Suomi NPP VIIRS Land Surface Temperature Product Quality Assessment toward Validated Maturity

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Outline

- VIIRS LST product introduction
- VIIRS LST quality assessment
  - Temperature based validation
  - Radiance based validation
  - Cross satellite comparison
- Discussions and path forward

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 eachof the 17 IGBP surface types.

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

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(Day: <= 85 degree, Night: > 85 degree)

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

LST Processing Chain

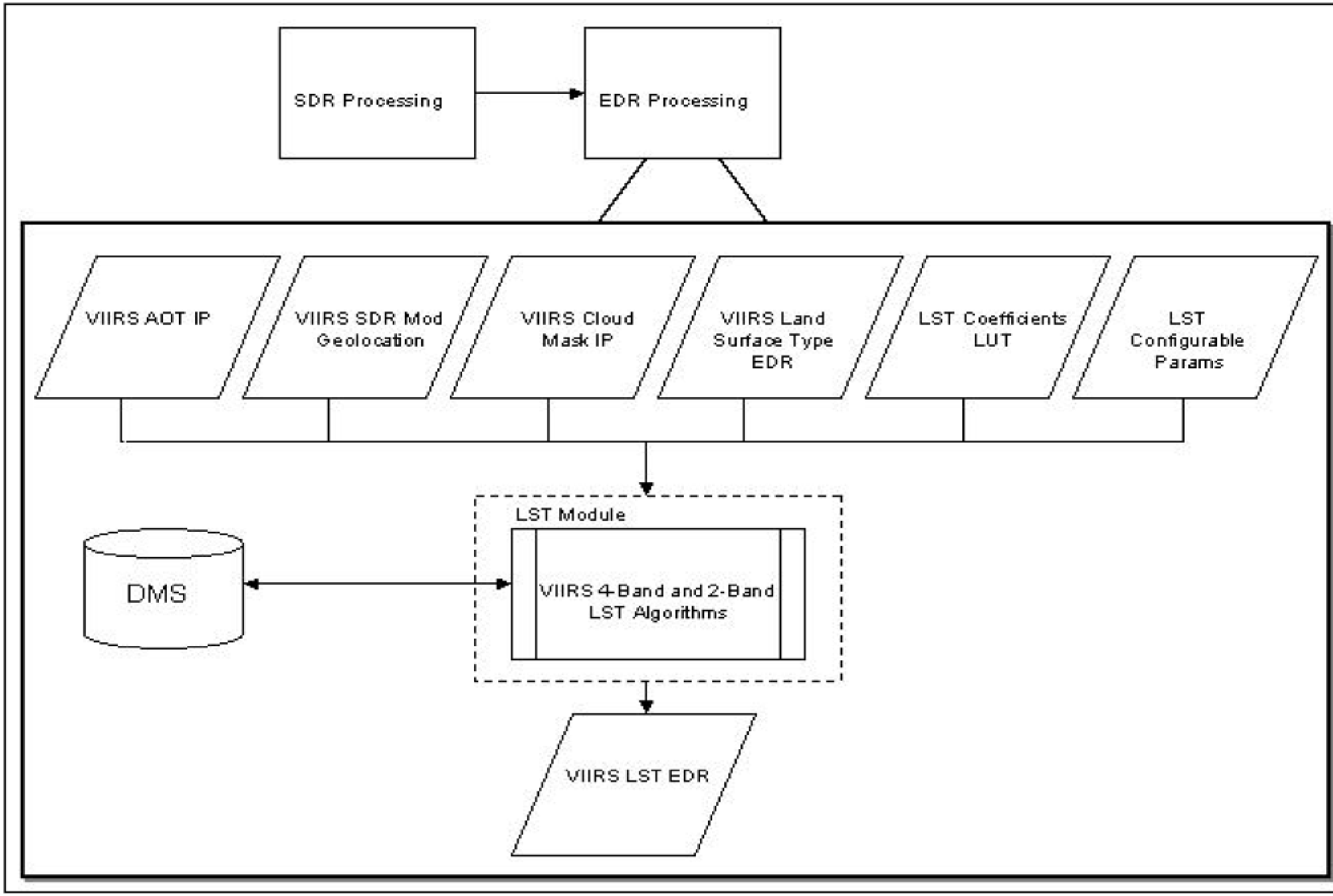


Figure 1. VIIRS LST OAD 474-00070 RevA 20120127

LST Retrieval Flow Chart

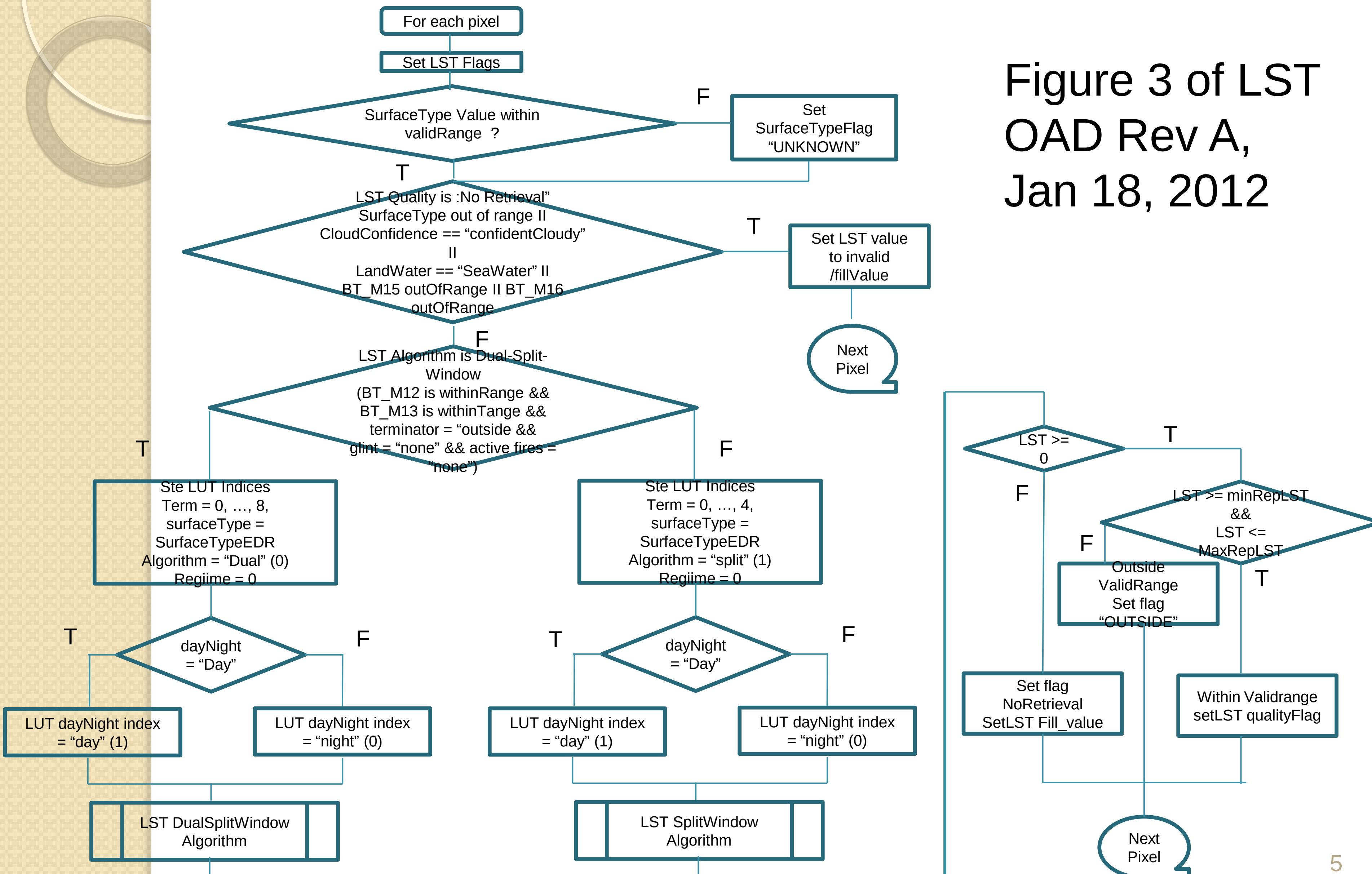


Figure 3 of LST OAD Rev A, Jan 18, 2012

Quality Analysis/Validation Approach

- Temperature based validation approach
  - SURFRAD
  - CRN
  - Africa data
- Radiance based validation approach
- Cross satellite comparison
  - MODIS Aqua LST

Match-up Procedure

- Ground data quality control
