Developing and Validating Satellite Land Surface Temperature Product for JPSS Mission

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Outlines

- VIIRS LST Basics
- VIIRS LST Map samples
- Validation/evaluation effort
- Issues Found
- Summary and Path Forward

Basic of the VIIRS LST Product

- The VIIRS LST is a moderate bands pixel-by-pixel determination of effective land surface skin temperature. It is produced as Environmental Data Record (EDR)
- Represents continuity with NSAS EOS MODIS and NOAA POES AVHRR LST production, also with international missions such as (A)ATSR
- VIIRS design allows for full (high) resolution LST measurements over global land covers, *under clear, probably clear and probably cloudy* conditions.
- Product is expected to be used by weather forecasting models, Agriculture monitoring, drought prediction and monitoring, ecosystem monitoring; climate studies etc.

L1RD Requirements for Land Surface Temperature

Attribute	Threshold	Objective
LST Applicable Conditions: Clear		
a. Horizontal Cell Size	4 km	1 km
Nadir	(800 m)	(500 m)
b. Mapping Uncertainty, 3 Sigma	1 Km at Nadir (800 m)	1 km at Edge of Scan (500 m)
c. Measurement Range	213 – 343 K	183 – 343 K
d. Measurement Precision (1 sigma)	2.5 K	1.5 K
e. Measurement Accuracy (bias)	1.4 K	0.8 K
f. Refresh	At least 90% coverage of the globe every 24 hours (monthly average)	

VIIRS LST basics: S-NPP LST EDR Algorithm

Baseline Algorithm -- Split Window Regression Algorithm

$$LST_i = a_0(i) + a_1(i)\,T_{11} + a_2(i)\,(T_{11} - T_{12}) + a_3(i)\,(\sec\theta - 1) + a_4(i)\,(T_{11} - T_{12})^2$$

Back-up Algorithm -- Dual Split Window Regression Algorithm

Nighttime

$$LST_i = b_0(i) + b_1(i)T_{11} + b_2(T_{11} - T_{12}) + b_3(i)(\sec\theta - 1) + b_4(i)T_{3.75} + b_5(i)T_{4.0} + b_6(i)T_{3.75}^{\ 2} + b_7(i)T_{4.0}^{\ 2} + b_8(i)(T_{11} - T_{12})^2$$

Daytime

$$LST_i = a_0(i) + a_1(i)T_{11} + a_2(T_{11} - T_{12}) + a_3(i)(\sec\theta - 1) + a_4(i)T_{3.75} + a_5(i)T_{4.0} + a_6(i)T_{3.75}\cos\varphi + a_7(i)T_{4.0}\cos\varphi + a_8(i)(T_{11} - T_{12})^2$$

Note:

i -- index of the 17 International Geosphere Biosphere Program (IGBP) surface types

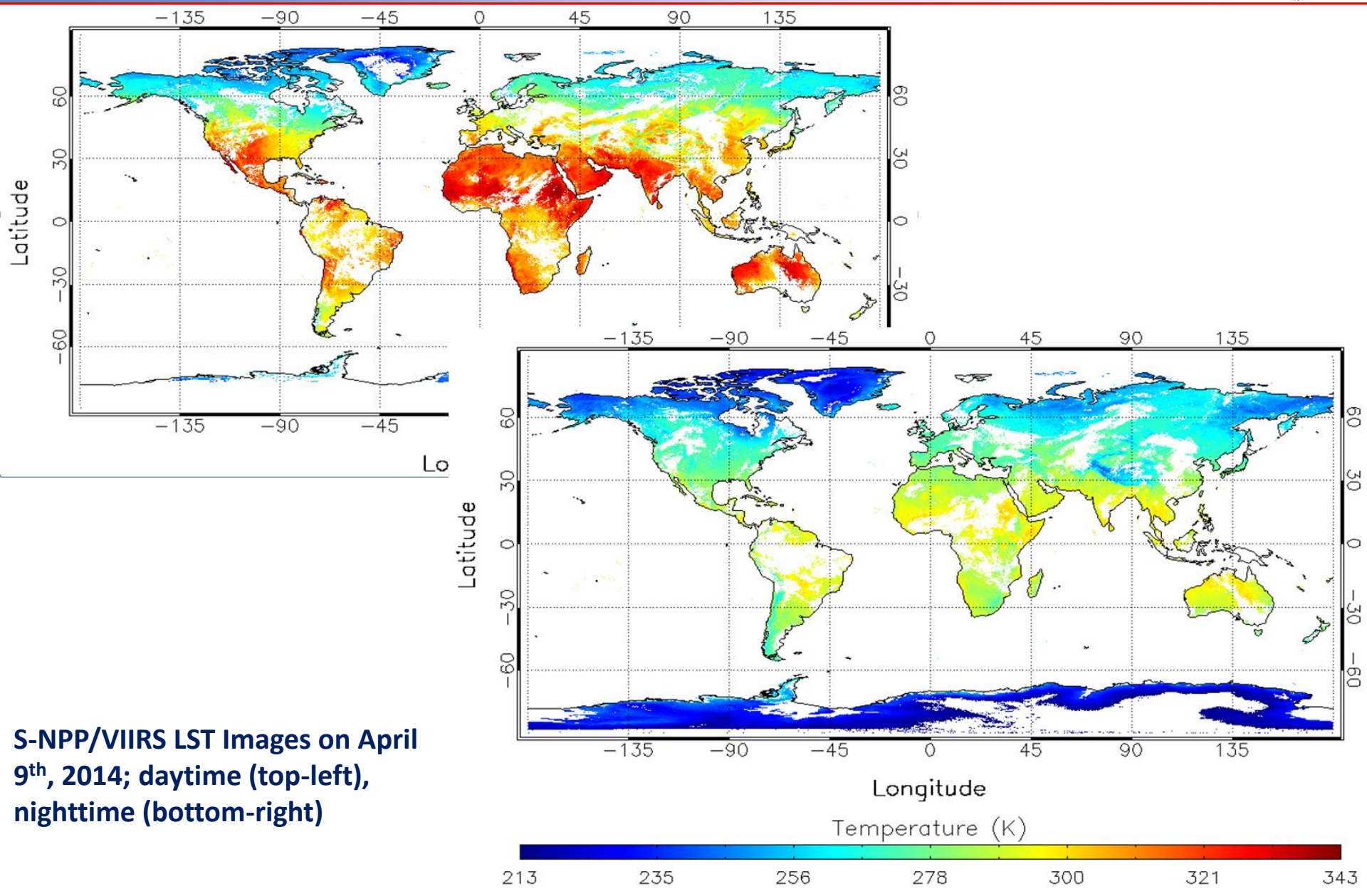
T_{11}, T_{12}, $T_{3.75}$, and $T_{4.0}$ -- brightness temperatures of the VIIRS 10.8, 12, 3.75, and 4.0 μm bands, respectively

θ and φ -- sensor and solar zenith angles, respectively

$a_j(i)$ and $b_j(i)$ -- regression coefficients for the j_{th} IBGP surface type for daytime and nighttime LST retrievals, respectively

