Suomi NPP EDR Performance

Ivan Csiszar, Lihang Zhou

NOAA/NESDIS Center for Satellite Applications and Research (STAR)

Ray Godin

Johns Hopkins University, Applied Physics Laboratory

Thomas Atkins, Murty Divakarla, Xingpin Liu

I.M. Systems Group

NOAA JPSS Science Teams

Outline

- JPSS product requirements
- Algorithm and product maturity stages
- Current product maturity levels
- Summary

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

JPSS Product Maturity (2/1)

Beta

- Product is **minimally validated**, and may still contain significant identified and unidentified errors.
- Information/data from validation efforts can be used to make initial qualitative or very limited quantitative assessments regarding product fitness-for-purpose.
- Documentation of product performance and identified product performance anomalies, including recommended remediation strategies, exists.

Provisional

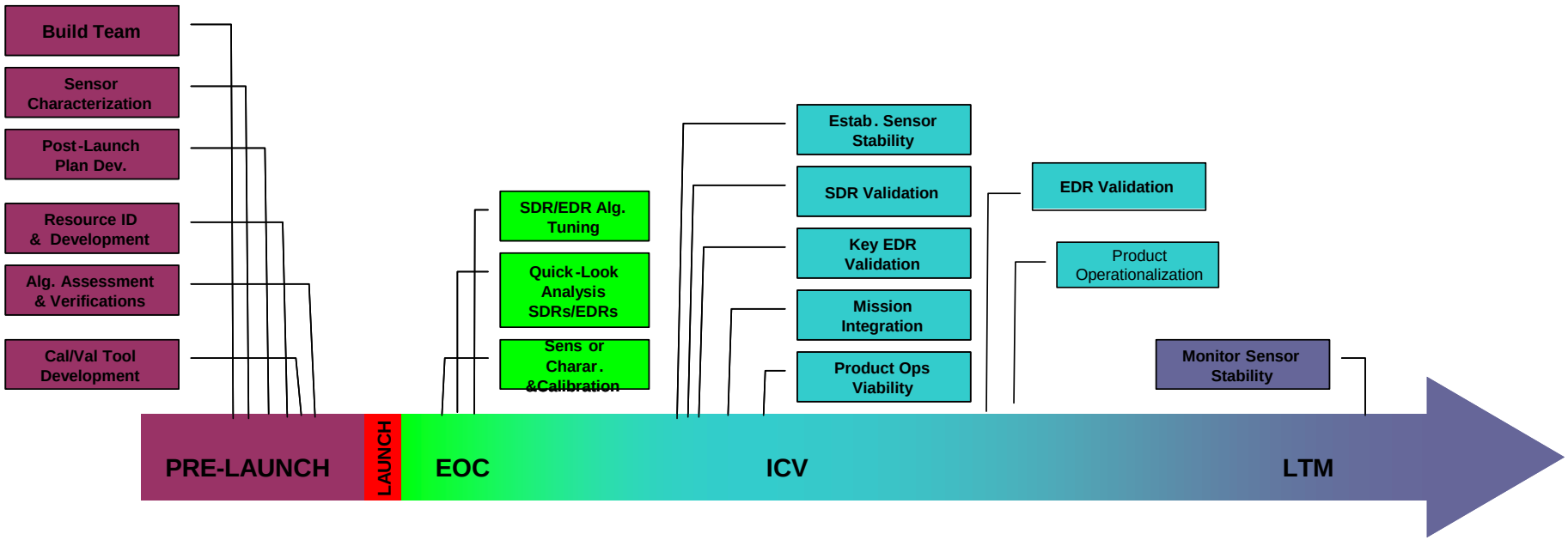
- Product performance has been demonstrated through analysis of a **large, but still limited** (i.e., not necessarily globally or seasonally representative) number of independent measurements obtained from selected locations, time periods, or field campaign efforts.
- Product analyses are sufficient for qualitative, and limited quantitative, determination of product fitness-for-purpose.
- Documentation of product performance, testing involving product fixes, identified product performance anomalies, including recommended remediation strategies, exists.
- Product is **recommended for operational use (user decision)** and in scientific publications.

JPSS Product Maturity (2/2)

Validated

- Product performance has been demonstrated over a **large and wide range of representative conditions** (i.e., global, seasonal).
- Comprehensive documentation of product performance exists that includes all known product anomalies and their recommended remediation strategies for a full range of retrieval conditions and severity level.
- Product analyses are sufficient for full qualitative and quantitative determination of product fitness-for-purpose.
- Product is **ready for operational use** based on documented validation findings and user feedback.
- Product validation, quality assurance, and algorithm stewardship continue through the lifetime of the instrument.

Cal/Val Process Overview



Four Phases of Cal/Val:

1. Pre-Launch; all time prior to launch – Algorithm verification, sensor testing, and validation preparation
2. Early Orbit Check-out (first 30-90 days) – System Calibration & Characterization
3. Intensive Cal/Val (ICV) – xDR Validation
4. Long-Term Monitoring (LTM); through life of sensors

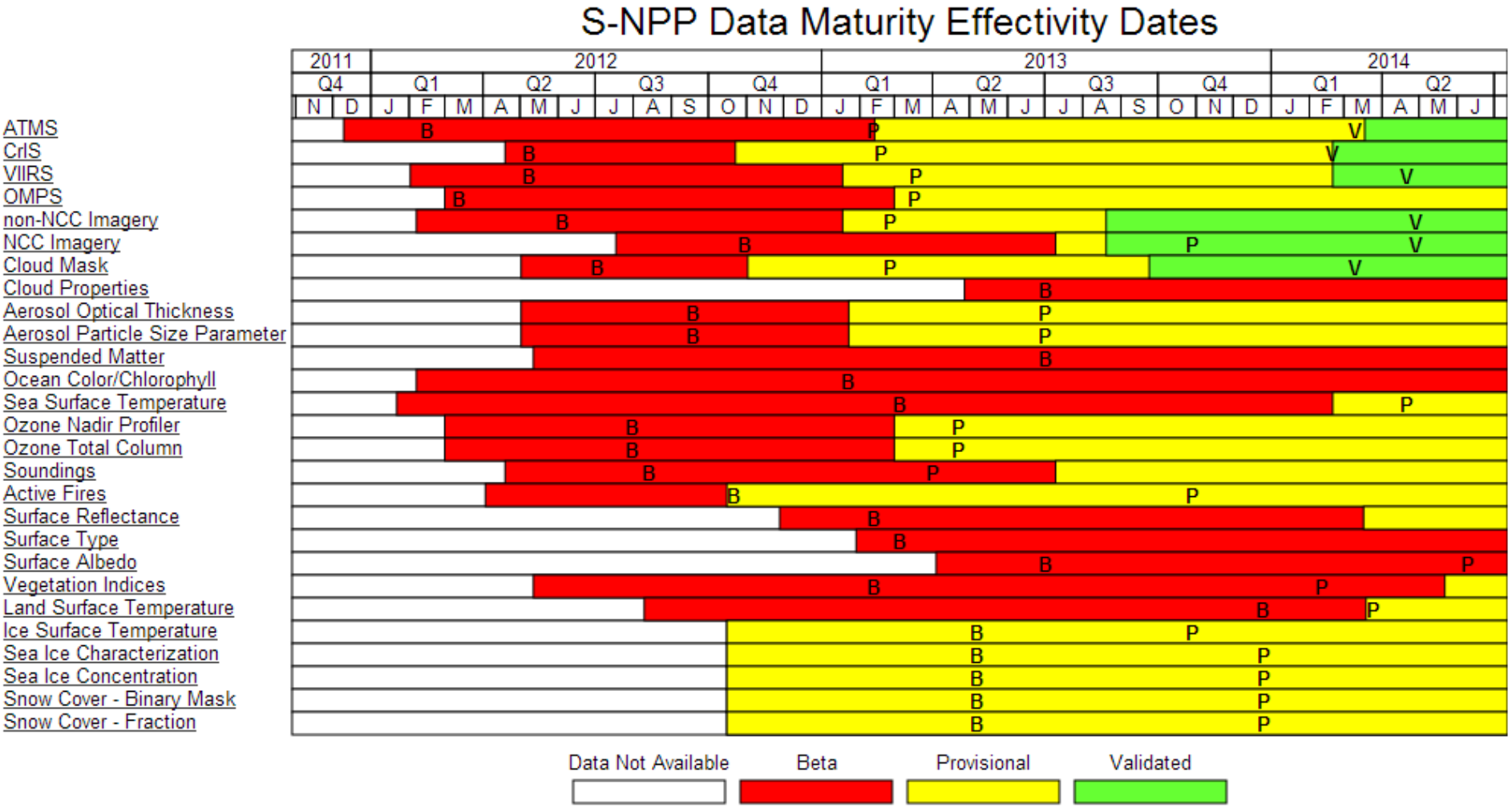
Product maturity dates

- Date when ***algorithm development is completed*** and is ready for implementation
  - Science teams "did their job"
  - Science review and formal approval
- Date after which the ***operational product was generated*** using the specific updated algorithm
  - "Product effectivity date"
  - An attribute of the product in the CLASS* archive
- Maturity dates and critical product information (including caveats) are reported in the CLASS "Readme" files
- Currently only products from IDPS** are tracked

*CLASS: Comprehensive Large Array-data Stewardship System; www.class.ncdc.noaa.gov
**Interface Data Processing System

IDPS product maturity timeline

https://www.star.nesdis.noaa.gov/jpss/AlgorithmMaturity.php



Letters: dates of approval for algorithm maturity

Color bars: products generated with the algorithm having the given maturity level

NOTES: **1. ONGOING PRODUCT ASSESSMENT MAY RESULT IN RETROSPECTIVELY DECLARING HIGHER MATURITY LEVELS FOR RECENT TIME PERIODS.**

2. NOAA-UNIQUE PRODUCT MATURITIES PLANNED TO BE INCLUDED IN 2015

From Suomi NPP to JPSS 1

- **Many Suomi NPP** products will **continue** in their current form
  - JPSS 1 preparation, varification and post-launch calibration / validation are still critical
- **Some** EDR products will include **critical updates**
  - **Vegetation Index**: add top-of-canopy Normalized Difference Vegetation Index (NDVI)
  - **Active Fire**: add Fire Radiative Power (FRP) and spatially explicit fire mask
  - **Snow cover fraction**: improved algorithm
  - **Aerosol / suspended matter**: improved algorithm
  - **Ocean color**: include coastal pixels and inland water

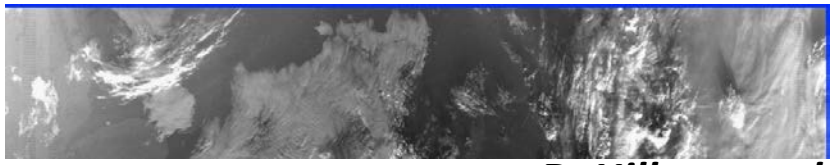
Examples of product performance and maturity status

Sensor Data Record (SDR) to Imagery Environmental Data Record (EDR)

- **Ground Track Mercator (GTM)** remapping software.
  - GTM is a **remapping** of the data, but the **same radiances/reflectances** for Non-NCC bands only.
- For **NCC Imagery** there is **additional radiance processing**

Non-DNB (SDR) → **GTM software** → **Non-NCC (EDR)**

DNB (SDR) → **GTM software plus** → **NCC (EDR)**

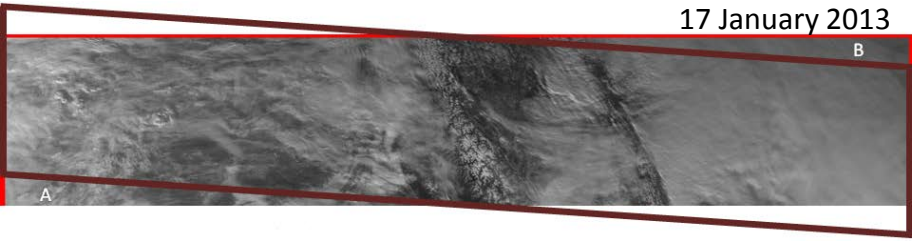


D. Hillger et al.

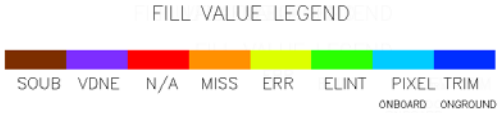
Imagery EDR issues resolved

Missing Triangles

17 January 2013

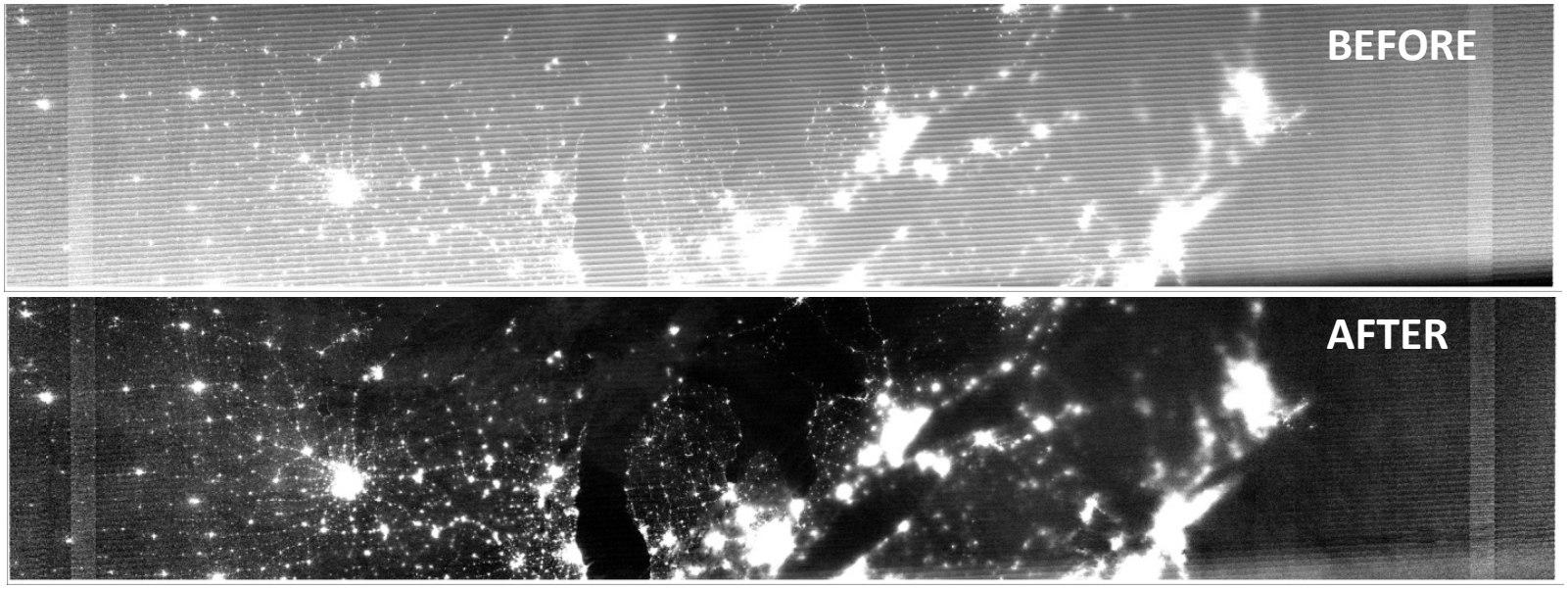


24 February 2012



The brown outline shows where a SDR granule matches up with a given EDR granule. It takes three SDR granules to produce one EDR granule. If an SDR granule is missing when the EDR is created, you get a "missing triangle"…

Improved NCC Imagery EDR after DNB SDR Stray Light Correction



Before August 2013 the most significant of these was a stray light issue with the DNB on the dark side of the terminator. The DNB SDR algorithm was adjusted to correct for this error in August 2013.

