

VIIRS land Surface Temperature (LST) Provisional Status

Dr. Yunyue YU – LST EDR Lead

Dr. Ivan Csiszar – Land Product EDR Lead

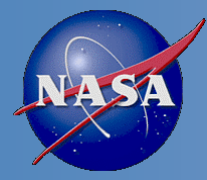
Dr. Jeffrey Privette – Land Product Validation Lead

Contributors:

Yuling Liu, Zhuo Wang, Pierre Guillevic, Peng Yu, Leslie Belsma

May 31, 2013

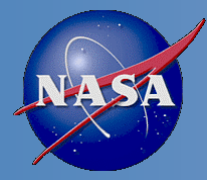




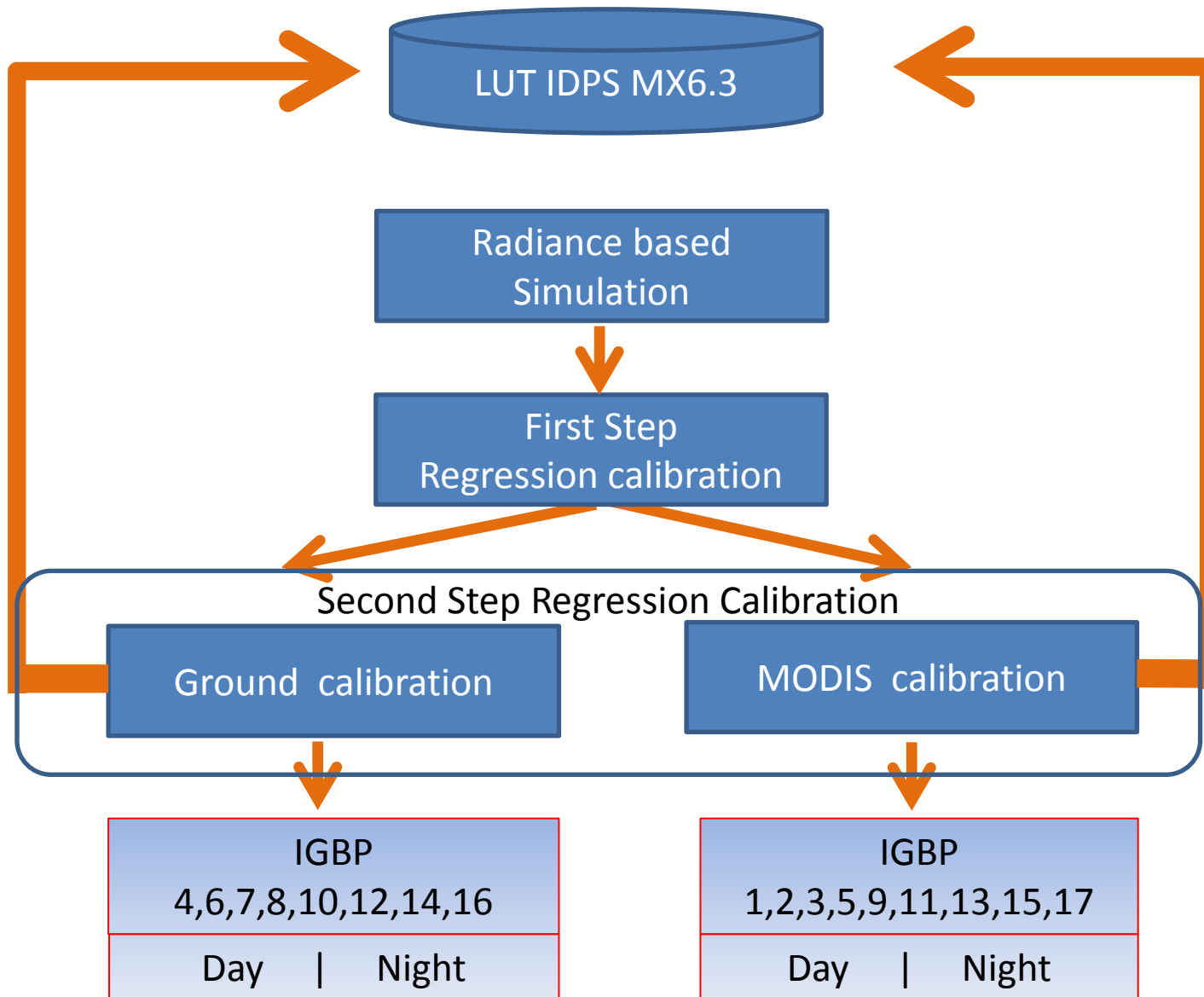
LST Calibration Approach

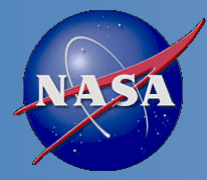


- Improvement for LST EDR is based on update of algorithm coefficients. The algorithm keeps the same format as baseline split window algorithm.
- Two steps of calibration:
 1. *calibration from the radiance based simulation*
 2. *calibration from comparisons to the reference dataset, i.e. ground truth and MODIS Aqua LST product.*
- All the 34 coefficients sets need to be calibrated (17 surface types, day and night conditions).
- Calibration is based on the annual performance rather than the seasonal performance.



Flow chart of LST Calibration





Calibration Equations



Split Window Algorithm:

$$LST_i = a_0(i) + a_1(i)T_{m15} + a_2(i)(T_{m15} - T_{m16}) + a_3(i)(\sec\theta - 1) + a_4(i)(T_{m15} - T_{m16})^2$$

Regression Calibration :

$$\Delta LST_i = a'_0(i) + a'_1(i)T_{m15} + a'_2(i)(T_{m15} - T_{m16}) + a'_3(i)(\sec\theta - 1) + a'_4(i)(T_{m15} - T_{m16})^2$$

First step calibration :

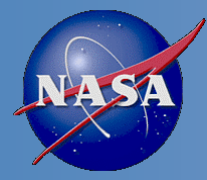
$$\Delta LST^1_i = LST_{simulated(i)} - LST_{IDPS(i)}$$

Second step calibration :

$$\Delta LST^2_i = LST_{FirstStepCalibrated(i)} - LST_{ReferenceLST(i)}$$

Calibrated LST:

$$LST'_i = LST_i + \Delta LST^1_i + \Delta LST^2_i$$

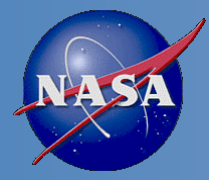


Data sets for LST calibration



Data sets

- Radiance based simulation data set
- Ground truth data set for the time period from Jan. 2012 to March 2013.
- MODIS Aqua LST (MYD11_L2).
- VIIRS LST data set retrieved from baseline split window algorithm using LUT compatible to MX6.3 build in IDPS.

