Evaluation of the Suomi NPP VIIRS Land Surface Temperature Product

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Introduction

The Visible Infrared Imaging Radiometer Suite (VIIRS), aboard the Suomi National Polar-orbiting Partnership (S-NPP) satellite, is the sensor to provide measurements of the atmospheric, land and oceanic parameters which are referred to as Environmental Data Records (EDRs). Land Surface Temperature (LST), one of the EDR products, provides the measurement of the skin temperature over global land coverage including coastal and inland water. The LST EDR is derived from a baseline split-window regression algorithm. Coefficients of the LST algorithm are surface type dependent, referring 17 International Geosphere-Biosphere Programme (IGBP) types, with a separation for day and night.

This study presents an evaluation of the LST product 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 ground evaluation result shows that VIIRS LST agrees well with the measurements from SURFRAD, with a better performance at nighttime than at daytime. However, the performance varies over surface types.

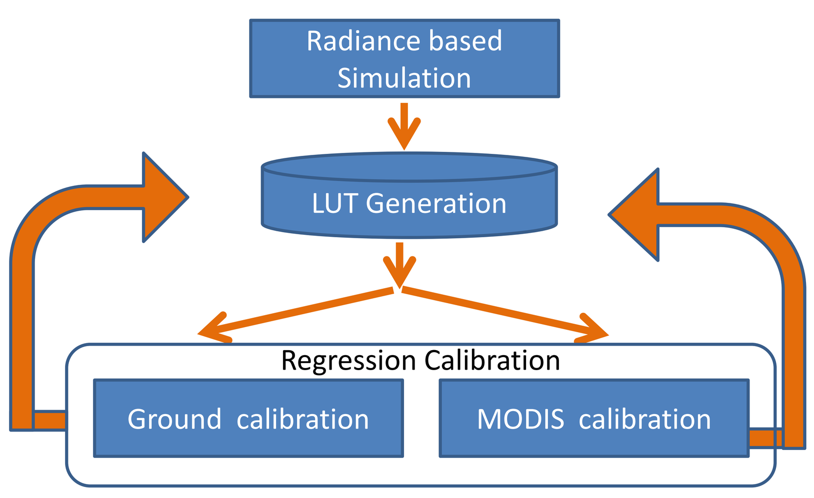
The cross satellite evaluation is mainly conducted with MODIS considering that VIIRS LST will replace MODIS LST in the future, and the comparisons are mostly over Simultaneous Nadir Overpasses (SNO) between VIIRS and Aqua. Comparison results show an overall close agreement between VIIRS and MODIS LST, but the difference in LST displays a regional stripe feature. In detail, a relatively large LST difference is found in low latitude areas such as South America and northern Australia, attributed to the significant brightness temperature difference between the two split window channels which the current VIIRS algorithm cannot handle well.

VIIRS LST EDR Calibration

❖ **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.

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



Flow chart of LST calibration

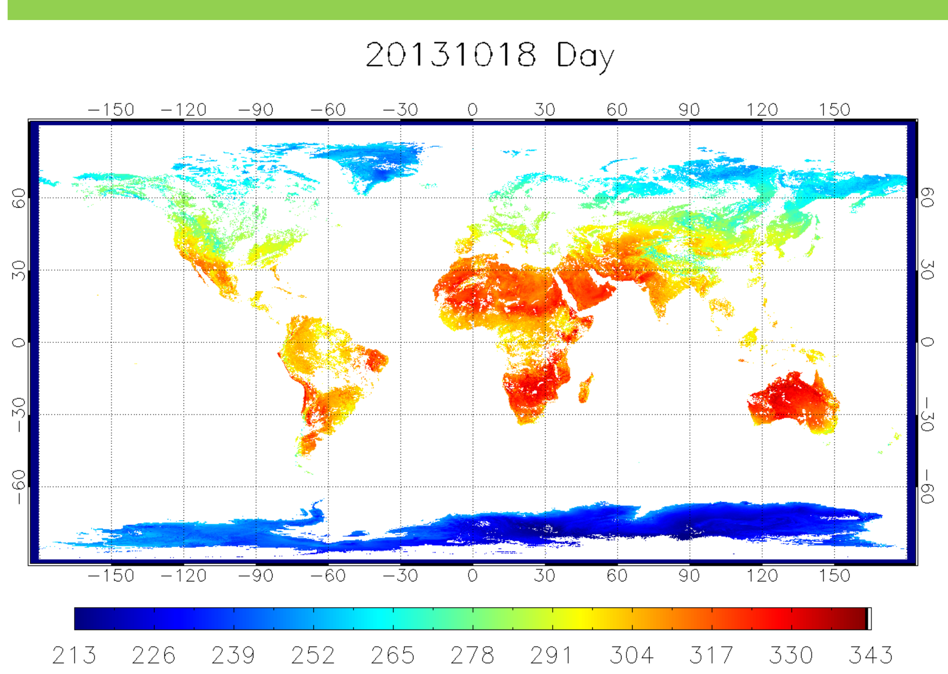
Improvement for LST EDR is based on update of algorithm coefficients.

