



JPSS LAND SURFACE TEMPERATURE EDR

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UMD/CICS

- Cal/Val Team Members
- JPSS LST Production
 - Algorithm/Product Overview
 - Algorithm Improvement
- Validation and Monitoring
- S-NPP LST reprocessing
- JPSS-1 Readiness
- Gridding LST product development
- External Cooperation
- Summary and Path Forward

Cal/Val Team Members

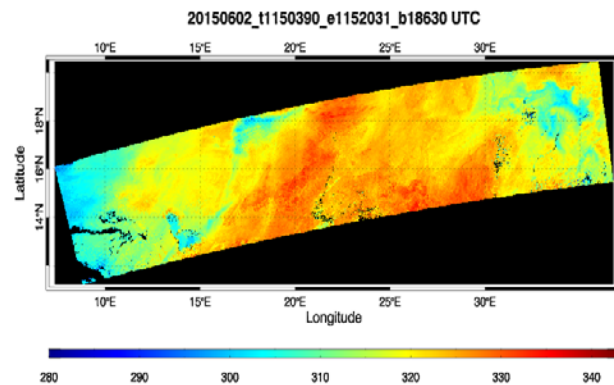
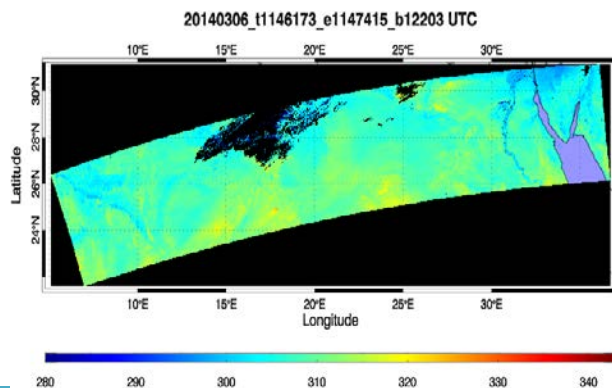
PI	Organization	Team Members	Roles and Responsibilities
Ivan Csiszar	NOAA/NESDIS/SATR		Land Lead, Project Management
Yunyue Yu	NOAA/NESDIS/SATR		LST Lead, algorithm development, validation, user promotion, team management
	NOAA Affiliate, UMD/CICS	Yuling Liu	product monitoring and validation ; algorithm development
	NOAA Affiliate, UMD/CICS	Heshun Wang	algorithm improvement, emissivity development
	NOAA Affiliate, UMD/CICS	Peng Yu	product validation, monitoring tool
Walter Wolf	NOAA/NESDIS/SATR		STAR ASSIST Lead, System Integration/transition
		Valerie Mikles	System Integration, Transition
Michael Ek	NOAA/NCEP/EMC		Model application Lead
		Weizhong Zheng	User readiness : Model albedo application, verification
		Yihua Wu	User readiness : Model albedo application, verification
Miguel Roman	NSAS/GSFC		NASA Land Science Investigator-led Processing System Lead
		Sadashiva Devadiga	System support, product monitoring

VIIRS LST Algorithm Overview

IDPS LST Algorithm

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

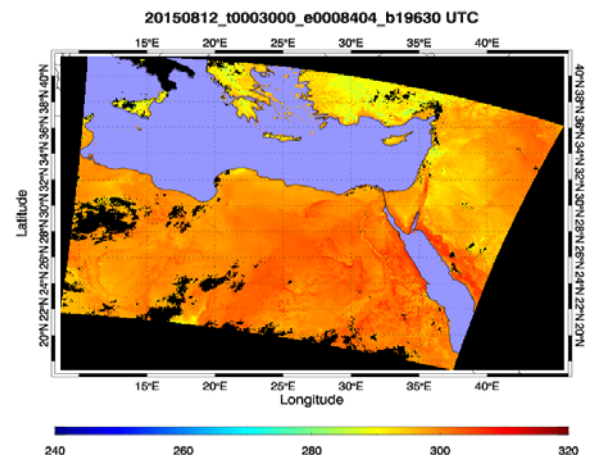
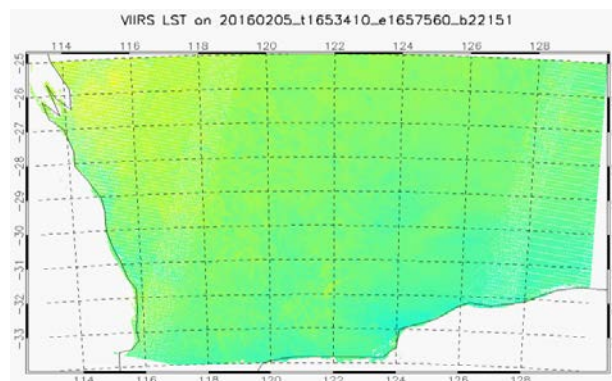
Where a_k (with $k=0$ to 4) are coefficients depending on surface type (with $i=0$ to 16 for 17 IGBP surface types) and day/night condition (with $j=0$ to 1), and θ is satellite viewing zenith angle.



Enterprise LST Algorithm

$$T_s = A_0 + A_1T_{11} + A_2(T_{11} - T_{12}) + A_3\varepsilon + A_4\varepsilon(T_{11} - T_{12}) + A_5\Delta\varepsilon$$

Where A_k (with $k=0$ to 5) are coefficients stratified by day/night, viewing angle and precipitable water vapor. ε and $\Delta\varepsilon$ are the mean and difference of the spectral emissivity of the two split windows. T_{11} and T_{12} are brightness temperature at $11\mu\text{m}$ and $12\mu\text{m}$.



Improvement: Enterprise Algorithm Status

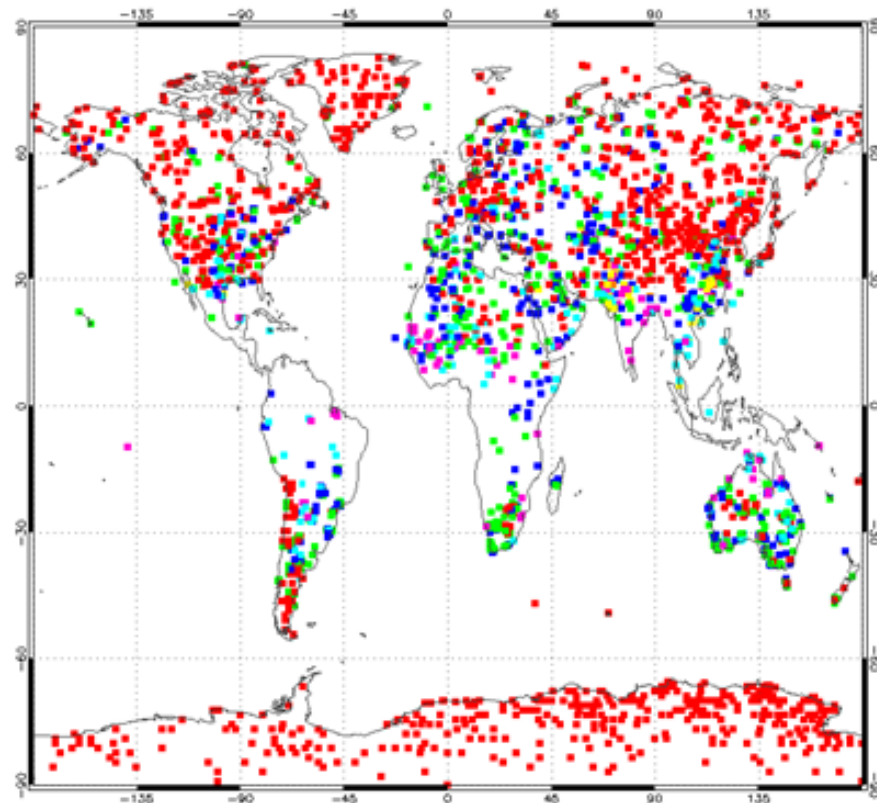
- Enterprise LST algorithm is ready for implementation
 - Algorithm test, uncertainty and sensitivity analysis has been performed
 - Consistent quality flags
 - Preliminary tests using real satellite data from multiple sensors including VIIRS, MODIS, AHI and SEVIRI have been conducted.
 - Preliminary validation with in-situ observations from SURFRAD, BSRN, ARM and GMD, and cross satellite comparisons using the above satellite data.
- The enterprise LST algorithm has gone through the critical design review; test readiness review will be conducted by Aug 24th.
- The DAP files are ready to deliver, which includes the science code, test data, LUT, configuration file, input and output I-O structure etc. The system integration is undergoing.
- The first version of the enterprise LST ATBD has been completed.

