Maturity of the Terrestrial Environmental Data Products from the Suomi NPP satellite

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NOAA JPSS Land Calibration and Validation Team

NASA SNPP VIIRS Land Discipline Team

NOAA JPSS Suomi NPP VIIRS Land Products and Team Principals

Role or Product Focus	Name (+ et al.)	Affiliation
NOAA Product Team Lead, **Fire**	*Ivan Csiszar* / Wilfrid Schroeder	NOAA / UMD
NASA Coordination, Validation co-lead	Miguel Román, Chris Justice	NASA / UMD
Surface Reflectance, VCM, calibration	*Eric Vermote*	NASA
Surface Reflectance	Alexei Lyapustin	NASA
Vegetation Index, Green Vegetation Fraction*	*Marco Vargas*	NOAA
Vegetation Health*	*Felix Kogan*	NOAA
Vegetation Index	Tomoaki Miura	Univ. of Hawaii
Albedo	*Yunyue (Bob) Yu* / Shunlin Liang	NOAA / UMD
Albedo	Crystal Schaaf	Univ. Mass.
Land Surface Temperature	*Bob Yu*	NOAA
NOAA CDR coordination, LST	Jeff Privette / Pierre Guillevic	NOAA / NASA JPL
Surface Type	*Jerry Zhan* / Chengquan Huang	NOAA / UMD
Surface Type	Mark Friedl	Boston Univ.
STAR AIT Land	Walter Wolf, Marina Tsodulko	NOAA
NASA LandPEATE, **gridding/granulation**	Sadashiva Devadiga, Carol Davidson	NASA
Raytheon	Daniel Cumpton	Raytheon
JPSS Algorithm Manager	Leslie Belsma	Aerospace

*All products generated by IDPS (Interface Data Processing Segment), except *: NOAA-Unique (NDE)*

JPSS Product Performance Requirements

- JPSS **Level 1** Requirements Document
  - "identify the **top-level, user-driven requirements** for NOAA's polar environmental satellite observing capability (data products and functional and performance requirements) needed to achieve NOAA's mission"
- JPSS **Level 1** Requirement Document **Supplement**
  - "The L1RD describes the JPSS **Sensor Data Records (SDRs), Environmental Data Records (EDRs)** and key system requirements at a high level"
- Product **maturity** levels are linked to **performance relative to product requirements**
- For some SNPP products **changes** need to be implemented to meet requirements for the **JPSS 1** satellite and beyond

- Key JPSS technical documents are **available** at http://www.jpss.noaa.gov/technical_documents.html

SNPP Validation and Maturity Stages

Beta:

Early release product that is **minimally validated** and may contain significant errors; available to allow users to gain familiarity with the product; **not appropriate for quantitative scientific studies and publications**

Provisional:

Product **quality is still not optimal** and incremental improvements are still occurring; the research community is encouraged to participate in QA and validation, but need to be aware that **QA and validation are still ongoing**; ready for **operational evaluation**

Validated Stage 1:

Using a **limited set of samples**, the algorithm output is shown to **meet the threshold performance attributes** identified in the JPSS Level 1 Requirements Supplement with the **exception of the S-NPP Performance Exclusions**

Validated Stage 2:

Using a **moderate set of samples**, the algorithm output is shown to **meet the threshold performance attributes** identified in the JPSS Level 1 Requirements Supplement with the **exception of the S-NPP Performance Exclusions**

Validated Stage 3:

Using **a large set of samples** representing global conditions over four seasons, the algorithm output is shown to **meet the threshold performance attributes** identified in the JPSS Level 1 Requirements Supplement with the **exception of the S-NPP Performance Exclusions**

Surface Reflectance Intermediate Product Requirements (proposed)*

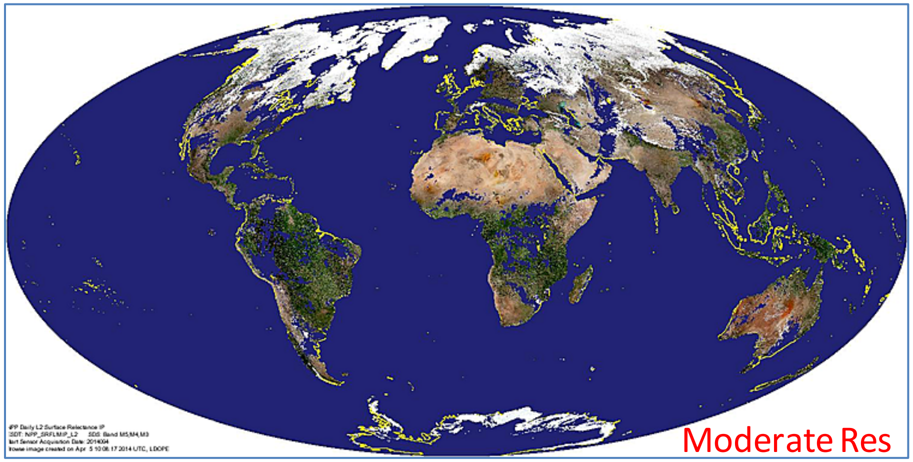
Attribute	Threshold	Objective
Geographic coverage	Land, Cloud Clear.	Global, All atmospheric condition
Vertical Coverage	NA	NA
Vertical Cell Size	NA	NA
Horizontal Cell Size	Nadir Moderate Resolution: 0.75km Image Resolution: 0.375 km	
Mapping Uncertainty	Pixel geolocation uncertainty	
Measurement Range	0-1 (with exceptions)	
Measurement Accuracy**	0.01 + 10%	0.005 + 5%

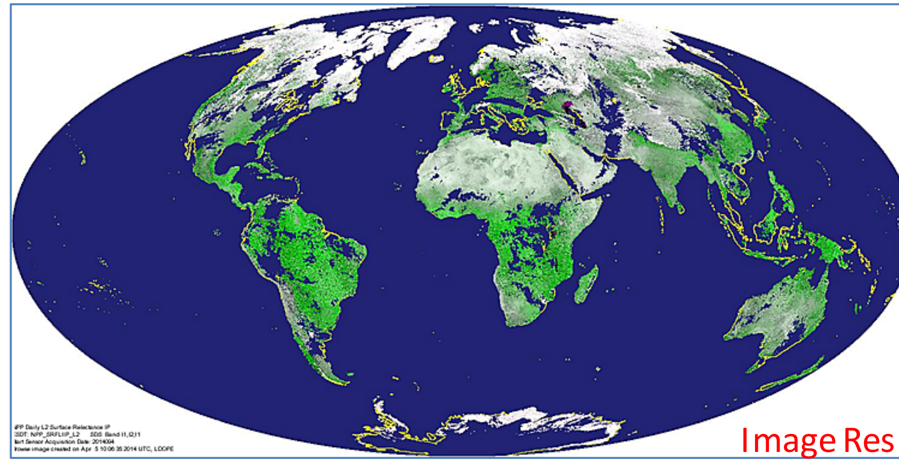
**Surface reflectance IP requirements are currently not listed in the L1RD Supplement*

***The performance is dependent on both the spectral band and the magnitude of the reflectance (increased surface brightness results in a multiplicative error of 5%).*

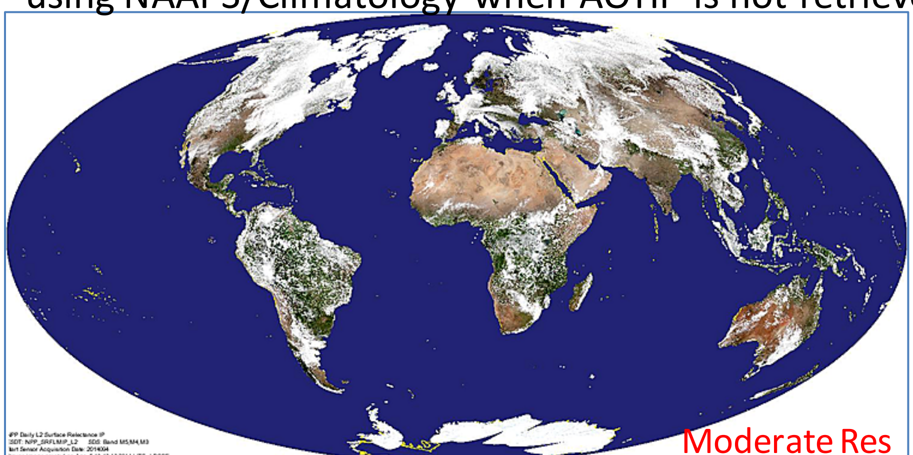
Surface Reflectance IP from Day 2014094

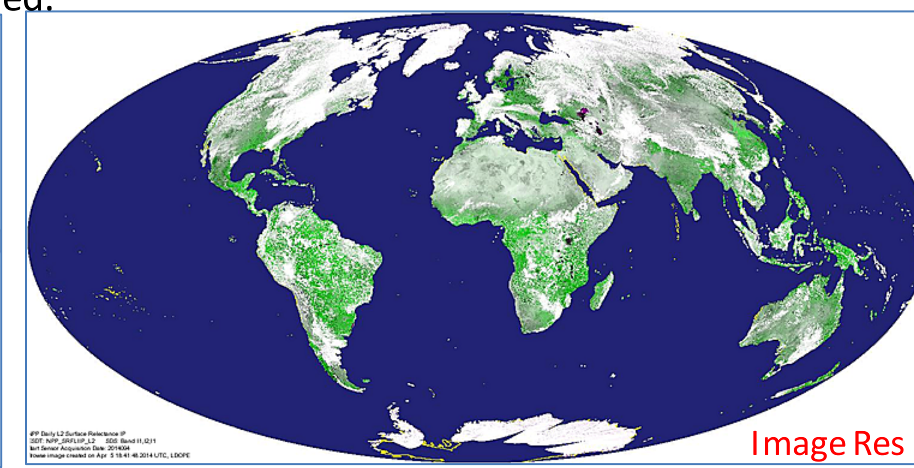
Retrieved under all atmospheric conditions for all non-ocean (not sea-water) pixels except for night pixels and where input L1B is invalid





Retrieval using Mx73 at Land PEATE – SRIP not retrieved under confidently cloud and heavy aerosol, using NAAPS/Climatology when AOTIP is not retrieved.





Retrieval using Mx83 at IDPS – SRIP retrieved under all atmospheric conditions replacing NAAPS/Climatology with MODIS Climatology.

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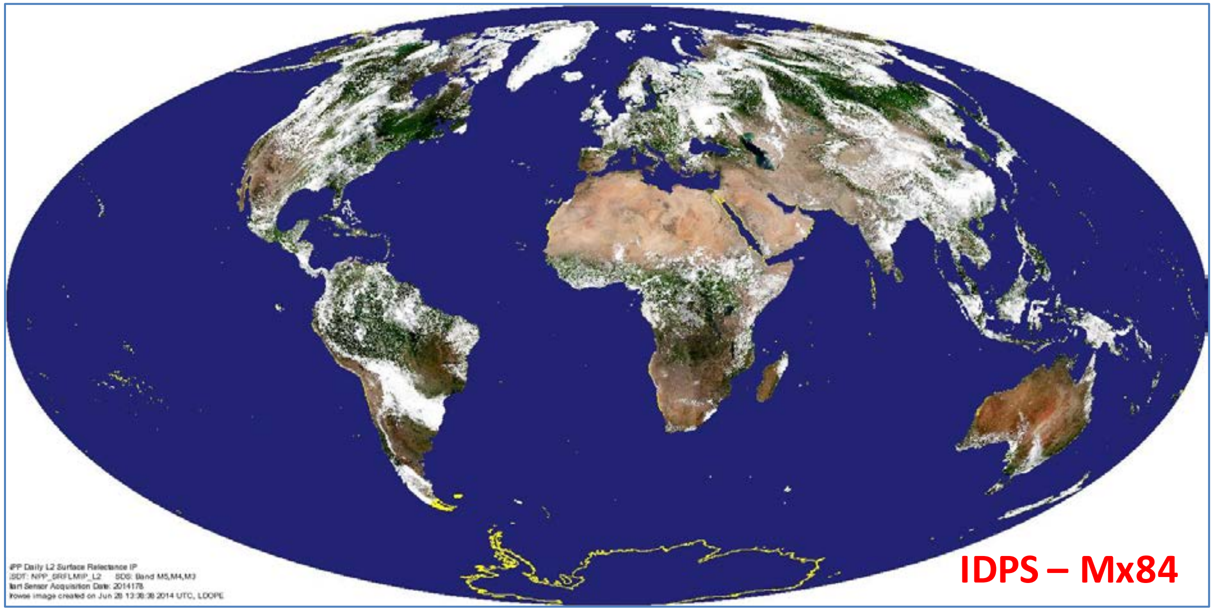
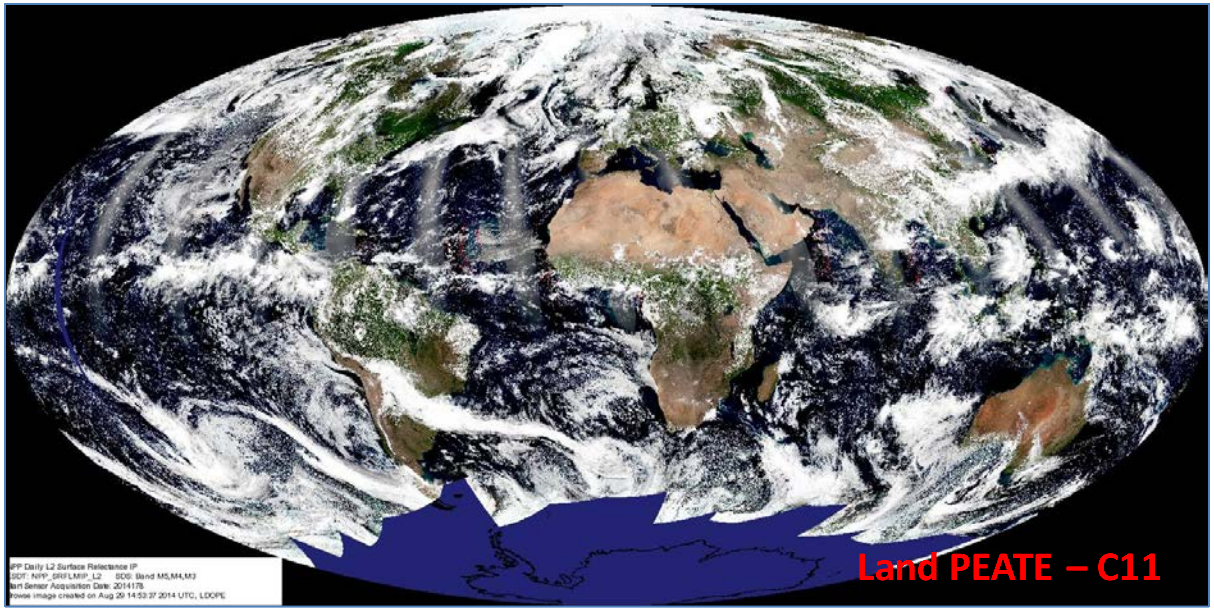
Evaluation of SR Algorithm Performance

