# STAR Algorithm and Data Products (ADP)
# Beta Review

# Suomi NPP Land Surface Temperature EDR Product

Yunyue Yu
LST EDR Lead

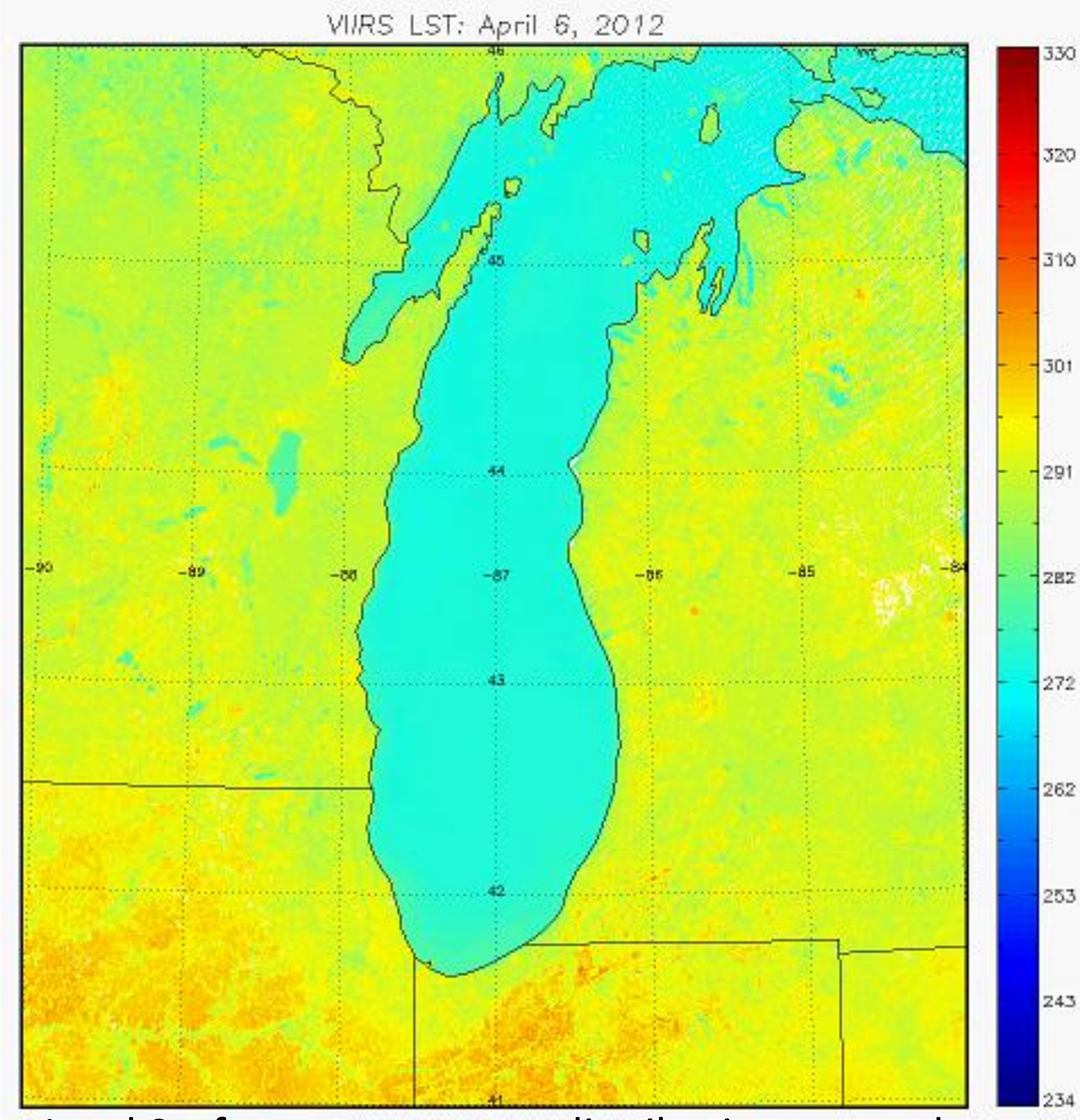
Dec. 19, 2012

# STAR ADP LST EDR Team Members

- Ivan Csiszar (NOAA/NESDIS/STAR) *STAR Land EDRs Chair, management*
- Jeff Privette (NOAA/NESDIS/NCDC) *product validation Lead*
- Yunyue Yu (NOAA/NESDIS/STAR) *STAR LST EDR lead, product monitoring and validation; algorithm development, project management*
- Yuling Liu (NOAA Affiliate, UMD/ESSIC) *product monitoring and validation ; algorithm development*
- Zhuo Wang (NOAA Affiliate, SciTech/IMSG) *algorithm development*
- Donglian Sun (GMU/Geography and GeoInformation) *Product evaluation*
- Youhua Tang (NOAA Affiliate, SciTech/IMSG) *ADL verification*
- Pierre Guillevic (NOAA Affiliate, NCSU/CICS) *product validation*
- Michael EK (NOAA/EMC/NCEP) *user readiness*
- Jesse Meng (NOAA Affiliate) *user readiness*

# Background of LST Product

- Land Surface Temperature (LST) is produced as Environmental Data Record (EDR) .
- Represents continuity with NASA EOS MODIS and NOAA POES AVHRR LST production, also with international missions such as (A)ATSR.
- VIIRS design allows for full 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.




Land Surface temperature distribution around Lake Michigan, 6, April 2012, 08:37 UTC.

# L1RD Requirements

| Land Surface Temperature | | |
|---|---|---|
| Attribute | Threshold | Objective |
| LST Applicable Conditions:<br>Clear only | | |
| a. Horizontal Cell Size | 4 km | 1 km |
| Nadir | *(800 m)* | *(500 m)* |
| b. Mapping Uncertainty, 3 Sigma | 1 Km at Nadir<br>*(800 m)* | 1 km at Edge of Scan<br>*(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) | |

# Major Users of LST product (Point of Contact)

- **U. S. Users:**
  - NOAA National Weather Service Environmental Modeling Center (Michael EK, Jesse Meng, Weizhong Zheng )
  - USDA Agricultural Research Services(Martha Anderson)
  - USDA Forest Service (Brad Quayle)
  - NOAA/NESDIS Center for Satellite Applications and Research (Jerry Zhan)
  - NOAA/NESDIS National Climate Data Center (Peter Thorne)
  - Academy -- University of Maryland (Konstantin Vinnikov, Shunlin Liang, Cezar Kongoli )
  - Army Research Lab ( Kurt Preston)

- **Foreign Users (coordinated by Earth Temp Network and GlobTemp User Consultation Network): – Edinburgh, UK , 2012**
  - ESA/ESRIN, Italy (Simon Pinnock & Olivier Arino)
  - Univ. Of Edinburgh, UK (Chris Merchant)
  - OBSPM, and LSCE, France (*Catherine Prigent & Carlos Jimenez, and Catherine Ottlé*)
  - *Universitat de les Illes Balears, Spain* (*Maria Antonia Jimenez Cortes*)
  - *eLEAF, The Netherlands (Henk Pelgrum & Wim Bastiaanssen)*
  - *Centre for Ecology and Hydrology, UK (Rich Ellis)*
  - *Institute of Geodesy and Cartography, Poland (Katarzyna Dabrowska-Zielinska)*

# Overview of LST Products

- LST is a full resolution product for each granule
- LST value is produced for each land surface pixel under cloud conditions of clear, probably clear, probably cloudy
- Since 10 August 2012, the baseline has been a split window algorithm. The previous baseline was a duel split window algorithm.
- This release has met the beta version product requirements:
  - *Early release product*
  - *Initial calibration applied*
  - *Minimally validated and may still contain significant errors (additional changes are expected)*
  - *Available to allow users to gain familiarity with data formats and parameters*
  - *Product is not appropriate as the basis for quantitative scientific publications, studies and applications*
- Several issues have been solved in the recent build (Mx6.2).
  - *Split window algorithm is used for baseline production.*
  - *The LUT has been updated : corrections for water body surface type*
- Assumption of the LST validation: VIIRS SDR is calibrated