Improvement: Simulation Database

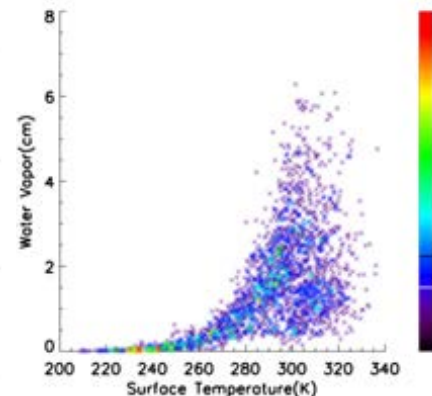
Improvements on the global representativeness of the simulation database with regard to the regional climate, water vapor range, elevation and seasonality etc.

- TIGR collection: v3.0, 2311 profiles in total
- SEEBOR collection: v5.0, 15704 profiles in total.

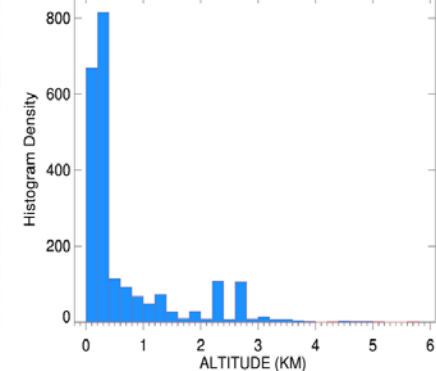
SEEBOR Selected Profiles Tpw Distribution: (4668)



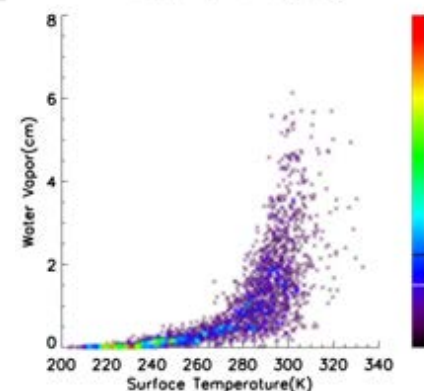
SEEBOR Tpw vs Ts (2230)



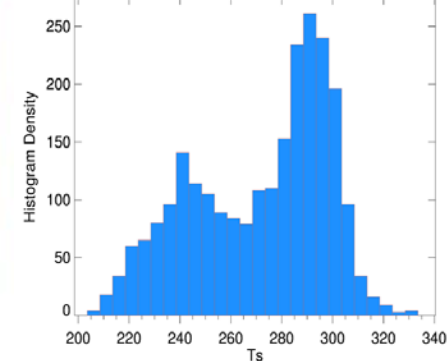
SEEBOR Altitude Histogram (2230)



SEEBOR Tpw vs Ts (2433)

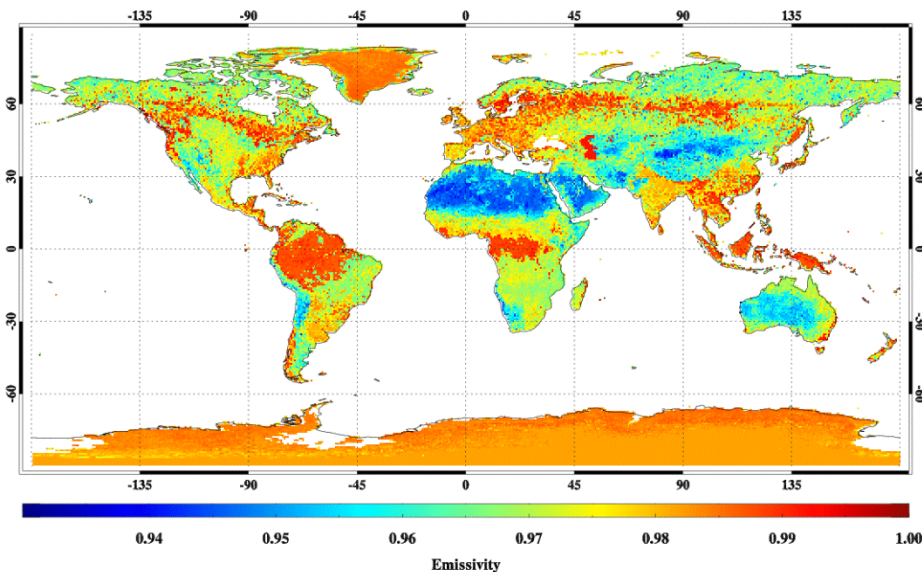


SEEBOR Ts Histogram (2433)

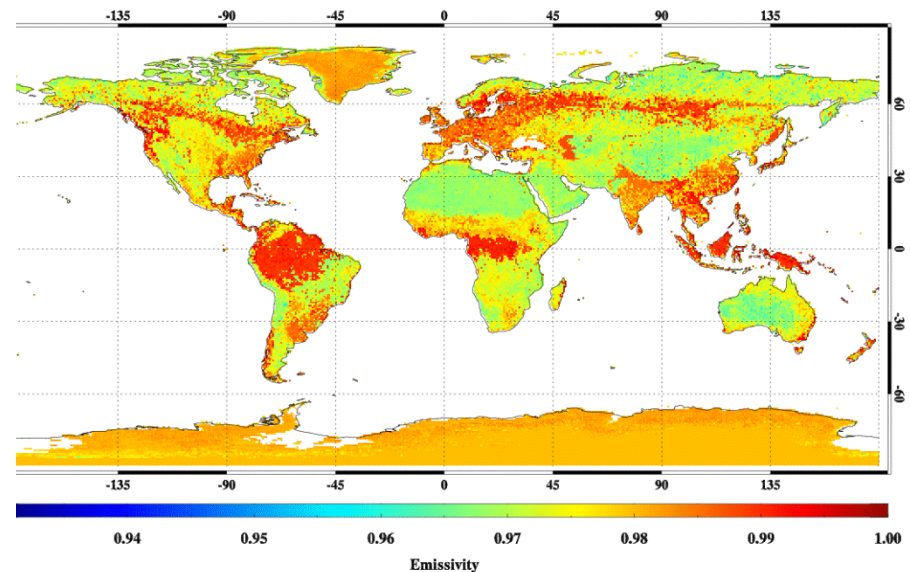


- **Emissivity algorithm is developed and implemented**
 - Using historical emissivity products to generate background emissivity climatology.
 - Employing a relationship between emissivity and GVF & Snow fraction to account for dynamic change.
 - Produce high resolution (0.009 degree) daily emissivity product for JPSS mission, and GOES-R mission as well.