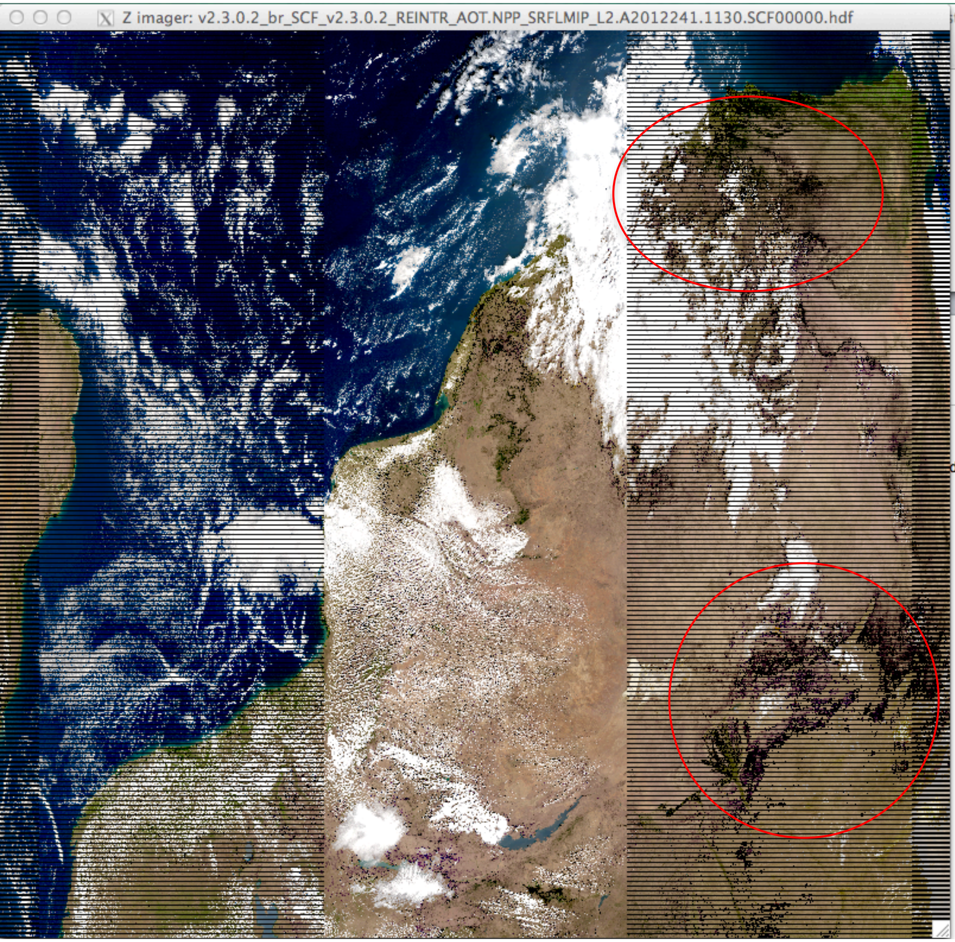


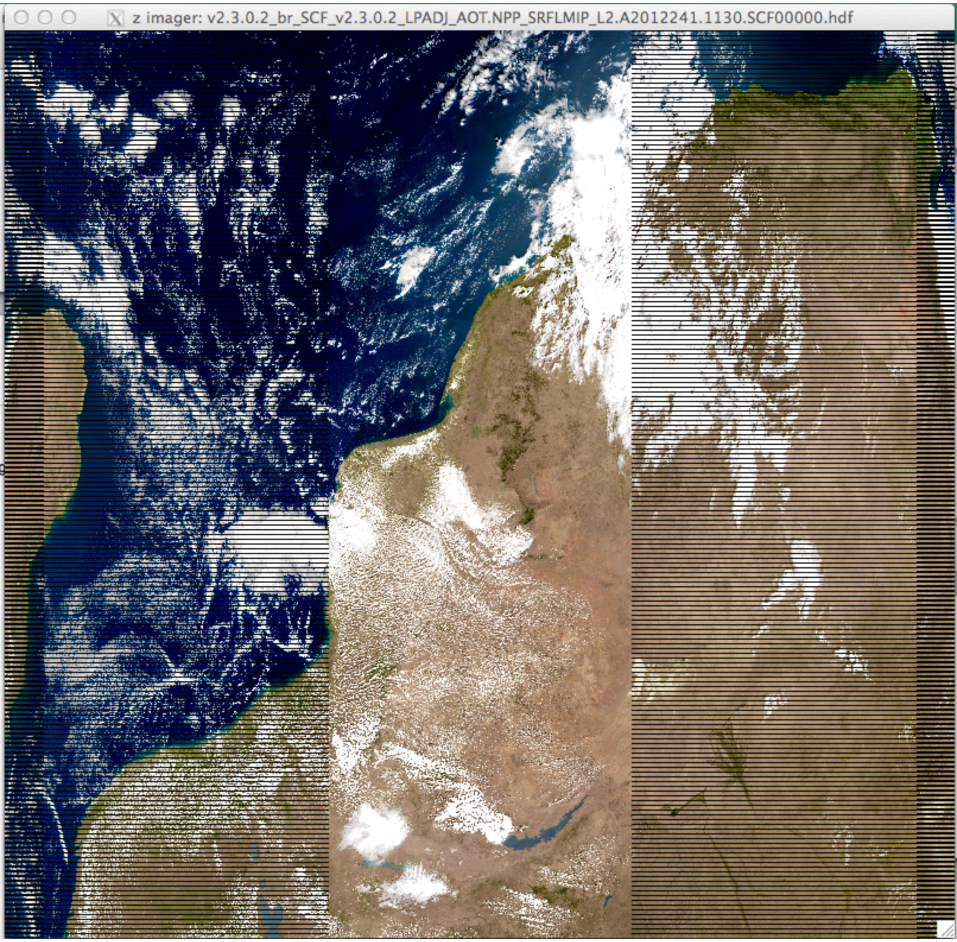


- Global browse of Surface Reflectance IP generated using RGB composite of bands 5, 4, and 3 in SRIP – Data Day 2014178
- IDPS operational version doesn't process ocean pixels.
- IDPS version of SRIP generated using Mx84 build version of the algorithm.
- C11 reprocessing used proposed changes to SRIP and AOTIP algorithm.

E. Vermote, S. Devadiga, NASA GSFC

SR comparison: Left with Dust model on , Right with dust model off





Negative reflectance values in the visible are present in the left picture (dark spot in RGB)

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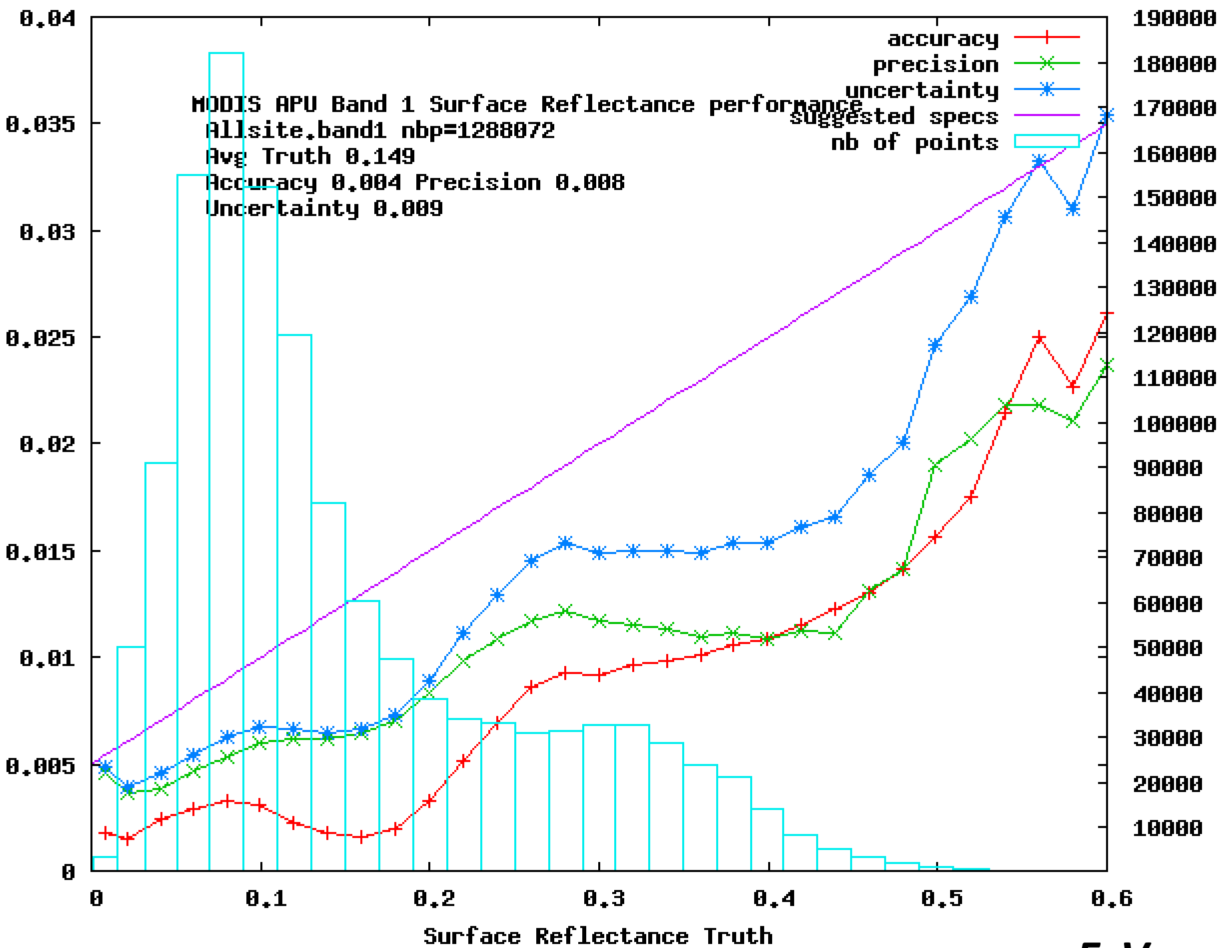
MODIS Collection 5



1,3 Millions 1 km pixels were analyzed for each band.

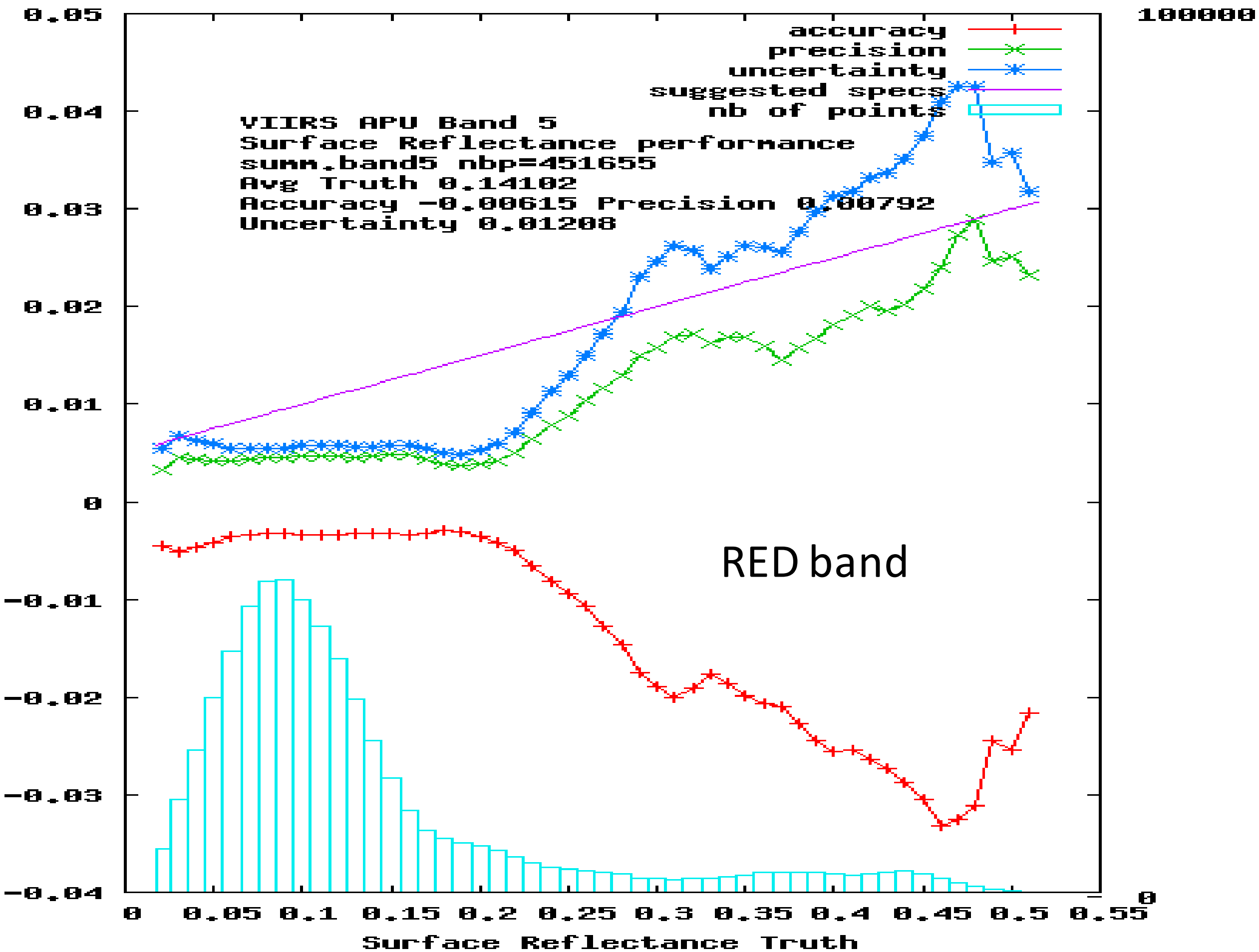
Red = Accuracy (mean bias)
Green = Precision (repeatability)
Blue = Uncertainty (quadratic sum of A and P)

On average well below magenta theoretical error bar

E. Vermote, S. Devadiga, NASA GSFC

Evaluation of SR Algorithm Performance

VIIRS C11 reprocessing



450000 pixels were analyzed for each band.

Red = Accuracy (mean bias)
Green = Precision (repeatability)
Blue = Uncertainty (quadratic sum of A and P)

On average well below magenta theoretical error bar

E. Vermote, S. Devadiga, NASA GSFC

VIIRS Vegetation Index EDR Requirements

Table 5.5.9 - Vegetation Indices (VIIRS)		
EDR Attribute	**Threshold**	**Objective**
Vegetation Indices Applicable Conditions		
1. Clear, land (not ocean),day time only		
a. Horizontal Cell Size	0.4 km	0.25 km
b. Mapping Uncertainty, 3 Sigma	4 km	1 km
c. Measurement Range		
1. NDVITOA	-1 to +1	NS
2. EVI (1)	-1 to +1	NS
3. NDVITOC	-1 to +1	NS
d. Measurement Accuracy - $NDVI_{TOA}$ (2)	0.05 NDVI units	0.03 NDVI units
e. Measurement Precision - $NDVI_{TOA}$ (2)	0.04 NDVI units	0.02 NDVI units
f. Measurement Accuracy - EVI (2)	0.05 EVI units	NS
g. Measurement Precision - EVI (2)	0.04 EVI units	NS
h. Measurement Accuracy - $NDVI_{TOC}$ (2)	0.05 NDVI units	NS
i. Measurement Precision - $NDVI_{TOC}$ (2)	0.04 NDVI units	NS
j. Refresh	At least 90% coverage of the globe every 24 hours (monthly average)	24 hrs.

Notes:

1. EVI can produce faulty values over snow, ice, and residual clouds (EVI > 1).
2. Accuracy and precision performance will be verified and validated for an aggregated 4 km horizontal cell to provide for adequate comparability of performance across the scan.