# LST Processing Chain

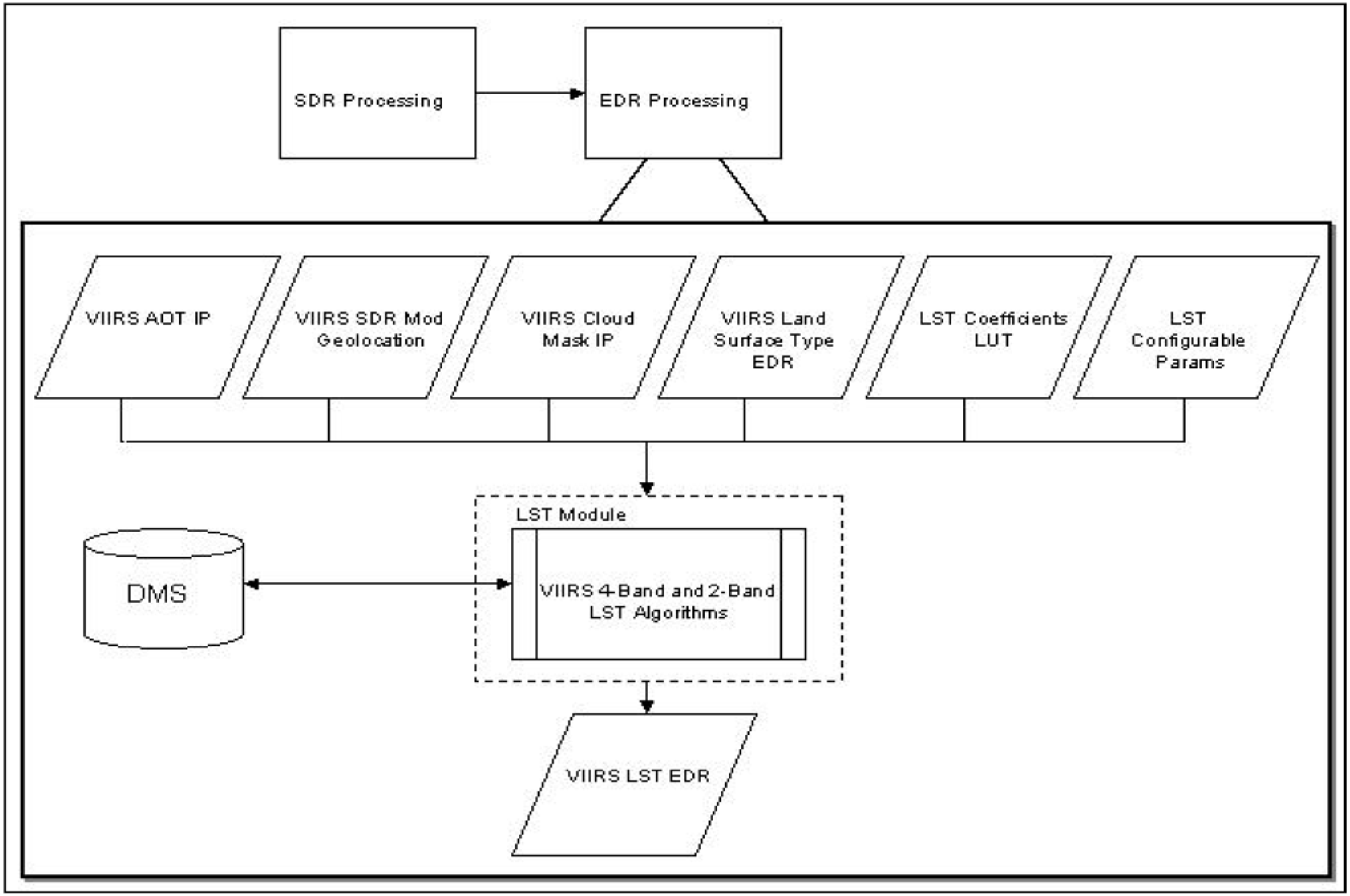



Figure 1. VIIRS LST OAD 474-00070 RevA 20120127

# LST Retrieval Flow Chart

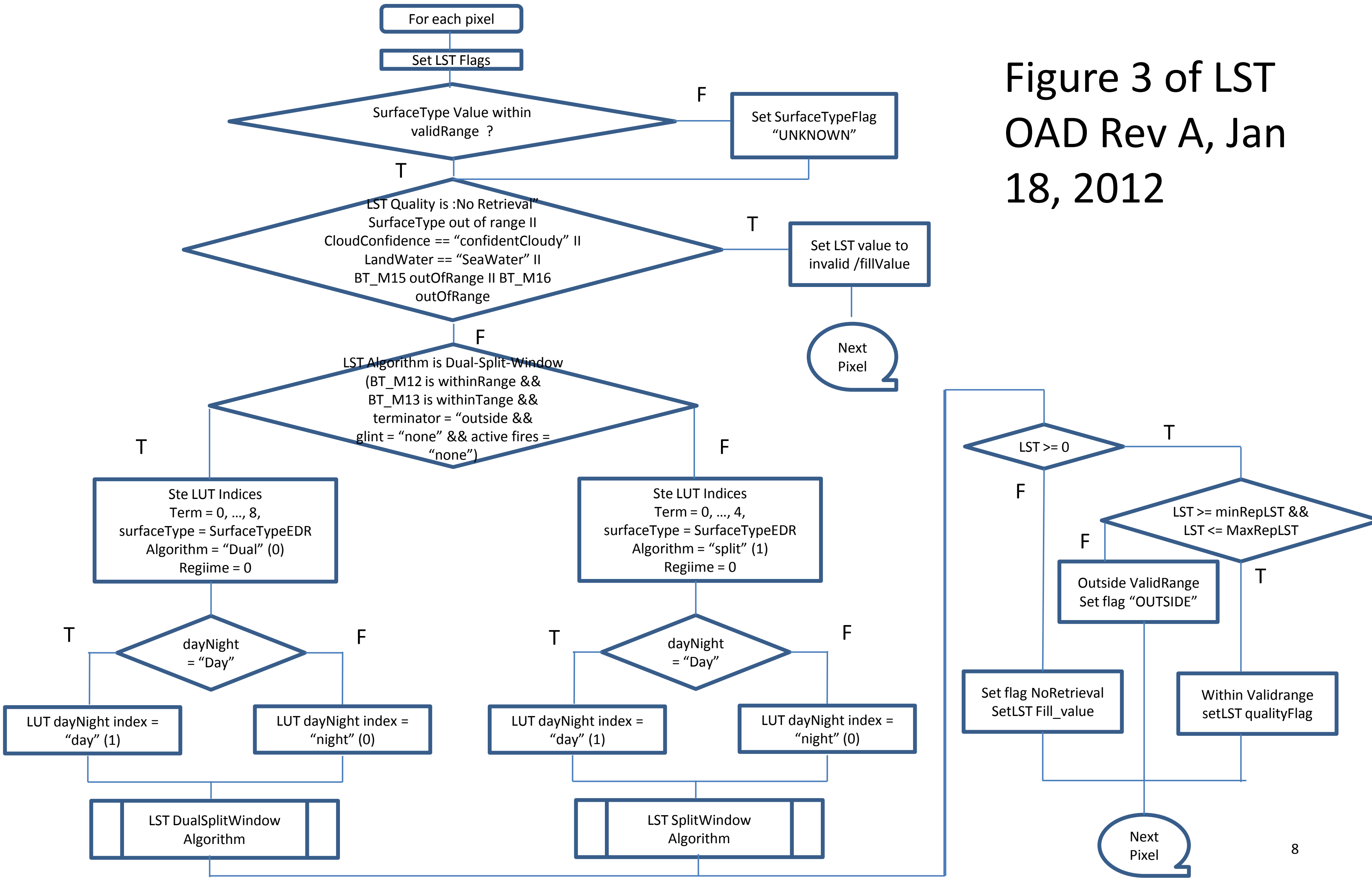



Figure 3 of LST OAD Rev A, Jan 18, 2012

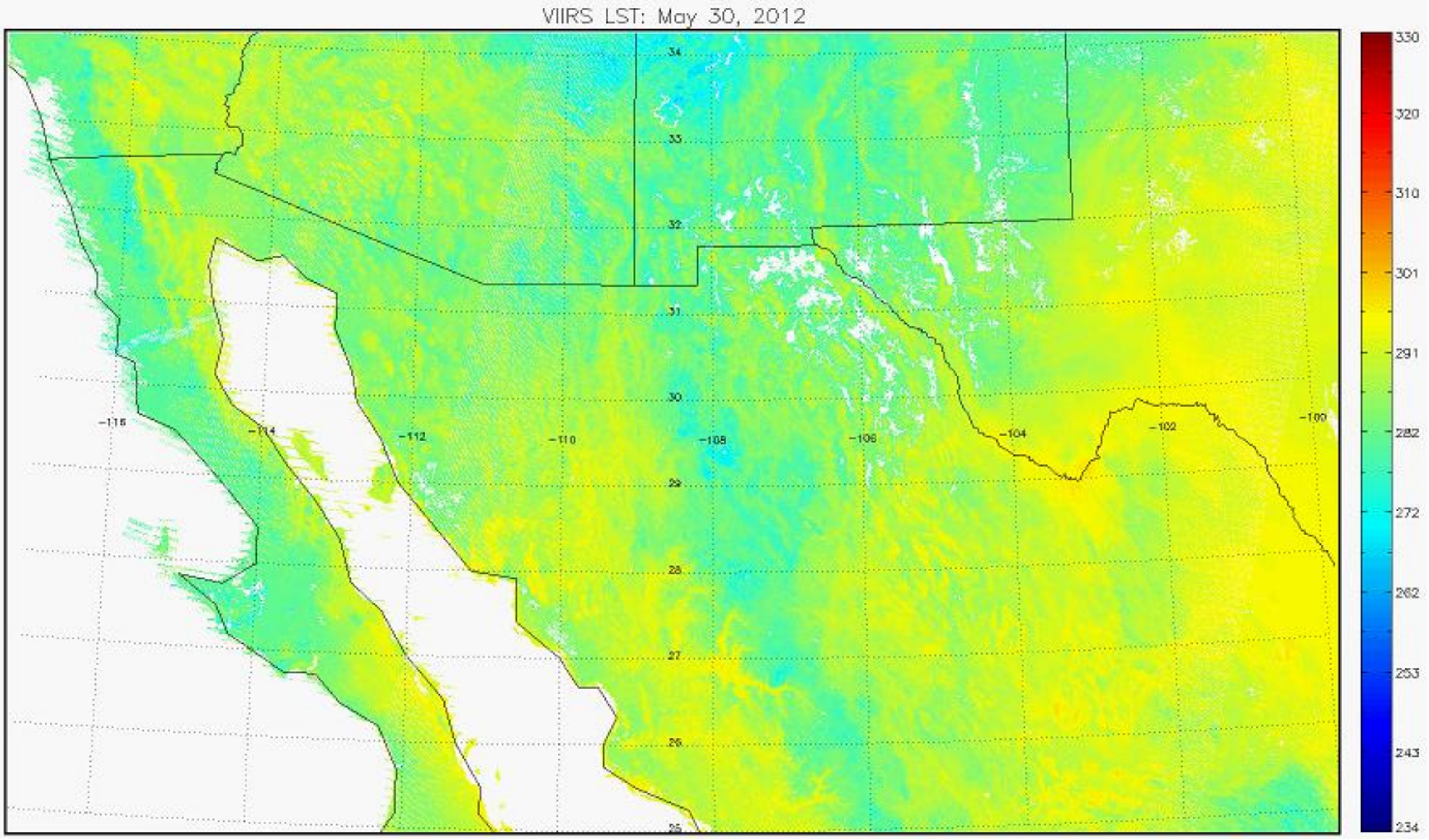
# History of Algorithm changes/updates

| Date | Update/DR# | Reason | Status |
|---|---|---|---|
| 02/28/12 | DR 4608 | Split-window algorithm - Baseline Coefficient files. LUT update #2 (same as"Updated LUT" in slides): DR 4608/CCR 12-0355: Corrects errors for both dual split window and split window. | **Closed .** Split Window algorithm turned to be baseline on 10 Aug, 2012. |
| 02/15/12 | DR 4582 | LST Day Night Land Water Misidentification, The LST EDR appears to have a coding error that may have incorrectly mixed up the Day/Night flag with the Land/Water and Surface Type QA Flag within the QF Byte 3 of the LST EDR... This same Day/Night flag is being correctly encoded in the bit3 of QF Byte1 of the LST EDR. | **closed** EDR team does not observe such error. Plan to close this DR. |
| 09/14/11 | DR 4353 | snow/ice field is always "no snow" at night if the Quarterly Surface Type does not indicate so. "temporal snow" can only be directed daytime by snow/ ice EDR | **Open** snow/ice team is proposing a change for the nighttime snow detection for the next builder. |
| 02/14/11 | DR 4203 | The OPS LST code, both v1.5.00.48 and v1.5.03.00, do not verify that the value for the Surface Type input falls within the valid range prior to calculating LST | **Closed** EDR team does not observe such error in the operational data. Plan to close this DR. |

# Perform VIIRS LST Internal Evaluation

- VIIRS LST LST data evaluation
- VIIRS LST quality flag and metadata check
- Upstream (SDRs, EDRs and IPs inputs) data check
- Evaluation is performed at levels of
  - *Single granule map*
  - *Granule aggregation map*
  - *Regional LST map*
  - *Global LST composite map*

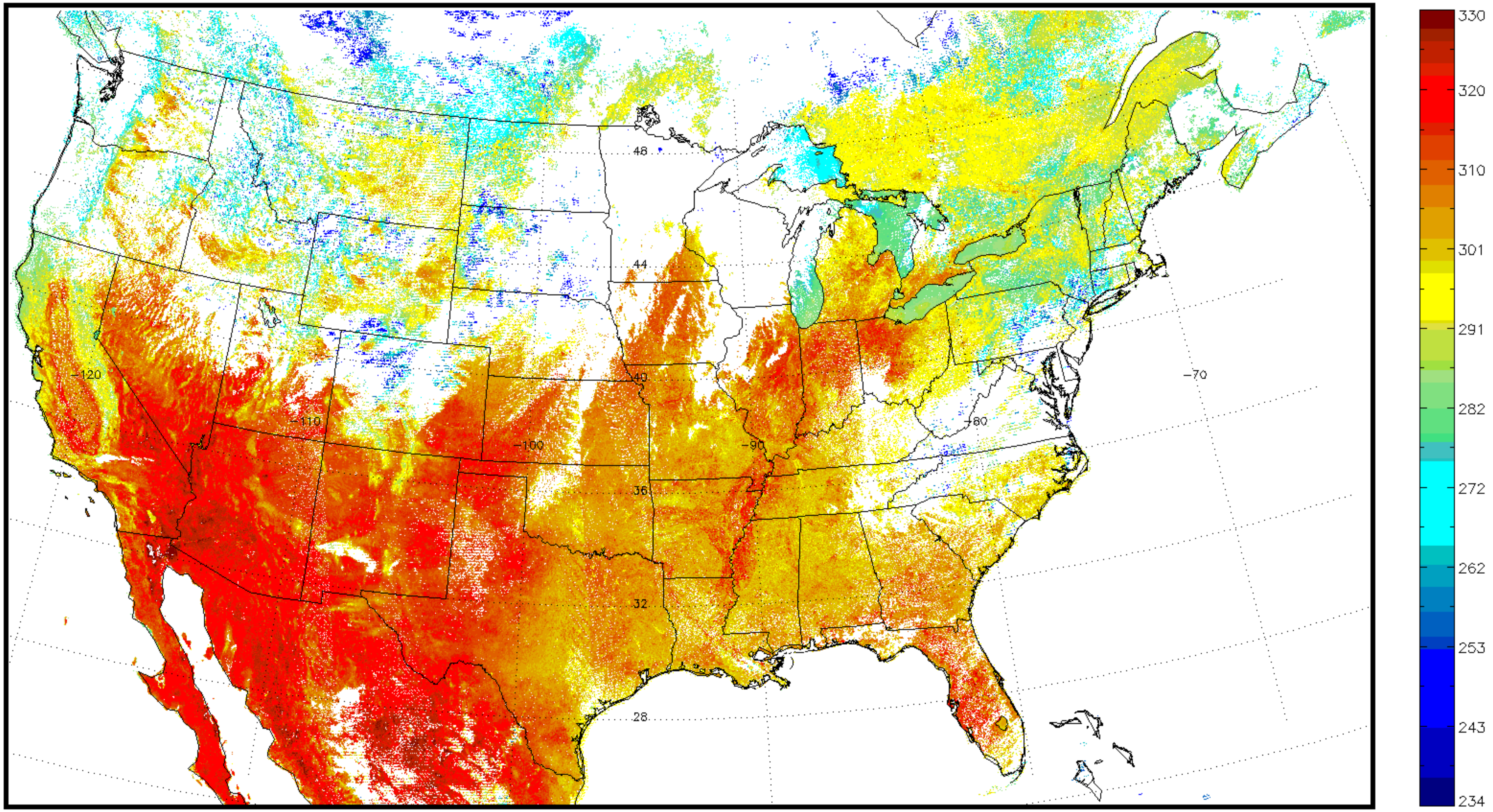
# Suomi NPP VIIRS LST Maps




Regional VIIRS LST, 30 May 2012
08:45 UTC (Nighttime)

