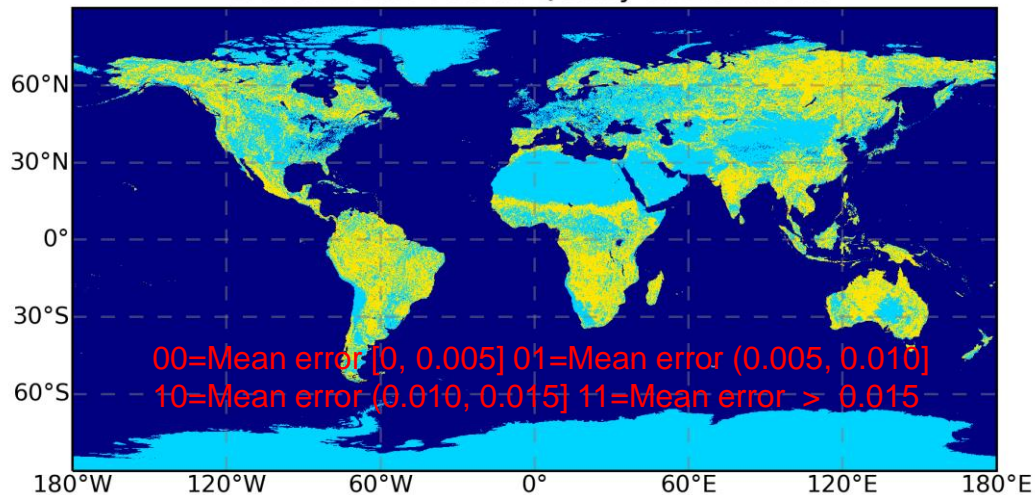
NOAA21 LSE QC on 20230609



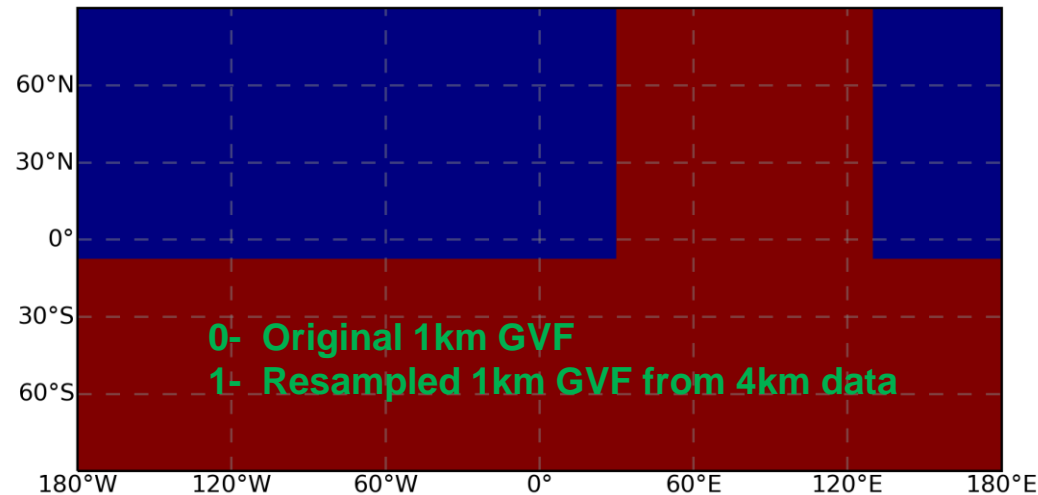
- The NOAA-21 LSE data set is verified using data on June 09, 2023 as an example.
- Band M15, M16 broadband LSE, and LSE quality flag data value and its global distribution looks reasonable.