VIIRS M15 Daily Emissivity of 2014, DOY = 073



VIIRS M16 Daily Emissivity of 2014, DOY = 073



Long Term Monitoring: ftp links

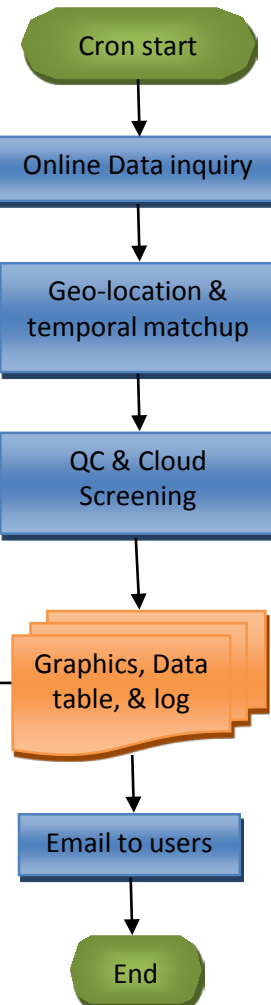
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VIIRS-Bondville_IL_2016121_yearly_color_Mx7.png	19.6 kB	5/3/16, 8:00:00 PM
VIIRS-Bondville_IL_2016121_yearly_color_Mx8.png	19.5 kB	5/3/16, 8:00:00 PM
VIIRS-Bondville_IL_2016121_yearly_diff_timeseries.png	24.6 kB	5/3/16, 8:00:00 PM
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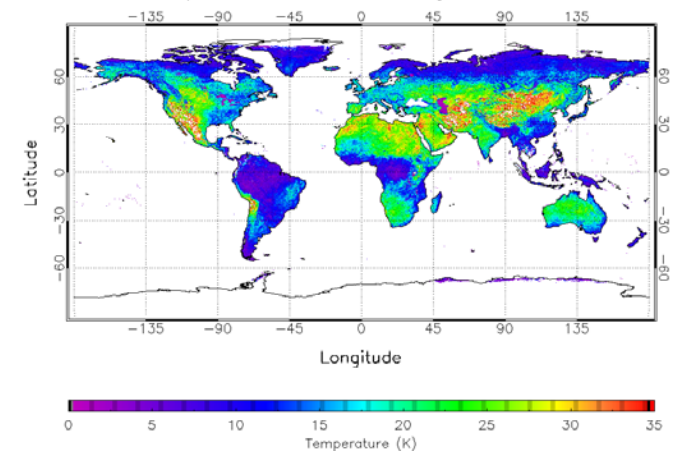
From lstmonitor.awg@gmail.com
Subject **SNPP VIIRS LST monitoring results: 20170717 to 20170723** 7/26/2017 4:11
To heshun.wang@noaa.gov, Me, yunyue.yu@noaa.gov, peng.yu@noaa.

The LST monitoring task for SNPP VIIRS has been completed. The period for monitoring is 20170717 to 20170723. Please visit ftp://ftp.star.nesdis.noaa.gov/pub/smcd/emb/pyu/LTM/single/SNPP_VIIRS/site/ for detailed results.

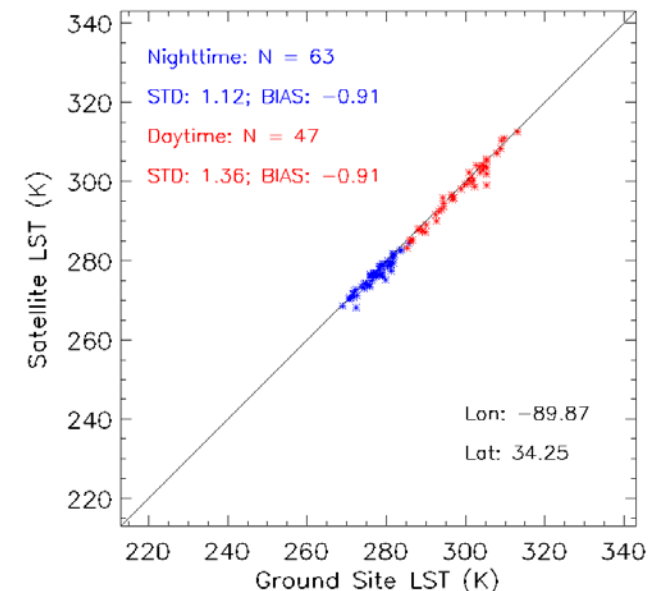
44 valid data pairs have been found.
Some problems have been found and listed as follow:
Bondville_IL: date = 20170717; time = 1929; lst_diff = -7.15;
lst_sat = 298.72; lst_gnd = 305.87; cloud = 1; cloud_3x3 = 3;
std_bt11_3x3 = 3.22; std_dwt_site = 4.00;
Goodwin_Creek_MS: date = 20170720; time = 1831; lst_diff = -6.80; lst_sat = 302.27; lst_gnd = 309.07; cloud = 0; cloud_3x3 = 3; std_bt11_3x3 = 3.21; std_dwt_site = 3.55;



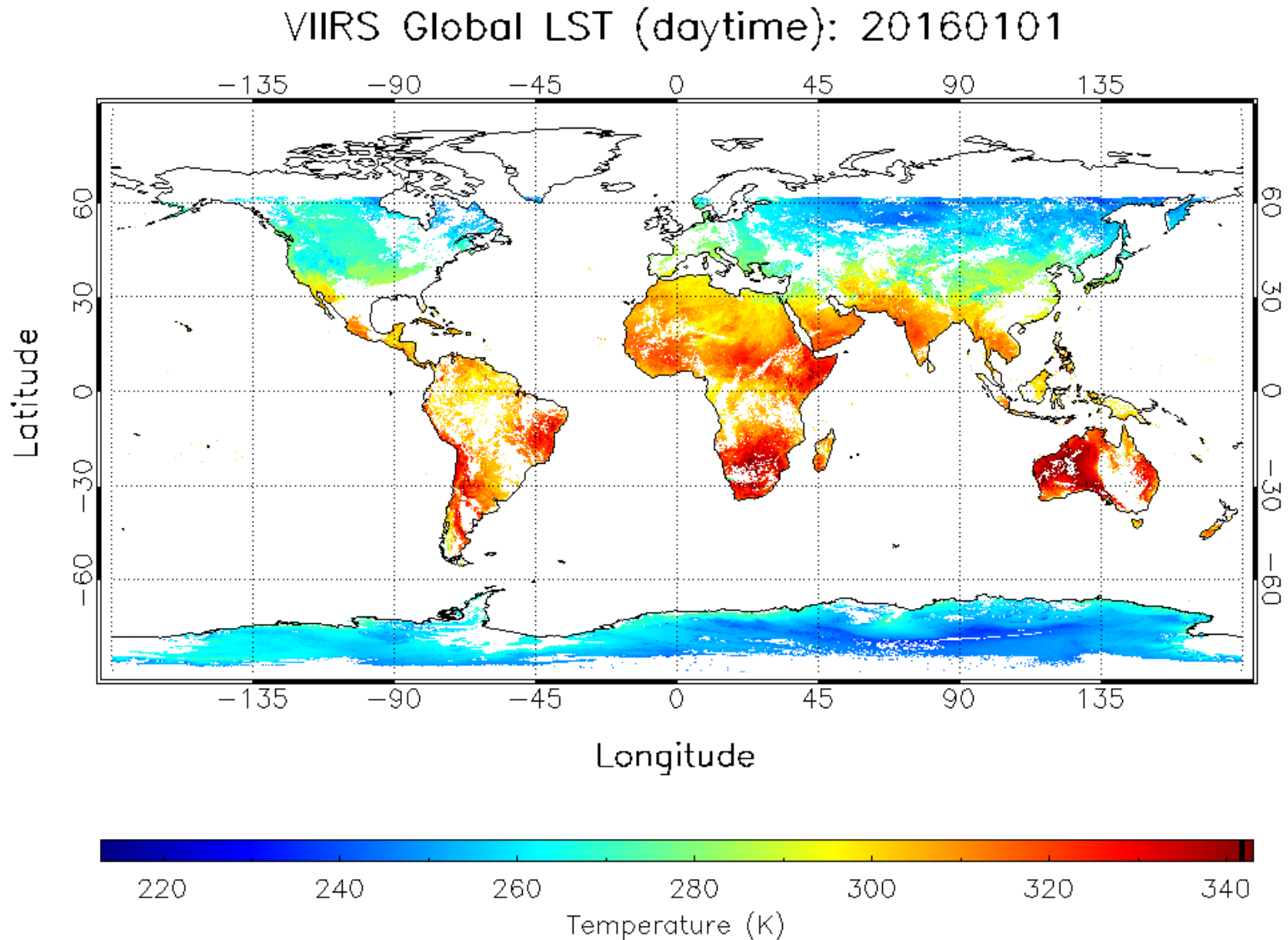
Global Monthly mean diurnal LST range from VIIRS: 201705



