Evaluation of the SNPP VIIRS Land Surface Temperature Product: Provisional Maturity

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Introduction

VIIRS LST EDR, the measurement of the skin temperature over global land coverage including coastal and inland-water, is derived utilizing the split-window technique. The regression based algorithm coefficients are surface type dependent, referring 17 International Geosphere-Biosphere Programme (IGBP) types. Since January 19th, 2012, VIIRS LST data has been generated at pixel level with 750m moderate spatial resolution at nadir.

VIIRS LST maturity has transitioned from beta to provisional status and the LST data calculated with the updated LUT is available in NOAA's Comprehensive Large Array-data Stewardship System (CLASS) archive since April 07, 2014. A lot of efforts have been devoted to the validation of the beta version LST and this study presents an evaluation of the provisional LST and addresses some issues in the algorithm development. The evaluation is mainly carried out using the conventional temperature-based approach by comparisons between the VIIRS LSTs and in-situ LSTs, and cross satellite comparison with MODIS LST.

The evaluation results suggest that the VIIRS LST EDR meets the provisional maturity criteria but the performance varies over surface types and day/night conditions. VIIRS LST agrees well with ground LST measurements and achieves comparable accuracy with MODIS LST over SURFRAD sites. Improvements are needed over open shrub land, snow/ice, barren surface and cropland surface. The cross satellite comparisons are mostly over Simultaneous Nadir Overpasses (SNO) between VIIRS and Aqua and the results show an overall close agreement between VIIRS and MODIS LST. However, we do observe some discrepancies between VIIRS LST and MODIS LST under some specific conditions, e.g., over Australia under circumstances of significant brightness temperature (BT) difference between the two split window channels, which is not observed in the ground evaluations. Although the BT difference correction has been applied to provisional LST and the impact of high BT difference on LST retrieval has been reduced compared to beta LST, VIIRS LST is degraded under this special situation. The possible causes of the LST degradation include: a very wide range of BT differences (can reach 16K over Australia, under hot and humid atmospheric condition with high water vapor content, or significant emissivity difference between the two split channels); limitations of the regression method and the radiative transfer simulation database being regressed; the VIIRS LST algorithm form, i.e., quadratic term of the BT difference. Efforts are made toward the investigation of the impacts of water vapor, emissivity, and sensor view angles on the LST retrieval, which will direct our focus on the further algorithm improvement.

VIIRS LST EDR Algorithm

❖ Baseline Split window algorithm

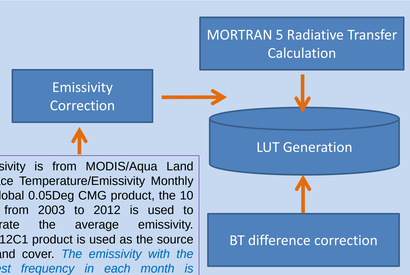
Establish the 2-band 10.76μm(M15) and 12.01μm(M16) split window algorithm for both day and night based on regression equation for each of the 17 IGBP surface types.

$$LST_{i,j} = a_0(i,j) + a_1(i,j)T_{15} + a_2(i,j)(T_{15} - T_{16}) + a_3(i,j)(\sec\theta - 1) + a_4(i,j)(T_{15} - T_{16})^2$$

Where

$a_k(i,j)$ (with k=0 to 4) depending on surface type (with i =0 to 16 for 17 IGBP surface types) and day/night condition (with j=0 to 1), are coefficients and θ is satellite viewing zenith angle.

VIIRS LST EDR Calibration



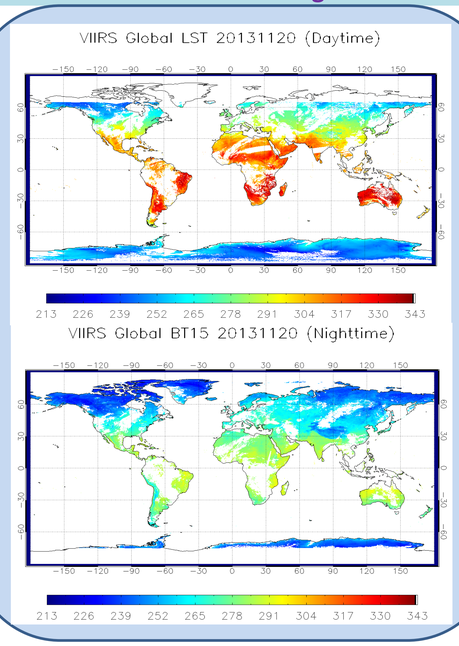
Emissivity is from MODIS/Aqua Land Surface Temperature/Emissivity Monthly L3 Global 0.05Deg CMG product, the 10 year from 2003 to 2012 is used to generate the average emissivity. MCD12C1 product is used as the source for land cover. *The emissivity with the highest frequency in each month is selected to represent the emissivity for each surface type.*