D. Hillger et al.

Cloud Mask

Overall: VCM meets the specification and Application Teams expressed their satisfaction

VCM Overall Results (Daytime) / Taken from Provisional

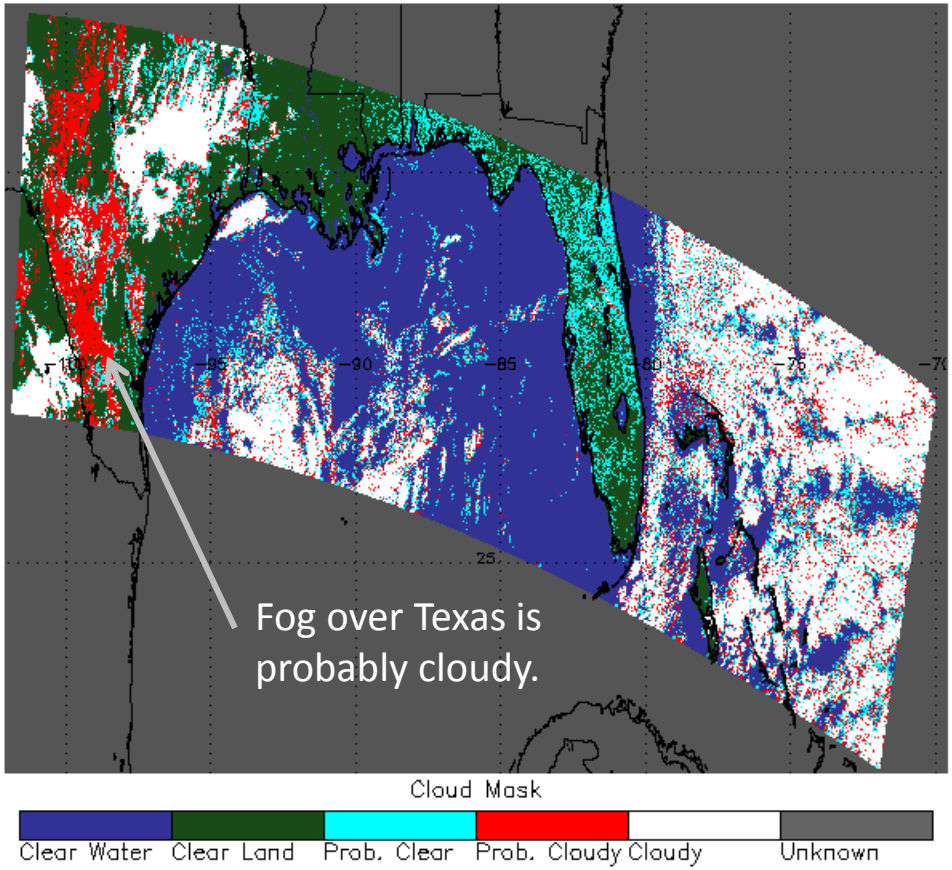
Requirement	Level 1	Match-Up	Golden Granule
PCT: Daytime, ocean	94%	95.3%	96.5%
PCT: Daytime, land	90%	93.9%	94.4%
PCT: Daytime, desert	90%	96.0%	95.7%
Leakage: Daytime, ocean	1%	0.6%	0.1%
Leakage: Daytime, land	3%	2.2%	0.7%
Leakage: Daytime, desert	3%	2.8%	1.2%
False Alarms: Daytime, ocean	5%	3.5%	2.6%
False Alarms: Daytime, land	7%	3.6%	4.2%
False Alarms: Daytime, desert	7%	1.2%	2.9%

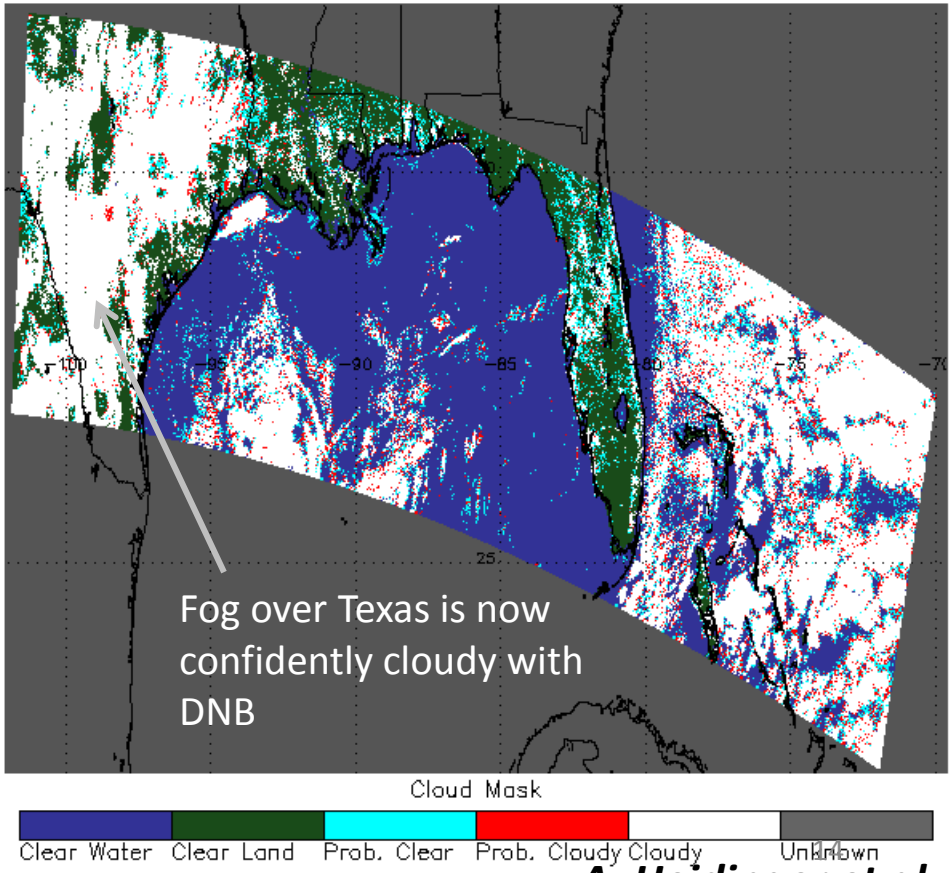
Filter: No Probably Clear or Cloudy and COT > 1

A. Heidinger et al.

Impact of DNB on Cloud Mask

- Image on left is without DNB. Image on right uses DNB. Everything else is the same.
- Note, improvement seen in Fog over land. It is detected more confidently (red to white) and more of it is detected. Fog at night is hard to detect confidently using on IR data.
- Impact over ocean as well but less so (makes sense since IR modeling is much more certain over ocean).

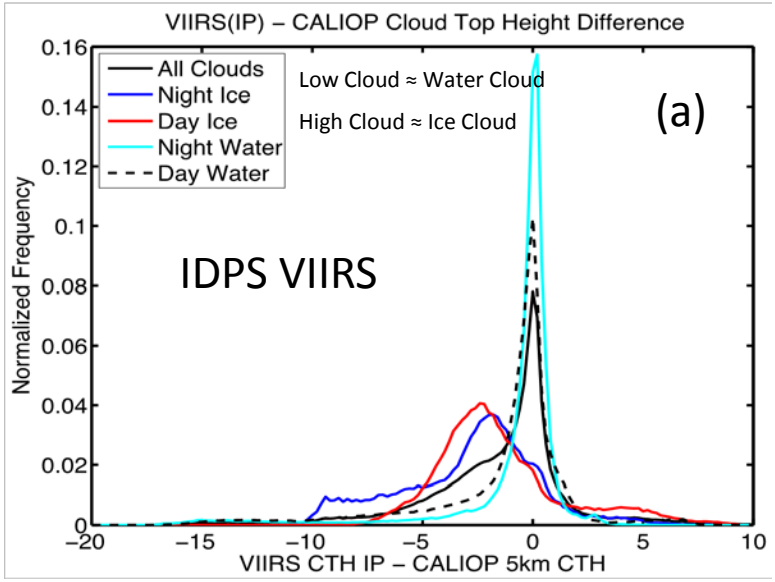


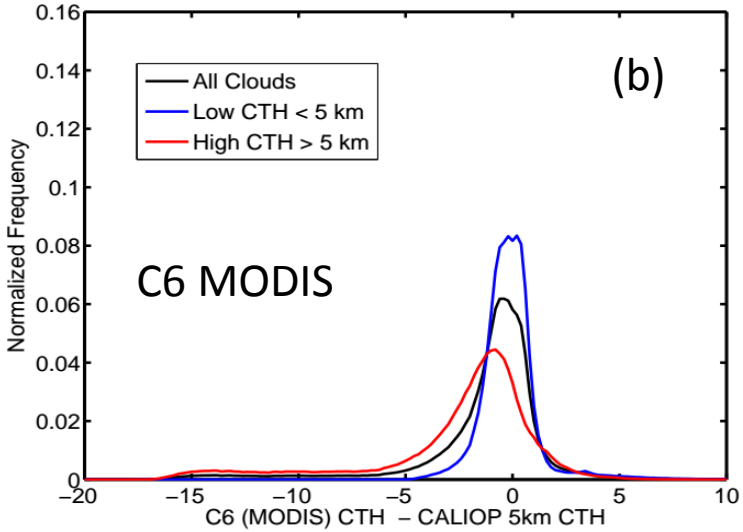


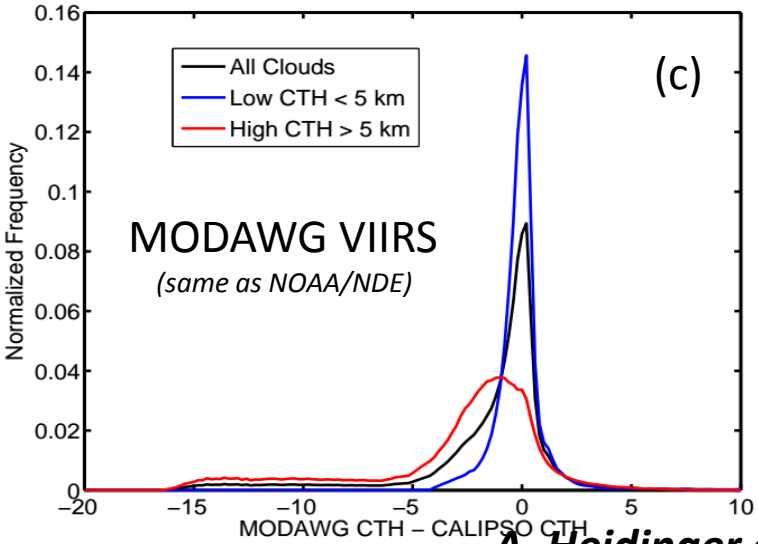
A. Heidinger et al.

Continuity of VIIRS and MODIS Cloud Products

- **Decadal cloud climate studies will require consistency of MODIS and VIIRS.**
- Images show the cloud-top height (CTH) bias relative to CALIPSO for January 2014 generated by UW/SSEC Atmos. PEATE and JPSS Cloud CAL/VAL Team.
- Results in (a) are from IDPS and exhibit the known issues of low height bias in cirrus clouds.
- Results in (b) are for the C6 AQUA/MODIS from NASA Goddard Atmospheric Science Team.
- Results in (c) show the NOAA VIIRS Algorithm for the same period. NOAA Algorithm is run in the **MODAWG = MODIS + NOAA AWG** = Processing System which is an **NPP project**.
- MODAWG is much more similar to C6 MODIS than IDPS.





