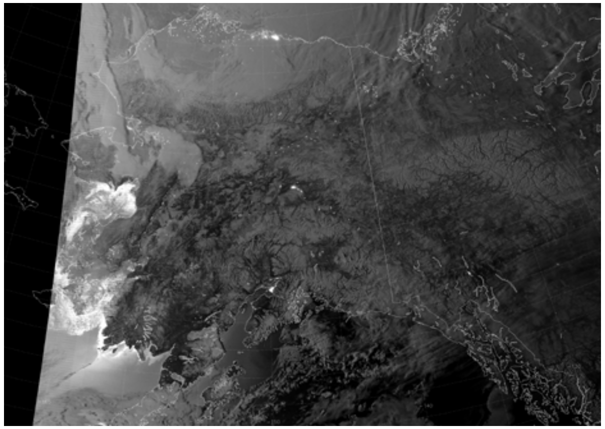
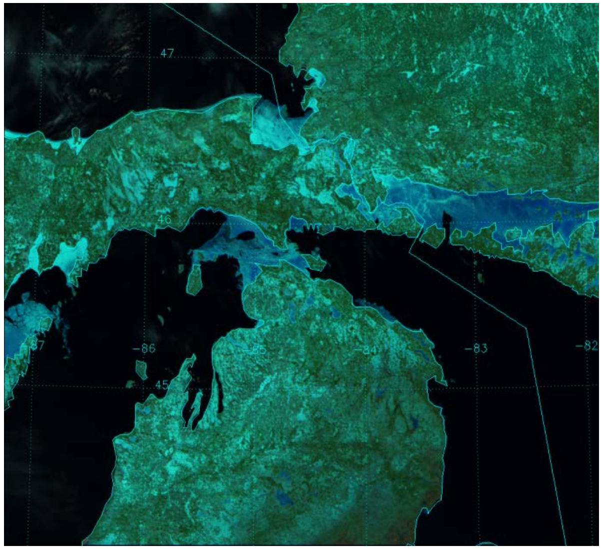
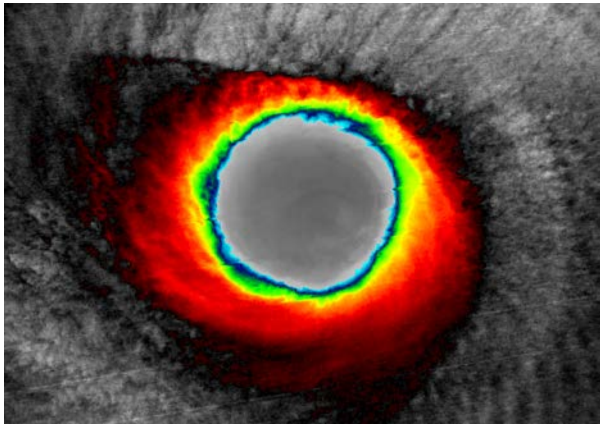
# Evaluation of Suomi NPP VIIRS Imagery





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NOAA/NESDIS/Satellite Applications and Research


1st STAR JPSS Annual Science Team Meeting, College Park, MD, May 2014

# VIIRS Imagery: SDRs and EDRs

- VIIRS: Visible Infrared Imaging Radiometer Suite
- All 22 bands are available as Sensor Data Records (SDRs)
- Bands highlighted in red are available as Environmental Data Records (EDRs)
- Day/Night Band (DNB) SDRs are converted to Near Constant Contrast (NCC) EDRs

| VIIRS Band | Central Wavelength (µm) | Band Explanation | Spatial Resolution (m) @ nadir |
|---|---|---|---|
| M1 | 0.412 | Visible/ Reflective | 750 m |
| M2 | 0.445 | | |
| M3 | 0.488 | | |
| M4 | 0.555 | | |
| M5 | 0.672 | | |
| M6 | 0.746 | Near IR | |
| M7 | 0.865 | | |
| M8 | 1.240 | Shortwave IR | |
| M9 | 1.378 | | |
| M10 | 1.61 | | |
| M11 | 2.25 | | |
| M12 | 3.7 | Medium-wave IR | |
| M13 | 4.05 | | |
| M14 | 8.55 | Longwave IR | |
| M15 | 10.76 | | |
| M16 | 12.01 | | |
| DNB (NCC) | 0.7 | Visible / Reflective | 750 m across full scan |
| I1 | 0.64 | Visible / Reflective | 375 m |
| I2 | 0.87 | Near IR | |
| I3 | 1.61 | Shortwave IR | |
| I4 | 3.74 | Medium-wave IR | |
| I5 | 11.45 | Longwave IR | |