  - Two procedures are used for ground data quality control: one is the QC for upwelling and downwelling radiation and the other is the temporal test by checking the standard deviation of 30 minutes temporal box.
- Satellite data quality control
  - Two procedures are used in satellite data quality control: one is to control the cloud to be confidently clear only, the second is the spatial variation test. The STD of the 3*3 pixel BT 15 value, in this study the threshold is set as 1.5. High quality data is also checked in order to investigate the influence from the atmosphere condition.
- Match up process
  - Spatially closest pixel is used for the matchup and temporally match with the granule start time.

Ground LST Calculation-SURFRAD

$$T_s = ((R^{\uparrow} - (1-\varepsilon)R^{\downarrow}) / \sigma\varepsilon)^{1/4}$$

where

$R^{\uparrow}$ and $R^{\downarrow}$ are upwelling and downwelling long wave fluxes respectively,

ε is surface broadband emissivity,

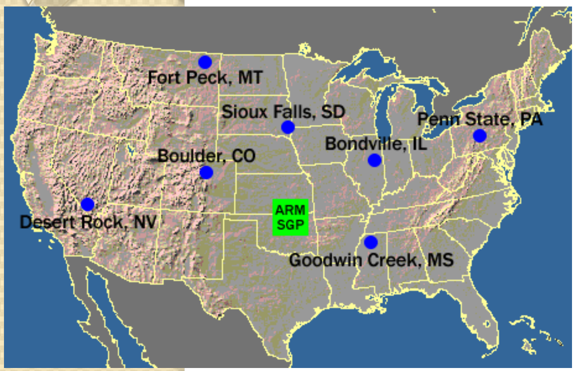
σ is Stefan-Boltzmann constant i.e. 5.67051 × 10-8 Wm-2K-4.

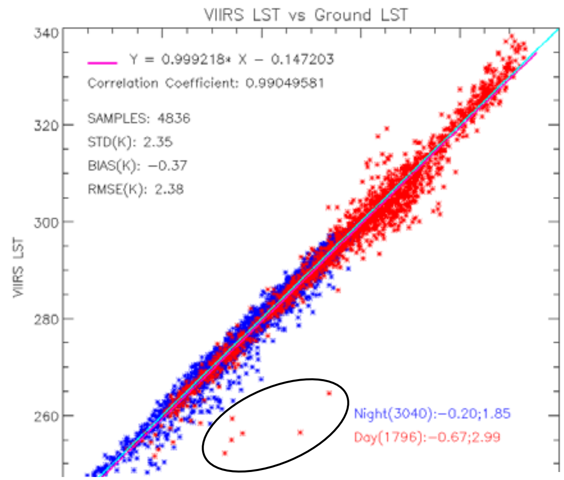
$$\varepsilon = 0.2122 * \varepsilon_{29} + 0.3859 * \varepsilon_{31} + 0.4029 * \varepsilon_{32}$$