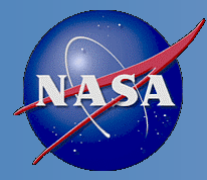


Calibrated LUT



Table : Calibrated coefficient sets for daytime

Surface Type	a_0	a_1	a_2	a_3	a_4
1	14.09725	0.952054	3.628772	1.063013	-0.72116
2	46.49631	0.84317	3.630332	2.42386	-0.46282
3	19.15561	0.93878	2.243532	0.813863	-0.16193
4	83.20458	0.717731	0.66112	-2.70106	1.030025
5	21.09595	0.928608	3.659621	1.246776	-0.75761
6	34.68417	0.892991	2.057732	0.370878	-0.11038
7	23.29719	0.929813	2.111201	1.213785	-0.17932
8	14.12894	0.961051	3.660384	1.372316	-0.56754
9	-19.2834	1.067944	2.605338	1.021086	-0.28965
10	29.04222	0.908072	0.834016	0.059388	0.091796
11	41.10021	0.854104	5.427233	1.036486	-0.82492
12	87.5046	0.694267	6.799456	2.728394	-1.57036
13	-8.22047	1.032807	1.166056	0.978909	0.306121
14	36.49564	0.879512	2.740735	2.379238	-0.2124
15	51.80619	0.813552	0.487301	0.352144	2.713991
16	46.3273	0.85738	2.404385	0.889798	-0.15684
17	-13.4006	1.053738	-0.07923	1.479963	0.327909

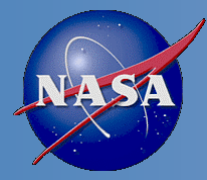


LUT after Calibration



Table : Calibrated coefficient sets for nighttime

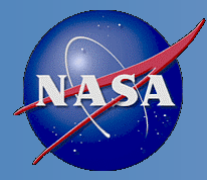
Surface Type	a_0	a_1	a_2	a_3	a_4
1	-13.0319	1.050311	-1.3172	0.397226	0.444173
2	-17.1079	1.064144	-0.03215	1.192763	1.273679
3	-5.53066	1.023238	-0.51264	0.782135	2.940489
4	-0.67262	1.008506	1.782233	1.031163	0.193119
5	-6.20065	1.025126	-0.74568	0.874003	1.161099
6	16.87514	0.956207	1.272964	0.40632	0.273115
7	8.16033	0.985068	1.112239	0.974629	-0.69782
8	-6.7826	1.027303	1.131303	0.819621	0.519747
9	-10.5868	1.041501	-1.04836	1.250769	1.219346
10	-1.92048	1.016412	2.017803	1.304318	0.193718
11	5.66736	0.979304	-0.58598	0.313569	1.468379
12	-0.98175	1.010598	1.322288	-0.39396	0.397286
13	-6.66112	1.028283	0.94247	0.363574	-0.78628
14	25.0644	0.914246	2.680287	0.810411	0.093822
15	3.73122	0.985113	-1.38143	0.251886	1.766198
16	8.40627	0.984474	0.974452	0.83134	0.913031
17	-4.65634	1.019516	-0.07639	1.511793	0.162857



Provisional Definition



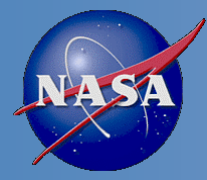
- Product quality may not be optimal
 - Optimal would be LST attains all of its requirements
- Incremental product improvements still occurring
 - DR history and future planned efforts will be shown
- Version control is in effect
- General research community is encouraged to participate
 - LST status and issues are posted and discussed in meetings
 - International cooperative activities involved
- Users urged to consult the EDR product status
- May be replaced in the archive
- Ready for operational evaluation



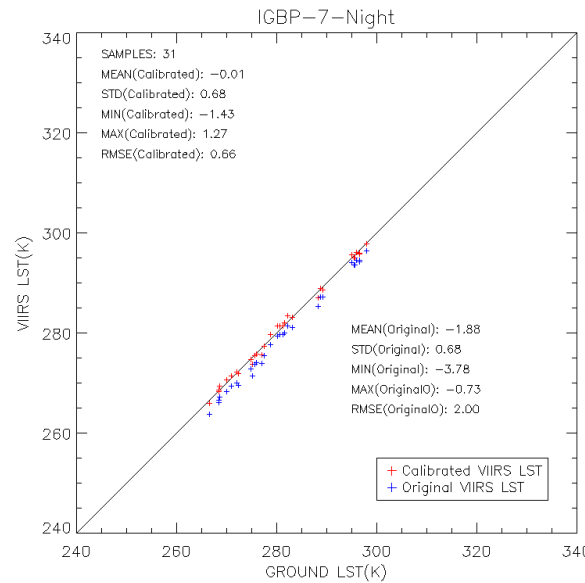
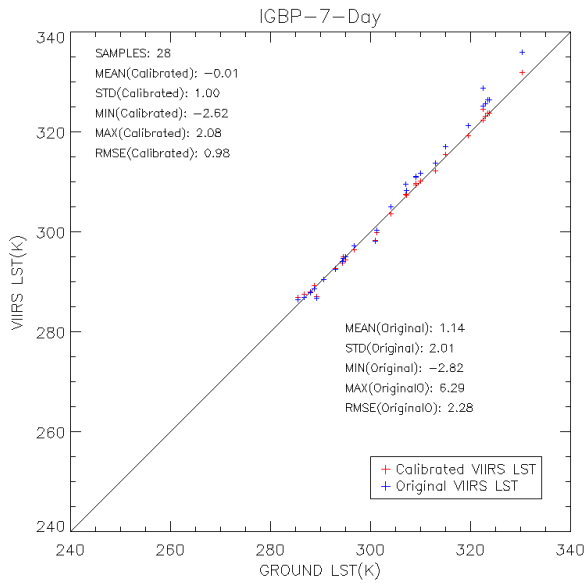
Product Quality



- Product quality is evaluated using ground data from SURFRAD and MODIS Aqua LST over the four representative months of January, April, July and October.
 - *The latest coefficients set are implemented and compared with the IDPS LST built using the latest LUT in Mx6.3 build.*
 - *Results for the ground comparison and cross-satellite comparison are shown.*
- The product is expected for an improvement over a whole year not necessarily favor a certain season.
- Only high quality data is used for the evaluation.

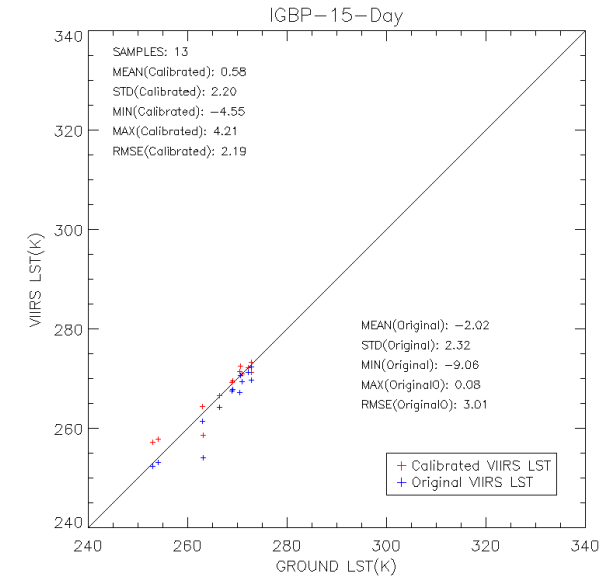
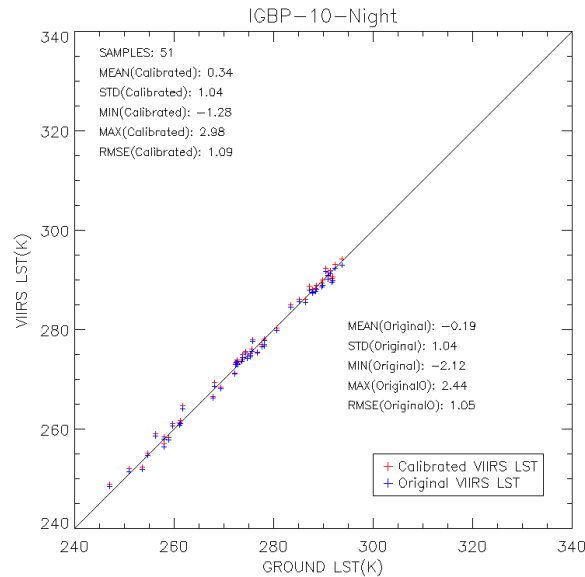
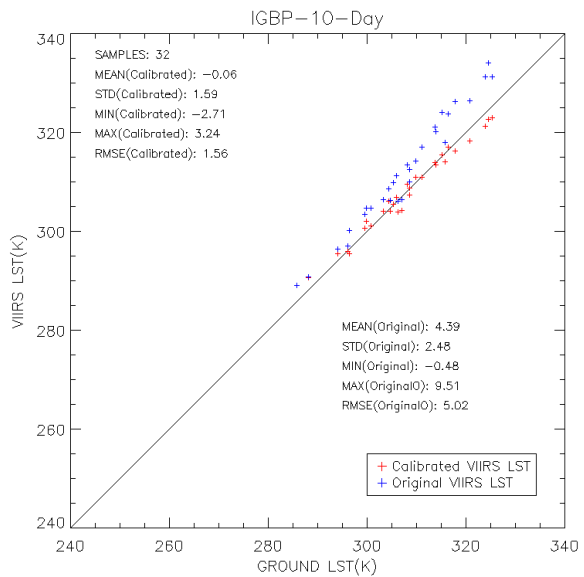