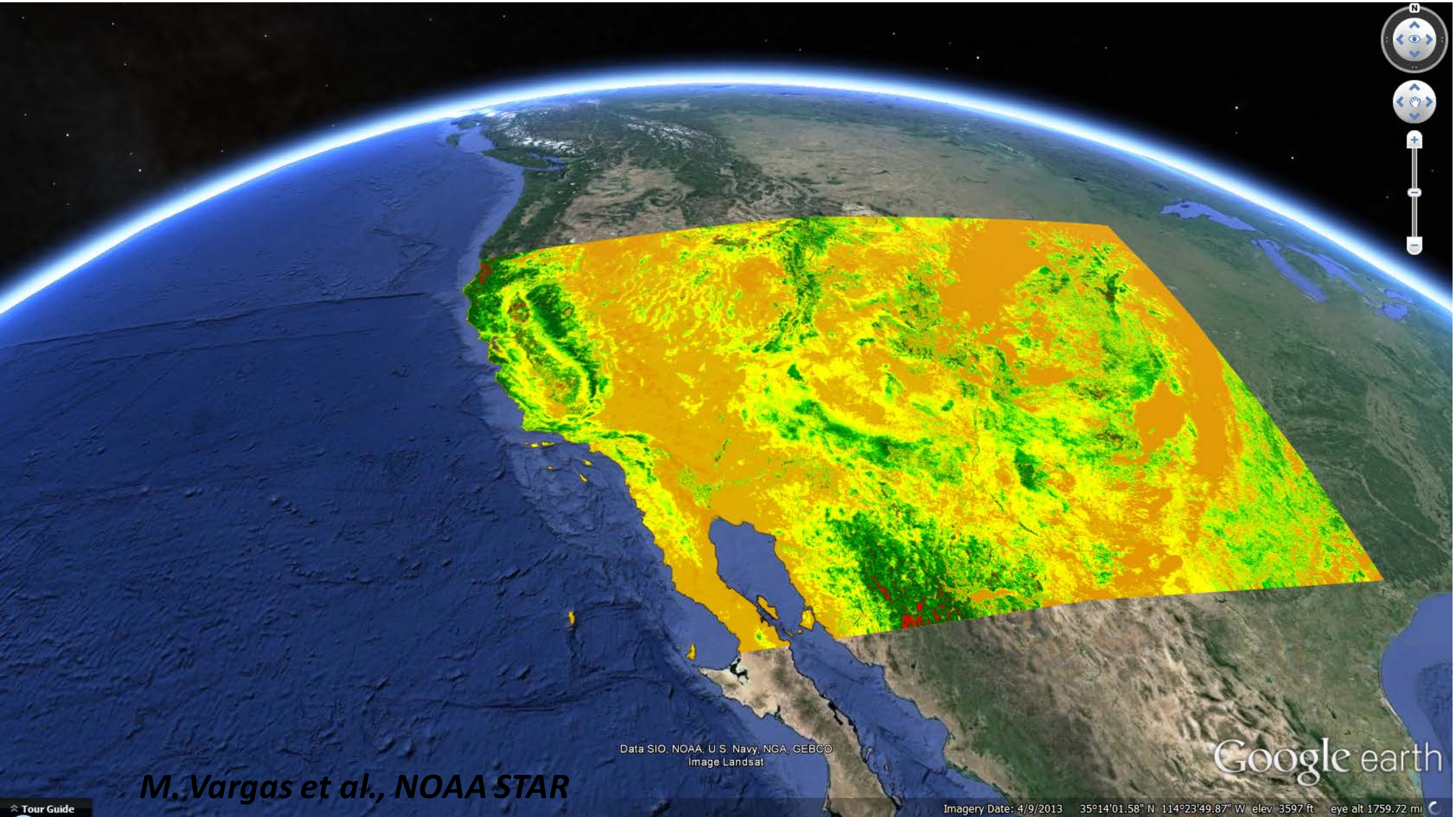
New for JPSS1

$NDVI_{TOC}$ Excluded for SNPP (L1RD-S Appendix D, Table D-1)

Source: Level 1 Requirements Supplement – Final Version:2.9 June 27, 2013

TOA NDVI August 28, 2014 (Mx8.5)

VIVIO_npp_d20140828_t2038279_e2039520_b14691_c20140829030212719401_noaa_ops.h5
VIVIO_npp_d20140828_t2039533_e2041174_b14691_c20140829030212719401_noaa_ops.h5
VIVIO_npp_d20140828_t2041187_e2042428_b14691_c20140829031109580173_noaa_ops.h5



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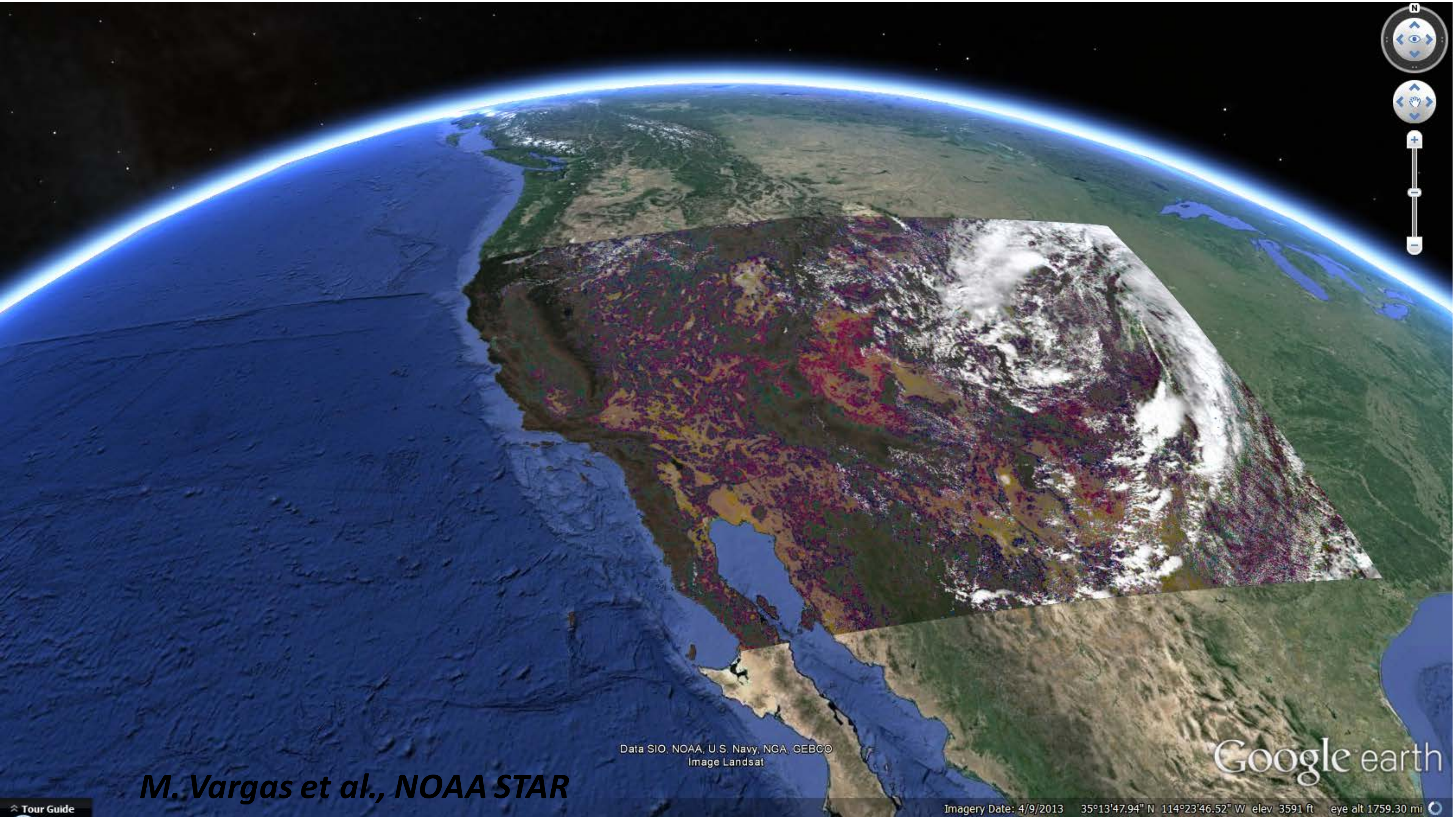
RGB composite August 28, 2014

Surface Reflectance bands M5, M4 and M3 (Mx8.5)



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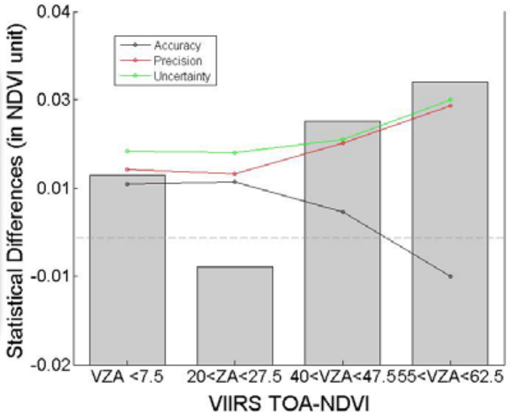
VIIRS VI EDR APU Metrics
MODIS Reference; All Data Days

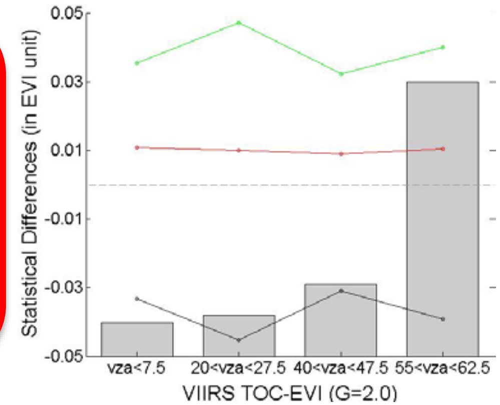
TOA NDVI

	Summary
A	0.005
P	0.017
U	0.020

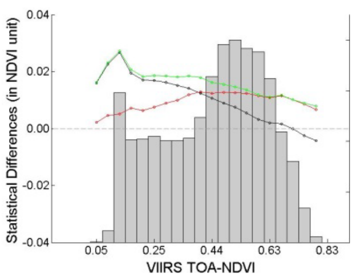


TOC EVI

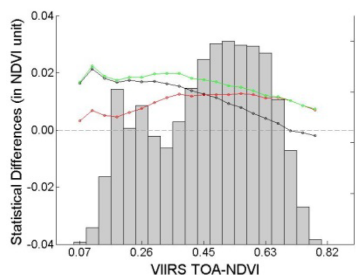
	Summary
A	-0.037
P	0.011
U	0.039



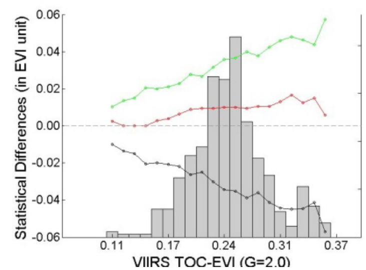
VZ <7.5°



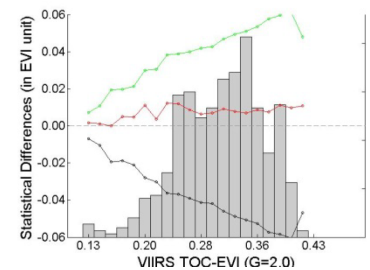
20° < VZ <27.5°



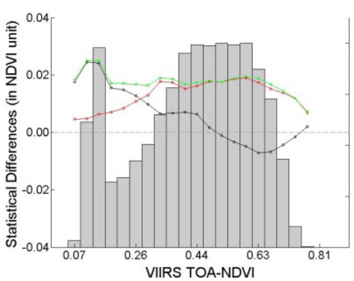
VZ <7.5°



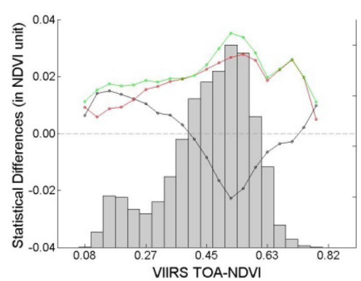
20° < VZ <27.5°



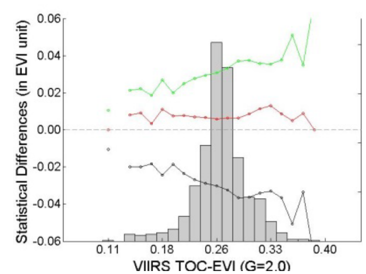
40° < VZ <47.5°



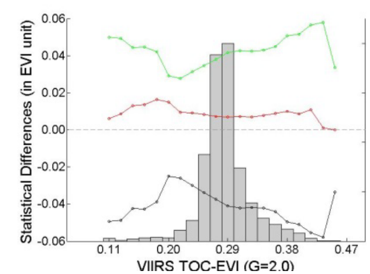
55° < VZ <62.5°



40° < VZ <47.5°



55° < VZ <62.5°



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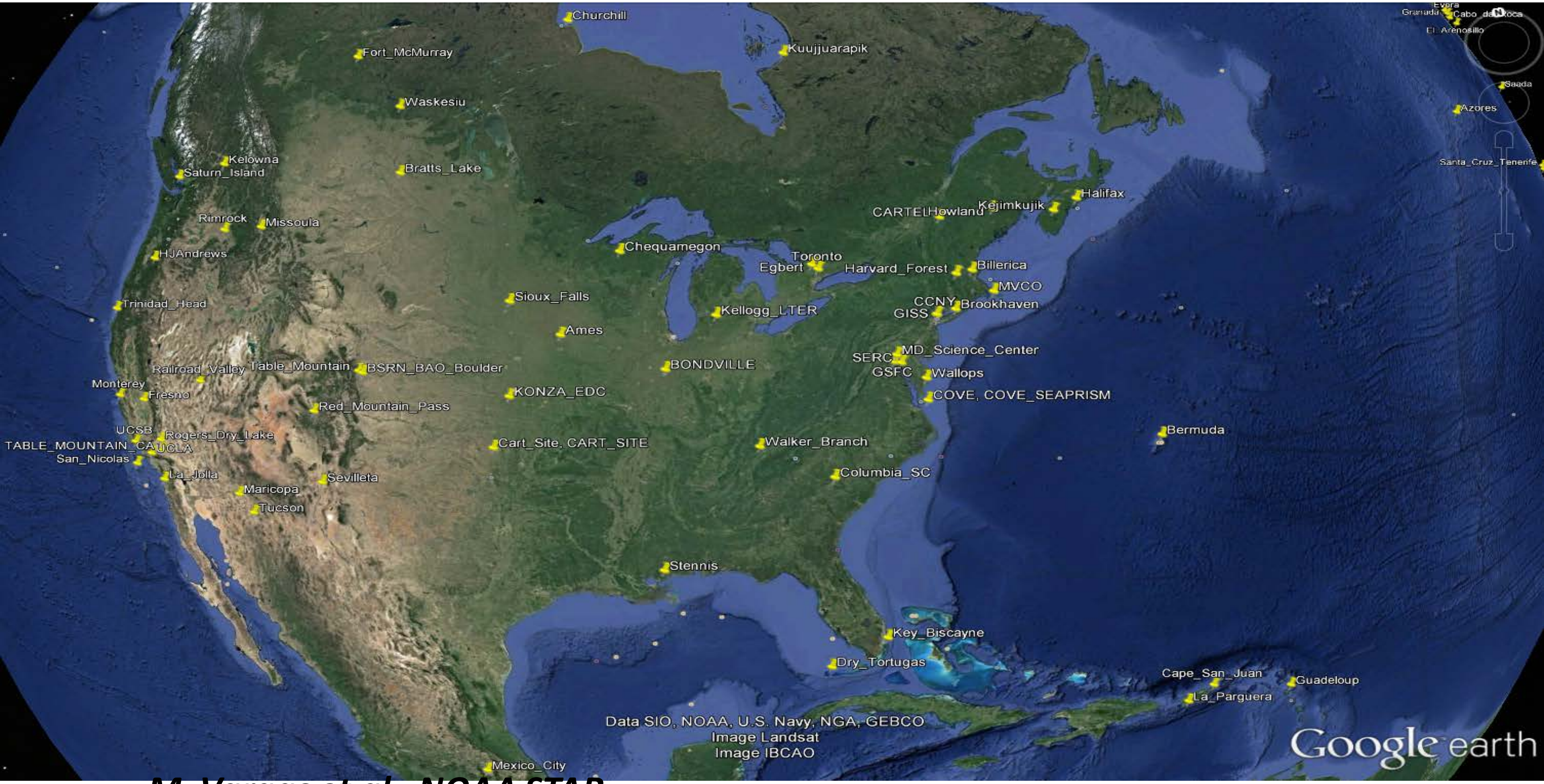
VI EDR Validation: Matchup Data Analysis

Surface Reflectance and VI cutouts collected daily at 229 Aeronet sites: North America Example