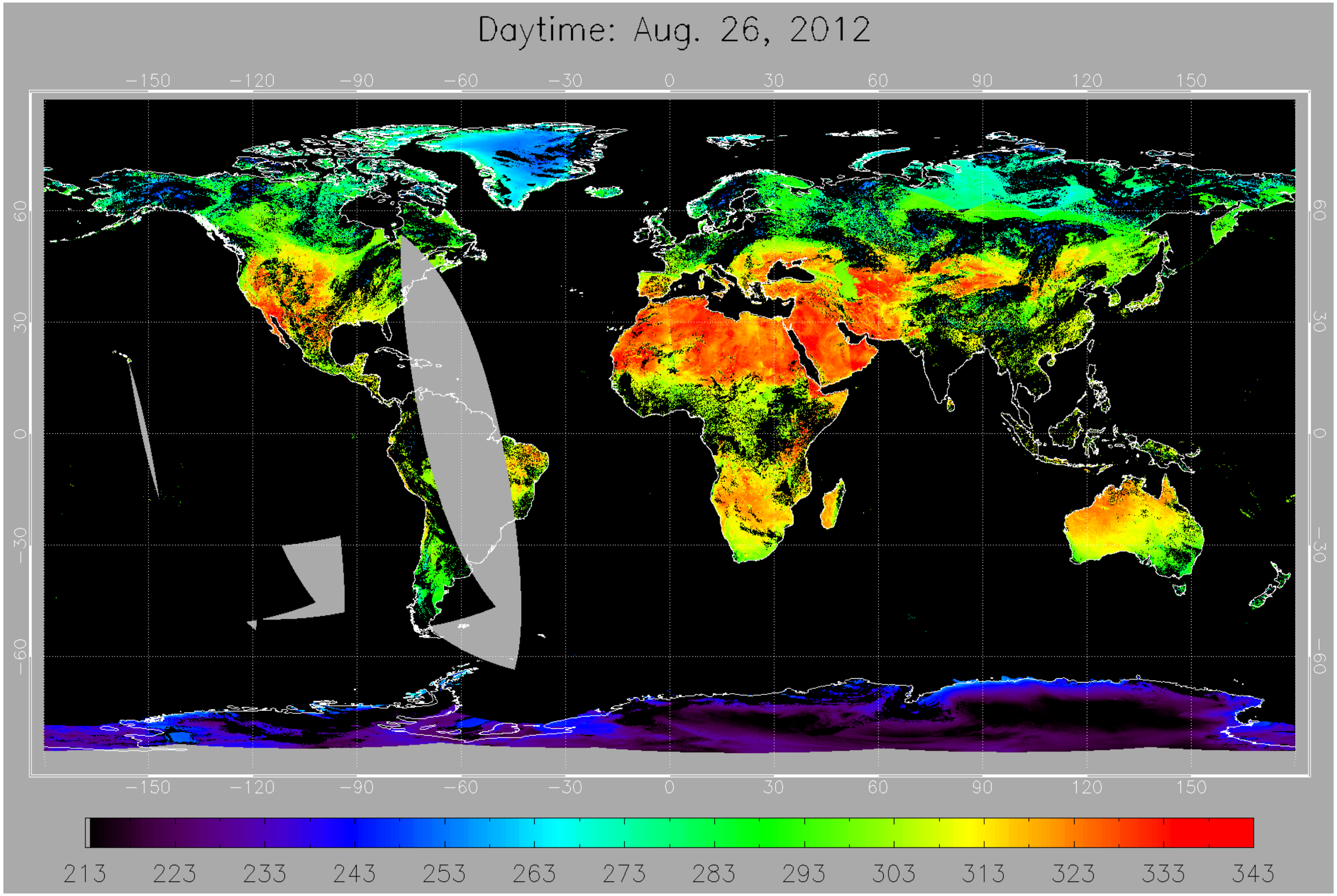
# Suomi NPP VIIRS LST Maps

VIIRS LST: VLSTO_npp_d20120523_t1536538_e2226331_b02959



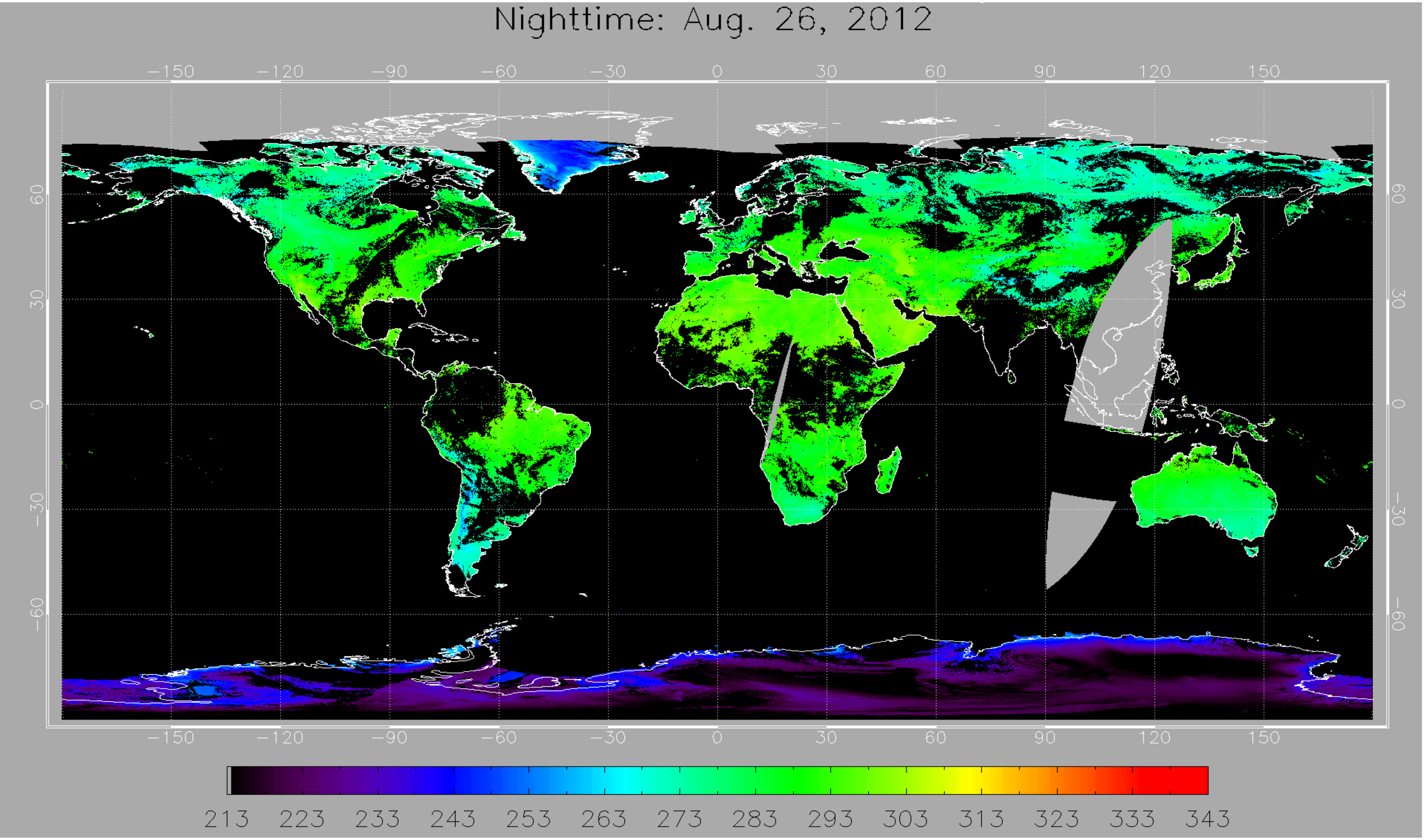

Aggregated daytime VIIRS LST, 23 May 2012,

# Suomi NPP VIIRS LST Maps




Daytime VIIRS LST Global Composite. 26 August 2012

# Suomi NPP VIIRS LST Maps




Nighttime VIIRS LST Global Composite. 26 August 2012

# Internal Evaluation summary

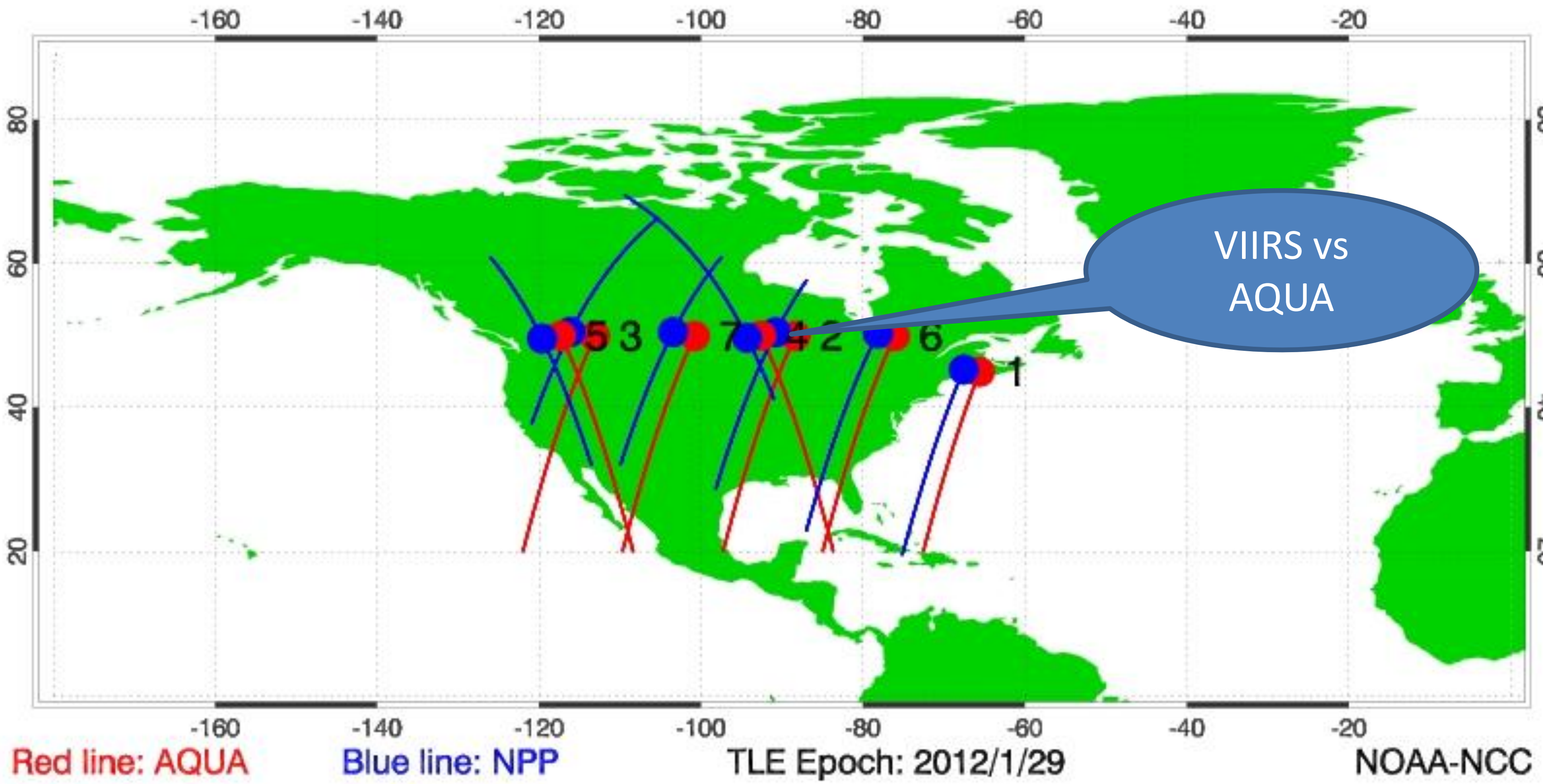
- There are 3 bytes pixel-level quality flag in total. Every bit in each byte is retrieved and compared with the value from the original input file. The result shows that the quality flag is correctly generated from input data.
- Granule level quality flag and metadata are checked and the result shows that they are correctly generated
- The internal evaluation reveals no issues with upstream SDRs, EDRs and IPs.

# Perform VIIRS LST Validation

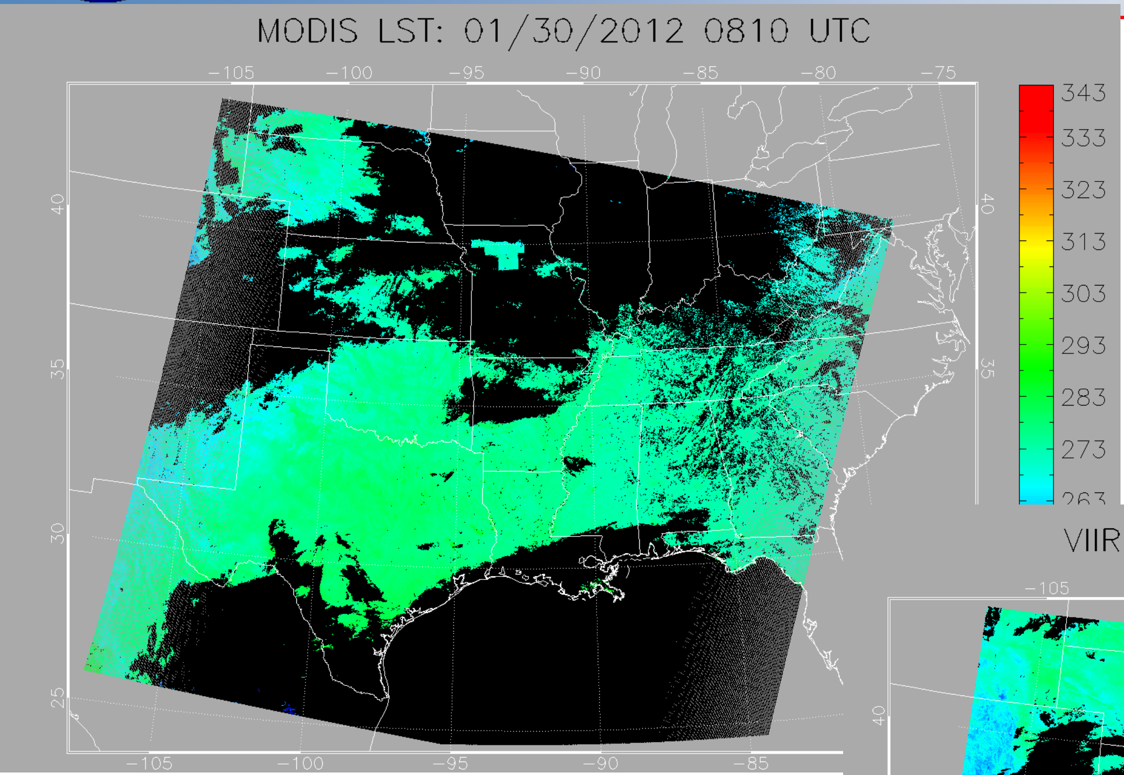
- Inter-comparison with MODIS LSTs
- Validation against ground truth data
  - Traditional in-situ data validation
  - Pixel-station correction data validation
- Near real time monitoring of LST product

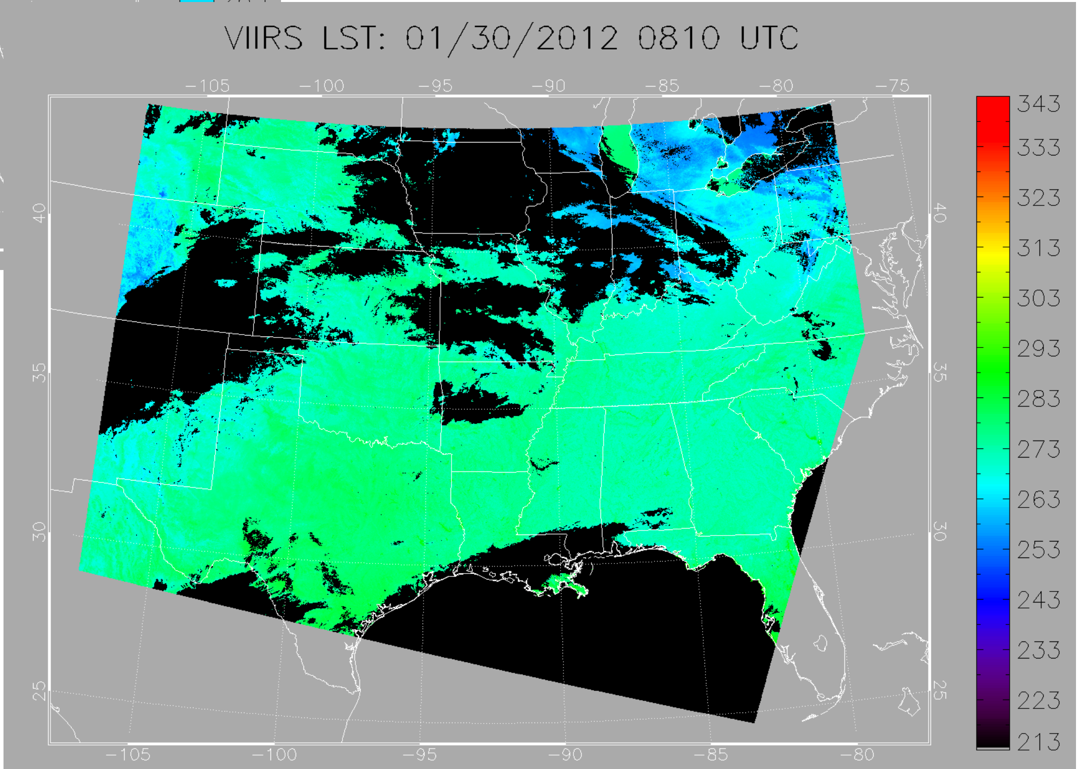
# MODIS-Nighttime

| Index | Date (AQUA) | Time (AQUA) | AQUA Lat,Lon | Date (NPP) | Time (NPP) | NPP Lat,Lon | Distance(km) | Time Diff (sec) |
|---|---|---|---|---|---|---|---|---|
| 2 | 01/30/2012 | 08:07:59 | 49.94, -88.35 | 01/30/2012 | 08:10:04 | 50.44, -90.78 | 181.29 | 125 |



