Initial Assessment of Suomi NPP VIIRS Land Surface Temperature(LST) Algorithms*

Yuling Liu[1] , Yunyue Yu[2],Dan Tarpley[3], Xiaolong Wang[4] and Zhuo Wang[4]

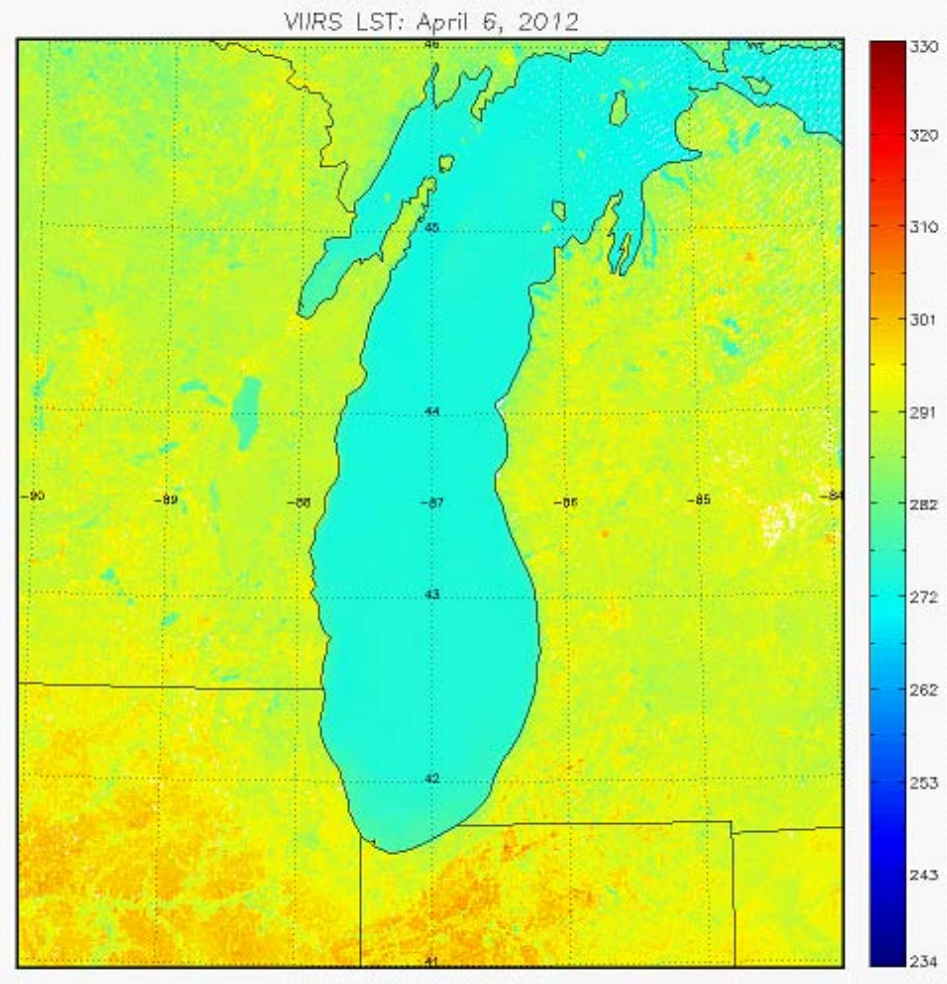
[1]CICS/University of Maryland, College Park
[2]STAR/NESDIS, NOAA
[3] Short & Associates, Camp Spring
[4]IMSG Inc.

Jan 10, 2013

* This research is supported by JPSS project.

Outline

- Algorithm introduction
- Evaluation results
  - Granule level comparison
  - Global comparison of SWLST and DWLST
  - Performance over surface type
  - Ground evaluation against SURFace RADiation budget network (SURFRAD).
- Summary



Land Surface temperature distribution around Lake Michigan, 6, April 2012, UTC.

Algorithm

- **Baseline Split window algorithm**

Establish the 2-band 10.76μm(M_{15}) and 12.01μm (M_{16}) split window algorithm for both day and night based on regression equation for each of the 17 IGBP surface types.

$$LST_i = a_0(i) + a_1(i)T_{M15} + a_2(i)(T_{M15} - T_{M16}) + a_3(i)(sec\theta - 1) + a_4(i)(T_{M15} - T_{M16})^2 \quad i = 1, \ldots, 17$$

Where

LST_i is the retrieved land surface temperature over surface type i.

A_n and bn are coefficients retrieved from the LST LUT .

Θ is the sensor zenith angle

Φ is the solar zenith angle

T_m is the brightness temperature at m=VIIRS band M_{12},M_{13},M_{15} and M_{16}

SWLST Coefficients-Nighttime

Surface Type	a_0	a_1	a_2	a_3	a_4
1	-2.44023	1.013721	1.597063	0.397226	0.243329
2	-10.9737	1.043302	1.337757	1.192763	0.433421
3	-2.81076	1.015627	1.253511	0.782135	0.474349
4	-0.67262	1.008506	1.782233	1.031163	0.193119
5	-1.58225	1.011321	1.569283	0.874003	0.341845
6	-2.86866	1.017388	1.169604	0.40632	0.470555
7	-3.67031	1.020234	1.367489	0.974629	0.383254
8	-6.1826	1.027303	1.131303	0.819621	0.519747
9	-7.93398	1.034157	1.219383	1.250769	0.450993
10	-2.19848	1.015395	1.473563	1.304318	0.286378
11	-4.76334	1.021443	1.198395	0.313569	0.606909
12	-0.98175	1.010598	1.322288	-0.39396	0.397286
13	0.269089	1.006037	1.40562	0.363574	0.370285
14	-3.08412	1.016865	1.563887	0.810411	0.296177
15	-3.29337	1.013452	1.323036	0.251886	-0.22787
16	-8.63783	1.037961	1.034632	0.83134	0.478393
17	-8.89917	1.033886	1.848356	1.511793	0.354354

SWLST Coefficients-Daytime

Surface Type	a_0	a_1	a_2	a_3	a_4
1	-6.33485	1.028104	1.310552	1.063013	0.441287
2	-5.47409	1.024861	1.660752	2.42386	0.327702
3	-4.58919	1.022091	1.103522	0.813863	0.571229
4	-5.45372	1.033022	1.811434	-2.70106	0.298936
5	-7.51475	1.033524	1.201031	1.246776	0.438322
6	-2.44143	1.016145	1.566102	0.370878	0.193816
7	-7.09271	1.033233	1.350841	1.213785	0.367221
8	-9.81976	1.041334	0.970194	1.372316	0.55345
9	-10.6068	1.04433	1.158848	1.021086	0.463121
10	-6.44958	1.031742	1.303886	0.059388	0.394892
11	-7.78559	1.033159	0.558588	1.036486	0.740771
12	-11.9967	1.049311	1.160366	2.728394	0.434421
13	-7.32977	1.034073	1.576136	0.978909	0.268421
14	-9.31956	1.04016	1.069135	2.379238	0.469663
15	-4.9299	1.01913	1.683574	0.352144	-0.26357
16	-12.7833	1.052898	0.944545	0.889798	0.506456
17	-8.92885	1.033913	1.870167	1.479963	0.354069

Algorithm

- **Fallback dual split window algorithm**

Fallback to 4-band,3.75μm(M_{12}), 4.05μm(M_{13}), 10.76μm(M_{15}) and 12.01μm(M_{16}).