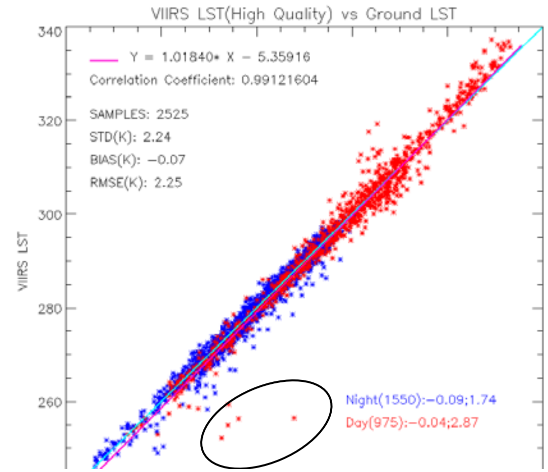
Where

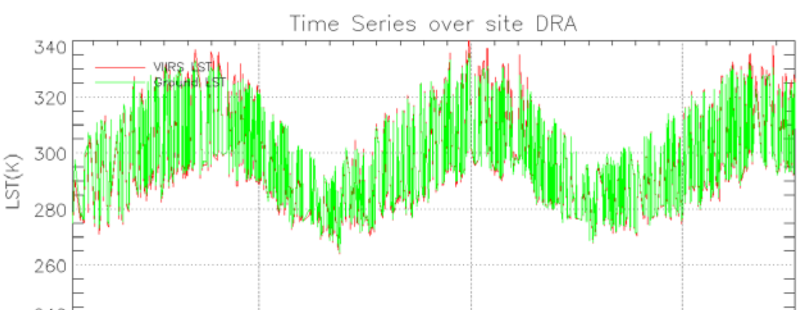
ε_{29}, ε_{31} and ε_{32} are narrowband emissivities at 8.3 µm ,10.8 µm and 12.1 µm