Provisional Evaluation against Ground truth

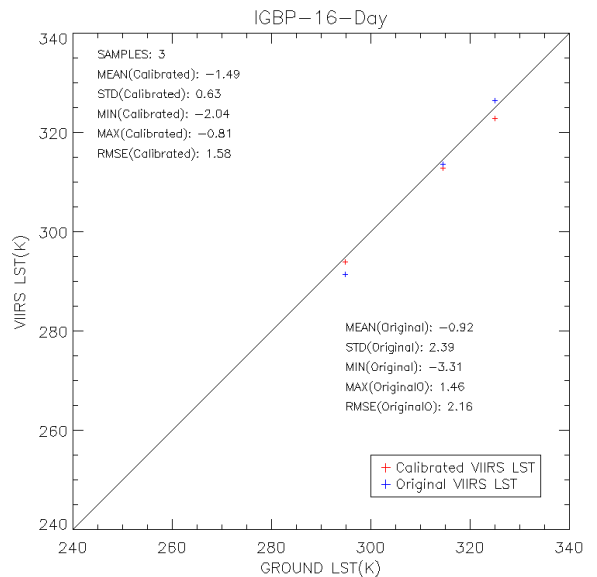
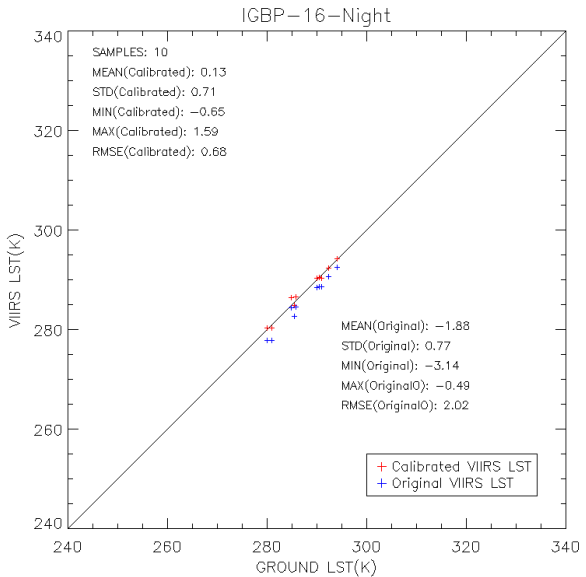
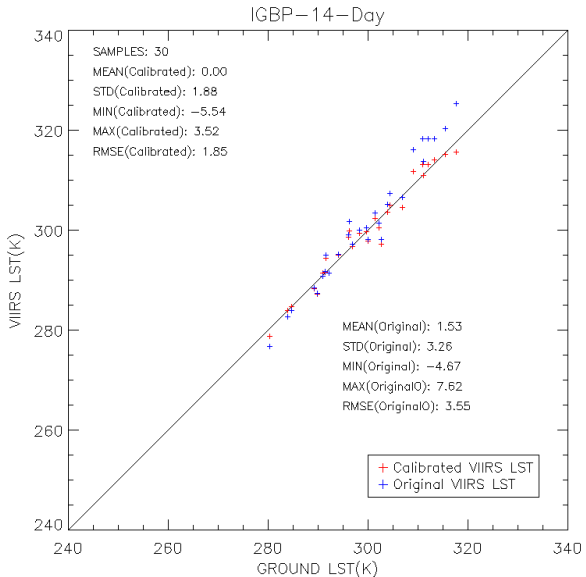
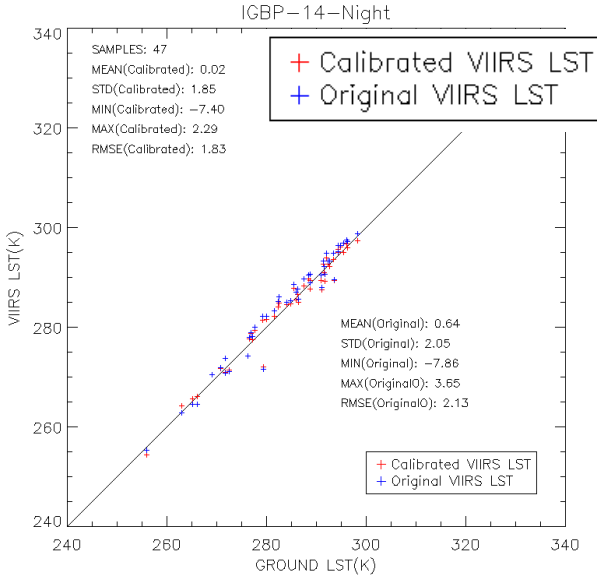
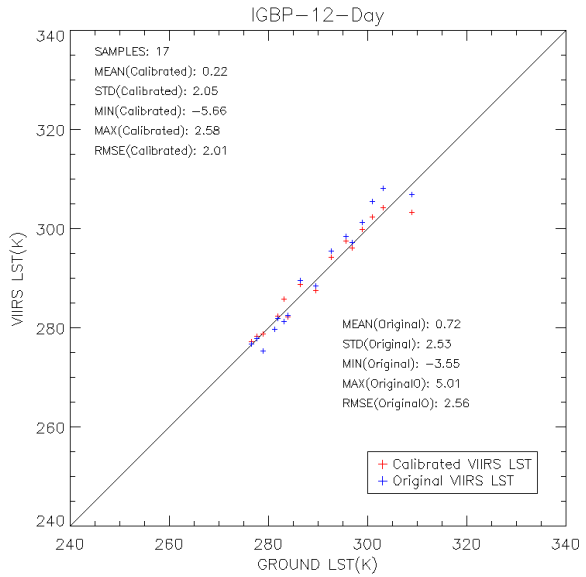
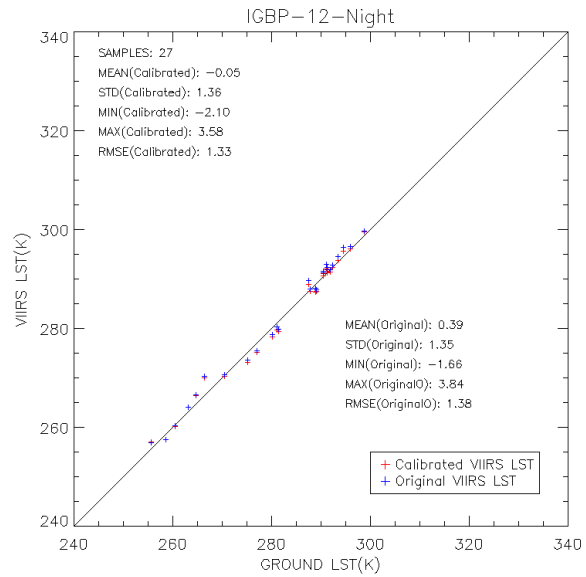