Daytime:

$$LST_i = a_0(i) + a_1(i)T_{M15} + a_2(i)(T_{M15} - T_{M16}) + a_3(i)(sec\theta - 1) + a_4(i)T_{M12} + a_5(i)T_{M13} + a_6(i)T_{M12}cos\varphi + a_7(i)T_{M13}cos\varphi + a_8(i)(T_{M15} - T_{M16})^2 \quad i = 1, \ldots, 17$$

Nighttime:

$$LST_i = b_0(i) + b_1(i)T_{M15} + b_2(i)(T_{M15} - T_{M16}) + b_3(i)(sec\theta - 1) + b_4(i)T_{M12} + b_5(i)T_{M13} + b_6(i){T_{M12}}^2 + b_7(i){T_{M12}}^2 + b_8(i)(T_{M15} - T_{M16})^2 \quad i = 1, \ldots, 17$$

DWLST Coefficients-Daytime

Surface Type	a_0	a_1	a_2	a_3	a_4	a_5	a_6	a_7	a_8
1	-10.6264	1.015881	1.512591	0.872806	0.076074	-0.04944	0.023013	-0.0259	0.400733
2	-32.5916	0.7125	1.443134	4.037757	0.800019	-0.40614	-1.11145	1.12661	0.138115
3	-7.03512	1.015631	1.232327	1.148399	0.075216	-0.06249	-0.0544	0.056096	0.474338
4	-20.9519	1.018334	1.85156	-0.02221	0.25691	-0.19947	-0.11679	0.117968	0.303552
5	-10.8193	1.055794	1.43037	0.742617	0.09498	-0.10771	0.000131	-0.00153	0.438895
6	-5.50115	1.094663	1.933453	0.29939	0.045112	-0.11516	0.108701	-0.11237	0.19801
7	-13.1587	1.043763	1.585591	1.140085	0.093137	-0.08603	-0.01961	0.018718	0.33105
8	-16.6581	0.981675	1.377081	1.295195	0.127631	-0.04492	-0.03011	0.025662	0.419721
9	-20.283	1.020627	1.512081	1.134536	0.236476	-0.18318	-0.183	0.182684	0.358789
10	-10.5703	1.026307	1.495061	0.107394	0.099904	-0.08243	-0.05853	0.058368	0.335597
11	-14.9289	0.916092	0.888205	1.040938	0.114046	0.028764	-0.04043	0.036607	0.550104
12	-16.9384	0.992476	1.361397	2.172763	0.119642	-0.0455	-0.06192	0.059177	0.360206
13	-13.6199	1.012754	1.681872	0.885495	0.335734	-0.29924	-0.28576	0.290556	0.204145
14	-15.2004	1.083951	1.493224	1.829164	0.283395	-0.31473	-0.19302	0.197514	0.385082
15	-3.64165	1.052121	1.6614	0.300995	-0.00346	-0.03486	0.00813	-0.00764	-0.18685
16	-12.8172	1.04788	1.492339	0.794587	0.076985	-0.07502	-0.02332	0.022463	0.352328
17	-9.5285	0.879117	1.721264	1.878115	0.288336	-0.13315	-0.40859	0.413519	0.251188

DWLST Coefficients-Nighttime

Surface Type	a_0	a_1	a_2	a_3	a_4	a_5	a_6	a_7	a_8
1	-12.892	0.99831	1.616662	0.203161	0.054545	0.041762	0.000097	-0.00026	0.28715
2	79.40045	0.108876	1.42831	-0.07202	-0.2436	0.62226	0.002714	-0.00189	0.02386
3	-4.16993	0.178985	1.039093	0.643614	0.477167	0.372154	0.001009	-0.00105	0.271888
4	-17.5727	0.22971	1.562529	0.37413	-1.36959	2.292686	0.004332	-0.00464	-0.03222
5	-9.25964	0.178187	1.390277	0.274986	0.5124	0.37974	0.000979	-0.0011	0.00529
6	-4.06056	1.220165	1.344295	0.533922	-0.83376	0.647263	0.001321	-0.00137	0.559685
7	-10.9428	1.216438	1.501889	0.561789	-2.37908	2.263373	0.00433	-0.00454	0.506879
8	1.299196	0.393933	0.945797	0.376929	0.234911	0.343704	0.000981	-0.00088	0.241437
9	-3.71372	0.630064	1.213327	0.257407	0.281764	0.105944	0.000786	-0.00079	0.303222
10	-13.8604	0.494264	1.388227	1.085832	0.370223	0.238392	0.00045	-0.00062	0.070813
11	-4.48986	-0.16558	1.360877	-0.10685	1.161332	0.026794	0.000352	-0.00037	-0.18564
12	-13.0345	0.407582	1.421927	-0.20542	-0.9224	1.63264	0.003347	-0.00359	0.1616
13	-49.3424	-0.14168	1.165626	0.516062	1.820166	-0.33056	-0.00094	0.000337	-0.13858
14	-106.558	0.381422	1.573608	-0.85853	-2.56599	3.997955	0.006672	-0.00821	0.171923
15	13.90152	0.714295	1.106491	0.123164	0.287513	-0.1219	0.000217	0.00004	-0.21723
16	-13.324	1.304551	1.356587	0.726186	-1.31011	1.094774	0.001951	-0.00208	0.500258
17	0.789767	0.045261	1.312416	1.190602	0.660713	0.286574	0.000606	-0.00058	-0.02139

