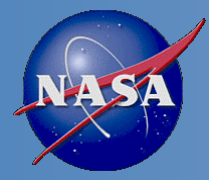


JPSS S-NPP Land Surface Temperature Product: Beta and Provisional Releases

Yunyue Yu, Ivan Csiszar, Yuling Liu, Zhuo Wang, Peng Yu,
NOAA/NESDIS, Center for Satellite Applications and Research

Jeffrey Privette, Pierre Guillevic
NOAA/NESDIS, National Climate Data Center

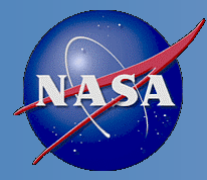




Basic of the VIIRS LST Product



- Fundamentally the LST is a moderate band pixel-by-pixel determination of effective land surface skin temperature. It is produced as Environmental Data Record (EDR)
- Represents continuity with NSAS EOS MODIS and NOAA POES AVHRR LST production, also with international missions such as (A)ATSR
- VIIRS design allows for full (high) resolution LST measurements over global land covers, *under clear, probably clear and probably cloudy* conditions.
- Product is expected to be used by weather forecasting models, Agriculture monitoring, drought prediction and monitoring, ecosystem monitoring; climate studies etc.

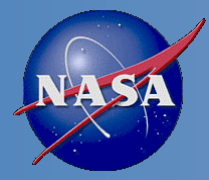


Basic of the VIIRS LST Product

Cont'



- VIIRS LST EDR provides effective land surface skin temperature value at the time of overpass
- Two algorithms have been implemented
 - Split Window LST(SWLST) is derived using two thermal infrared channels (31, 32)
 - baseline algorithm
 - Dual Split Window LST (DSWLST) is derived using two thermal infrared channels (31, 32) and two shortwave infrared channels (14, 15)
 - Back-up algorithm
- Evaluation underway
 - Comparison with MODIS LST product
 - Comparison with Ground LST measurements
 - Results of preliminary evaluation are promising : Beta version release was in October, 2012; Provisional version in June 2013.
- Recent Build Changes
 - SWLST is switched as baseline algorithm (DSWLST was the baseline)
 - LUT (alg coefficients) were updated two times after the launch



L1RD Requirements



Land Surface Temperature

Attribute	Threshold	Objective
LST Applicable Conditions: Clear		
a. Horizontal Cell Size	4 km	1 km
Nadir	(800 m)	(500 m)
b. Mapping Uncertainty, 3 Sigma	1 Km at Nadir (800 m)	1 km at Edge of Scan (500 m)
c. Measurement Range	213 – 343 K	183 – 343 K
d. Measurement Precision (1 sigma)	2.5 K	1.5 K
e. Measurement Accuracy (bias)	1.4 K	0.8 K
f. Refresh	At least 90% coverage of the globe every 24 hours (monthly average)	

LST Processing Chain

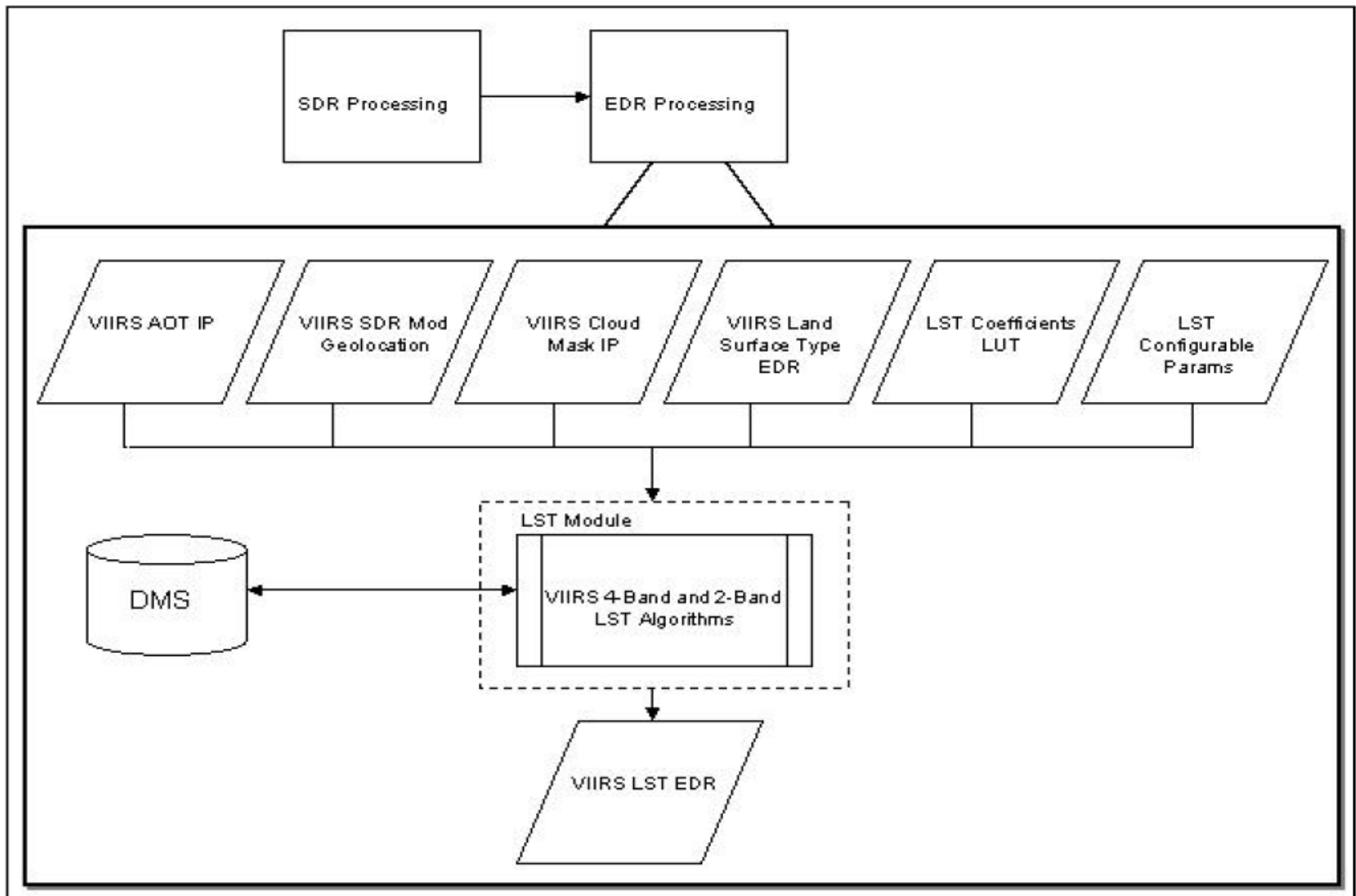
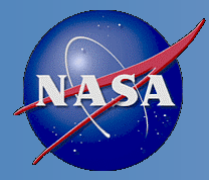


Figure 1. VIIRS LST OAD 474-00070 RevA 20120127



NPP/JPSS LST EDR Algorithm



Baseline Algorithm -- Split Window Regression Algorithm

$$LST_i = a_0(i) + a_1(i) T_{11} + a_2(i) (T_{11} - T_{12}) + a_3(i) (\sec \theta - 1) + a_4(i) (T_{11} - T_{12})^2$$
$$i = 1, \dots, 17$$

Alternative Algorithm -- Dual Split Window Regression Algorithm (baseline before beta)

Nighttime

$$LST_i = b_0(i) + b_1(i) T_{11} + b_2(i) (T_{11} - T_{12}) + b_3(i) (\sec \theta - 1) + b_4(i) T_{3.75} + b_5(i) T_{4.0} + b_6(i) T_{3.75}^2 + b_7(i) T_{4.0}^2 + b_8(i) (T_{11} - T_{12})^2$$
$$i = 1, \dots, 17$$

Daytime

$$LST_i = a_0(i) + a_1(i) T_{11} + a_2(i) (T_{11} - T_{12}) + a_3(i) (\sec \theta - 1) + a_4(i) T_{3.75} + a_5(i) T_{4.0} + a_6(i) T_{3.75} \cos \varphi + a_7(i) T_{4.0} \cos \varphi + a_8(i) (T_{11} - T_{12})^2$$
$$i = 1, \dots, 17$$

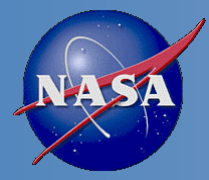
Note:

i is the index of the 17 International Geosphere Biosphere Program (IGBP) surface types

T_{11} , T_{12} , $T_{3.75}$, and $T_{4.0}$ are the brightness temperatures of the VIIRS 10.8, 12, 3.75, and 4.0 μm bands respectively

θ and φ are the sensor and solar zenith angles respectively

$a_j(i)$ and $b_j(i)$ are the regression coefficients for the j th IGBP surface type for daytime and nighttime LST retrievals respectively



Status at Beta

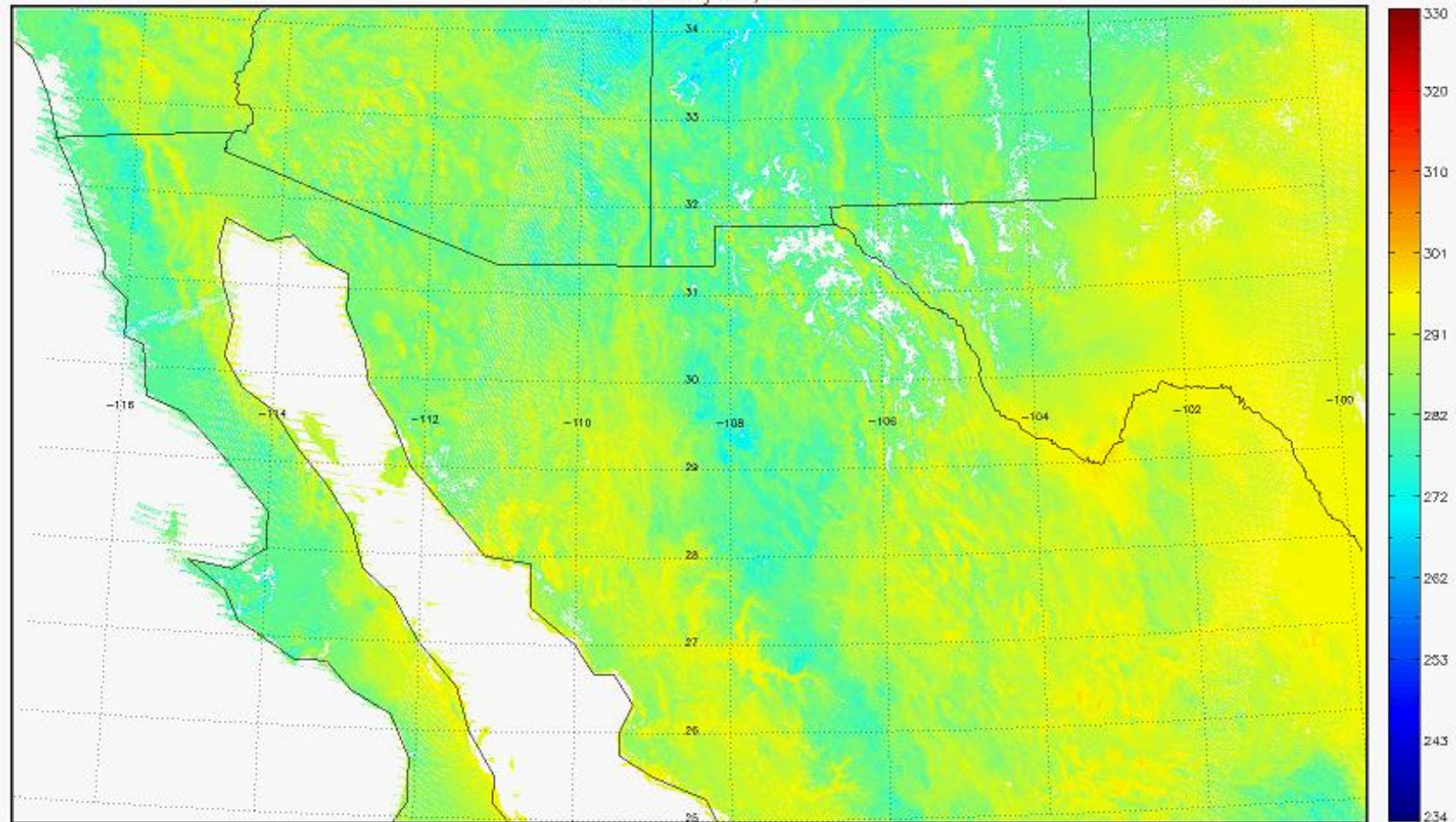


- Split window algorithm is applied as baseline algorithm
- Performance of LST is marginally around the requirement (accuracy and precision)
- LST shows significant seasonal variance according to the analysis based on evaluations against SURFRAD for the whole year of 2012.
- Comparing to upscaled SURFRAD station data, accuracy and precision of the VIIRS LST are better than comparing to the regular SURFRAD station data.
- Surface type dependency of the LST quality is significant.
- Nighttime LST performance is better than the daytime

The evaluation/validation is performed with limited ground data (surface types).