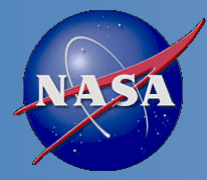
The Calibrated LSTs are evaluated using SURFRAD data in January, April, July and October, the four months representing winter, spring, summer and fall seasons.

+ Calibrated VIIRS LST
+ Original VIIRS LST



Some more ...



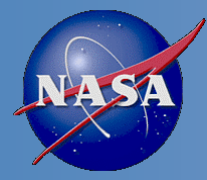


Summary of evaluation against ground in-situ



Table : Evaluation of calibration performance using SURFRAD data in January, April, July and October.

Surface type & Day/night	After Calibration		Before Calibration		Samples
	BIAS	STD	BIAS	STD	
16-day	-1.49	0.63	-0.92	2.39	3
16-night	0.13	0.71	-1.88	0.77	10
15-day	0.58	2.20	-2.02	2.32	13
14-day	0.00	1.88	1.53	3.26	30
14-night	0.02	1.85	0.64	2.05	47
12-day	0.22	2.05	0.72	2.53	17
12-night	-0.05	1.36	0.39	1.35	27
10-day	-0.06	1.59	4.39	2.48	32
10-night	0.34	1.04	-0.19	1.04	51
8-day	-0.28	1.39	-2.14	1.48	4
8-night	0.97	0.79	1.57	0.79	3
7-day	-0.01	1.00	1.14	2.01	28
7-night	-0.01	0.68	-1.88	0.68	31
6-day	0.13	1.04	1.3	1.95	5
6-night	0.63	0.36	-1.31	0.21	4
4-day	-0.45	1.43	3.31	1.06	5
4-night	-0.55		-0.55		1

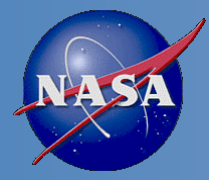


Evaluation of Calibration Performance

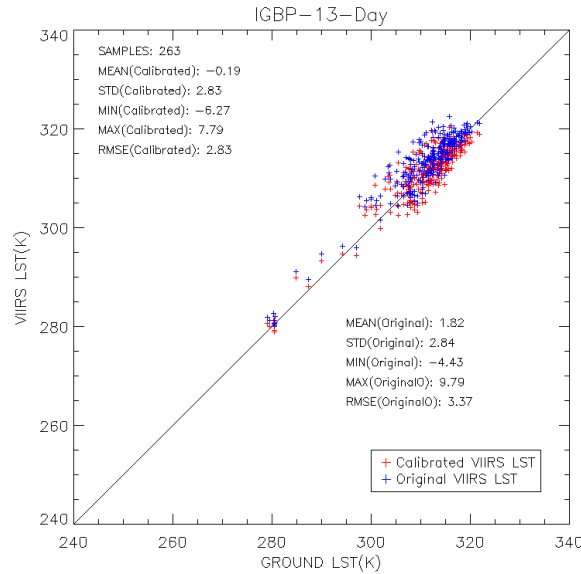
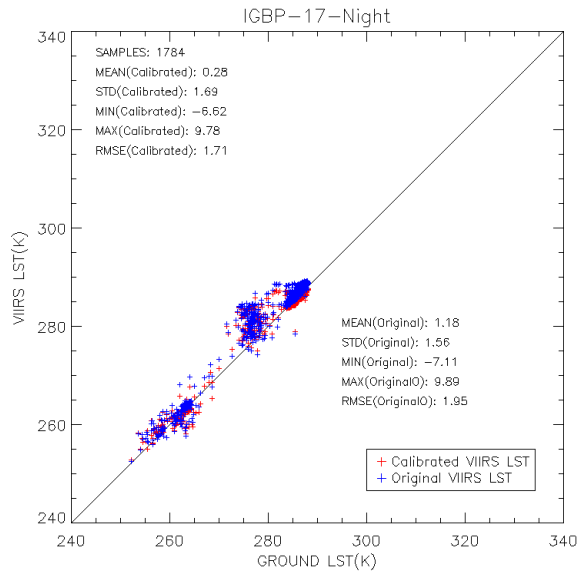


Calibration performance is evaluated using MODIS Aqua LST as a reference. Two SNOs for both day and night between NPP and AQUA in each month of January, April, July and October are selected. Below is the table for the SNOs obtained for evaluation

Index	Date (AQUA)	Time (AQUA)	AQUA Lat,Lon	Time (NPP)	NPP Lat,Lon
1	01/08/2013	08:58:00	49.94,-100.82	08:59:29	50.45,-103.41
2	01/10/2013	19:56:10	50.00,-105.05	19:49:46	49.67,-107.02
3	04/06/2013	06:32:38	41.51, -66.84	06:31:11	41.89, -68.97
4	04/08/2013	20:46:15	49.96,-117.41	20:42:01	49.55,-119.91
5	07/08/2012	06:32:19	40.13, -67.27	06:30:29	40.46, -69.32
6	07/18/2012	21:31:06	36.43,-124.99	21:27:35	35.94,-127.42
7	10/04/2012	07:18:57	48.14, -76.73	07:18:26	48.53, -78.91
8	10/22/2012	19:55:35	49.97,-104.94	19:49:45	49.60,-107.02