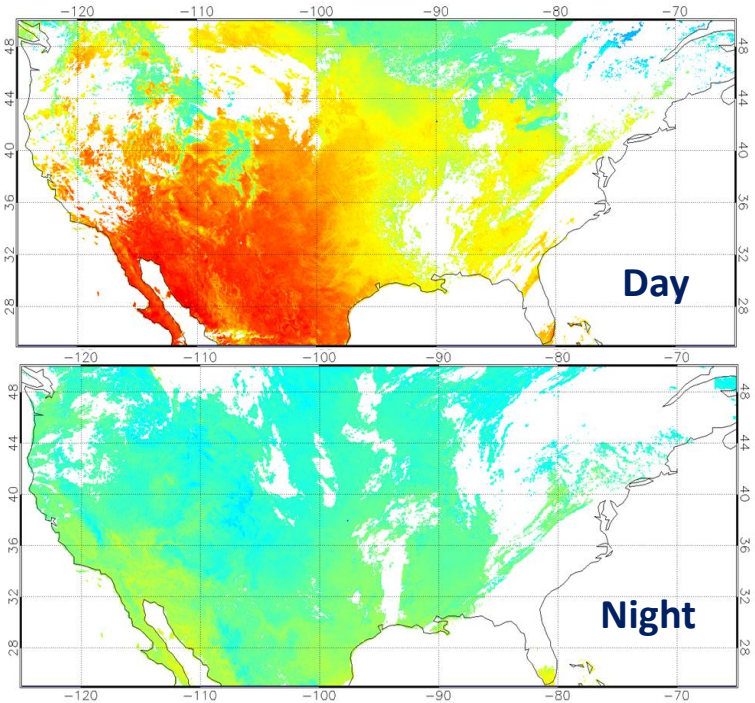
- Two algorithms have been implemented
  - Baseline: Split Window LST(SWLST) is derived using two TIR channels (M15, M16)
  - Back-up: Dual Split Window LST (DSWLST) is derived using TIR channels (M15, M16) and SIR infrared channels (M12, M13)
- Evaluation underway
  - Comparison with MODIS LST product
  - Comparison with Ground LST measurements
  - Results of preliminary evaluation are promising : Beta version release was in October, 2012; Provisional version in October 2013 (modified in April 2014).

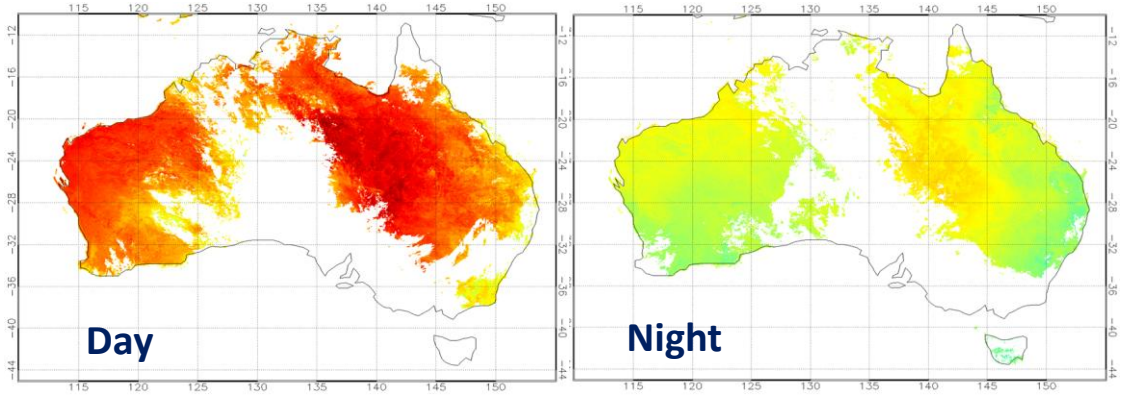
S-NPP VIIRS LST Maps

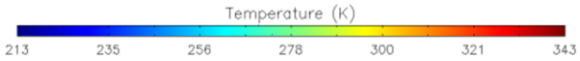


S-NPP/VIIRS LST Images on April 9th, 2014; daytime (top-left), nighttime (bottom-right)

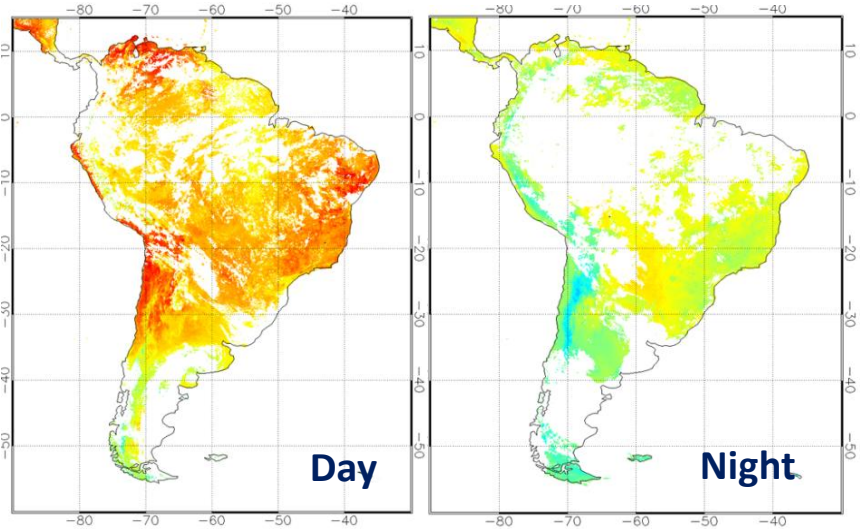
S-NPP VIIRS LST Maps

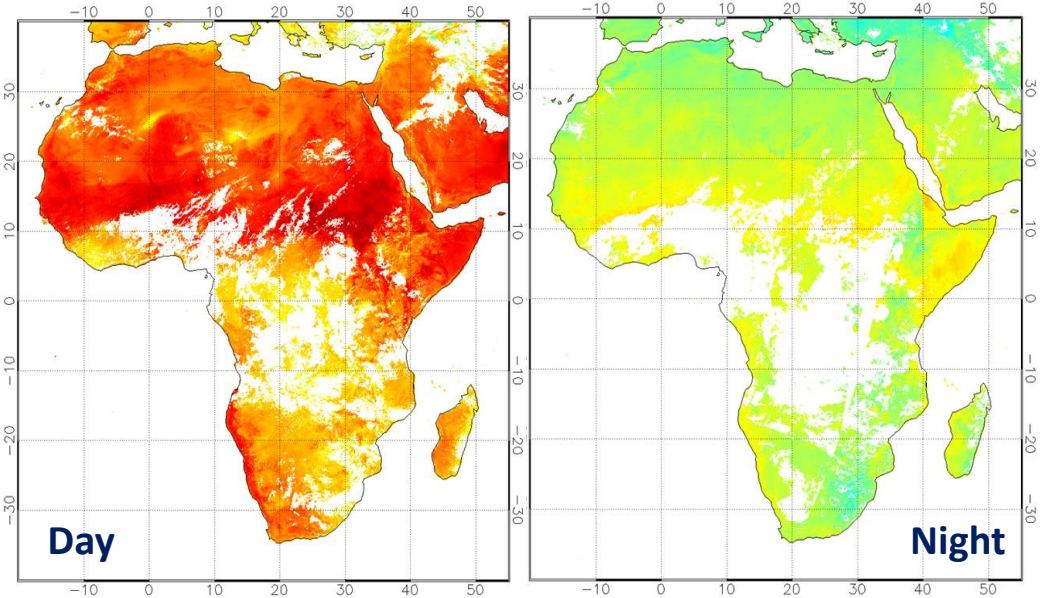




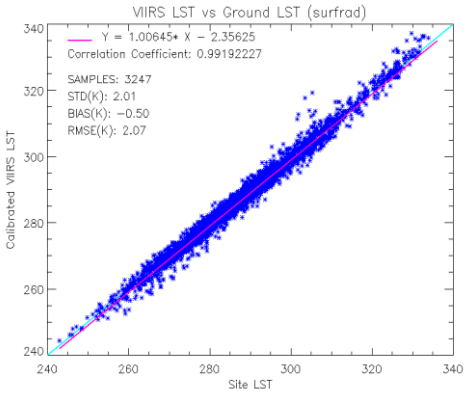


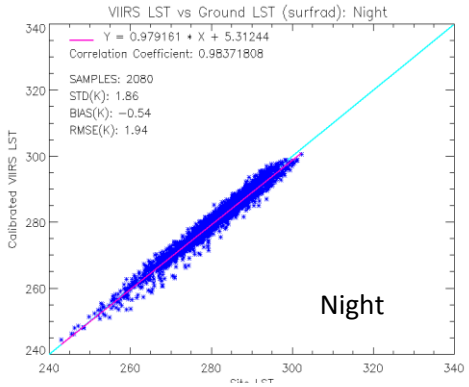
S-NPP/VIIRS LST Images on April 9^{10h}, 2014; daytime and nighttime