NOAA-21 Emissivity QC

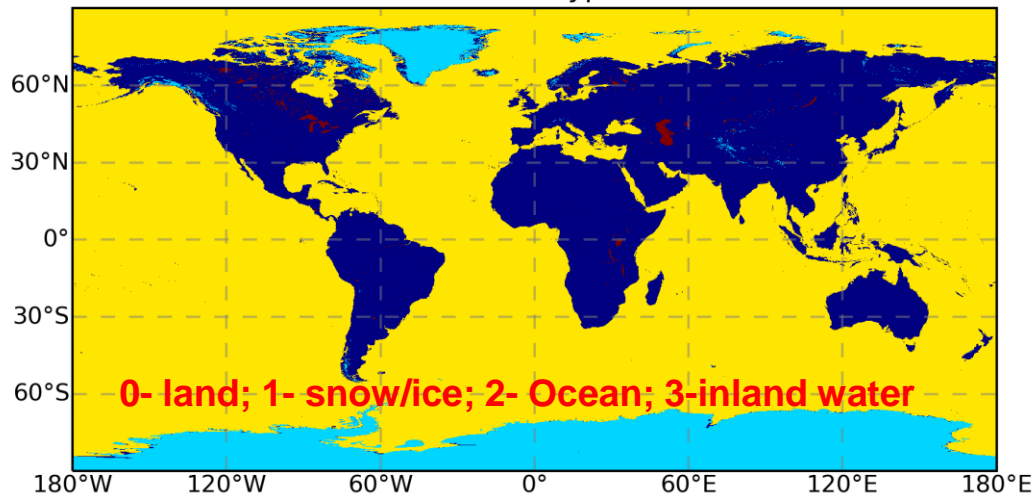
NOAA21 LSE Overall Quality on 20230609



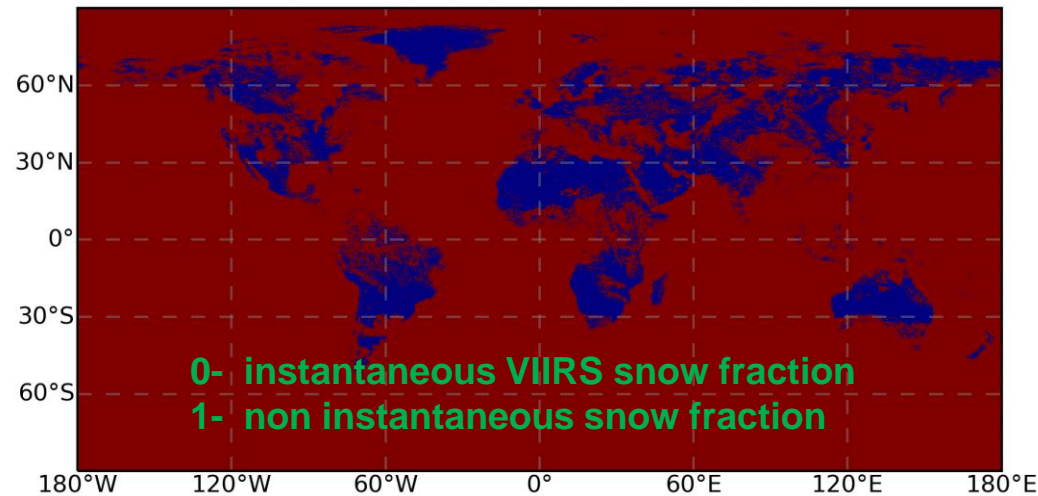
NOAA21 LSE GVF Data Source on 20230609



NOAA21 LSE Surface type on 20230609



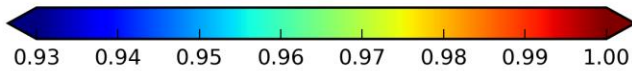
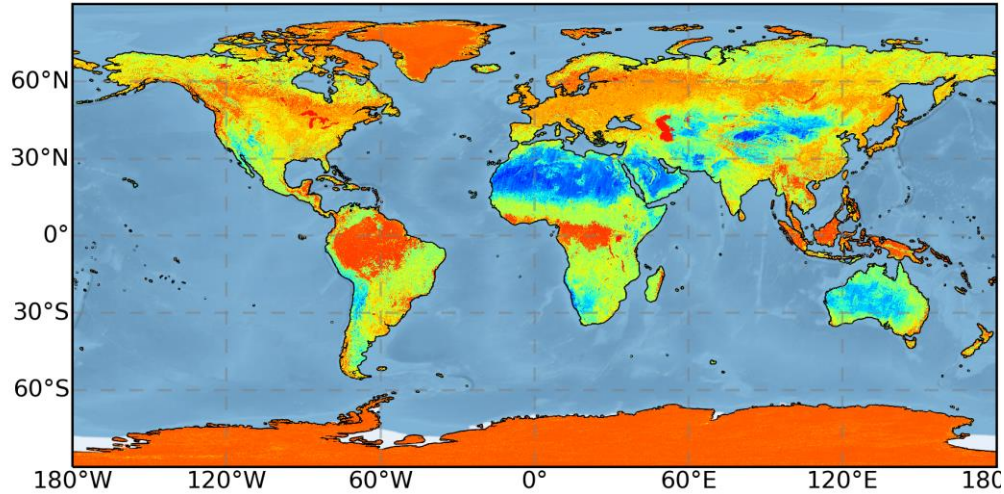
NOAA21 LSE SnowSource on 20230609



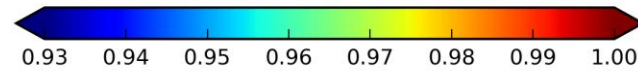
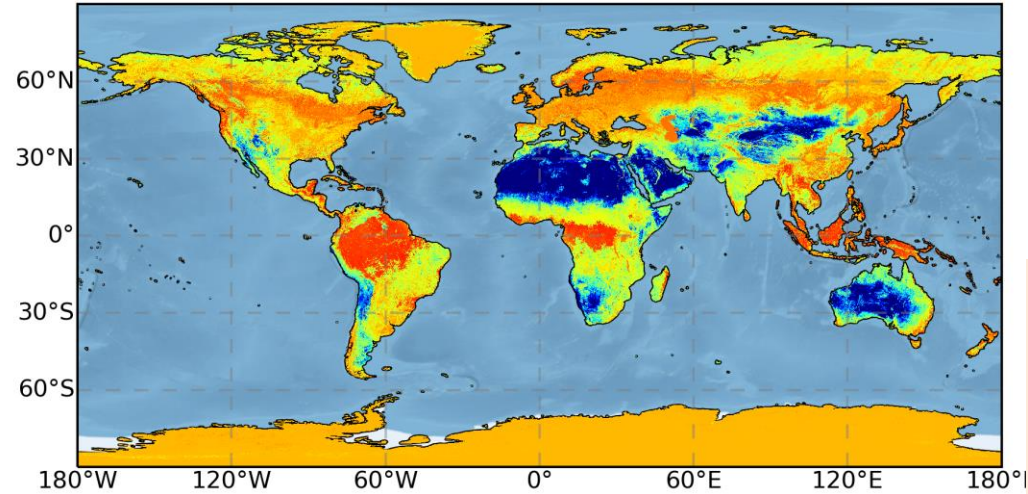
- The NOAA-21 LSE data quality flag and extracted bits are verified.
- The data value range and its global distribution looks reasonable.

SNPP Emissivity Data

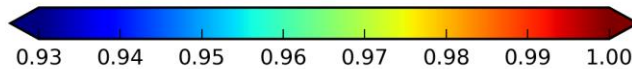
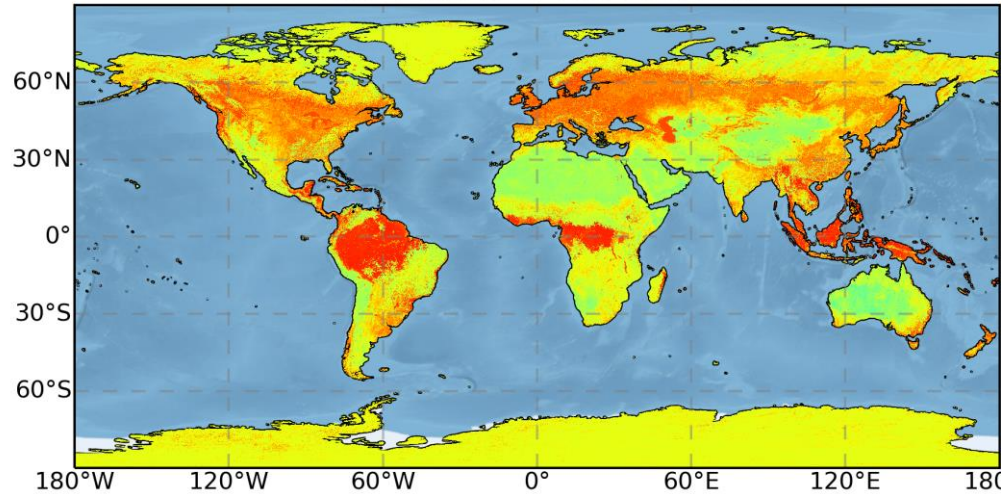
VIIRS Band15 LSE on 20230609



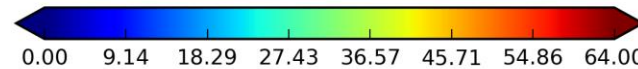
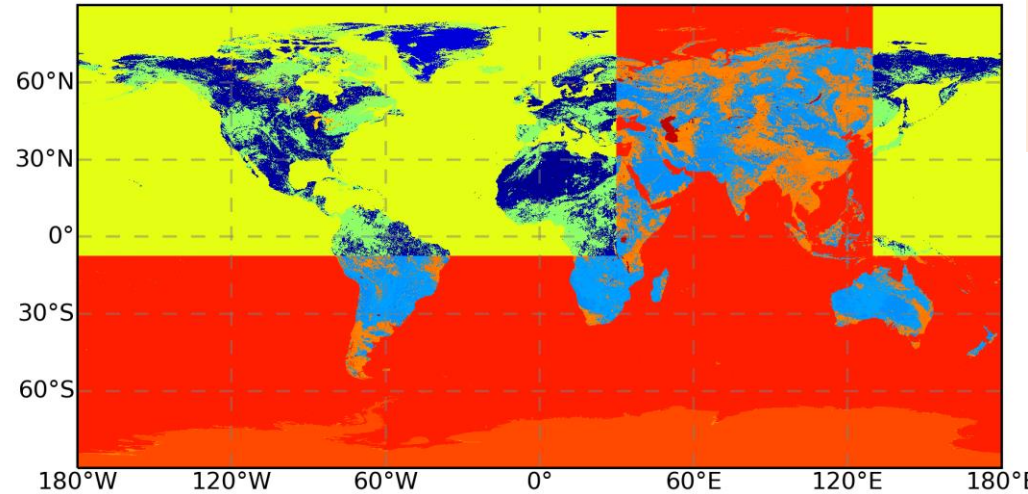
VIIRS Broadband LSE on 20230609