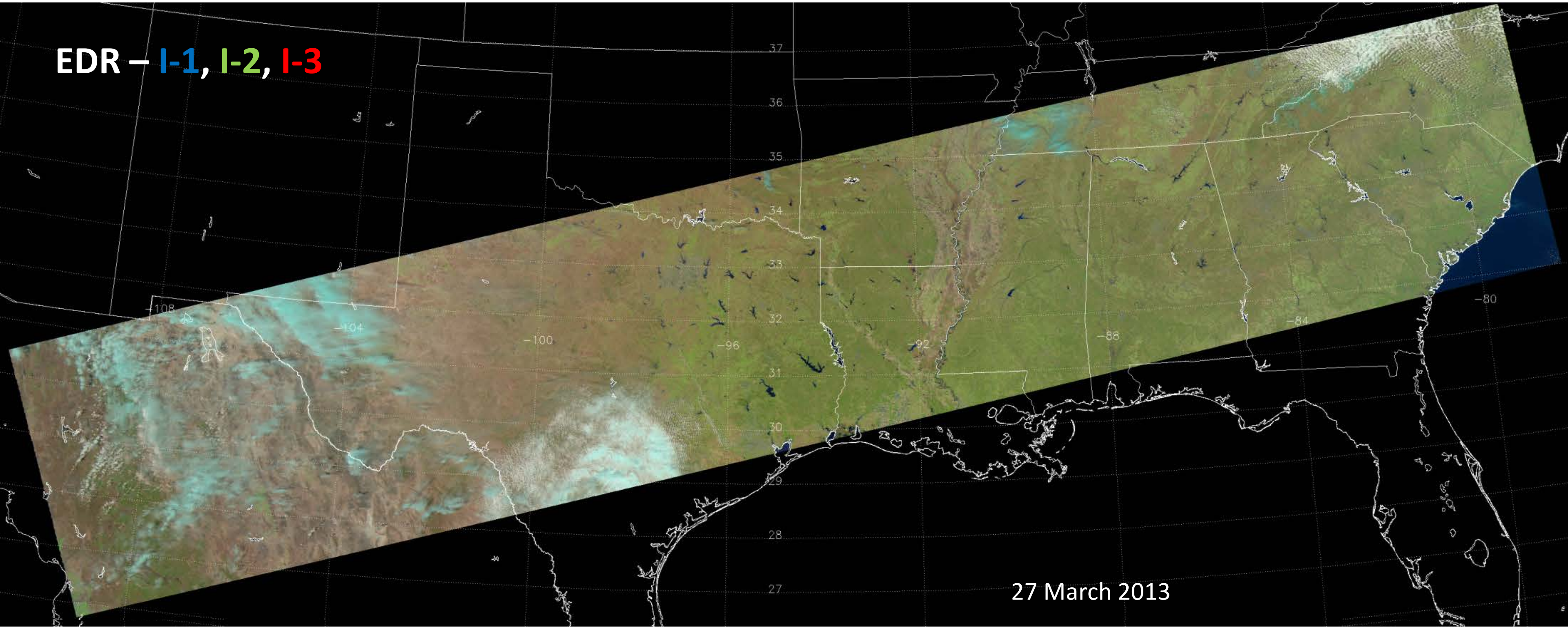
# SDRs and EDRs: What's the difference?