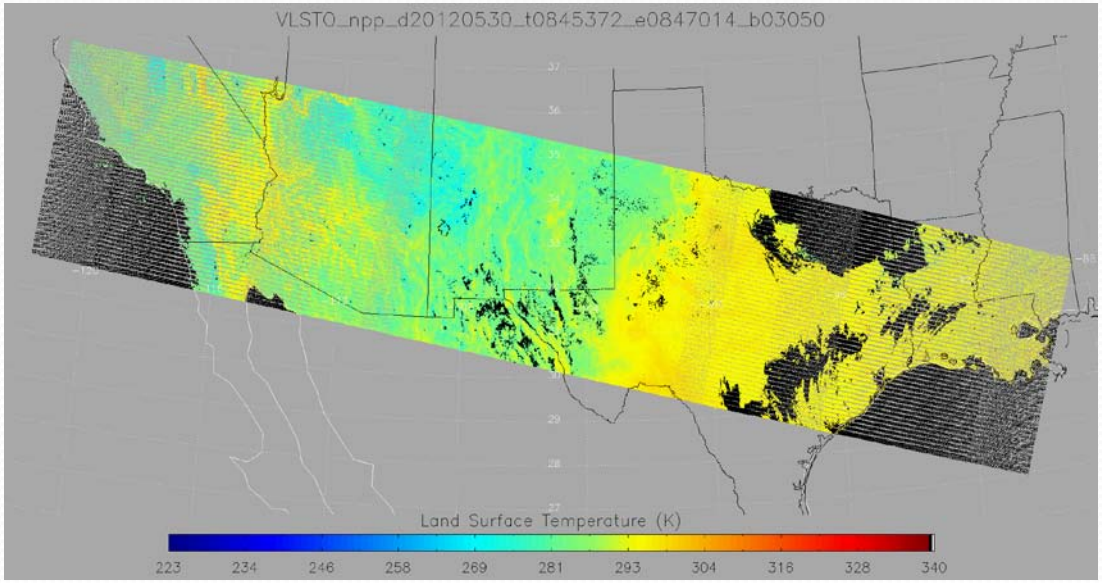
Data repository

- LUT
  - LUT in Mx6.3 build is employed for generation of both SWLST and DWLST. After August 10, 2012, the SW algorithm is performed as baseline algorithm and the DSW is as fallback algorithm in CLASS ; before that, it was vice versa so the LST data available on CLASS is DSWLST before Aug. 10, 2012 and SWLST after that.

- Spatial coverage
  - Granule level coverage
  - Continental U.S.
  - Global coverage

- Temporal Coverage
  - CONUS: January 19 to June 30, 2012
  - Global: Aug. 26. 2012

