# VIIRS LST Validation with Ground Based Measurements

Yuling Liu[12], Yunyue Yu[1] , Peng Yu[12], Heshun Wang [12]

[1]STAR/NESDIS/NOAA; [2]CICS/ESSIC, University of Maryland, College Park

## Introduction

The focus of this study is on the validation of the V1 VIIRS LST product, which has been released to public since December, 2014 with a newly implemented algorithm coefficient set, using ground in-situ observations in US SURFRAD, ARM and Africa. In comparison with US SURFRAD observations, VIIRS LST presents an accuracy of -0.41 K and precision of 2.35 K over all seven sites and three years observations with a better accuracy and precision of -0.20 K and 1.85 K at nighttime, compared to that at daytime of -0.67 K and 2.99 K, respectively. Two ARM sites in Southern Great Plains (SGP), OK and Darwin, Australia (TWP_Darwin) are selected and the results indicate an accuracy of 0.19 K and -0.95 K, precision of 2.13 K and 1.87 K, respectively. The result over arid regions in Africa suggests that VIIRS underestimates the LST about 1.57 K. The validation result is analyzed over sites, seasons, day/night condition as well as surface types. In addition, the same data set is used to validate the heritage LST products from MODIS Aqua and AATSR, as a reference for cross satellite comparison. Some issues have been found and can be summarized as: (1) Cloud contamination, particularly the cloud detection error over snow/ice surface, shows significant impacts on LST validation; (2) Performance of the VIIRS LST is strongly dependent on a correct classification of the surface type.

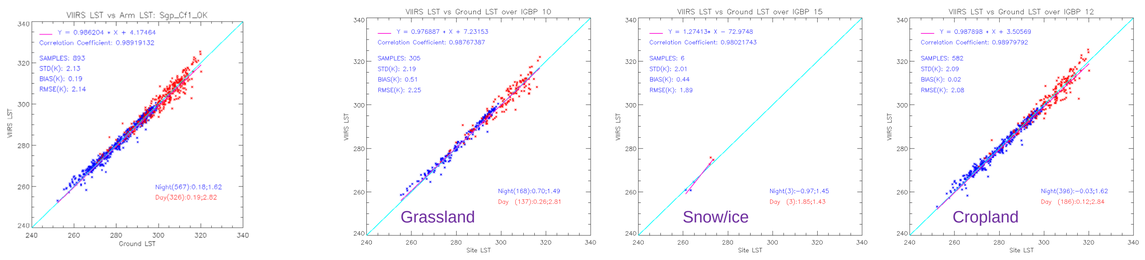
## VIIRS LST Algorithm

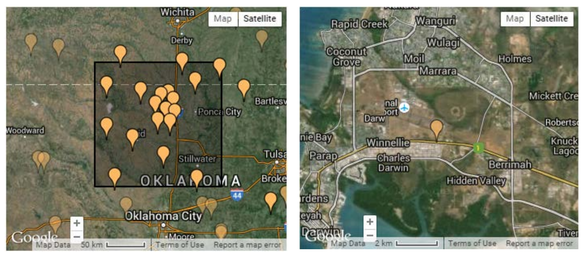
Establish the 2-band 10.76µm(M15) and 12.01µm(M16) split window algorithm for both day and night based on regression equation for each of the 17 IGBP surface types.