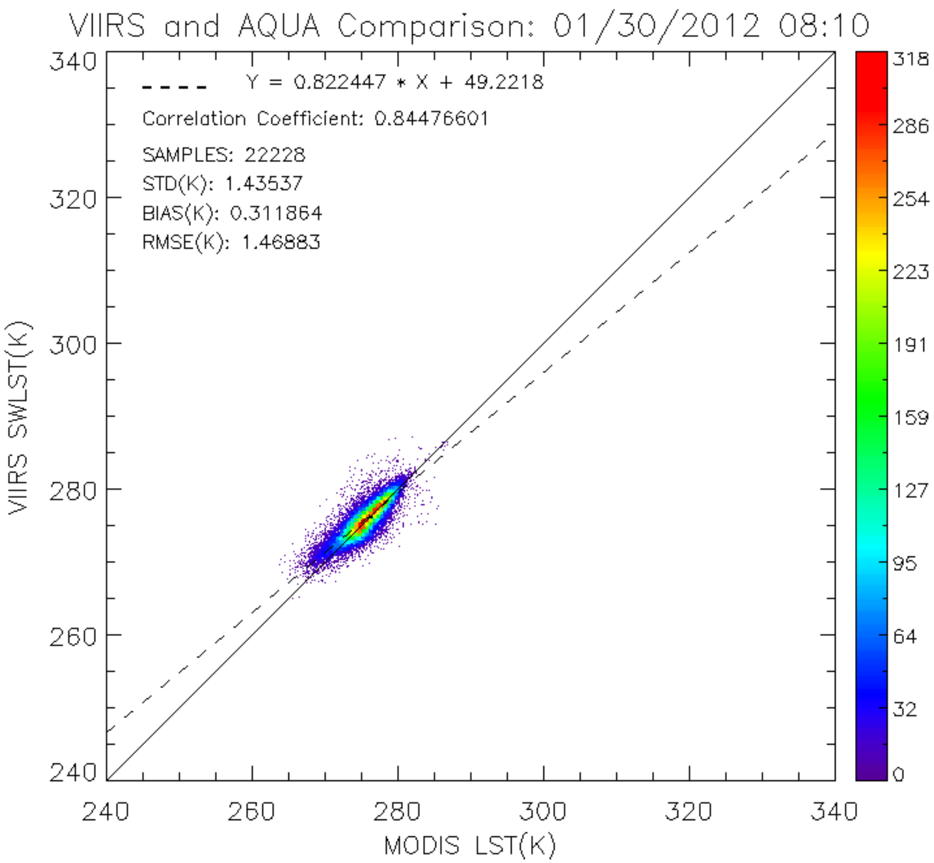
# Comparisons to MODIS data: Nighttime

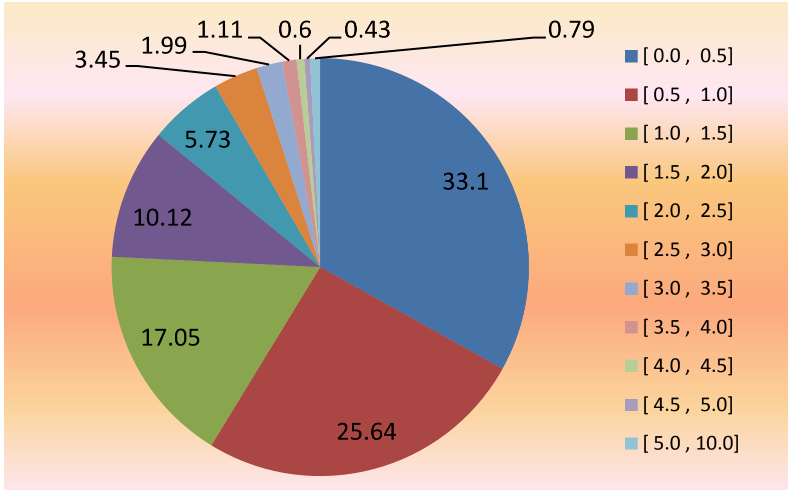



Sample of the VIIRS-MODIS LST comparisons: Nighttime case

# Comparison Detail



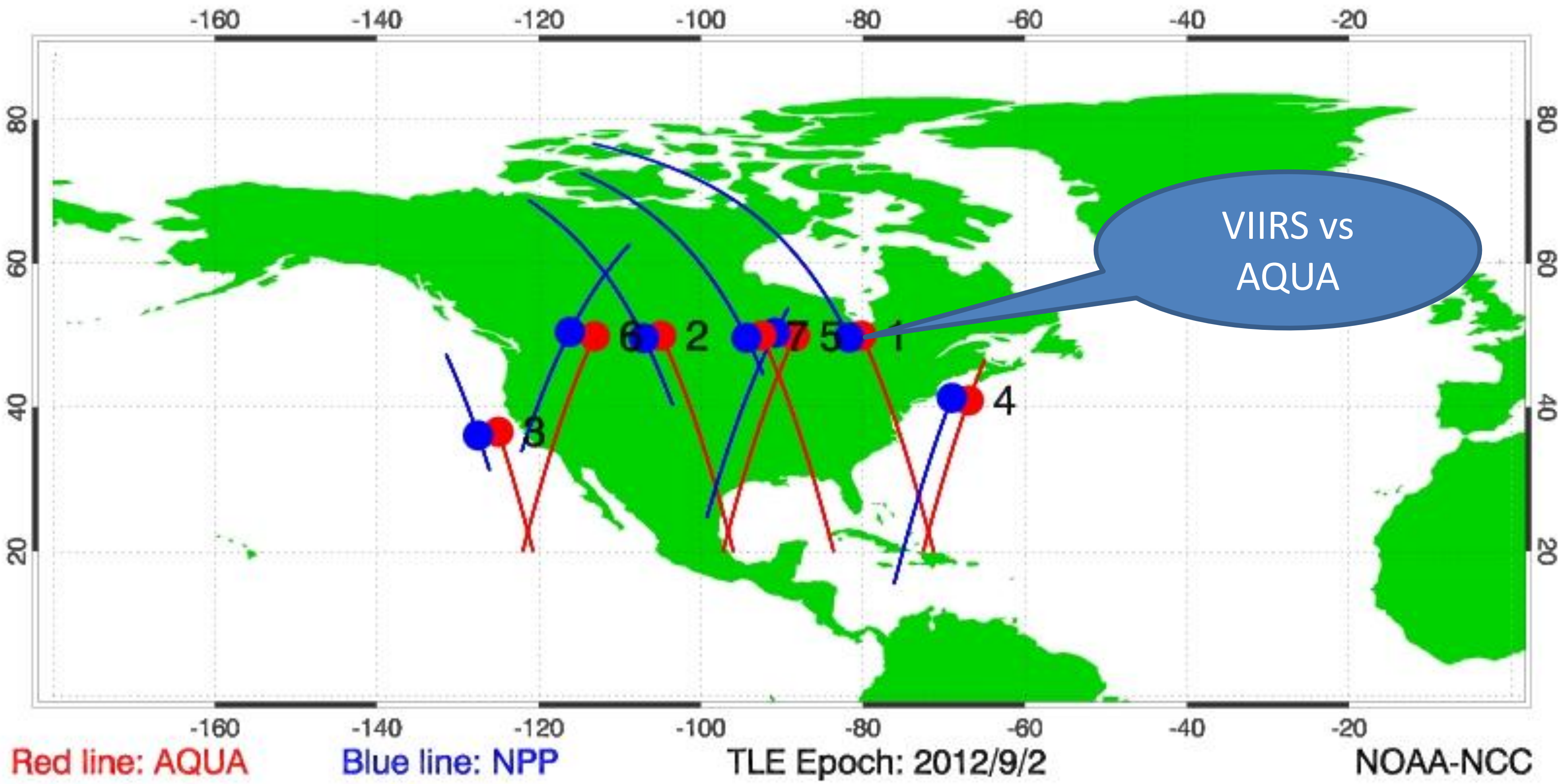




| IGBP_Type | Samples | BIAS | STD | RMSE | MIN_DIFF | MAX_DIFF |
|---|---|---|---|---|---|---|
| 1 | 397 | -0.359 | 1.805 | 1.838 | -8.316 | 8.059 |
| 2 | 325 | -0.719 | 1.421 | 1.59 | -9.999 | 3.196 |
| 4 | 1160 | 0.085 | 1.663 | 1.665 | -6.335 | 8.05 |
| 5 | 1264 | -0.142 | 1.755 | 1.76 | -8.301 | 8.845 |
| 6 | 40 | 0.756 | 1.773 | 1.906 | -2.568 | 5.498 |
| 7 | 1429 | 0.82 | 1.45 | 1.665 | -4.216 | 8.451 |
| 8 | 2446 | -0.192 | 1.42 | 1.432 | -6.532 | 7.491 |
| 9 | 606 | 0.033 | 1.402 | 1.401 | -4.704 | 6.804 |
| 10 | 8092 | 0.574 | 1.26 | 1.385 | -7.621 | 8.351 |
| 11 | 9 | 2.498 | 3.781 | 4.353 | -1.198 | 8.01 |
| 12 | 3982 | 0.394 | 1.271 | 1.331 | -5.879 | 9.557 |
| 13 | 192 | 0.536 | 1.419 | 1.513 | -2.3 | 6.173 |
| 14 | 2068 | 0.098 | 1.314 | 1.318 | -6.741 | 9.37 |
| 16 | 89 | 0.881 | 1.528 | 1.756 | -5.451 | 6.761 |
| 17 | 129 | 0.124 | 3.188 | 3.178 | -8.178 | 9.018 |

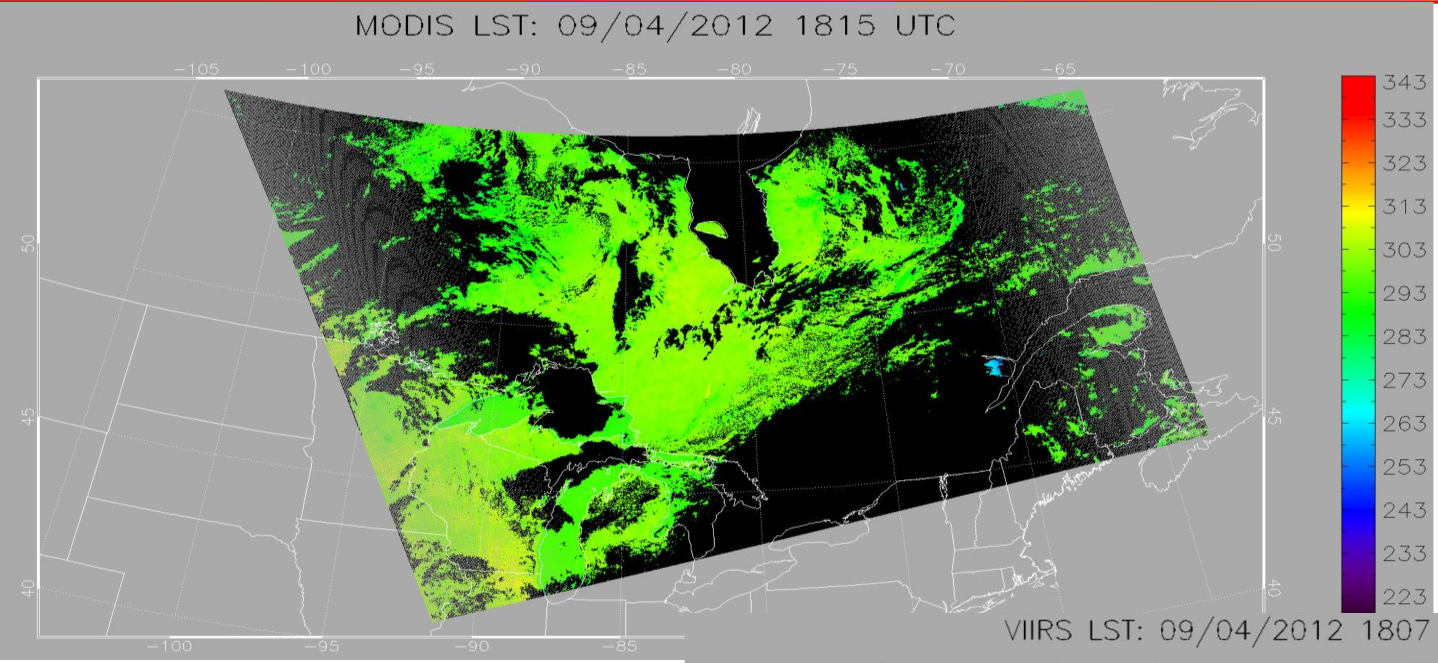
| LST Range | Samples | BIAS | STD | RMSE |
|---|---|---|---|---|
| 260-270 | 263 | 0.326 | 1.794 | 1.82 |
| 270-280 | 21082 | 0.262 | 1.389 | 1.413 |
| 280-290 | 883 | 1.488 | 1.849 | 2.373 |