Improvement for LST EDR is based on update of algorithm coefficients. Two steps of calibration:

1. *calibration from the radiance based simulation*
2. *Emissivity correction and BT difference correction*

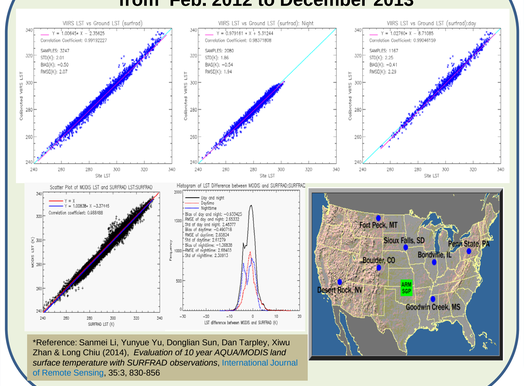
Flow chart of LST calibration

Global LST Image



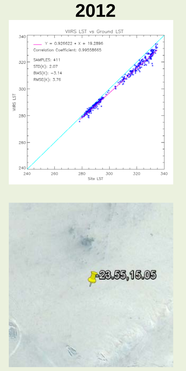
Ground Evaluation

The Surface Radiation Budget Network(SURFRAD): from Feb. 2012 to December 2013



*Reference: Sanmei Li, Yunyue Yu, Donglian Sun, Dan Tarpley, Xiwu Zhan & Long Chiu (2014). *Evaluation of 10 year AQUA/MODIS land surface temperature with SURFRAD observations*, International Journal of Remote Sensing, 35:3, 830-856

Gobabeb in Namibia*: 2012



* The data is provided by Frank Goettsche, Thanks Pierre for sharing the data.

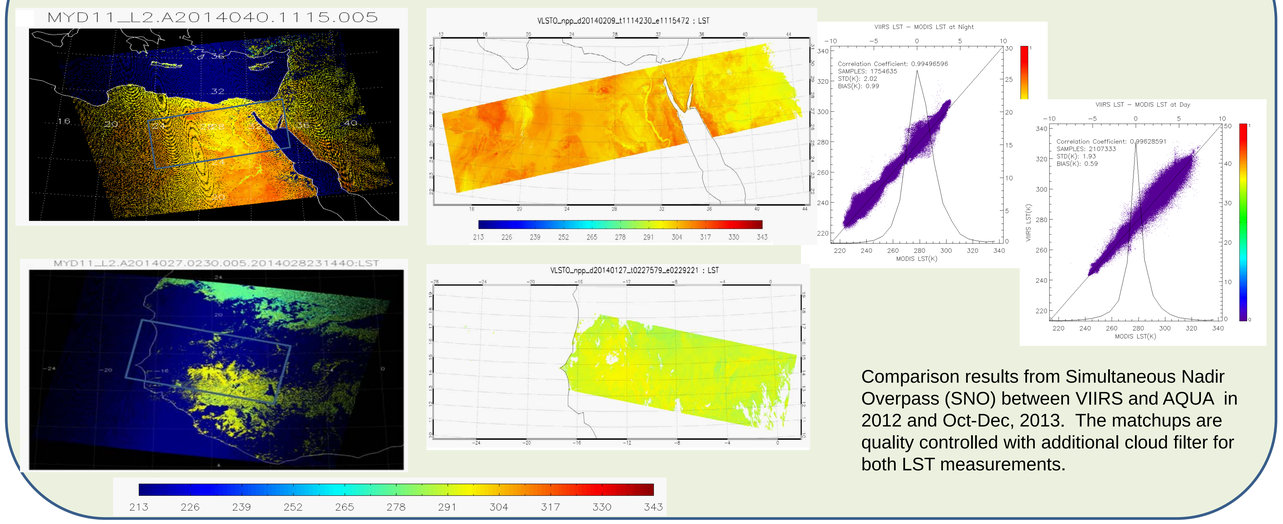
LST performance over surface types and day/night conditions (SURFRAD)