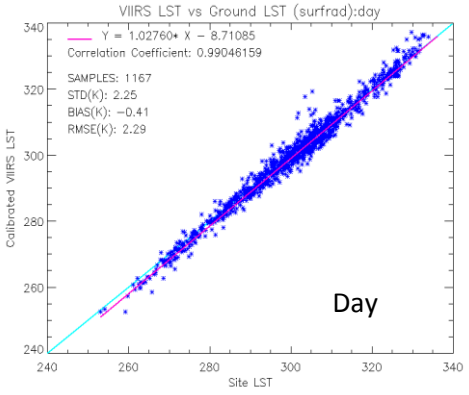




VIIRS LST In-situ Validation







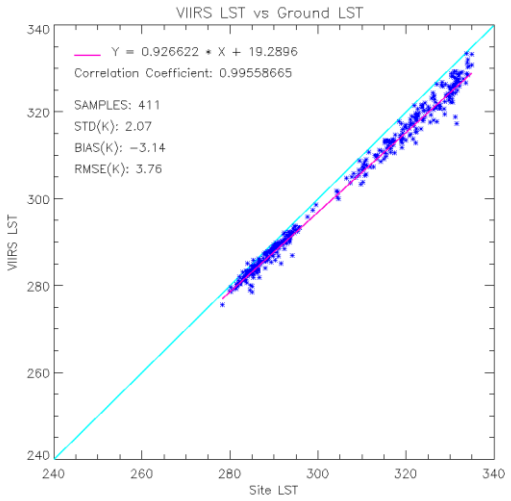
Evaluation against ground data

Surface type	Day/ Night	data num	Provisional		*Beta*	
			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 Veg 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*

SURFRAD LST over 6 sites covering the time period from Feb. 2012 to December 2013

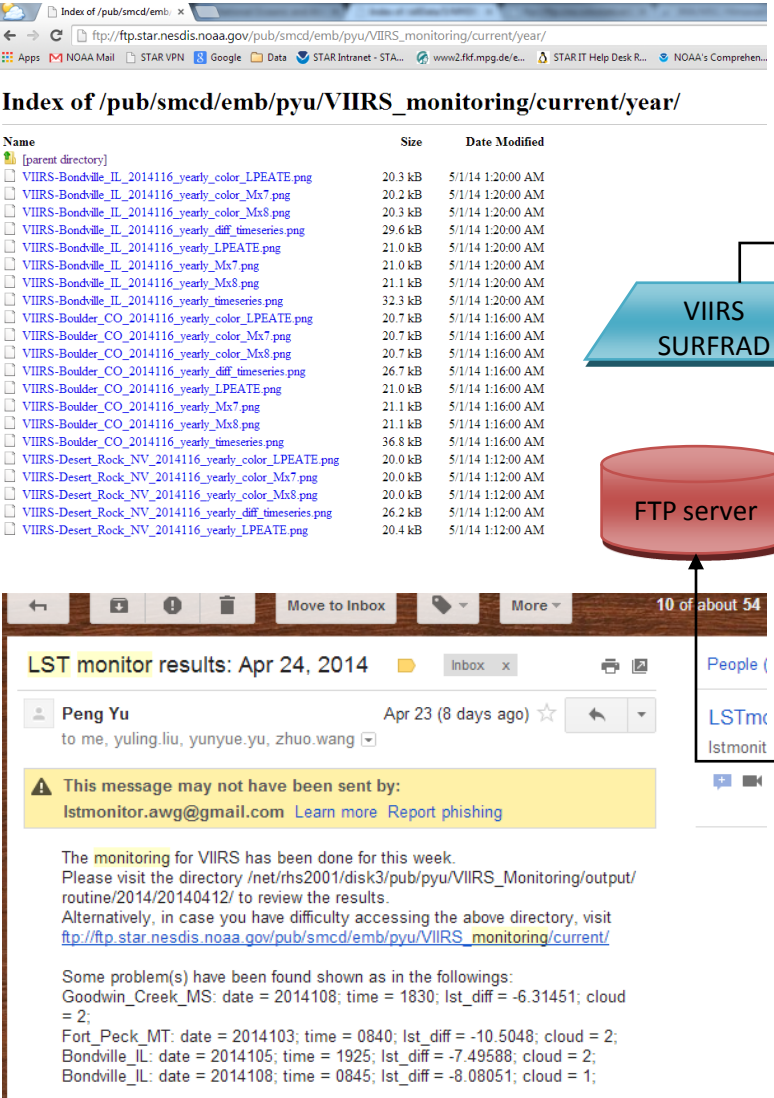
A ground dataset at Gobabeb in Namibia covering the time period of 2012.

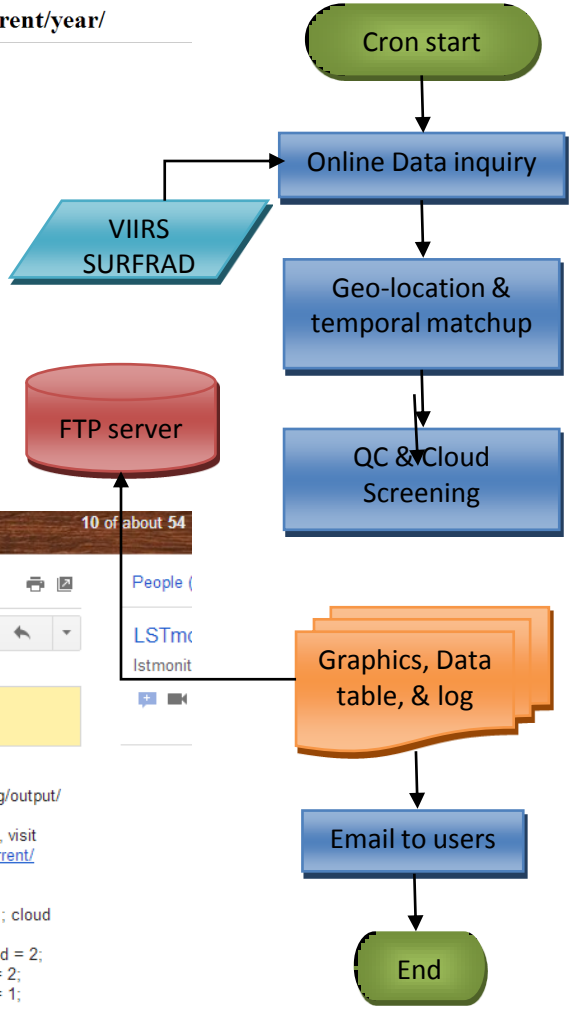
*The data is provided by Frank Goettsche (KIT)