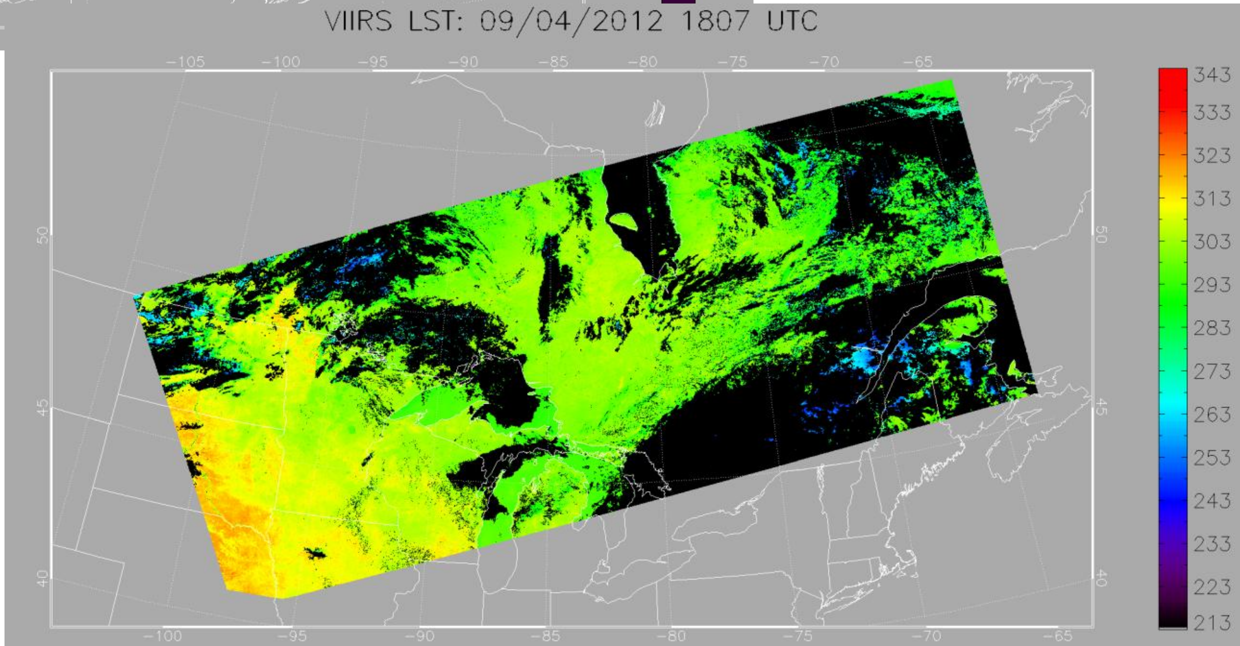
# MODIS-Daytime

| Index | Date (AQUA) | Time (AQUA) | AQUA Lat,Lon | Date (NPP) | Time (NPP) | NPP Lat,Lon | Distance(km) | Time Diff (sec) |
|---|---|---|---|---|---|---|---|---|
| 1 | 09/04/2012 | 18:16:45 | 49.96, -80.19 | 09/04/2012 | 18:08:29 | 49.71, -81.71 | 112.40 | 496 |



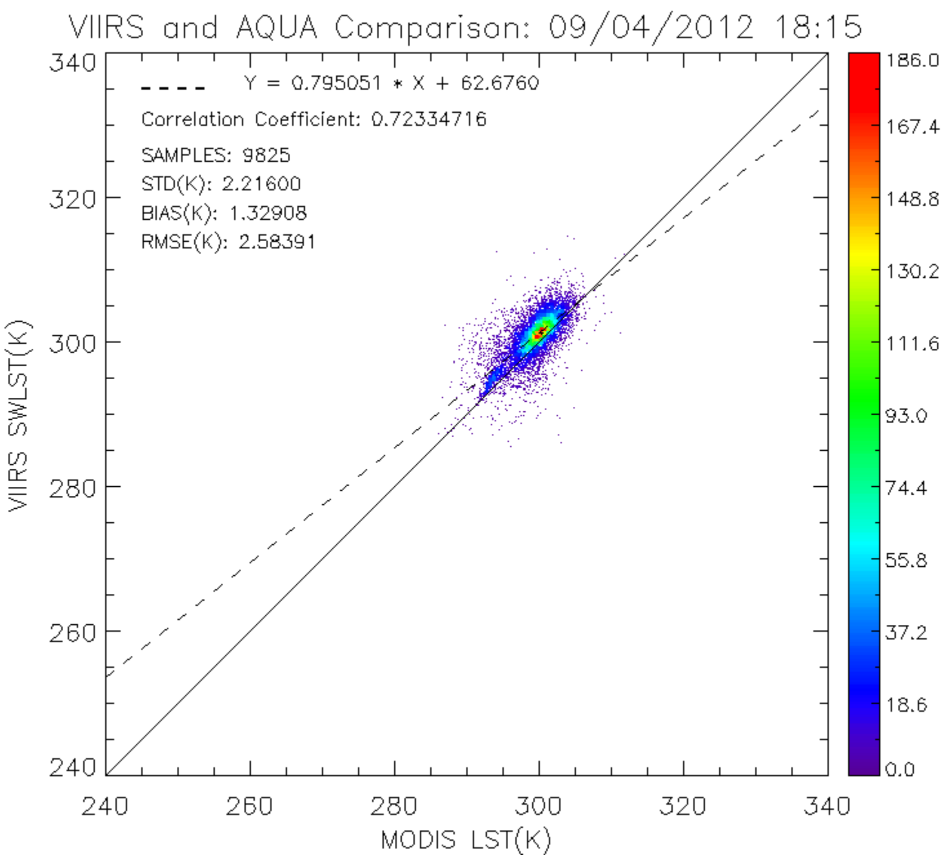
# Comparisons to MODIS data:Daytime

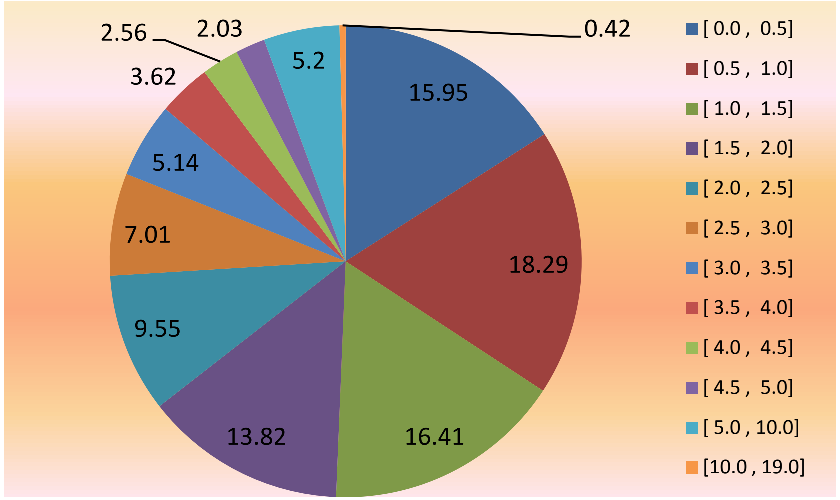



Sample of the VIIRS-MODIS LST comparisons: Daytime case

# Comparison Detail




| IGBP_Type | Samples | BIAS | STD | RMSE | MIN_DIFF | MAX_DIFF |
|---|---|---|---|---|---|---|
| 1 | 2906 | 1.222 | 2.134 | 2.459 | -16.829 | 18.502 |
| 2 | 2 | 2.454 | 1.708 | 2.735 | 1.246 | 3.662 |
| 3 | 75 | 0.762 | 1.599 | 1.761 | -2.569 | 7.177 |
| 4 | 160 | 3.209 | 1.655 | 3.608 | -8.123 | 7.542 |
| 5 | 2951 | 1.306 | 1.855 | 2.269 | -9.997 | 11.891 |
| 6 | 2 | 2.466 | 1.206 | 2.61 | 1.613 | 3.319 |
| 7 | 1283 | 1.589 | 2.286 | 2.783 | -13.401 | 12.397 |
| 8 | 767 | 1.318 | 2.544 | 2.864 | -10.392 | 13.002 |
| 9 | 369 | 1.726 | 2.326 | 2.894 | -12.693 | 10.574 |
| 10 | 158 | 2.085 | 2.213 | 3.035 | -4.236 | 10.812 |
| 11 | 133 | 0.367 | 2.394 | 2.413 | -7.593 | 9.921 |
| 12 | 54 | 3.642 | 3.195 | 4.825 | -7.304 | 13.137 |
| 13 | 1 | 8.185 | NaN | 8.185 | 8.185 | 8.185 |
| 14 | 129 | 2.624 | 2.28 | 3.47 | -1.717 | 10.703 |
| 16 | 1 | 4.82 | NaN | 4.82 | 4.82 | 4.82 |
| 17 | 834 | 0.552 | 2.637 | 2.693 | -13.982 | 15.387 |

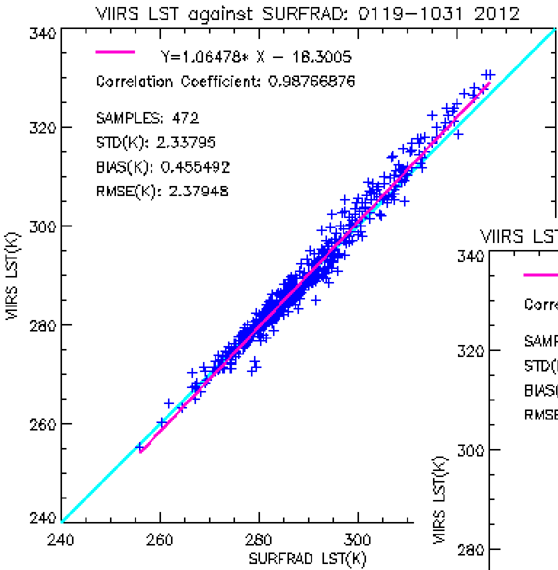
| LST Range(K) | Samples | BIAS | STD | RMSE |
|---|---|---|---|---|
| 280-290 | 45 | -5.163 | 4.686 | 6.937 |
| 290-300 | 3197 | 0.462 | 2.315 | 2.36 |
| 300-310 | 6574 | 1.785 | 1.899 | 2.606 |
| 310-320 | 9 | 8.756 | 5.794 | 10.32 |

# Cross-satellite evaluation

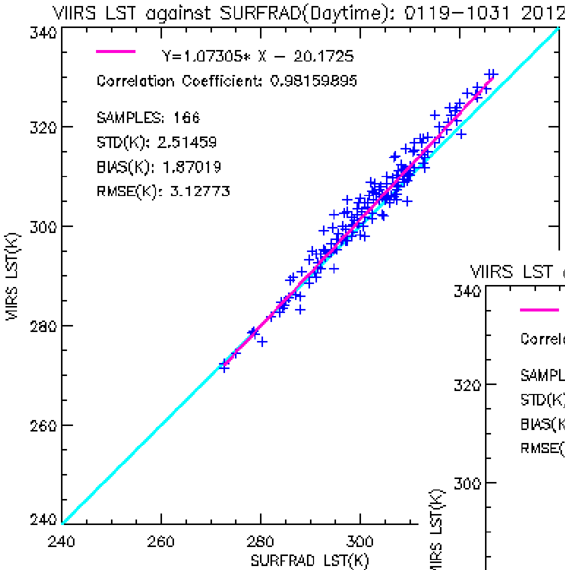
## MODIS LST *vs.* ADL-SWLST over 17 IGBP surface types

| IGBP Land Type | Sample Size | | STD(K) | | BIAS(K) | |
|---|---|---|---|---|---|---|
| | Day | Night | Day | Night | Day | Night |
| **Evergreen Needle Leaf Forests** | 78576 | 169041 | 3.869 | 2.53 | -0.353 | 0.263 |
| **Evergreen Broadleaf Forests** | 42370 | 53237 | 2.466 | 1.737 | **0.749** | 0.241 |
| **Deciduous Needle leaf Forests** | 136 | 850 | **4.018** | 2.392 | -0.396 | 0.152 |
| **Deciduous Broadleaf Forests** | 419490 | 319971 | **1.938** | 1.68 | -0.22 | -0.293 |
| **Mixed Forests** | 235425 | 321087 | 2.559 | 1.986 | -0.184 | -0.226 |
| **Closed Shrub Lands** | 101179 | 71349 | 3.415 | 2.353 | 0.021 | -0.116 |
| **Open Shrub Lands** | 1142242 | 752619 | 3.03 | 2.224 | -0.346 | -0.868 |
| **Woody Savannahs** | 346408 | 354723 | 2.661 | 1.868 | 0.106 | -0.643 |
| **Savannahs** | 93405 | 99398 | 2.517 | 1.773 | 0.419 | 0.047 |
| **Grasslands** | 833455 | 891019 | 2.712 | 1.662 | 0.206 | -0.356 |
| **Permanent Wetlands** | 5029 | 5247 | 3.82 | **3.254** | 0.351 | **0.901** |
| **Croplands** | 413472 | 480492 | 2.497 | 1.631 | 0.157 | -0.125 |
| **Urban Built-Up** | 76174 | 79016 | 2.833 | 1.823 | -0.237 | -0.75 |
| **Natural Vegetation Mosaics** | 395406 | 410113 | 2.122 | **1.562** | 0.245 | -0.175 |
| **Snow ice** | 447385 | 11 | 2.389 | 2.7432 | -0.287 | **-2.116** |
| **Barren** | 135049 | 89471 | 3.644 | 2.663 | -0.147 | -0.202 |
| **Water Bodies** | 55646 | 127271 | 3.993 | 2.977 | **-1.484** | 0.151 |