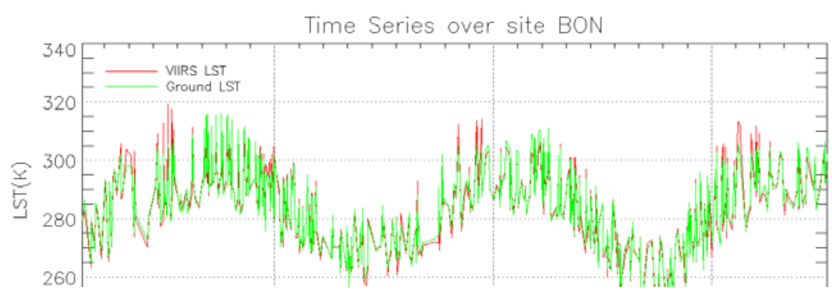
T-based Validation-SURFRAD

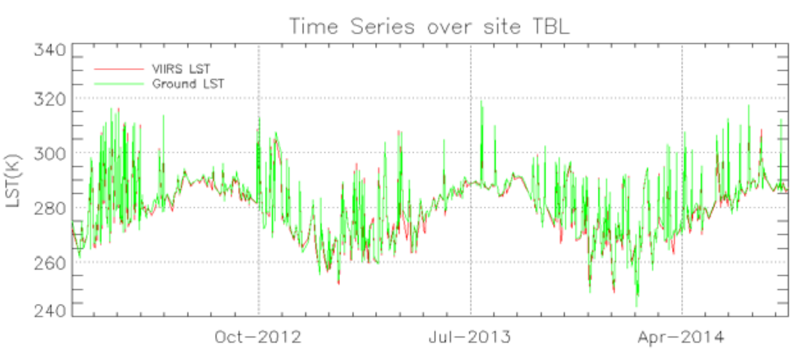


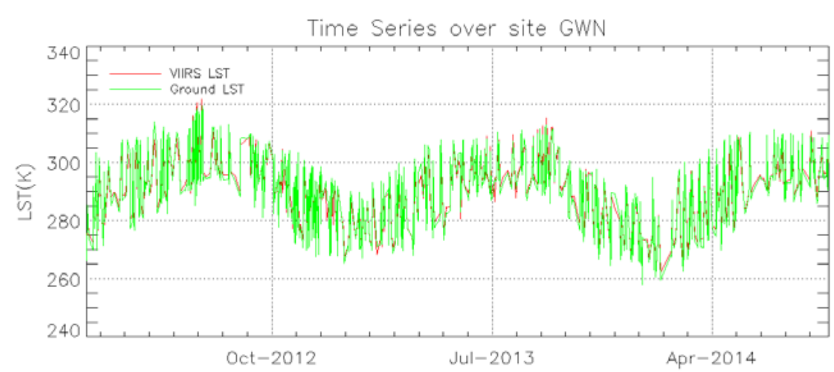










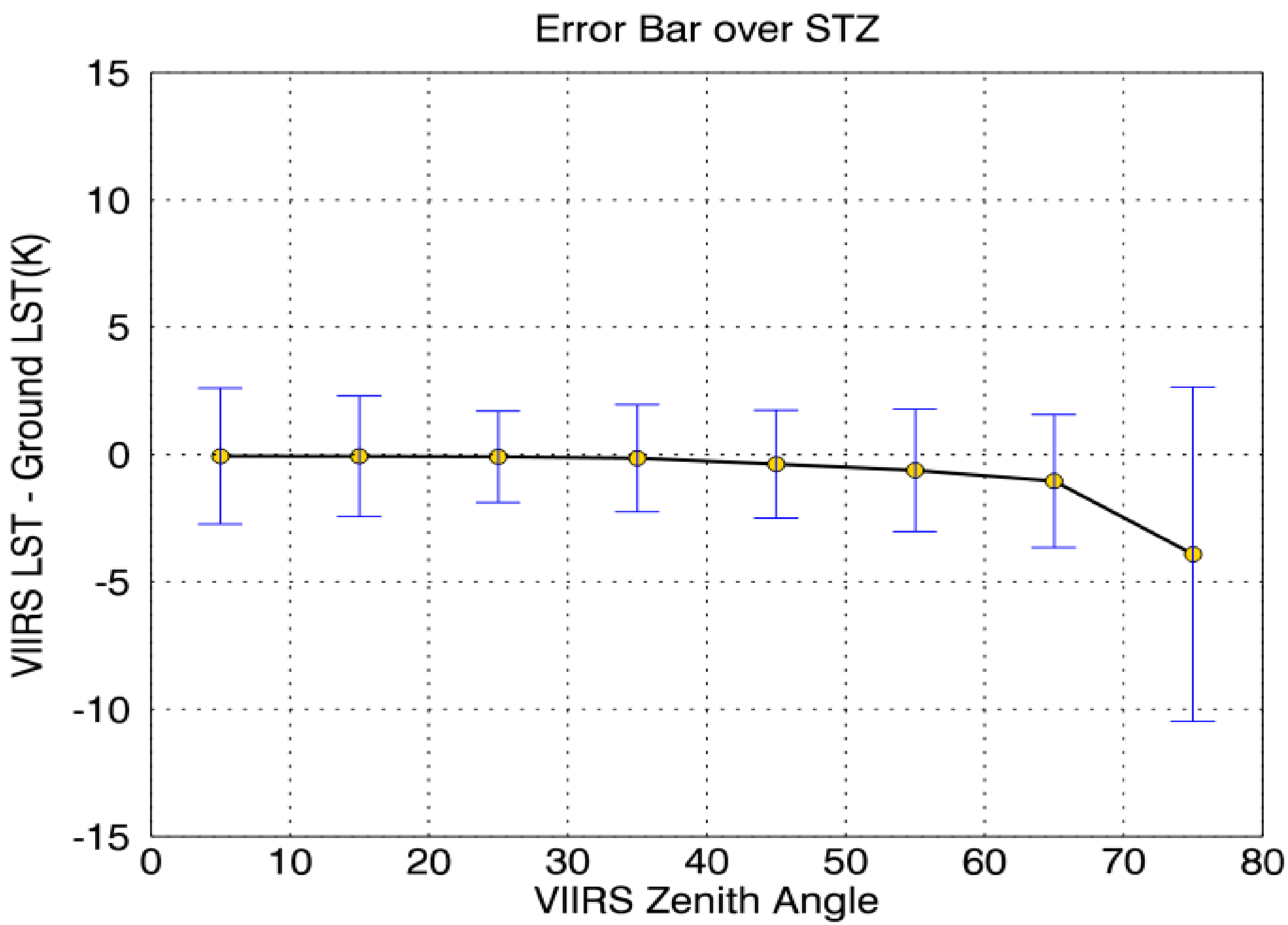


T-based Validation-SURFRAD

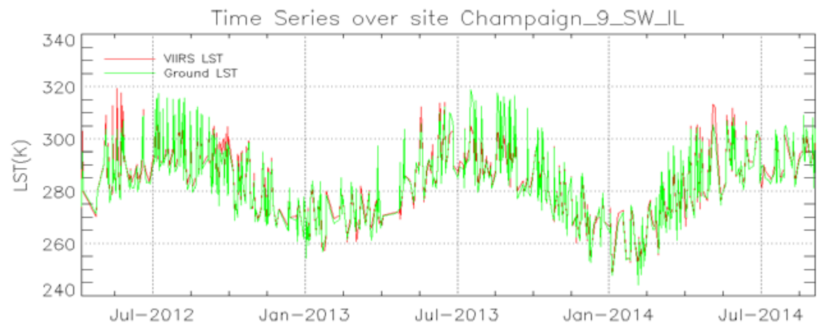
Season	Samples	Overall		Day		Night	
		Bias	STD	Bias	STD	Bias	STD
Spring	1297	-0.54	2.78	-0.69	3.82	-0.46	1.97
Summer	1403	-0.1	2.43	-0.87	3.68	0.26	1.39
Fall	1160	-0.28	1.9	-0.32	2.04	-0.24	1.79
Winter	976	-0.65	2.01	-0.83	1.65	-0.53	2.21

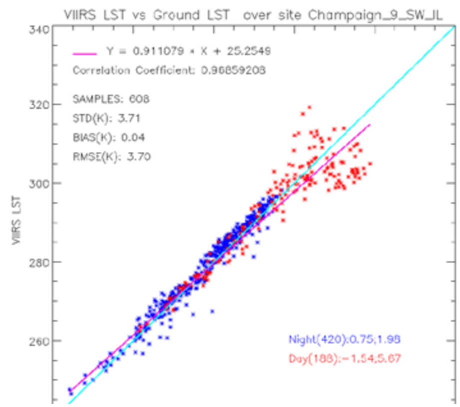
IGBP type	Samples	Overall		Day		Night	
		Bias	STD	Bias	STD	Bias	STD
4	18	-1.41	3.01	-1.82	2.66	-1.26	3.22
6	96	-0.98	1.41	-0.5	1.88	-1.32	0.84
7	955	-0.2	1.59	0.24	2.06	-0.61	0.79
8	286	0.19	2.56	-1.7	2.6	1.38	1.66
10	1048	-0.49	1.81	-0.85	2.3	-0.37	1.59
12	1238	-0.35	2.68	-0.63	3.8	-0.22	1.91
14	857	-0.28	2.54	-1.28	2.4	0.19	2.47
15*	189	-1.72	4.31			-1.72	4.31
16	149	-0.23	1.55	0.87	1.67	-1.04	0.75