Suomi NPP VIIRS LST Maps

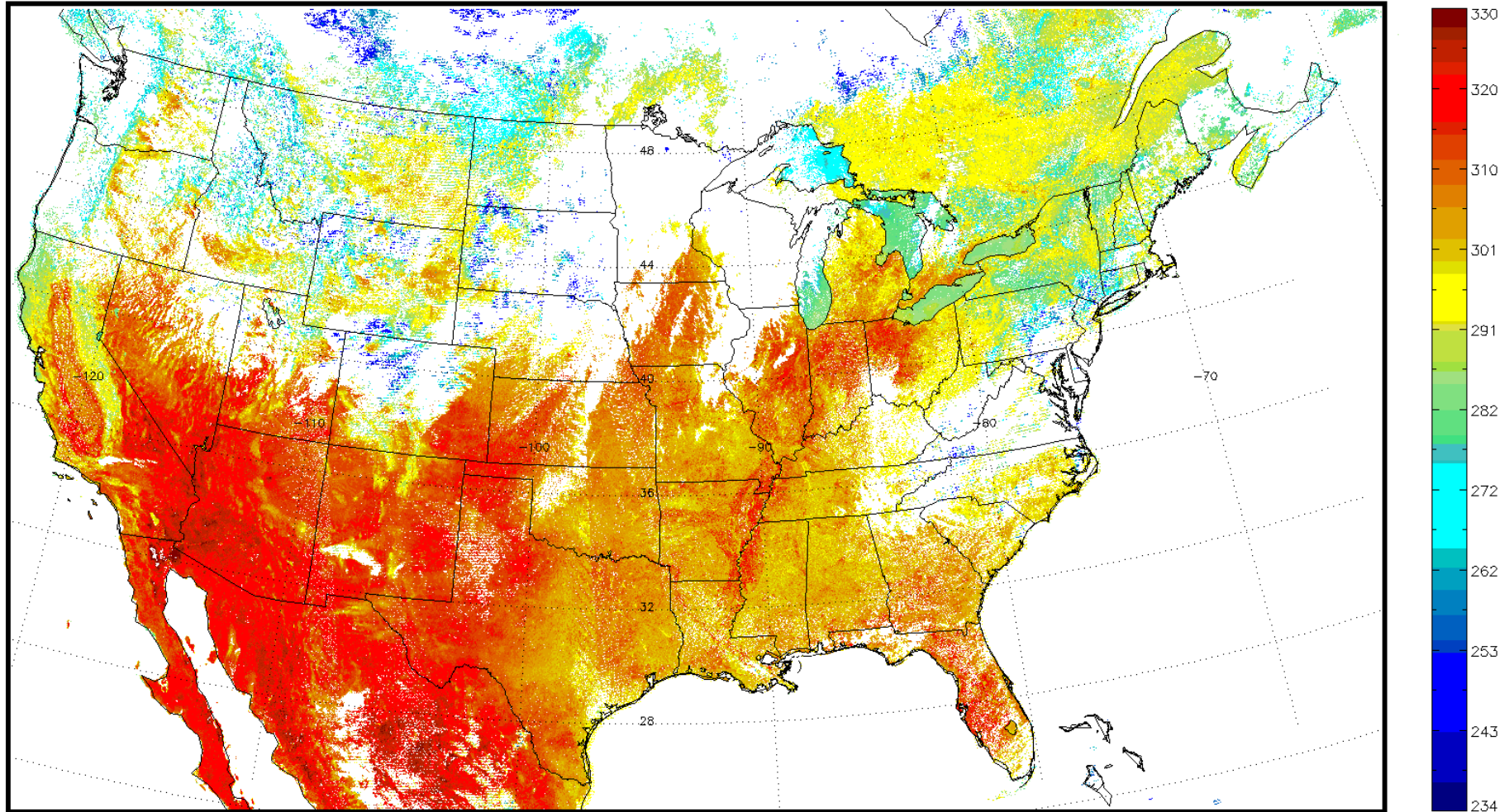
VIIRS LST: May 30, 2012



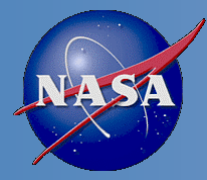
Regional VIIRS LST, 30 May 2012
08:45 UTC (Nighttime)

Suomi NPP VIIRS LST Maps

VIIRS LST: VLSTO_npp_d20120523_t1536538_e2226331_b02959



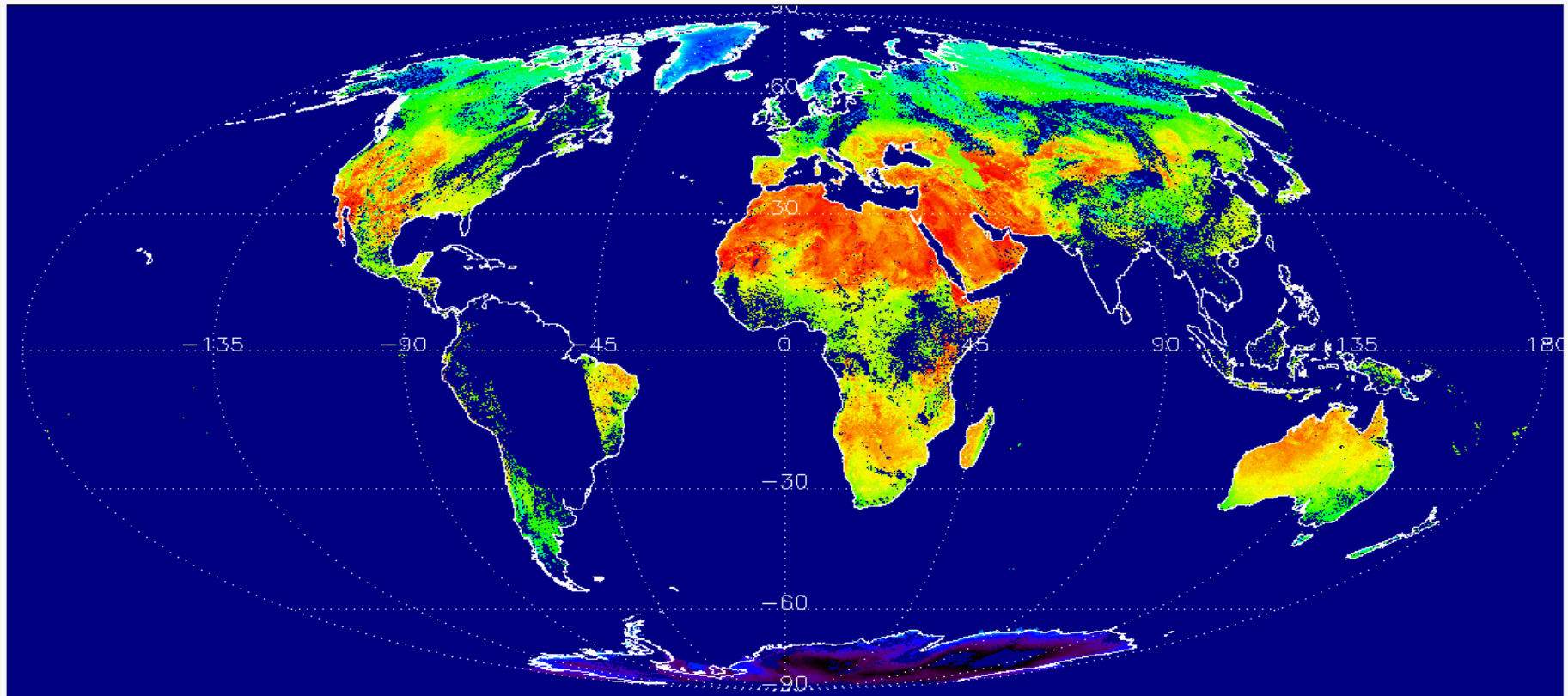
Aggregated daytime VIIRS LST, 23 May 2012



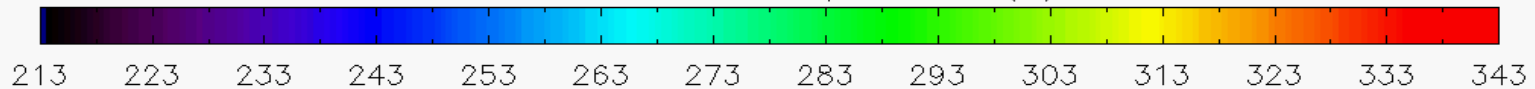
Suomi NPP VIIRS LST Maps



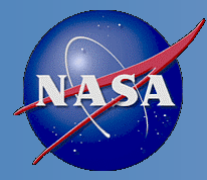
Daytime: Aug. 26, 2012



Land Surface Temperature (K)



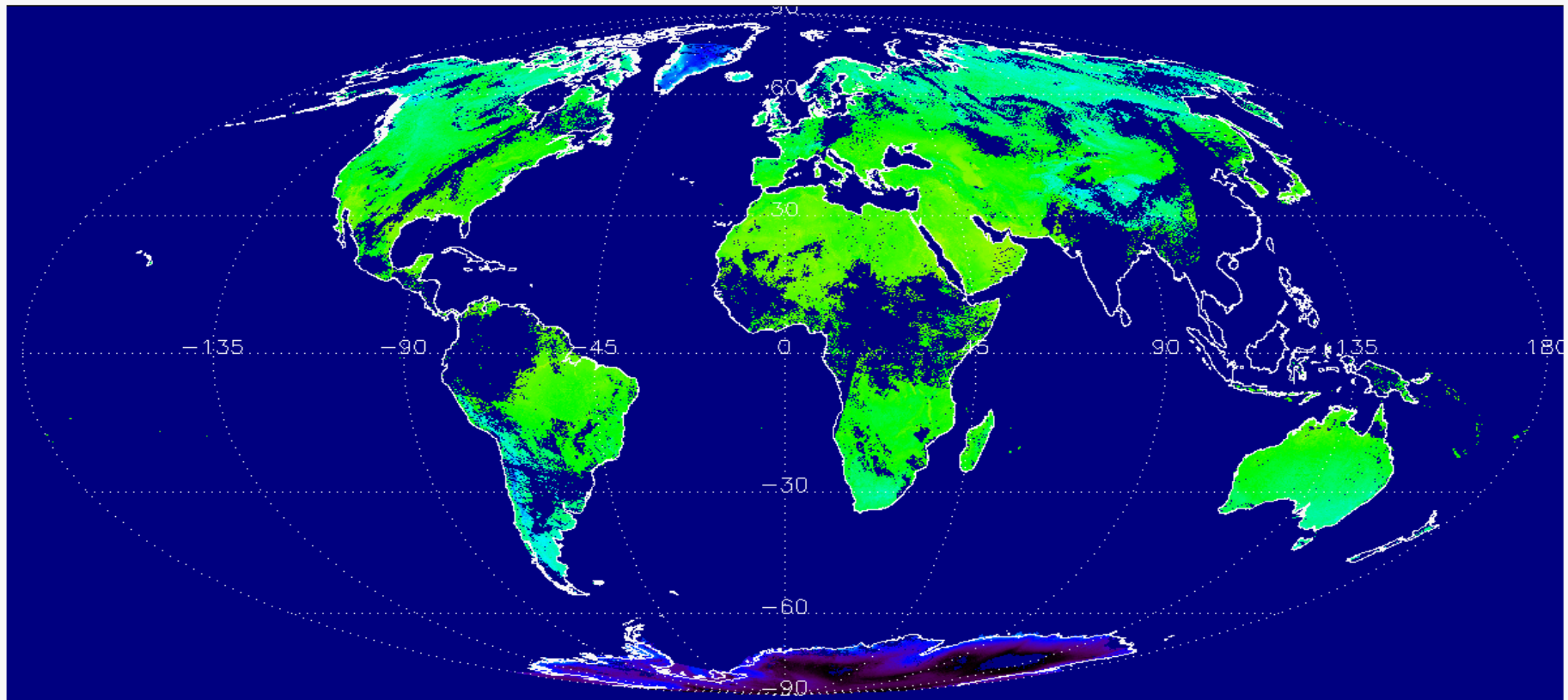
Daytime VIIRS LST Global Composite. 26 August 2012