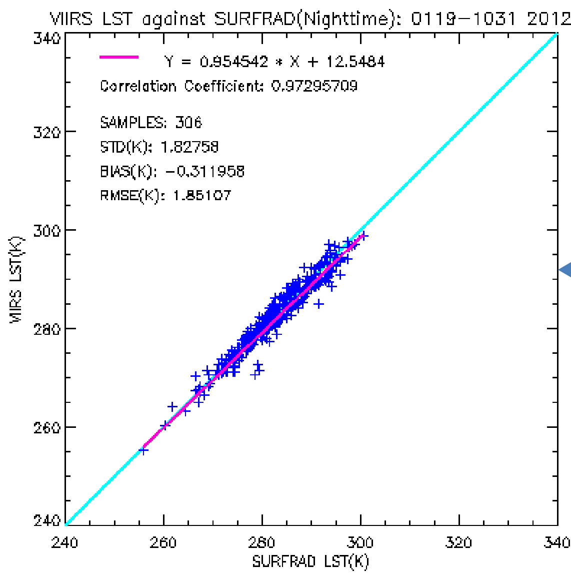
# Validation against ground truth data




Whole Day

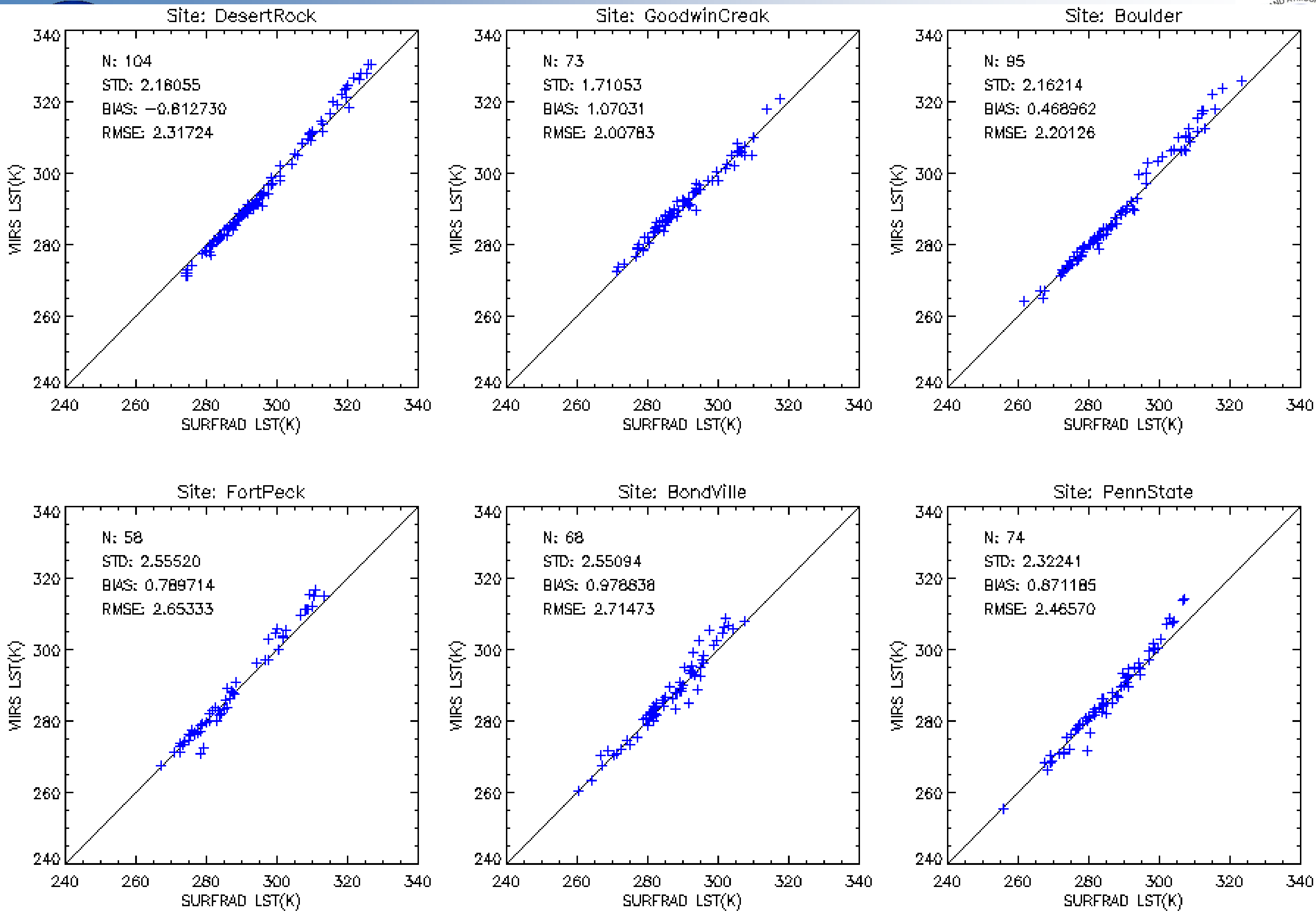



Daytime




Nighttime

Ground measurements from Six SURFRAD Stations are applied for the in-situ validation



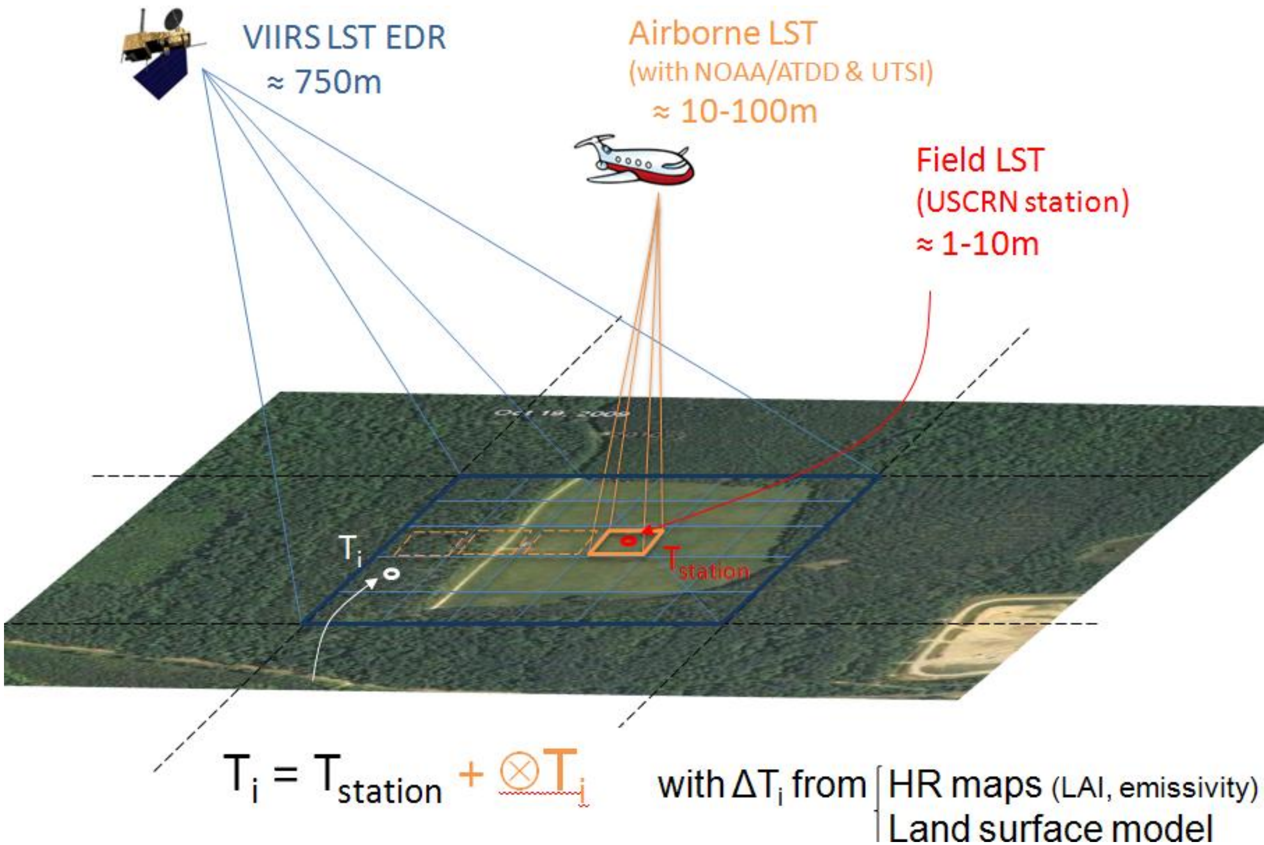

Station based validation results ( From Jan. 19 to Oct. 31, 2012)

# Pixel-Station Correction

- To account for the spatial variability of LST within a VIIRS pixel, a new scaling methodology is developed based on:
  - *High resolution (<250m) information about spatial variability of land type and biophysical properties*
  - *A land surface model to describe the LST spatial variability associated with the variability of surface properties*

- Comparisons with in situ LST derived from SURFRAD and CRN stations show the very good performance of VIIRS sensor and LST algorithm
- Methodology just published in peer-reviewed literature:

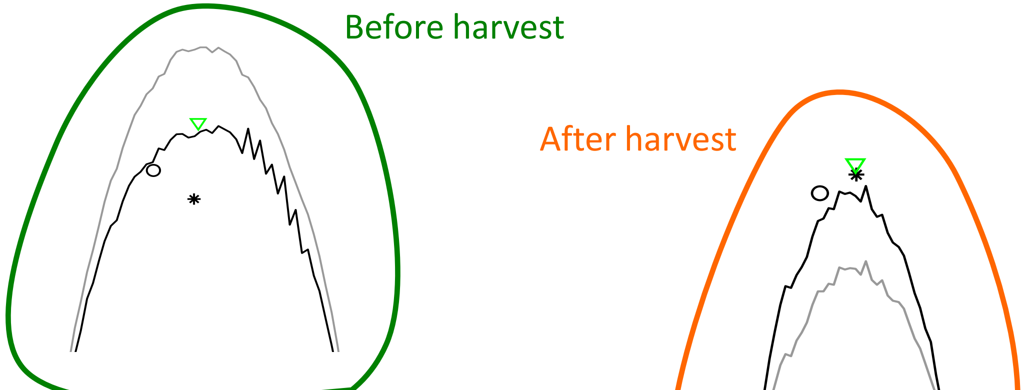
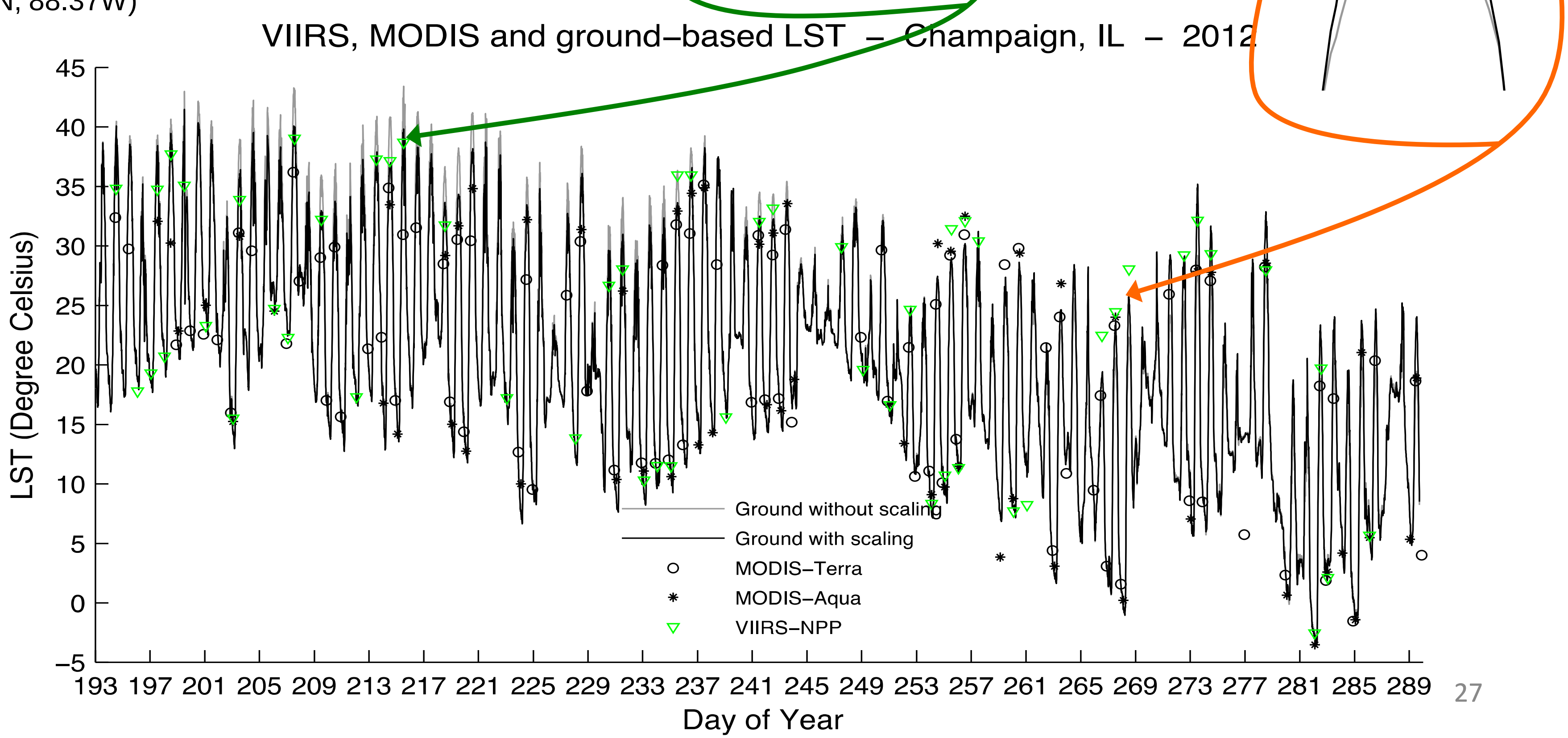
*Guillevic P., Privette J., Coudert B., Palecki M. A., Demarty J., Ottlé C. and Augustine J. A. (2012). Land Surface Temperature product validation using NOAA's surface climate observation networks – Scaling methodology for the Visible Infrared Imager Radiometer Suite (VIIRS). Remote Sensing of Environment, 124 (2012) 282–298.*