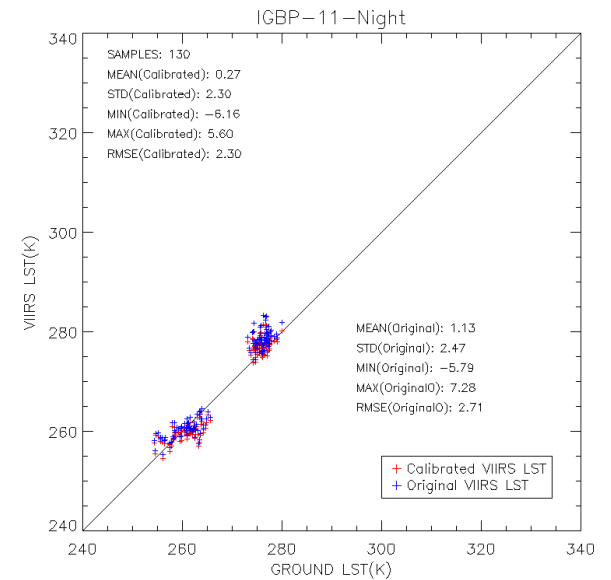
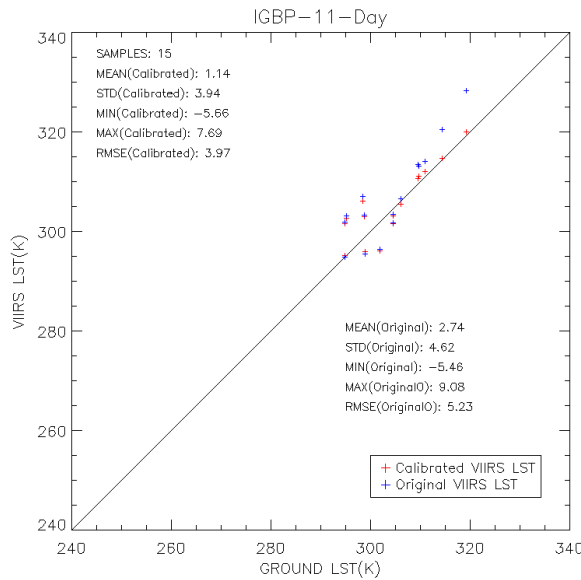
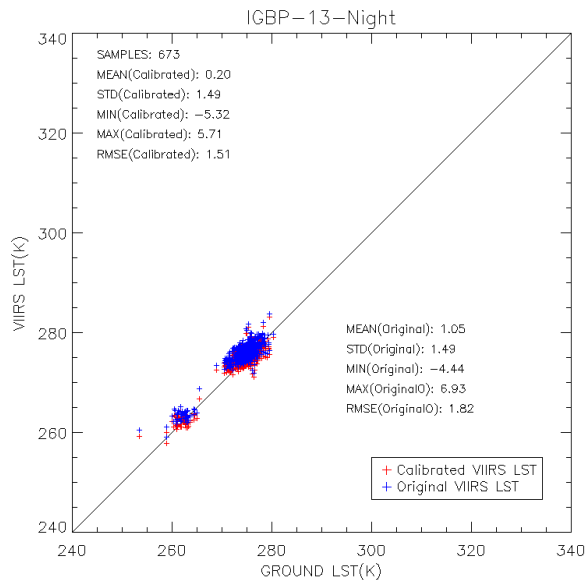


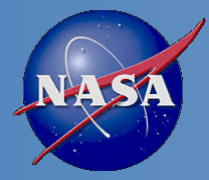
Provisional LSTs against MODIS LST



The Calibrated LSTs are evaluated using MODIS LSTs

+ Calibrated VIIRS LST
+ Original VIIRS LST

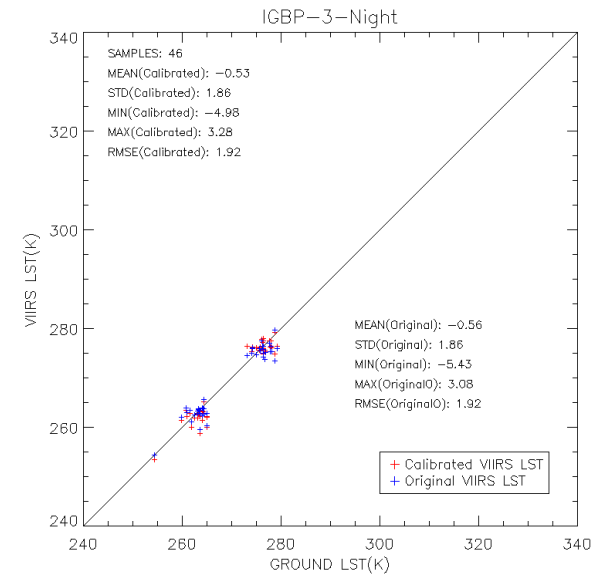
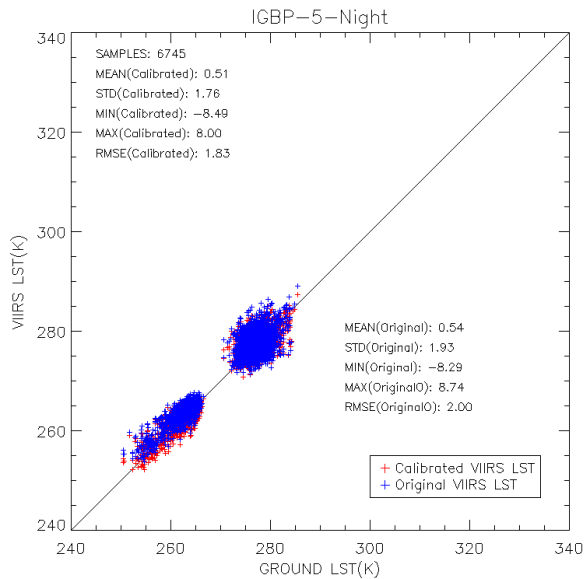
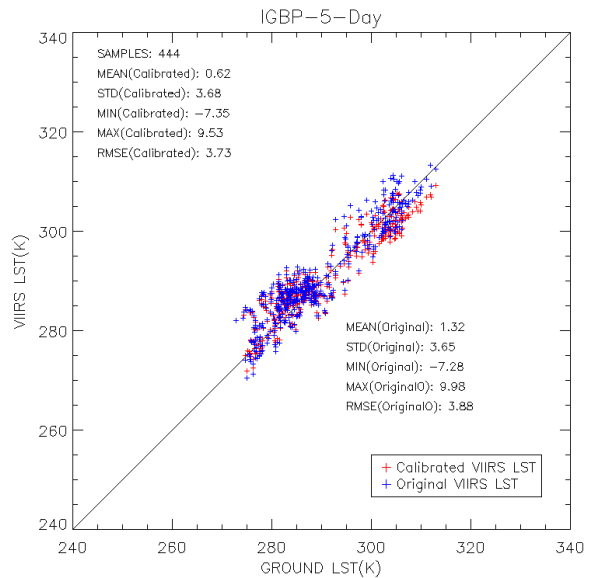
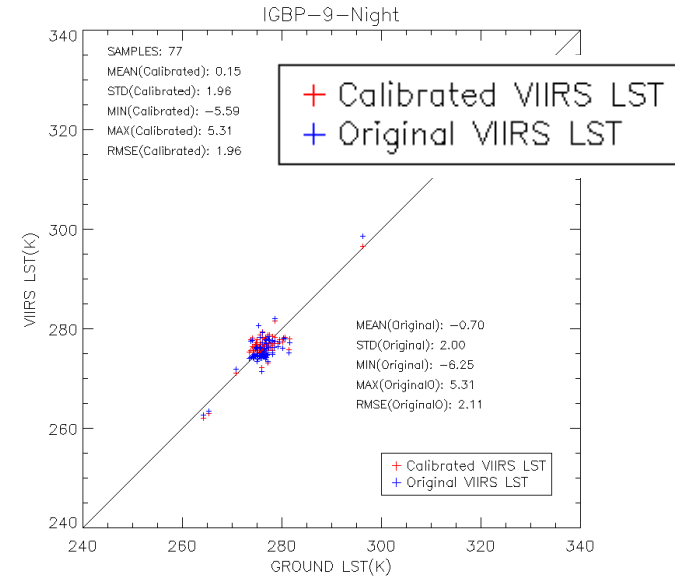
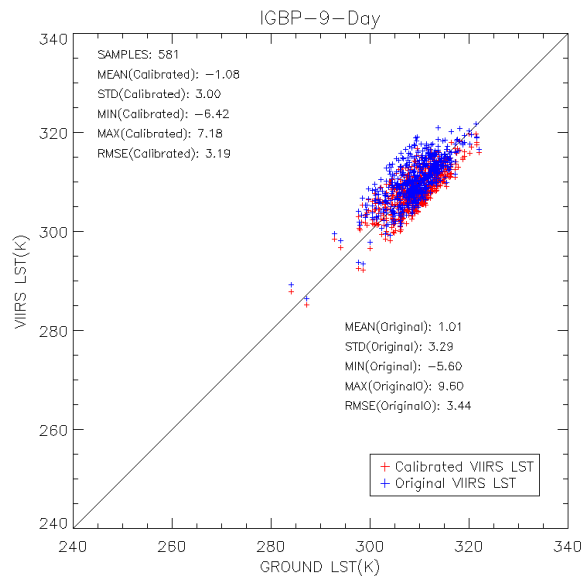
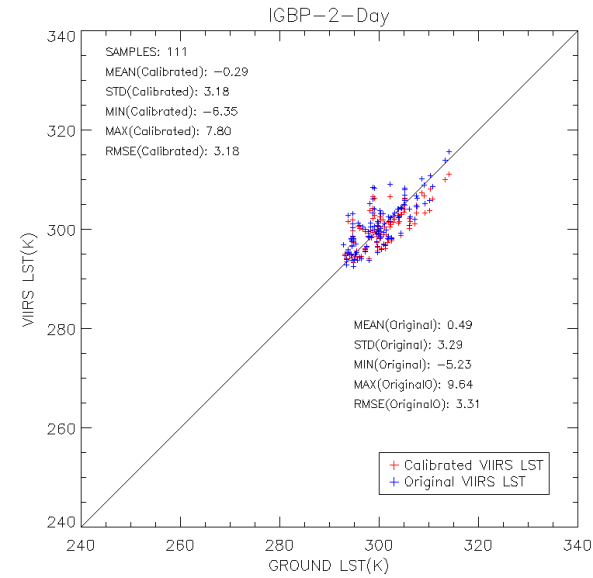