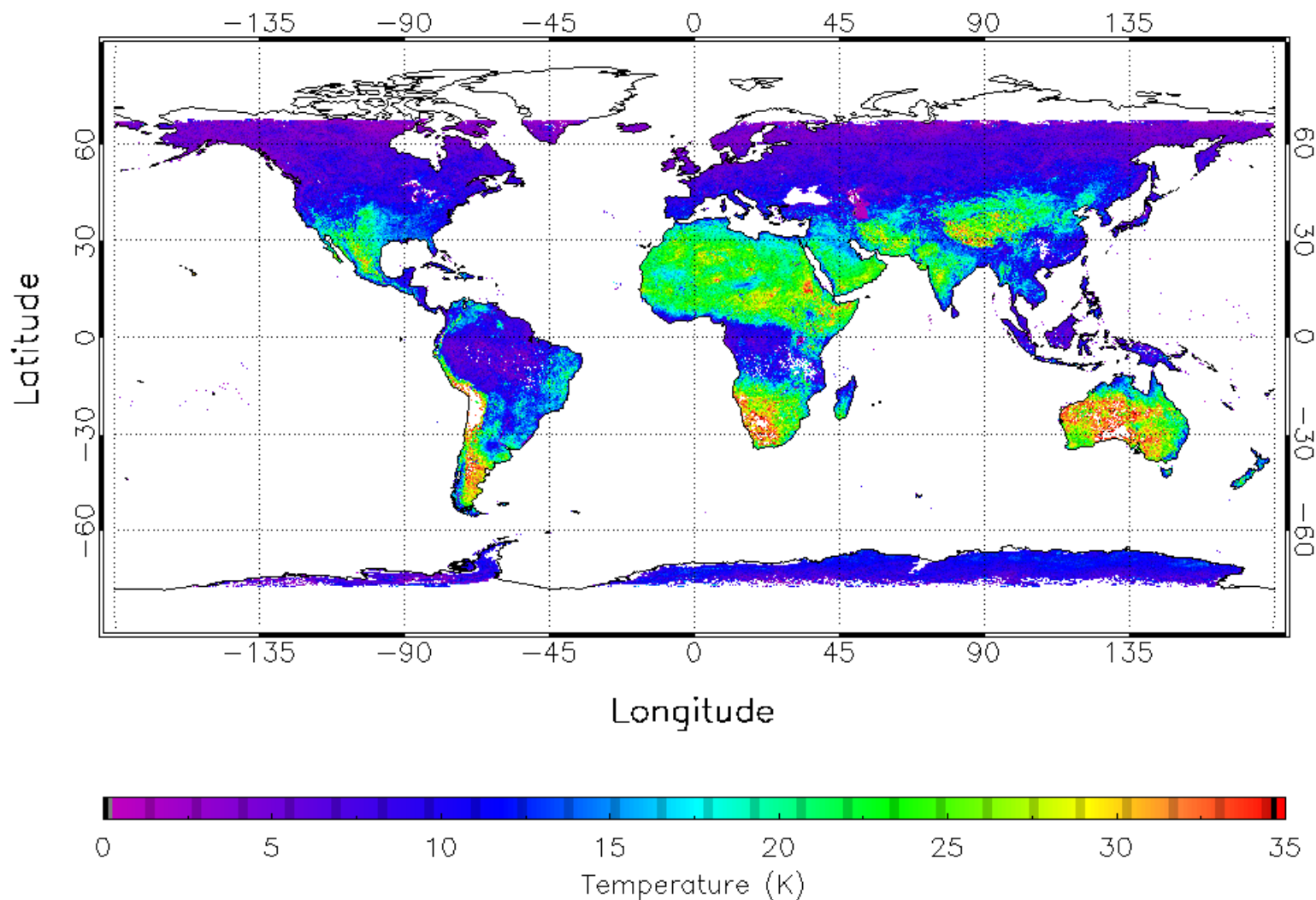
VIIRS v.s. Desert_Rock_NV: 2016001-2016121



ftp://ftp.star.nesdis.noaa.gov/pub/smcd/emb/pyu/VIIRS_monitoring/current/year/

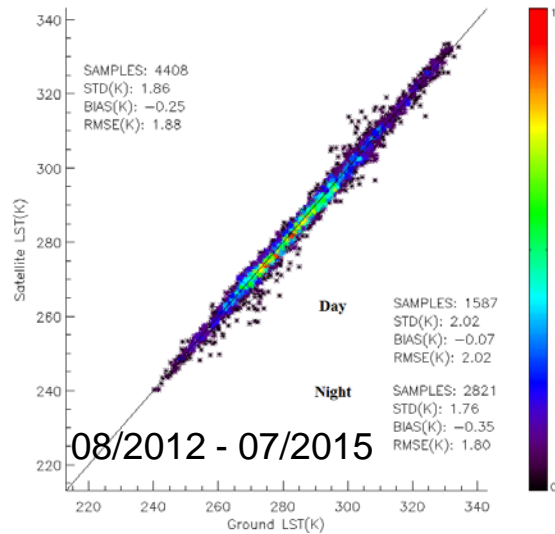


Global Monthly mean diurnal LST range from VIIRS: 201601

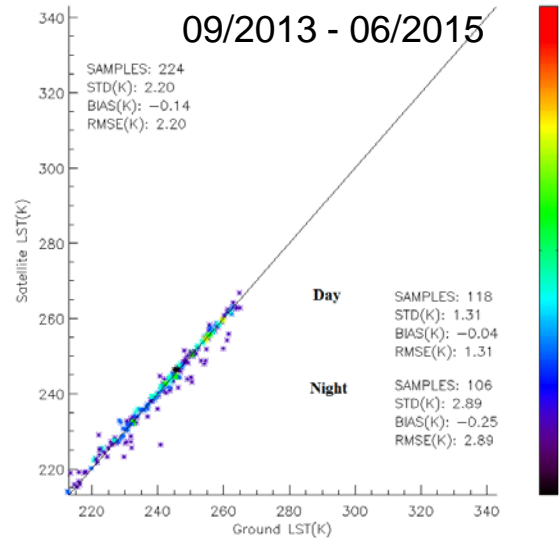


Validation and Evaluation

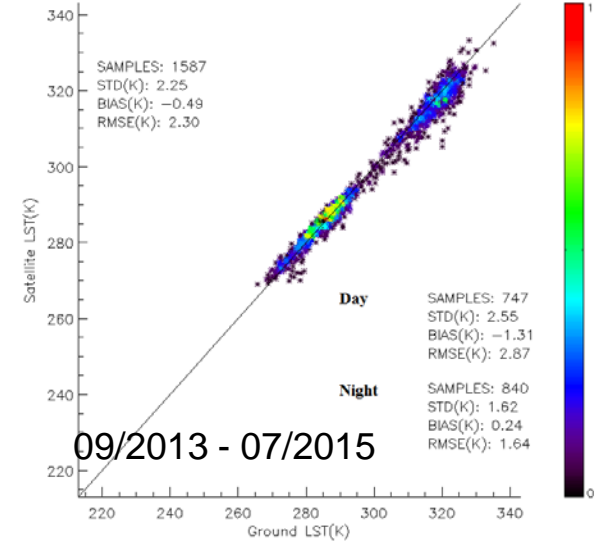
VIIRS LST(enterprise) vs Ground LST (SURFRAD)