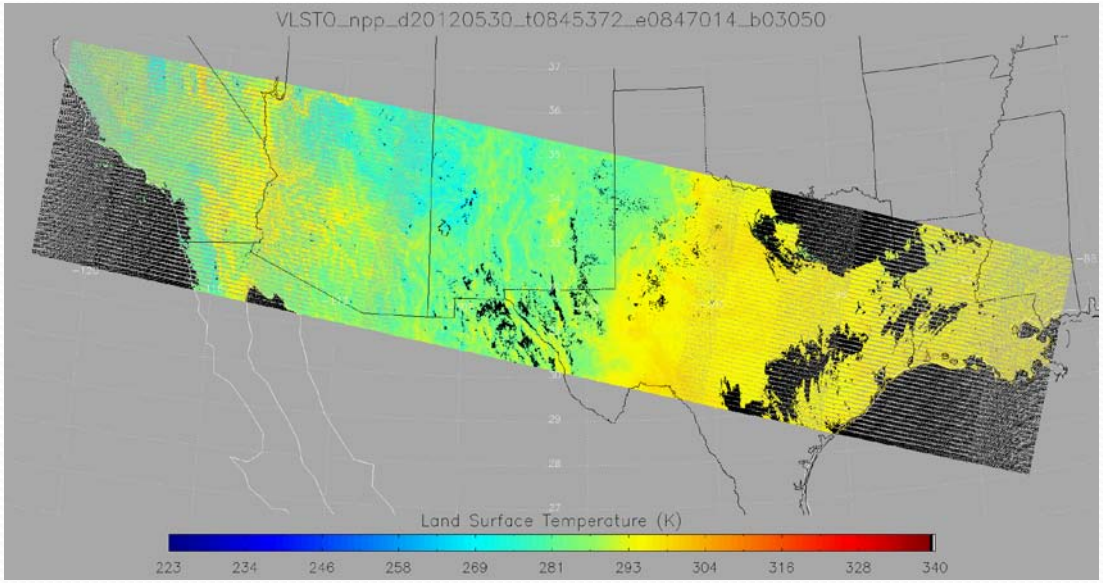
Granule Level : SWLST vs DWLST



SWLST

May 30, 2012 at 08:45 UTC

DWLST



Global comparison: SWLST vs DWLST

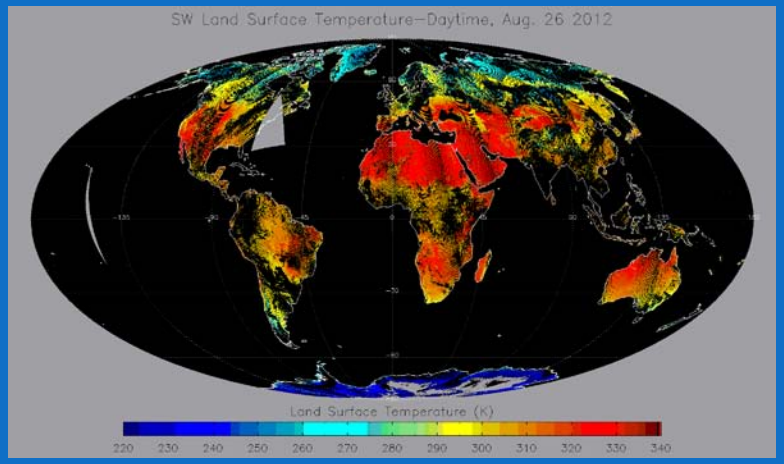


Figure 1a. Global image of daytime SWLST on Aug. 26, 2012

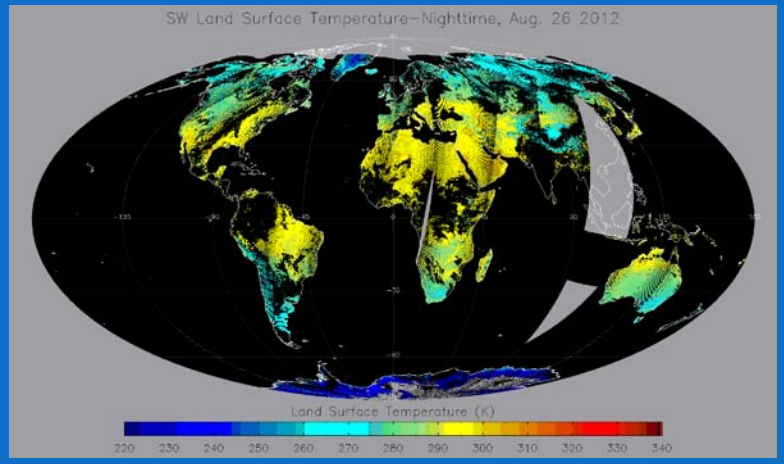


Figure 1b. Global image of nighttime SWLST on Aug. 26, 2012

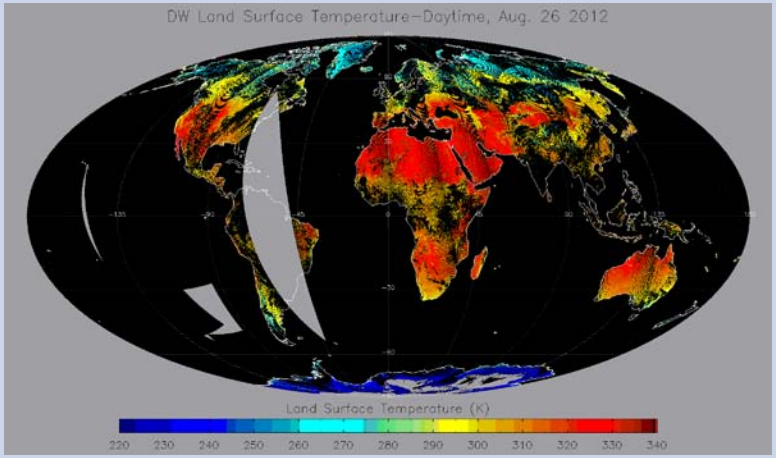


Figure 2a. Global image of daytime DWLST on Aug. 26, 2012

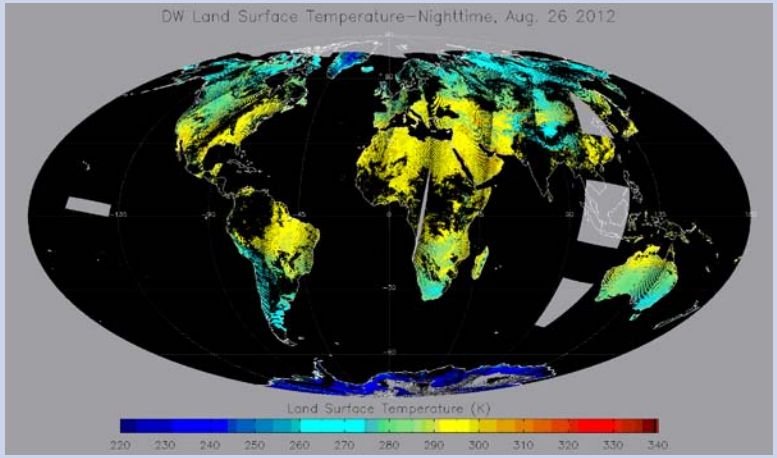
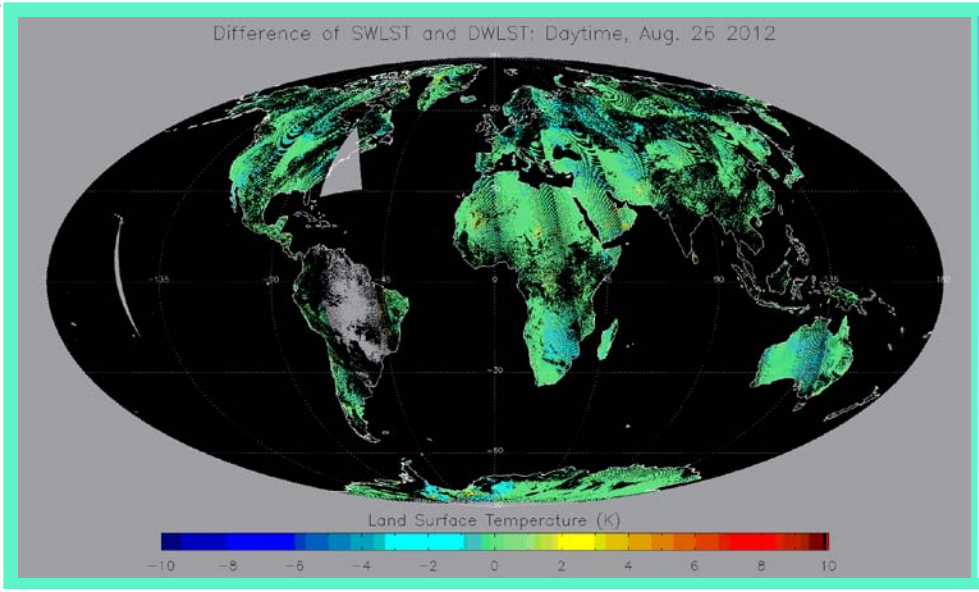
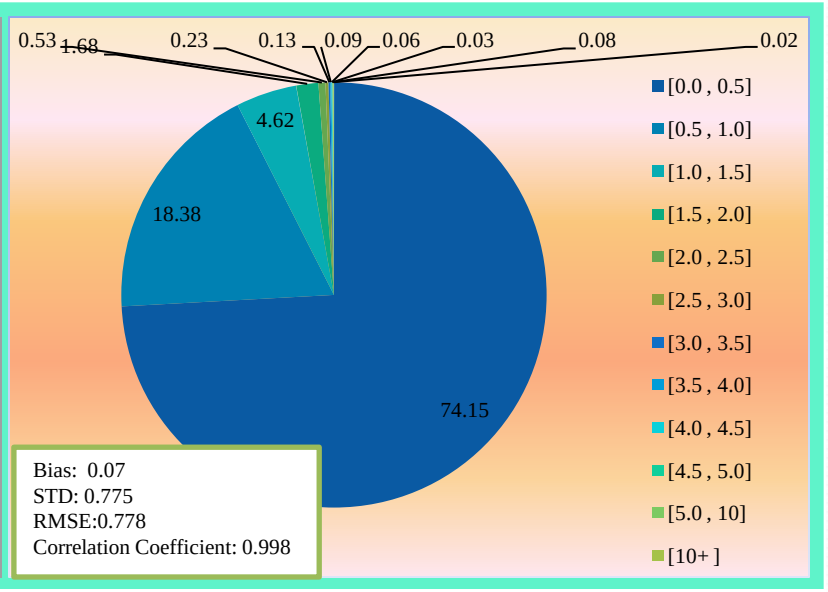
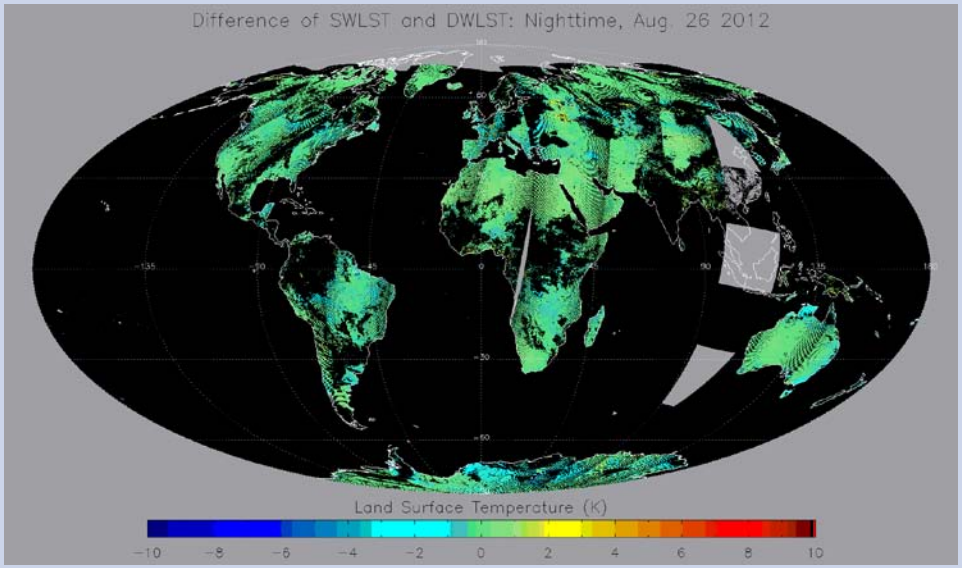