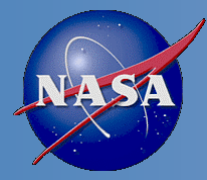


Provisional LSTs against MODIS LST



Some more ...





Summary of provisional evaluation against MODIS LST



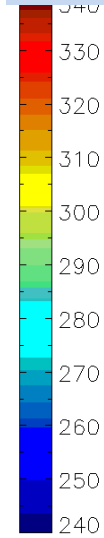
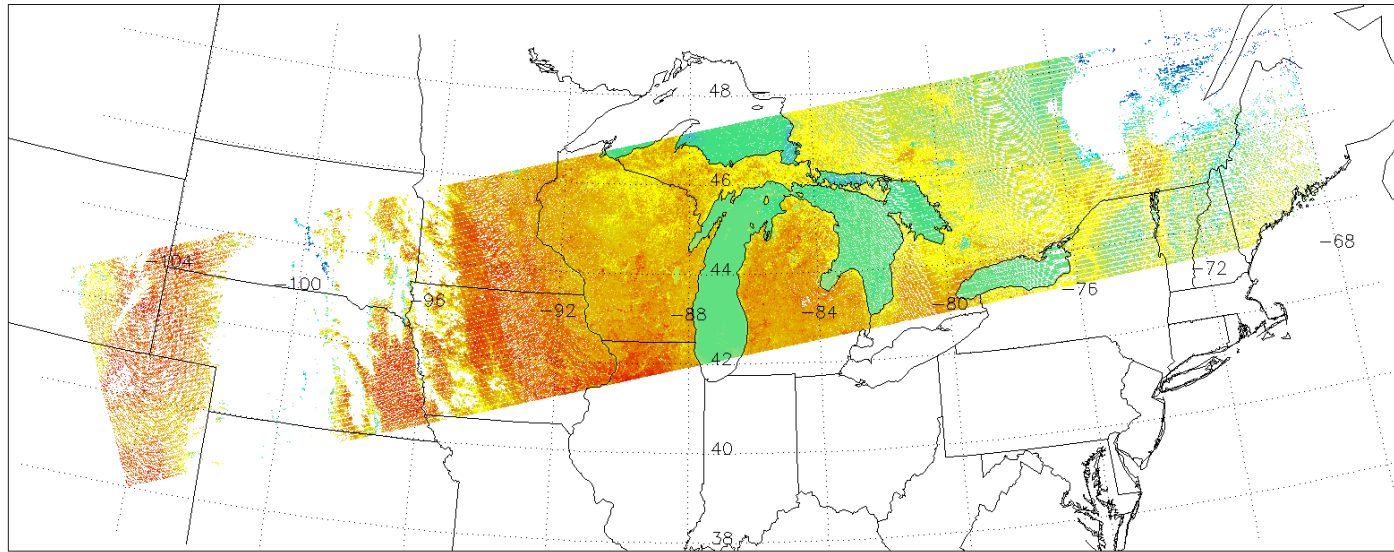
Table : Evaluation of calibration performance using MODIS Aqua LST data in January, April, July and October.

Surface type & Day/Night	After Calibration		Before Calibration		Samples
	BIAS	STD	BIAS	STD	
1-day	-0.56	3.45	0.13	3.42	1835
1-night	0.75	1.98	0.07	2.31	1207
2-day	-0.29	3.18	0.49	3.29	111
2-night	-1.31	3.69	-1.91	3.83	4
3-day	1.80	0.57	0.81	0.6	4
3-night	-0.53	1.86	-0.56	1.86	46
5-day	0.62	3.68	1.32	3.65	444
5-night	0.51	1.76	0.54	1.93	6745
9-day	-1.08	3.00	1.01	3.29	581
9-night	0.15	1.96	-0.7	2.00	77
11-day	1.14	3.94	2.74	4.62	15
11-night	0.27	2.30	1.13	2.47	130
13-day	-0.19	2.83	1.82	2.84	263
13-night	0.2	1.49	1.05	1.49	673
17-day	0.13	3.29	-0.01	3.16	166
17-night	0.28	1.69	1.18	1.56	1784

Image comparison before and after

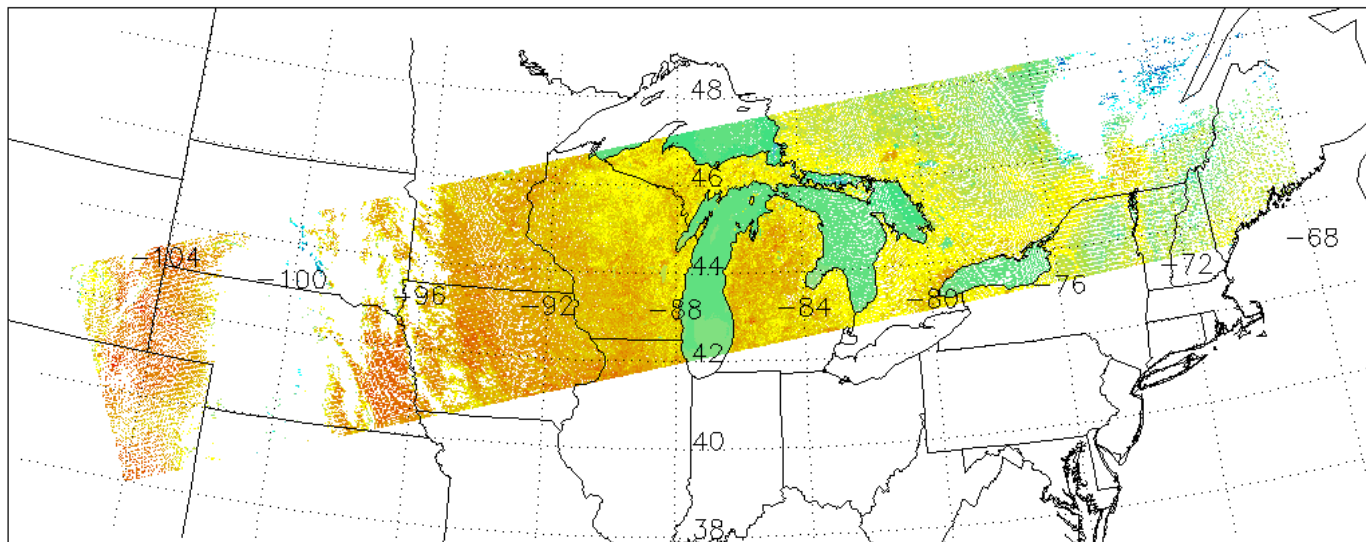
VIIRS LST: VLSTO_npp_d20120406_t1839167_e1840409_b02290