VIIRS Band16 LSE on 20230609



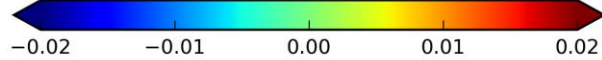
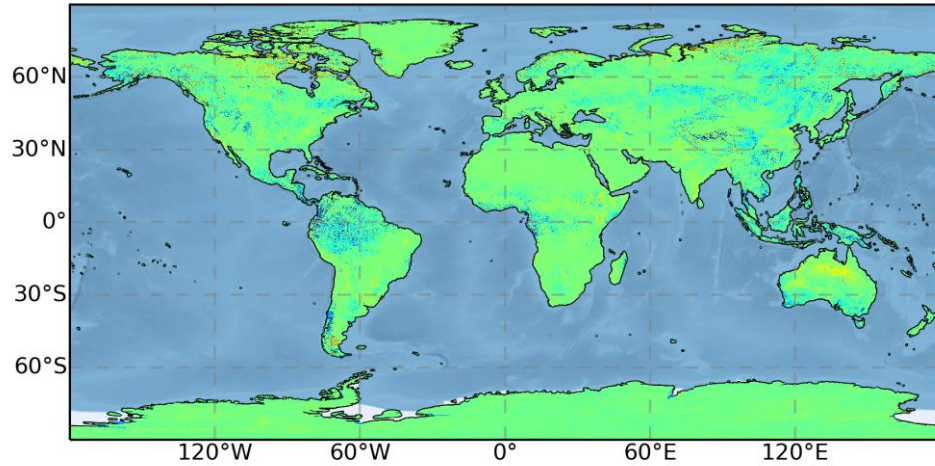
VIIRS LSE QC on 20230609



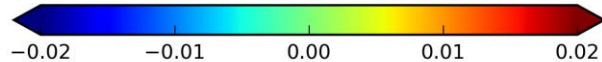
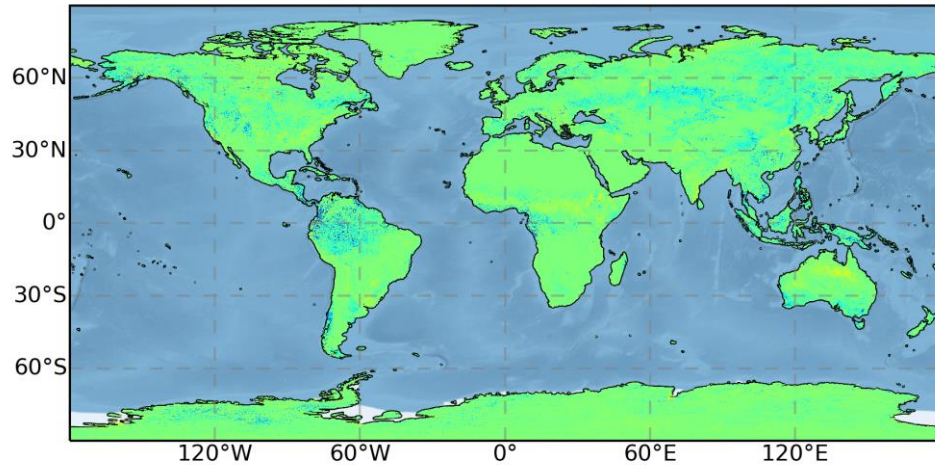
- Figures show the LSE from SNPP VIIRS on the same day 20230609.
- It is observed that SNPP LSE is higher over the vegetated area than NOAA-21 LSE.

NOAA-21 LSE comparison with SNPP LSE

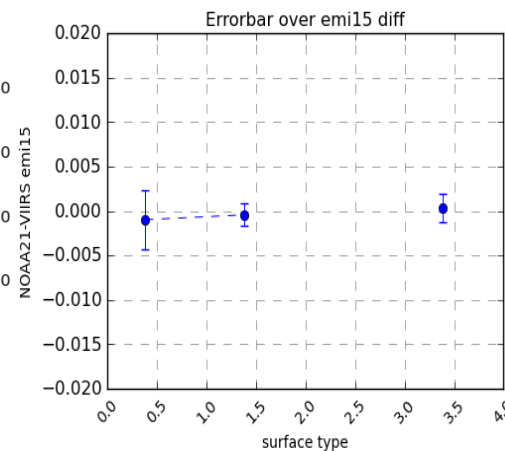
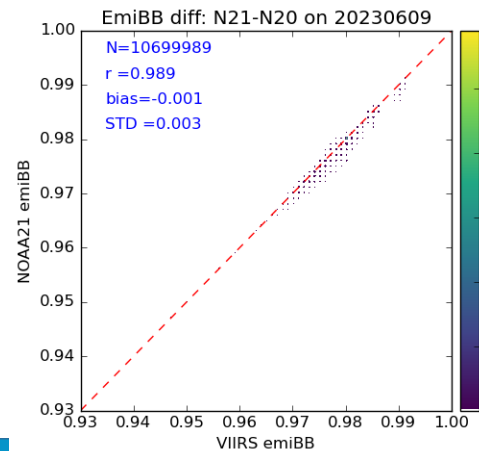
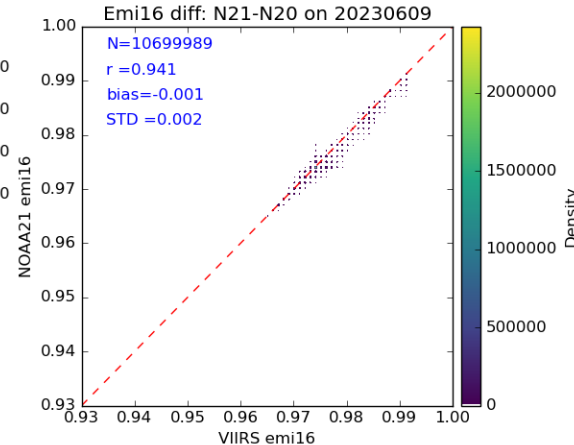
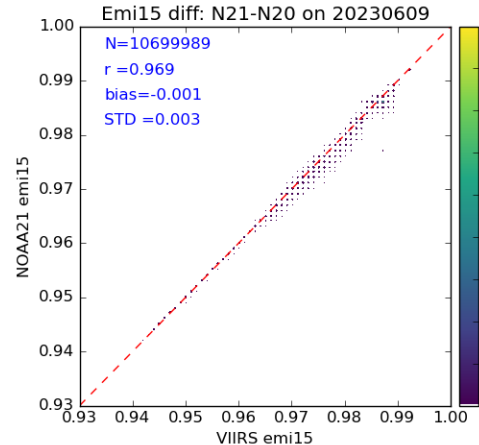
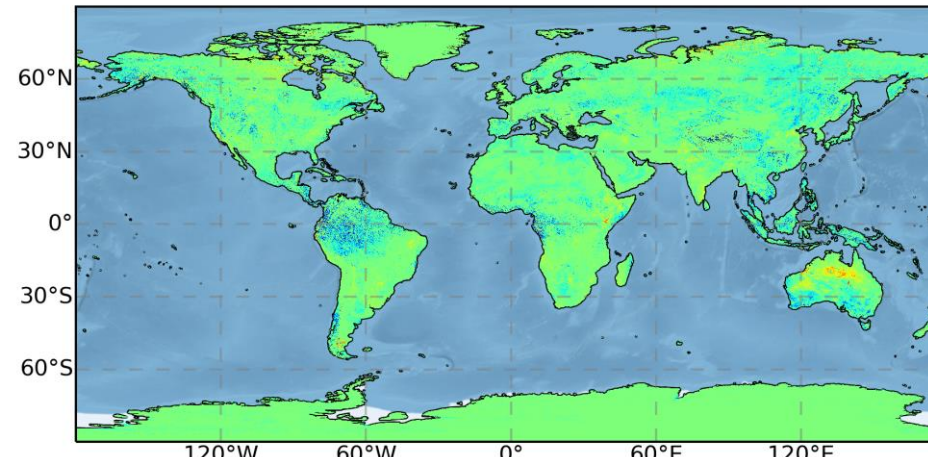
NOAA21-VIIRS emi15 Diff on 20230609