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

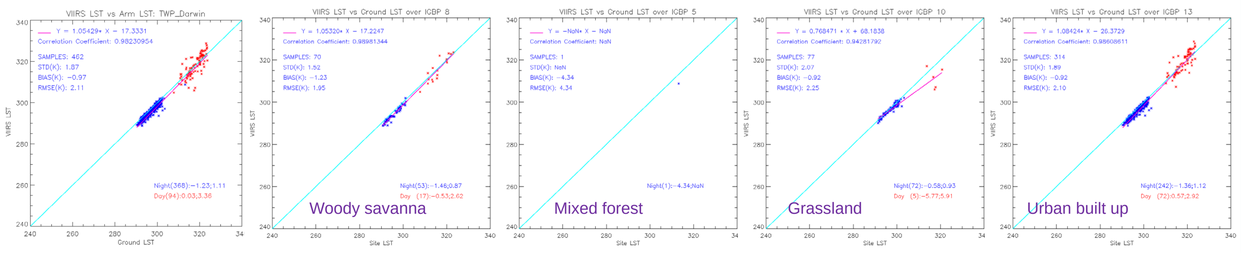
Where $a_k(i,j)$ (with k=0 to 4) are coefficients depending on surface type (with i =0 to 16 for 17 IGBP surface types) and day/night condition (with j=0 to 1), and θ is satellite viewing zenith angle.

## ARM Measurements

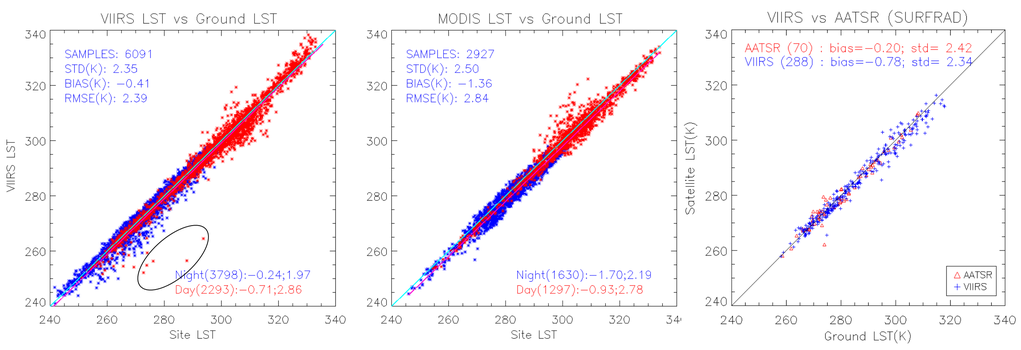


| Site | Season | Sample Count | Bias | STD |
|---|---|---|---|---|
| SGP_CF_OK | Spring | 232 | 0.04 | 2.03 |
| | Summer | 262 | 0.02 | 2.43 |
| | Fall | 204 | 0.35 | 2.04 |
| | Winter | 195 | 0.42 | 1.89 |
| TWP_Darwin | Spring | 149 | -0.77 | 2.13 |
| | Summer | 18 | 0.37 | 3.67 |
| | Fall | 80 | -1.08 | 2.00 |
| | Winter | 215 | -1.19 | 1.28 |



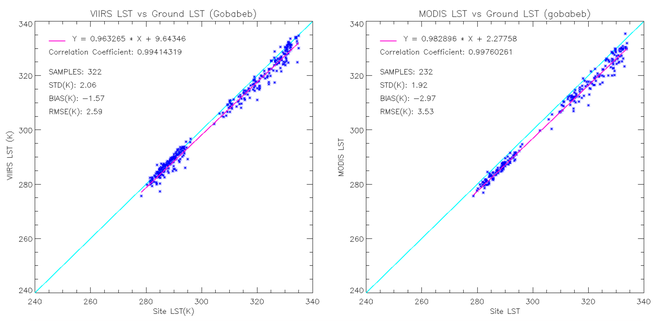

## SURFRAD Measurements

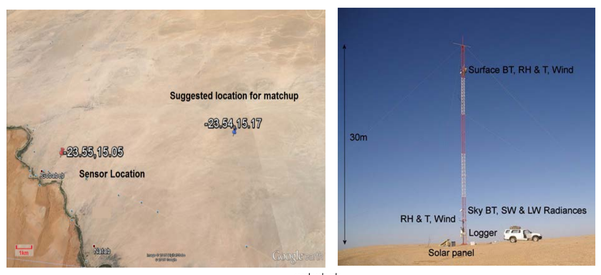


Corresponding matchups for VIIRS ,MODIS Aqua and AATSR:
Time span: Feb. 2012 – Apr. 2015 (VIIRS and MODIS); Feb.1-Apr.8, 2012(AATSR)