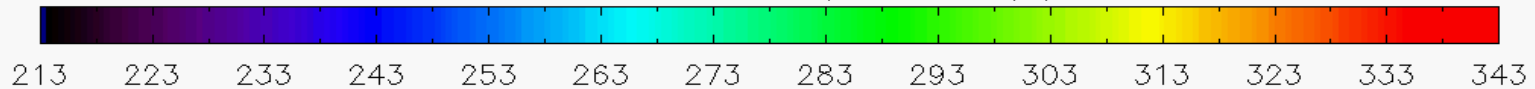
Suomi NPP VIIRS LST Maps



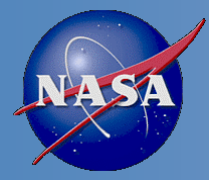
Nighttime: Aug. 26, 2012



Land Surface Temperature (K)



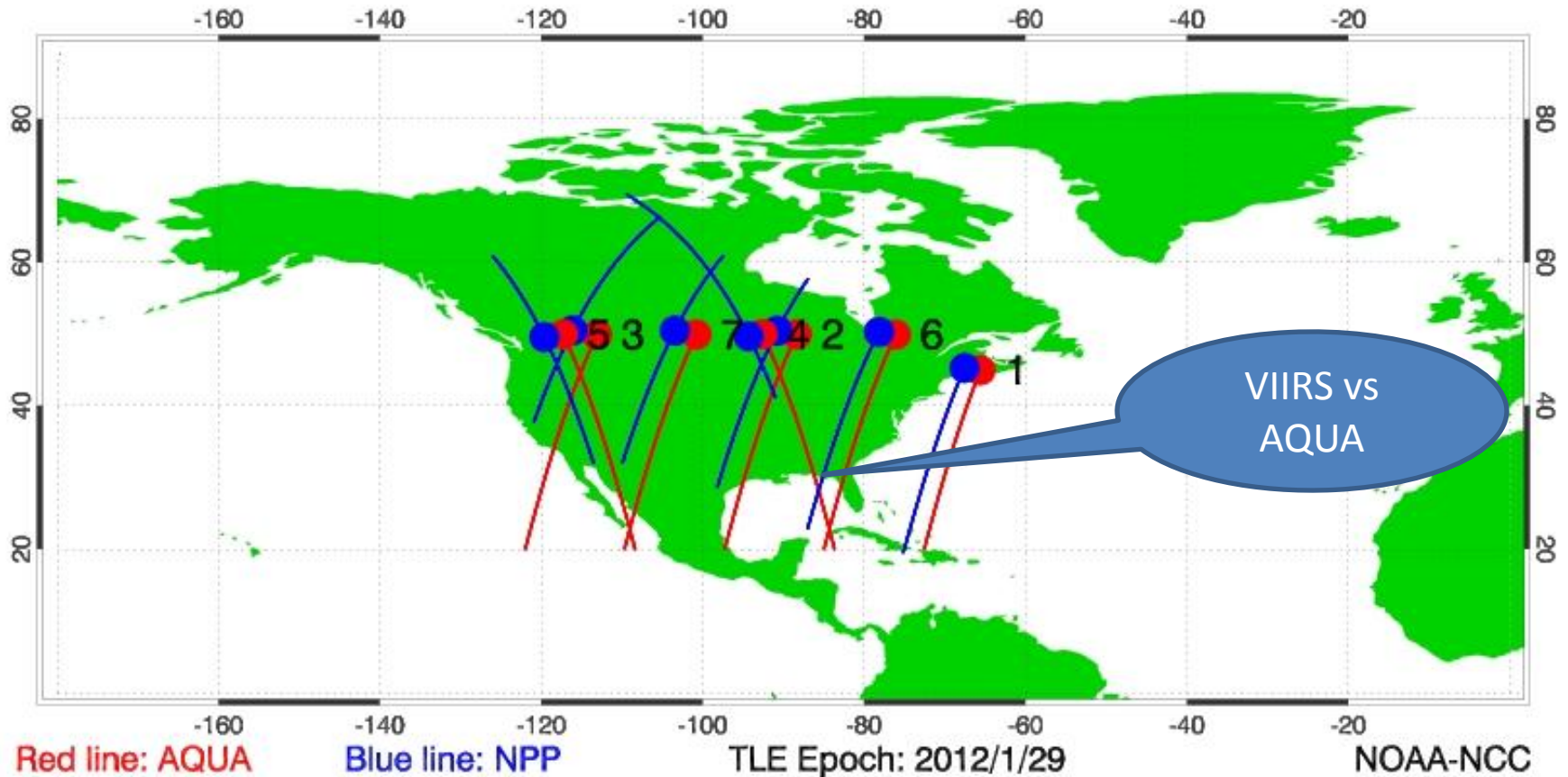
Nighttime VIIRS LST Global Composite. 26 August 2012



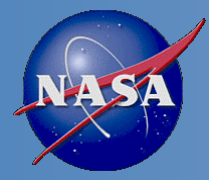
Cross comparison with MODIS



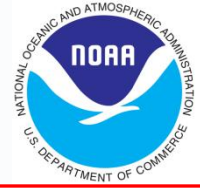
Simultaneous Nadir Observations



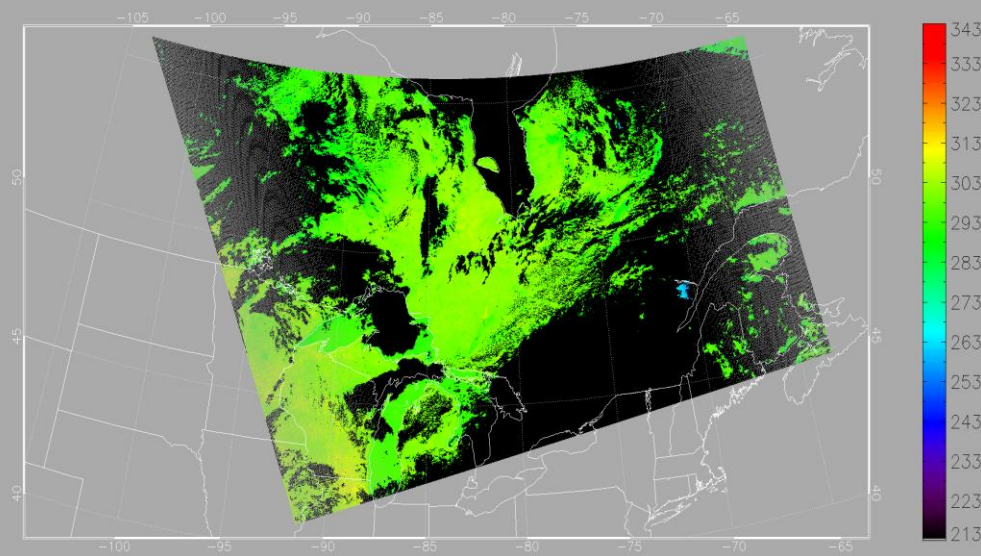
Index	Date (AQUA)	Time (AQUA)	AQUA Lat,Lon	Date (NPP)	Time (NPP)	NPP Lat,Lon	Distance(km)	Time Diff (sec)
2	01/30/2012	08:07:59	49.94, -88.35	01/30/2012	08:10:04	50.44, -90.78	181.29	125