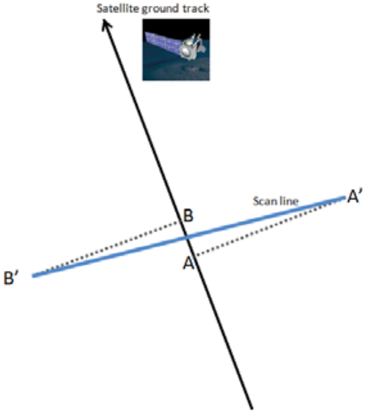
FILL VALUE LEGEND


Unmapped SDR and EDR granules from 08:14 UTC 24 October 2013

# SDRs and EDRs: Apparent Rotation

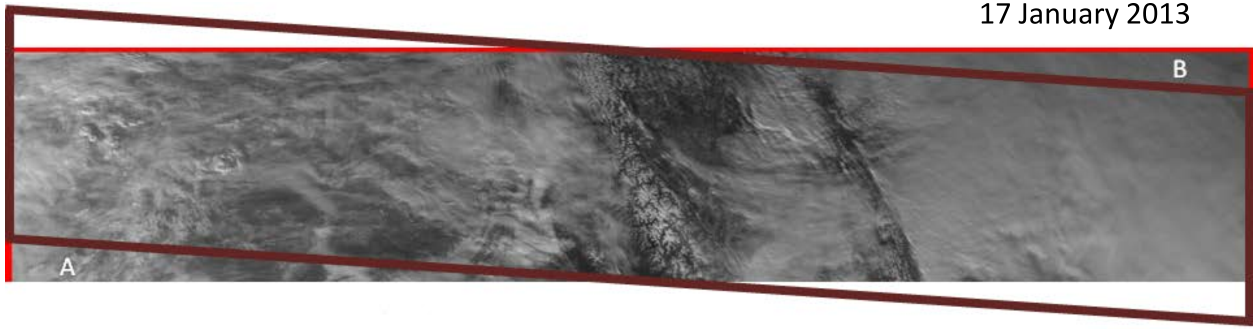



Scan lines in SDR data are not orthogonal to the satellite ground track, due to the constant motion of the satellite. Mapping the data to the Ground Track Mercator (GTM) grid restores orthogonality. This is the cause of the apparent rotation between SDRs and EDRs.