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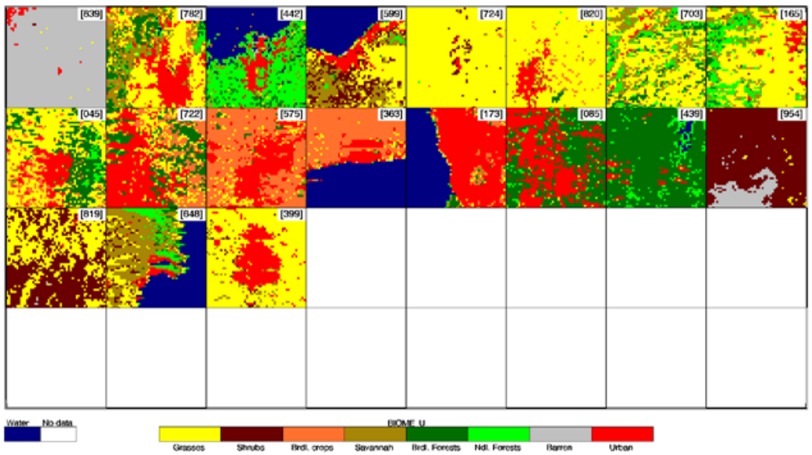
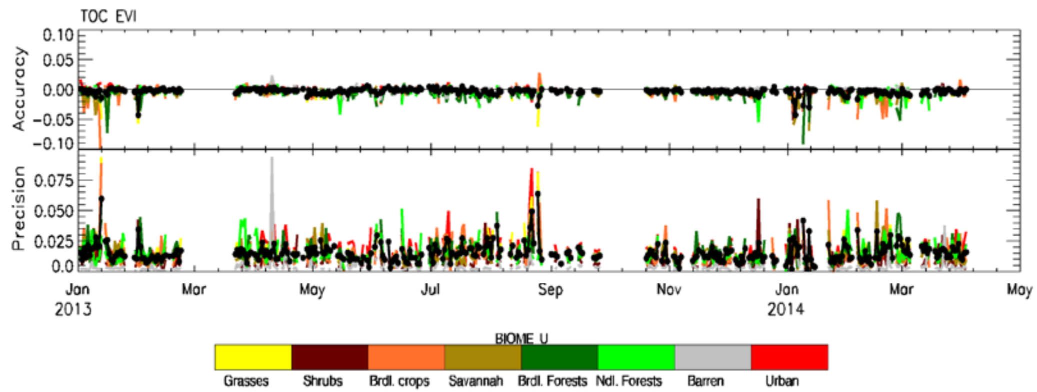
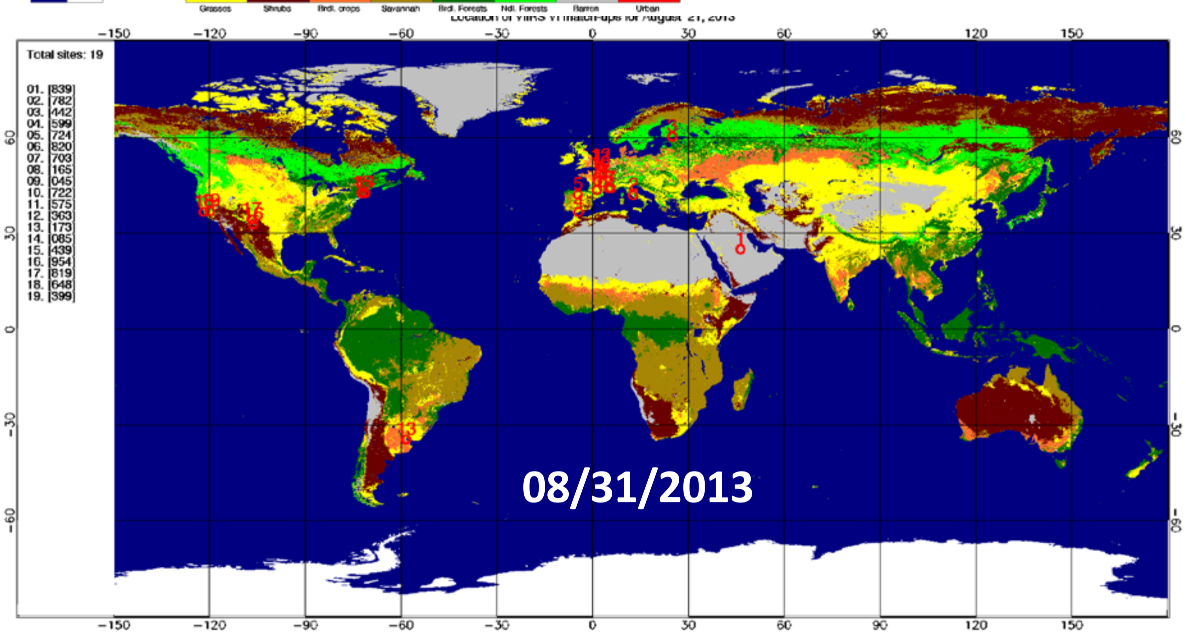
VI EDR Validation
Using AERONET Based SR (Matchup Data)

Sample of global daily distribution of match-up sites (August 21, 2013) covering different surface types and including urban areas. Global Land cover is derived from Combined Terra & Aqua MODIS LAI/FPAR LC product (MCD12C1, ver. 5.1).







Global APUs
(Jan 1, 2013 – Mar 31, 2014)

	TOC EVI	TOC NDVI
A	-0.004	0.009
P	0.015	0.035
U	0.016	0.038

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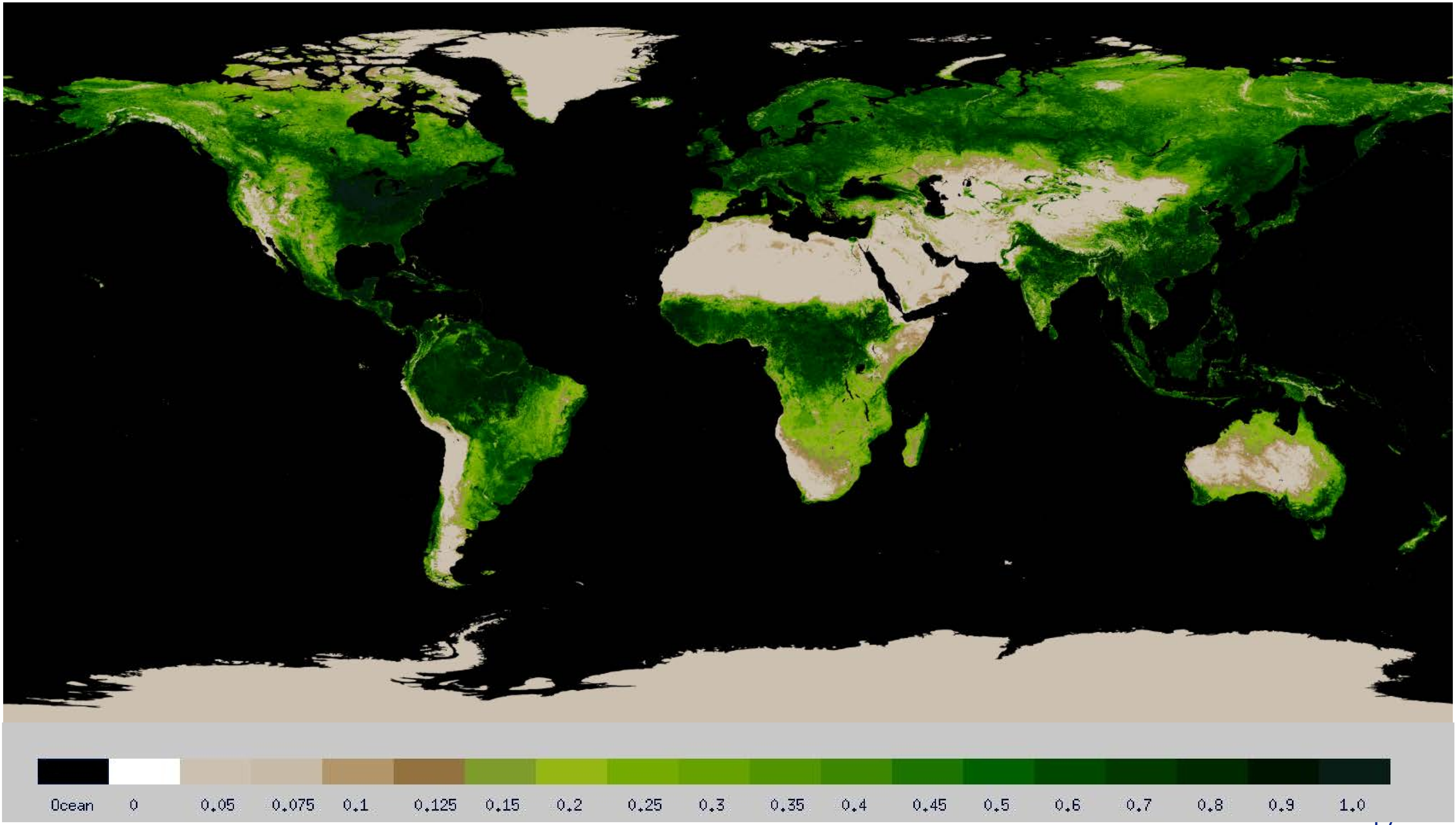
VIIRS Green Vegetation Fraction

4-km Global GVF (Sep 1-7, 2014)



Coverage Lat 90°N - 90°S, Lon 180°W - 180°E

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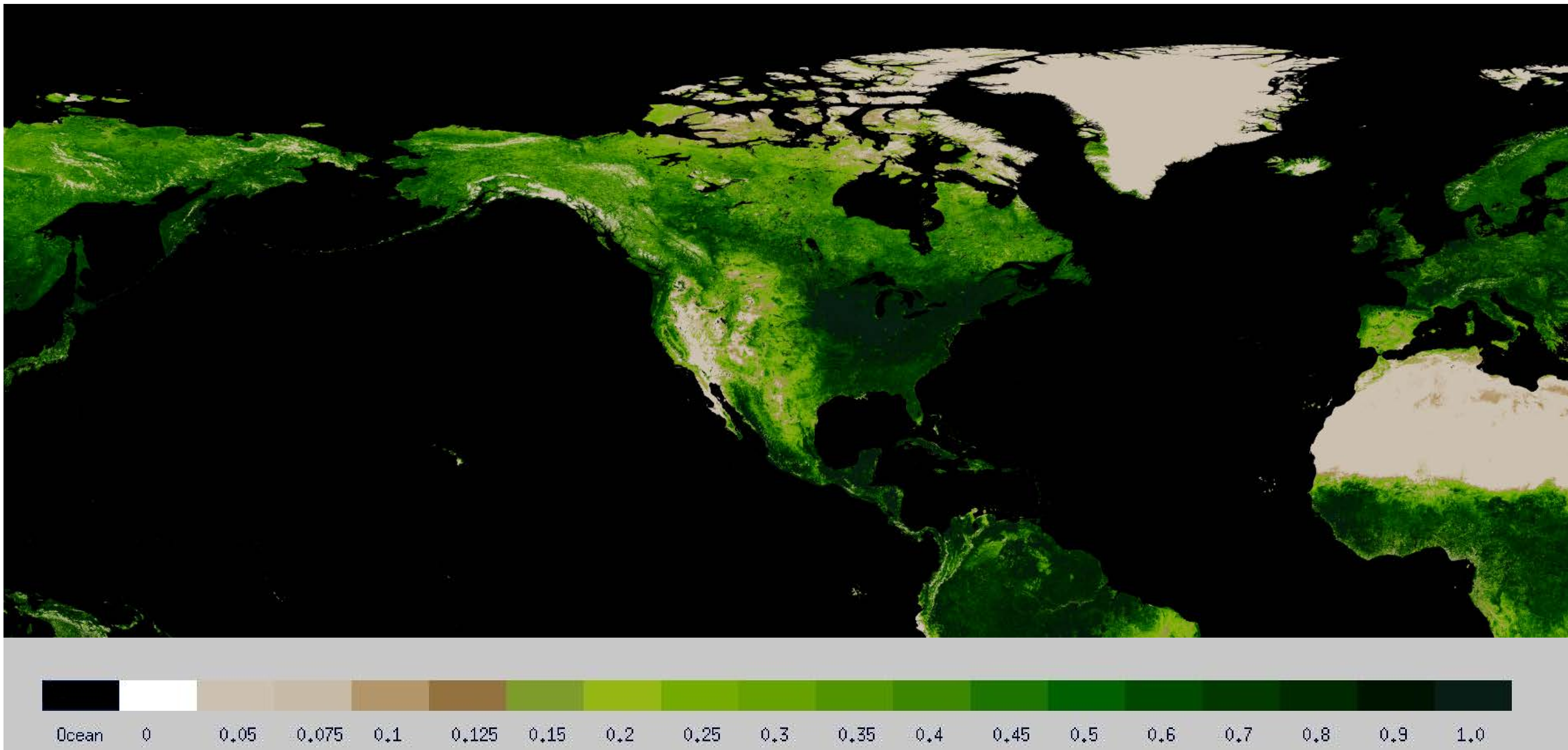
VIIRS Green Vegetation Fraction

1-km Regional GVF (Sep 1-7, 2014)



Coverage Lat 90°N - 7.5°S, Lon 130°E - 30°E

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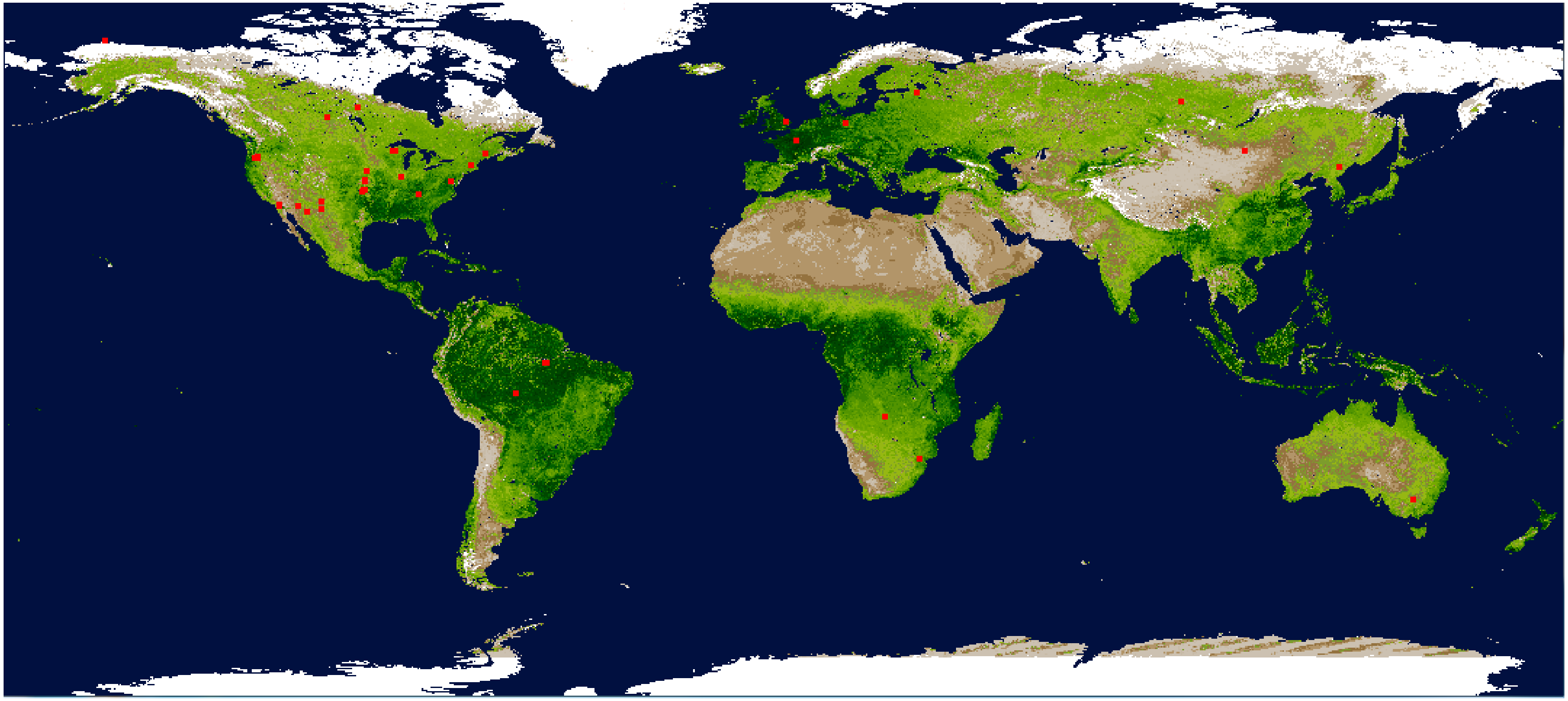
VIIRS Green Vegetation Fraction