NOAA21-VIIRS emi16 Diff on 20230609



NOAA21-VIIRS emiBB Diff on 20230609

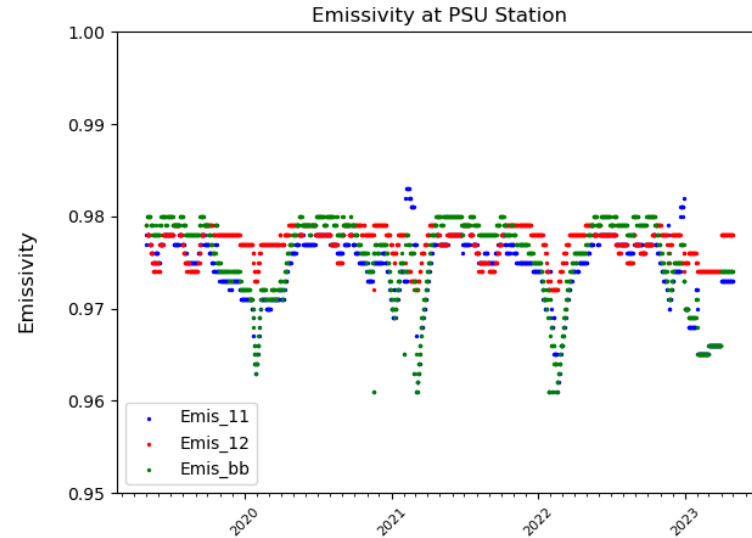
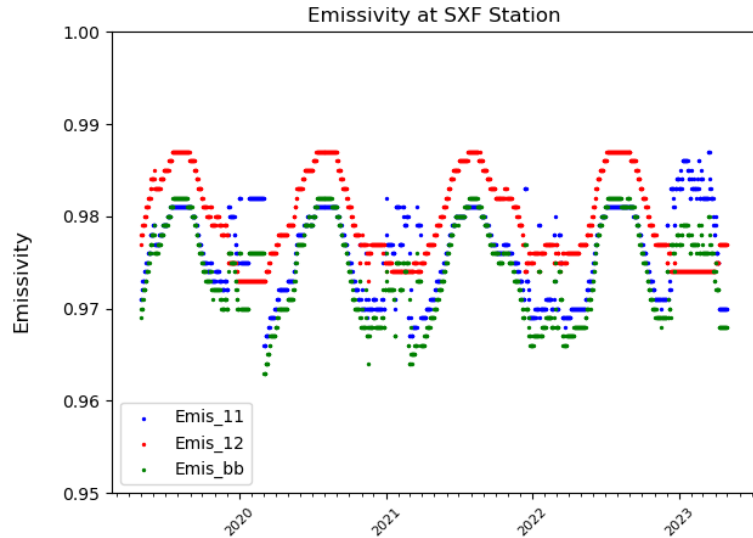
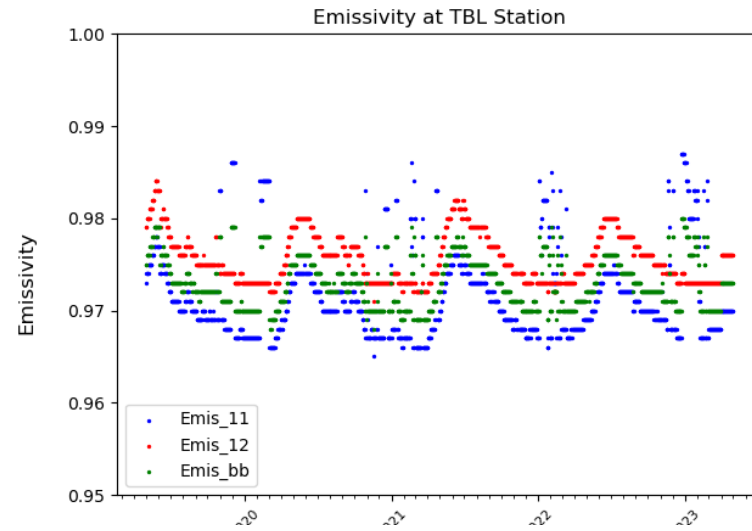
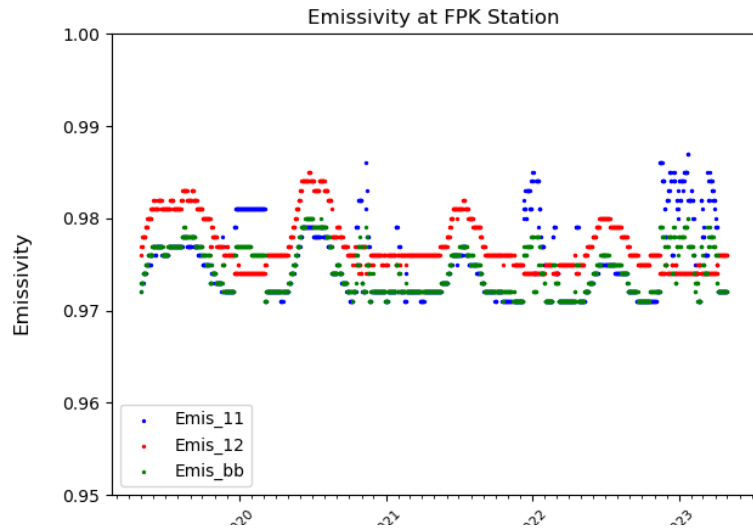


- NOAA21 LSE is compared with the emissivity for SNPP VIIRS
- N21 LSE is statistically lower than SNPP VIIRS LSE for both spectral bands and broadband with a bias of -0.001 and STD of 0.003 for emi15 and BBE and 0.002 for emi16.
- The statistical difference is smaller for snow/ice and inland water surface.