Daytime single granule



Beta

VIIRS LST: VLSTO_npp_d20120406_t1839167_e1840409_b02290



Provisional

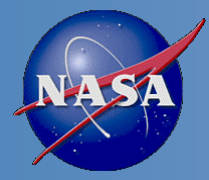
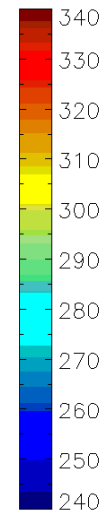
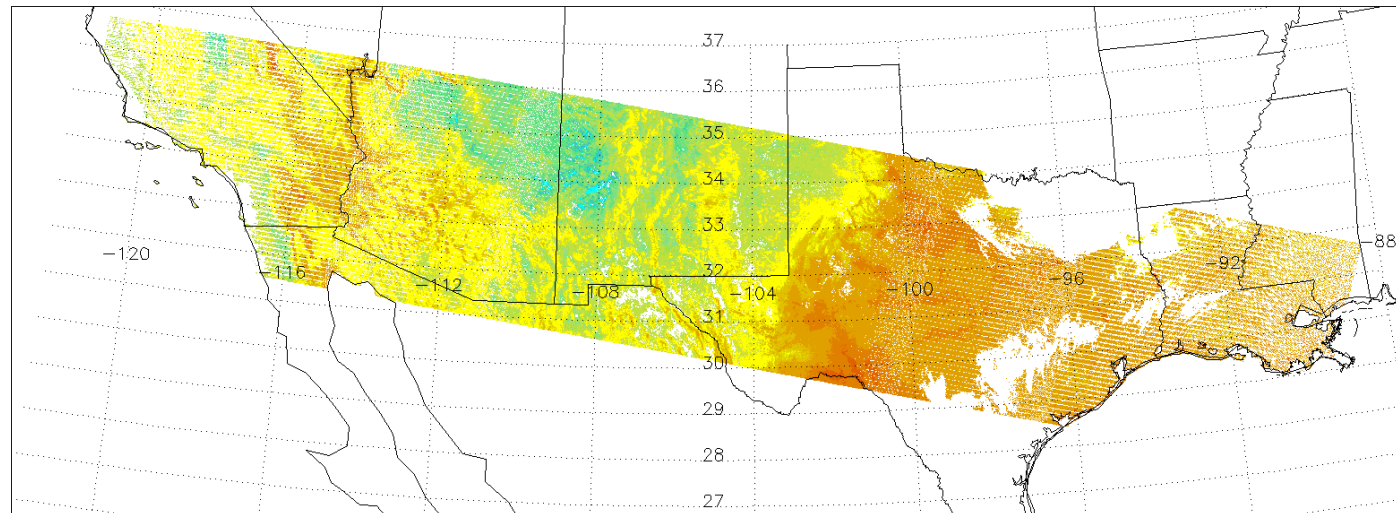


Image comparison before and after



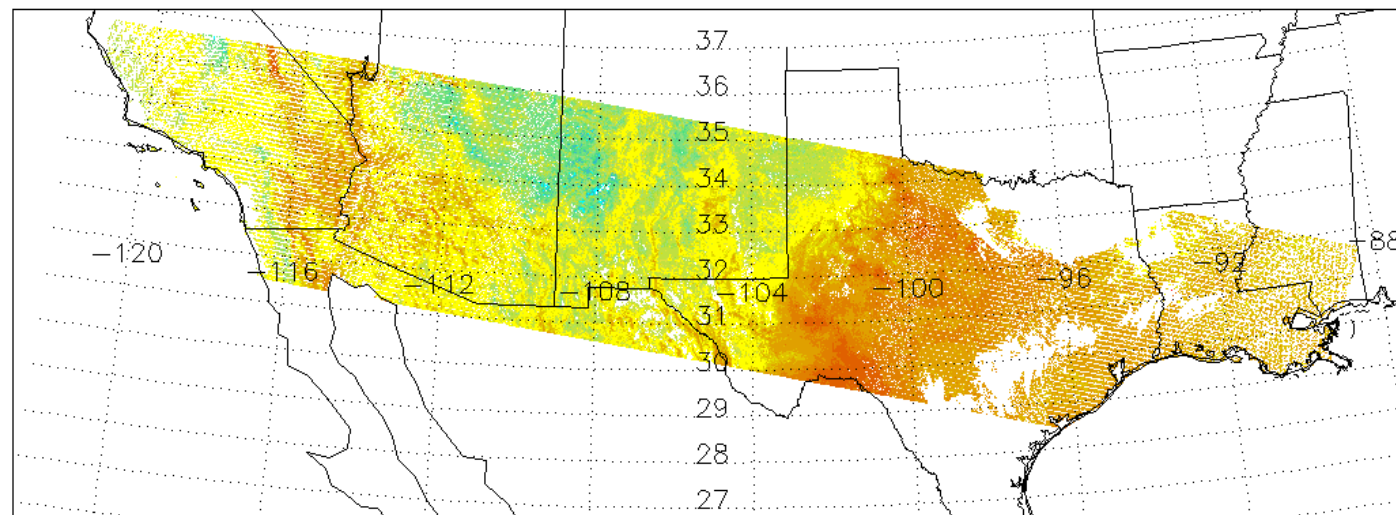
Nighttime single granule

VIIRS LST: VLST0_npp_d20120530_t0845372_e0847014_b03050

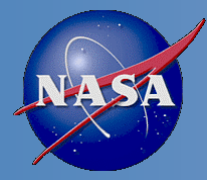


Beta

VIIRS LST: VLST0_npp_d20120530_t0845372_e0847014_b03050



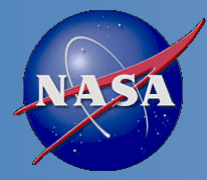
Provisional



Product Quality Summary



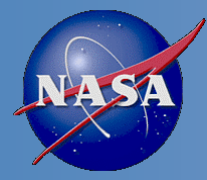
- LST has shown marked improvement after beta release
 - *Evaluation result shows an improved performance for some surface types such as IGBP 6,7,10,12,14 and 16.*
 - *Daytime LST gets significantly improved over some surface types and the performance is close or better than requirements e.g. IGBP 7,12 daytime.*
 - *VIIRS LSTs presents closer measurement with MODIS LSTs after calibration over some cases e.g. IGBP 1 at nighttime, IGBP 9 at daytime.*
 - *The seasonal pattern gets weak in the provisional version*
- The LST meets provisional criteria
 - *Feedback from users and our continuous evaluations have been occurring since beta*
 - *Documentation up-to-date*