GVF Validation Sites



- **The EOS Land Validation Core Sites are intended as a focus for land product validation over a range of biome types (http://landval.gsfc.nasa.gov/coresite_gen.html)**

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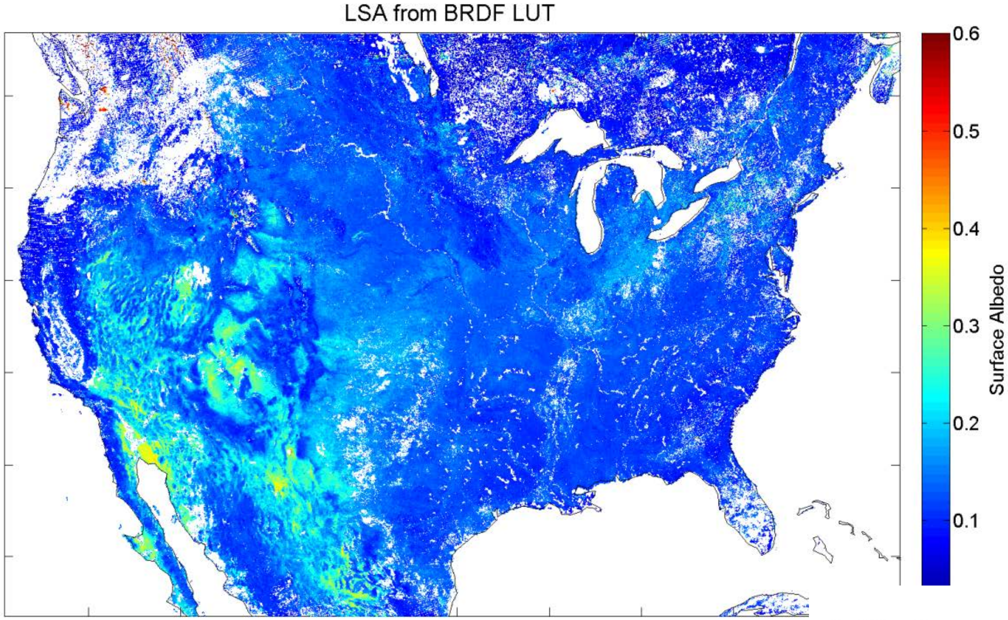
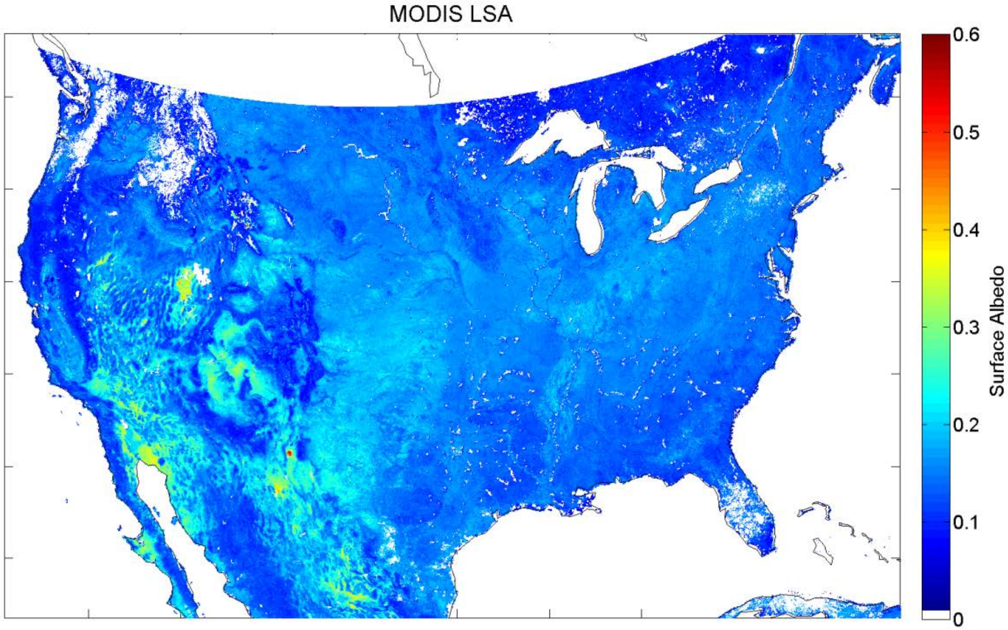
VIIRS Green Vegetation Fraction

Attribute Analyzed	L1RD Threshold	VIIRS GVF
Measurement accuracy		
1. Global	12%	7.9%
2. Regional	12%	6.5%
Measurement precision		
1. Global	15%	10.9%
2. Regional	15%	12.6%
Measurement uncertainty		
1. Global	17%	13.4%
2. Regional	17%	14.2%

Maps of 16-day mean albedo



An LUT update for the VIIRS provisional albedo (BPSA – Bright Pixel Surface Albedo) is being implemented in IDPS Mx8.6 (October 2014)



Contiguous US maps of 16-day (DOY 145-160, 2012) mean LSA and MODIS albedo.

Top: the VIIRS BPSA albedo

Bottom: the MODIS albedo

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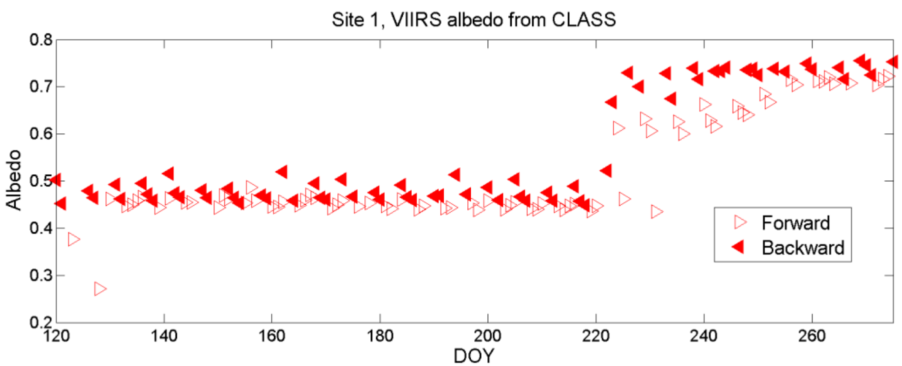
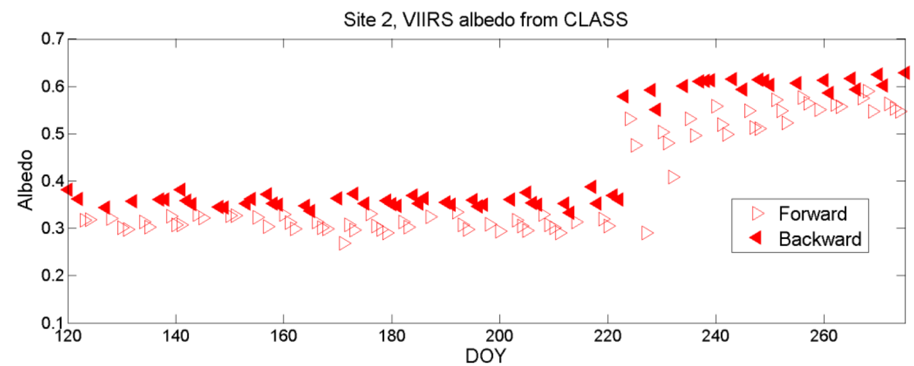
Land Surface Albedo

The LSA retrievals in the summer of 2012 over two Libya desert sites (Site 1: 24.42˚N 13.35˚E and Site 2: 26.45˚N, 14.08˚E) are used to illustrate the issue of temporal variability of LSA.

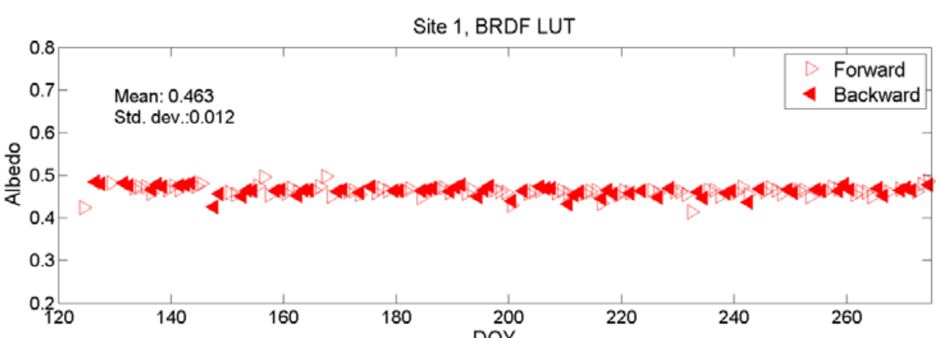


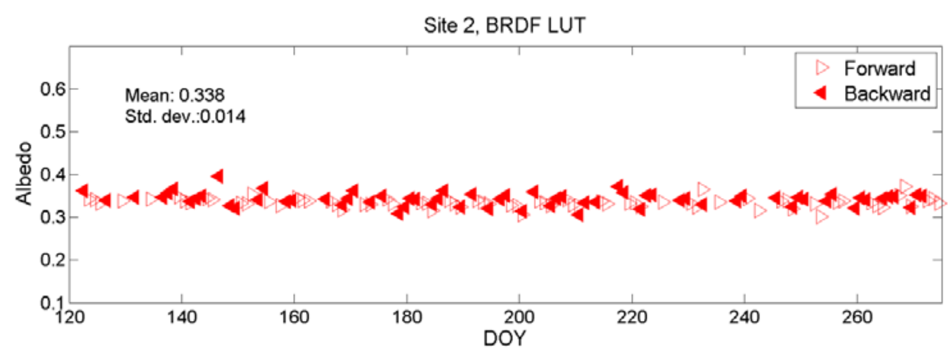


“Forward” means pixels with relative azimuth angle >90° and “backword” means those with relative azimuth angle <90°.
Jumps around 8/9 were caused by the bugs in a early version of the operational codes.

New albedo estimated with the BRDF LUT has improved in temporal stability

LSA retrieved from new BRDF LUT. The spurious retrievals caused by undetected cloud and cloud shadow are excluded with the threshold of mean ± 0.05.





Y. Yu, NOAA/STAR, D. Wang (UMD)

VIIRS LST Product L1 requirements

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

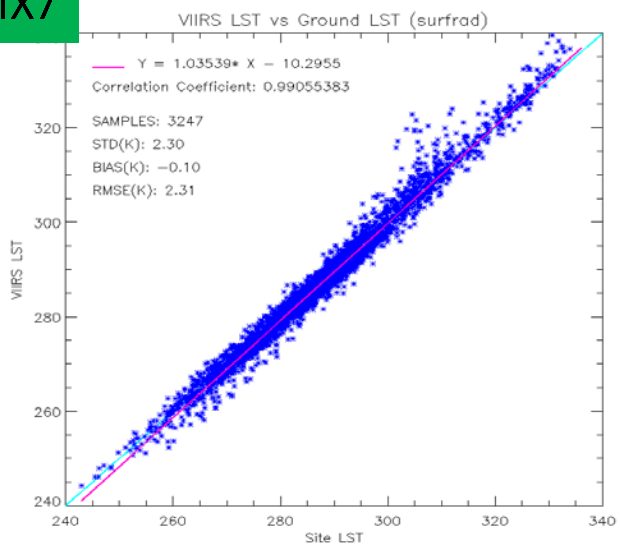
θ and φ -- sensor and solar zenith angles, respectively

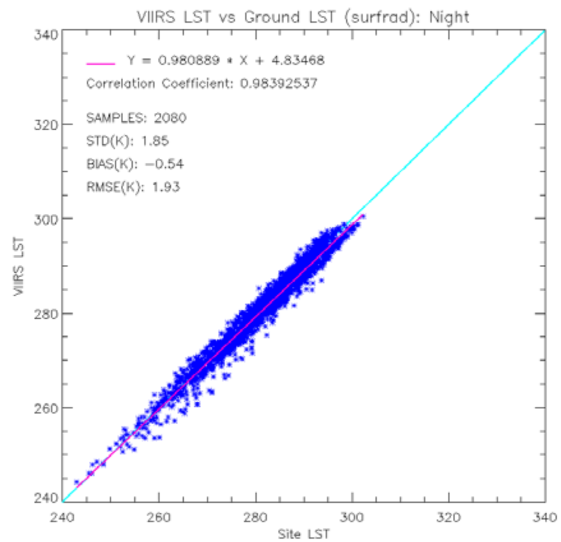
$a_j(i)$ and $b_j(i)$ -- regression coefficients for the j_{th} IBGP surface type for daytime and nighttime LST retrievals, respectively

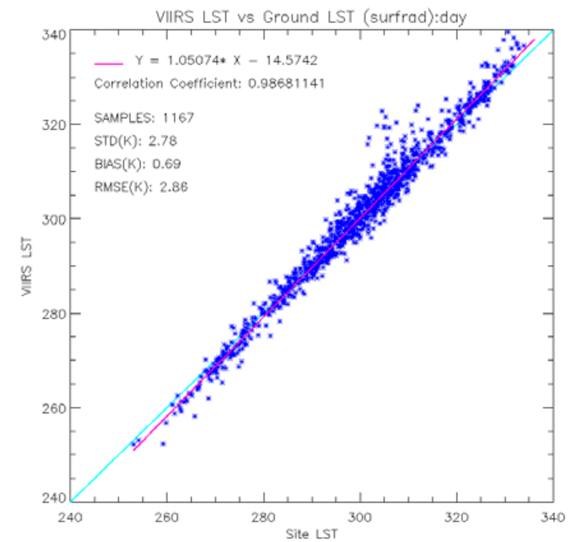
- Two algorithms have been implemented
  - Baseline: Split Window LST(SWLST) is derived using two TIR channels (M15, M16)
  - Back-up: Dual Split Window LST (DSWLST) is derived using TIR channels (M15, M16) and SIR infrared channels (M12, M13)
- Evaluation underway
  - Comparison with MODIS LST product
  - 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).