LSE data evaluation summary

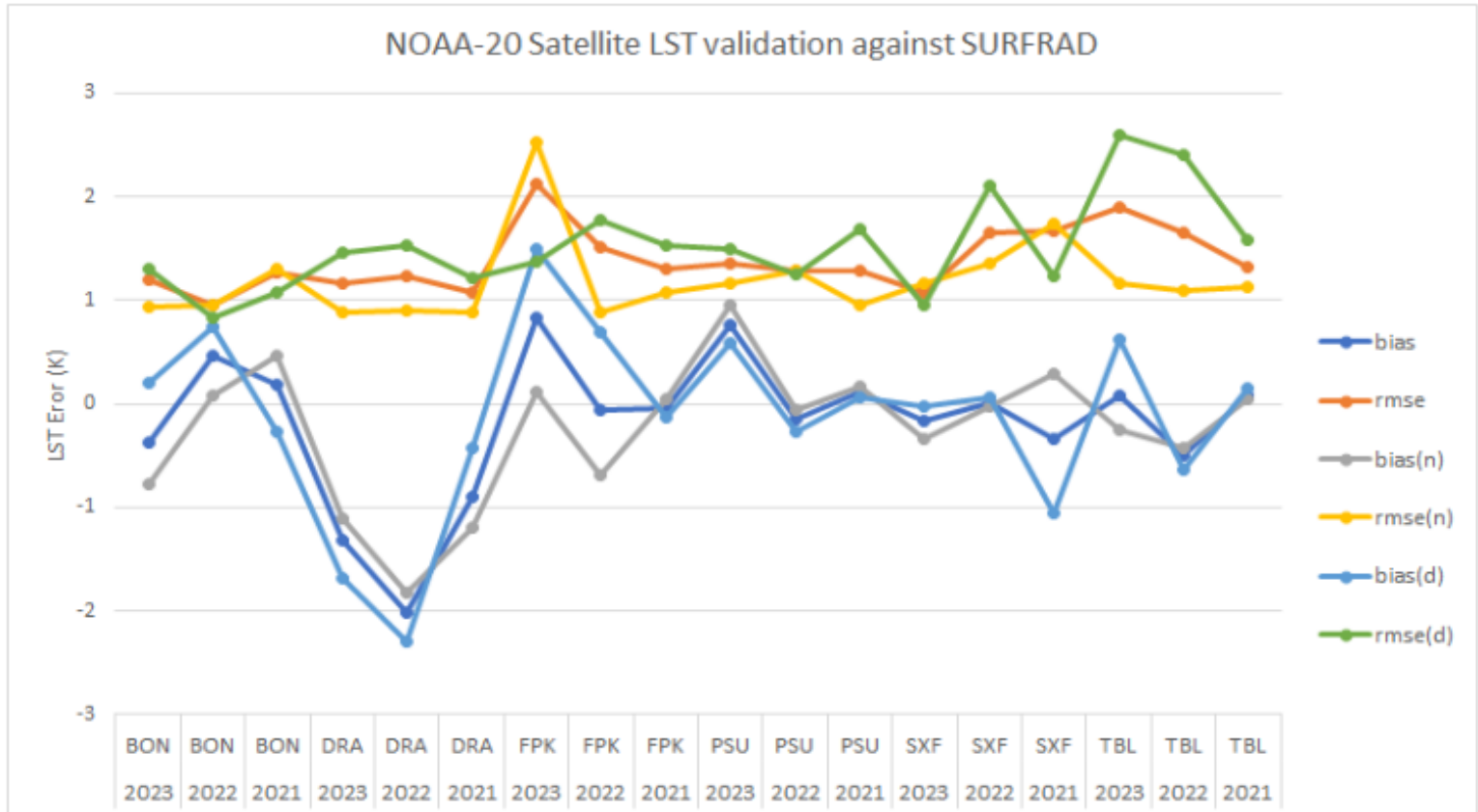
- All data layers have been verified, and their value ranges and global distributions appear reasonable.
- The inter-comparison shows a close estimation of Land Surface Emissivity (LSE) between NOAA-21 and SNPP LSE.
- NOAA-21 LSE is statistically lower than SNPP VIIRS LSE in both spectral bands and broadband, with a bias of -0.001 for all and a standard deviation of 0.003 for emi15 and BBE, and 0.002 for emi16.
- The statistical difference is smaller for snow/ice and inland water surfaces but relatively prominent over vegetated areas.

Impact of Problematic GVF on Downstream LSE and LST (1)



- GVF is found problematic in the operational run for both SNPP and NOAA20.
- Abnormal variations in emissivity, particularly emis_11, have been observed compared to previous years. This confirms the impact of the GVF issue on LSE, mainly affecting vegetated stations. However, the LSE measurement over barren surface, shrubland, snow/ice surface and inland water surface are not impacted
- The impact is more significant on Emissivity at 11microns than on emissivity at 12 microns, and it also affects broadband emissivity.
- Both emissivity at 11 micron and broadband emissivity have increased.

Impact of Problematic GVF on Downstream LSE and LST (2)



Sitewide LST error comparison

- LST error were compared for the period from January 1st to April 25 over the past three years for six stations in the SURFRAD network.
- The results indicate no clear impact, except for FPK site, which shows a more significant discrepancy, and SXF site, which shows slightly better statistics, as shown in the figure. The colors in the figure represent statistics of bias and RMSE for the combined results (day+night), with "n" representing nighttime and "d" representing daytime.

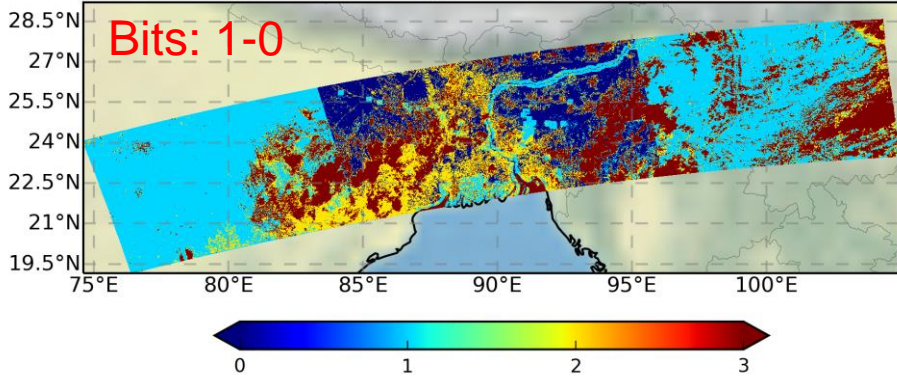
- Defined Quality Flags
 - Variable
 - Description
 - Value
- Quality flag analysis/validation
 - Test / example / ground truth data sets
 - Analysis / validation results
 - Analysis / validation plan