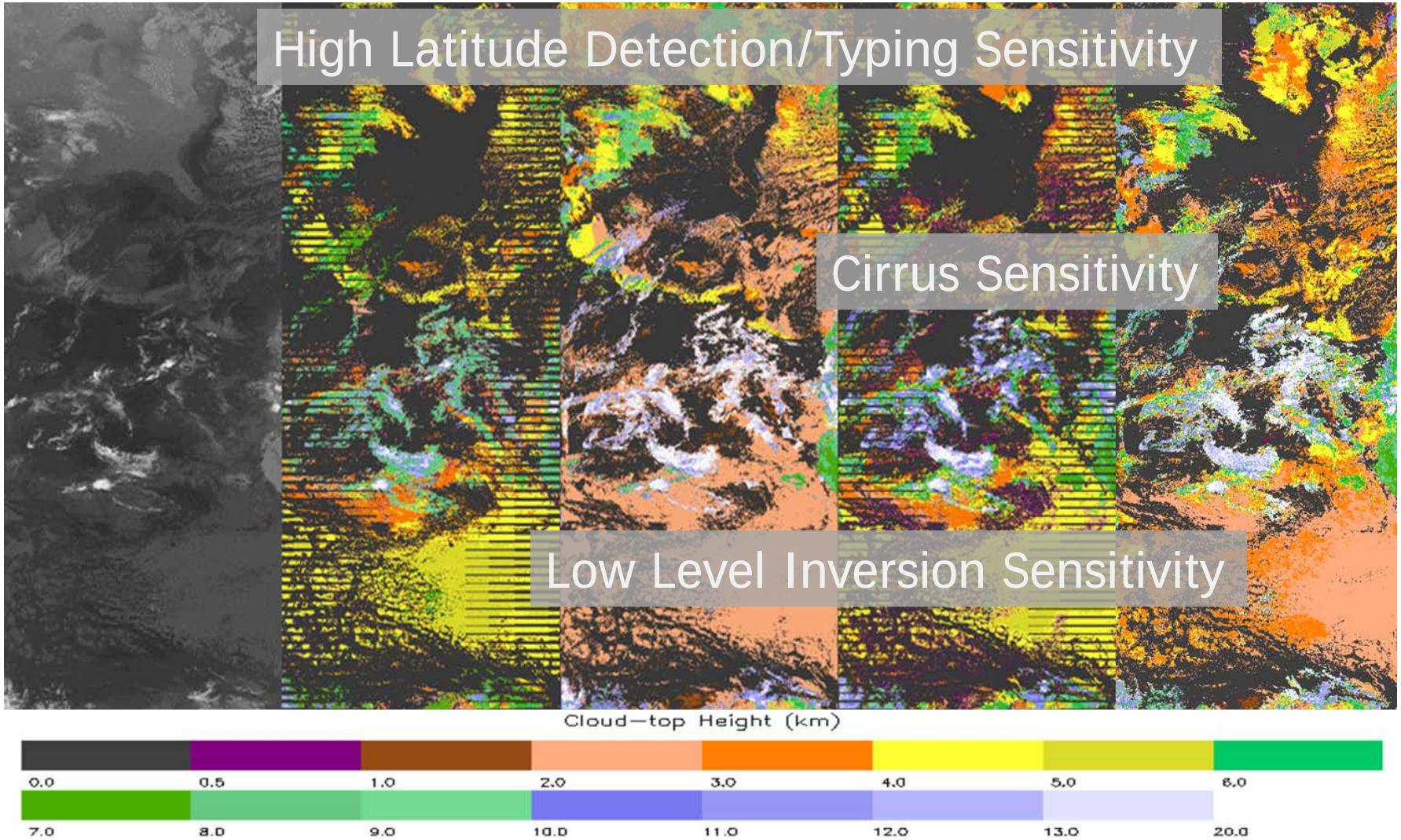


A. Heidinger et al.

Inter-algorithm Consistency Polar satellites

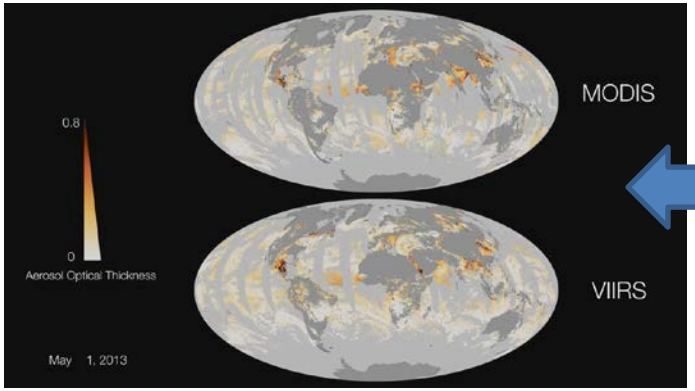
VIIRS Cloud Height 29 March 2014

11 μm BT | **IDPS** | **NOAA/ACHA** | **NWCSAF/PPS** | **NASA/LARC**



A. Heidinger et al.

Aerosol



VIIRS and MODIS daily global mean AOT maps

IP and EDR AOT files are available from NOAA CLASS

Daily gridded (0.25° x 0.25°) data are available from NOAA/NESDIS/STAR

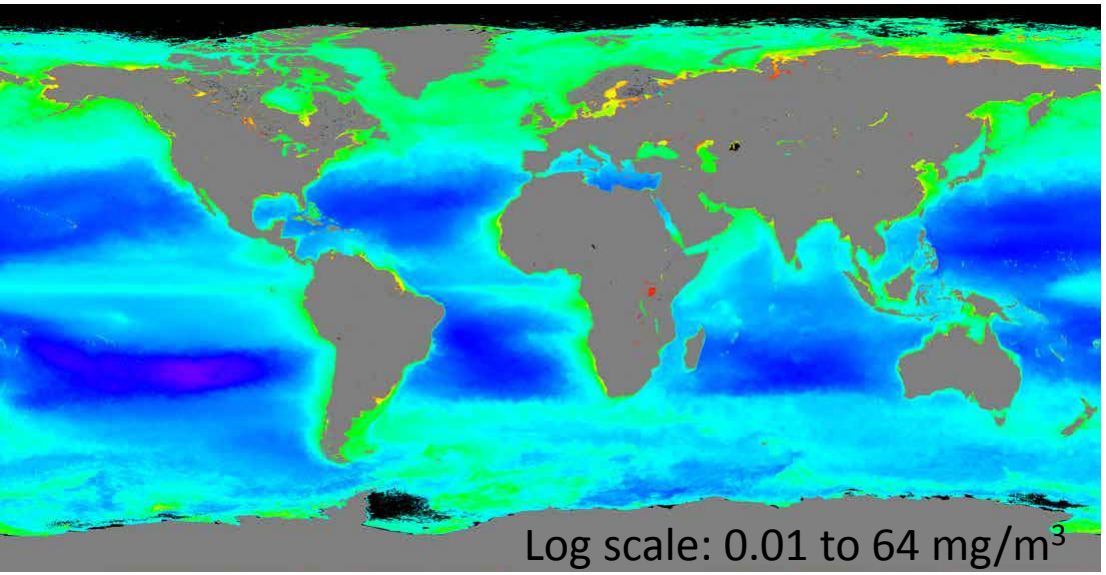
Conversion tools to convert VIIRS data from HDF5 to EOS HDF format are available from NOAA/NESDIS/STAR

- **VIIRS Environmental Data Record (EDR: ~ 6 km) and Intermediate Product (IP: ~750m) AOT products meet requirements and are ready for operational use.**
  - IP is a pixel level retrieval
  - EDR is an aggregate of 8 x 8 IP pixels
- Data artifacts remain:
  - ✓ Snow/ice contamination in high latitudes, especially during snow melt
  - Residual cloud contamination (~13% of pixels are estimated to be contaminated by clouds)
  - ✓ High AOTs during episodic events (smoke and dust plumes) are flagged out of range due to measurement range being 0 to 2.

✓ to be fixed within the next six months

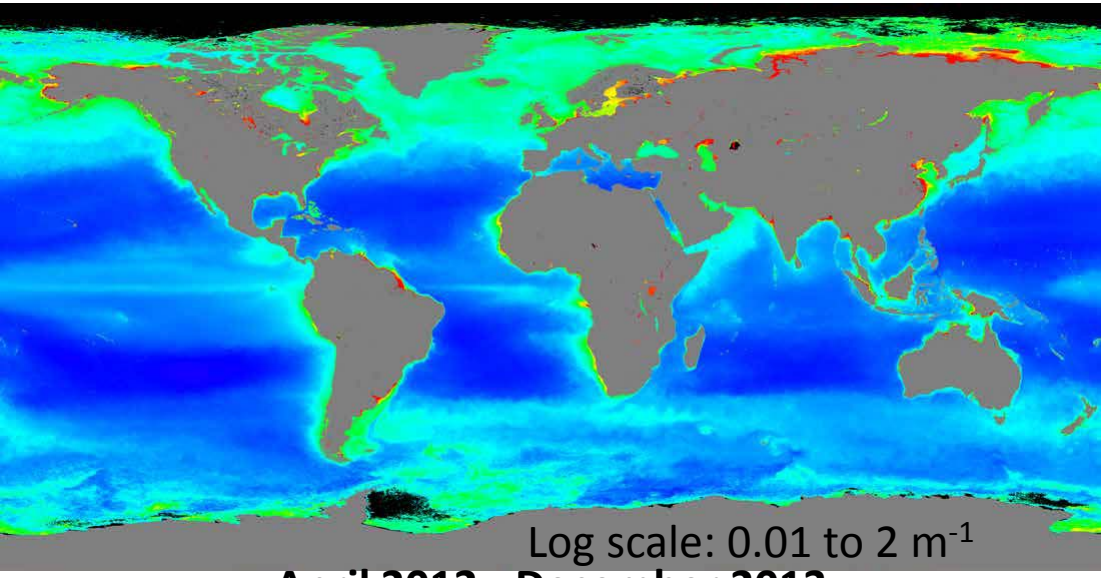
S. Kondragunta, I. Laszlo et al.

Ocean Color



VIIRS Chlorophyll-a Climatology

Wang, M., X. Liu, L. Tan, L. Jiang, S. Son, W. Shi, K. Rausch, and K. Voss, "Impacts of VIIRS SDR performance on ocean color products," *J. Geophys. Res. Atmos.*, ***118, 10,347–10,360, 2013. http://dx.doi.org/10.1002/jgrd.50793***



VIIRS *Kd(490)* Climatology

Wang, M., S. Son, and L. W. Harding, Jr., "Retrieval of diffuse attenuation coefficient in the Chesapeake Bay and turbid ocean regions for satellite ocean color applications," *J. Geophys. Res.*, ***114, C10011, 2009. http://dx.doi.org/10.1029/2009JC005286.***