VIIRS LST(enterprise) vs Ground LST (GMD-SUM)

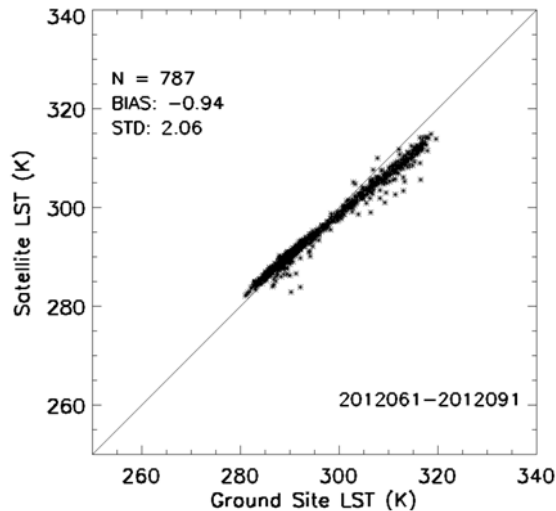


VIIRS LST(enterprise) vs Ground LST (BSRN)

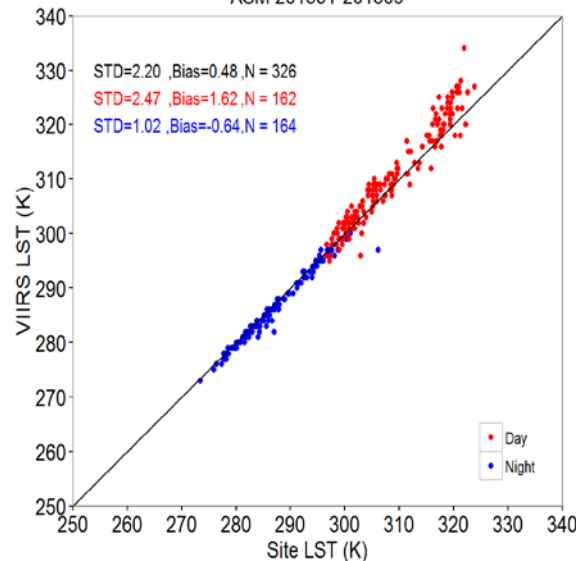


Enterprise VIIRS LST against ground data from SURFRAD, BSRN and GMD

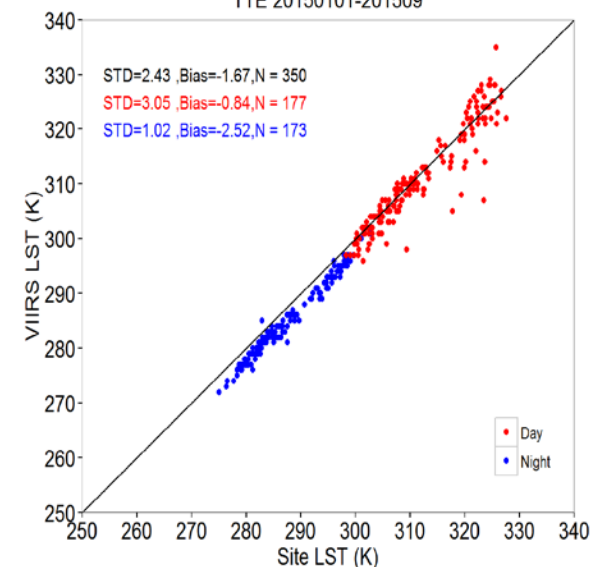
Enterprise SEVIRI LST vs Heimat



ASM 201501-201509



TTE 20150101-201509



Enterprise SEVIRI and VIIRS LST against ground data from KIT(left) and OZFlux(Middle and Right)

Reprocessing Status

- Investigated three weeks of reprocessed SDR data and its impact on LST product.
 - Investigation results have been presented in the reprocessing workshop
 - The brightness temperature of the band 15 and band 16 and geometry data are investigated and the statistics of the difference between the reprocessed SDR and the operational SDR are summarized.
 - It is found that the reprocessed sdr data in 2012 will cause a significant LST change at local scale under specific time span.
- Reprocessing is planned for LST derived from the enterprise algorithm for the time period from 11/19/2012 to present.
- Based on the reprocessing of the upstream data: SDR, enterprise cloud mask and AOD and the availability of the ancillary data such as total precipitable water and snow/ice information .

JPSS-1 Readiness (1)

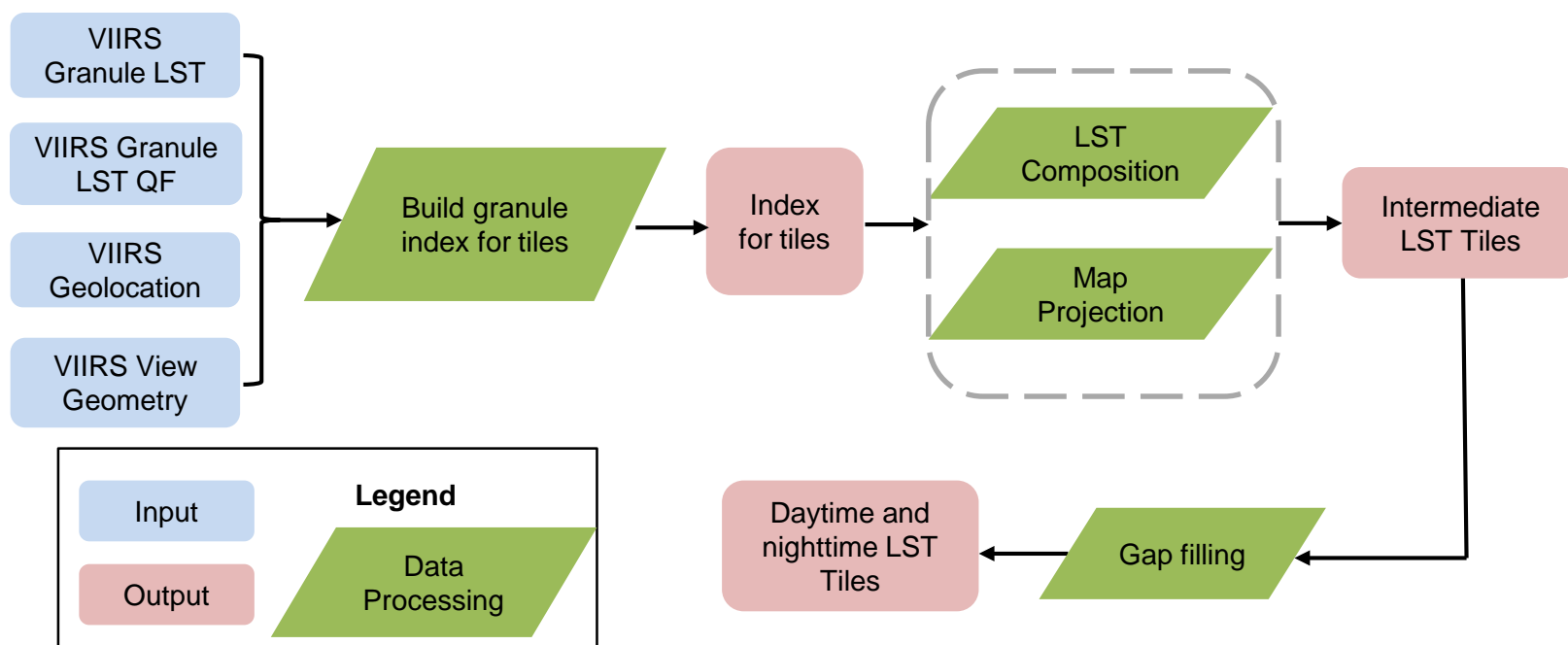
- ❑ Enterprise LST algorithm will be run at NOAA NDE system to replace the IDPS LST algorithm
 - Emissivity explicit algorithm
 - Consistent QC flags
 - Detail LUT dimension
 - Comprehensive evaluation and calibration
- ❑ Pre-launch Characterization
 - SNPP data serves as proxy for JPSS-1.
 - Simulation software package and database are updated for J-1 LST LUT generation
 - Calibration/validation/monitoring tools developed for SNPP are applicable for J1 mission
- ❑ Post-Launch Cal/Val Plans
 - In-situ validation: existing + new site data; domestic + international
 - Cross comparisons: S-NPP, MODIS, +Sentinel-3
 - Schedules and Milestones: based on the mission requirement