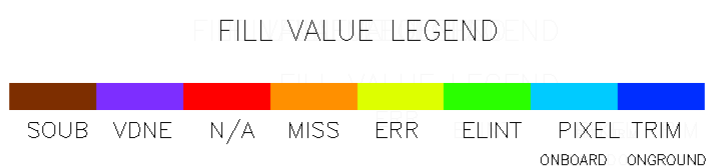
# The Case of the Missing Triangles

17 January 2013

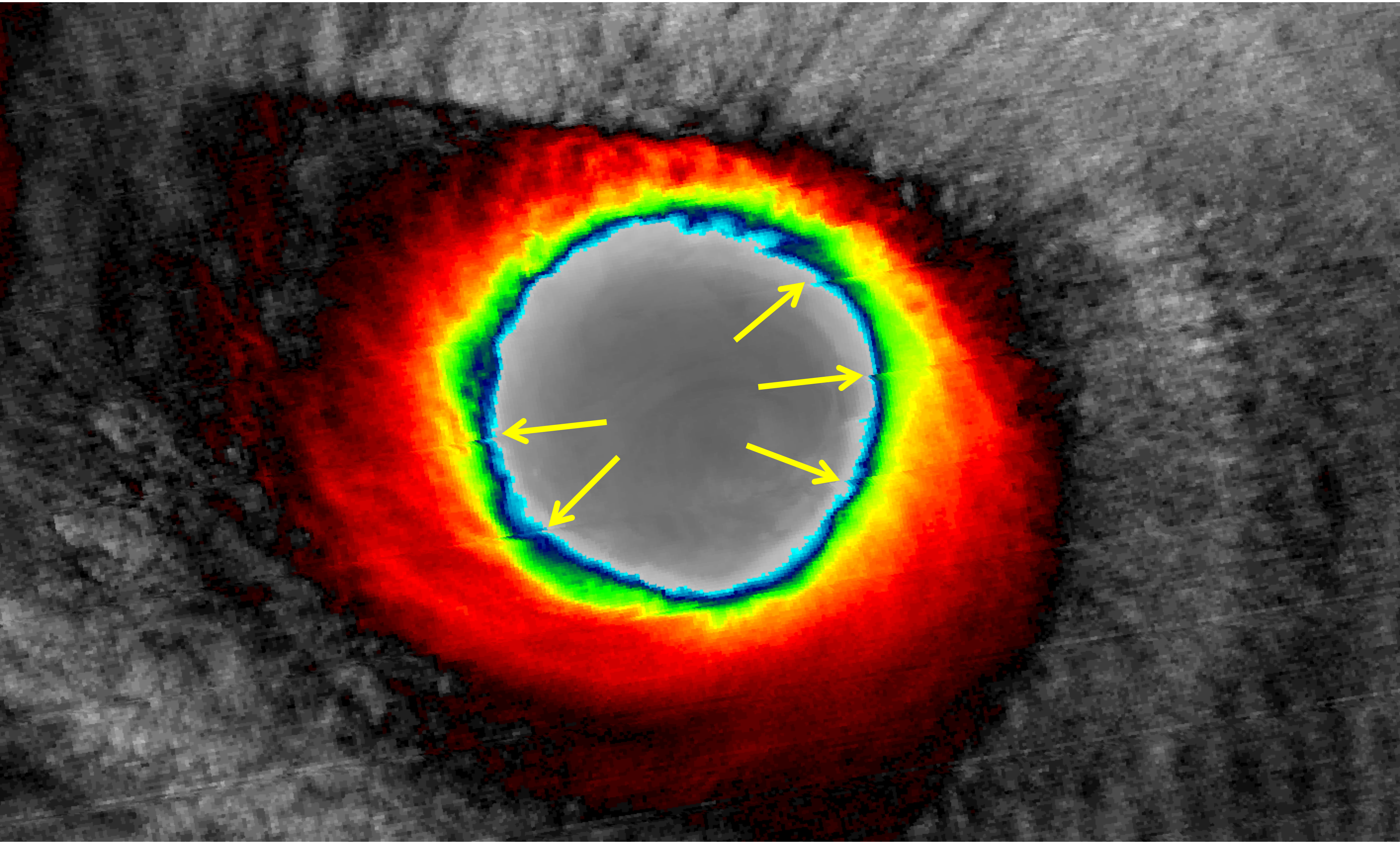



The brown outline shows where a SDR granule matches up with a given EDR granule. It takes three SDR granules to produce one EDR granule. If an SDR granule is missing when the EDR is created, you get a “missing triangle”…

24 February 2012

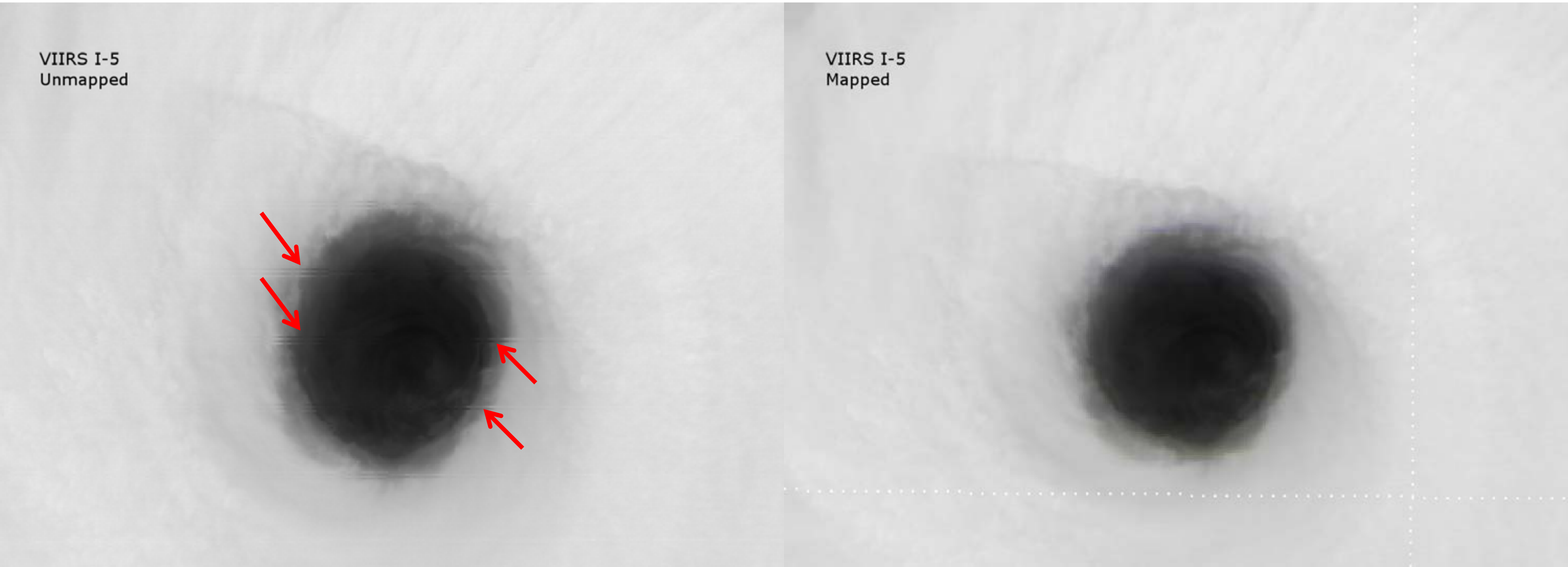


# The Case of the Sawtoothed Eye



I-5 SDR image of the eye of Typhoon Jelawat (25 September 2012) produced using McIDAS-v