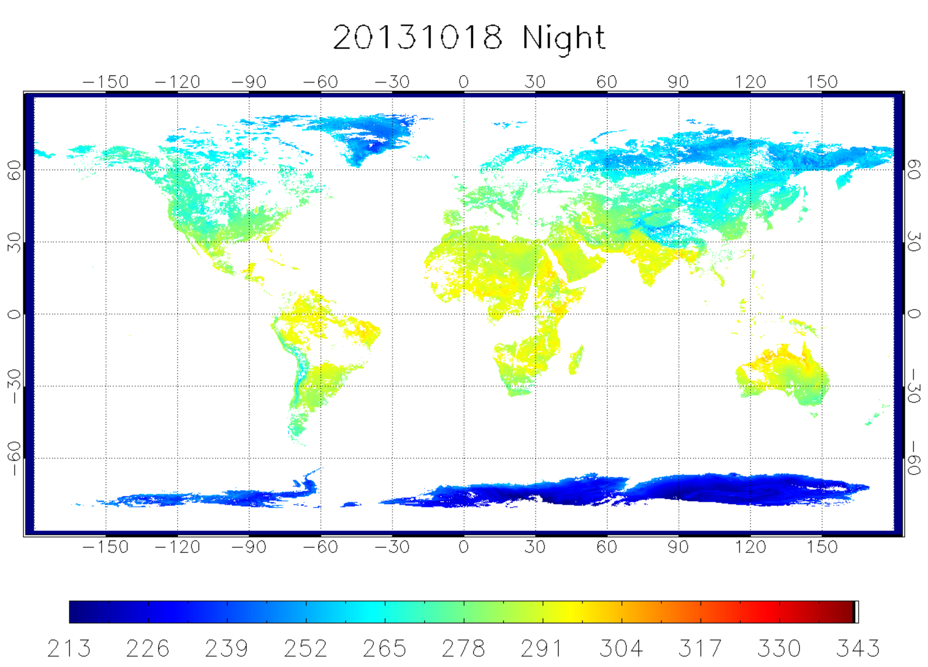
Two steps of calibration:

1. *calibration from the radiance based simulation*
2. *calibration from comparisons to the reference dataset, i.e. ground truth and MODIS Aqua LST product.*

Calibration is based on the annual performance rather than the seasonal performance.