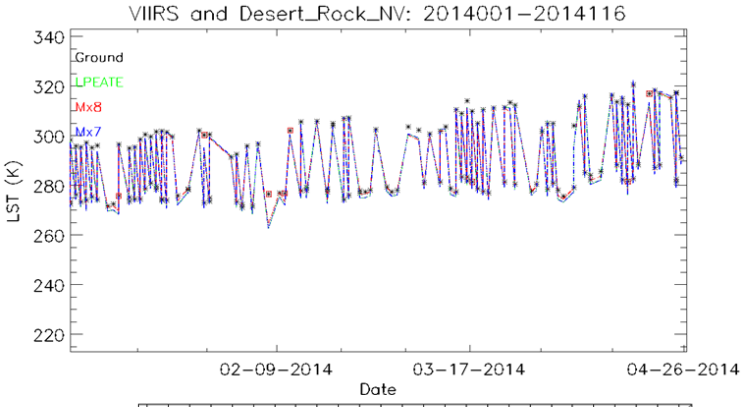


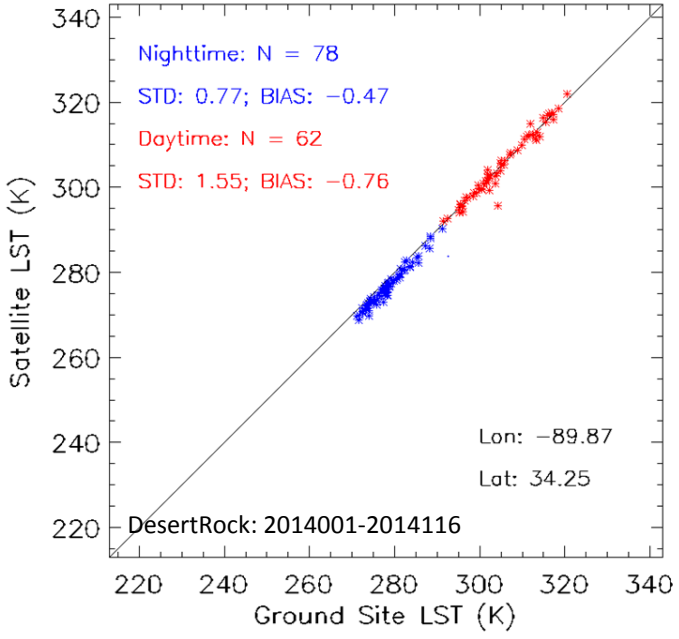
Product Monitoring

A monitoring tool developed



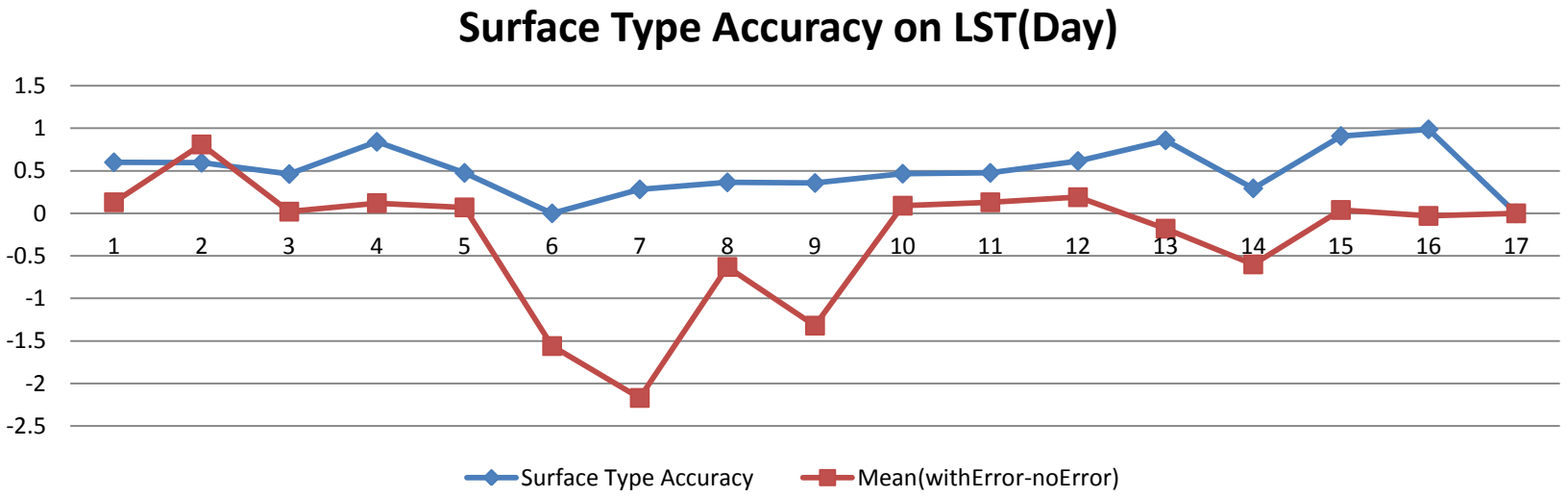


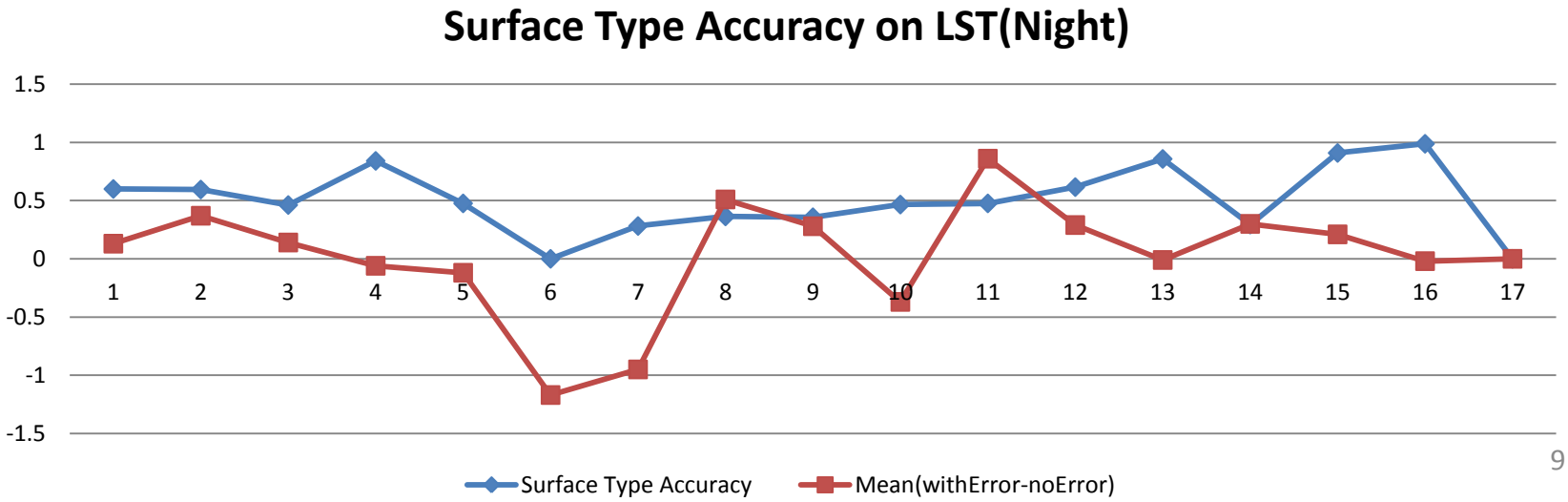




Issues – Surface Type Dependency

Impact of the Type EDR error

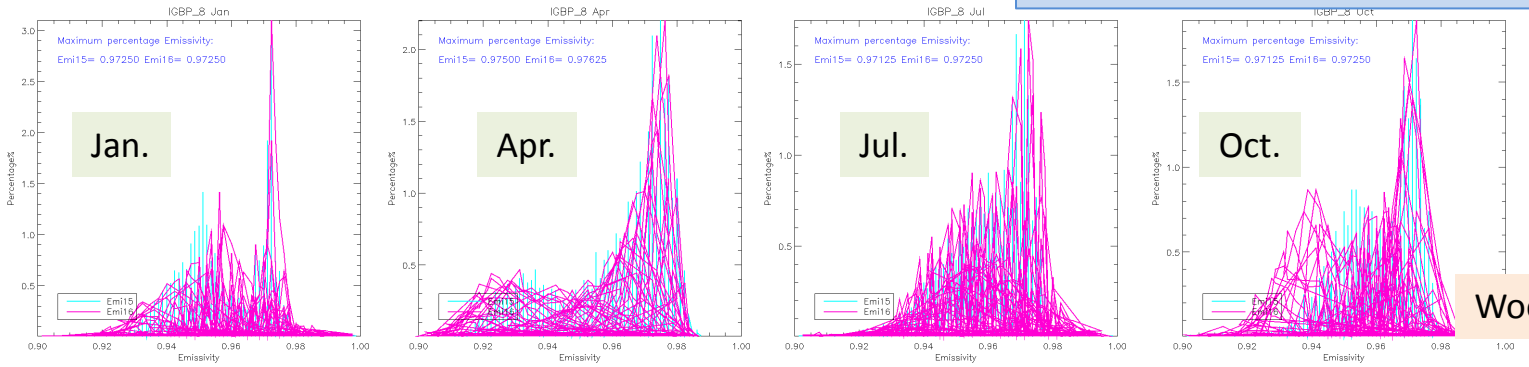