LST evaluation using ground data

MX7

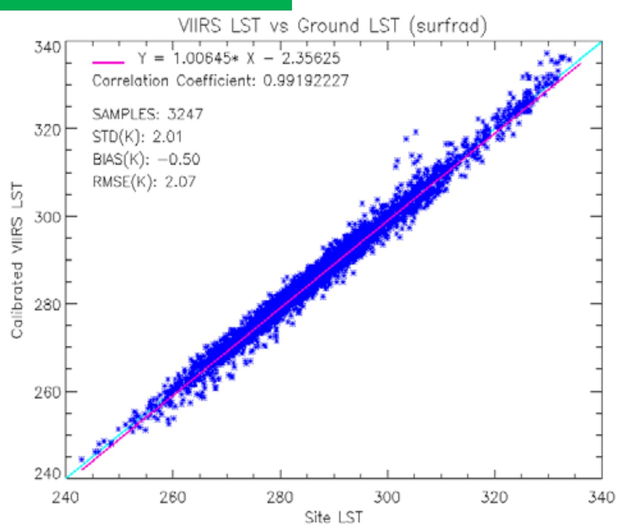


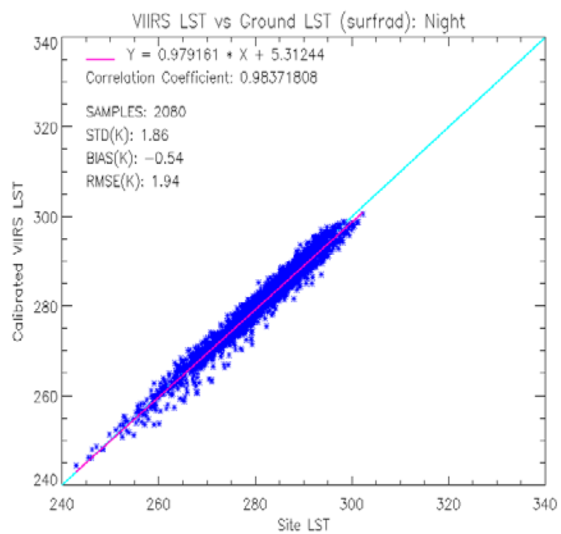


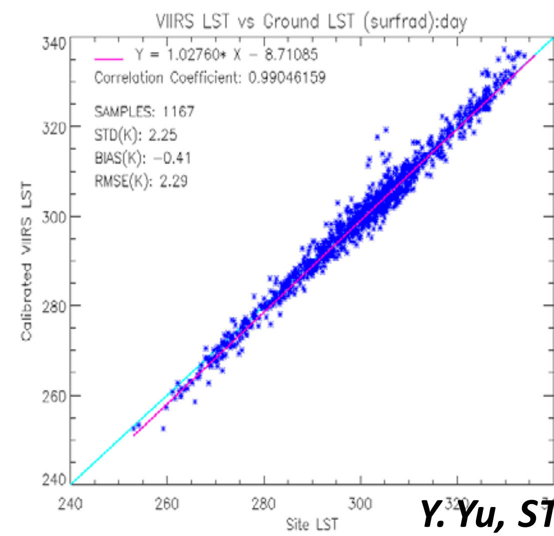


MX8_corrected

Implemented in IDPS on August 13, 2014

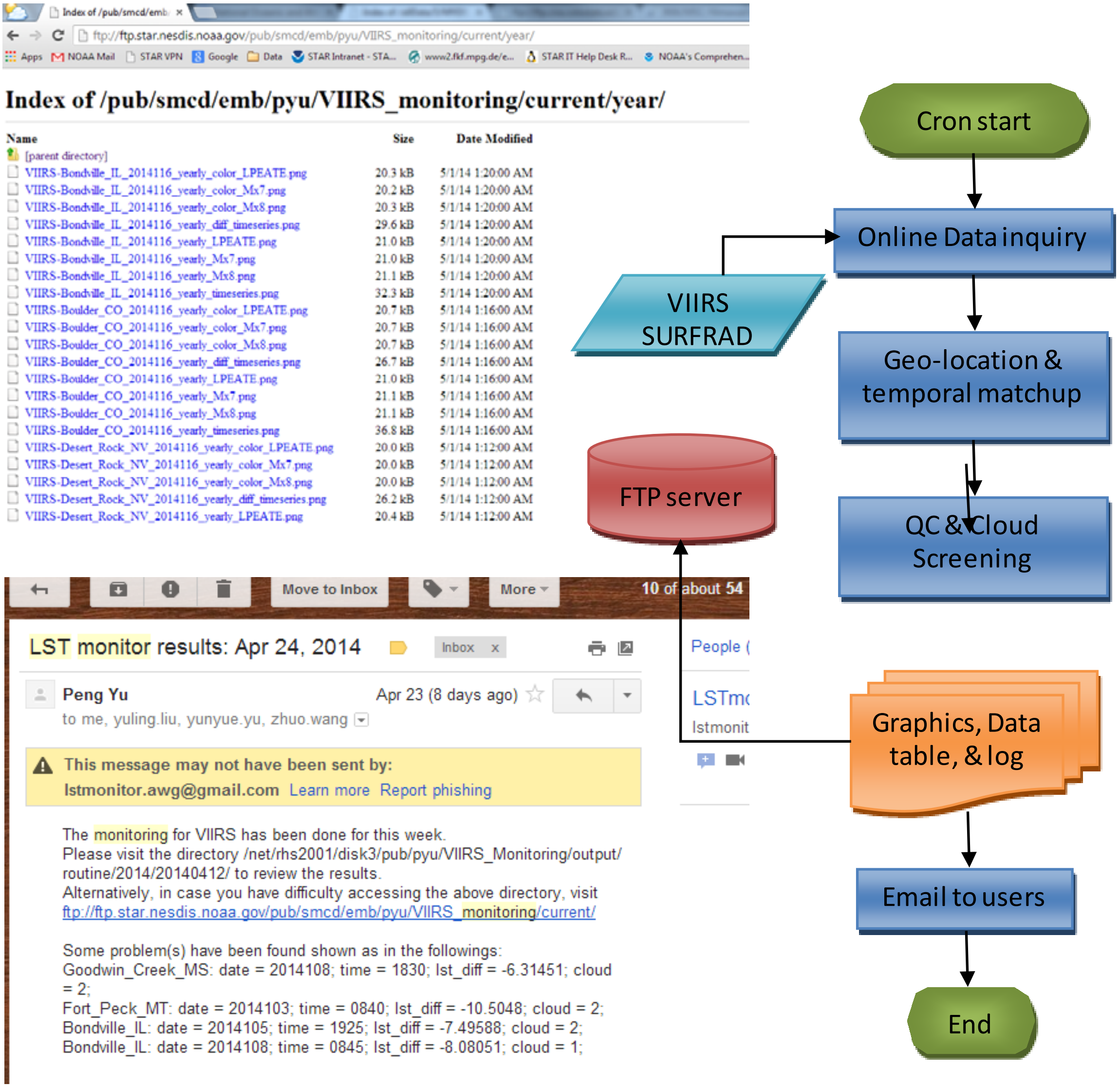


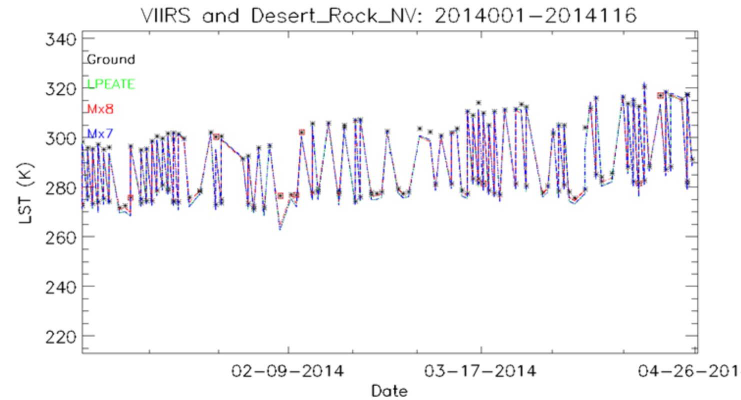


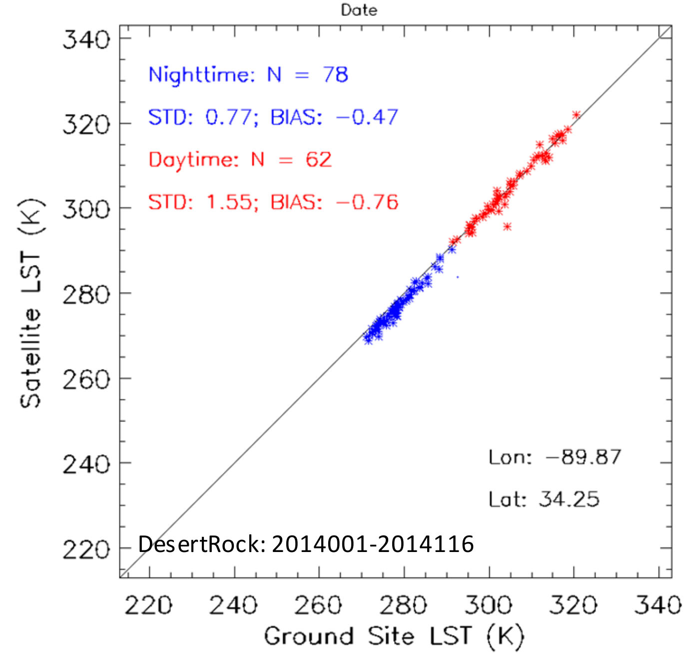


Y. Yu, STAR

LST Product Monitoring







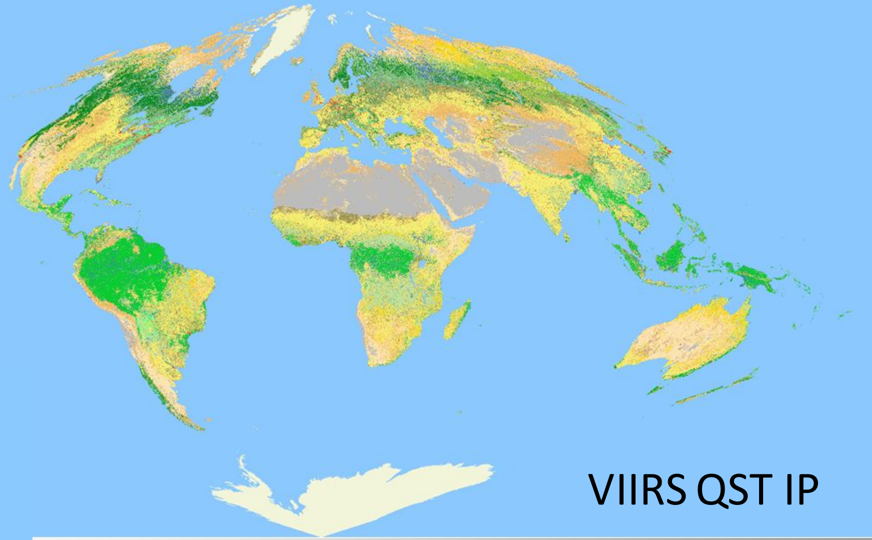
Y. Yu et al., NOAA STAR

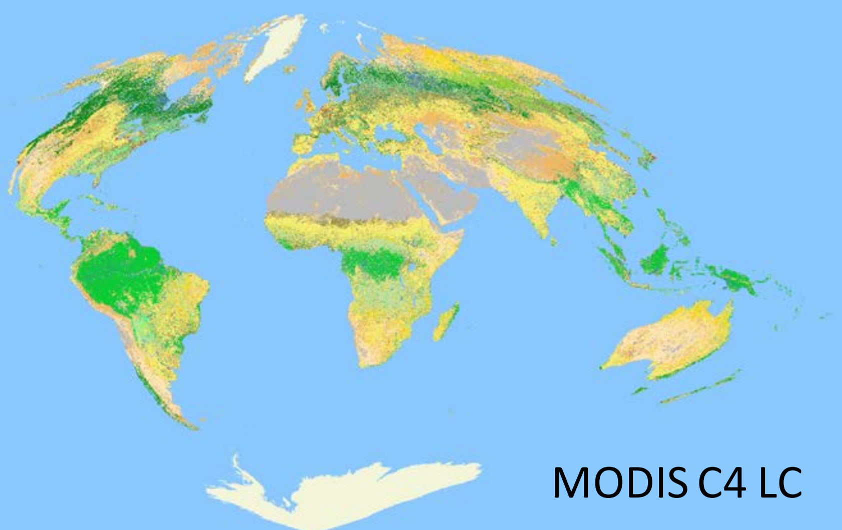
Surface Type L1RD Requirements

Table 4.5.4.2 - Surface Type (VIIRS)		
EDR Attribute	**Threshold**	**Objective**
SURF Applicable Conditions: 1. Both clear and partly cloudy sky conditions		
a. Horizontal Cell Size	1 km at Nadir	1 km at Edge of Scan
b. Mapping Uncertainty, 3 Sigma	5 km	1 km
c. Measurement Range	17 IGBP classes specified in Table 4.5.4.1	17 IGBP classes
d. Measurement Precision *	10%	0.1%
e. Measurement Accuracy *	70% correct for 17 types	2%
f. Refresh	At least 90% coverage of the globe every 24 hours (monthly average)	3 hrs.
		v2.0, 9/23/12

* *Current IDP product was designed to meet heritage NPOESS requirements. Beta evaluation is done against those heritage requirements. Precision and accuracy numbers are to be corrected in the JPSS L1RD.*

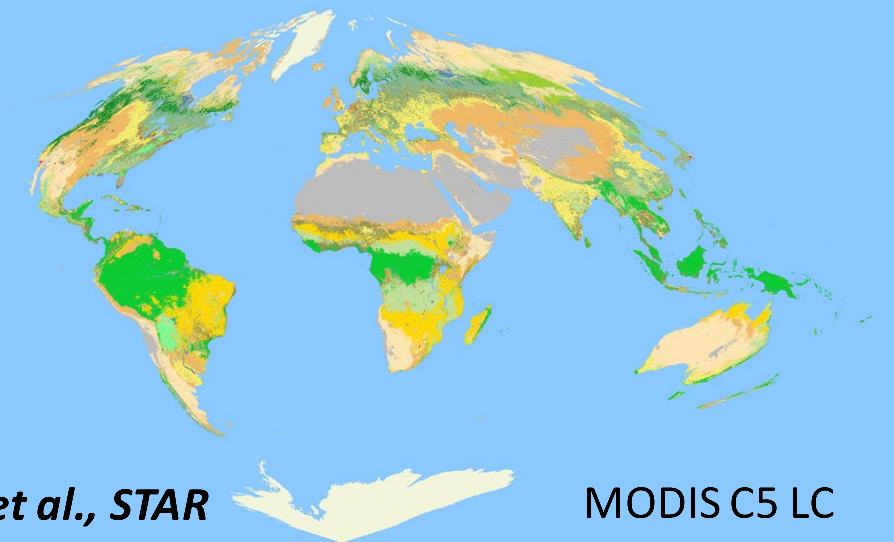
Surface Type: Comparison with MODIS C4/C5 LC





Legend

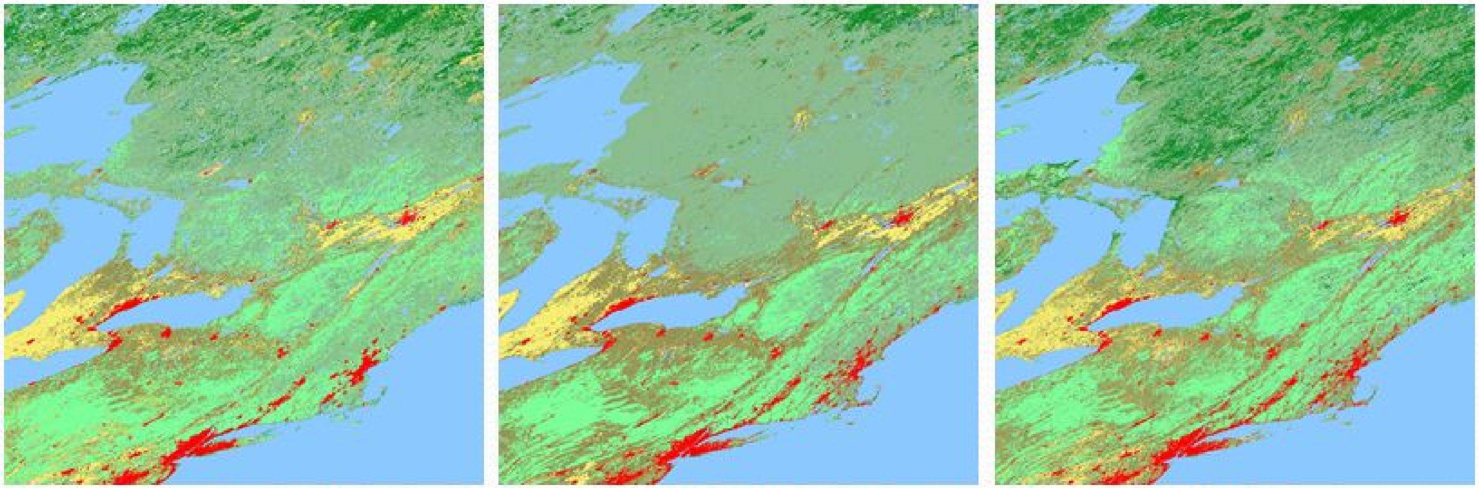
- Evergreen Needleleaf Forest
- Evergreen Broadleaf Forest
- Deciduous Needleleaf Forest
- Deciduous Broadleaf Forest
- Mixed Forest
- Closed Shrublands
- Open Shrublands
- Woody Savannas
- Savannas
- Grasslands
- Permanent Wetlands
- Croplands
- Urban and Built-Up
- Cropland/Natural Vegetation Mosaic
- Snow and Ice
- Barren or Sparsely Vegetated
- Water Bodies