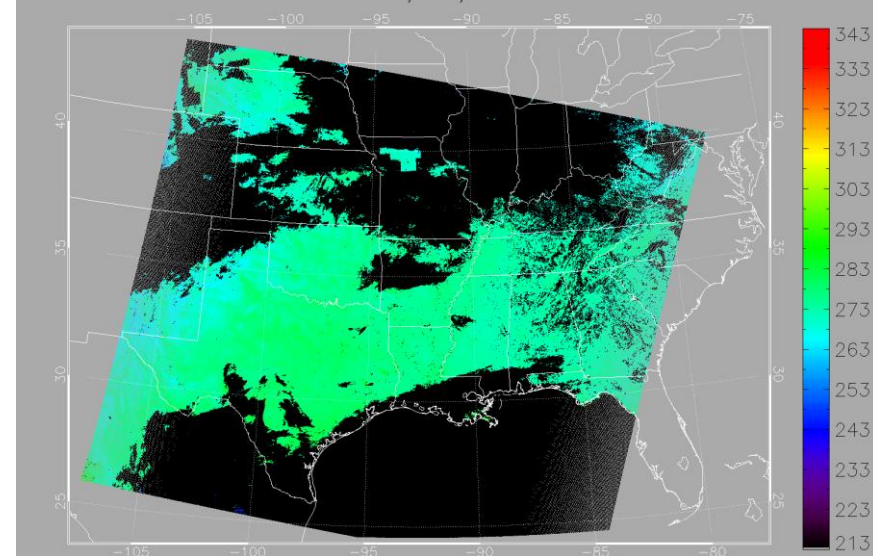
Comparisons to MODIS data



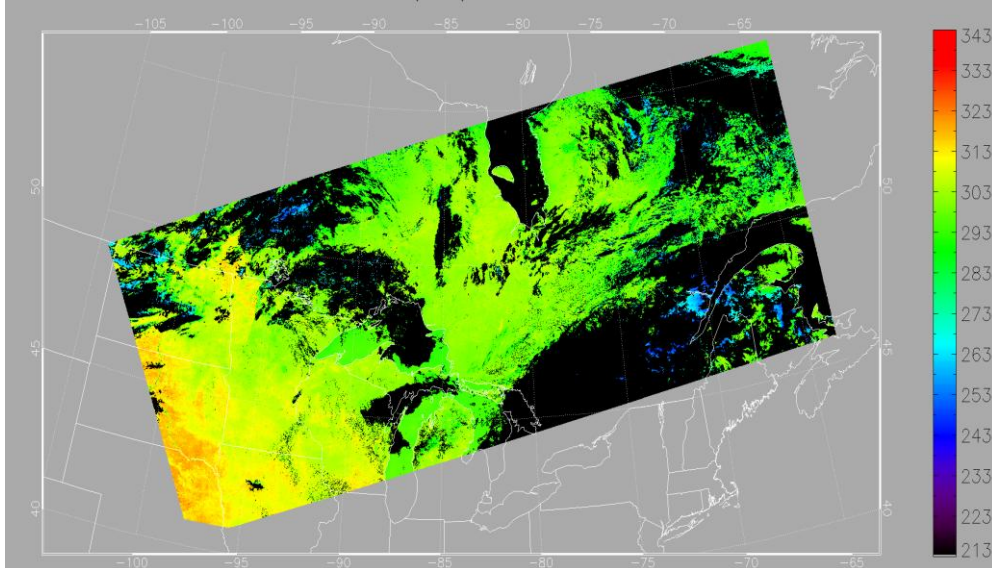
MODIS LST: 09/04/2012 1815 UTC



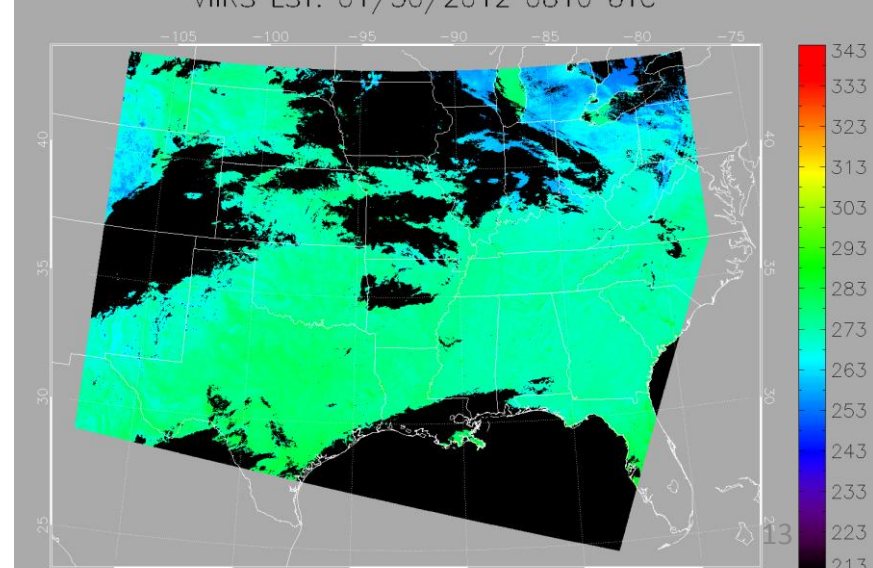
MODIS LST: 01/30/2012 0810 UTC

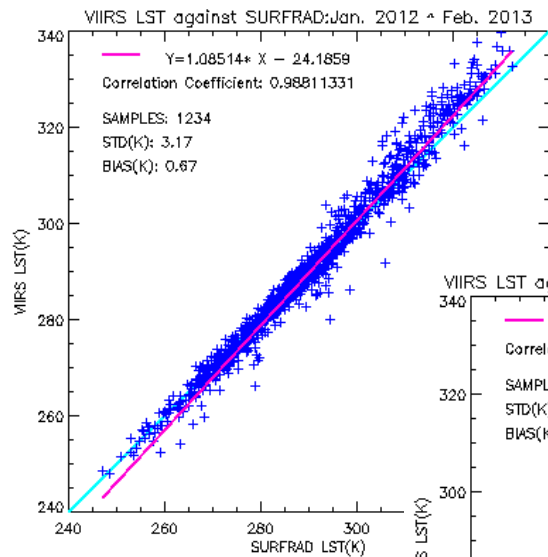


VIIRS LST: 09/04/2012 1807 UTC

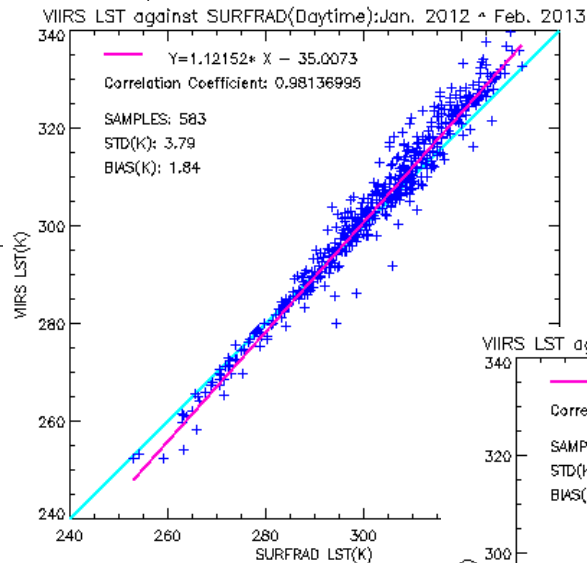


VIIRS LST: 01/30/2012 0810 UTC

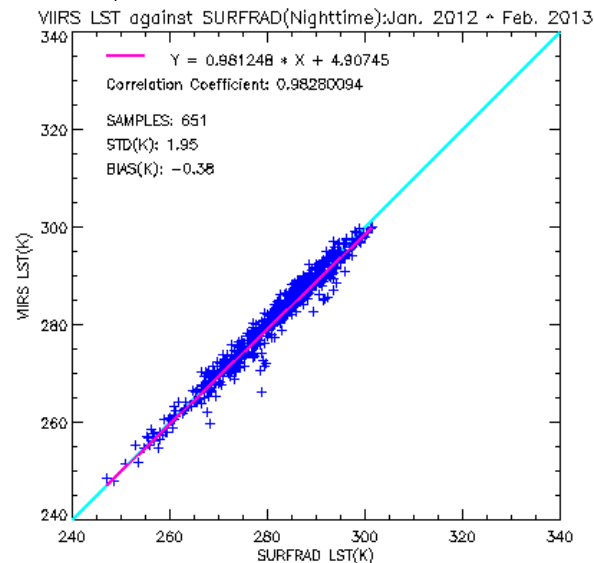




Whole Day

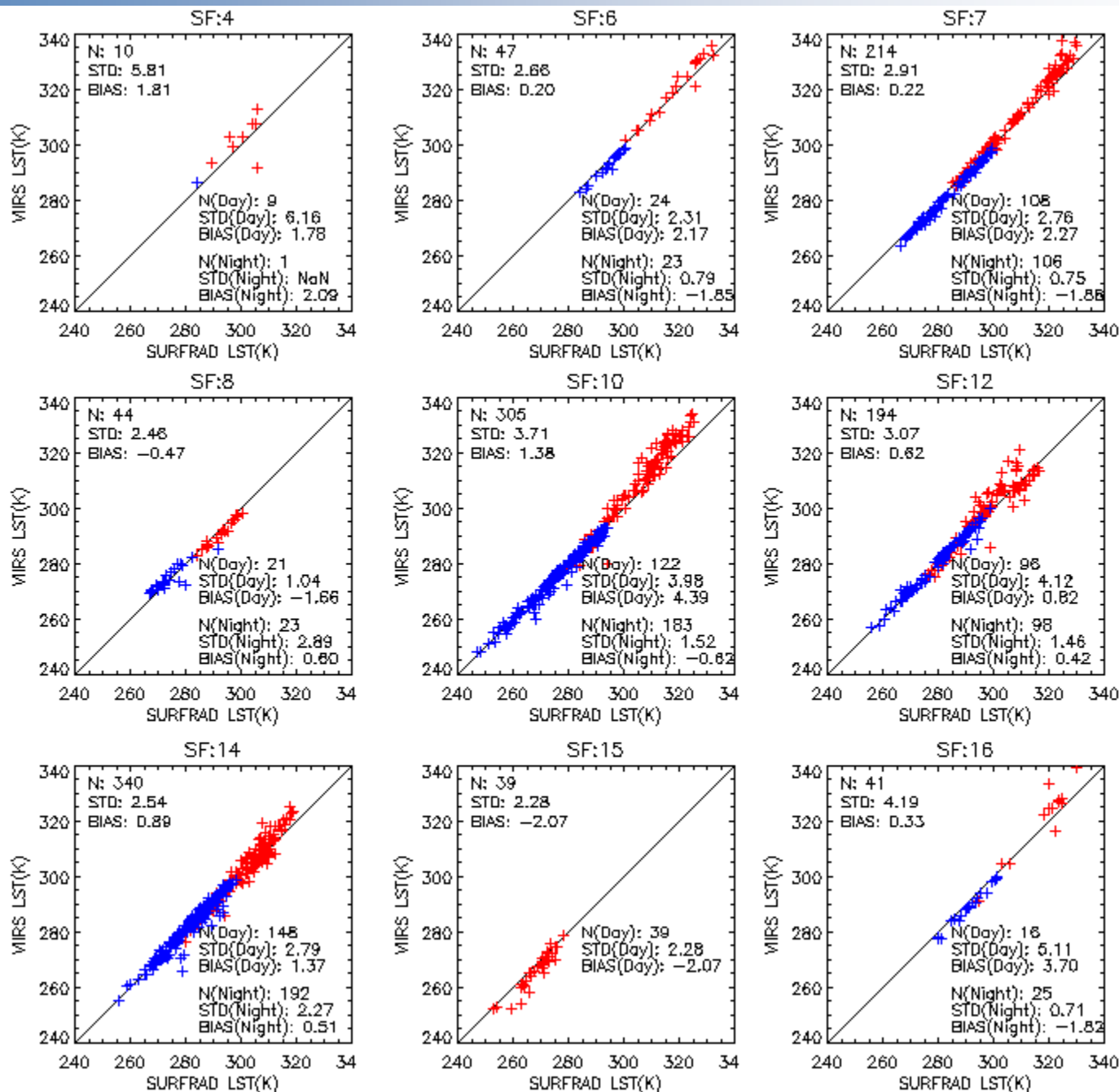


Daytime

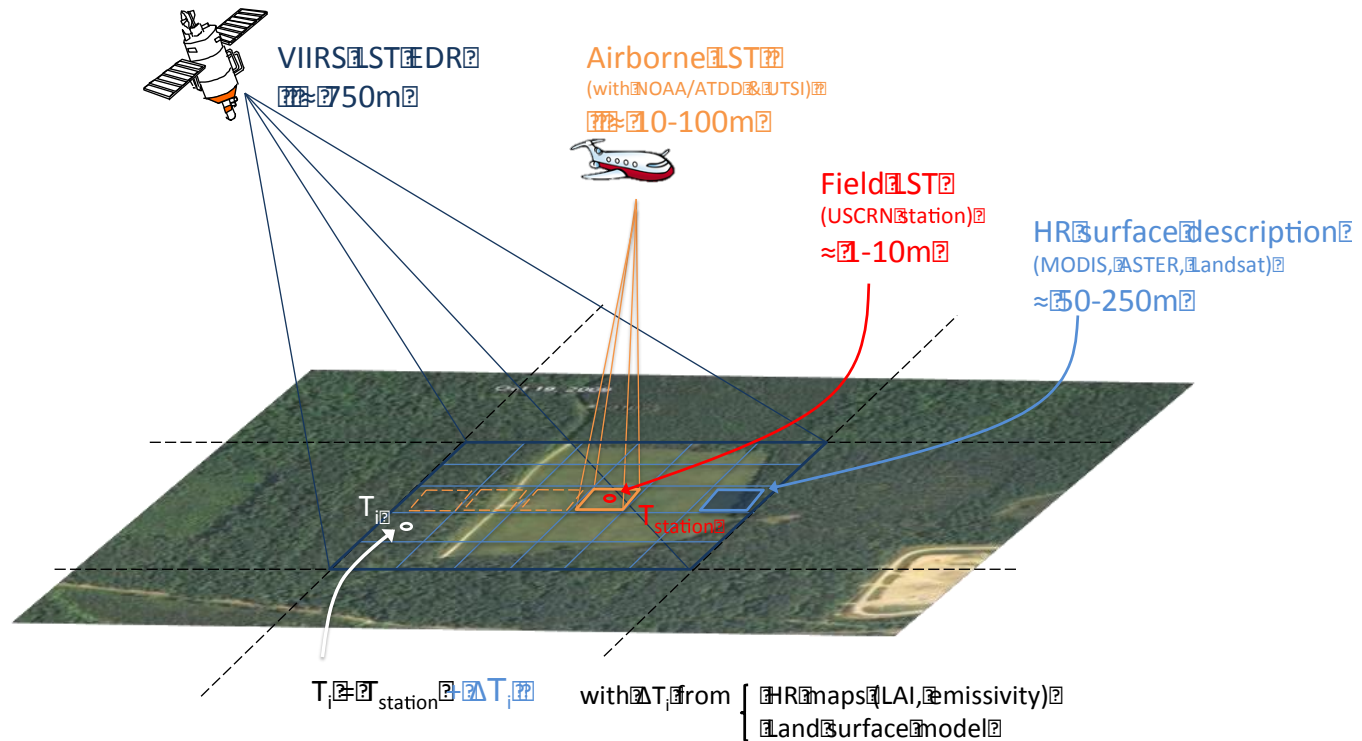


Nighttime

Ground measurements from Six SURFRAD Stations are applied for the in-site validation

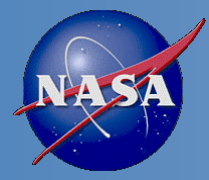


- To account for the spatial variability of LST within a VIIRS pixel, a new scaling methodology is developed based on:
 - High resolution (<250m) information about spatial variability of land type and biophysical properties
 - A land surface model to describe the LST spatial variability associated with the variability of surface properties



- Methodology just published in peer-reviewed literature:

Guillevic P., Privette J., Coudert B., Palecki M. A., Demarty J., Ottlé C. and Augustine J. A. (2012). Land Surface Temperature product validation using NOAA's surface climate observation networks – Scaling methodology for the Visible Infrared Imager Radiometer Suite (VIIRS). *Remote Sensing of Environment*, 124 (2012) 282–298.



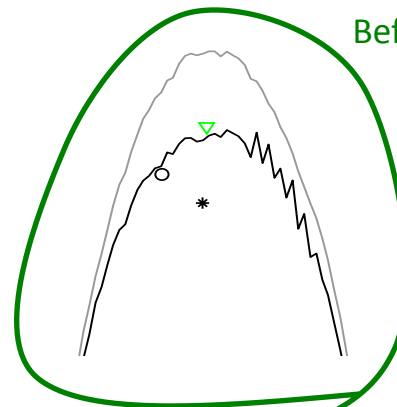
Upscaled in situ LST vs. satellite LST -- Site Bondville, IL



Champaign, IL

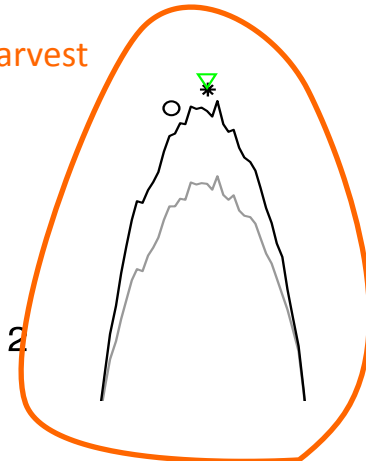


(40.05N, 88.37W)