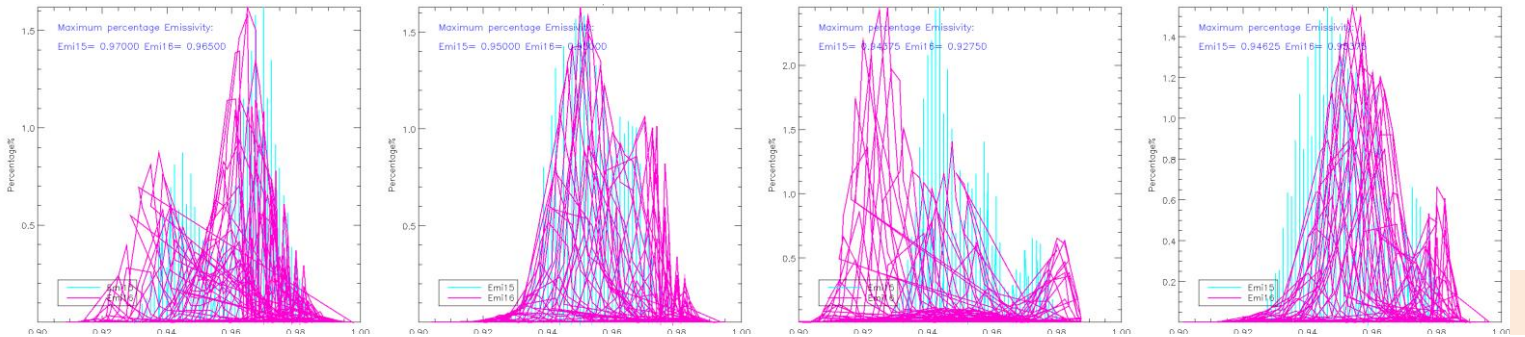
Issues – Emissivity Variation Impact

Emissivity Impact to LST

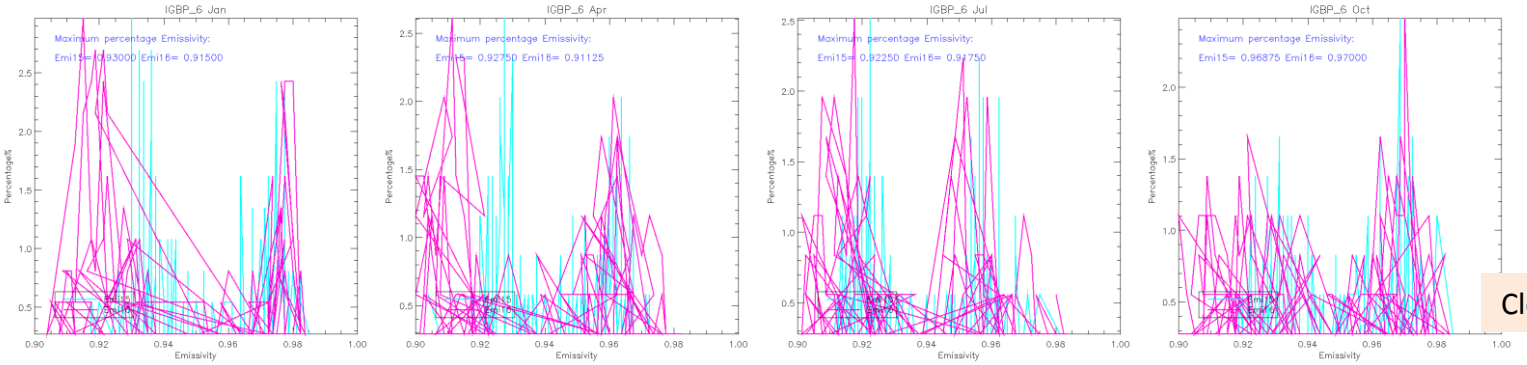
- *Considerable seasonal emissivity variation over some surface types*
- *Considerable emissivity variation within cover types*



Woody Savannas (2012)



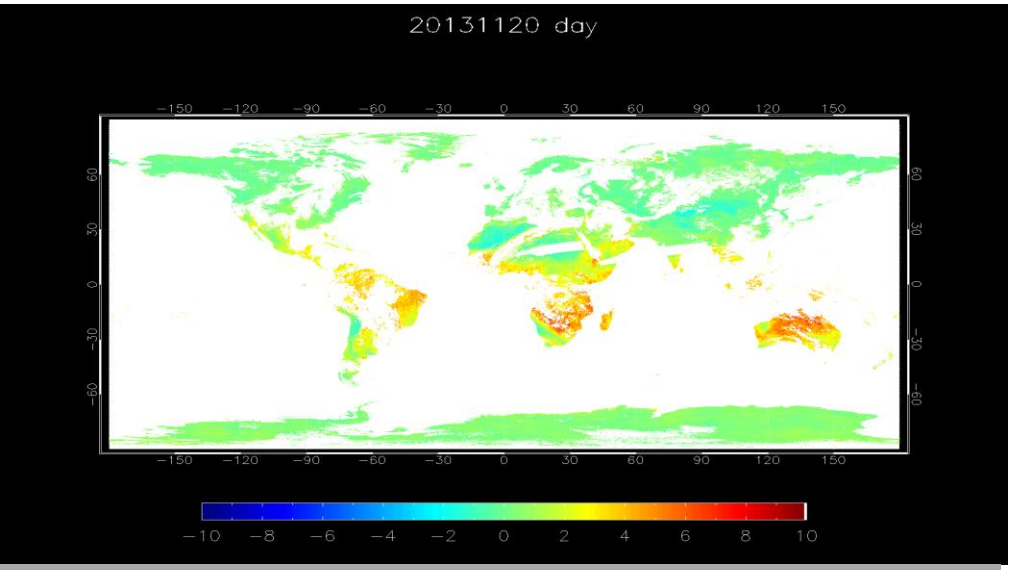
Grassland(2011)