X. Zhan et al., STAR

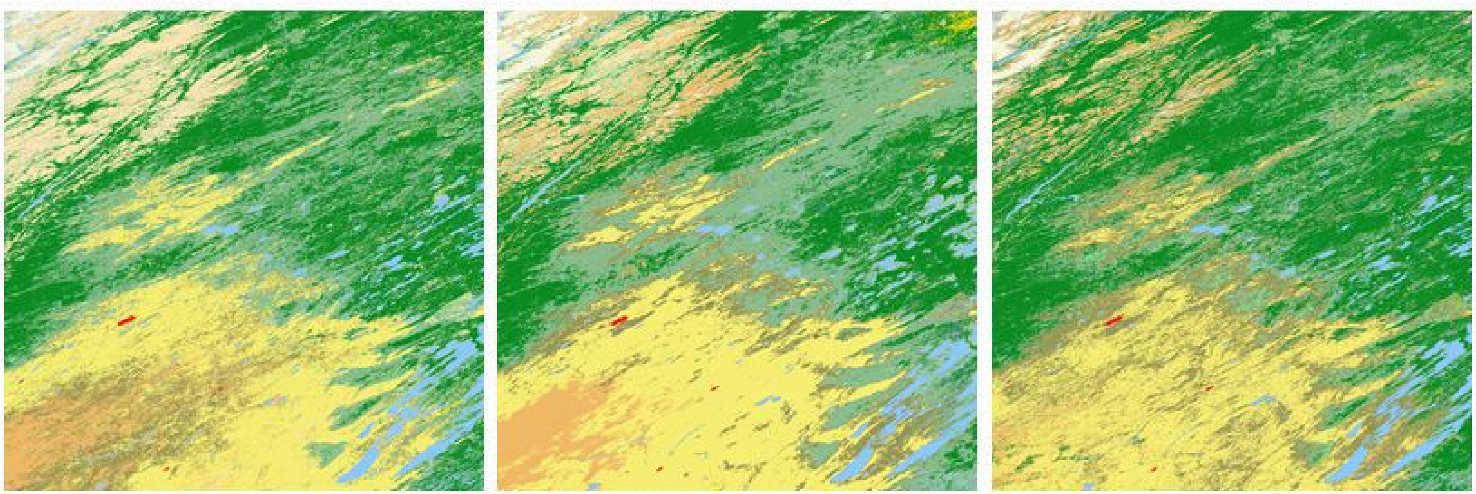
Detailed Comparisons

MODIS C4 MODIS C5 VIIRS QST IP



Great Lakes Region, MODIS Tiling system H12V04

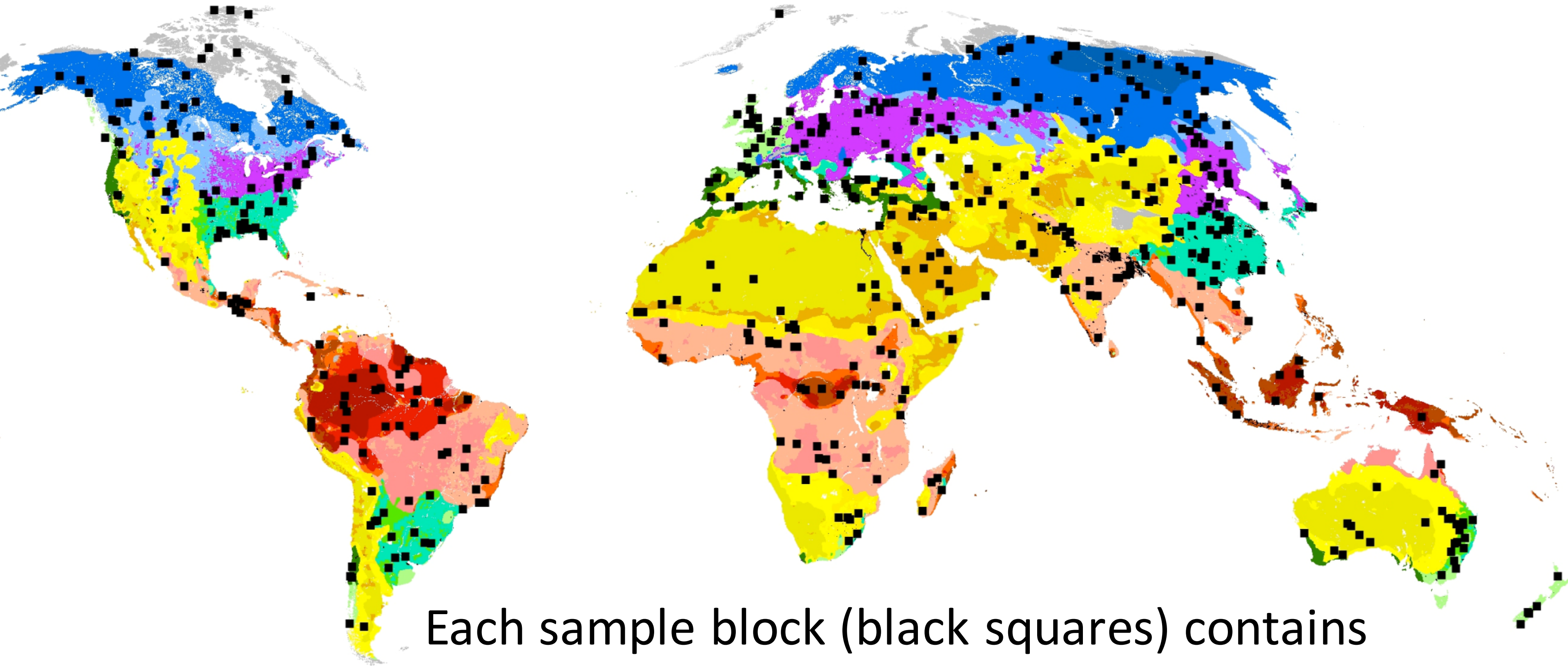
MODIS C4 MODIS C5 VIIRS QST IP



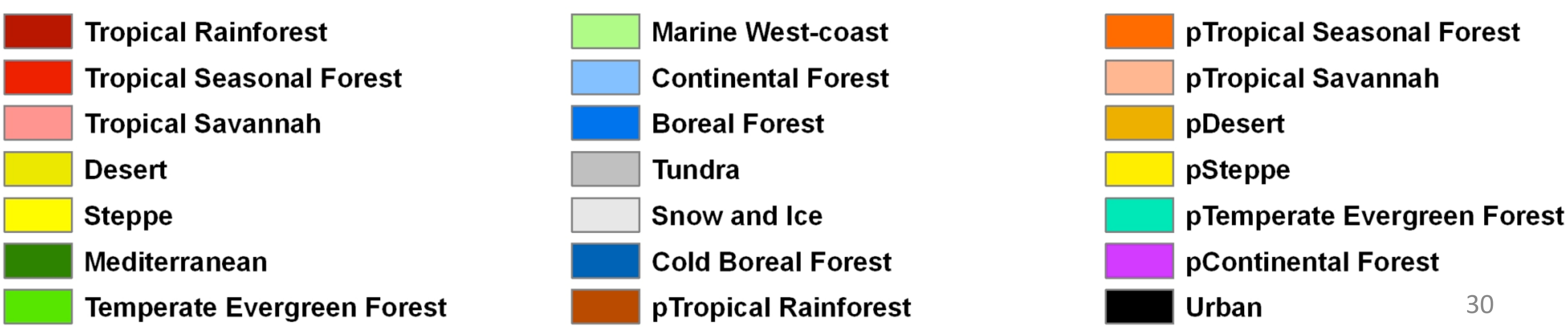
Western Canada Region, MODIS Tiling system H11V03

M. Friedl , D. Sulla-Menashe (BU)

Validation Sample Design

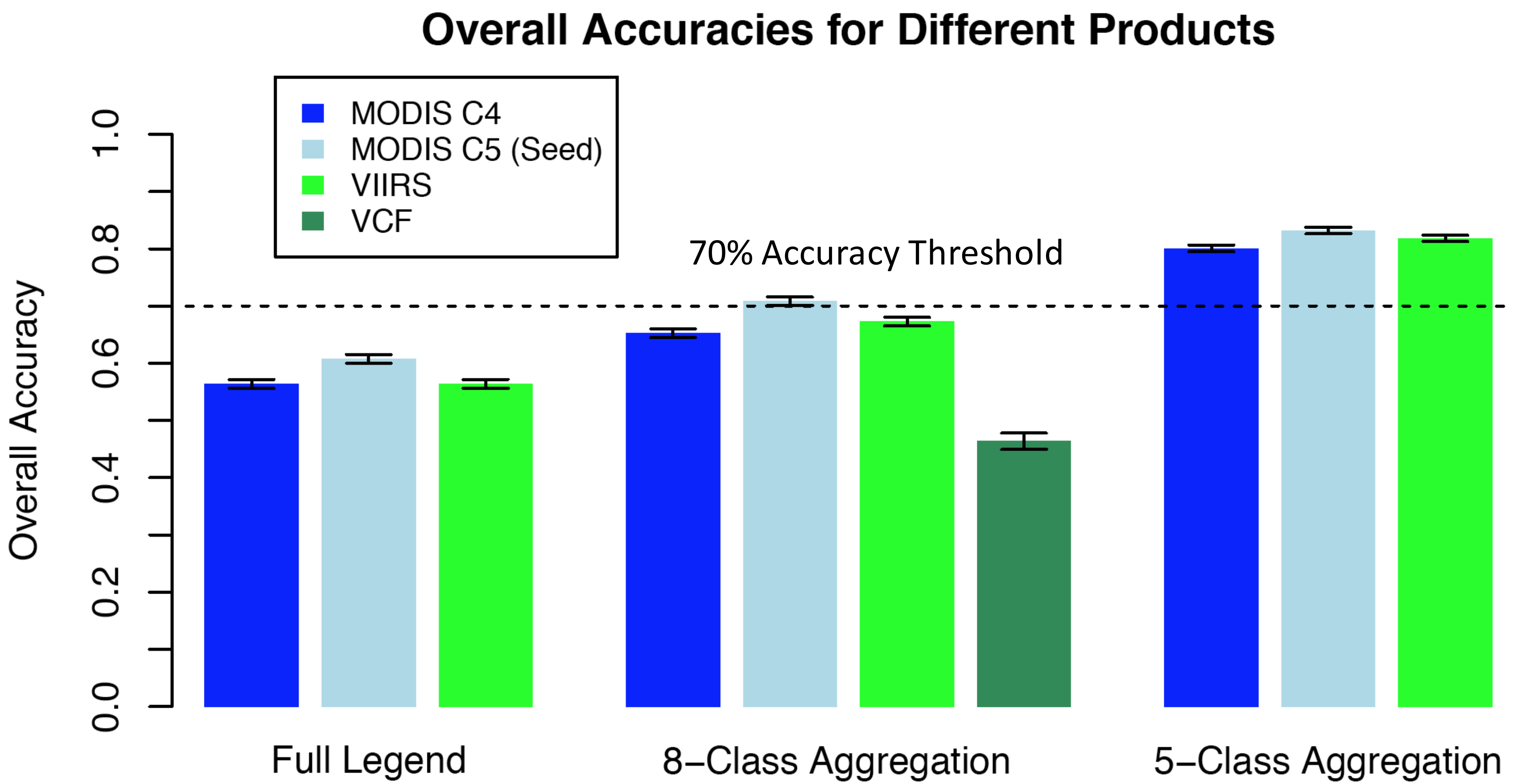


Each sample block (black squares) contains between 10 and 35 1-km VIIRS pixels.



M. Friedl , D. Sulla-Menashe (BU)

Surface Type Validation Results



There is more variance in overall accuracies across aggregation levels than between maps.

M. Friedl , D. Sulla-Menashe (BU)

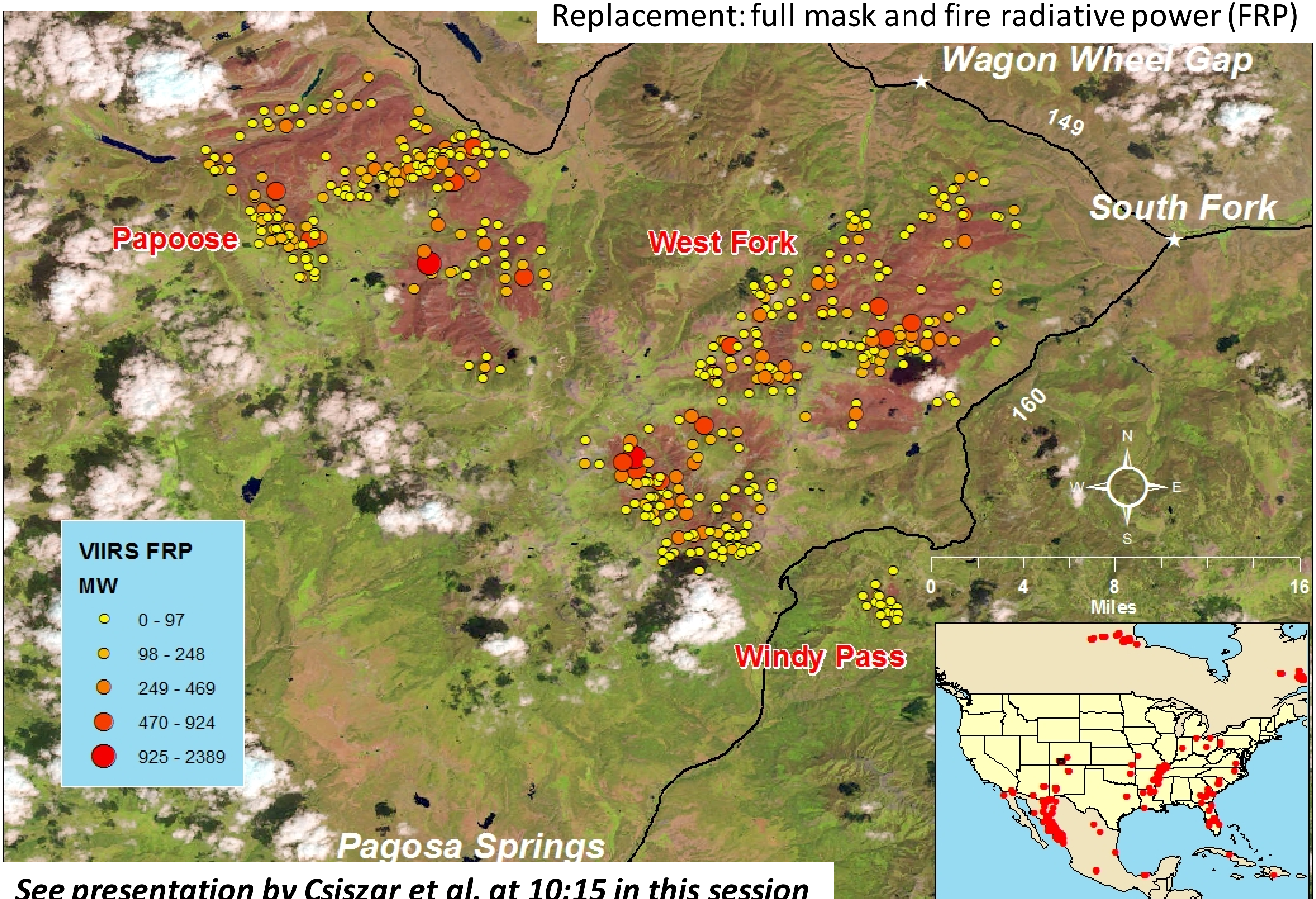
West Fork Complex: 6/14 - 7/4/2013

Active Fire

Landsat-8 background: July 31, 2013

Current: locations only

Replacement: full mask and fire radiative power (FRP)