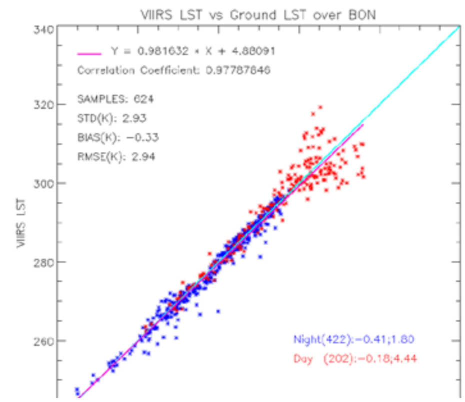
Error Budget over STZ

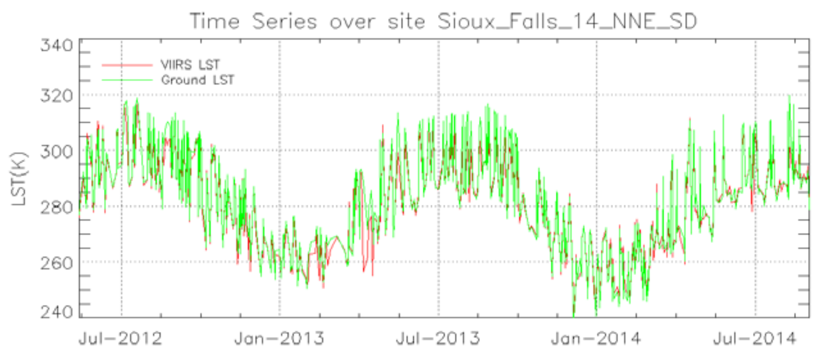


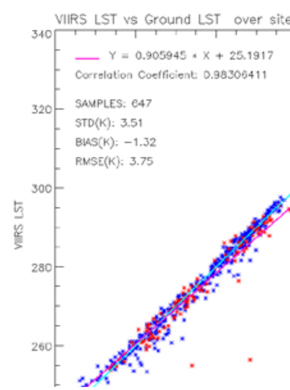
T-based Validation-CRN data



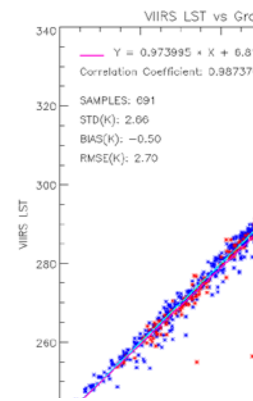




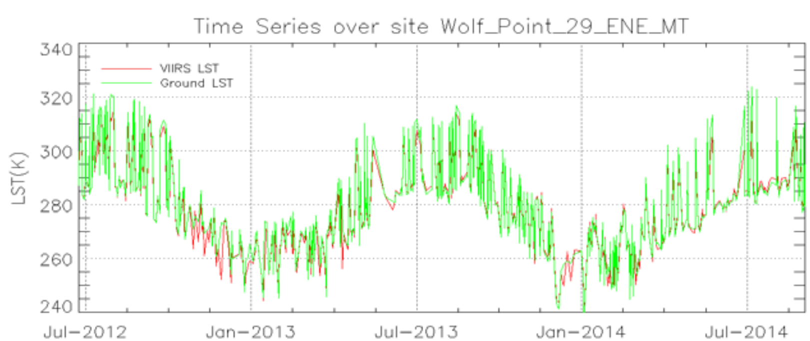


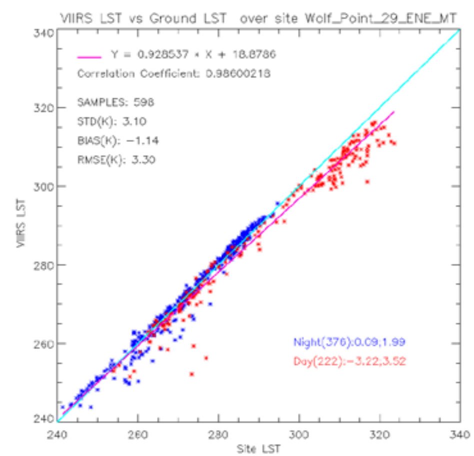


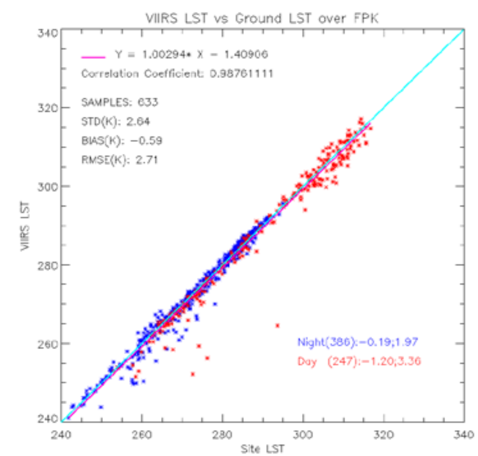
CRN



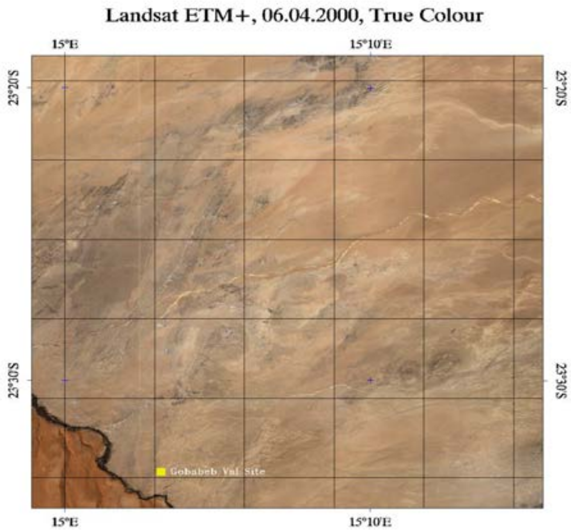
SURFRAD

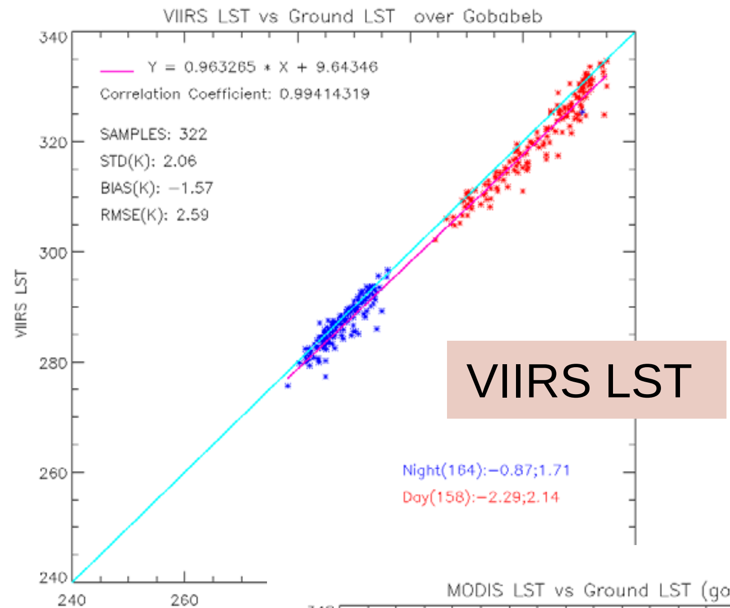


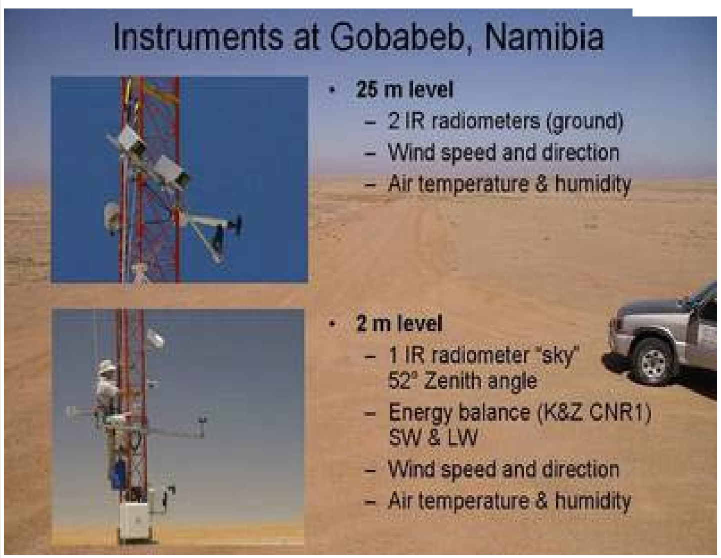


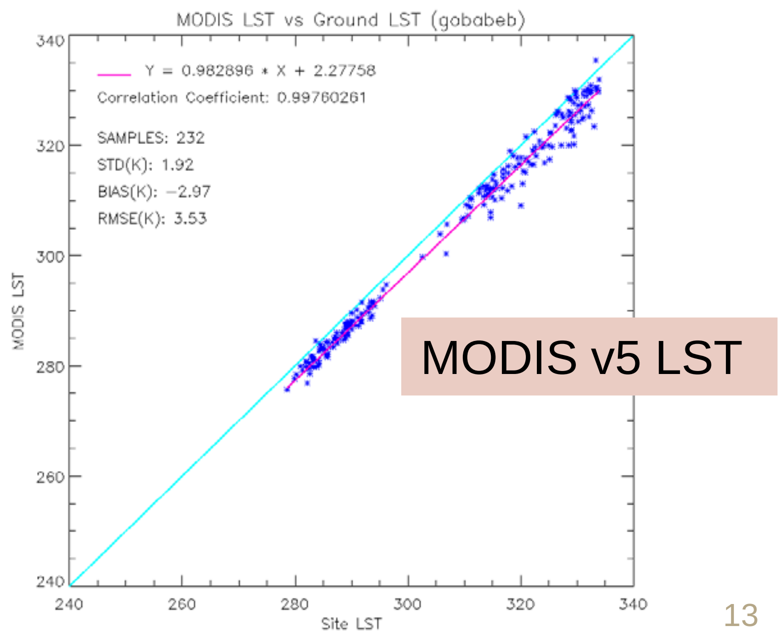


T-based Validation- Africa data









Radiance based validation

Validation Results over areas

Areas	Overall			Day			Night		
	Samples	Bias	STD	Samples	Bias	STD	Samples	Bias	STD
Algeria	850088	1.41	0.79	110433	0.22	0.56	739655	1.59	0.66
Australia	5164739	0.54	1.27	3021553	-0.18	1.05	2143186	1.56	0.72
Brazil	3436612	0.48	0.89	1002784	-0.32	0.94	2433828	0.81	0.61
China	1603865	0.83	0.91	528628	0.15	0.8	1075240	1.17	0.17
France	3014553	0.07	0.93	1530488	-0.53	0.91	1484065	0.70	0.39
Greenland	1059702	0.08	0.55	294543	0.62	0.50	765159	-0.13	0.41
Gobabeb	959981	0.52	1.53	595335	-0.5	0.75	364646	2.18	0.90
Indian	2482012	0.39	1.23	656915	-0.98	1.53	1825097	0.88	0.54
USA	3408392	0.43	1.17	1565562	-0.41	0.85	1842830	1.14	0.92