# The Case of the Sawtoothed Eye

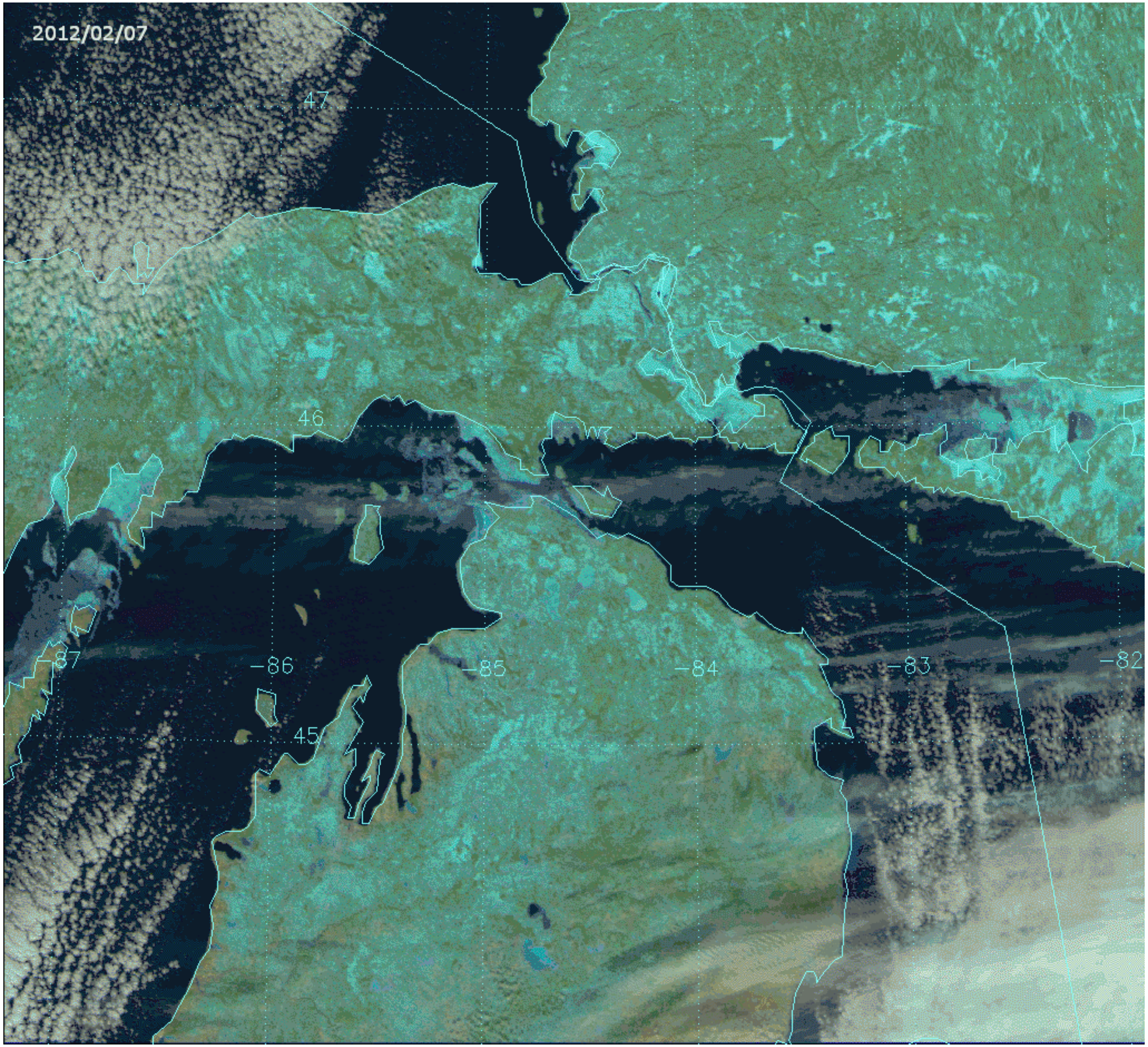



The unmapped image of the typhoon eye (left) shows artifacts caused by the bowtie effect. These artifacts disappear when the same data was correctly mapped to the Earth's surface using IDL.