Figure 2b. Global image of nighttime DWLST on Aug. 26, 2012

Global LST difference: SWLST - DWLST







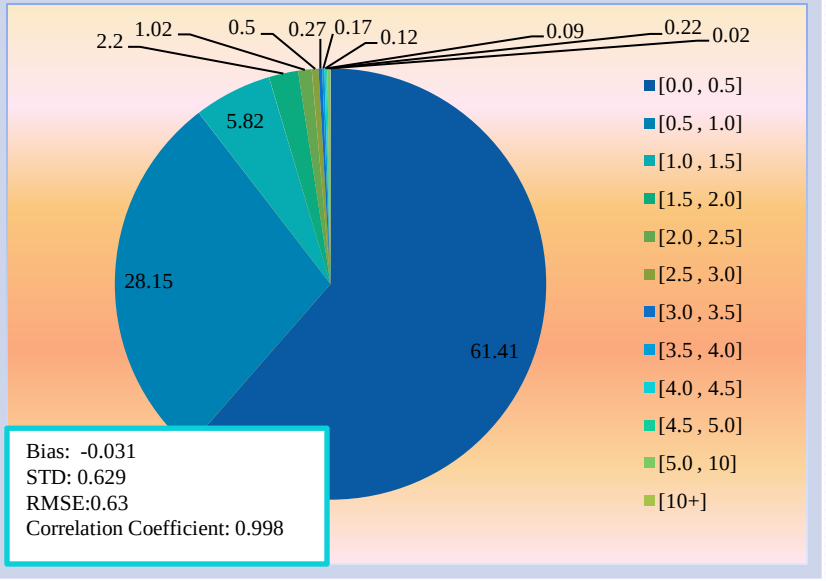


Figure 3. Difference of SWLST and DWLST : daytime(top) and nighttime(bottom) on Aug. 26, 2012

Evaluation over surface type

IGBP Land Type	Sample Size		STD(K)		BIAS(K)		RMSE(K)	
	Day	Night	Day	Night	Day	Night	Day	Night
Evergreen Needle Leaf Forests	120791	106054	0.53	0.45	-0.311	-0.085	0.614	0.458
Evergreen Broadleaf Forests	50442	129079	0.679	0.851	0.718	-0.205	0.989	0.876
Deciduous Needle leaf Forests	12368	4900	0.444	2.791	-0.381	-0.919	0.585	2.938
Deciduous Broadleaf Forests	25137	43351	1.544	0.839	-0.439	-0.004	1.605	0.839
Mixed Forests	110139	124088	0.417	1.487	-0.153	-0.102	0.445	1.491
Closed Shrub Lands	10497	13455	0.495	0.245	-0.474	0.106	0.685	0.267
Open Shrub Lands	520023	428612	0.579	0.484	-0.066	0.309	0.582	0.574
Woody Savannahs	128977	150433	0.738	0.877	-0.087	-0.358	0.743	0.947
Savannahs	102374	166008	0.669	0.437	-0.203	-0.063	0.699	0.442
Grasslands	213900	253770	0.384	0.569	-0.135	-0.116	0.407	0.58
Permanent Wetlands	3765	3125	0.716	1.642	-0.003	-0.245	0.716	1.66
Croplands	173351	230340	0.528	0.86	-0.151	-0.098	0.549	0.866
Urban Built-Up	10324	14193	0.554	1.253	-0.325	-0.102	0.642	1.257
Croplands/Natural Vegetation Mosaics	29726	58604	0.682	0.72	-0.171	-0.048	0.703	0.722
Snow ice	201485	96706	0.619	0.816	0.084	-0.211	0.625	0.842
Barren	365204	476154	0.487	0.333	0.286	0.508	0.565	0.608
Water Bodies	47530	54557	0.972	1.188	-0.407	-0.283	1.054	1.221

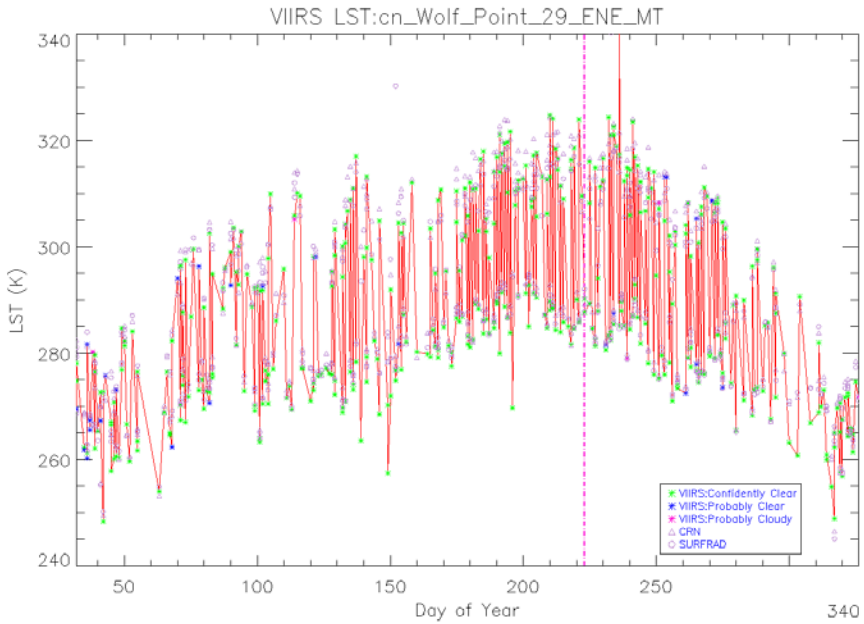
Near Real Time Monitoring*

- Near real time monitoring of VIIRS LST under different cloud conditions and surface types
- The monitoring starts from February 1, 2012 to present
- Two sites are selected including cn_Wolf_Point_29 in Montana with grass land type and cn_Mercury_3_SSW in Nevada with open shrub land type.
- CRN and SURFRAD ground truth data are used as reference for the monitoring