JPSS-1 Readiness (2)

- Major Risks/Challenges/ and Mitigation
 - The enterprise algorithm may not be able to run by Sept. 2017, as scheduled
Mitigation: Current IDPS LST algorithm will be kept running before then
 - Availability of full resolution GVF data for the emissivity data generation
Mitigation: full resolution GVF product is in development
 - Available water vapor data is in coarse resolution and forecast accuracy is unknown
Mitigation: theoretical analysis of the water vapor uncertainty on LST quality
 - Limitation on emissivity data evaluation and monitoring
Mitigation: limited in-situ validation; LST application ; LST monitoring tool for LSE
 - Lack of high quality, global validation data set.
Mitigation: continue data collection through international cooperation;
 - Cloud contamination impact
Mitigation: additional cloud filtering in deep-dive validation
- Collaboration with LST community and Stake Holders/User Agencies
 - Keep a close contact with ground data measurements providers for data quality issues and data stream anomalies
 - Provided technical support for user's questions in their applications.
 - Actively working with EMC/NCEP users and External Users

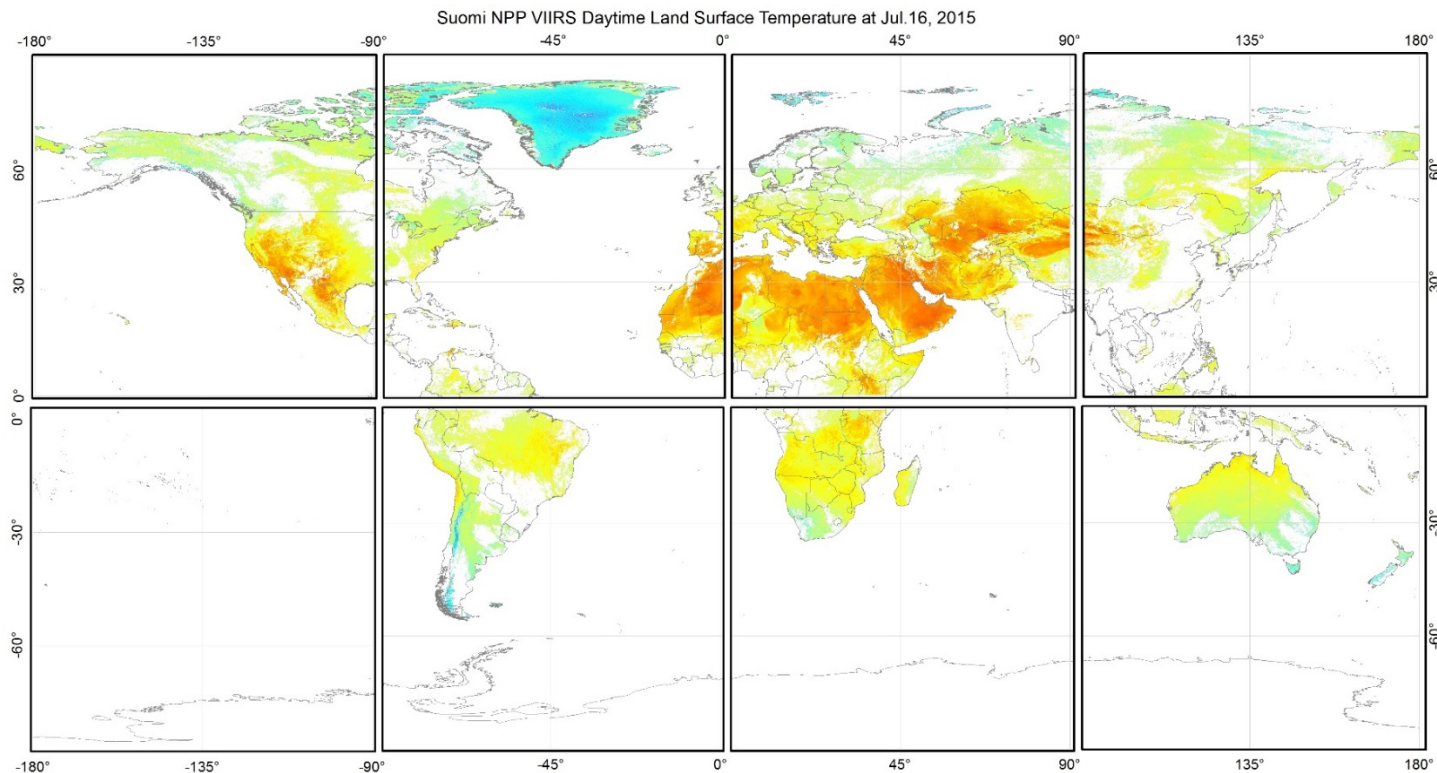
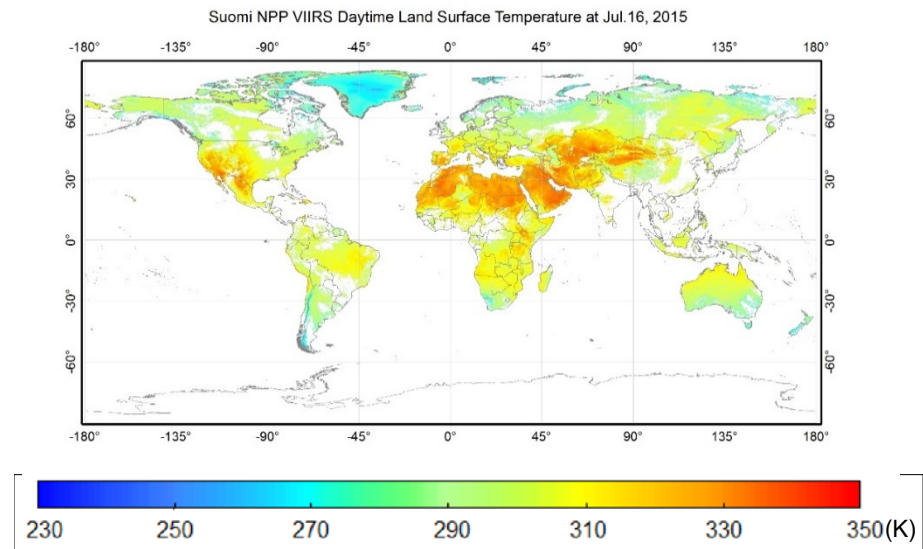
Gridded LST Development

- From Users: a global continuous gridded LST product is required, in addition to the current granule LST data.
- An investigation was performed on developing a Level-3 VIIRS Gridded LST product, with intensive user interactions; major product features were determined:
 - Global coverage with two spatial resolutions: 0.009 degree and 0.036 degree
 - Gridded with tile system management
 - Gap-filled at invalid pixel (TBD)
 - Daytime and nighttime daily products.