Surface type	Day/night	Samples	Provisional LST		Beta LST	
			Bias	STD	Bias	STD
Deciduous Broadleaf Forest	day	4	-0.67	0.80	0.31	3.10
	night	11	-0.13	1.60	-0.13	1.60
Closed Shrub lands	day	37	-0.81	1.77	-1.16	1.77
	night	57	-1.37	0.80	-2.48	0.63
Open Shrub lands	day	277	-0.1	1.90	0.67	1.90
	night	327	-0.88	0.79	-2.38	0.79
Woody Savannas	day	46	-1.09	2.39	-0.34	2.81
	night	81	1.38	1.35	1.38	1.35
Grasslands	day	172	-0.38	1.90	1.11	2.36
	night	500	-0.35	1.41	-0.35	1.41
Croplands	day	266	0.14	2.95	2.39	3.54
	night	558	-0.21	1.58	-0.21	1.58
Cropland/Natural Vegetation Mosaics	day	208	-0.83	1.98	0.13	2.15
	night	459	0.47	1.94	0.47	1.94
Snow/ice	day	97	-1.16	1.67	-1.95	1.70
	night					
Barren	day	60	0.72	1.68	0.12	2.10
	night	87	-1.17	0.88	-2.67	0.88

Cross Satellite Evaluation

MYD11_L2, MODIS/Aqua Land Surface Temperature 5-Minute L2 Swath at 1 km is used as a reference for the cross satellite evaluation.

North east Africa on Feb. 09,2014 : daytime (top) and North west Africa at nighttime on Jan. 27,2014(bottom):



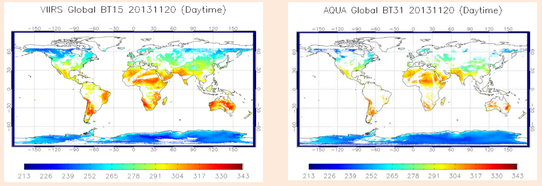
Comparison results from Simultaneous Nadir Overpass (SNO) between VIIRS and AQUA in 2012 and Oct-Dec, 2013. The matchups are quality controlled with additional cloud filter for both LST measurements.

Issues

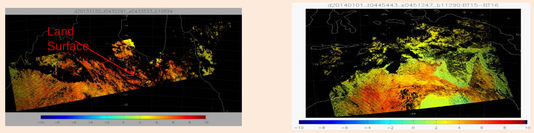
•Cross satellite comparisons at regional and global scale

-Temporal difference: BT change

- Composite process



• BT difference over land and sea water



• Causes of the LST degradation

- Very wide range of BT difference for some surface types at global distribution. The BT difference can reach 16K over Australia under hot and humid atmospheric condition
- Limitations of the regression method and the radiative transfer simulation database being regressed
- VIIRS LST algorithm form, i.e. quadratic term of BT difference

• Surface type accuracy on LST performance: a case study

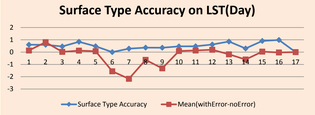
$$\Delta LST_i = \sum_{n=0}^{N} \sum_{j=1}^{17} (p_{ij}\varepsilon_{ijn})$$

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

Surface Type Accuracy on LST(Day)



Surface Type Accuracy on LST(Night)

Emissivity impact to surface type dependent LST retrieval

- seasonal variation of some surface types
- Emissivity variation within cover types
- Appropriate emissivity setting s for all surface types in building up the database for regression

Summary and Future Work

- VIIRS LST shows a good overall agreement with ground LST measurements, with a better performance achieved at nighttime than at daytime. However, the performance varies with surface type. LST is underestimated over closed shrub lands at both daytime and nighttime, open shrub lands and barren surface at nighttime, woody savannas and snow/ice surface at daytime. The evaluation results over barren surface at daytime conflict with the results obtained using measurements in Africa, the latter showing an obvious underestimation of VIIRS LST both at daytime and nighttime. Possible explanations for this apparent inconsistency include homogeneity of the site, ground in-situ quality control, emissivity used to calculate the ground LST and regional atmospheric condition that might affect LST retrieval.
- VIIRS LST is in close overall agreement with MODIS LST. Disagreements are shown over areas with large brightness temperature difference between the two retrieval channels, and these disagreements are reduced after calibration. However VIIRS LST is degraded under this special situation.
- Several issues need to be well addressed in the algorithm development. Since VIRIS LST algorithm is a surface type dependent algorithm, it underperforms over surface types that vary seasonally (which is not reflected in the surface type EDR), and misclassified surface types particularly if the misclassification happens between two surface types with distinct emission features. The appropriate emissivity setting for all IGBP surface types is very important for the simulation. The large variation of emissivity over surface types makes it difficult to determine the representative emissivity setting for each IGBP surface type and the uncertainty from the emissivity and land cover type product also introduce error into the procedure.