L2 VIIRS LST Quality Flag

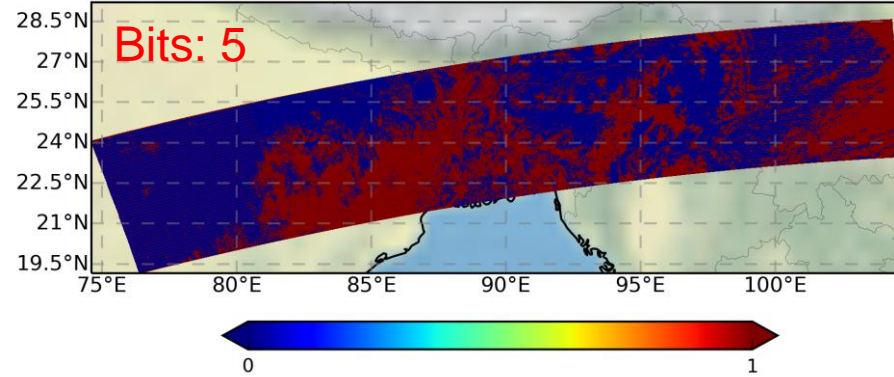
bit	Flag	Source	description
1-0	LST quality	LST	00=high, 01=medium, 10=low, 11=no retrieval
3-2	Cloud condition	Cloud mask	00=confidently clear, 01=probably clear, 10=probably cloudy, 11=confidently cloudy
4	SDR quality	SDR	0=normal, 1=bad data (bad quality or missing or out of space)
5	Aerosol Optical Thickness at 550 nm (slant path)	AOD	0=within range (AOD<=1.0); 1=outside range (AOD >1 or AOD missing)
7-6	Land surface cover	land/sea mask snow/ice mask	00=land; 01=snow/ice; 10=in land water; 11=coastal
9-8	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 quality	Emissivity	0=within LSE uncertainty, 1=beyond LSE uncertainty requirement (0.015)
11	Degradation by large viewing angle	SDR	0=no degradation, 1=large view degradation (VIIRS: <=40 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 (Only available for daytime)
14	Fire contamination flag	Cloud mask	0= no, 1= yes
15	Reserved		Reserved for future use

L2 VIIRS LST Quality Flag Verification (1)