* Traditional in-situ data validation. For Pixel-station correction data validation, please refer to presentation by Pierre C. Guillevic titled "NPP VIIRS Land Surface Temperature EDR validation using NOAA's observation networks"

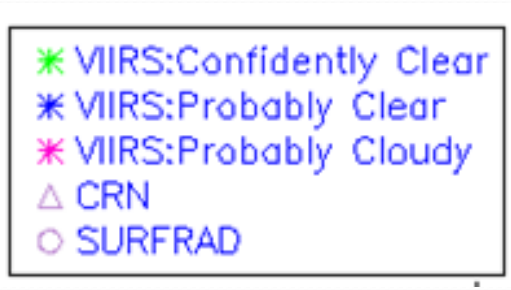
NASA LPEATE provided Site-matchup dataset

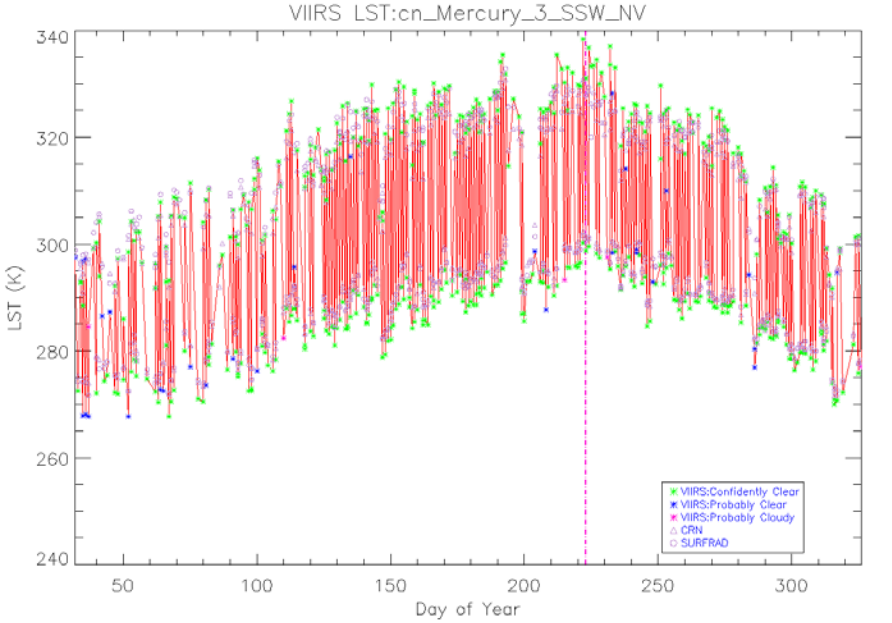
Near Real Time Monitoring



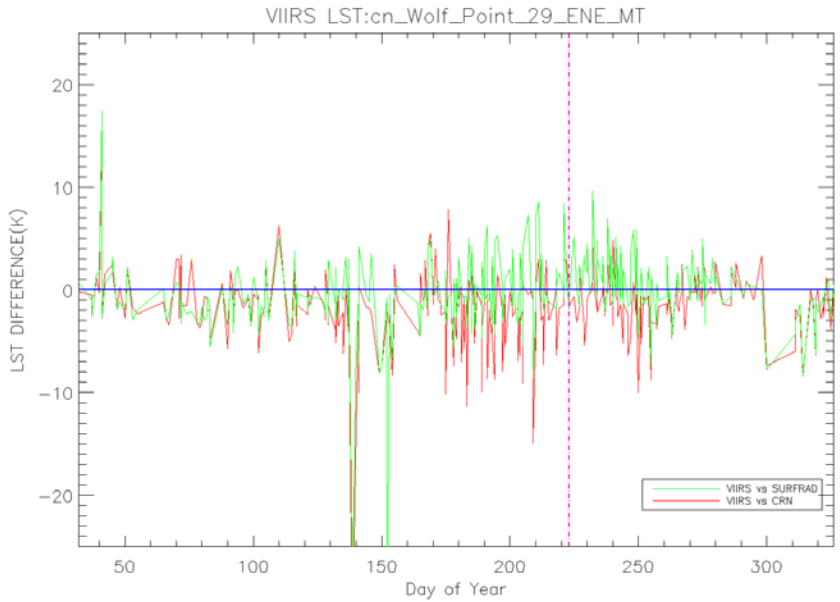
Sites: cn_Wolf_Point_29 (top-left), and cn_Mercury_3_SSW (bottom-right)

Day 32 ~ Day 221 —DWLST
Day 222 ~ Day 241 —SWLST
Day 242 ~ Day 262 —DWLST
Day 263 ~ present —SWLST