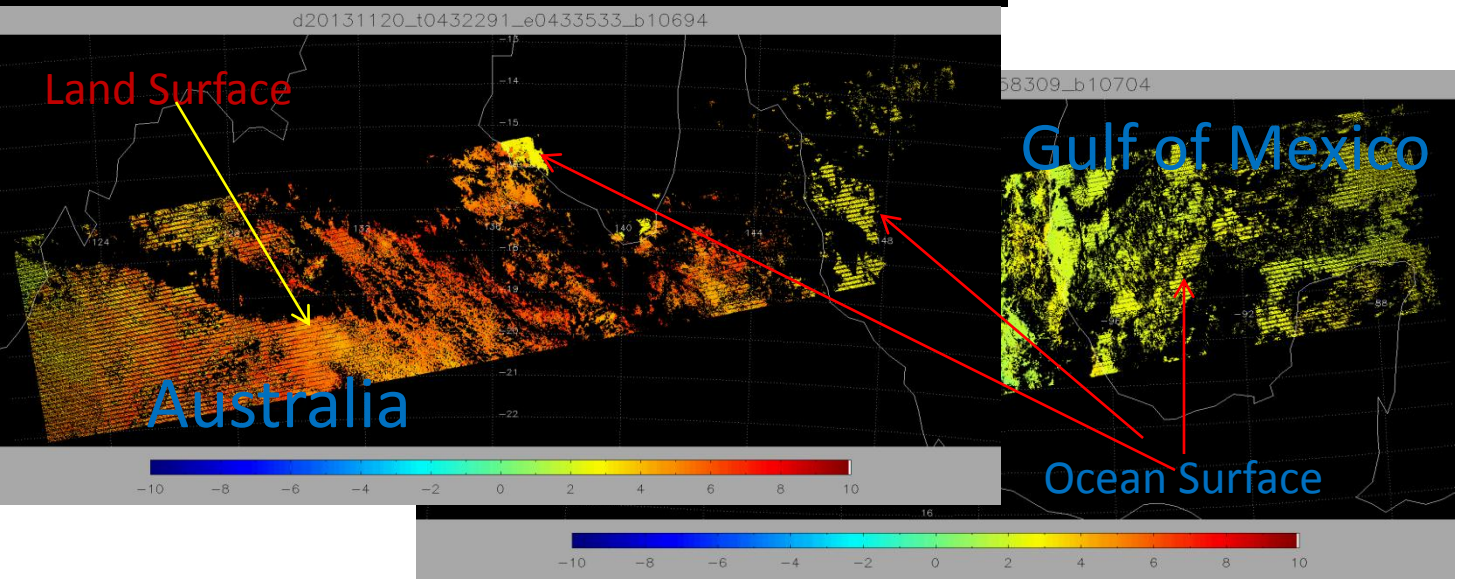
Closed Shrub lands (2012)

Issues – Atmospheric Correction

BT difference for atmospheric correction



BT difference at daytime

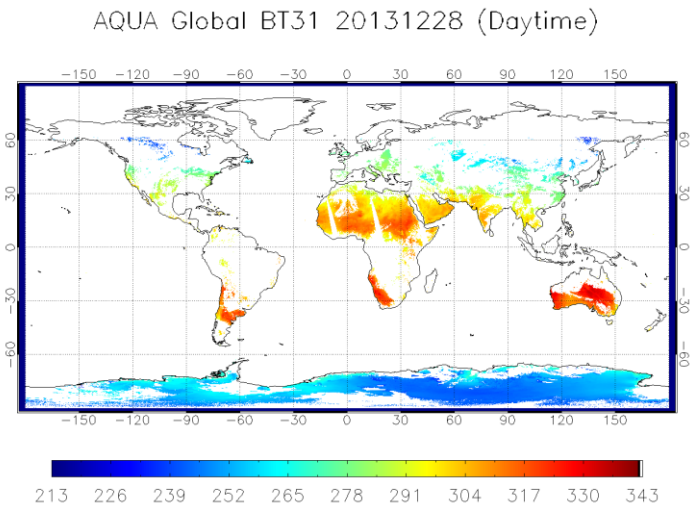


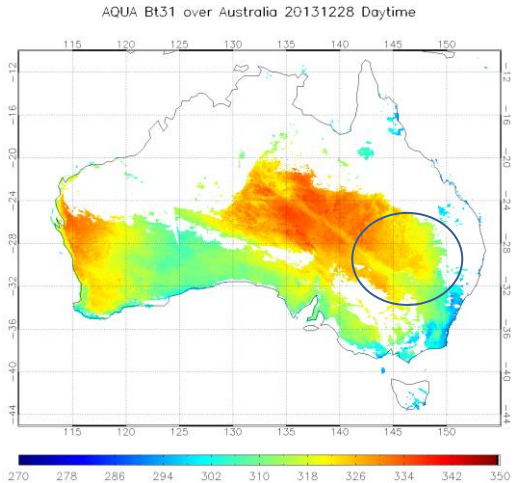
<u>Split-window algorithm feature</u>: brightness temperature (**BT**) difference at 11 and 12 μm is used for atmospheric correction. It is the SST heritage. However, the BT difference can be very different over land. Additional measure is needed.

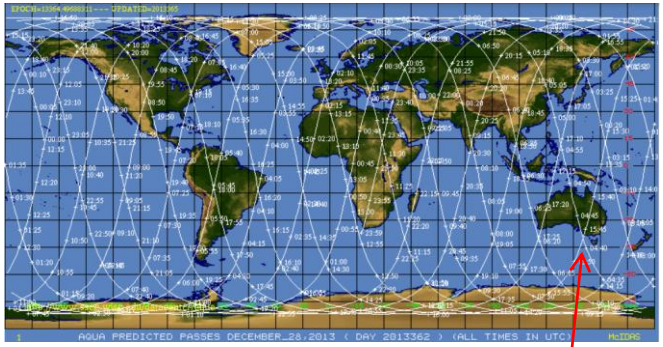
Left: Significant BT differences over land and sea water surface. The BT difference is much smaller over sea surface

Issues – Cross-satellite Comparison

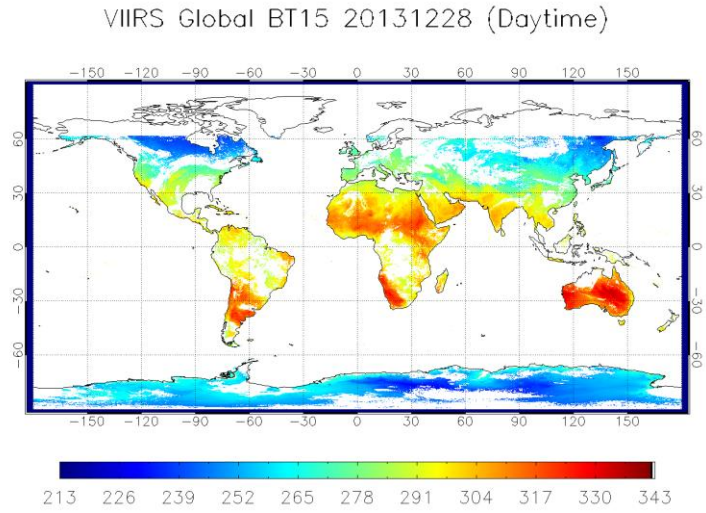
Impact of time difference in cross-satellite comparison