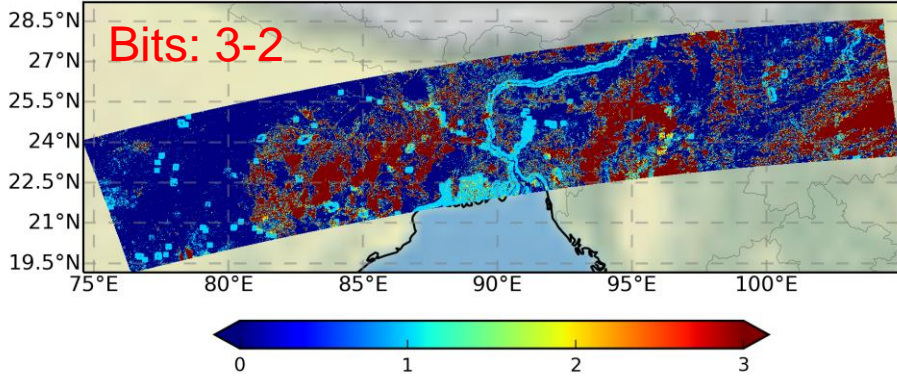
Data Quality on 202305310708



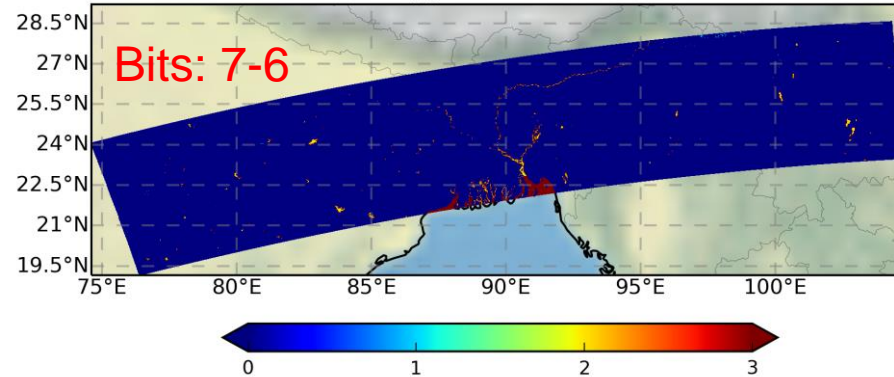
AOD on 202305310708



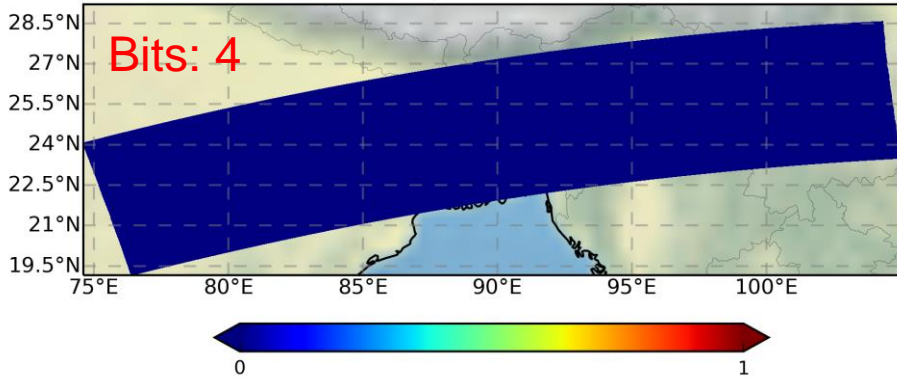
Cloud Mask on 202305310708



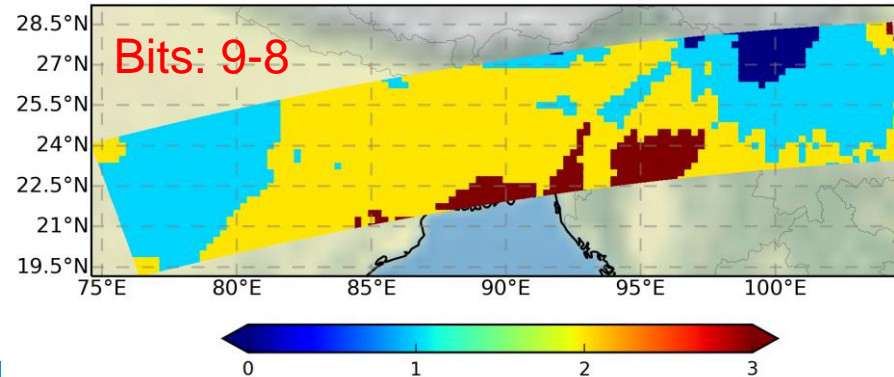
Surface type on 202305310708



SDR Quality on 202305310708



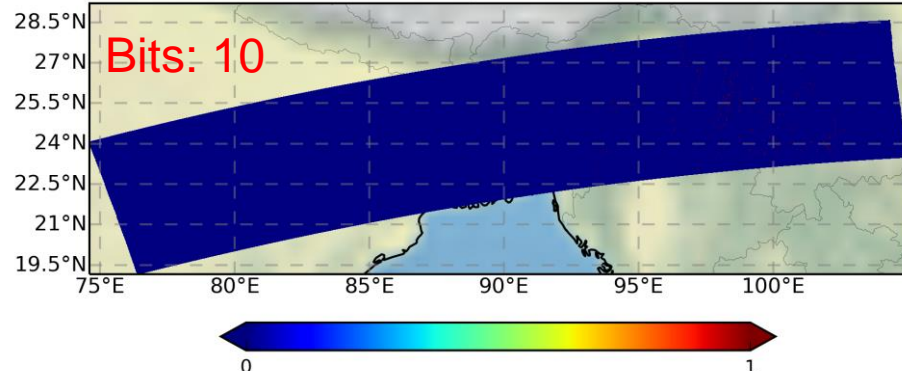
TPW on 202305310708



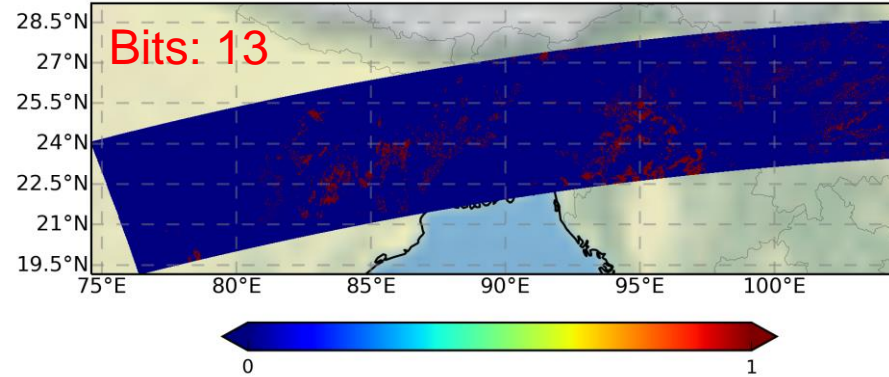
- The plots show the bits 0 to 9 map extracted from LST quality flag.
- Small blocks were observed in the cloud mask (bits 3-2), which results in small blocks in the data quality (bits 1-0)
- The quality flag bits value and global distribution look reasonable. No other issues were observed.

L2 VIIRS LST Quality Flag Verification (2)