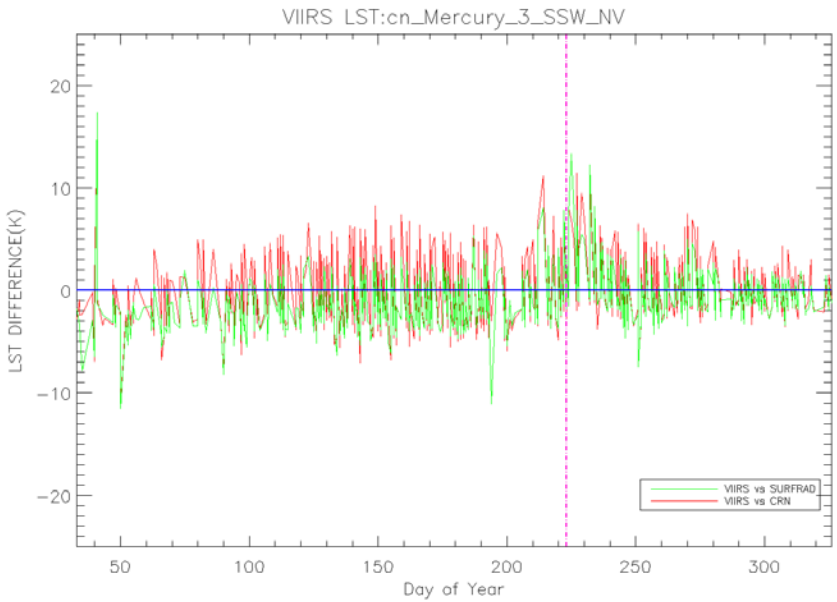


Near Real Time Monitoring



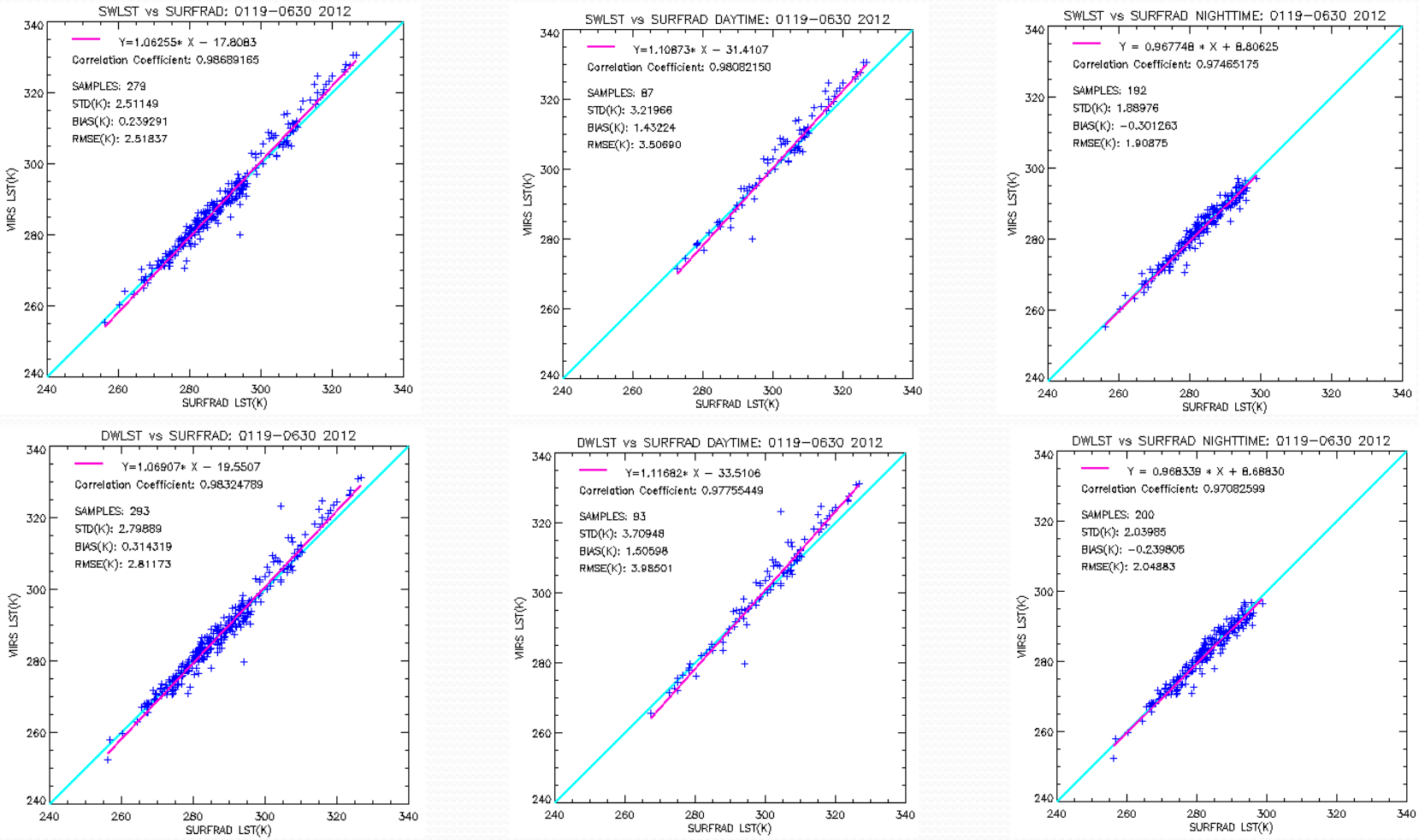
On-site monitoring of VIIRS LST vs. ground (SURFRAD and CRN) LST data

The ground-satellite LST difference is significant (impact of glint, large view angle, etc. not removed);
cloud impact observed;
Abnormal high LST observed;