Results over surface type

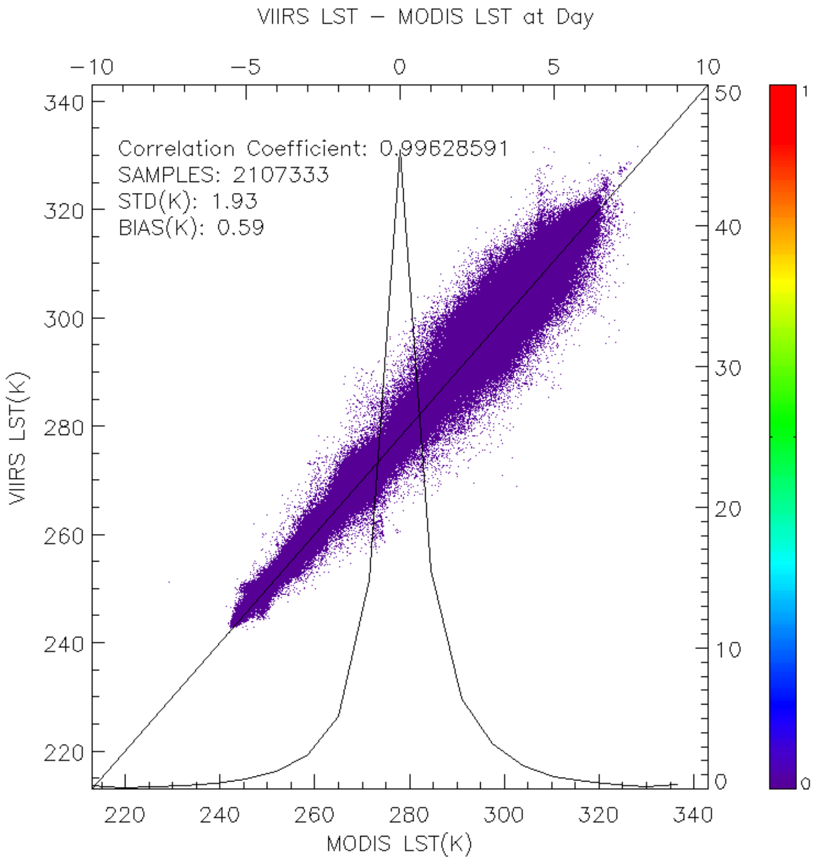
SurfaceType	Overall			Day			Night		
	Samples	Bias	STD	Samples	Bias	STD	Samples	Bias	STD
Evergreen Needleleaf Forests	216593	0.19	0.54	70324	-0.22	0.54	146269	0.38	0.41
Evergreen Broadleaf Forests	207839	-0.4	0.97	107698	-0.68	1.02	100141	-0.09	0.82
Deciduous Needleleaf Forest	13554	0.25	0.74	5932	-0.44	0.46	7622	0.78	0.42
Broadleaf Forests	385231	0.22	0.55	204843	-0.05	0.56	180388	0.54	0.32
Mixed Forests	597413	-0.02	0.8	359702	-0.42	0.76	237711	0.59	0.34
Closed Shrublands	92393	0.94	1.13	30537	-0.21	0.97	61856	1.5	0.69
Open Shrublands	5906708	0.72	1.29	3305495	-0.22	0.85	2601213	1.92	0.53
Woody Savannahs	917791	0.31	0.7	407793	-0.12	0.65	509998	0.66	0.52
Savannahs	3142202	0.48	0.81	1008898	-0.22	0.81	2133304	0.81	0.56
Grasslands	1124800	-0.07	1.42	517457	-1.2	1.25	607343	0.9	0.6
Permanent Wetlands	28282	0.02	0.54	4013	0.09	0.91	24269	0.01	0.45
Croplands	4072551	0.15	1.2	1491236	-1.02	1.21	2581315	0.82	0.44
Urban Built-Up	190876	0.27	0.52	89295	0.04	0.5	101581	0.47	0.45
Croplands/Natural Vegetation Mosiacs	1276644	0.31	0.56	543193	-0.08	0.45	733451	0.59	0.45
Snow Ice	1142843	0.04	0.51	336615	0.54	0.55	806228	-0.17	0.31
Barren	2389775	1.29	0.89	699333	0.54	0.75	1690442	1.6	0.75
Water Bodies	161468	-0.22	0.86	45826	-0.35	1.35	115642	-0.16	0.55

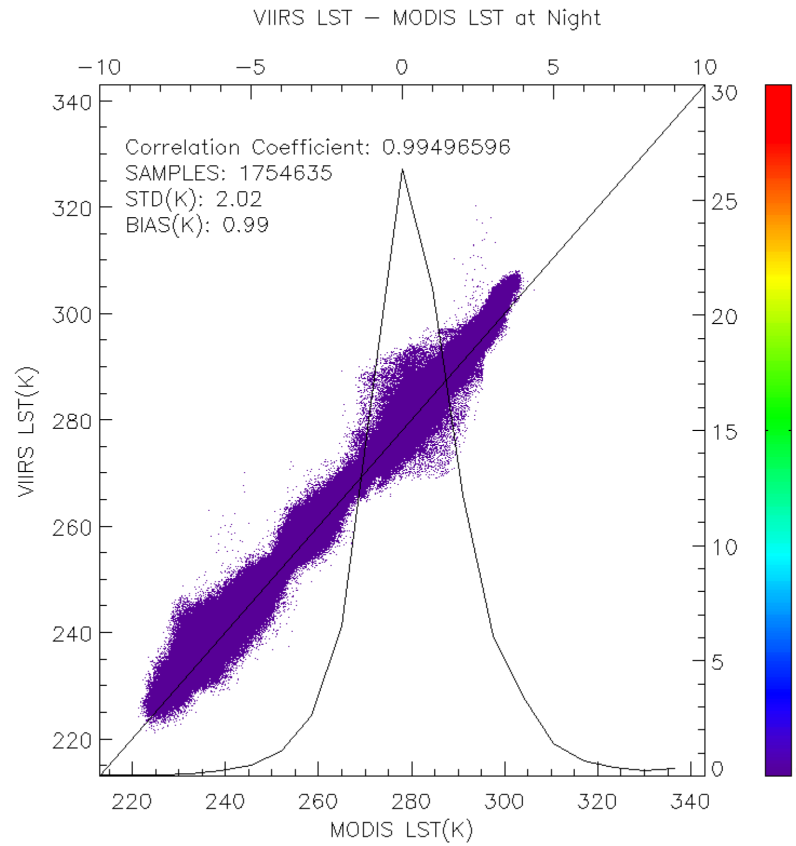
over temperature range

Temperature Range	Samples	Bias	STD	RMSE
220-230	12978	-0.05	0.18	0.19
230-240	355782	-0.08	0.28	0.29
240-250	622961	0.1	0.57	0.58
250-260	371442	0.54	0.56	0.78
260-270	303642	0.75	0.72	1.04
270-280	1648372	0.89	0.78	1.18
280-290	3732633	1.05	0.82	1.33
290-300	7990823	0.89	0.92	1.28
300-310	2173475	-0.52	1	1.13
310-320	2481185	-0.51	1	1.12
320-330	1578097	-0.22	1.26	1.28
330-340	465266	-0.01	1.28	1.28

Cross satellite comparison

Cross Satellite Comparison: VIIRS vs MODIS Aqua LST





Comparison results from Simultaneous Nadir Overpass (SNO) between VIIRS and AQUA in 2012 over US , Oct-Dec, 2013 over US, polar and low latitude. The matchups are quality controlled for both LST measurements.