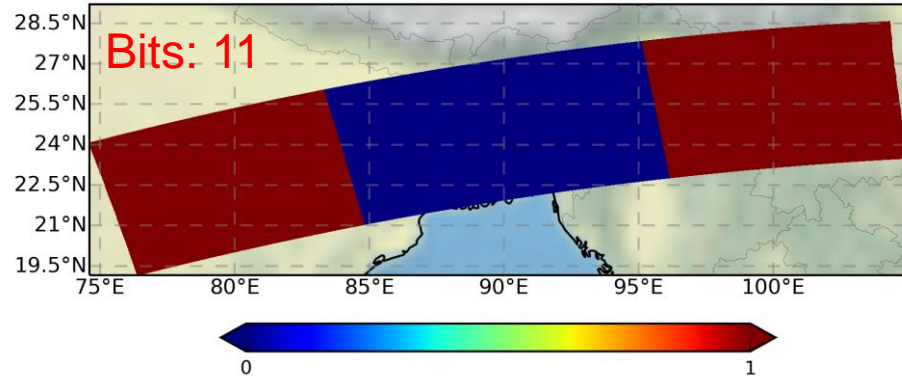
Emis uncertainty on 202305310708



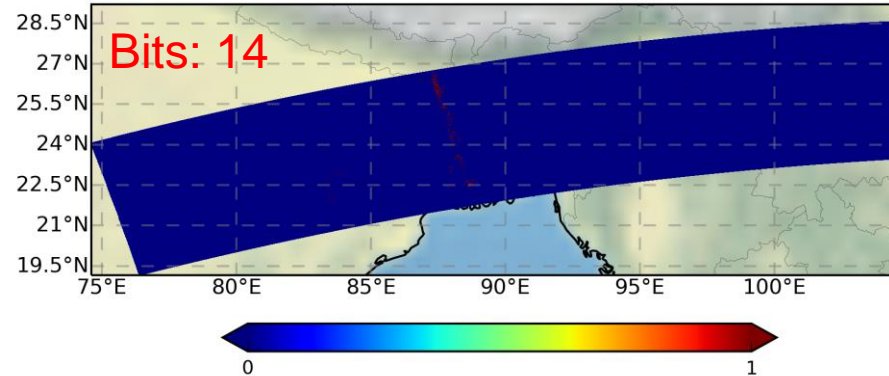
Thin cirrus on 202305310708



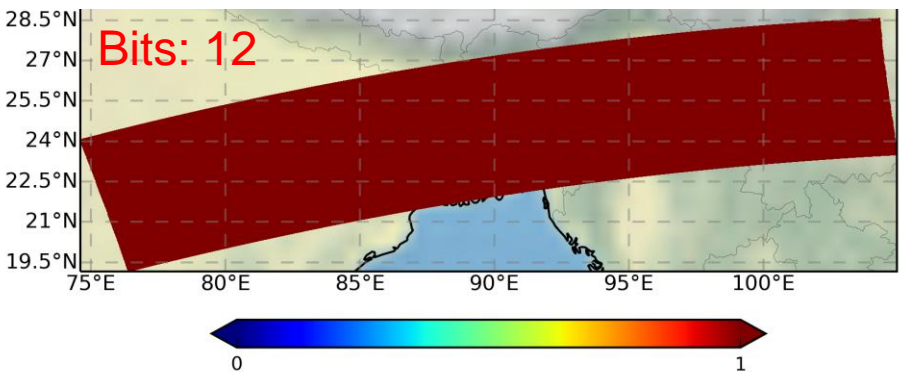
Large angle on 202305310708



Active Fire on 202305310708

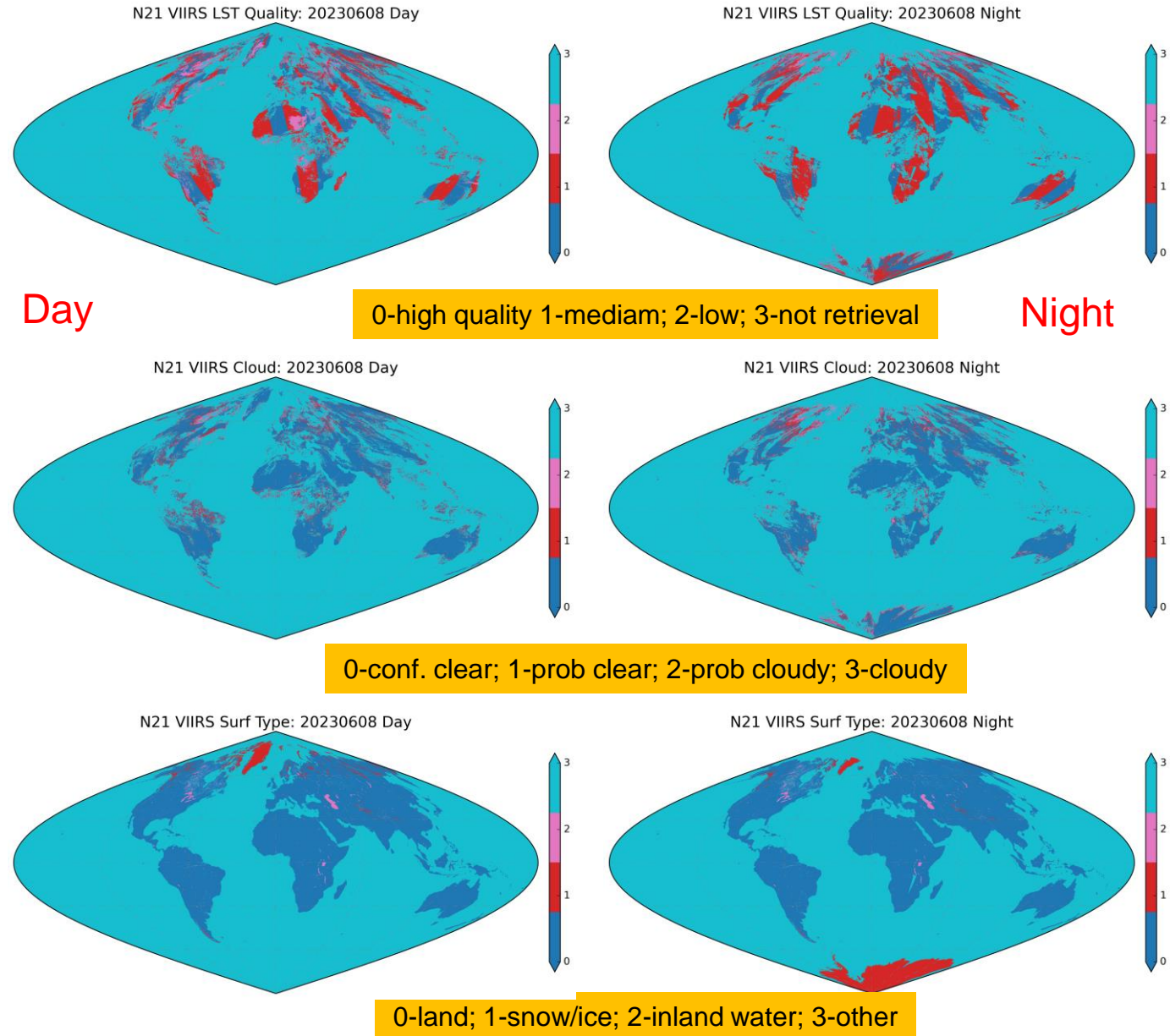


- The plots show the bits 10 to 14 map extracted from LST quality flag.
- The quality flag bits value and global distribution look reasonable.
- No obvious issues were observed.



L3 VIIRS LST Quality Flag

Bits	Long Name	Comments
1 & 0	Data quality flag	00=high quality 01=Medium quality 10=low quality 11=no retrieval
3 & 2	Cloud Confidence	00=confidently clear 01=probably clear 10=probably cloudy 11=confidently cloudy
5 & 4	Land/water	00=land 01=snow/ice 10=in land water 11=coastal/sea water
7 & 6	Empty	For future use



- Table shows the L3 LST quality flag list; the plots on the right display the corresponding bits extracted from the quality flag for daytime (left) and nighttime LST (right)
- The quality flag value and global distribution look reasonable.

Error Budget

Compare analysis/validation results against requirements, present as a table. Error budget limitations should be explained. Describe prospects for overcoming error budget limitations with future improvements of the algorithm, test data, and error analysis methodology.

Attribute Analyzed	DPS	Requirement/ Threshold	Pre-Launch Performance	On-orbit Performance			Meet Requirement?	Additional Comments
				NOAA-21	NOAA-20	S-NPP		
Accuracy		1.4 K		0.88/1.54	0.39/0.8	0.53/0.89	Marginally	Based on the ground validation results with SURFRAD and ARM
Precision		2.5 K		2.52/2.4	2.28/2.45	2.31/2.4	Marginally	Significant daytime bias is mostly attributed to the seasonal representativeness issue of ground observations. The statistics is not stable due to small sample number. Long term data validation is necessary.
Uncertainty								

User Feedback

Name	Organization	Application	User Feedback - User readiness dates for ingest of data and bringing data to operations
Jifu Yin	STAR/NESIS	Soil moisture product downscaling from 25 km to 1 km	There is an inherent relationship between soil moisture and land surface temperature, which provides ancillary information on soil moisture distributions and estimations. In addition, microwave soil moisture product has coarse spatial resolution (25 km), the VIIRS LST product with high spatial resolution thus can be used to produce finer resolution satellite soil moisture retrievals. The gridded LST over CONUS and global domain has been routinely ingested in the generation of soil moisture product in high spatial resolution.
Li Fang	STAR/NESIS	Global ET product generation based on VIIRS LST product at 1 km spatial resolution	VIIRS day/night LST product has been routinely collected as a key input in the global ET/drought system.

Risks, Actions, and Mitigations

- Provide updates for the status of the risks/actions identified during the previous maturity review(s); add new ones as needed

Identified Risk	Description	Impact	Action/Mitigation and Schedule
Land Surface Emissivity	The GVF issue was observed for NPP and NOAA20 and there is a possibility of it occurring on NOAA-21 as well, although it is unable to confirm yet. GVF at the beginning is of poor quality, which also affects LSE.	Issues in LSE will affect LST quality	The GVF issue needs to be identified first and then its impact on LSE will be evaluated and monitored.
LST composition method update	The new composition method has been applied in NOAA-21 LST, while NOAA-20 and SNPP are still using the previous composition method.	Inconsistency among the L3 VIIRS LST, particularly at high latitude.	Further testing is needed once SNPP and NOAA20 applies new update. In the meantime monitor the NOAA-21 LST performance over a longer time period.
Data missing	The data stream is not stable yet. Data missing happens sometime.	Incomplete LST dataset. Statistical and time series analysis might be affected	

Documentations (Check List, 1 slide)

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 (for ESPC products)	Yes
Peer Reviewed Publications (Demonstrates algorithm is independently reviewed)	Yes
Regular Validation Reports (at least annually) (Demonstrates long-term performance of the algorithm)	Yes

Check List - Beta Maturity

Beta Maturity End State	Assessment
<p>Product is minimally validated, and may still contain significant identified and unidentified errors</p>	<p>Yes. The validation covers all available dataset to date. The validation consists of temperature based validation using ground observations also the inter-satellite comparison with SNPP and NOAA-20.</p>
<p>Information/data from validation efforts can only be used to make initial qualitative or very limited quantitative assessments regarding product fitness-for-purpose</p>	<p>Yes, the assessments is based on one and a half months of data since June 8, 2023, the statistical results based on it might be insufficient for a sound quantitative assessment yet.</p>
<p>Documentation of product performance and identified product performance anomalies, including recommended remediation strategies, exists</p>	<p>Yes. A report will be prepared for any issues observed.</p>

Conclusion

- Cal/Val results summary:
 - Team recommend the NOAA-21 LST Beta maturity
 - The LST output layers and quality flag have been verified for both L2 and L3 NOAA-21 VIIRS LST. The data is within a valid range and its distribution looks reasonable.
 - The LST data has been preliminarily validated with ground measurements from SURFRAD and ARM. The results marginally meet the requirement.
 - The inter-comparison is conducted among VIIRS LSTs. Overall it is statistically close for most areas. Inconsistency was observed under certain situations attributed to the different composition method applied in NOAA-21 LST and NOAA-20/SNPP LST.
 - The GVF issue was observed for NPP and NOAA-20 and there is a possibility of it occurring on NOAA-21 as well, although it is unable to confirm yet. It will have an impact on LSE as well as on LST data. We will pay attention to the GVF evaluation and monitor LSE time series.
 - The data stream is not yet stable and data missing happens sometime.

Path Forward

- Lessons learned for NOAA-21 Cal/Val
 - Very limited data availability, which is insufficient for statistical evaluation of the product performance
- Planned improvements
 - NOAA-21 LST LUT may need update
 - Comprehensive evaluation is planned using longer time period of data.
 - Closely monitor the inconsistency among the VIIRS LSTs from SNPP, NOAA-20 and NOAA-21 resulting from the implementation of the new composition method.
- Future Cal/Val activities / milestones
 - Provisional maturity review in 6 months
 - Validated maturity review in 12 months