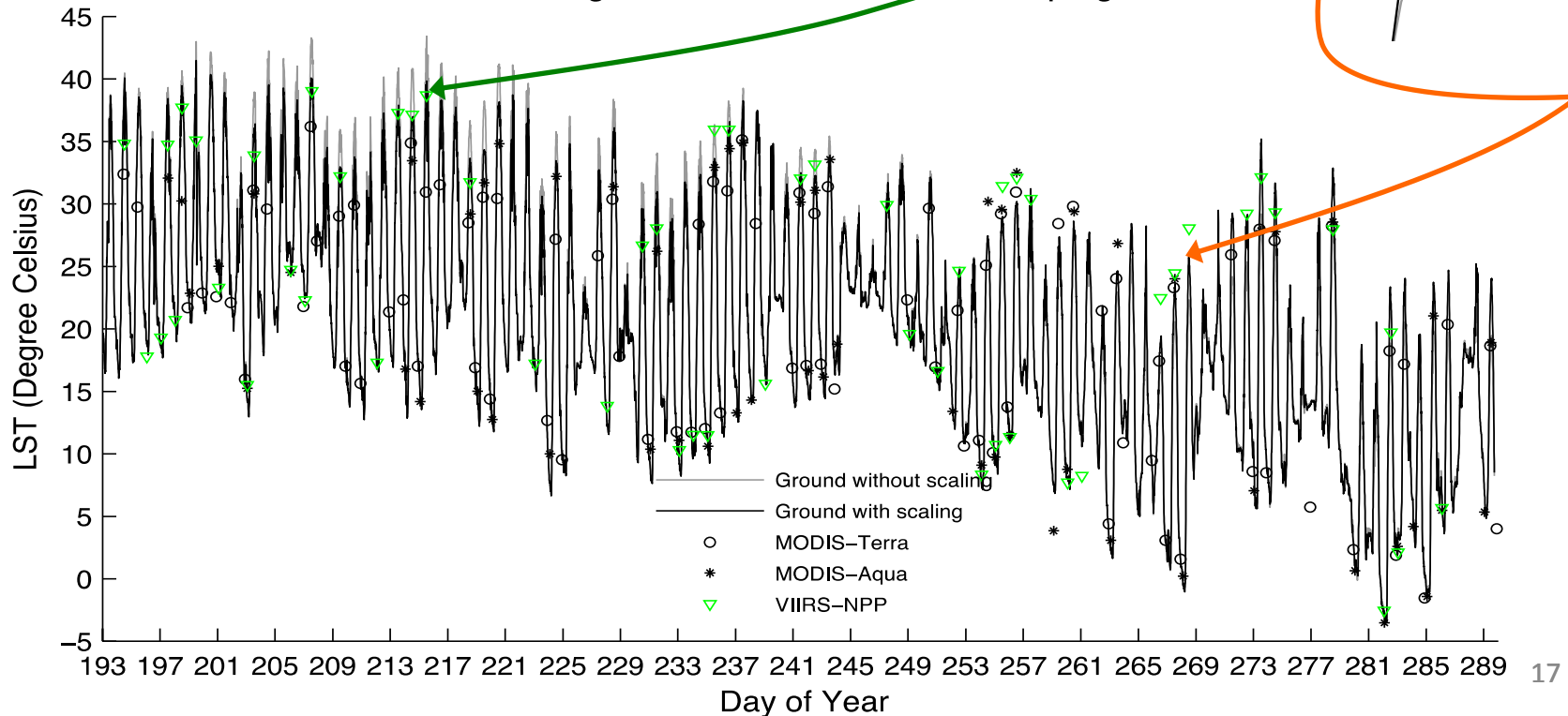


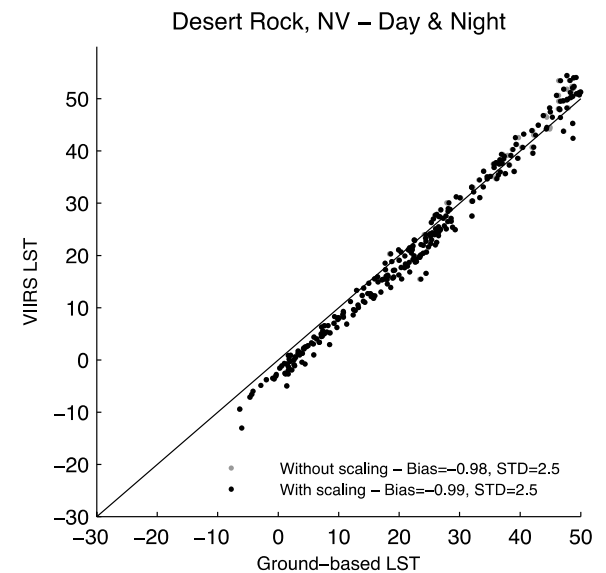
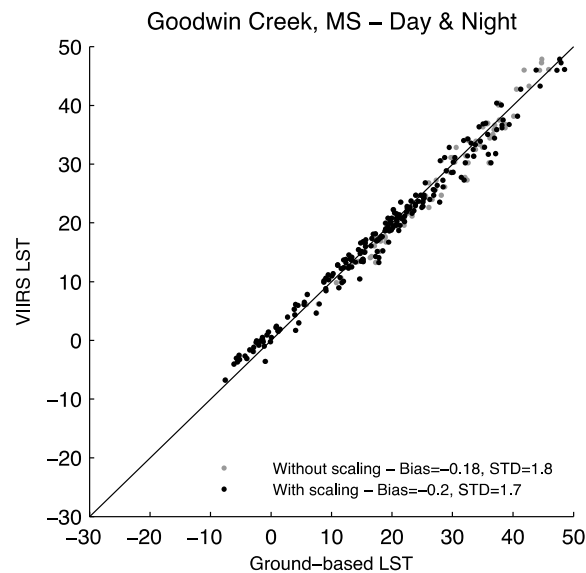
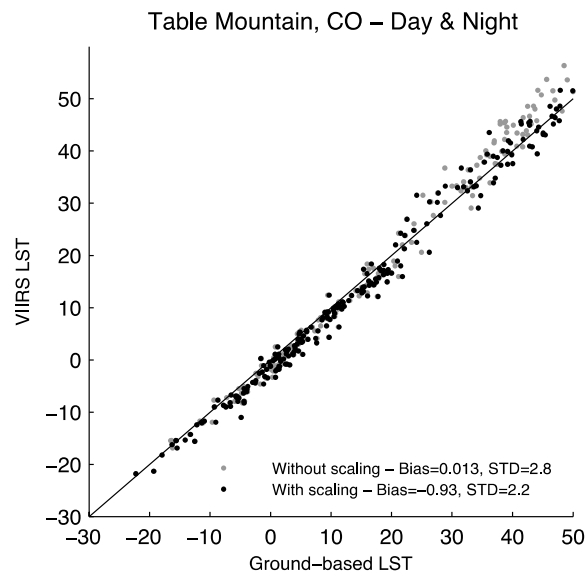
Before harvest

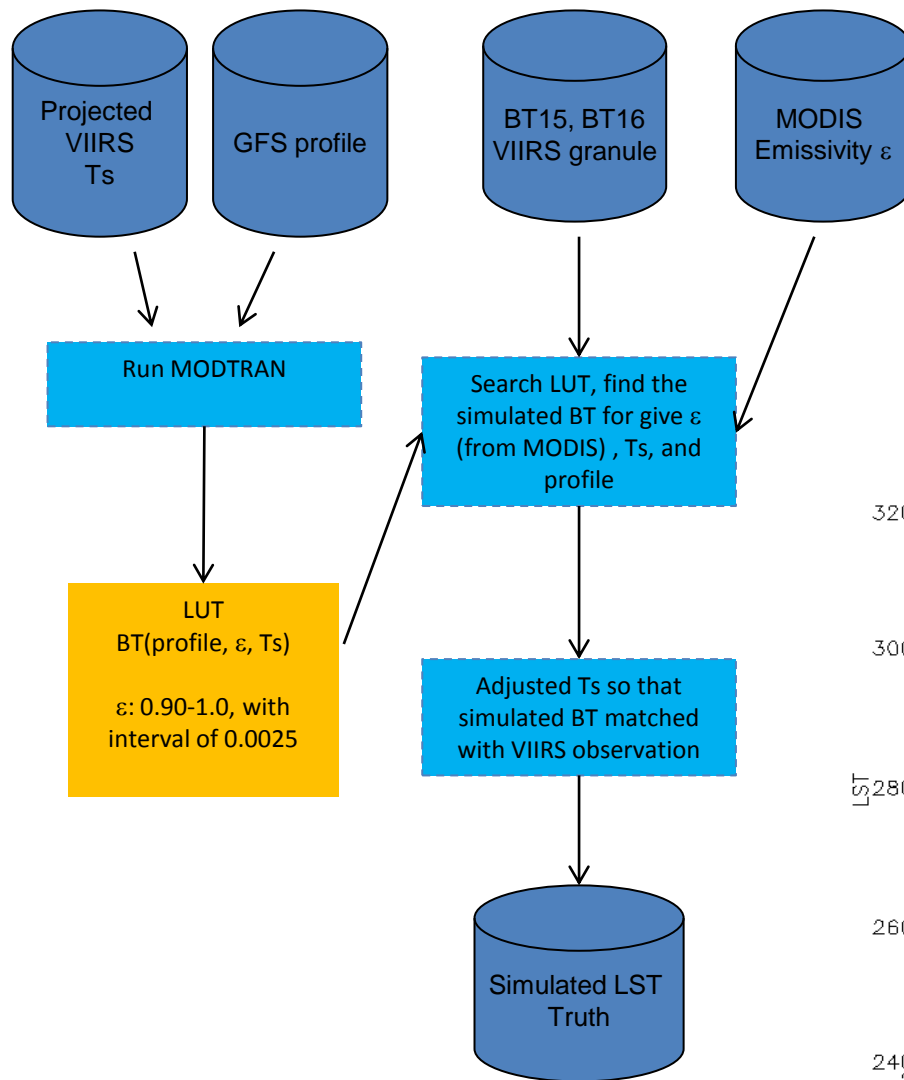
After harvest



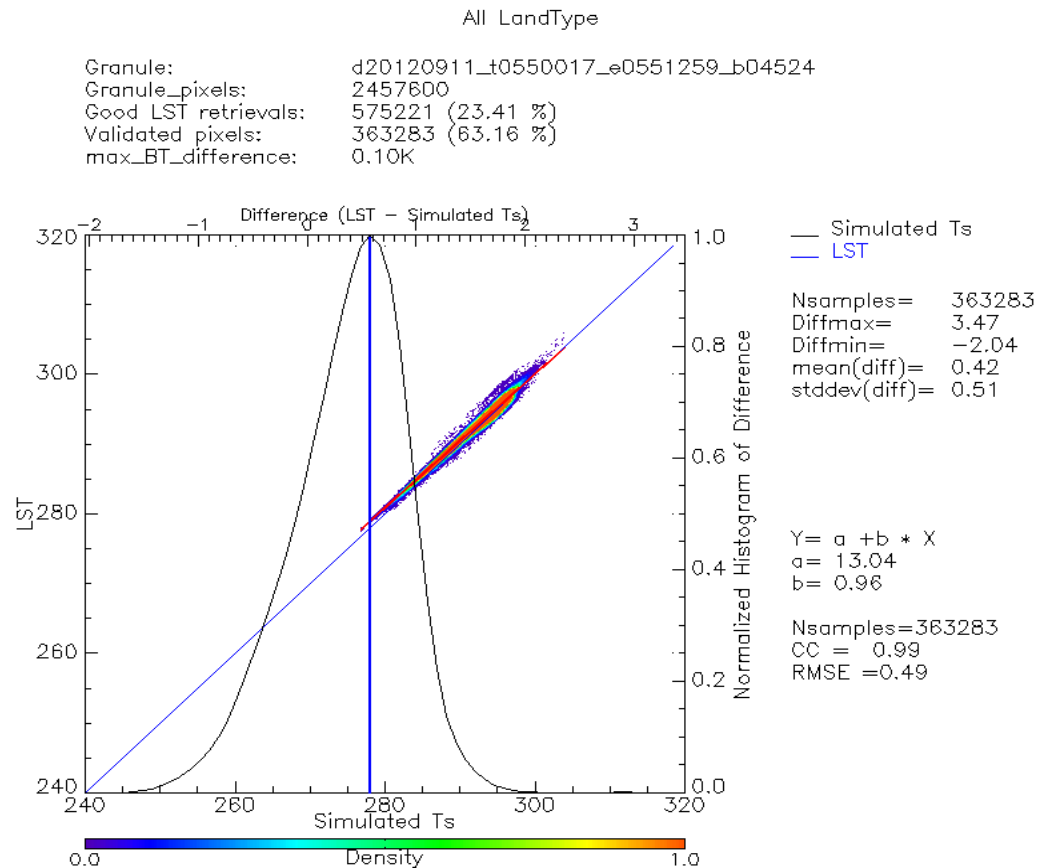
VIIRS, MODIS and ground-based LST – Champaign, IL – 2012