Evaluation of the effect of algorithm inputs on LST

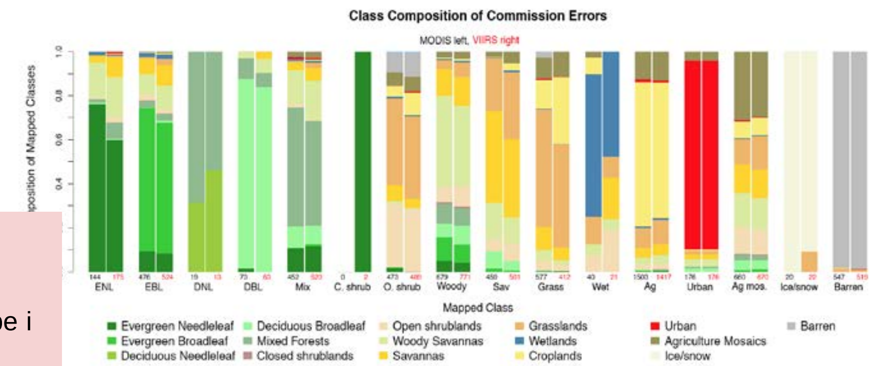
- Surface type

$$\Delta LST_i = \sum_{n=0}^{N} \sum_{j=1}^{17} (p_{ij}\varepsilon_{ijn})$$

ΔLST_i is the LST error of surface type i , separately for day and night condition

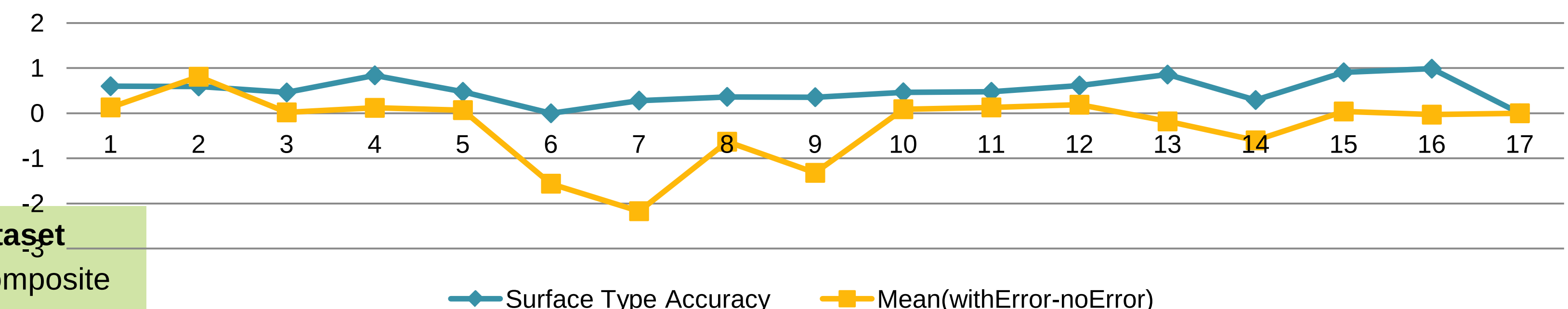
p_{ij} is the probability of mis-classfication of surface type i (i=1,2…17) to be j (j=1,2…17)

ε_{ijn} is the LST difference between LST calculated with the equation for surface type i and with the equation for surface type j for each pixel n with i surface type



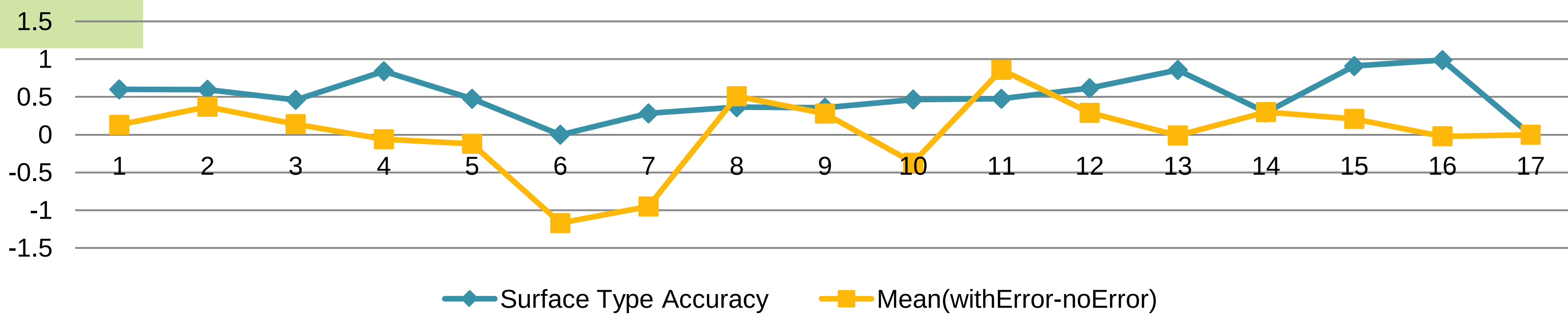
*Reference: Damien Sulla-Menashe, VIIRS ST V1 Quality Assessment April 02, 2014 EDR meeting

Surface Type Accuracy on LST(Day)



Test dataset
Global daily composite data on Nov. 20, 2013 for both daytime and nighttime

Surface Type Accuracy on LST(Night)



Summary

- Temperature based validation:
  - VIIRS LST agrees well with the ground measurements with an accuracy of -0.57 and precision of 2.35 for all angle measurements but the performance varies over day/night condition and surface types. Nighttime performance is better than that at daytime.
  - VIIRS LST demonstrates an obvious seasonal feature, a better performance achieved in fall and winter comparing that in spring and summer.
  - The validation results from the comparison of collocated ground site from SURFRAD and CRN suggest a difference in ground LST measurements. In addition, the comparison shows a regional difference over the same surface, i.e. DRA and Gobabeb site.
- Radiance based validation presents an overall good agreement between radiance calculated LST and satellite retrieved LST and the discrepancies vary over region, day/night and surface types. comparison results present a regional difference, the bias is from 0.07 to 1.41 with an average of 0.52 and STD is from 0.55 t 1.53 with an average of 1.03.
- Cross satellite comparison shows that VIIRS LST and MODIS LST are overall consistent to each other. But note that all SNO used in this study is limited within polar area, low latitude area and US.
- The input data particularly surface type input and cloud mask have a significant impact on VIIRS LST quality.