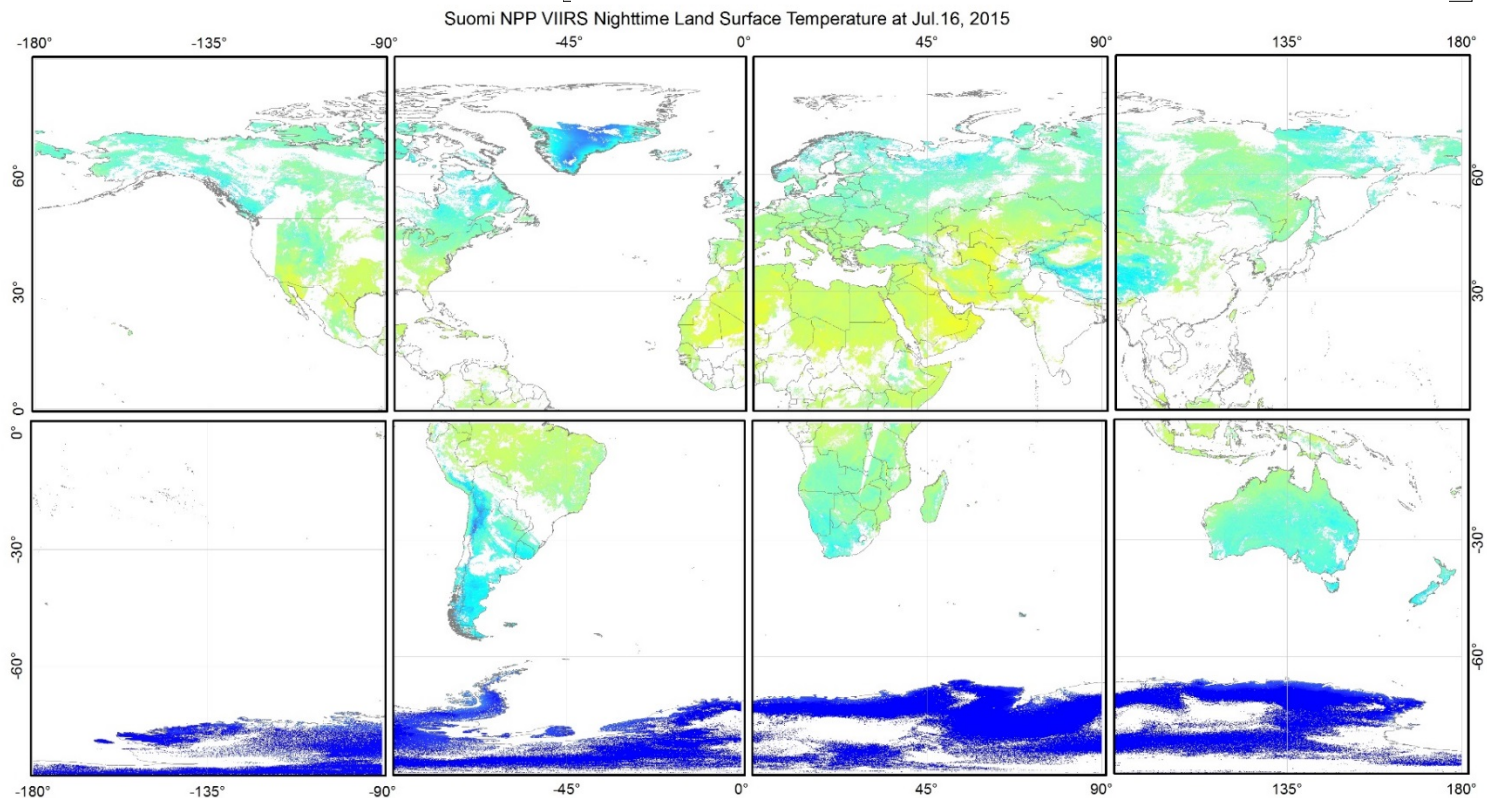
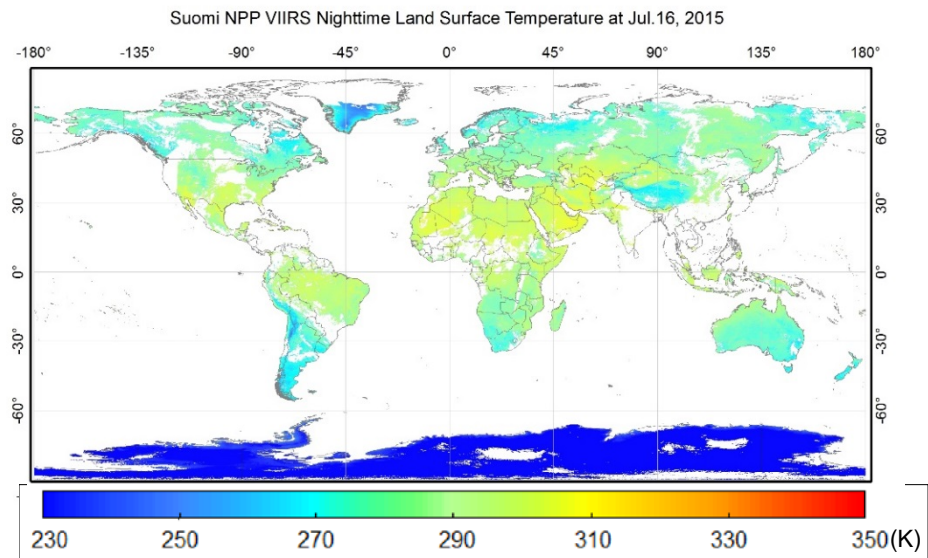
4km Gridded VIIRS Land Surface Temperature for daytime

1km Gridded VIIRS Land Surface Temperature for daytime
(4x2 tiles for globe)



4km Gridded VIIRS Land Surface Temperature for nighttime

1km Gridded VIIRS Land Surface Temperature for nighttime
(4x2 tiles for globe)



External Cooperation

Comprehensive VIIRS/LST vs SEVIRI/LST comparison

One year VIIRS subset data over 6 areas in Europe and Africa is used for the comprehensive cross comparison between VIIRS and SEVIRI LST. The result has been presented in EGU 2017.



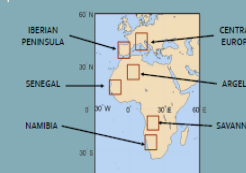
Comparison of S-NPP VIIRS Land Surface Temperature with SEVIRI

Sofia L. Ermida (1), Isabel F. Trigo (1,2), Ana C. Pires (2), Yuling Liu (3), Yunyue Yu (3)

(1) Instituto Dom Luiz (IDL), University of Lisbon, Portugal, (2) IPMA – Instituto Português do Mar e da Atmosfera, Portugal, (3) Center for Satellite Applications and Research, NOAA/NESDIS, USA

Abstract

Land surface temperature (LST) is one of the key parameters in the physics of land surface processes. LST can be globally measured from space by infrared radiometers, with a wide range of spatial and temporal resolutions depending on the sensor design and orbit. The Visible Infrared Imaging Radiometer Suite (VIIRS) instrument is the primary sensor onboard the Suomi National Polar-orbiting Partnership (S-NPP) satellite, which was launched in recent years. VIIRS was designed to improve upon the capabilities of the operational AVHRR and provide observation continuity with MODIS. A Split Window approach has been applied to the VIIRS moderate resolution channels M15 and M16 centered at 10.76 μm and 12.05 μm , respectively. VIIRS has a swath of 3000 km and a spatial resolution of 750 m (nadir) up to about 200 m (polar view), leading to relatively high re-visiting frequency. LST is retrieved for a wide range of viewing angles along the VIIRS path, allowing the study of the variability of LST with viewing geometry for various land cover types. Here we present a comparison of VIIRS LST data with data provided by the Spinning Enhanced Visible and Infrared Imager (SEVIRI) on-board EUMETSAT's Meteosat Second Generation (MSG). SEVIRI-based LST is available every 15-minute, but at coarser spatial resolution (3-km at nadir) when compared to VIIRS LST. The analysis is performed over 6 areas over the SEVIRI disk characterized by different surface conditions. VIIRS has generally slightly warmer nighttime LST compared with SEVIRI, with differences smaller than 2K. Larger differences are found during daytime, with VIIRS presenting overall lower LST values up to 5K. These differences are also analyzed taking into account the surface type, view zenith angle (VZA) and topography. As seen in previous comparison studies, high VZA and elevation values are associated to higher discrepancies of the LST products.