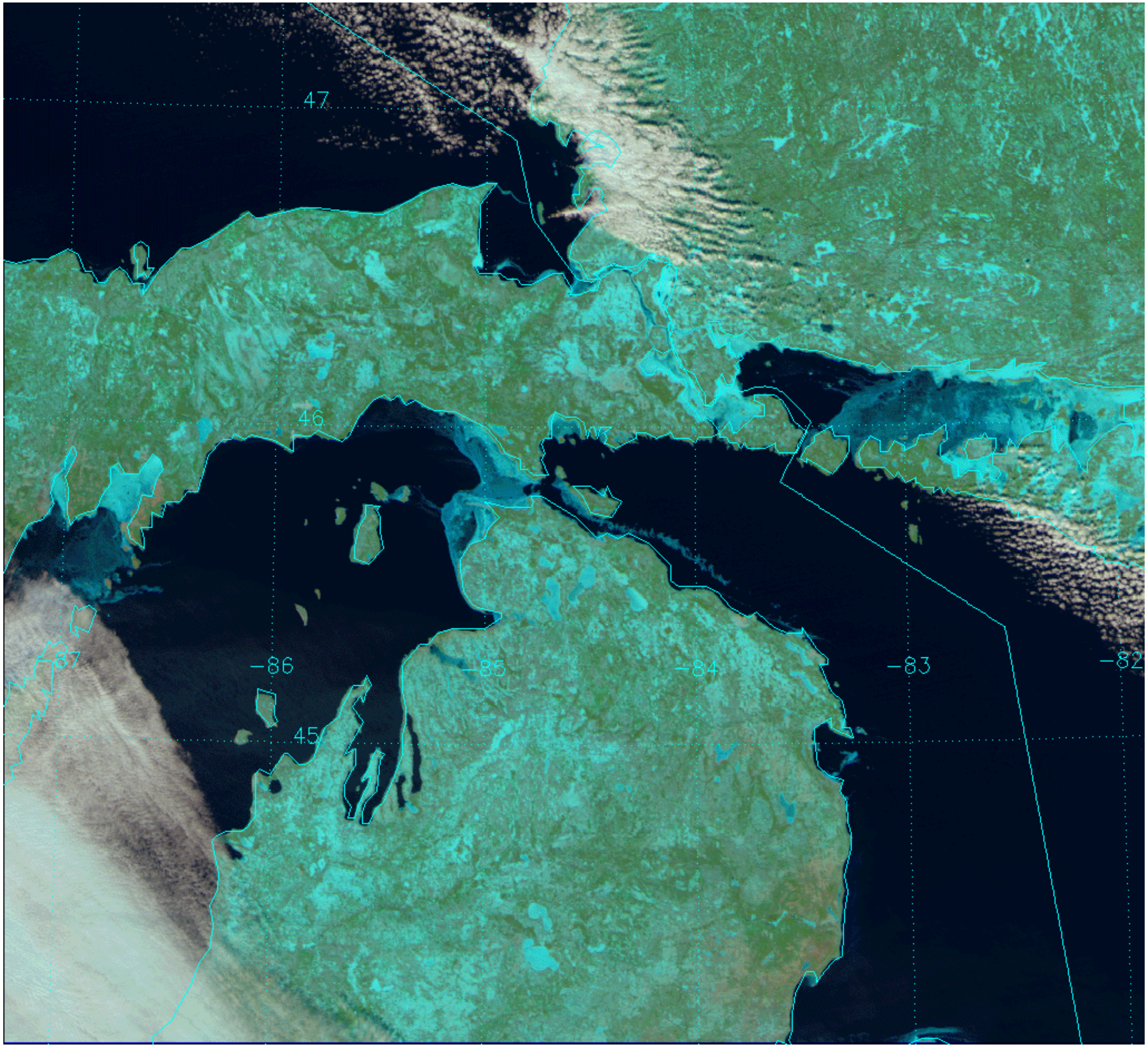
The "sawtooth pattern" was caused by improper mapping. It is a display issue, not a problem with the data!

NOTE: McIDAS-v does have the ability to properly map VIIRS data to avoid this issue.