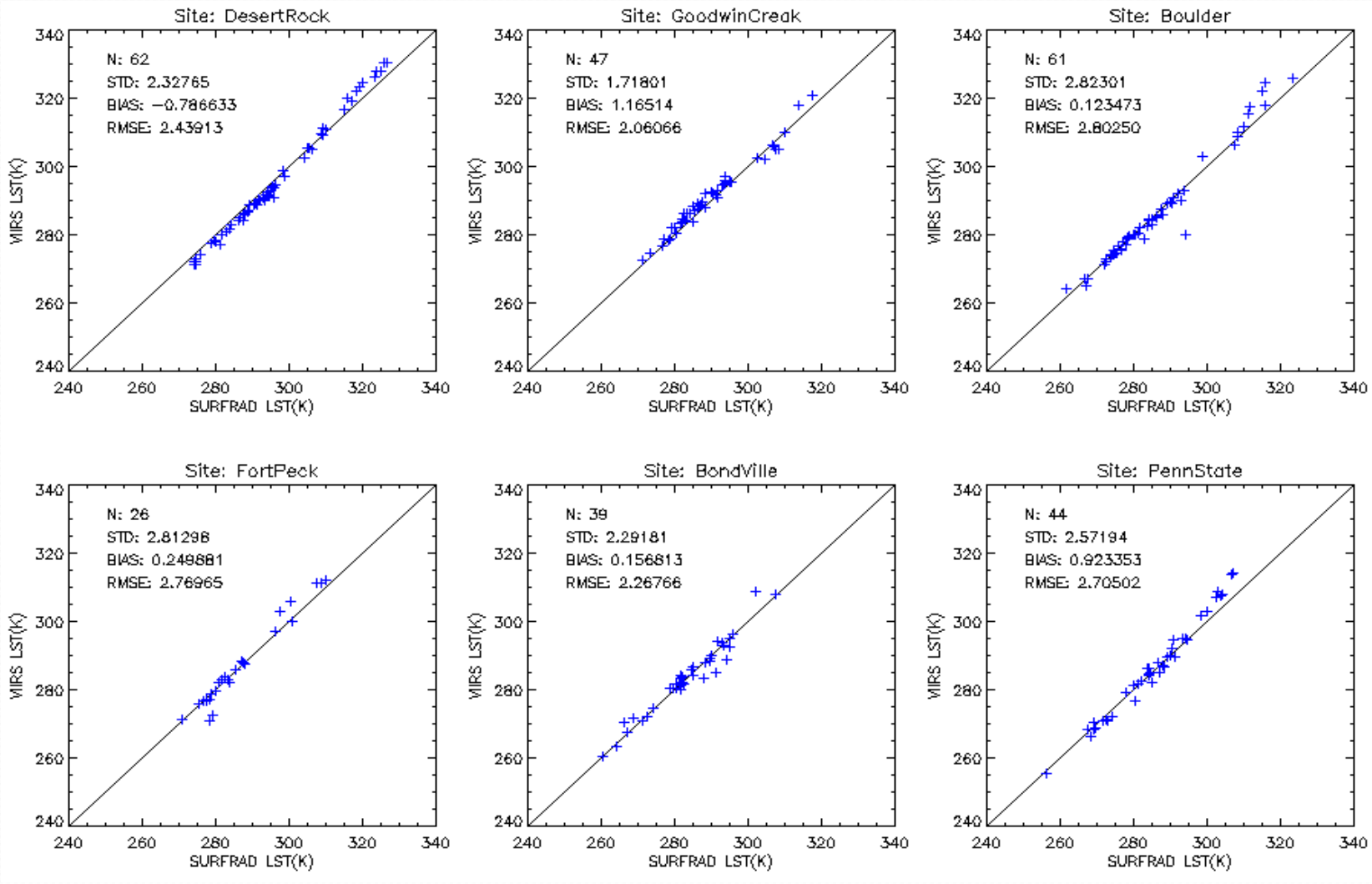
Evaluation against ground data

- SWLST and DWLST against SURFRAD



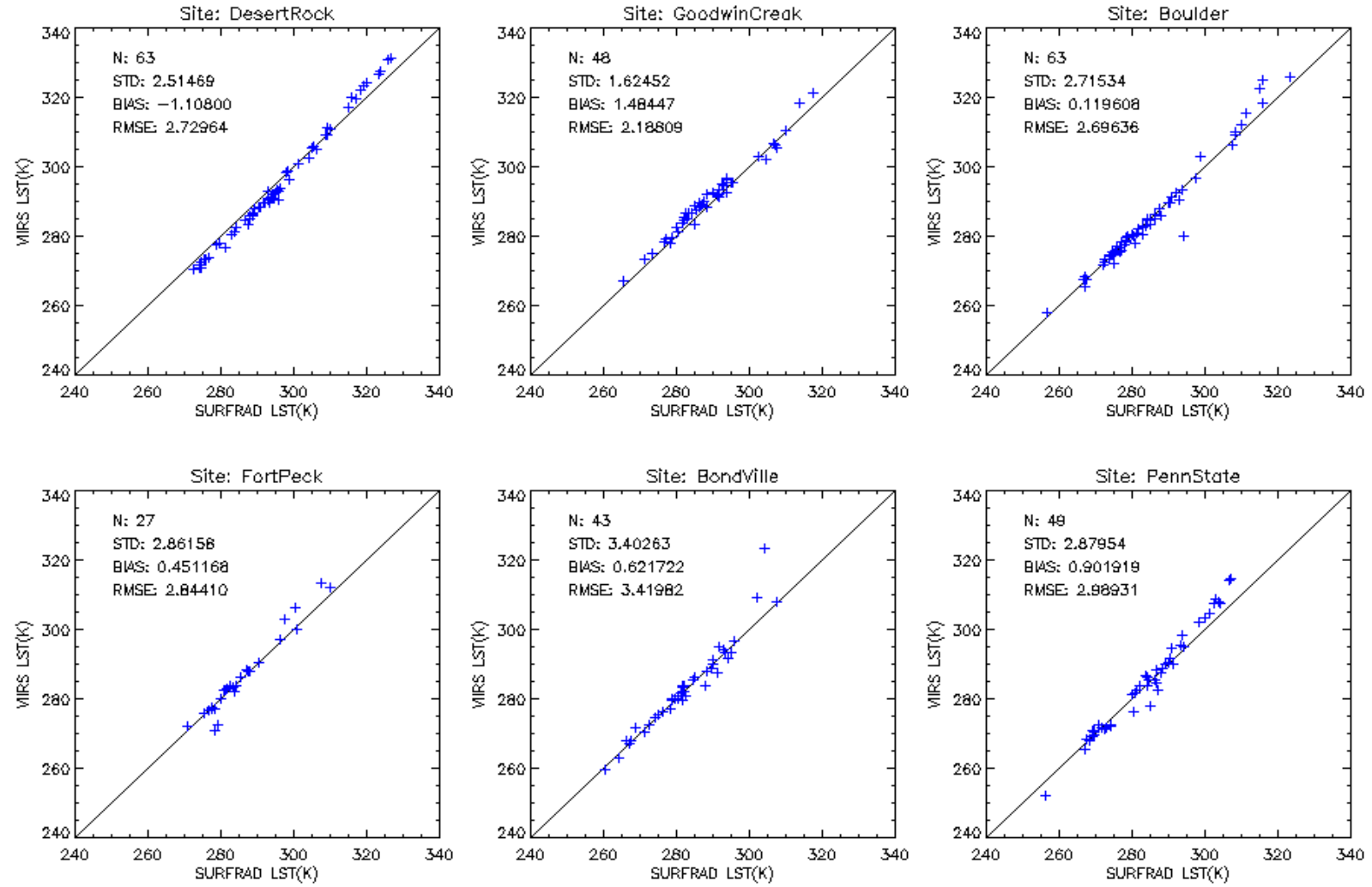
SWLST(top) and DWLST(bottom) against SURFRAD*: overall performance (left), daytime (middle) and nighttime performance (right)*

Ground site wide evaluation -SWLST



Site wide comparison of the SWLSTs and SURFRAD LSTs.

Ground site wide evaluation result-DWLST



Site wide comparison of the DWLSTs and SURFRAD LSTs.

Summary

- Overall, there is no significant difference of the LST patterns found between SWLST and DWLST. Over 90% records are within 1K difference.
- The surface type dependency of the two algorithms performance is significant.
  - The two algorithms perform similarly over evergreen needle leaf forests, closed shrub lands, open shrub lands, savannahs and barren at nighttime, over deciduous needle leaf forests, mixed forests, closed shrub lands, grasslands and barren at daytime.
  - The two algorithms perform significantly different over deciduous needle leaf forests, mixed forests, permanent wetlands, urban built-up, and water bodies at nighttime, over deciduous broadleaf forests at daytime.
- The evaluation results from ground data shows that the SW algorithm performs better than DWLST for whole day, daytime and nighttime.

Summary(Conti.)

- VIIRS LST nighttime performance exceeds the daytime performance for both algorithms.
- In daytime, both algorithms retrieve LST significantly higher than ground measurements with the bias about 1.5K. But In nighttime, both algorithms retrieve LST slightly lower than ground measurements with bias of -0.3K .
- The evaluation is performed with limited ground data(surface types)
- LST product has achieved the beta quality in December 2012 and it performs beyond the beta according to our continuous evaluation of the data quality.
- We will continue to monitor the LST data quality and make efforts to reach provisional maturity in May, 2013.