LST algorithms

SEVIRI

- Split Window Algorithm
- Channels: 10.8 μm and 12 μm
- Day/night coefficients
- Coefficients depend on land cover type
- Fixed emissivity for each cover type (implicit)
- Atmospheric effects are corrected through the term of square difference of temperature between channels
- Explicit dependence on view zenith angle

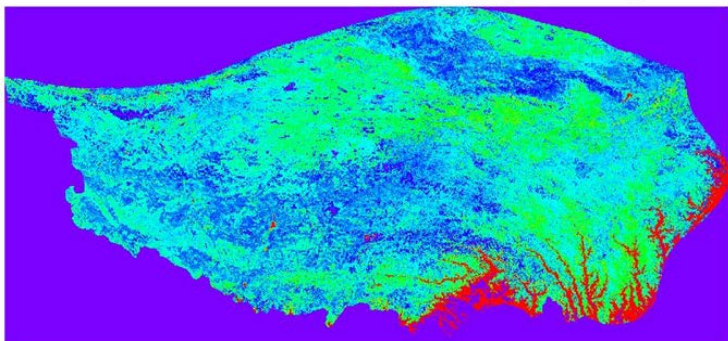
VIIRS

- Split Window Algorithm
- Channels: 11 μm and 12 μm
- Day/night coefficients
- Coefficients depend on land cover type
- Fixed emissivity for each cover type (implicit)
- Atmospheric effects are corrected through the term of square difference of temperature between channels
- Explicit dependence on view zenith angle

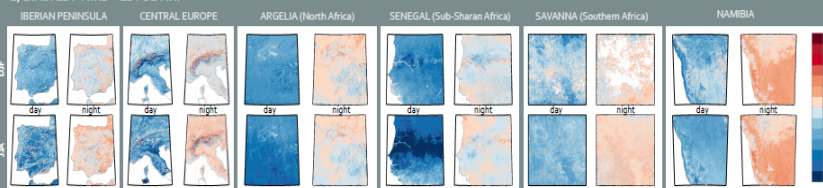
Above: Satellite LST is compared to the model LST output in time series

Bottom: VIIRS LST is used for the analysis of seasonal and diurnal cycle of freeze/thaw over Tibet Plateau area

Difference of Frozen days (LST-L05)

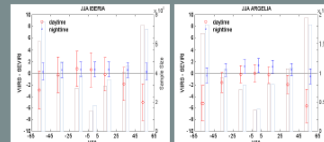


1) BIAS: LST VIIRS – LST SEVIRI



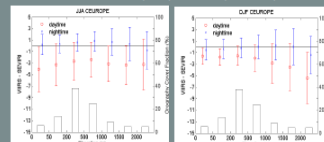
2) View Zenith Angle (VZA) dependence

VIIRS – SEVIRI LST bias (dots) and STD (whiskers)



3) Elevation dependence

VIIRS – SEVIRI LST bias (dots) and STD (whiskers)



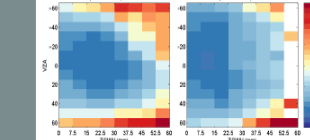
- Asymmetric dependence around 0° and no nighttime dependence suggest a dependence related to geometric (shadowing) effects
- Symmetric dependence for day and night suggests a dependence related to emissivity anisotropy

- There is an increase of the biases with elevation, especially during winter

- During daytime, VIIRS LST is overall lower than SEVIRI, with biases around 5K
- Nighttime biases are lower (around 1K) and SEVIRI LST is generally lower
- Some areas present patterns associated to surface topography and land cover
- The high day/night contrast may be attributed to the use of different algorithms for day/night by VIIRS

4) Total Column Water Vapour (TCWV) dependence

VIIRS – SEVIRI LST RMSE



- Strong increase of LST differences for high VZAs and TCWV
- These discrepancies are likely related to the different methodologies to correct atmospheric effects
- In situ validation of SEVIRI LST reported RMSE values below 2.5 K for these areas (Göttsche et al., 2016)

High daytime biases (around 5 K) with VIIRS LST lower than SEVIRI

Lower nighttime biases (around 1K) with VIIRS LST higher than SEVIRI

High increase of the LST differences with VZA related to shadowing effects and emissivity anisotropy

Increase of the LST differences with elevation related to the high heterogeneity of the surface

Increase of the LST differences with TCWV related to the different methods of atmospheric correction

References: Göttsche, H. M., Olesen, F. S., Trigo, I. F., Bank-Ullrich, A., & Moritz, M. A. (2016). Long-Term Validation of Land Surface Temperature Retrieved from MSG/SEVIRI with Continuous In-Situ Measurements in Africa. Remote Sensing, 8(2), 101.

Acknowledgments: This study was performed within the framework of ESA CLUE Data Temperature project and of the LSA SAF project, co-funded by ESA/ESR/CLUE. Research of Sofia L. Ermida was supported by the Portuguese Science Foundation (FCT) through a PhD grant (BPD/162/2016/00000).

VIIRS LST data available at <https://lvisland.gsfc.nasa.gov>

SEVIRI LST data available at <https://landsaf.ipma.pt/>

❑ SNPP LST performance

- The SNPP LST marginally meets the mission requirements based on the validation results
- Validation tools are run regularly for routing monitoring and web info update
- Working with EMC/NCEP for the model verification
- International cooperation with ESA/EUMETSAT LST groups for the cross comparison to Sentinel-3 LSTs and SEVIRI LSTs

❑ Enterprise LST algorithm progress

- The enterprise LST algorithm development went CDR in Sep. 2016, TRR in Aug 2017, ARR in Sept. 2017.
- The DAP files are ready to deliver.
- Land surface emissivity has been developed to support the enterprise LST.
- The first version ATBD for the enterprise LST and LSE are ready.

❑ Reprocessing status

- Sample reprocessed SDR data has been investigated and its impact on LST has been evaluated.
- Enterprise algorithm will be used for the reprocessing for LST consistency

❑ JPSS-1 readiness

- All the validation tools and simulation tools/database are ready for the J-1 mission
- J-1 LST production in NDE will be based on the Enterprise Algorithm
- J-1 Cal/Val plan has been reviewed

❑ Gridded LST development

- Major features of the gridded LST product has been determined with major users
- Software architecture and technical solutions have been investigated
- A very preliminary code has been developed and tested; a simple version of the gridded LST production is running in a local server for current LST product monitoring purpose.
- LST diurnal model and temporal interpolation has been studied.

Future Plans/Improvements

- Operational implementation of gridded LST data production
- Pre/post operational review and support
- Final version of the enterprise LST ATBD and related documentations
- Final DAP delivery
- Reprocessing LST data when the enterprise algorithm and upstream data is ready.
- JPSS-1 LST product evaluation, monitoring and maturity support
- Emissivity Data evaluation
- In-situ site upscaling model study
- LUT improvement : detail clarification of the LUT dimension
- Further interactive with EMC/NCEP model team: intensive LST model verification
- Resume international cooperation