Global LST Image

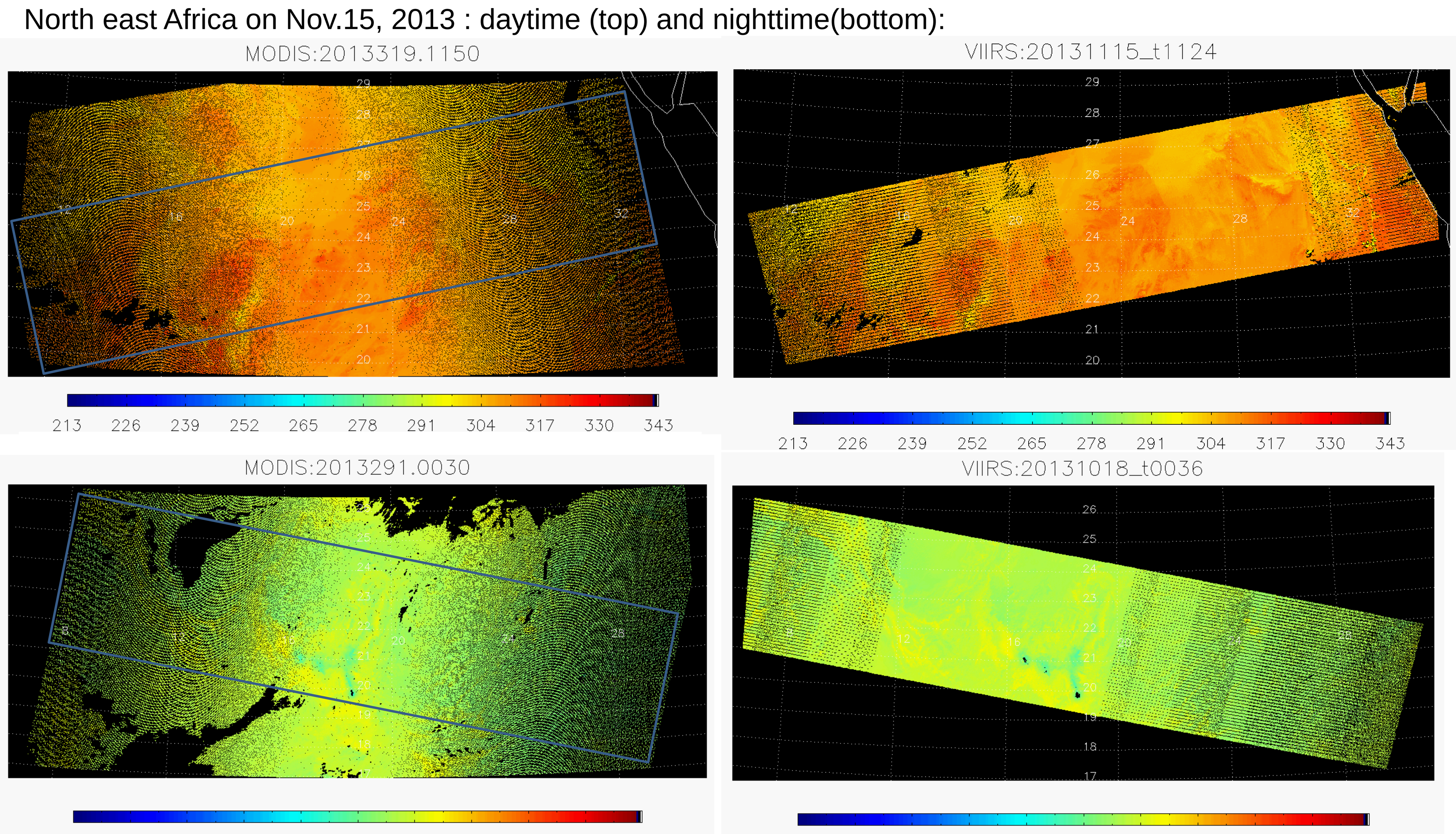


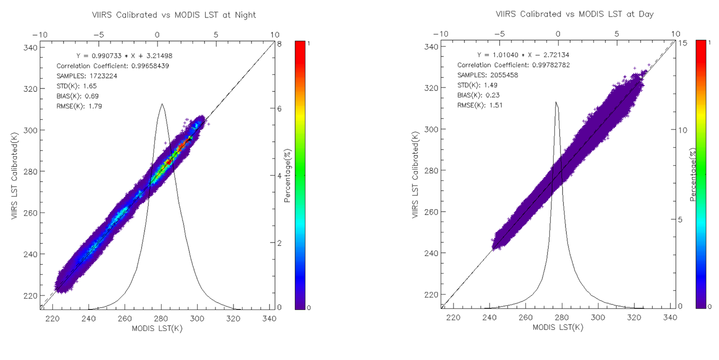


Cross Satellite Evaluation

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 Nov.15, 2013 : daytime (top) and nighttime(bottom):