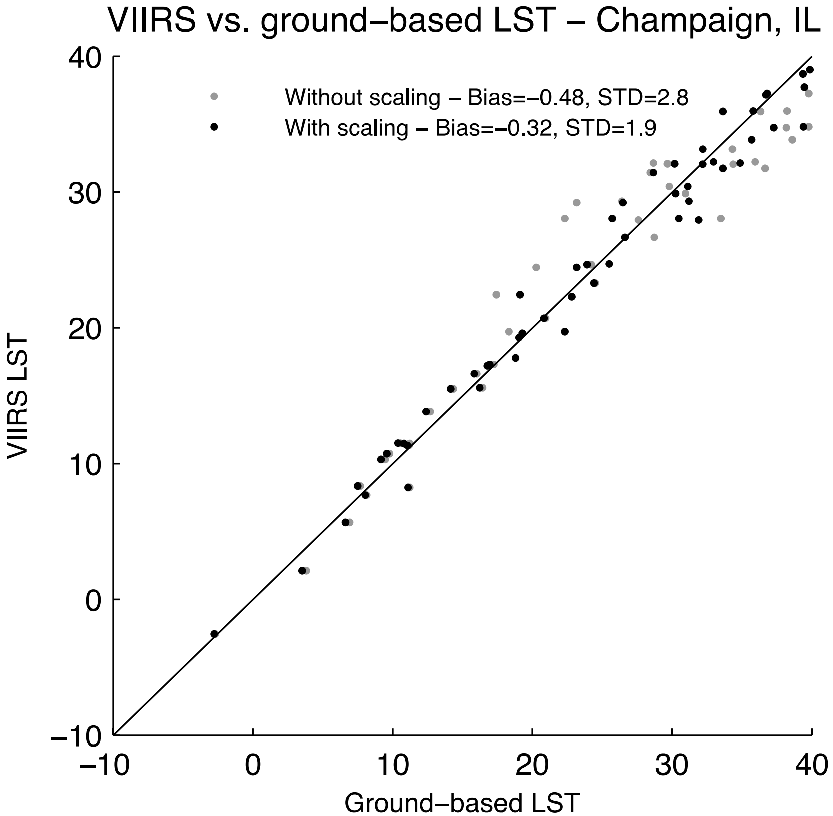
# Upscaled in situ LST vs. satellite LST -- Site Bondville, IL

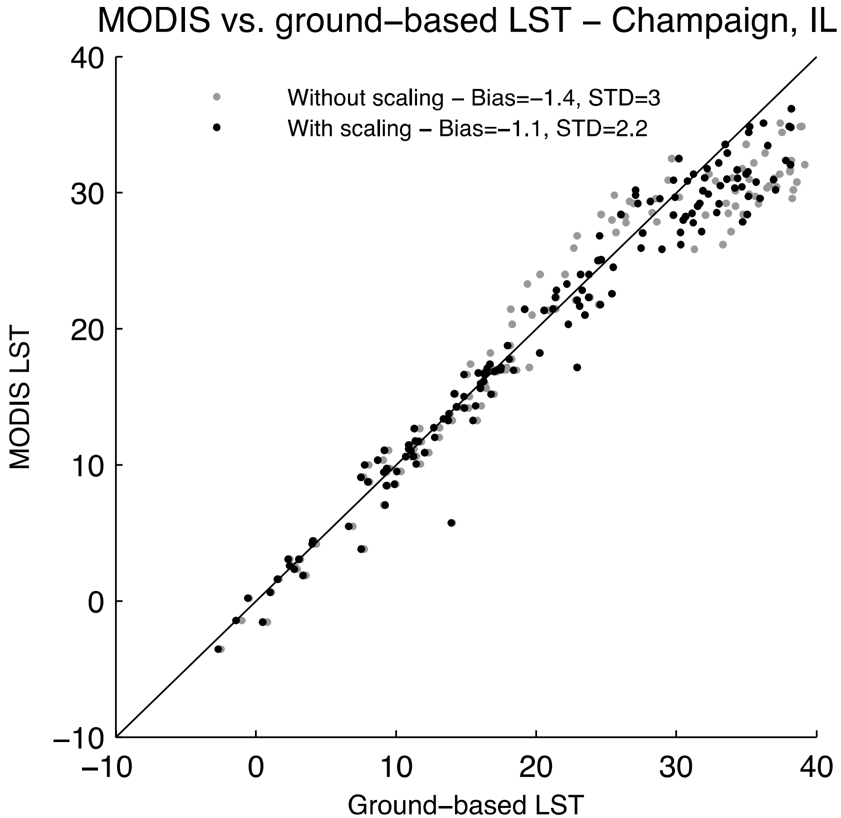
Champaign, IL

(40.05N, 88.37W)

# VIIRS LST EDR validation results



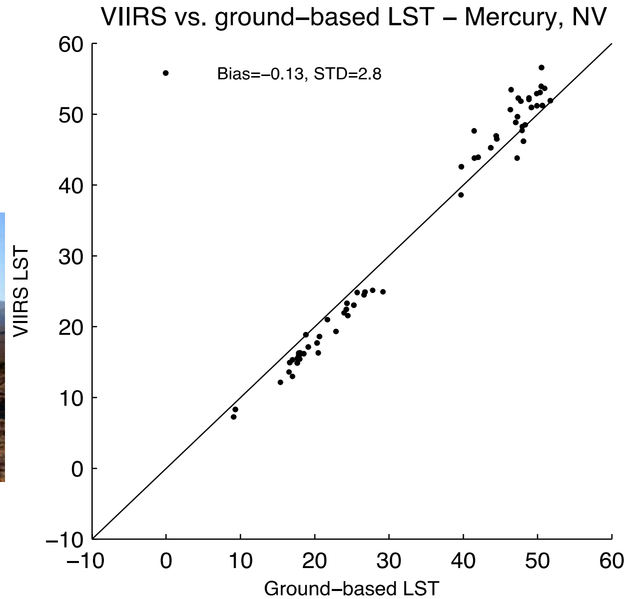



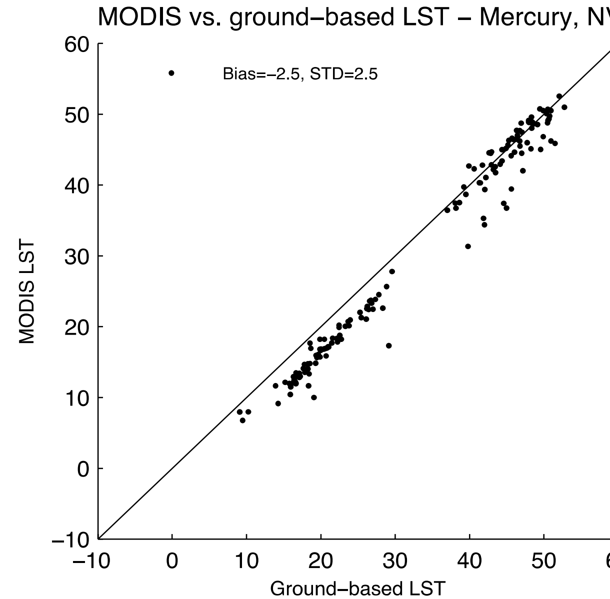

| | | Bias | RMSE |
|---|---|---|---|
| VIIRS | Satellite vs. Station | -0.5 | 2.8 |
| | Satellite vs. Scaled-up data | -0.3 | 1.9 |

# VIIRS LST EDR validation results

## Mercury, NV

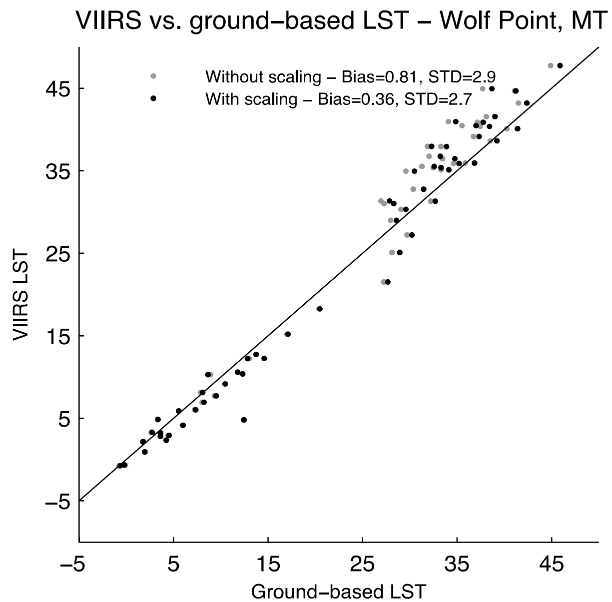
(36.62N, 116.02W)

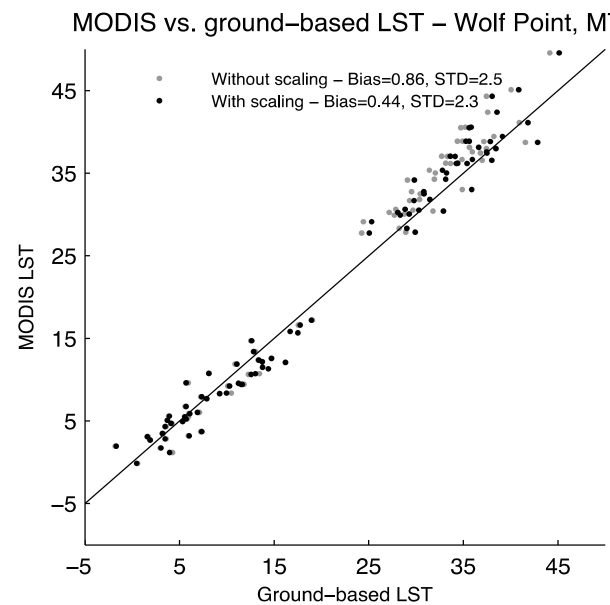



## Wolf Point, MT

(48.31N, 105.1W)



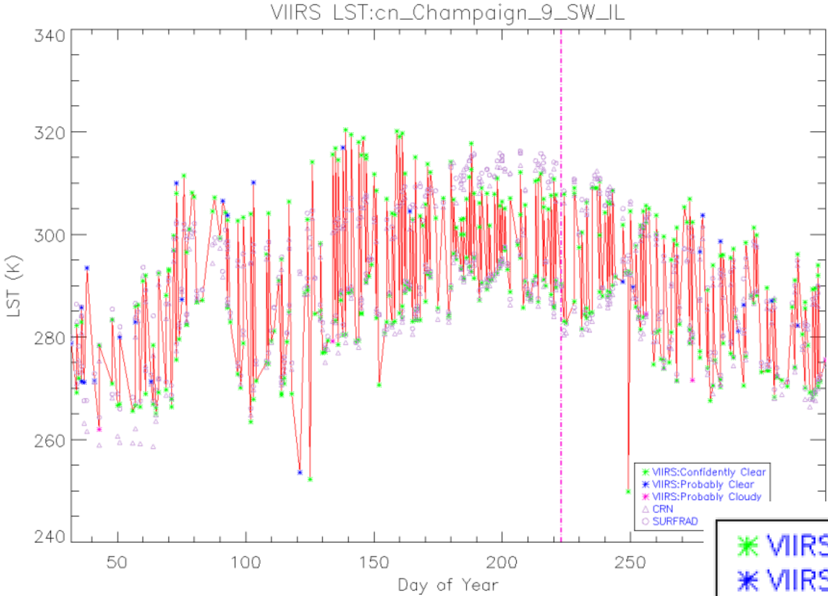



# Near Real Time Monitoring

- Near real time monitoring of VIIRS LST under different cloud conditions and surface types
- To monitor the diurnal and seasonal temperature change over each site
- The monitoring starts from February 1, 2012 to present
- Three sites are selected including cn_champaign_9_SW in Illinois with crop land surface type, cn_Wolf_Point_29 in Montana with grass land type and cn_Mercury_3_SSW in Nevada with open shrub land type.
- CRN and SURFRAD ground truth data are used as reference for the monitoring

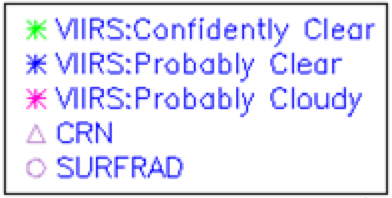
NASA LPEATE provided Site-matchup dataset