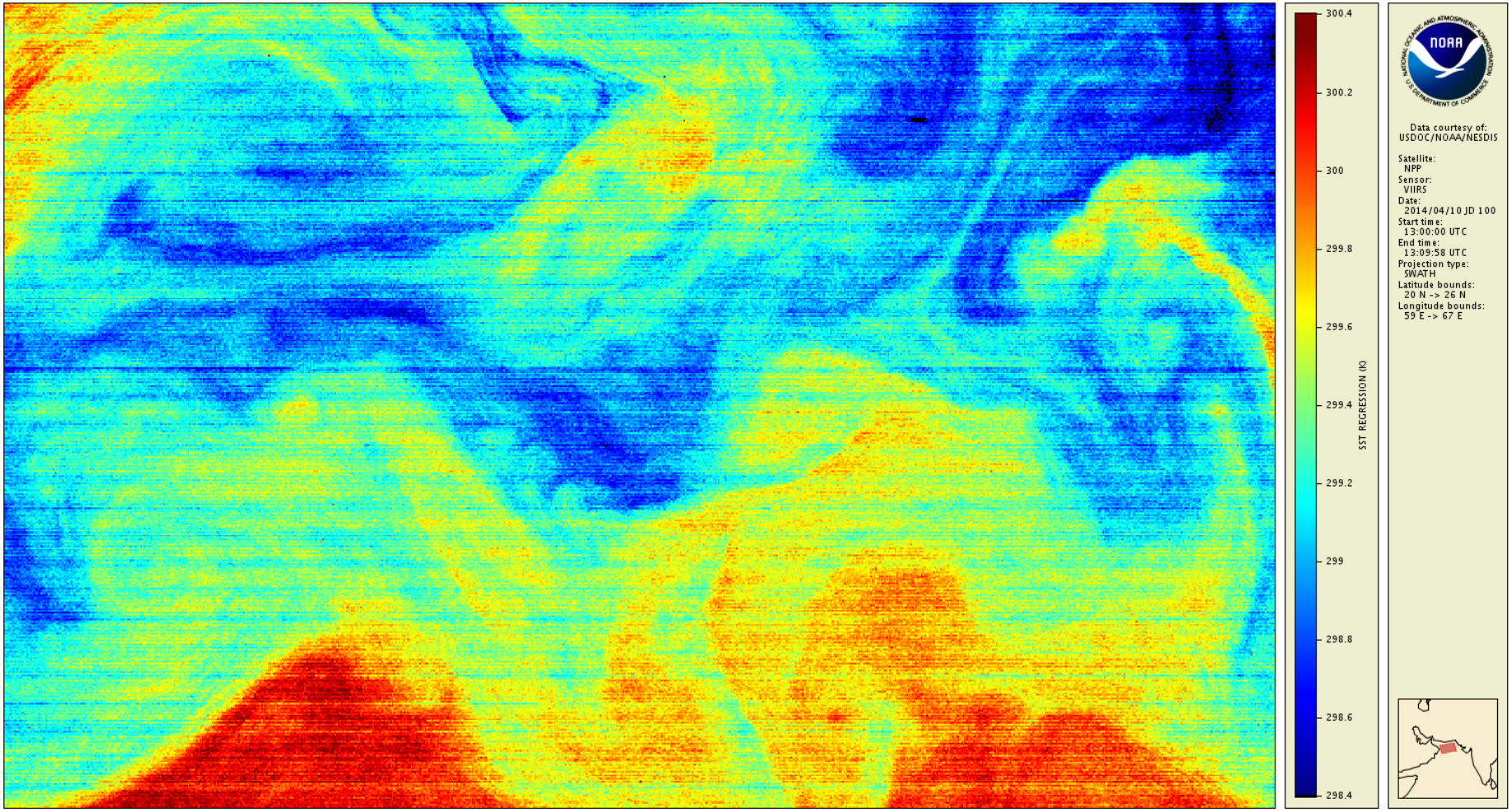
April 2012 - December 2013

NOAA-MSL12 for VIIRS ocean color data processing

M. Wang et al.

Sea Surface Temperature

DAY – SST from original BTs in M15 and M16

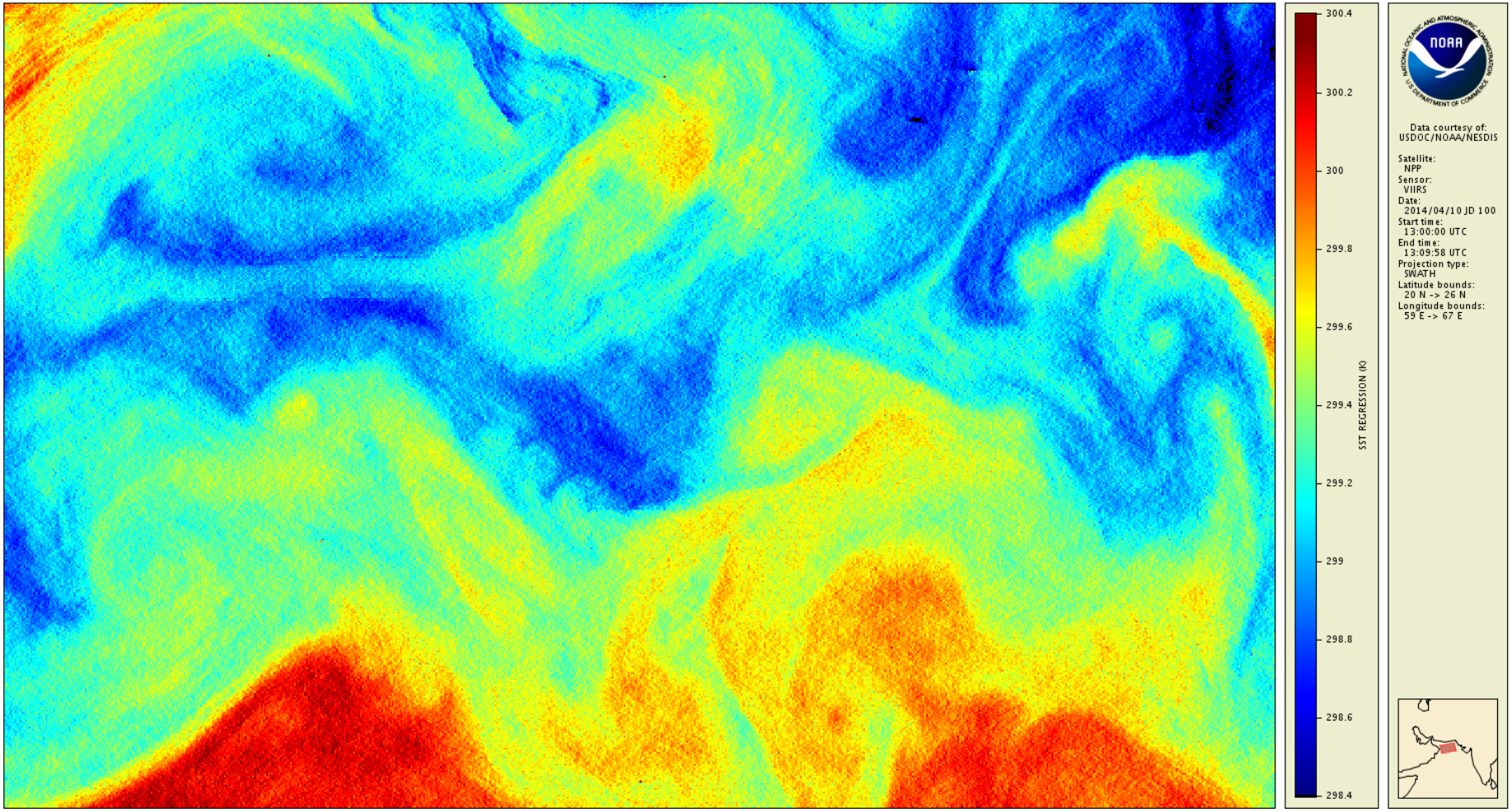


Striping affects quality of SST imagery and Ocean Dynamics Analyses

A. Ignatov et al.

Sea Surface Temperature

DAY – SST from destriped BTs in M15 and M16

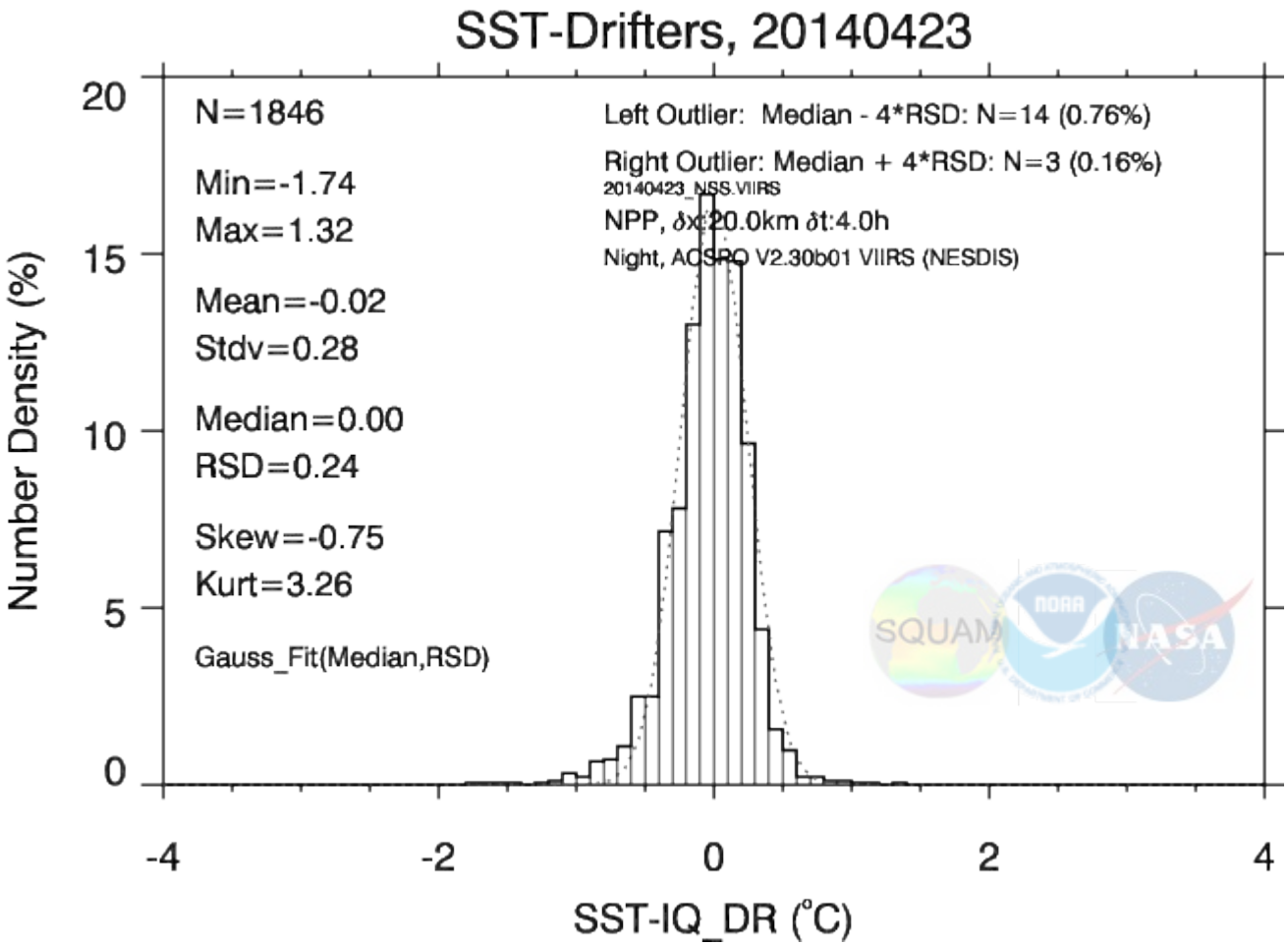


Destriping is applied to brightness temperatures and improves SST

A. Ignatov et al.

Sea Surface Temperature

NIGHT: ACSPO L2 minus *in situ* SST

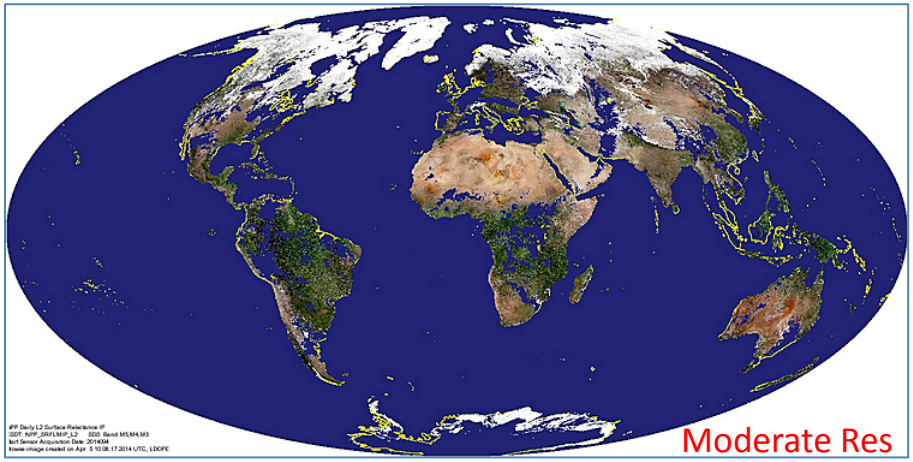


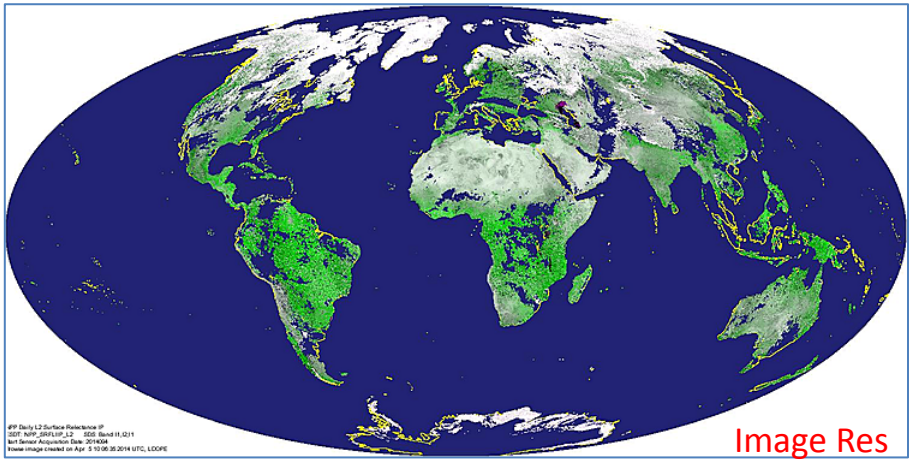
- *Shape close to Gaussian, a hint of cold tail (residual cloud)*
- *Performance Stats well within specs (Bias<0.2K, STD<0.6K)*

A. Ignatov et al.

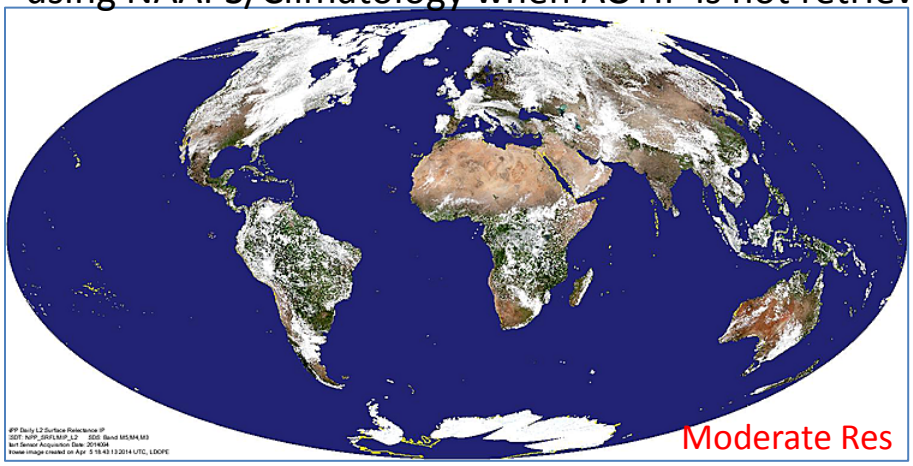
Surface Reflectance IP from Day 2014094

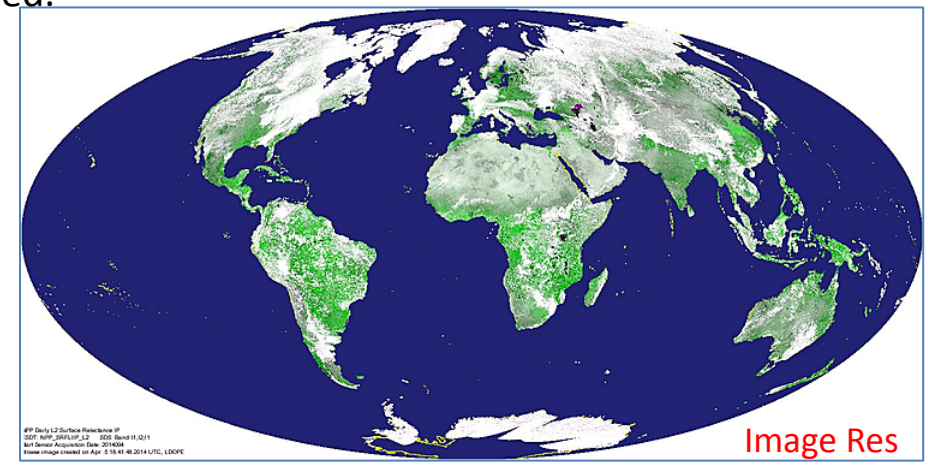
Retrieved under all atmospheric conditions for all non-ocean (not sea-water) pixels except for night pixels and where input L1B is invalid





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



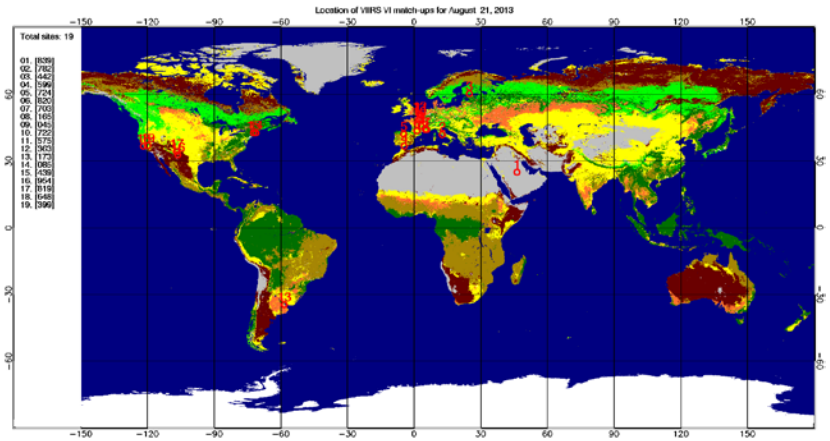


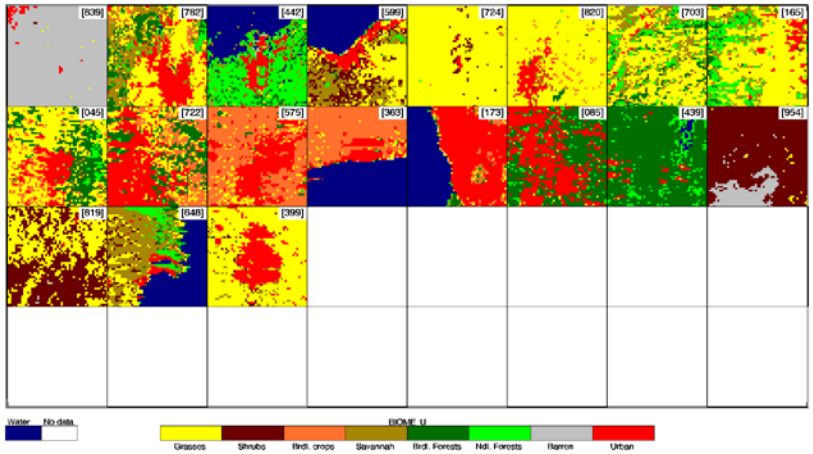
Retrieval using Mx83 at IDPS – SRIP retrieved under all atmospheric conditions replacing NAAPS/Climatology with MODIS Climatology.