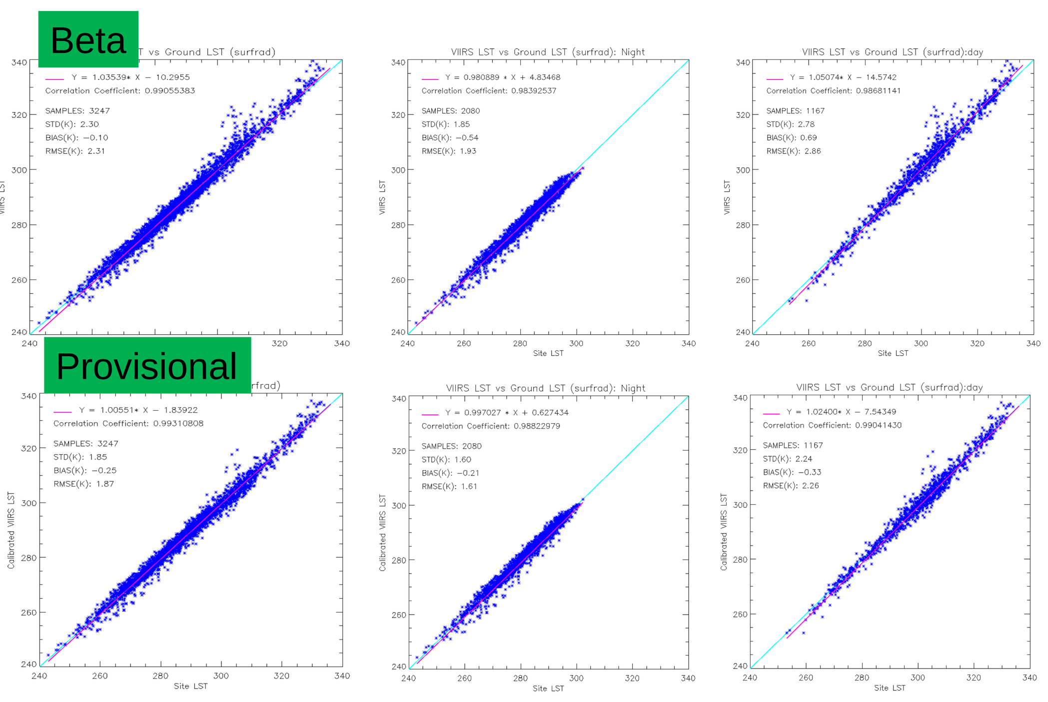


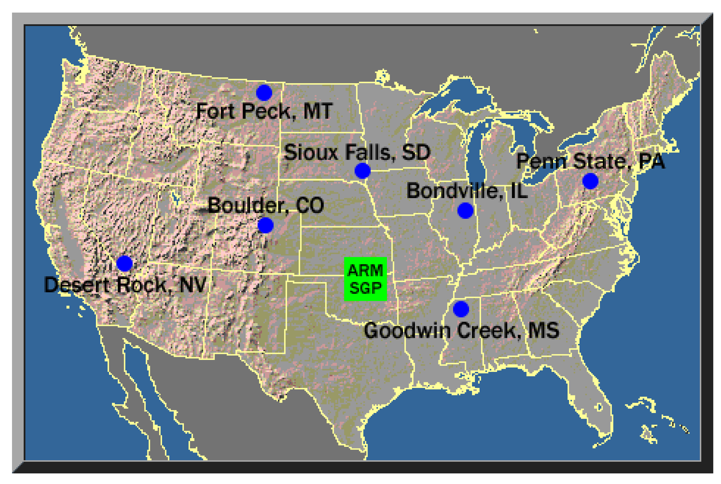


Comparison results from Simultaneous Nadir Overpass (SNO) between VIIRS and AQUA in 2012 and Oct-Dec, 2013. The matchups are quality controlled with additional cloud filter for both LST measurements.