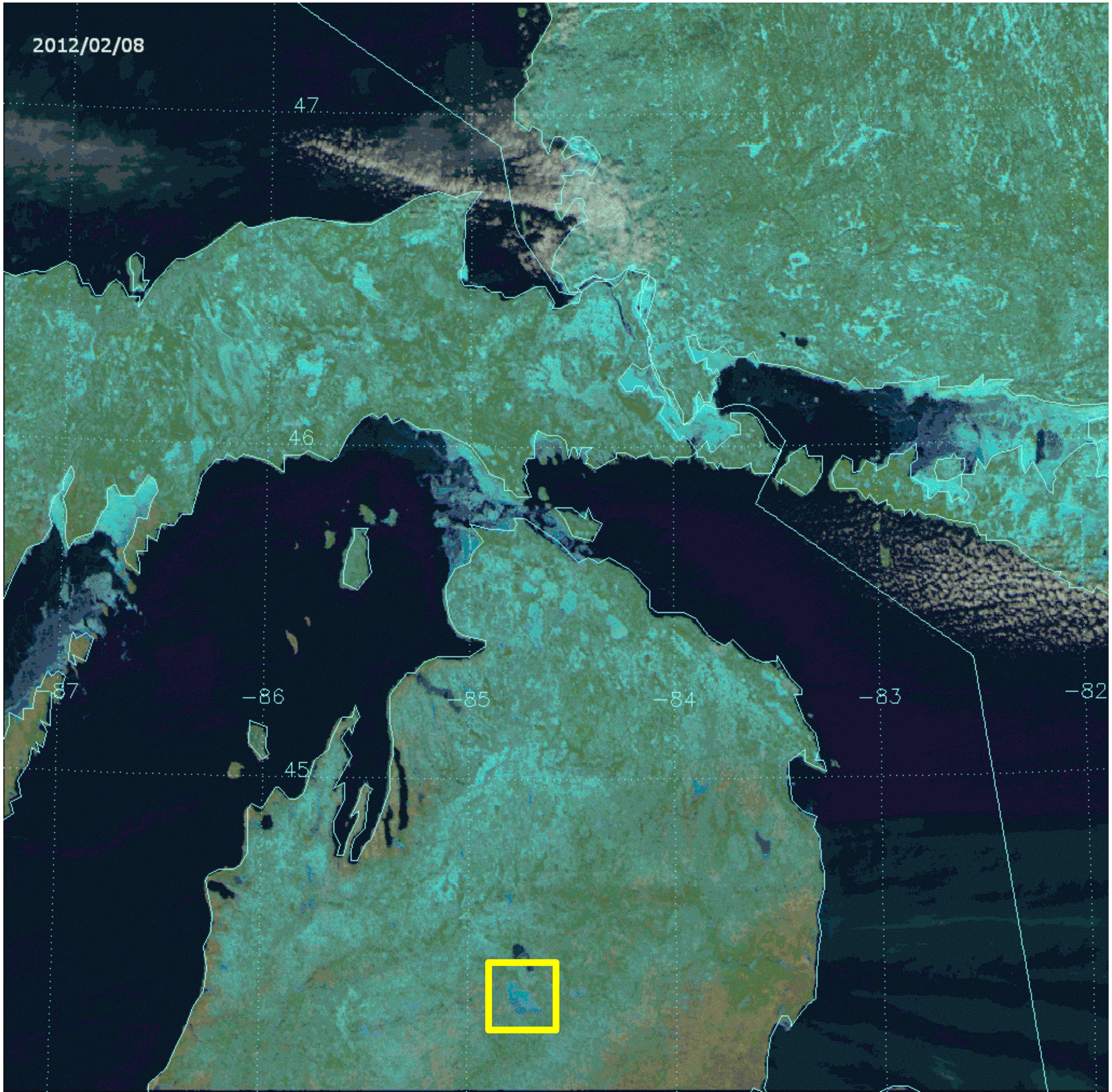
# Geolocation Evaluation: I-band SDR



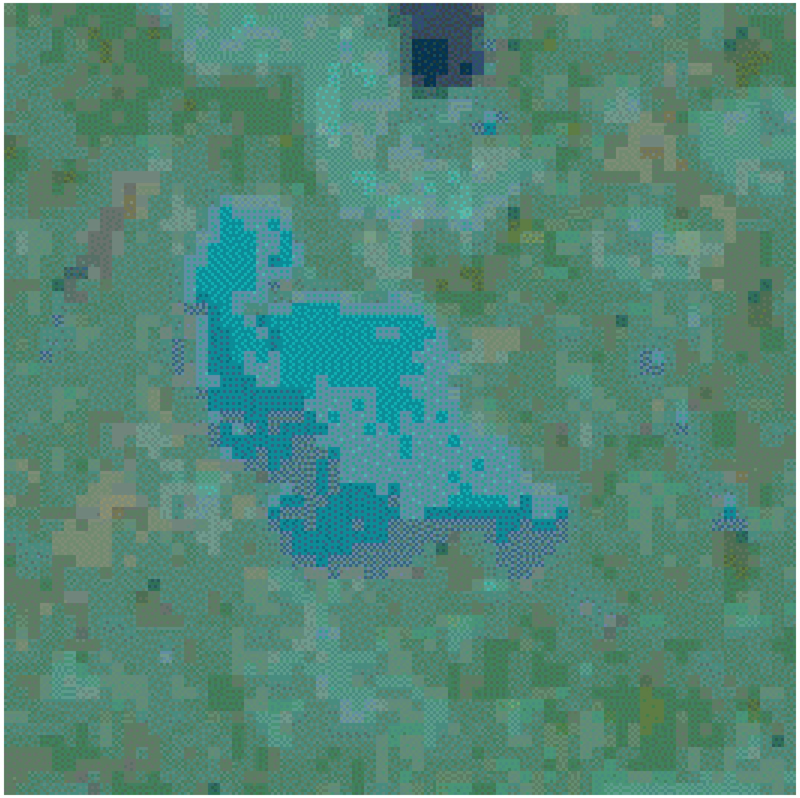