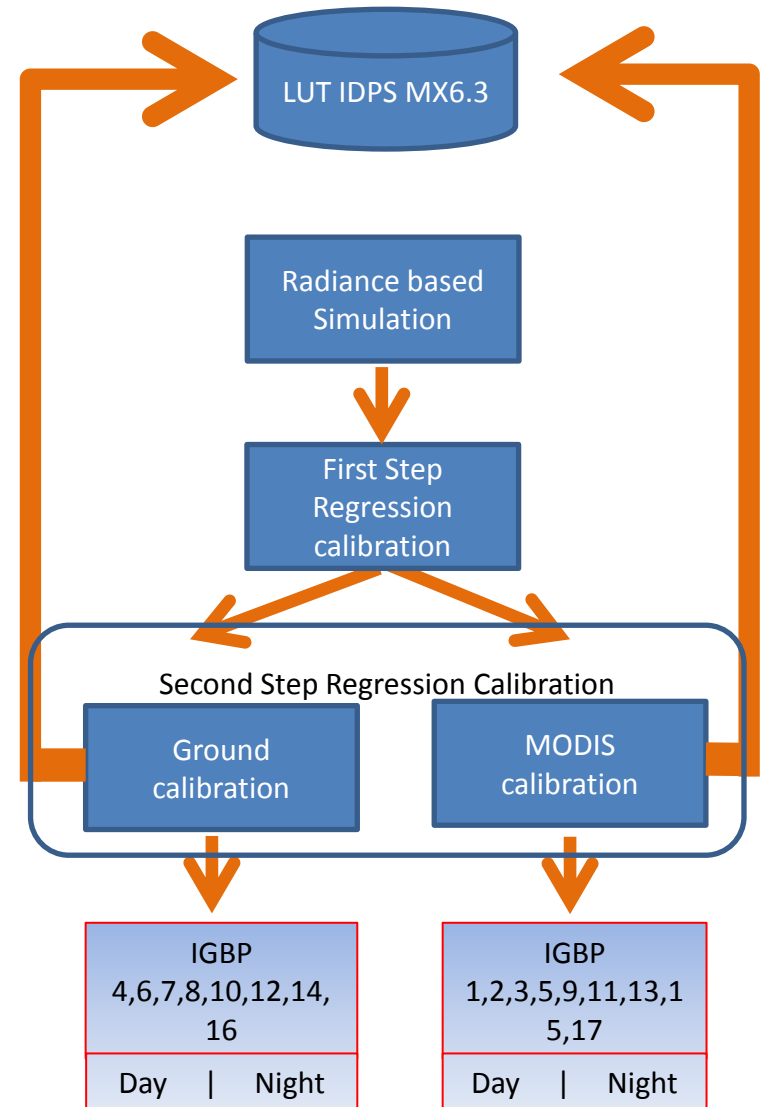


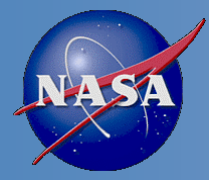
Sample Validation Results



Radiative Transfer Computation

- 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:
 - calibration from the radiance based simulation*
 - 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.



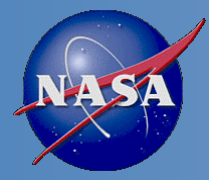


Data sets for LST calibration



Data sets

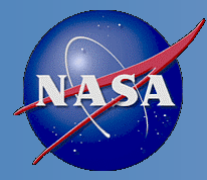
- Radiance based simulation data set
- Ground truth data set for the time period from Jan. 2012 to Mar. 2013.
- MODIS Aqua LST (MYD11_L2).
- VIIRS LST data set retrieved from baseline split window algorithm using LUT compatible to MX6.3 build in IDPS.



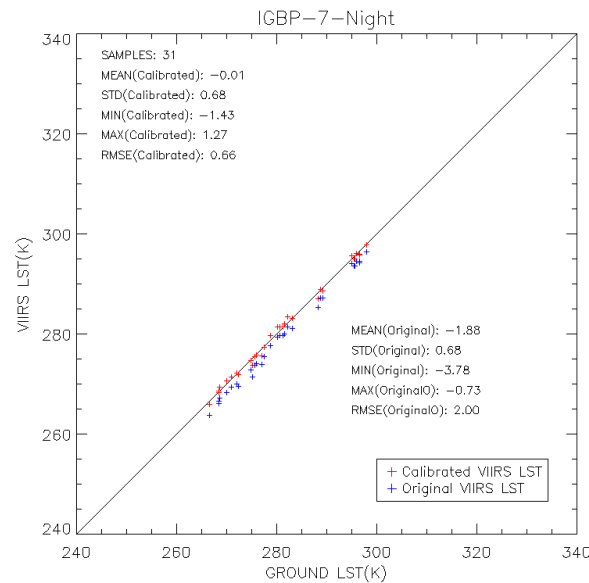
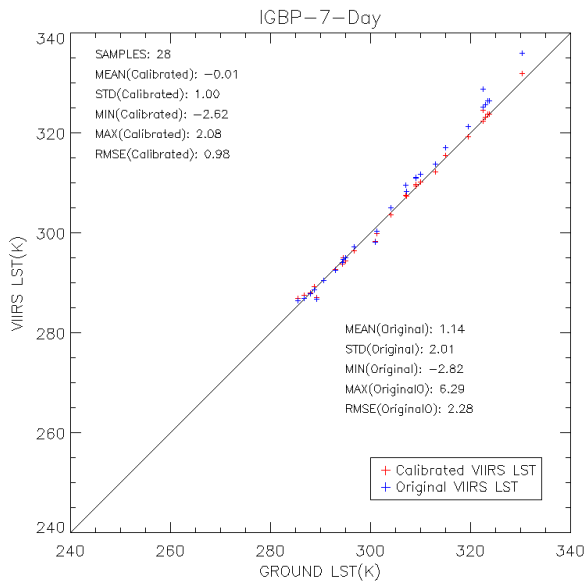
Provisional Definition



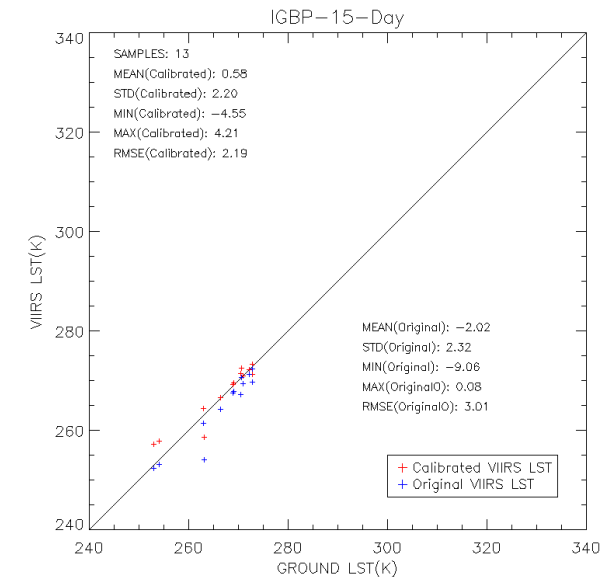
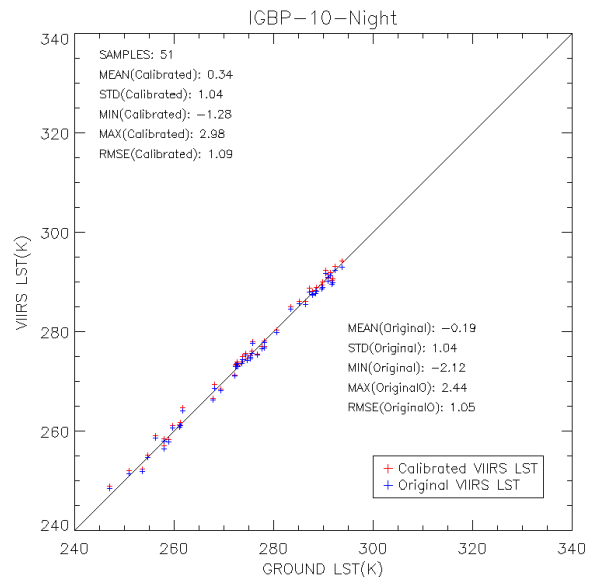
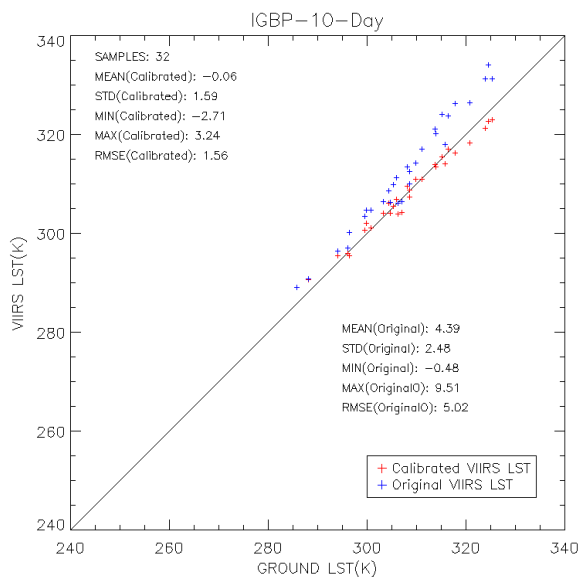
- Product quality may not be optimal
 - Optimal would be LST attains all of its requirements
- Incremental product improvements still occurring
 - DR process
- Version control is in effect
- General research community is encouraged to participate
 - LST status and issues are posted and discussed in meetings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



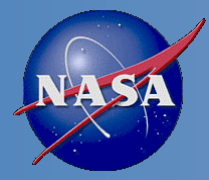
Provisional Evaluation against Ground truth



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

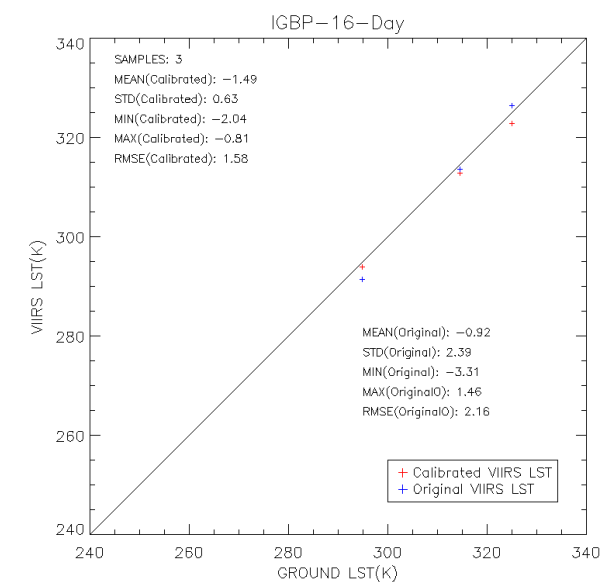
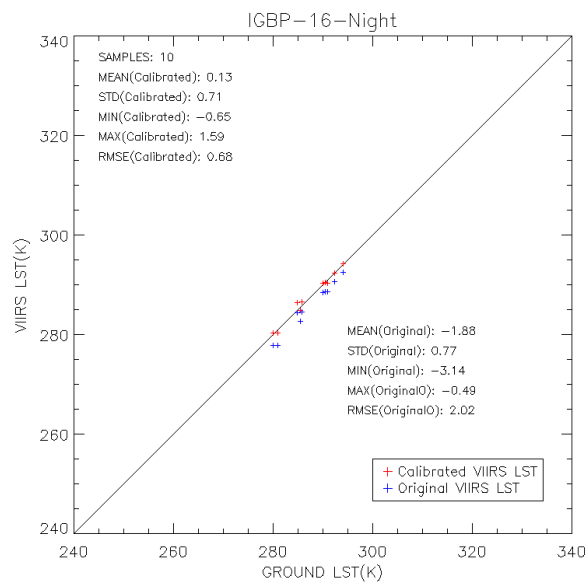
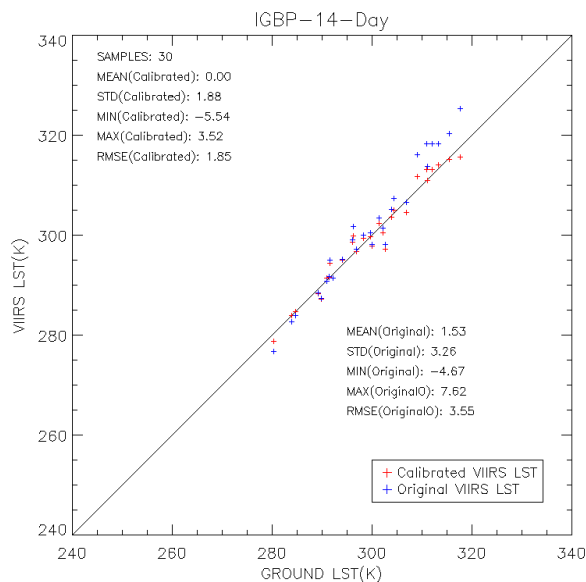
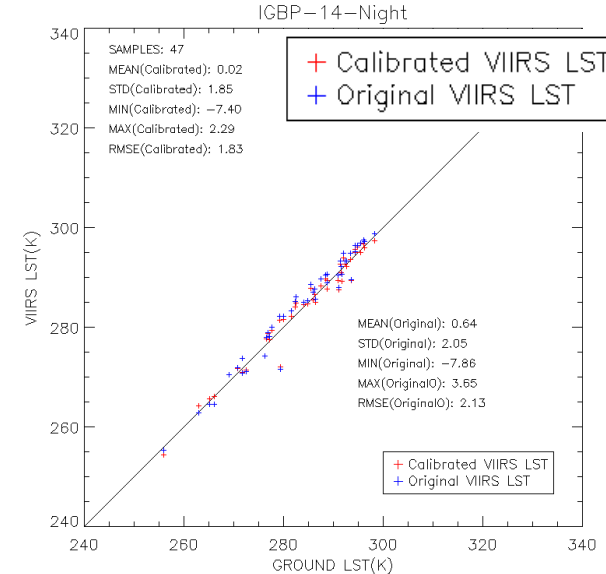
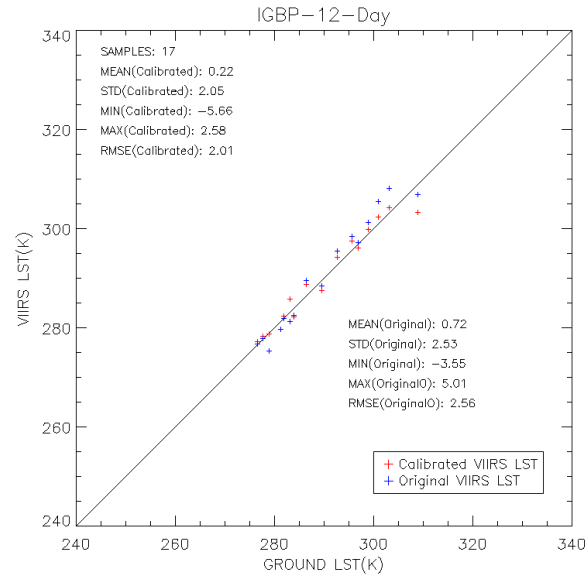
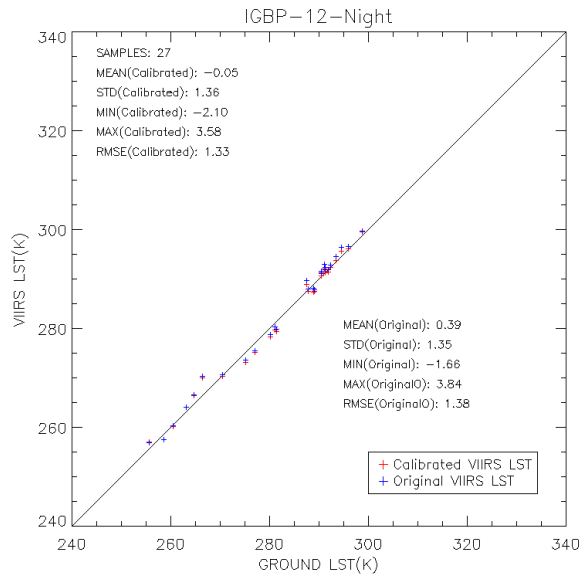