See presentation by Csiszar et al. at 10:15 in this session

SNPP Land Product Maturity

Product	Science Maturity	Operational product implementation date	NDE Operational status
Surface Reflectance	Validated 1	Spring 2015 (Mx8.8?)	N/A
Vegetation Index	Validated 1	August 13, 2014 (Mx8.5)	N/A
Green Vegetation Fraction	N/A	October 2014 (NDE)	Conditionally approved
Vegetation Health	N/A	TBD (NDE)	In progress
Albedo	Provisional	October 2014 (Mx8.6)	N/A
LST	Provisional	August 13, 2014 (Mx8.5)	N/A
Active Fire	Validated 1	August 13, 2014 (Mx8.5)	Operational
Surface Type	Provisional	October 2014 (off-cycle)	N/A

Summary and Conclusions

- S-NPP VIIRS land IDPS and NOAA-Unique NDE development and evaluation is progressing well
- Development of data products not in the suite of operational NOAA products (i.e. IDPS or NDE)
  - NOAA JPSS Proving Ground and Risk Reduction
  - NASA SNPP Science Team
- Teams are continuing the development of improved and additional products
- Development and operational implementation of products to meet new Level 1 requirements
  - Top-of-canopy vegetation index
  - Full active fire mask and fire radiative power

For more information

- NOAA JPSS
  http://www.jpss.noaa.gov/

- NOAA STAR
  http://www.star.nesdis.noaa.gov/jpss/

- NASA VIIRS Land
- http://viirsland.gsfc.nasa.gov/

- STAR JPSS 2014 Annual Science Team Meeting
  http://www.star.nesdis.noaa.gov/star/meeting_2014JPSSAnnual_agenda.php

- JGR-Atmospheres Special Issue Papers

VIIRS vs. MODIS for land monitoring

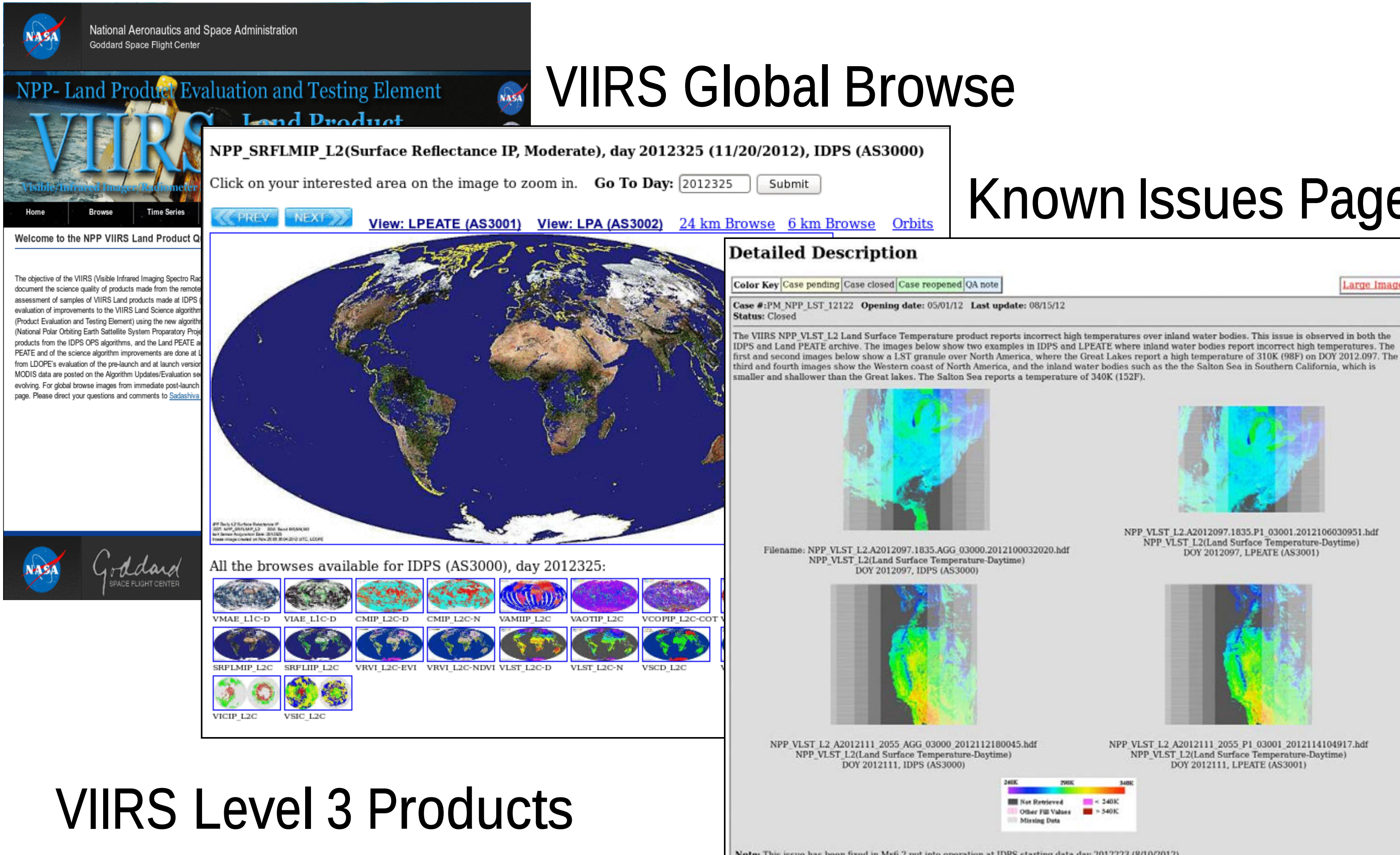
- What can VIIRS do better than MODIS?
  - Better coverage and scanning geometry, including higher resolution of "M" bands
    - Improved fire detections (25% higher VIIRS fire counts than MODIS in the three-pixel VIIRS aggregation zone)
    - No gaps at low latitudes, more consistent data for temporal compositing
- What can VIIRS do that MODIS cannot?
  - VIIRS Day/Night Band: VIIRS can directly assess a variety of phenomenon associated with human settlements (e.g., population, socio-economic activity, the built environment, and urbanization).
- What can MODIS do better than VIIRS?
  - *MODIS can 'see' the Amazon better*: TERRA-MODIS was designed to cross the equator at a time when cloud cover is at its daily minimum (10:30AM, descending).
- What can VIIRS do that is currently missing?
  - VIIRS can/should be used to measure the Earth's Biosphere: (i.e., not just daily VI and Surface Type, but also LAI/FPAR, NPP/GPP, Burned Area, Phenology, etc.)
  - Multiple threads of VIIRS product development and generation: IDPS, NOAA JPSS (NDE), Proving Ground, NASA Science Team and Applied Science etc.

The Land PEATE: meeting the needs of the NASA Science Team and helping the NOAA IDPS

VIIRS LDOPE QA: http://landweb.nascom.nasa.gov/NPP_QA/

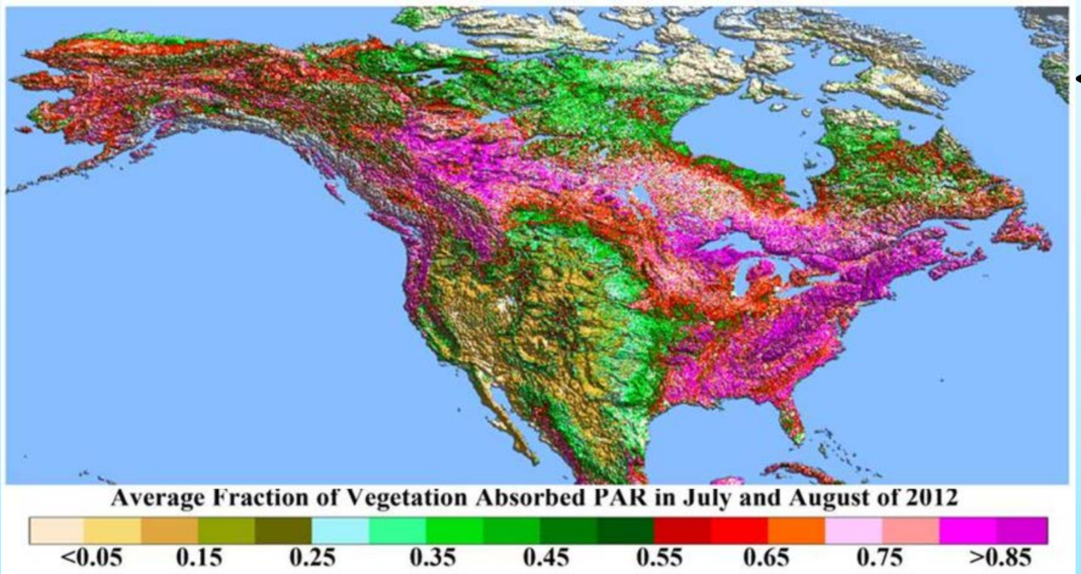
VIIRS Global Browse

Known Issues Page



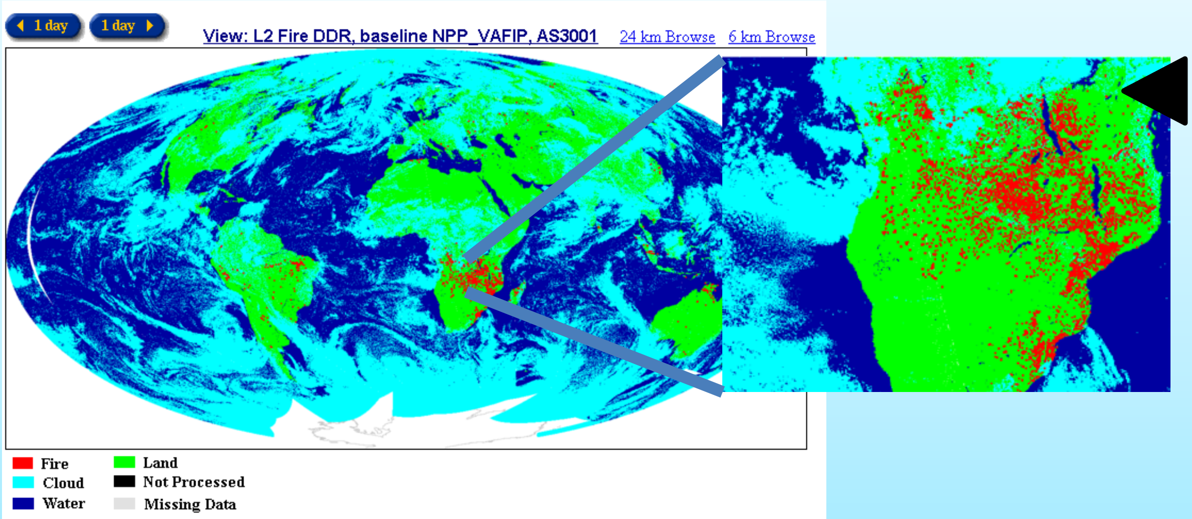
VIIRS Level 3 Products

VIIRS Land Science Team Support Activities



Conversion of MODIS code for Daily LAI/FPAR to VIIRS Land Science DDR is complete.

R. Myneni (BU)

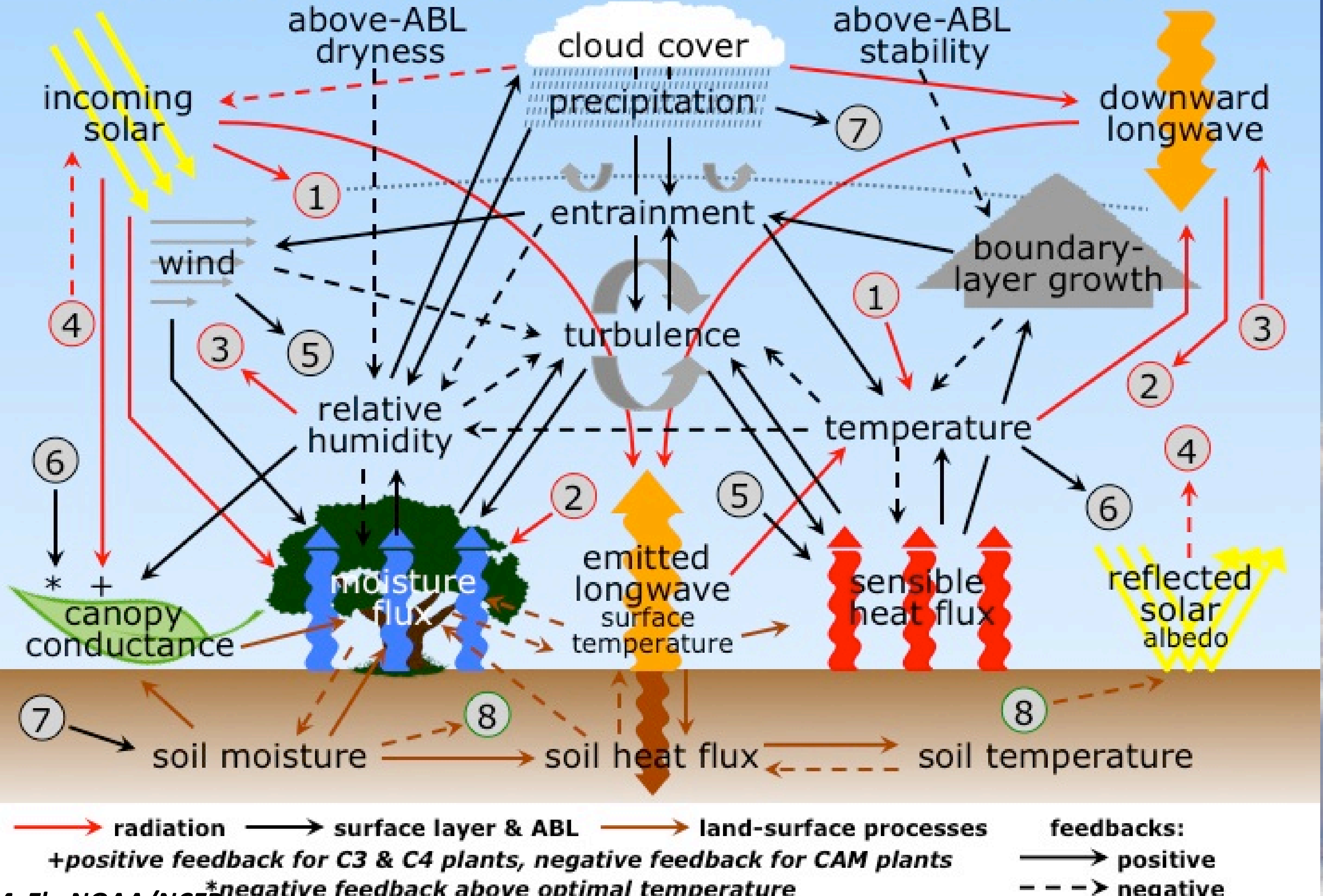


Level 2 Fire DDR, baseline NPP_VAFIP, 8/12/2012

Integration and testing of VIIRS Active Fire DDR. New PGE installed to operations.

L. Giglio (UMD)

Local Land-Atmosphere Interactions



M. Ek, NOAA/NCEP

Land Model Requirements

To provide these proper boundary conditions, land model must have:

- **Atmospheric forcing** to drive land model,
- Appropriate **physics** to represent land-surface processes,
- Proper **initial land states**, such as snow & soil moisture (analogous to initial atmospheric conditions, though land states may carry more "memory", especially deep soil moisture, similar to ocean SSTs),
- **Land data sets**, e.g. <u>land use/land cover (vegetation type)</u>, soil type, surface albedo, and associated parameters, e.g. surface roughness, soil and vegetation properties.

M. Ek, NOAA/NCEP