E. Vermote, S. Devadiga, NASA GSFC

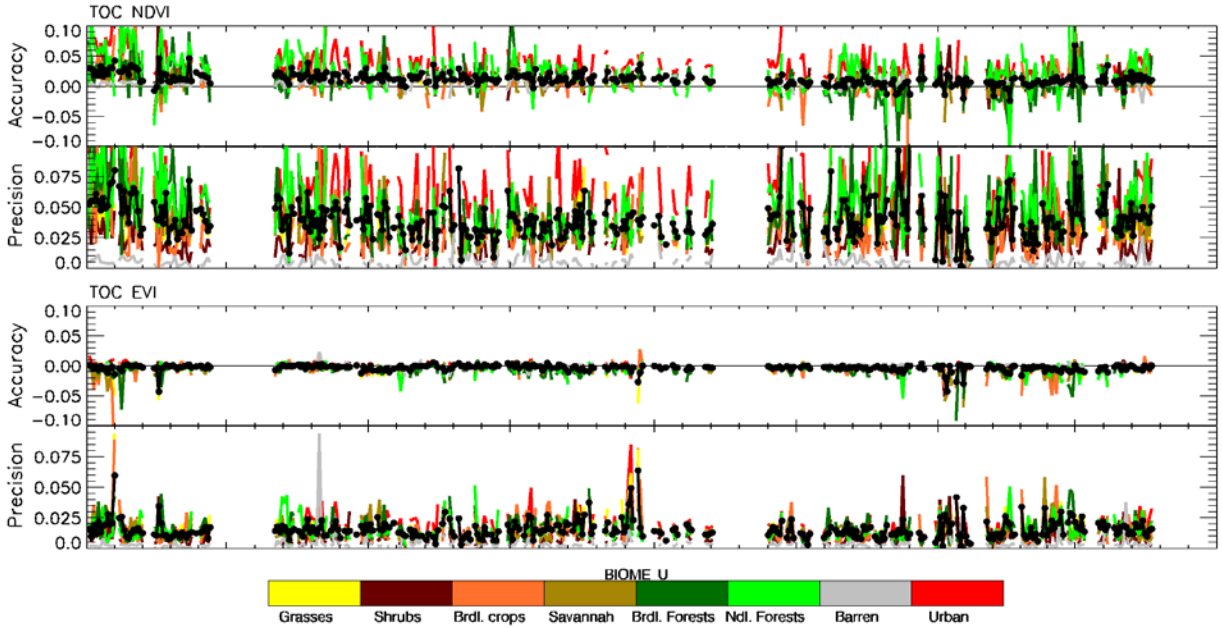
VI EDR Validation Using Aeronet Based SR

www.star.nesdis.noaa.gov/smcd/viirs_vi/Validation.htm





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 LA/FPAR LC product (MCD12C1, ver. 5.1).



M. Vargas et al.

Green Vegetation on Our Planet

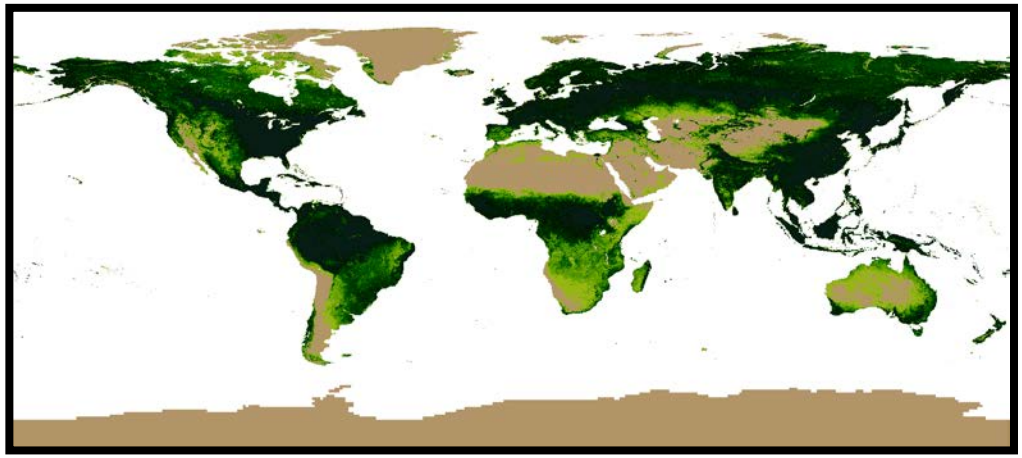
http://www.nnvl.noaa.gov/green.php

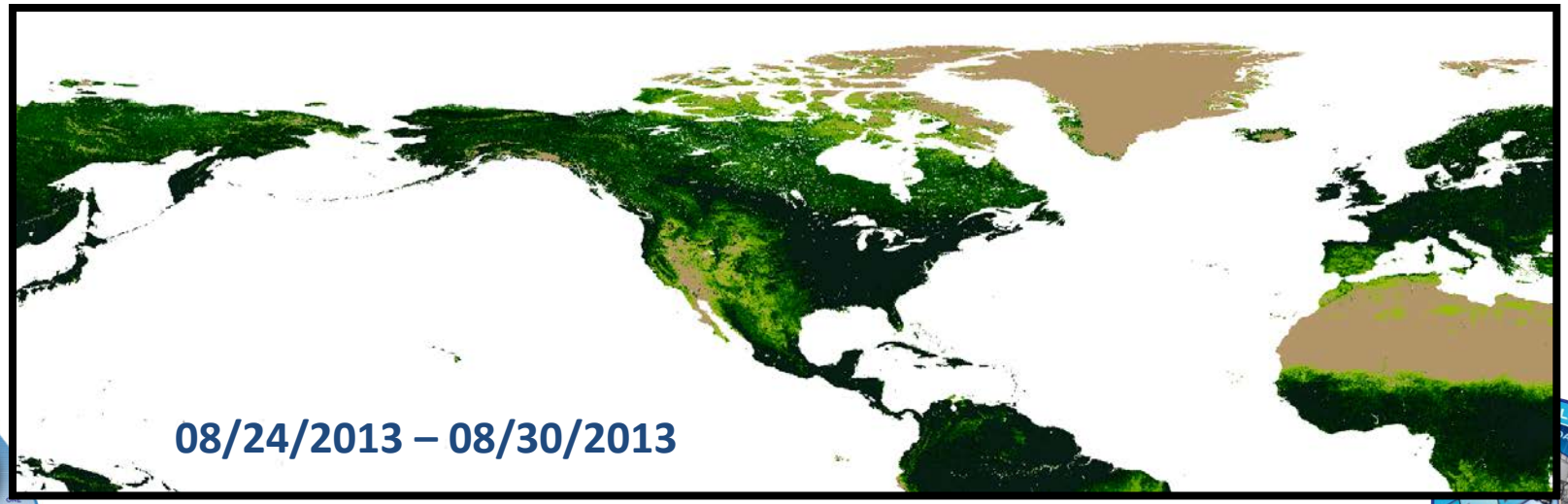
April 2012 – April 2013
500 m grid; NDVI weekly composite / gap filled

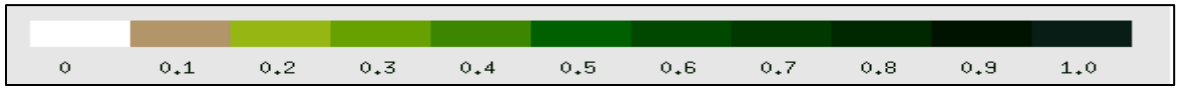
F. Kogan, NOAA/STAR
D. Pisut, NOAA Visualization Laboratory

NDE Green Vegetation Fraction

- GVF products: global (4km res) and regional (1km res)
- Global GVF product in NetCDF4 format will be archived at CLASS
- GVF transition to operations in Summer 2014



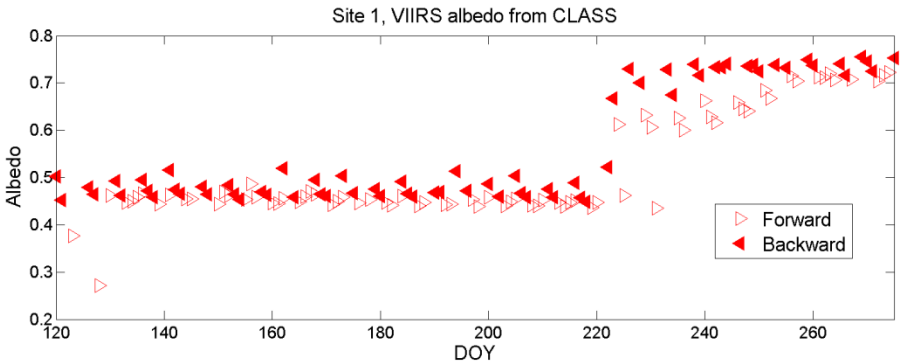


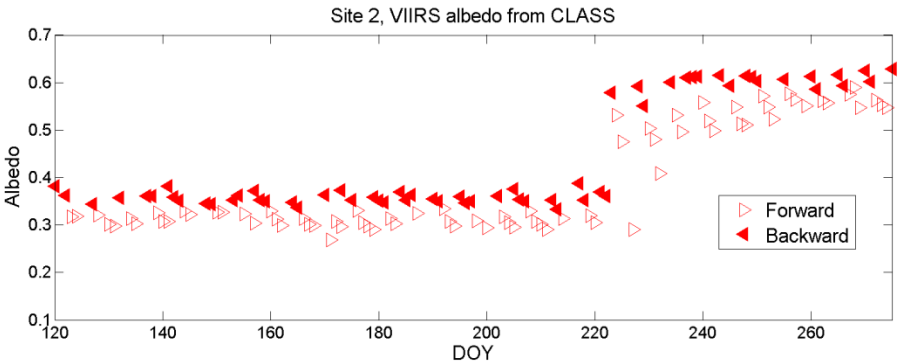


M. Vargas et al.

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.

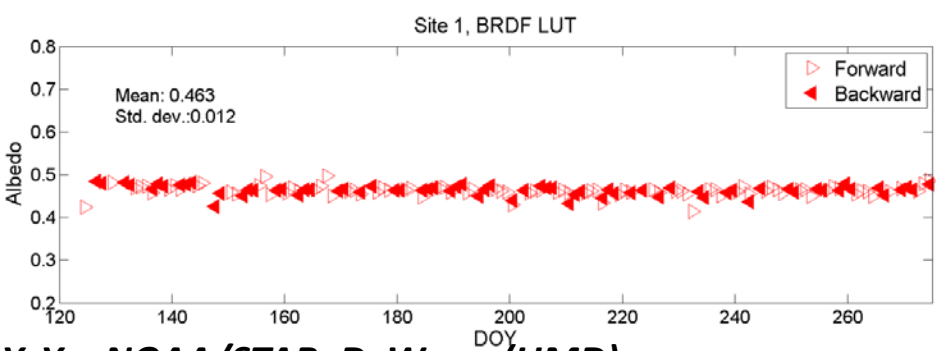


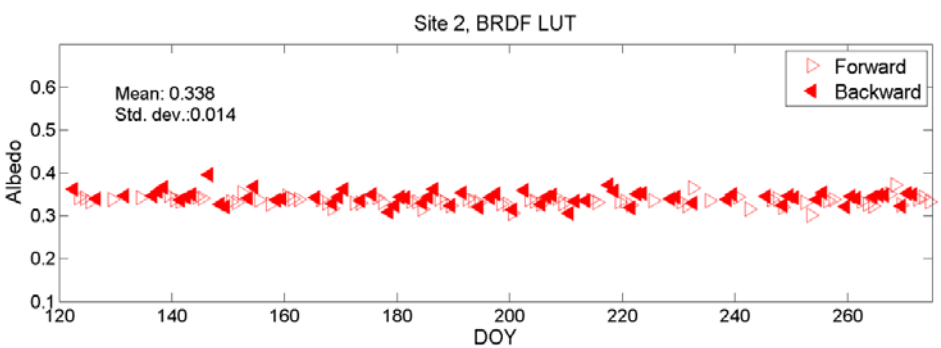


"Forward" means pixels with relative azimuth angle >90° and "backword" means those with relative azimuth angle <90°.
Jumps around 8/9 were caused by the bugs in a early version of the operational codes.

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

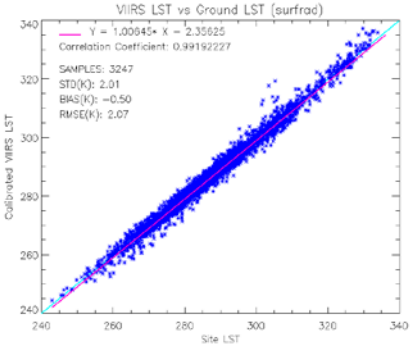
LSA retrieved from new BRDF LUT. The spurious retrievals caused by undetected cloud and cloud shadow are excluded with the threshold of mean ± 0.05.

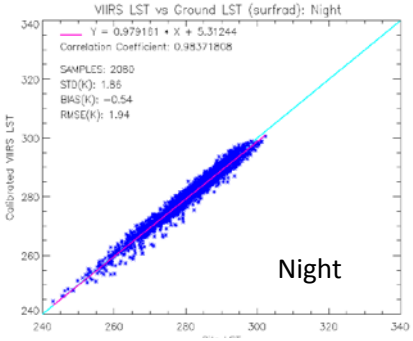


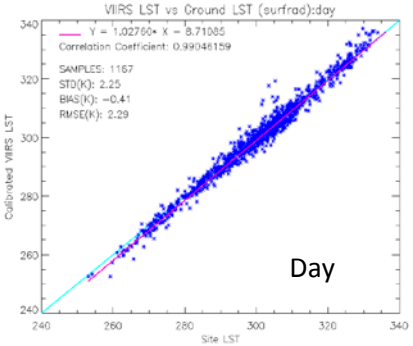


Y. Yu, NOAA/STAR, D. Wang (UMD)

Land Surface Temperature







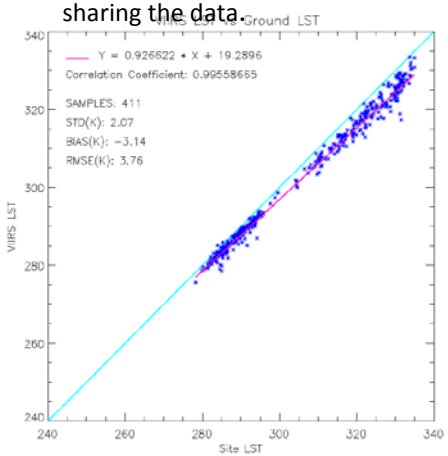
Evaluation against ground data

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.