| Season | Samples | Overall | | Day | | Night | |
|---|---|---|---|---|---|---|---|
| | | Bias | STD | Bias | STD | Bias | STD |
| Spring | 1549 | -0.57 | 2.55 | -0.58 | 3.16 | -0.56 | 2.13 |
| Summer | 1433 | -0.12 | 2.46 | -0.90 | 3.70 | 0.26 | 1.40 |
| Fall | 1734 | -0.23 | 1.82 | -0.46 | 1.97 | -0.07 | 1.70 |
| Winter | 1372 | -0.72 | 2.21 | -0.85 | 1.80 | -0.63 | 2.44 |

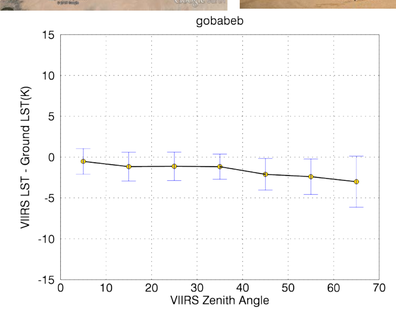
## Ground Measurements in Gobabeb, Africa




Corresponding matchups for VIIRS and MODIS Aqua:
Time span: Jan. 2012 – Dec. 2012

| Site | Season | Sample Count | Bias | STD |
|---|---|---|---|---|
| Gobabeb | Spring | 118 | -1.35 | 1.89 |
| | Summer | 70 | -1.83 | 2.59 |
| | Fall | 58 | -1.76 | 2.37 |
| | Winter | 89 | -1.44 | 1.73 |

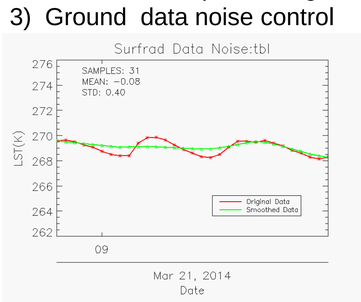



| Site | Surface type | Samples | Overall | | Nighttime | | daytime | |
|---|---|---|---|---|---|---|---|---|
| | | | Accuracy | Precision | Accuracy | Precision | Accuracy | Precision |
| BON | Cropland | 768 | -0.42 | 2.92 | -0.48 | 2.05 | -0.27 | 4.33 |
| BON | Snow/ice | 39 | 0.12 | 1.34 | 0.12 | 0.83 | 0.12 | 1.50 |
| DRA | Closed Shrublands | 97 | -0.96 | 1.42 | -1.32 | 0.84 | -0.45 | 1.88 |
| DRA | open shrublands | 1128 | -0.18 | 1.57 | -0.58 | 0.88 | 0.26 | 2.00 |
| DRA | Barren | 149 | -0.23 | 1.55 | -1.04 | 0.75 | 0.87 | 1.67 |
| FPK | Grass | 491 | -0.19 | 1.84 | 0.07 | 1.63 | -0.70 | 2.12 |
| FPK | Crop/vegetation Mosaic | 90 | -1.13 | 2.61 | -1.70 | 2.86 | -0.08 | 1.69 |
| FPK | Snow/ice | 56 | -3.16 | 5.57 | | | -3.16 | 5.57 |
| GWN | Woody Savannahs | 390 | 0.06 | 2.69 | 1.39 | 1.75 | -2.10 | 2.56 |
| GWN | Crop/vegetation Mosaic | 487 | -0.18 | 2.52 | 1.28 | 1.61 | -2.20 | 2.11 |
| PSU | Deciduous broadleaf forests | 21 | -0.85 | 2.52 | -0.48 | 2.55 | -1.77 | 2.39 |
| PSU | Grass | 157 | -0.28 | 1.85 | -0.21 | 1.93 | -0.37 | 1.75 |
| PSU | Cropland | 35 | -1.16 | 2.20 | -1.21 | 2.38 | -0.91 | 1.04 |
| PSU | Crop/vegetation Mosaic | 406 | -0.15 | 2.51 | -0.19 | 2.56 | 0.00 | 2.34 |
| PSU | Snow/ice | 105 | -1.30 | 3.10 | -2.29 | 3.67 | -0.72 | 2.56 |
| SXF | Cropland | 762 | -0.44 | 2.33 | -0.13 | 2.07 | -1.08 | 2.69 |
| SXF | Snow/ice | 119 | -1.91 | 3.64 | -1.94 | 1.94 | -1.90 | 4.10 |
| TBL | Grass | 749 | -0.68 | 1.81 | -0.70 | 1.59 | -0.63 | 2.35 |
| TBL | Snow/ice | 41 | -1.36 | 1.80 | -2.43 | 0.80 | -1.06 | 1.90 |