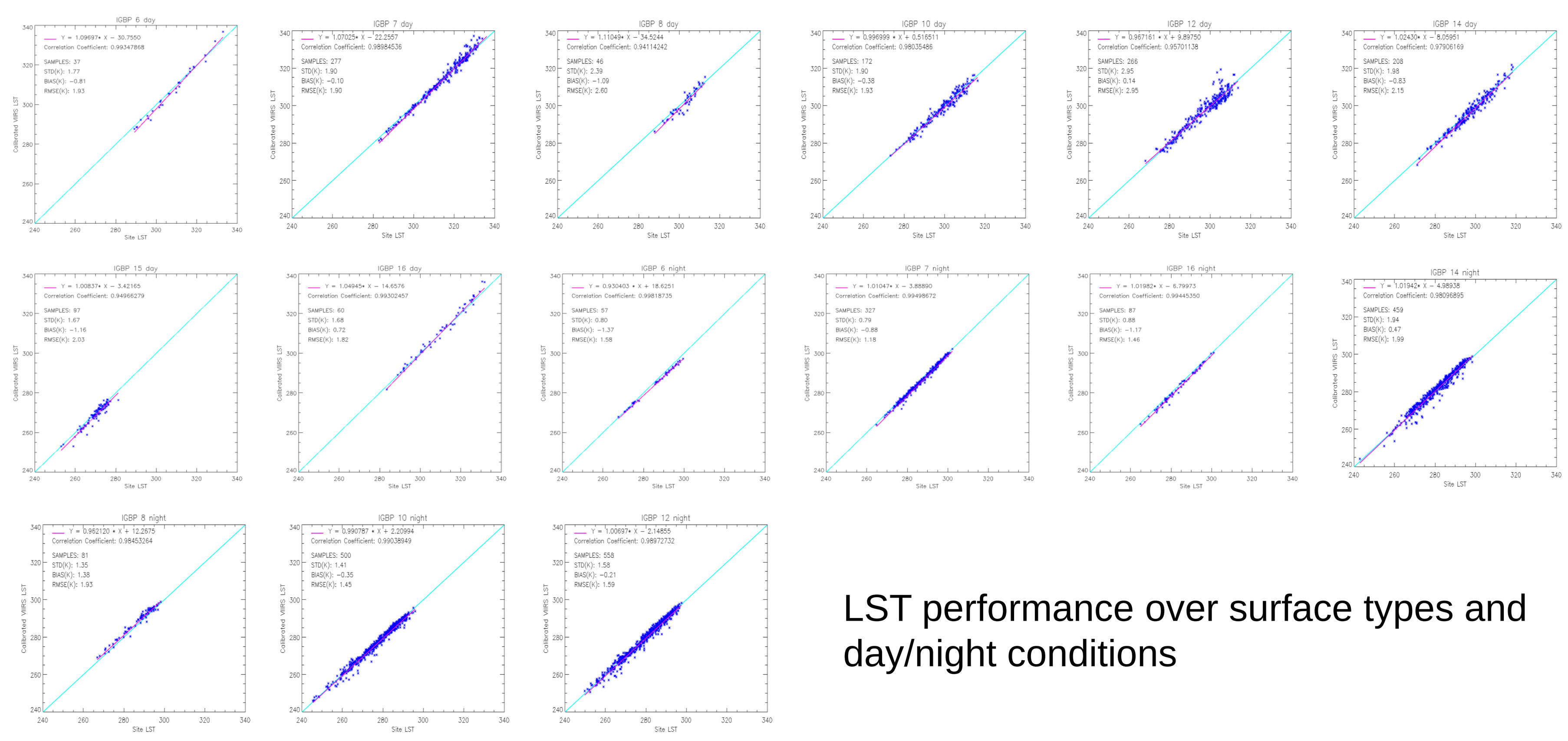
Ground Evaluation

❖Ground data from SURFRAD





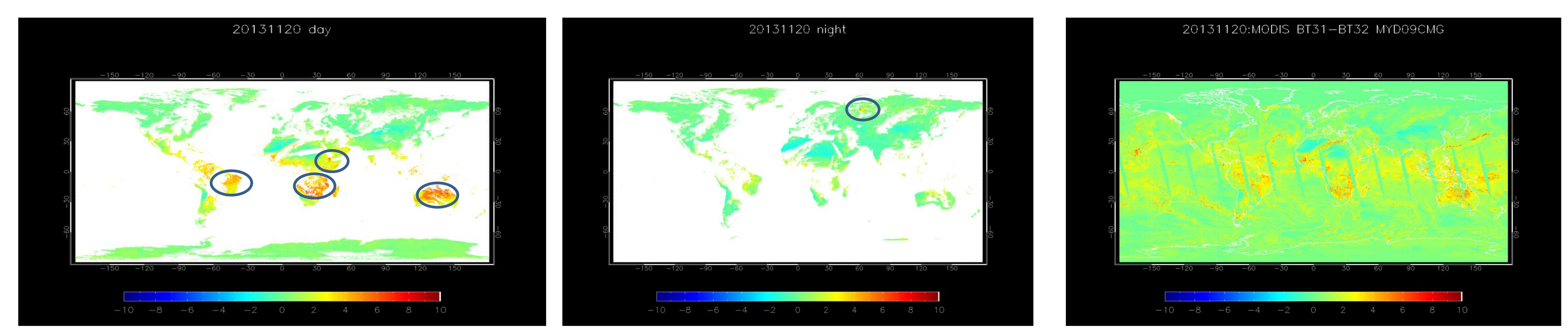
The ground data from The Surface Radiation Budget Network (SURFRAD) are used for the evaluation. The data covers the time period from Feb. 2012 to December 2013.



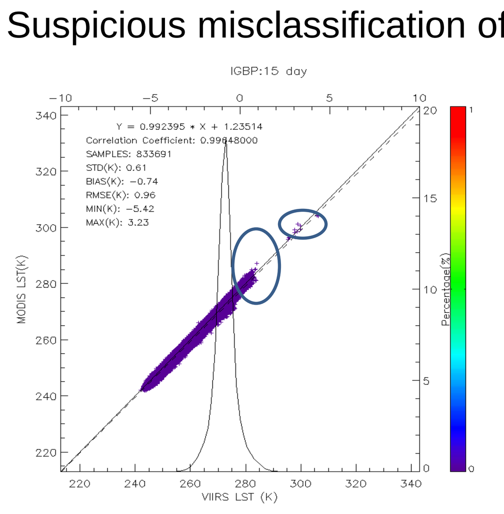
LST performance over surface types and day/night conditions

Issues

- Large brightness temperature difference between the two split window channels



- Suspicious misclassification of some surface types



- Emissivity range obtained from MOD11A2-Land Surface Temperature & Emissivity 8-Day L3 Global 1km with the land cover from UMD at 1km resolution

month	surface type	Emi31_min	Emi31_max	Emi31_mean	Emi32_min	Emi32_max	Emi32_mean
Jan	Water	0.964	0.994	0.979	0.966	0.99	0.978
Jan	Evergreen Needleleaf Forest	0.964	0.994	0.979	0.968	0.99	0.979
Jan	Evergreen Broadleaf Forest	0.966	0.994	0.98	0.972	0.99	0.981
Jan	Deciduous Needleleaf Forest	0.972	0.994	0.983	0.976	0.99	0.983
Jan	Deciduous Broadleaf Forest	0.966	0.994	0.98	0.972	0.99	0.981
Jan	Mixed Forest	0.964	0.994	0.979	0.972	0.99	0.981
Jan	Woodland	0.964	0.994	0.979	0.97	0.99	0.98
Jan	Wooded Grassland	0.964	0.994	0.979	0.97	0.99	0.98
Jan	Closed Shrubland	0.964	0.994	0.979	0.972	0.99	0.981
Jan	Open Shrubland	0.964	0.994	0.979	0.97	0.99	0.98
Jan	Grassland	0.964	0.994	0.979	0.97	0.99	0.98
Jan	Cropland	0.964	0.994	0.979	0.97	0.99	0.98
Jan	Bare Ground	0.964	0.994	0.979	0.968	0.99	0.979

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.
- 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. 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.