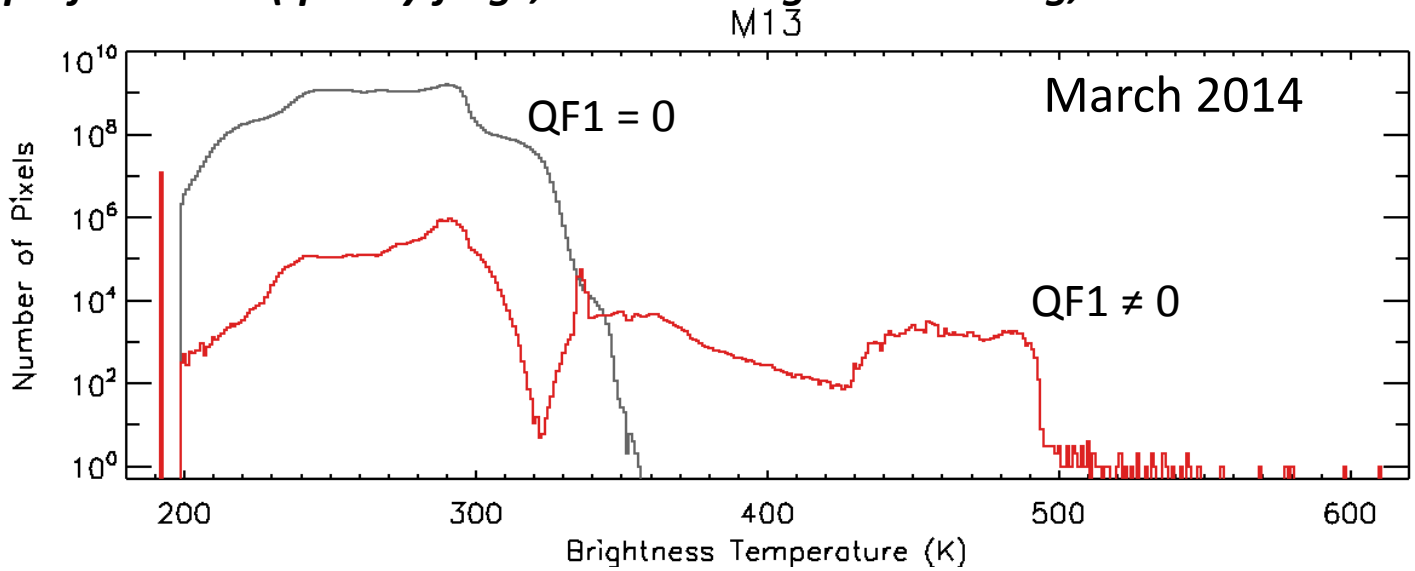
*The data is provided by Frank Goettsche, thanks Pierre for sharing the data.

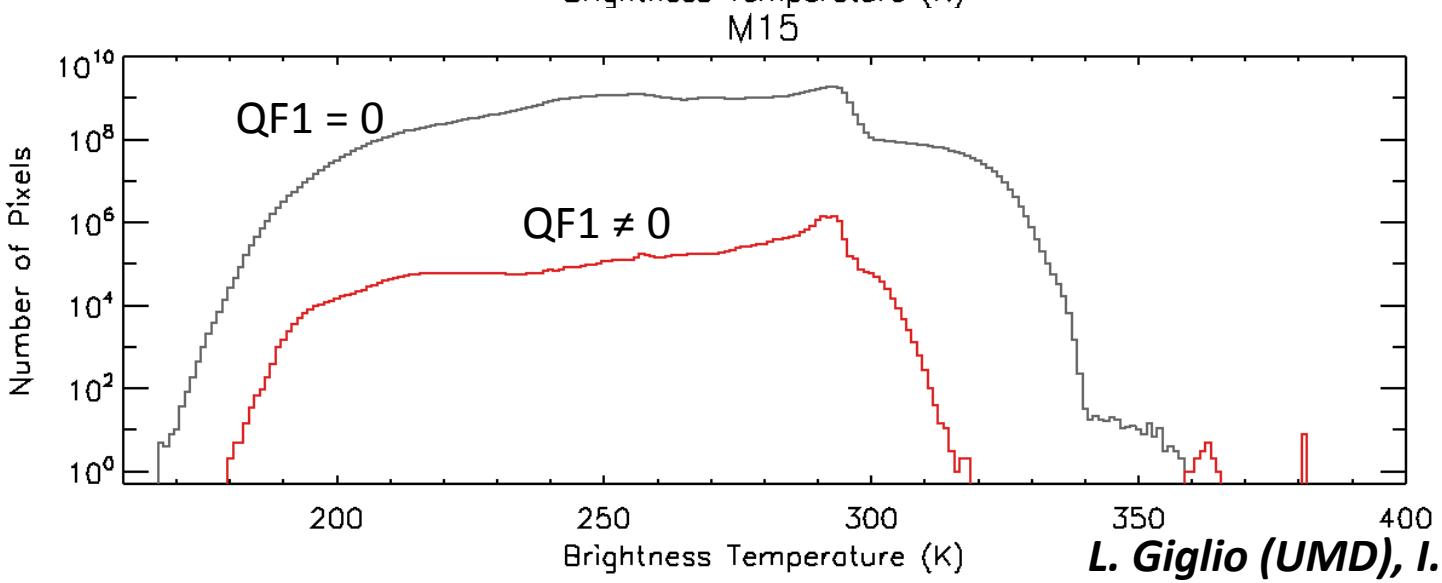


Y. Yu et al.

Active fires

Suomi NPP product quality and maturity has been driven by input VIIRS SDR performance (quality flags, calibration gain switching, saturation handling etc.)





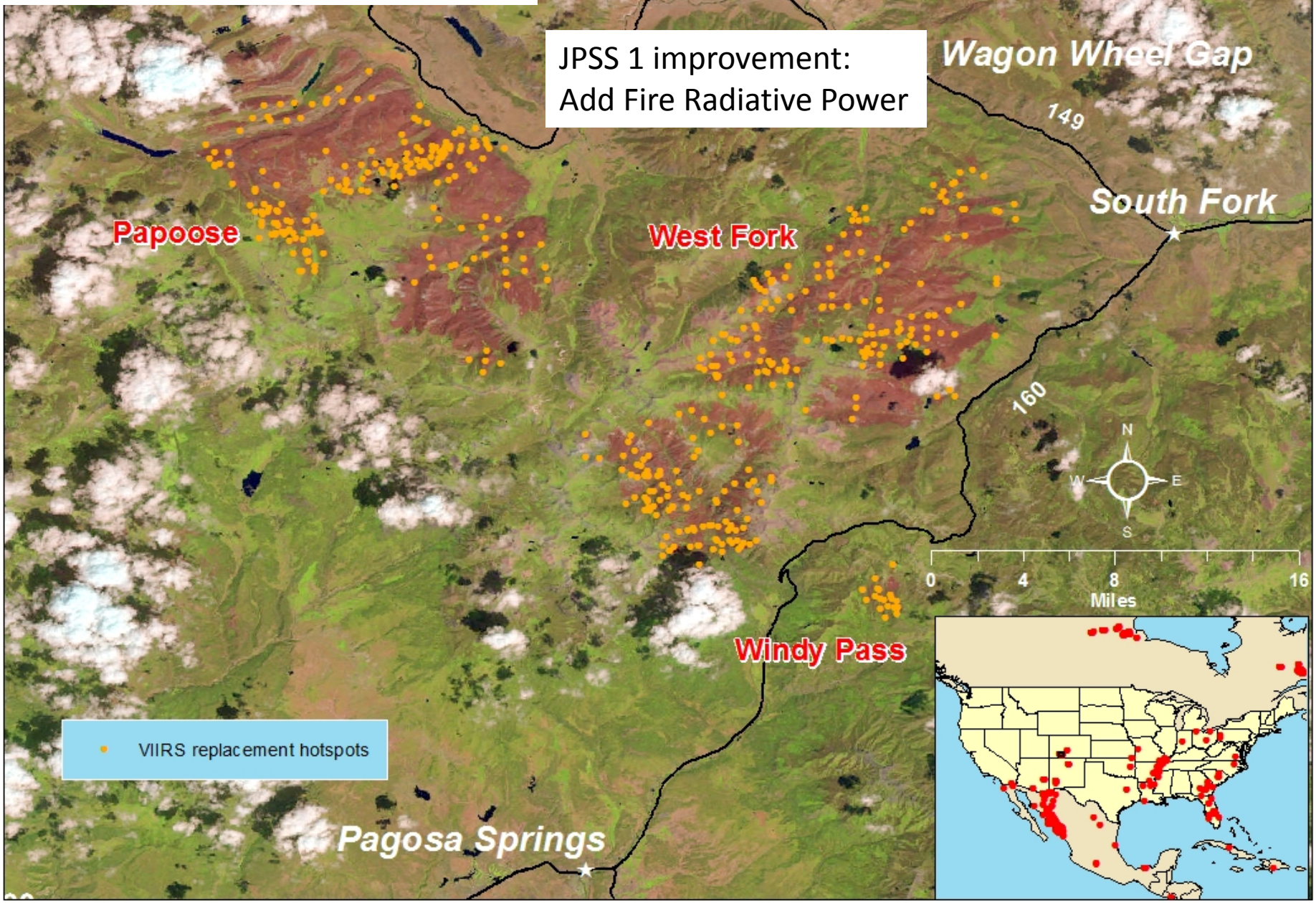
Major SDR changes implemented in Mx 8.5 in August 2014.

The fire team is preparing for verification by analyzing known granules and cumulative statistics.