## Issues in Ground based LST Validation

- ***Ground data quality control***

1) Quality flag of ground measurements to filter out the bad data
2) Temporal variation test : standard deviation of ground observations within the selected time period, e.g. 30 minutes
3) Ground data noise control




The envelop analysis for the site in TBL at 0855UTC to 0925UTC on May 21, 2014.

- ***Satellite data quality control***

The main purpose for satellite data quality control is to reduce the impact from the cloud contamination and suboptimal atmospheric conditions.

1) cloud condition by using confidently clear pixels only
2) Spatial variation test. The STD of brightness temperature at 11µm at 3 by 3 pixels box

- ***LST retrieval over vegetated site, impacted by the growth stage***

| VIIRS LST(K) | BON_LST(K) | BT15(K) | BT16(K) | Date | Time | STZ | STAZ | SOZ |
|---|---|---|---|---|---|---|---|---|
| 312.19 | 304.77 | 306.05 | 302.51 | 2013140 | 1905 | 33.39 | -98.15 | 26.34 |
| 313.65 | 305.98 | 308.04 | 304.88 | 2013163 | 1835 | 14.57 | 78.10 | 19.43 |
| 311.39 | 301.43 | 306.27 | 303.76 | 2013164 | 1815 | 39.15 | 74.33 | 17.73 |
| 313.91 | 304.41 | 307.21 | 303.14 | 2013169 | 1825 | 32.07 | 75.08 | 17.95 |
| 310.84 | 303.62 | 304.40 | 300.88 | 2013170 | 1805 | 50.70 | 72.09 | 16.85 |
| 313.14 | 305.44 | 308.69 | 306.60 | 2014128 | 1855 | 6.24 | -100.44 | 27.15 |
| 312.03 | 301.27 | 308.06 | 306.73 | 2014130 | 1815 | 44.90 | 73.11 | 23.26 |
| 308.33 | 300.28 | 302.04 | 299.51 | 2014130 | 2000 | 67.60 | -90.80 | 35.98 |
| 309.05 | 302.28 | 305.02 | 303.27 | 2014144 | 1855 | 6.25 | -97.24 | 24.05 |
| 311.75 | 303.35 | 307.29 | 305.41 | 2014151 | 1825 | 38.72 | 74.25 | 19.61 |

## Summary

- Limited ground in-situ measurements in SURFRAD, ARM and Africa are used to validate V1 VIIRS LST product. Cross comparisons against the ground observations from SURFRAD indicate an overall good agreement among VIIRS LST, MODIS LST and AATSR LST. The result over one field measurement dataset in Africa suggests that VIIRS and MODIS underestimate the LST about 1.57 K and 2.97 K, respectively.
- It also demonstrates a regional difference, day/night difference as well as the difference over surface types.
- Cloud contamination, particularly the cloud detection error over snow/ice surface, show significant impacts on LST validation quality therefore additional cloud filter is strongly recommended for LST validation and applications.
- VIIRS LST quality is strongly dependent on a correct classification of the surface type.