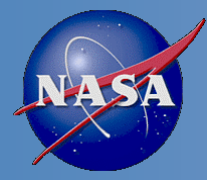
Provisional Evaluation against Ground truth

Conti.



Some more ...



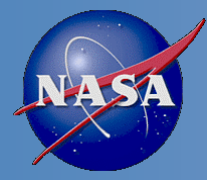


Summary of evaluation against ground in-situ



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

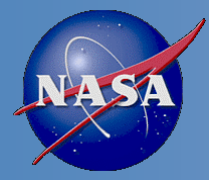


Evaluation of Calibration Performance

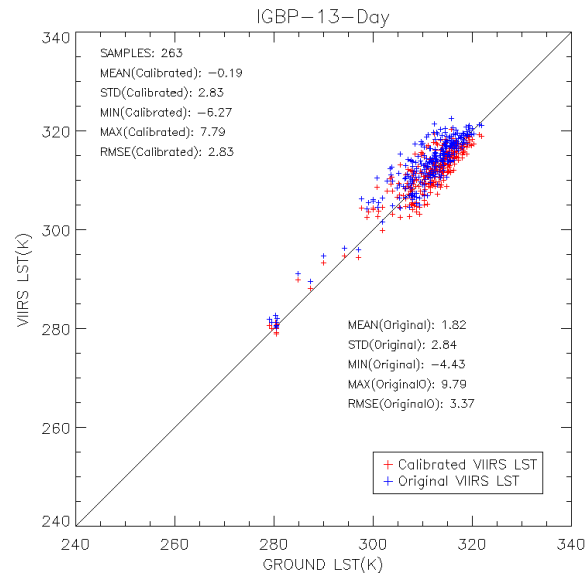
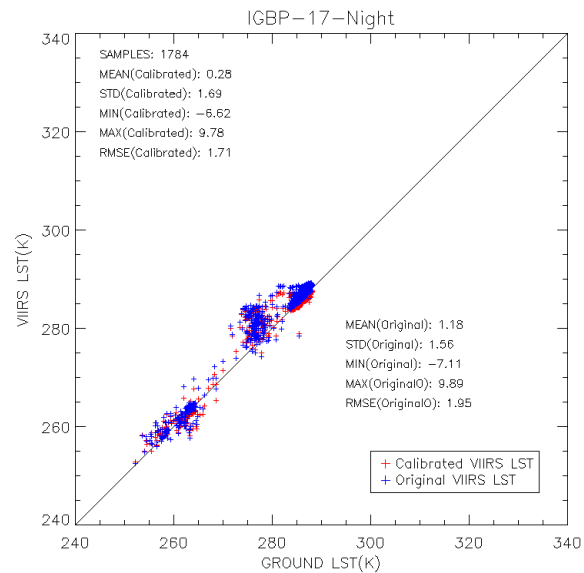


Calibration performance is evaluated using MODIS Aqua LST as a reference. Two SNOs for both day and night between NPP and AQUA in each month of January, April, July and October are selected. Below is the table for the SNOs obtained for evaluation

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

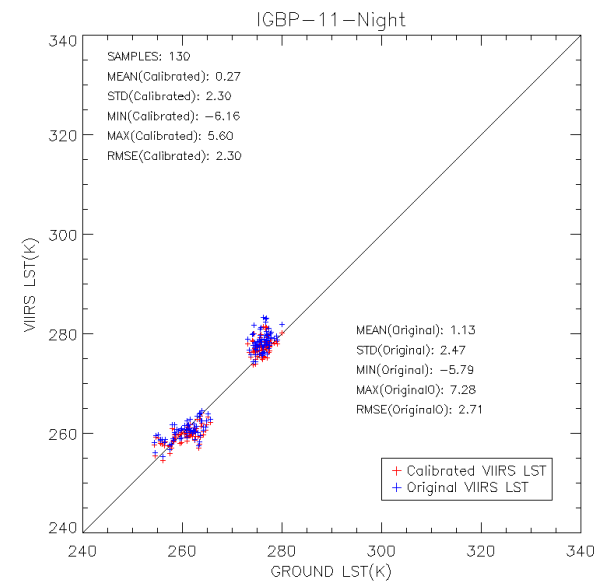
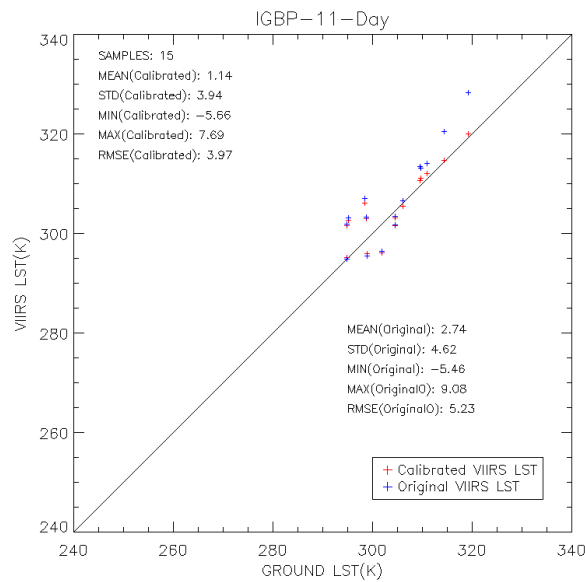
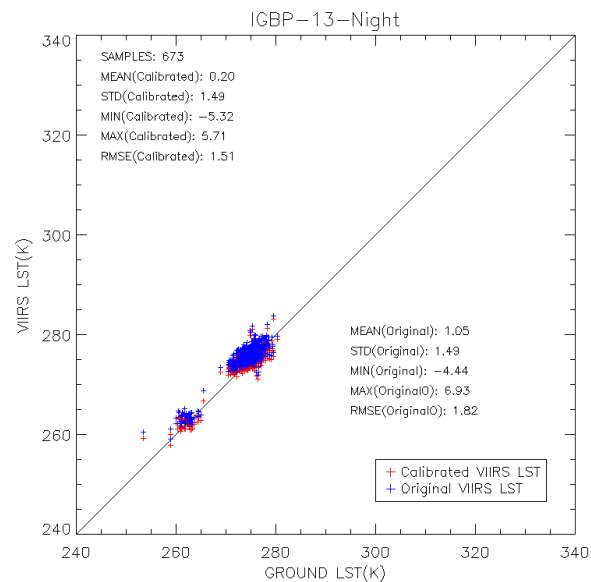


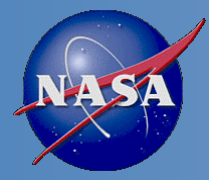
Provisional LSTs against MODIS LST



**The Calibrated LSTs are
evaluated using MODIS
LSTs**

+ Calibrated VIIRS LST
+ Original VIIRS LST

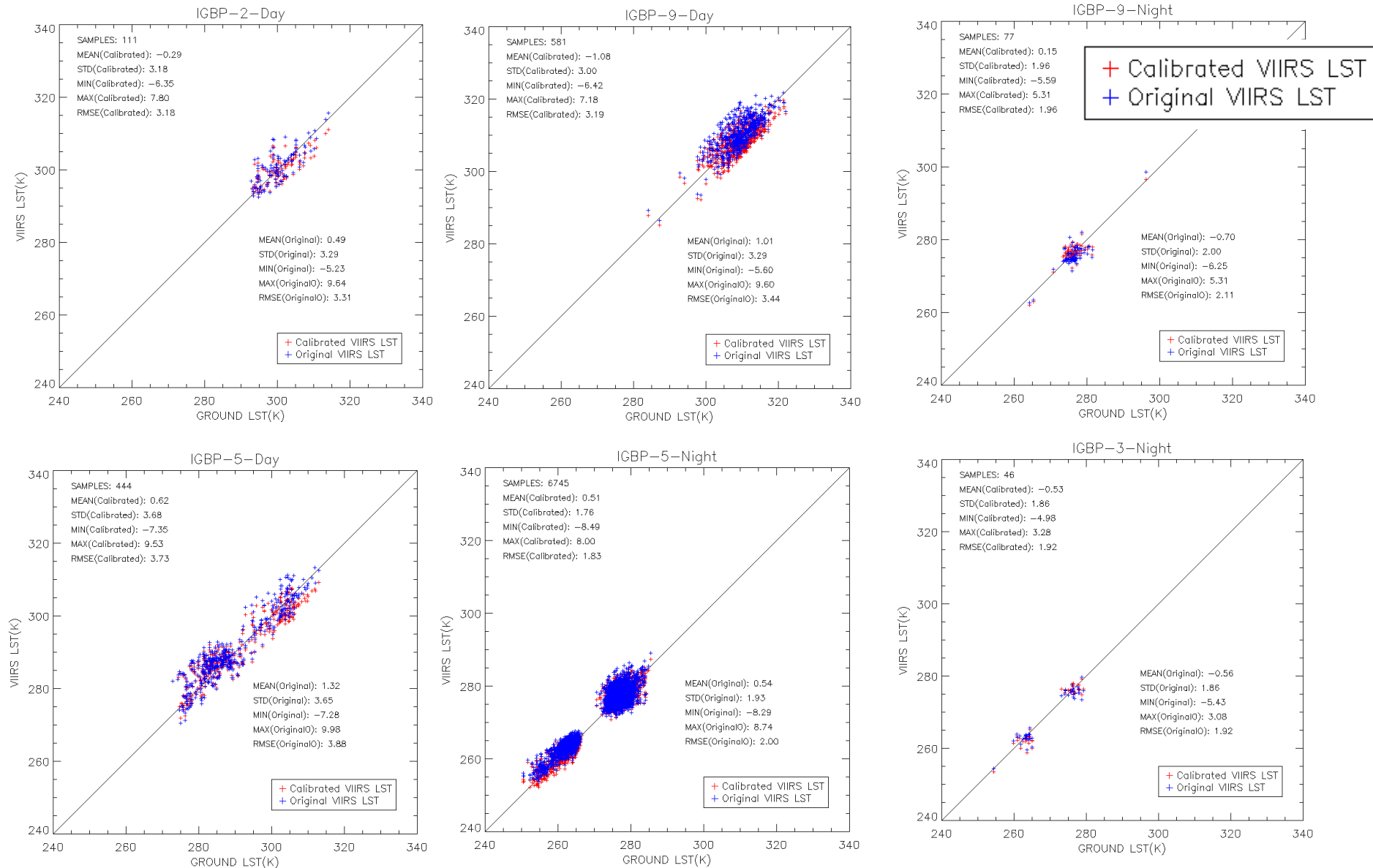


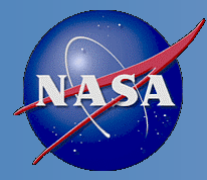


Provisional LSTs against MODIS LST



Some more ...