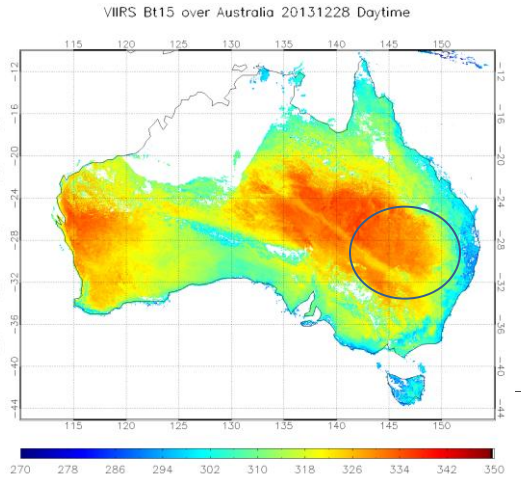


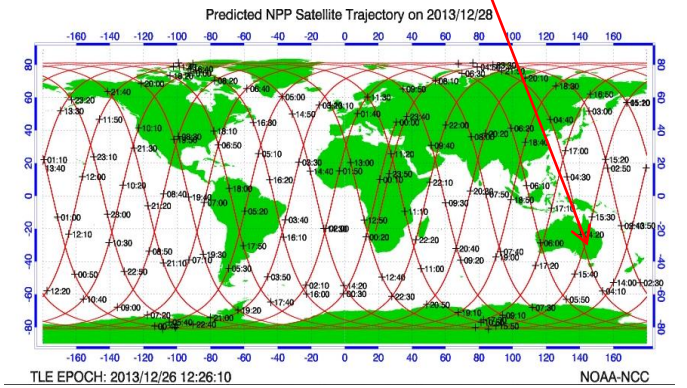




About 25 min difference between VIIRS and MODIS

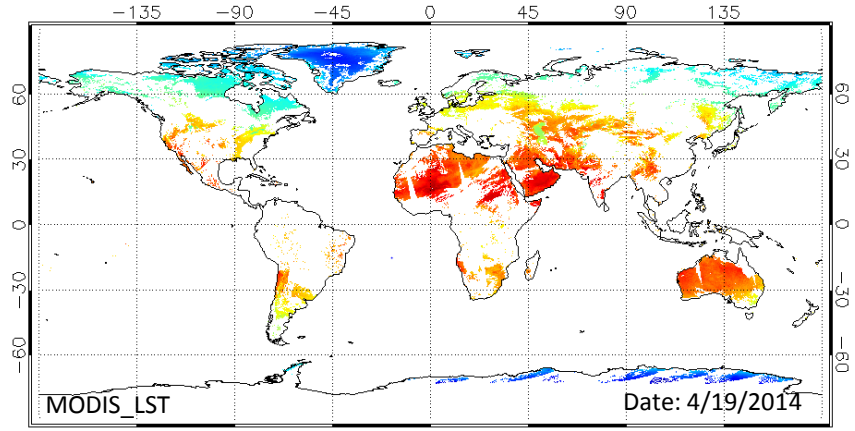


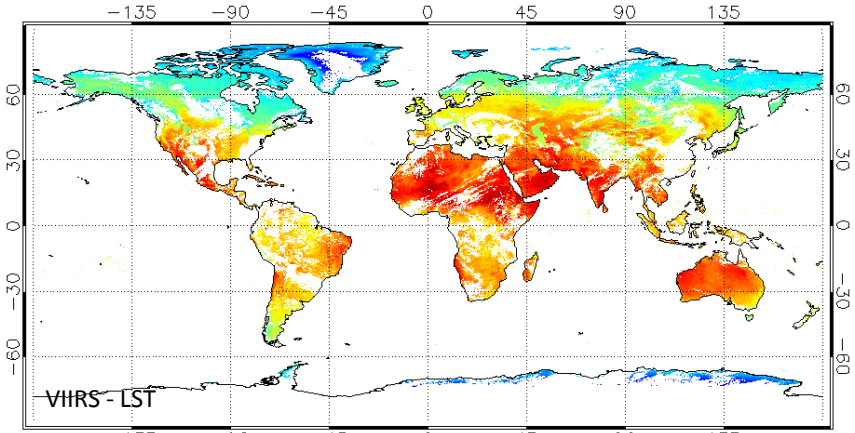


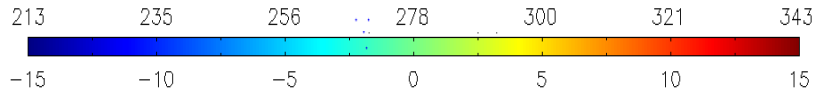


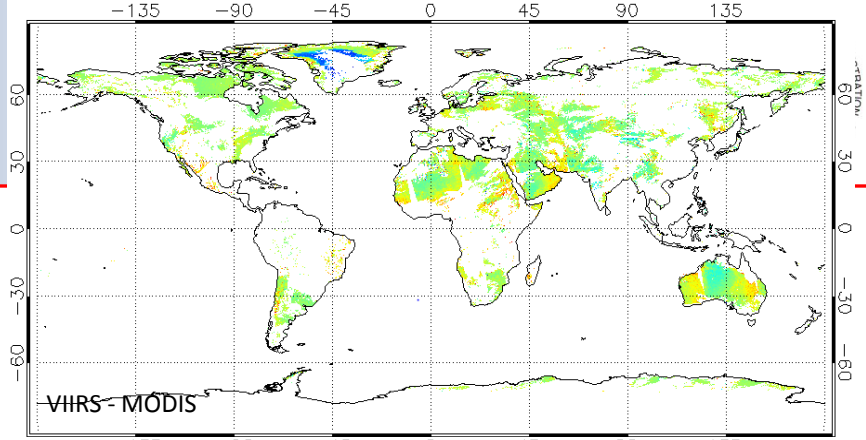
Issues – Cross Comparison

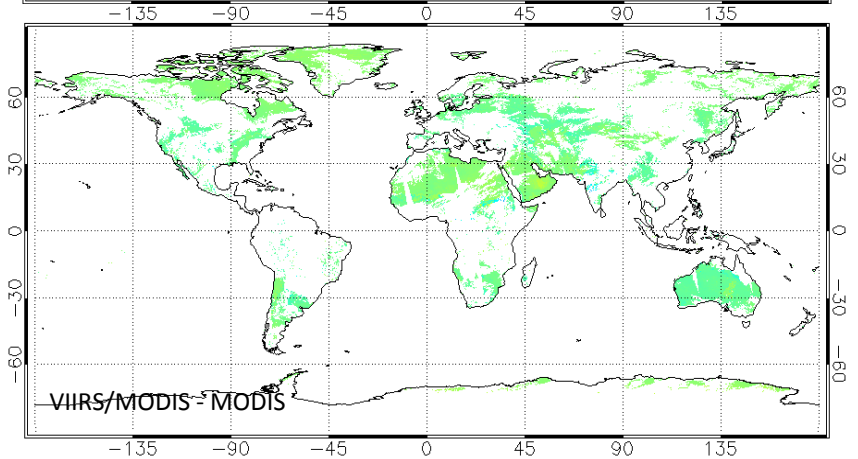
Cross-satellite Comparison: dataset difference