# Near Real Time Monitoring

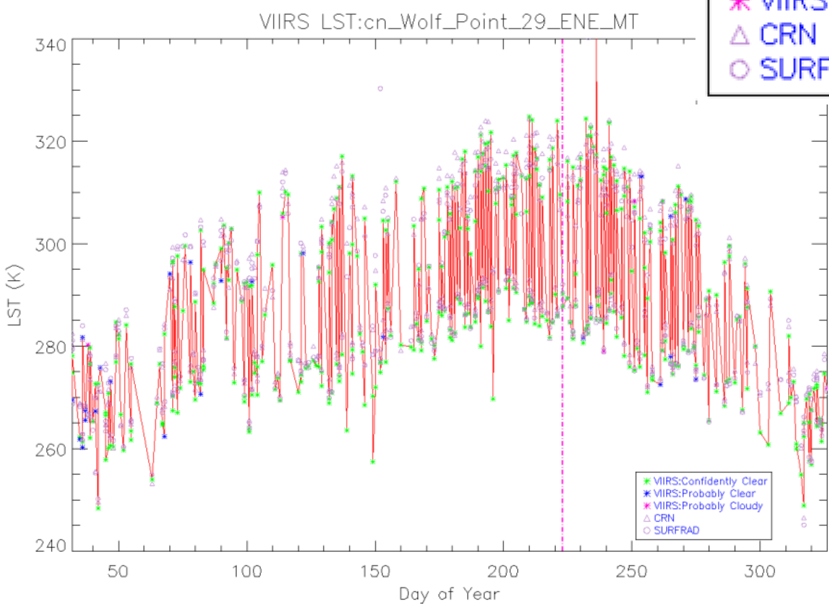


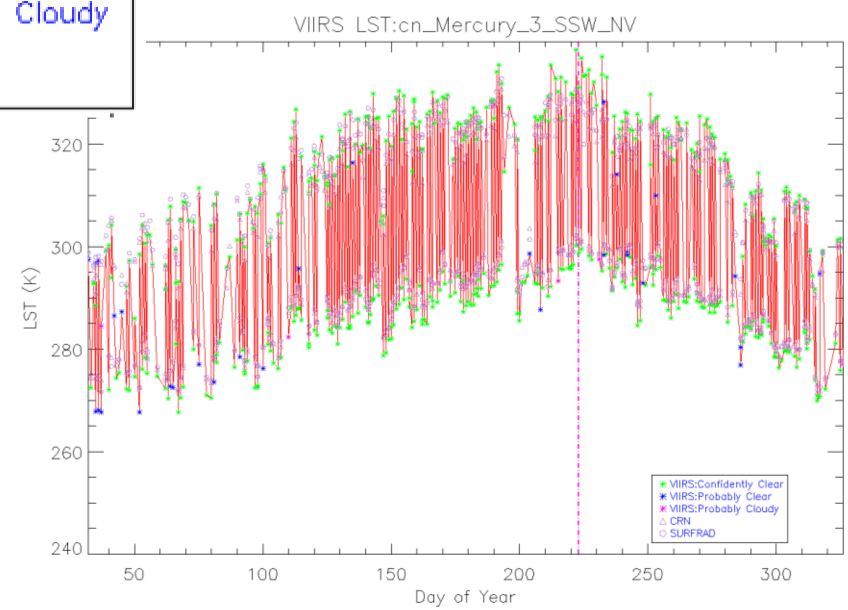

Sites: cn_champaign_9_SW (top-left), cn_Wolf_Point_29 (bottom-left), and cn_Mercury_3_SSW (bottom-right)

Reasonable variations and diurnal cycles observed

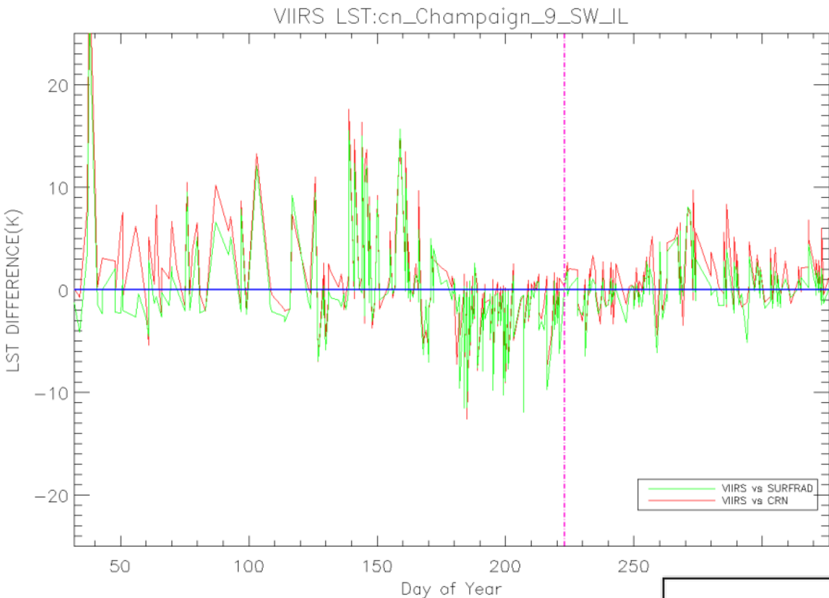



The dot red line shows time of builder Mx6.2 on Aug. 10, 2012



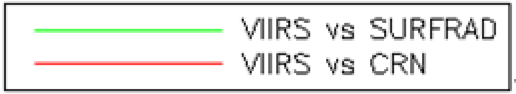
# Near Real Time Monitoring

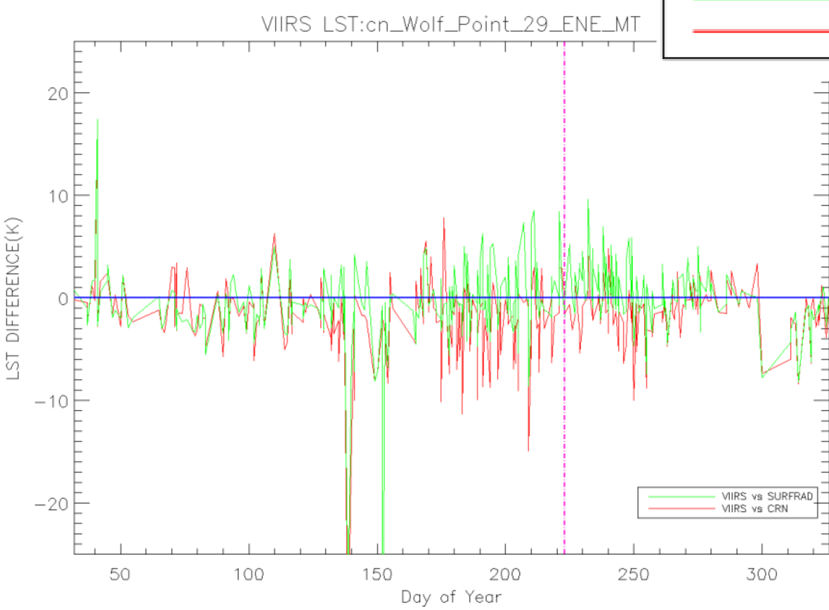


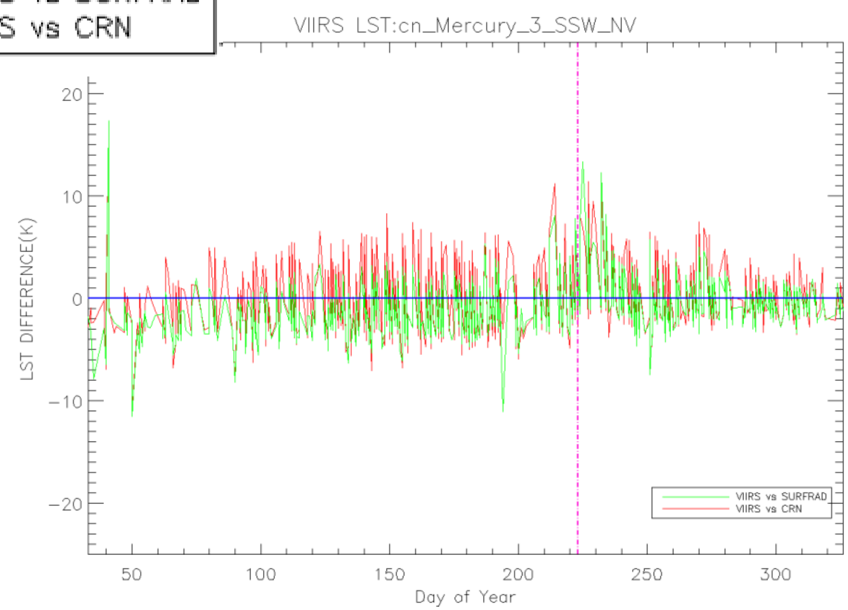

On-site monitoring of VIIRS LST vs. ground (SURFRAD and CRN) LST data

The ground-satellite LST difference is significant (impact of glint, large view angle, etc. not removed);
cloud impact observed;
SURFRAD reference is more stable;
results improved after Builder Mx6.2x

The dot red line shows time of builder Mx6.2 on Aug. 10, 2012

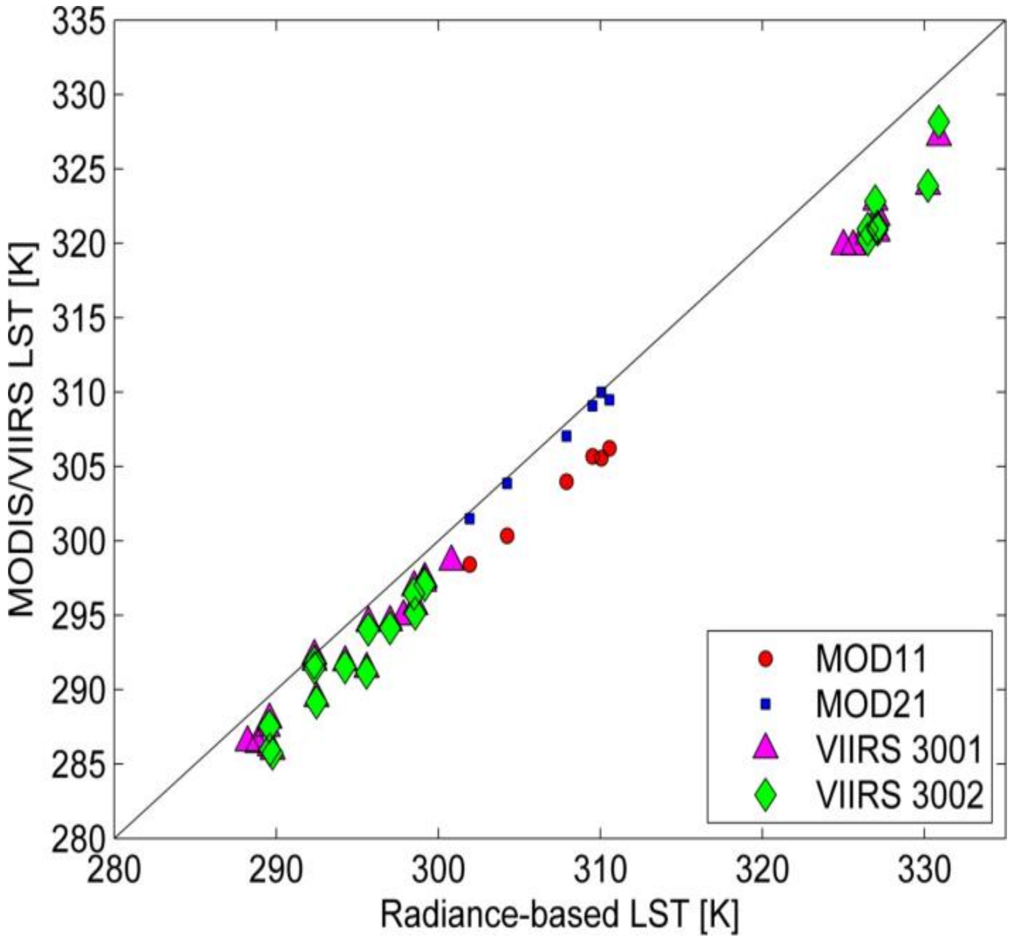


# Emissivity dependency issue

Figure on right shows a plot of the validation results using the MOD11, MOD21 and VIIRS main algorithm over one of the pseudo-invariant sites. This figure highlights the problem of using a static map for the emissivity coefficients seen with both MOD11 and VIIRS [Hulley and Hook, 2009]. In both cases the retrieved MOD11 and VIIRS LSTs are too low by 2-3 K (emissivity set too high) whereas the dynamic emissivity approach MOD21 gives the correct answer. The VIIRS retrieval does not meet the accuracy requirement.




***Courtesy by Simon Hook (NASA/JPL)***

*Plot of MODIS/VIIRS LST at the Kelso Dunes, CA pseudo invariant site versus radiance-based LST.*

# Evaluation/Validation Conclusion

- VIIRS LST has achieved beta quality and it performs beyond the beta according to our continuous evaluations of the data quality.
  - Comparing to MODIS LST data, accuracy and precision of **nighttime** VIIRS LST ranges from -2.1 to 0.9 K and 1.57 to 3.26 K, respectively; accuracy and precision of **daytime** VIIRS LST ranges from -1.48 to 0.75 K and 1.9 to 4.1 K, respectively
  - Comparing to SURFRAD station data, accuracy and precision of **nighttime** VIIRS LST are -0.3 K and 1.8 K, respectively; accuracy and precision of **daytime** VIIRS LST ranges from 1.9 K and 2.5 K, respectively.
  - Comparing to upscaled SURFRAD station data, accuracy and precision of the VIIRS LST are better than comparing to the regular SURFRAD station data.
- Surface type dependency of the LST quality is significant.
- Nighttime LST performance is better than the daytime
- The evaluation/validation is performed with limited ground data (surface types).

# Known Issues

General

- Nighttime snow/ice cover information maybe incorrectly identified and work is in progress
- LST over inland water was spurious (high values) before 10 August 2012, due to surface type order error in LUT
- Strong surface type dependency of LST retrieval quality -- consistency
- Seasonal dependency of LST retrieval quality -- emissivity variation
- Cloud residual impact -- may need additional cloud filter
- Validation difficulties
  - *Limited high quality in-situ data*
  - *Surface heterogeneity in a pixel*
  - *Emissivity variation within a surface type*
  - *Impact of cloud contamination*
  - *High LST temporal and spatial variation and its impact to match-up dataset*

# Future Plans

- Near-term
  - *Continue monitoring the LST data and comparisons to MODIS LSTs*
  - *Perform Radiance-based validation so the LST performance can be analyzed in detail for each surface type*
  - *Perform the LST validation with a global distribution of ground LST measurements*
  - *Develop new algorithm coefficients for the update*
  - *Explore additional cloud filtering method for better LST validation*
  - *Initial end user evaluation and feedback*

- Mid- to long-term
  - *Full evaluation of updated science algorithm and code*
  - <u>*Provisional status by May 2013*</u>
  - <u>*Validated Version 1 status by Nov. 2013*</u>

# Summary

- Preliminary results show that the VIIRS LST product is working well.
  - Results are preliminary
  - LST quality can be different significantly from one surface type to other
  - Nighttime LST retrieval is better than the daytime retrieval
  - "temporal snow" is not clarified
- Validations are performed with comparisons to MODIS LSTs, in-situ LSTs, LST map monitoring; upscaling method is applied.
- Beta release of Suomi NPP VIIRS LST is ready.