Incremental Improvement



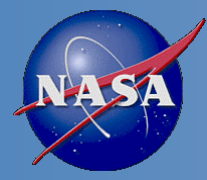
- Second version of LST validation report is finalized which summarizes the LST evaluation efforts since the beta release
- A radiance-based satellite LST evaluation tool has been established
- The LST algorithm coefficients have been calibrated using cross-satellite, simulation and ground measurement data
- All Discrepancy Reports related to LST have been closed except DR7055 which is in DPE functional test
- Longer term validation efforts using ground measurement data from Europe and from Asia are in progress, and will be reported before the next version (validated version) release



Incremental Improvement



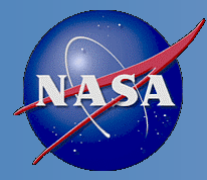
- The LST team has developed a list of activities either in progress or to be worked as priorities and resources allow
 - Coefficients updates
 - Built up high quality regression data set for the update of algorithm coefficients, correlation analysis with VI, water vapor for possible corrections.
 - Software/code improvements
 - Ongoing validation efforts
 - continued match-up analysis, ADA/ADL upgrades, continual presentation needs (conferences, workshops and communications with users, related SDR and EDR teams)



Incremental Improvement



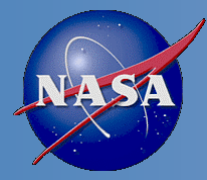
Date	DR#	Reason	Status
2/9/13	7055	LST QA is "low quality" when thin cirrus/active fire is et	In Work. Algorithm Change delivered to DPE for functional testing. Targeting IDPS Mx8
12/12/12	5028	LST QA not set correctly in all-ocean granules	Closed 3/31/13. Rejected b/c No land products over ocean will ever be used; illustrates larger IDPS architecture issue that land products should not be produced over ocean
11/26/12	4983	VIIRS LST beta Maturity	Closed 1/25/13 474-CCR-12-0773 deployed in ops
02/28/12	4608	Split-window algorithm - Baseline Coefficient files. LUT update #2 (same as "Updated LUT" in slides): DR 4608/CCR 12-0355: Corrects errors for both dual split window and split window.	Closed 06/10/12 Split Window algorithm implemented in IDPS baseline on 10 Aug, 2012.
02/15/12	4582	LST Day Night Land Water Misidentification, The LST EDR appears to have a coding error that may have incorrectly mixed up the Day/Night flag with the Land/Water and Surface Type QA Flag within the QF Byte 3 of the LST EDR... This same Day/Night flag is being correctly encoded in the bit3 of QF Byte1 of the LST EDR.	Closed 03/29/12 Rejected because EDR team did not observe such error.
09/14/11	4353	Snow/ice field is always "no snow" at night if the Quarterly Surface Type does not indicate so. "Temporal snow" can only be directed daytime by snow/ ice EDR	Closed 04/26/12. Reallocated to Cryo team as new DRs: 4699 Out of Date snow cover seeded grid & 4700 Alternative snow/ice grid needed to support algorithms; Both have been addressed.
02/14/11	4203	The OPS LST code, both v1.5.00.48 and v1.5.03.00, do not verify that the value for the Surface Type input falls within the valid range prior to calculating LST	Closed 1/9/13 Rejected because not a problem to LST production since LST code does check the ST.
12/12/12	5027	VIIRS LST should have NA fill in all-ocean granules	Waiting to learn status.



Considerations, Known Issues



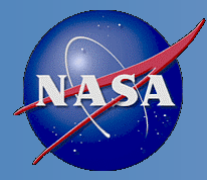
- Nighttime snow/ice cover information maybe incorrectly identified.
 - *DR 4699 was issued; Cryosphere team is working on it*
- Strong surface type dependency of the retrieval performance
 - *Consistency*
 - *Surface type mixed pixel*
 - *Misuse of surface type info*
- Seasonal dependency of the retrieval performance
- Cloud residual impact
 - *May need additional cloud filter*
- Validation difficulties
 - *Limited high quality in-situ data*
 - *Heterogeneity in a pixel*
- Fund issue
 - *Fund shortage since 2010 (less than 1 FTE)*
 - *Current fund (1.2 FTE)*



Version Control



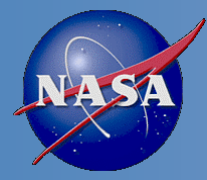
- Worked with DPE and Raytheon team for document changes, LUT updates, QA modification
- ATBD, OAD, CDFCB-X all match operational LST as of these versions
 - *474-00051_LandSurfTemp_Rev-_20110422.pdf*
 - *474-00070_OAD-VIIRS-LST-EDR_B.pdf*
 - *474-00001-04-03_JPSS-CDFCB-X-Vol-IV-Part-3_0123A.pdf*
- Upcoming LUT/code deliveries will require updates to all three documents noted above



Community Interaction



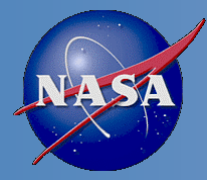
- Bi-weekly telecons are used, in part, to maintain open communication for both internal and external LST members with ongoing work and implementation dates
 - Regular (bi-weekly) meetings with Land CalVal team
 - Regular (bi-weekly) meetings with NASA VIIRS/MODIS and LPEATE groups
- Consistent contact is maintained with NCEP Land forecast model group; individual technical interactive meetings and discussion
- Invitations to LST research scientists participating special discussion meeting for the VIIRS LST issues, improvement and applications
- We will continue to keep communications with other land product teams
 - E.g. progress of surface type may have positive impact to LST



Archive of the LST



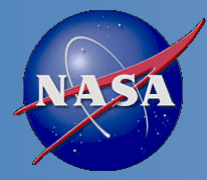
- The LST as a EDR product, is archived by CLASS
- There are no plans the LST team is aware of to reproduce and replace what is in the archive
- The LST team does not currently have any plans to reproduce the LST in the archive



Ready for Operational Evaluation



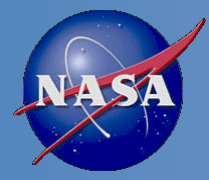
- The LST provisional data is preliminary evaluated during the development period; further evaluation is planned after this release.
- It has always been the intent that the LST would be ready for outside evaluation after the 30-day spin-up
- The operational evaluation is critical for the validated version release by the end of 2013.
- Proposed caveats for the LST at the provisional stage are:
 - *All users should explore the quality flags present in the LST*
 - Snow/ice bit at nighttime might not be correct
 - Thin cirrus/active fire might be not included in quality criteria matrix yet
 - Coastal pixel LST quality might be degraded by the surface type fraction



Path Forward



- Monitoring of the provisional LST production
- Continue the evaluation and validation of provisional LST product
 - *Global coverage of in situ validation*
 - *Upscaling model improvement*
 - *Users feedback*
- The further improvement before the validation I
 - *Improve the quality further over surface types especially those without ground in-situ as a reference.*
 - *Improved quality control procedure for regression analysis*
 - *Address the water vapor correction*
 - *Investigate on the possible improvement of the LST algorithm*



END