Summary of provisional evaluation against MODIS LST



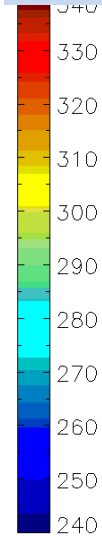
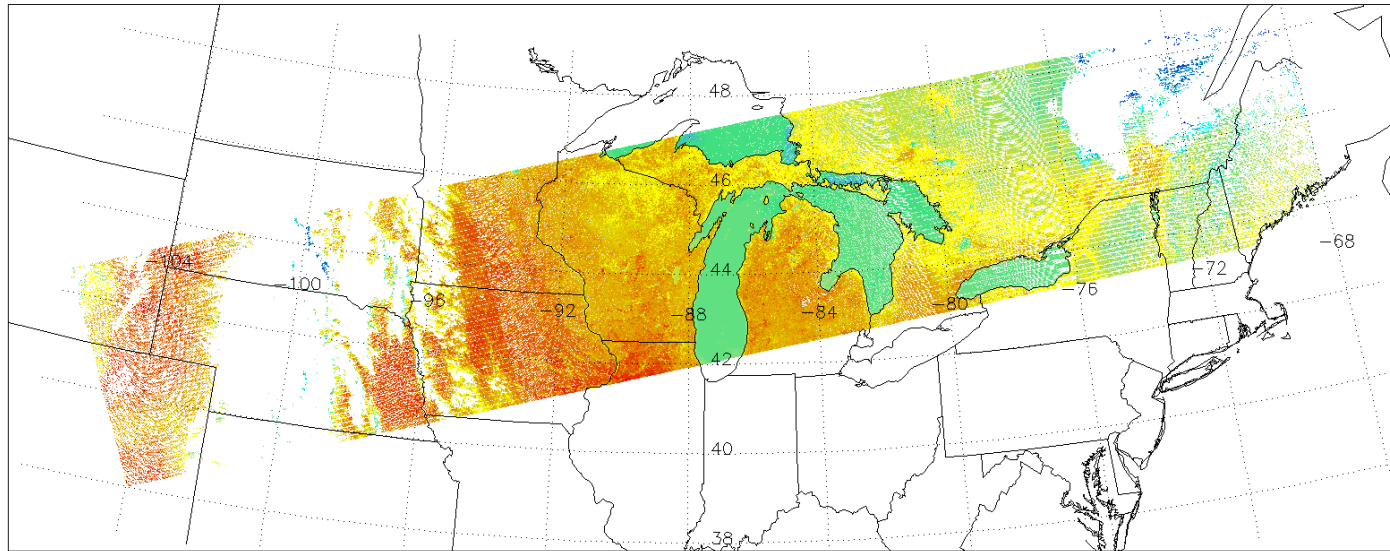
Table : Evaluation of calibration performance using MODIS Aqua LST data in January, April, July and October.

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

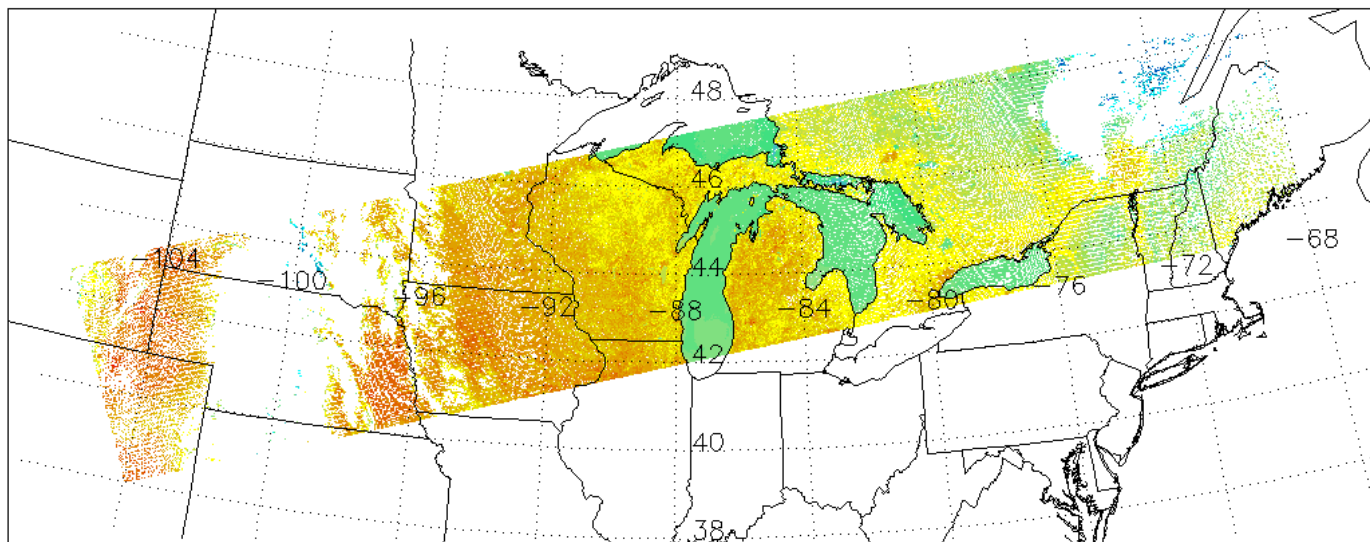
VIIRS LST: VLSTO_npp_d20120406_t1839167_e1840409_b02290

Daytime single granule



Beta

VIIRS LST: VLSTO_npp_d20120406_t1839167_e1840409_b02290



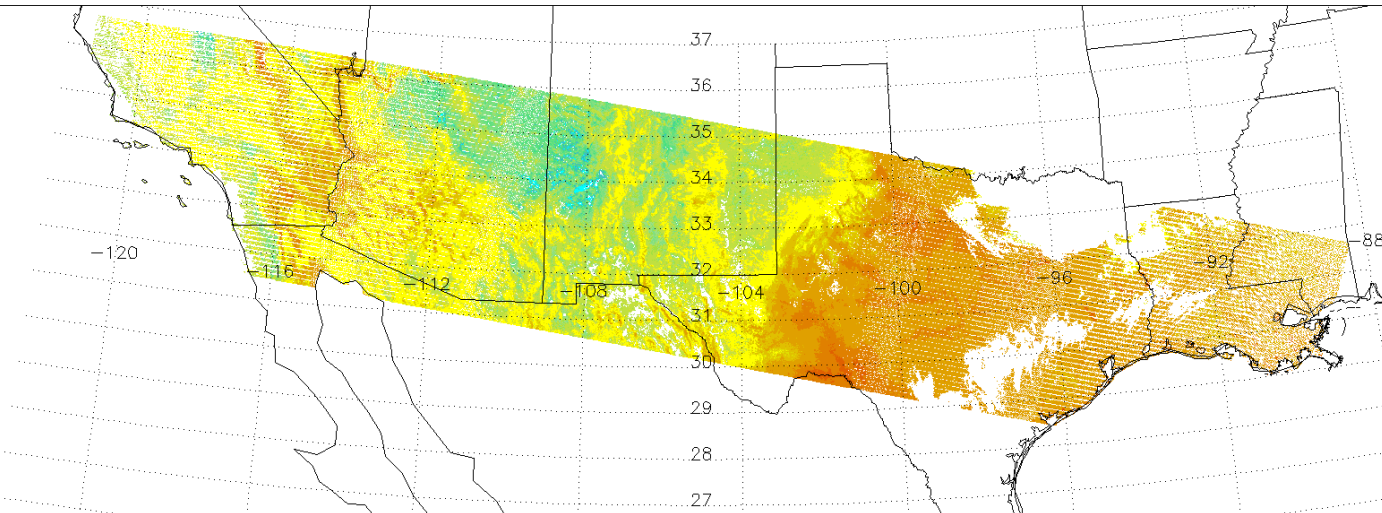
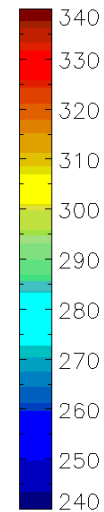
Provisional

Image comparison before and after

Nighttime single granule

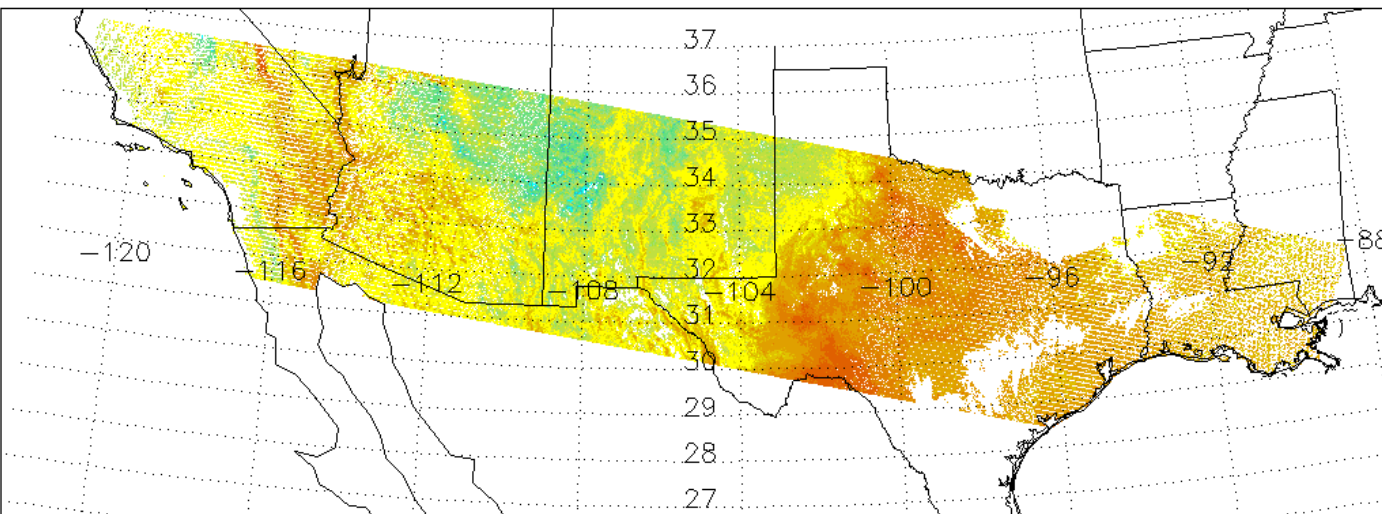
VIIRS LST: VLST0_npp_d20120530_t0845372_e0847014_b03050

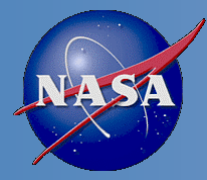
Beta



VIIRS LST: VLST0_npp_d20120530_t0845372_e0847014_b03050

Provisional

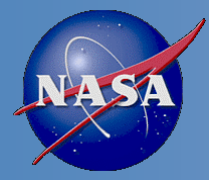




Product Quality Summary



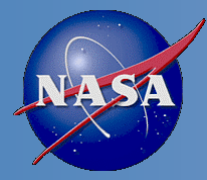
- LST has shown marked improvement after beta release
 - *Evaluation result shows an improved performance for some surface types such as IGBP 6,7,10,12,14 and 16.*
 - *Daytime LST gets significantly improved over some surface types and the performance is close or better than requirements e.g. IGBP 7,12 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*



Considerations, Known Issues



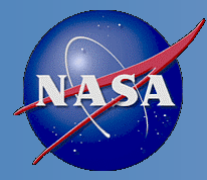
- Nighttime snow/ice cover information maybe incorrectly identified.
- Strong surface type dependency of the retrieval performance
 - *Consistency*
 - *Surface type mixed pixel*
 - *Miss use of surface type info*
- Seasonal dependency of the retrieval performance
- Cloud residual impact
 - *May need additional cloud filter*
- Validation difficulties
 - *Limited high quality in-situ data*
 - *Heterogeneity in a pixel*



Ready for Operational Evaluation



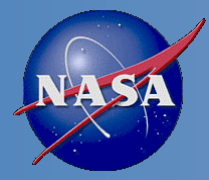
- The LST provisional data is preliminary evaluated during the development period; further evaluation is planned after this release.
- It has always been the intent that the LST would be ready for outside evaluation after the 30-day spin-up
- The operational evaluation is critical for the validated version 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