L. Giglio (UMD), I. Csiszar (STAR) et al.

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

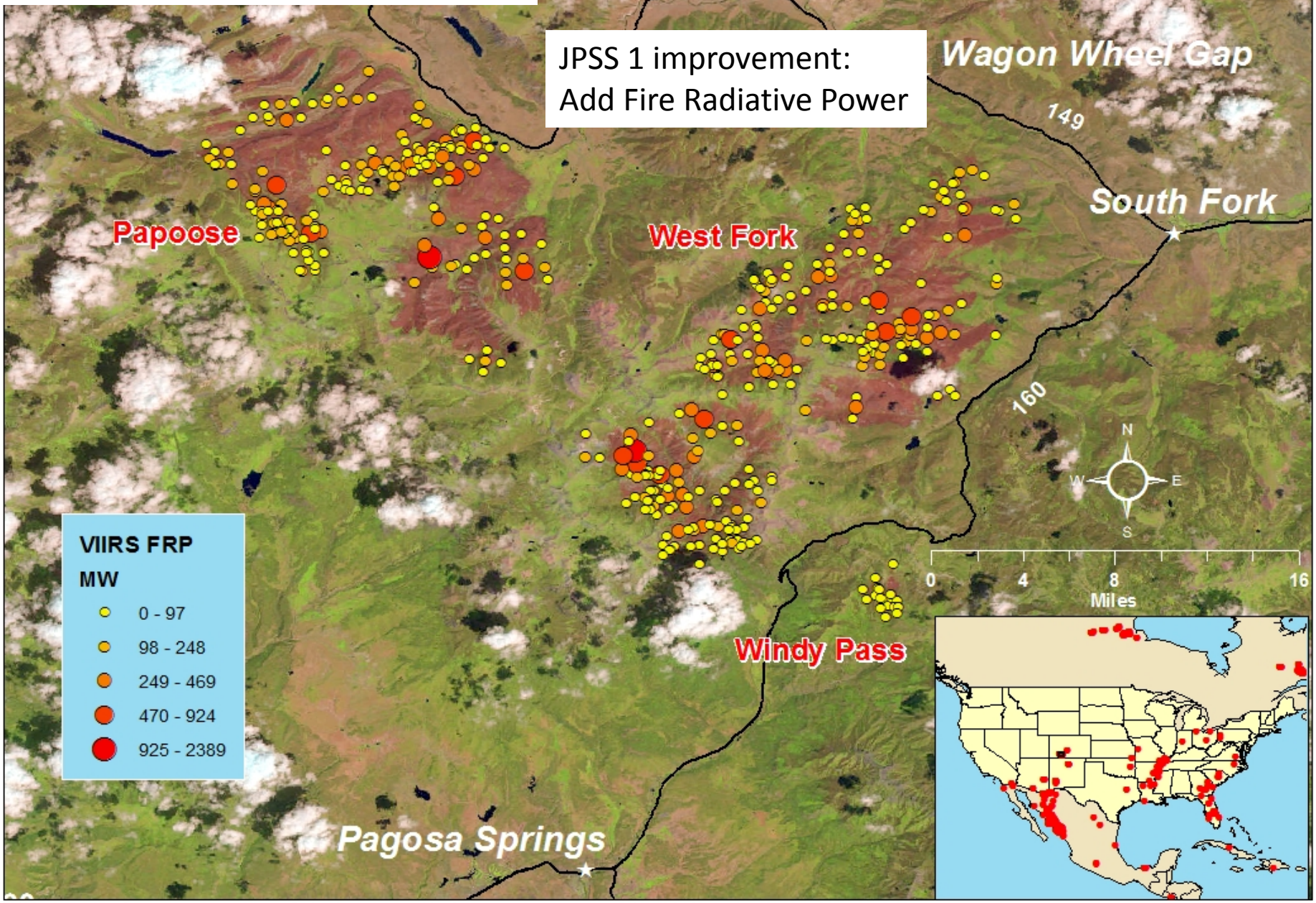
Landsat-8 background: July 31, 2013



JPSS 1 improvement:
Add Fire Radiative Power

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

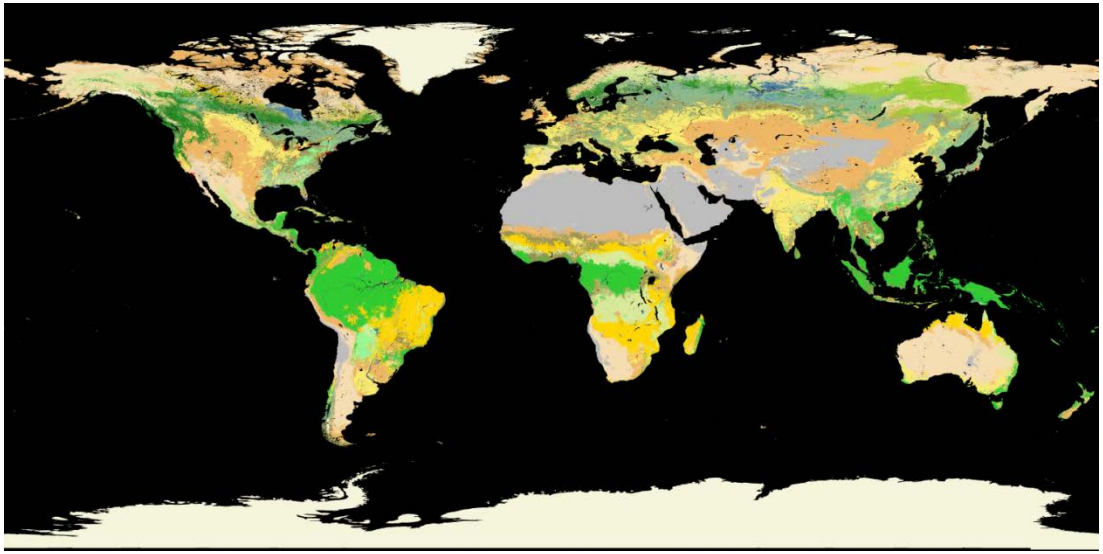
Landsat-8 background: July 31, 2013



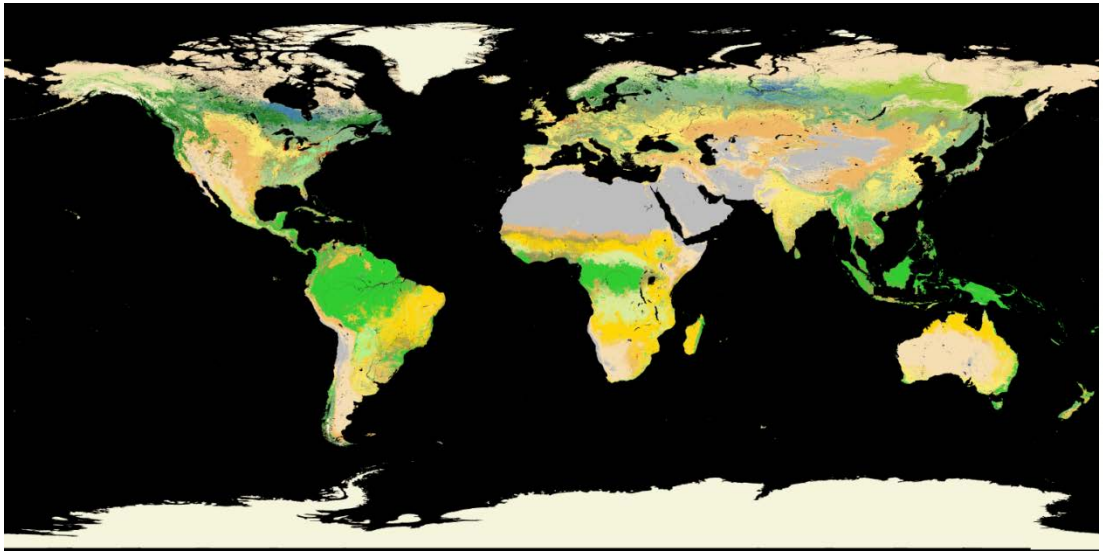
JPSS 1 improvement:
Add Fire Radiative Power

Quarterly Surface Type

MODIS Seed



VIIRS QST IP

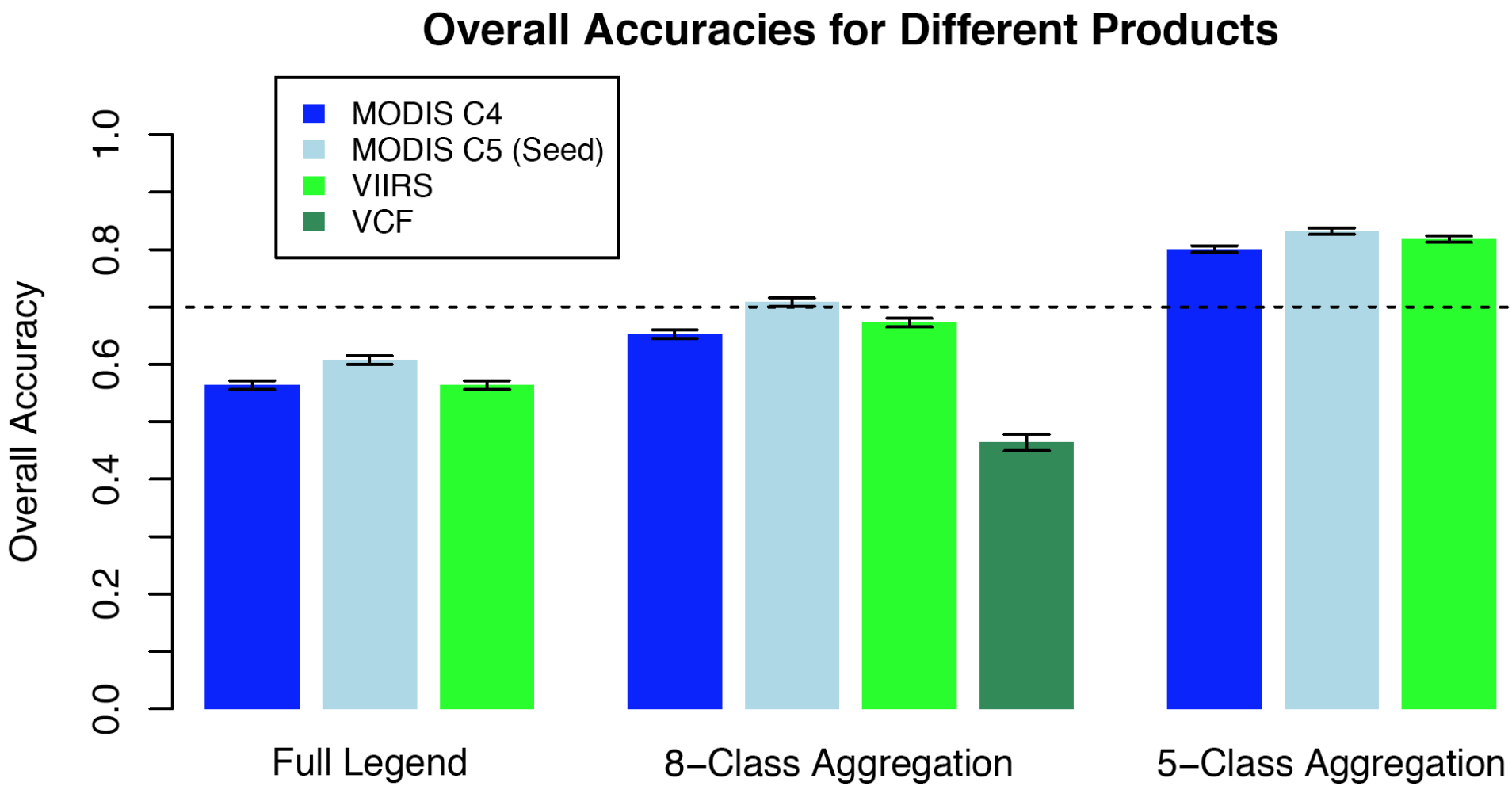


IGBP Legend

- Water Bodies
- Evergreen Needleleaf Forests
- Evergreen Broadleaf Forests
- Deciduous Needleleaf Forests
- Deciduous Broadleaf Forests
- Mixed Forests
- Closed Shrublands
- Open Shrublands
- Woody Savannas
- Savannas
- Grasslands
- Permanent Wetlands
- Croplands
- Urban and Built-up Lands
- Cropland/Natural Vegetation Mosaics
- Snow and Ice
- Barren

J. Zhan (STAR)
C. Huang (UMD)

QST Algorithm Evaluation



VIIRS QST overall accuracies are similar to MODIS C4 and C5 (Seed)

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

Binary Snow Cover

Mean agreement to IMS and cloud-clear fraction of daily automated snow products in 2013 Northern Hemisphere

	Agreement to IMS (%)	*Cloud-clear(%)**
VIIRS	**98.0**	**38.6**
MODIS (T)	97.3	49.1
MODIS(A)	97.1	48.3
AVHRR	97.9	55.0

*Cloud-clear fraction is estimated in 25-60^{0}N latitude band

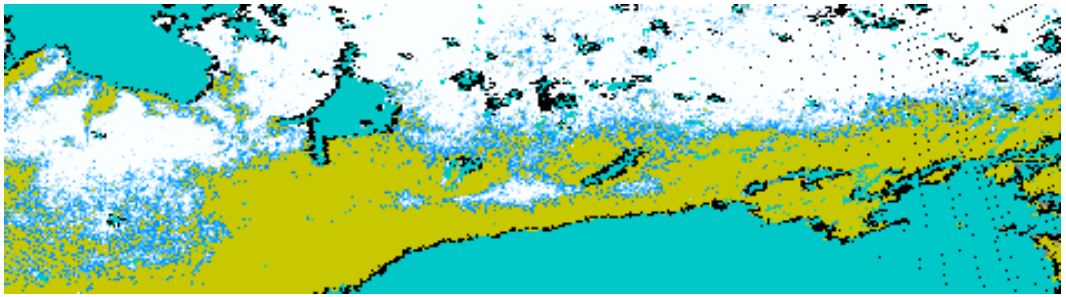
- Binary snow cover meets the accuracy requirement.
- Most issues are related to cloud masking; e.g., somewhat overestimated cloud extent and corrupted land/water mask.
- Some potential exists to improve the algorithm and the product, e.g., geometry-dependent threshold values.

P. Romanov (CREST/CUNY)

Fractional Snow Cover

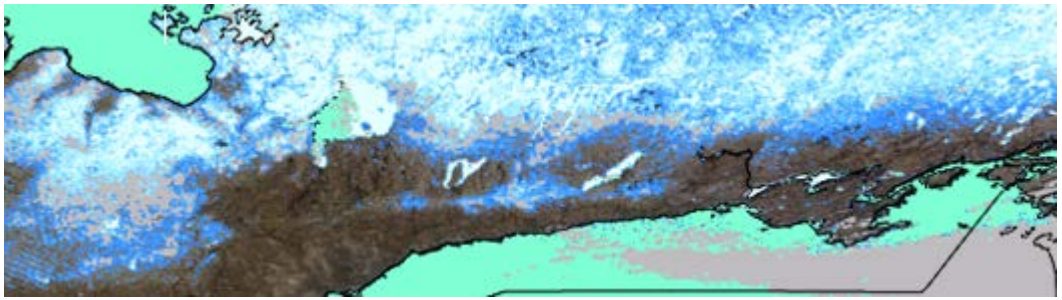
Description: VIIRS Snow Cover Fraction is derived from the Binary Snow Map as an aggregated snow fraction within 2x2 pixel blocks. The spatial resolution of the product is 750 m at nadir

VIIRS fraction



Image

MODIS fraction

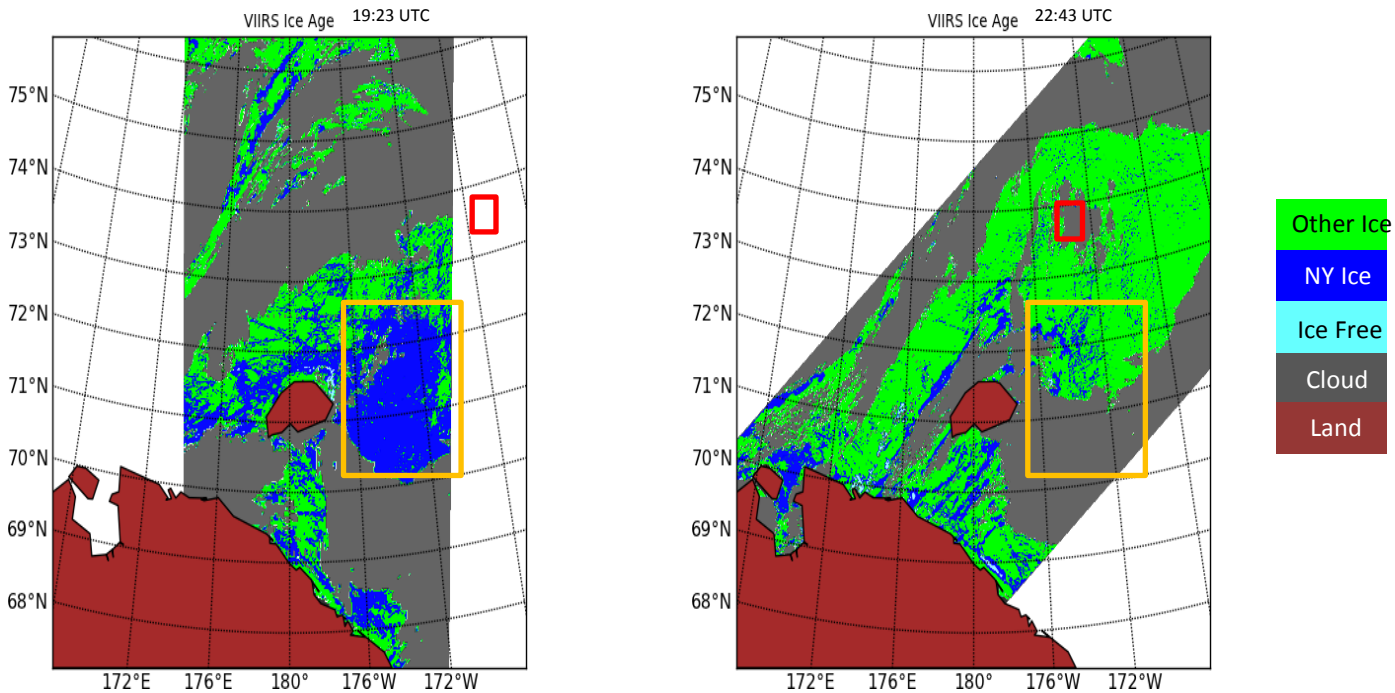


In 2x2 snow fraction (top) snow to no snow transition regions are unrealistically narrow compared to the MODIS based snow fractions.

I. Appel (IMSG)

Sea Ice Characterization

Overall, the product does not appear to be meeting the accuracy requirements. The algorithm is complex and improvements may be required in a number of areas.



Region near Wrangle Island showed significant amounts of sea ice that were correctly classified as thicker "Other Ice" in 22:43 UTC orbit being misclassified as NY in the 19:23 UTC orbit

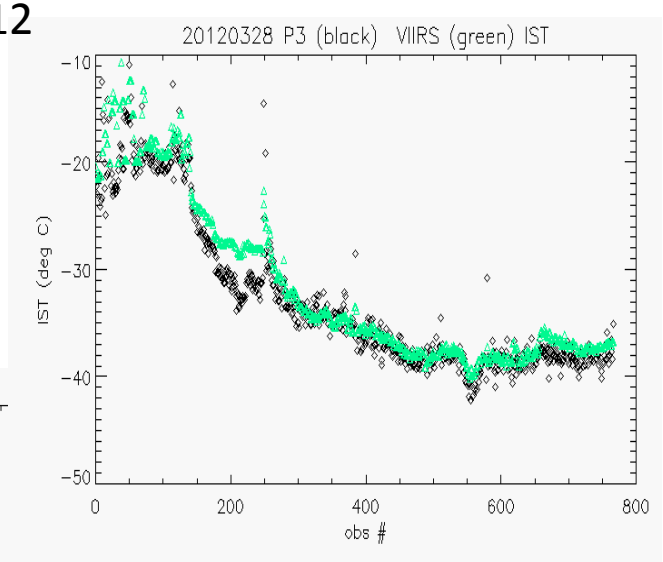
M. Tschudi (CU) et al.