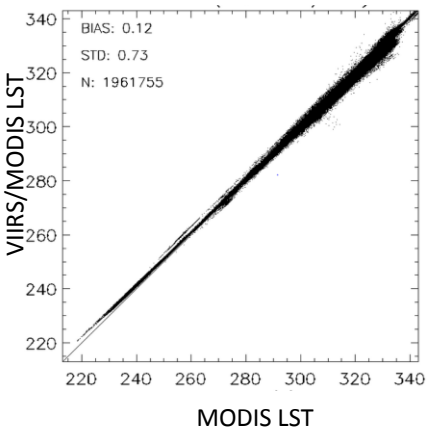












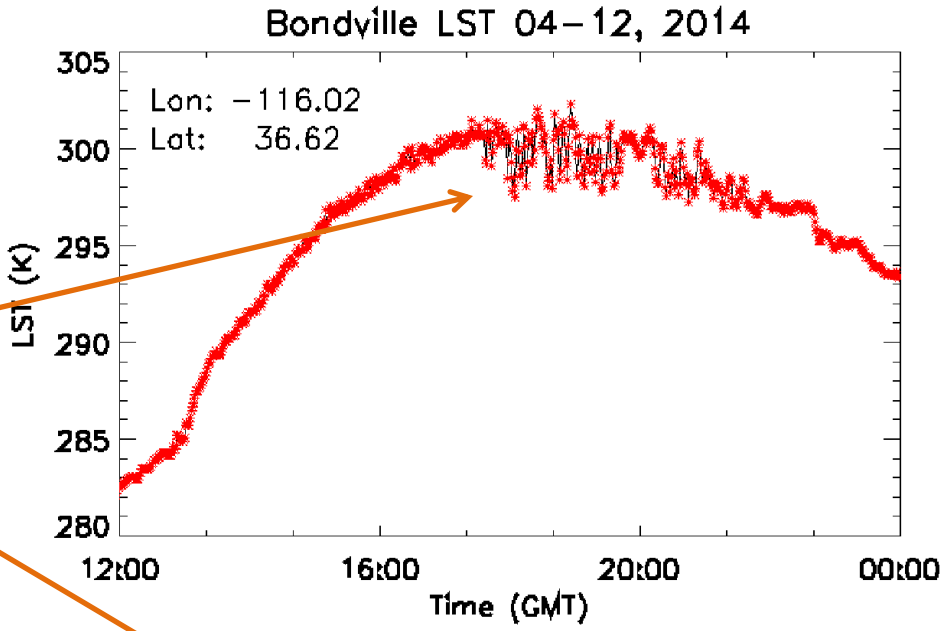
Cross-satellite LST comparison is used in VIIRS LST evaluation.

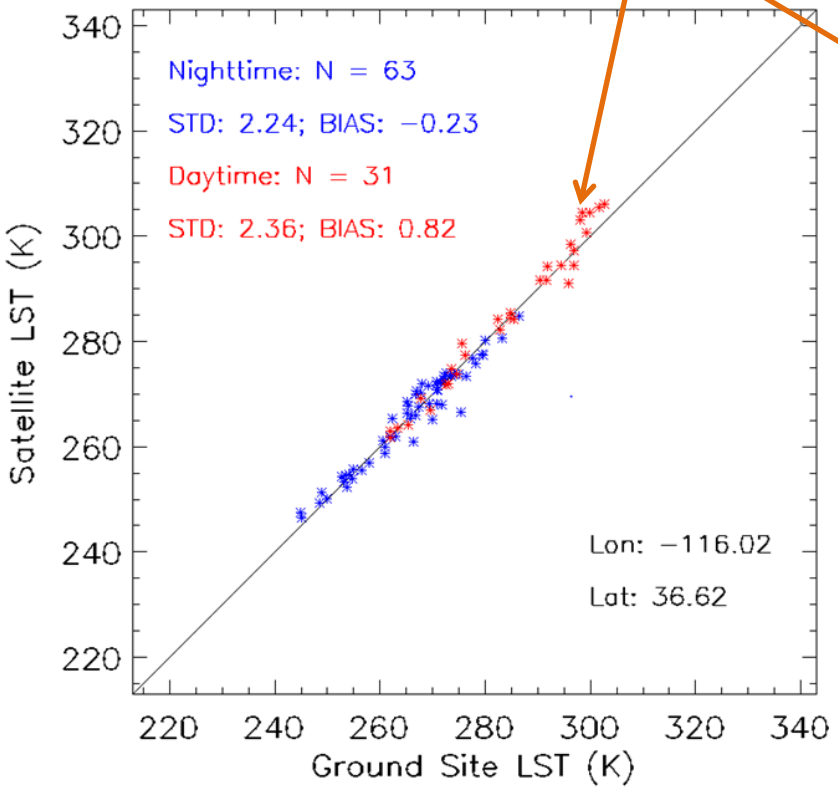
Caution: Time difference is a significant impact; granule level comparison is needed.

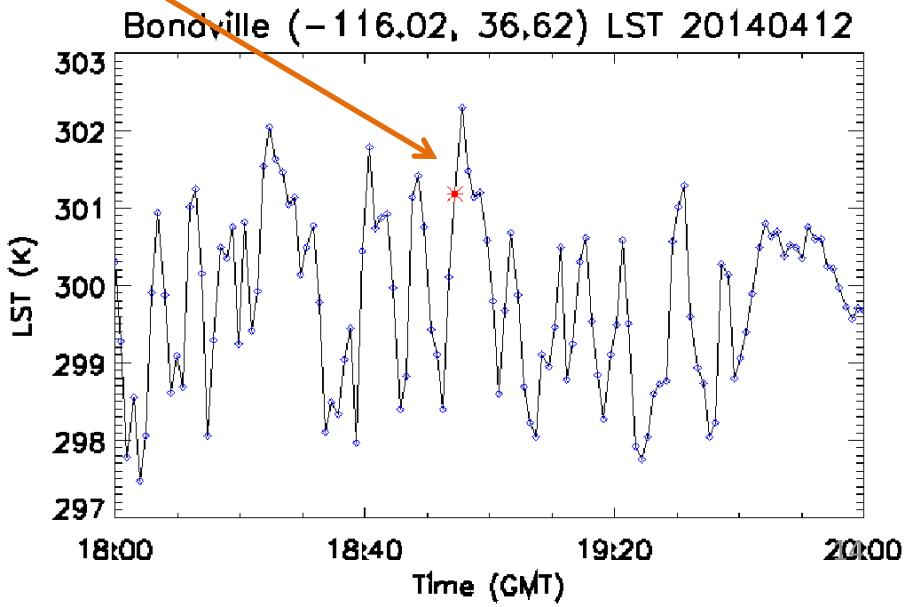
Issues – In Situ Comparison

Impact of Ground Data Fluctuation

The ground LST estimate can be fluctuated significantly, resulting big match-up uncertainty (~6K)







Summary

- Split Window LST(SWLST) is applied for VIIRS LST production
- Provisional release
  - Provisional version delivery done in 07/2013, in production in 10/2013
  - Errors found in 10/2013, switch back to beta in 11/2013
  - Provisional update delivery in 02/2014, in production in 04/2014
- Evaluation underway
  - Cross-satellite comparisons (MODIS LST product)
  - Ground data comparisons
    - Comparisons with SURFRAD LST estimates
    - Comparisons with individual field data
  - Radiance-base comparisons
  - Monitoring tool in use
- Issues found
  - Algorithm issues
    - significant impact from the Type EDR
    - Emissivity impact to LST (vs. to SST)
  - Validation issues
    - impact of time difference in cross-satellite comparison
    - limitation of ground data quality: heterogeneity.
- Cloud Mask Impact: cloud mask not reliable yet

Path Forward

- Monitoring of the provisional LST production
- Continue the evaluation and validation of provisional LST product
  - *Global coverage of in situ validation*
  - *Upscaling model improvement*
  - *Users feedback*
- The further improvement before the validated version
  - *Improve the quality further over surface types especially those without ground in-situ as a reference.*
  - *Improved quality control procedure for regression analysis*
  - *Address the water vapor correction*
  - *Investigate on the possible improvement of the LST algorithm*

END