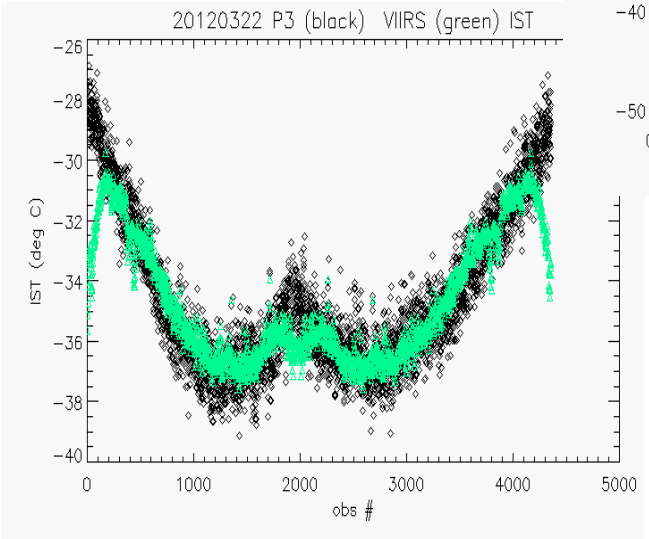
Ice Surface Temperature

BIAS = VIIRS - KT19

DATE	KT19	VIIRS	BIAS	RMS
3/14	-33.71	-33.15	0.56	0.08
3/15	-32.22	-33.05	-0.84	0.63
3/16	-29.88	-28.87	1.01	0.71
3/21	-36.01	-36.56	-0.55	0.41
3/22	-34.45	-34.66	-0.21	0.14
3/27	-31.15	-31.02	0.12	0.21
3/28	-32.61	-31.49	1.12	0.53
3/29	-37.85	-37.39	0.46	0.10
4/02	-33.36	-32.70	0.66	0.19

IceBridge KT19 vs VIIRS IST, 2012





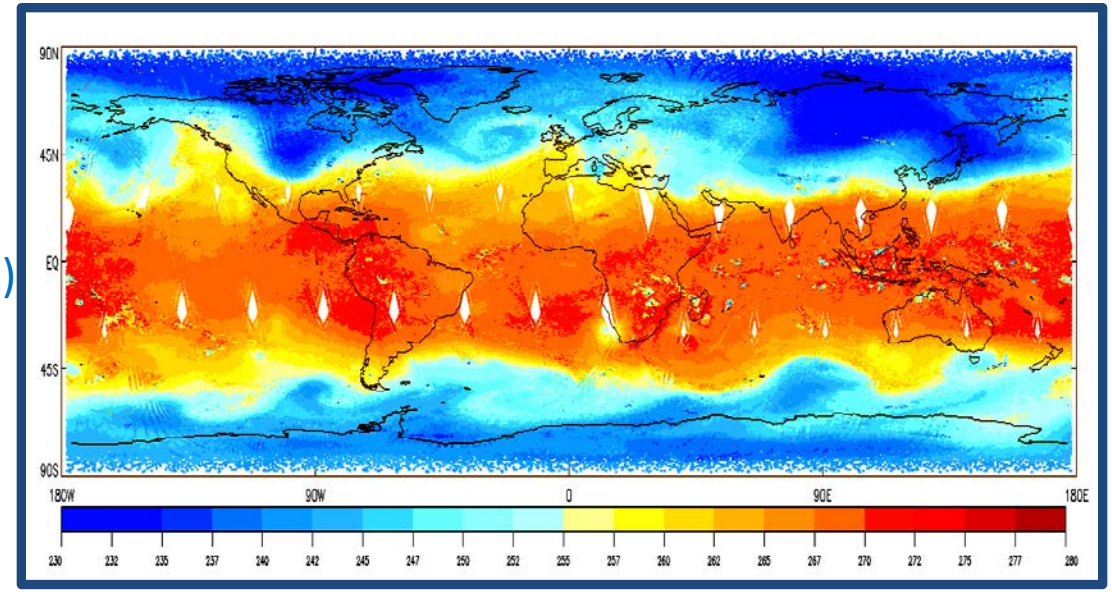
VIIRS IST has a 0.5+ K *cold bias* relative to the MODIS Ice Surface Temperature product. Comparisons to NCEP and International Arctic Buoy Program (IABP) air temperatures yield a VIIRS *warm bias* of 1 K. It meets the accuracy requirement under most conditions.

M. Tschudi (CU) et al.

NUCAPS Sounding Products Released at NOAA CLASS since April 8, 2014

- (Standard)
- Atmospheric Vertical Temperature Profile
- Atmospheric Vertical Moisture Profile
- Infrared Ozone Profile

NUCAPS Temperature retrieval @ 500mb January 5th 2014 (Polar Vortex Anomaly)



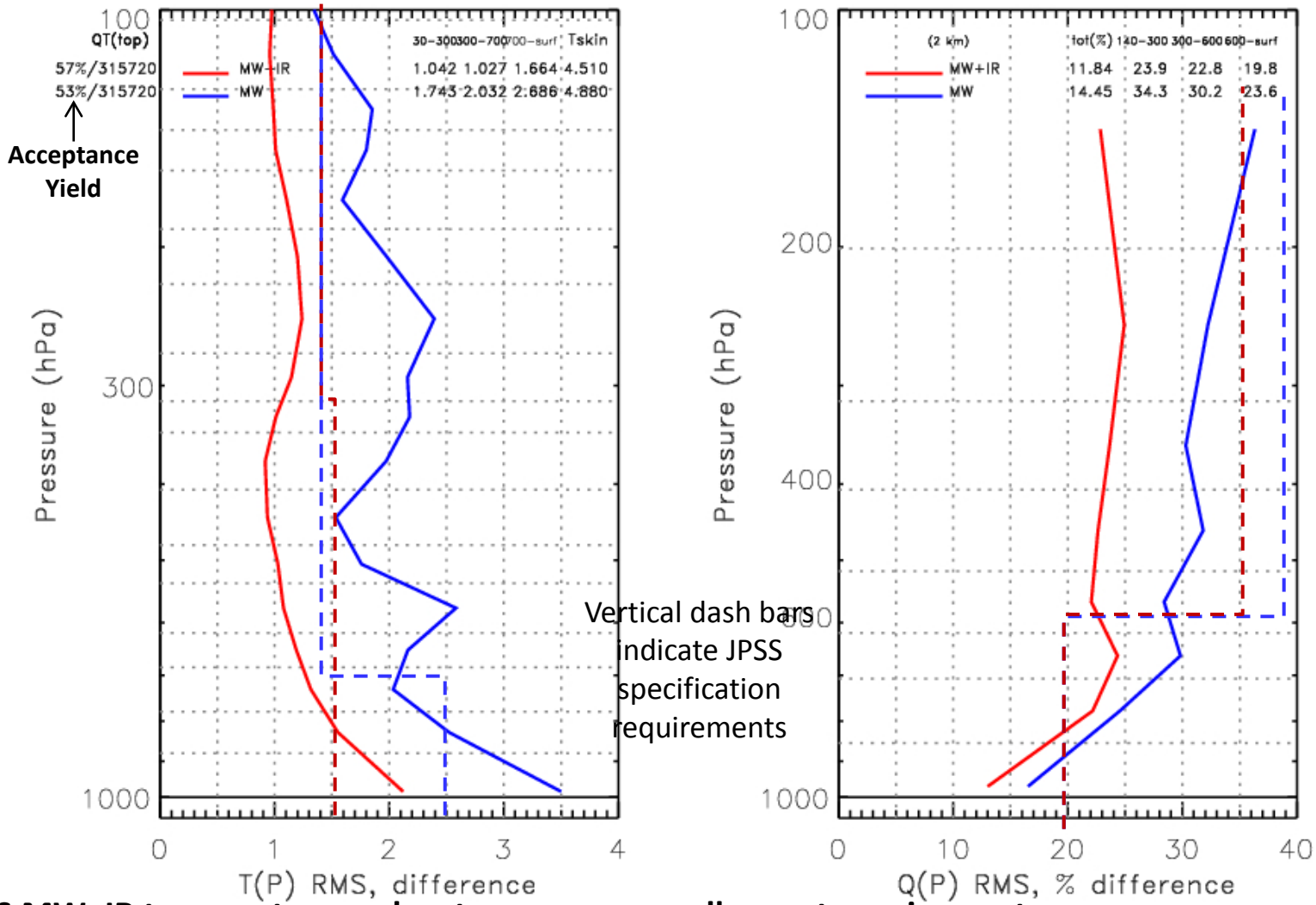
- (JPSS1 requirement: total column)
- Vertical CO Profile
- Vertical CO_2 Profile
- Vertical CH_4 Profile
- Outgoing Longwave Radiation (OLR)

- (Others)
- Vertical HNO_3 Profile
- Vertical N_2O Profile
- Vertical SO_2 Profile
- A flag indicating the presence of dust and volcanic emissions
- Cloud-Cleared Radiances

- **Integrated Retrieval System for CrIS/ATMS, IASI/AMSU, and AIRS/AMSU**

A. Gambacorta (IMSG), M. Liu (STAR) et al.

NUCAPS MW+IR & MW Only
Global RMS Statistics vs ECMWF Analysis



- **NUCAPS MW+IR temperature and water vapor generally meet requirements**
- **NUCAPS MW-Only water vapor meets requirements; temperature needs further optimization**

A. Gambacorta (IMSG), M. Liu (STAR) et al.

OMPS Ozone

The overall operational retrieval algorithm is working well. Cross-track calibration biases (bottom figure) are being worked on.

Daily global maps with false color images of three OMPS Version 8 algorithm products for June 9, 2014:

Top – Total column product (Dobson Units)

Middle – Effective Reflectivity (%)

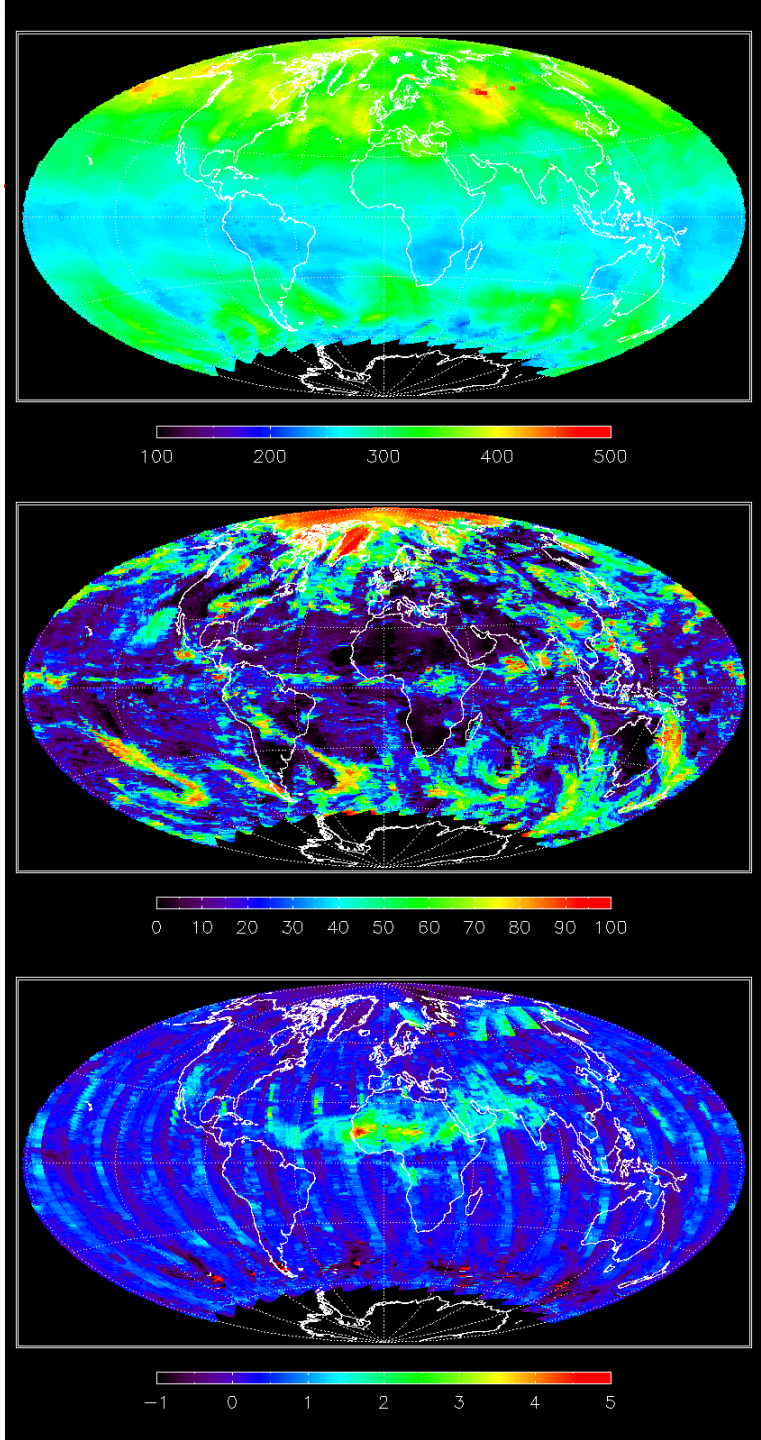
Bottom – Absorbing aerosol index product (N-values)

The colors show different levels of the index computed as a measurement residual for the 360 nm channel using the reflectivity estimate from the 331 nm channel. The units are in N-values which are approximately equivalent to 2.3% per unit. Sun-glint regions have not been filtered in this map.

Daily images for the full record to date are available through links at

ww.star.nesdis.noaa.gov/icvs/index.php.

L. Flynn, Z. Zhang, J. Niu, E. Beach, W. Yu



Summary

- Most of the operational Suomi NPP EDRs have reached Validated maturity level
- Remaining complex and downstream algorithms either
  - either are reaching Validated maturity
  - have been identified as not suitable to meet requirements
- Product evaluation and updates are continuing
  - Long-term monitoring and reactive maintenance
  - Replacement and upgrade of current Suomi NPP algorithms
    - State-of-the art or proven NOAA heritage algorithms
    - New and enhanced algorithms to meet JPSS Level 1 requirements

For more information

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

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

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

- JGR-Atmospheres Special Issue Papers