# Geolocation Evaluation: I-band SDR



# Geolocation Evaluation: I-band EDR

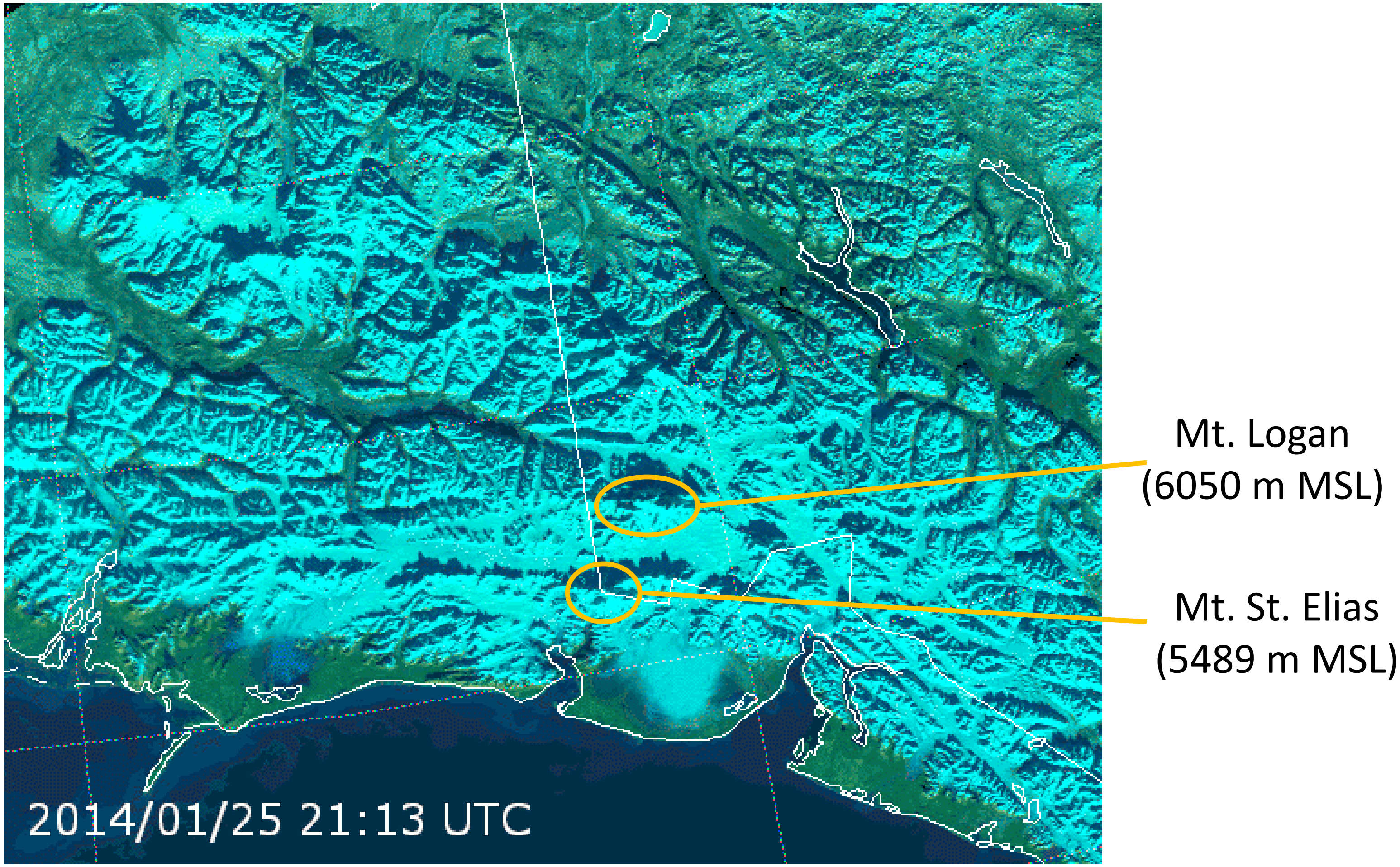


# Geolocation Evaluation: I-band EDR

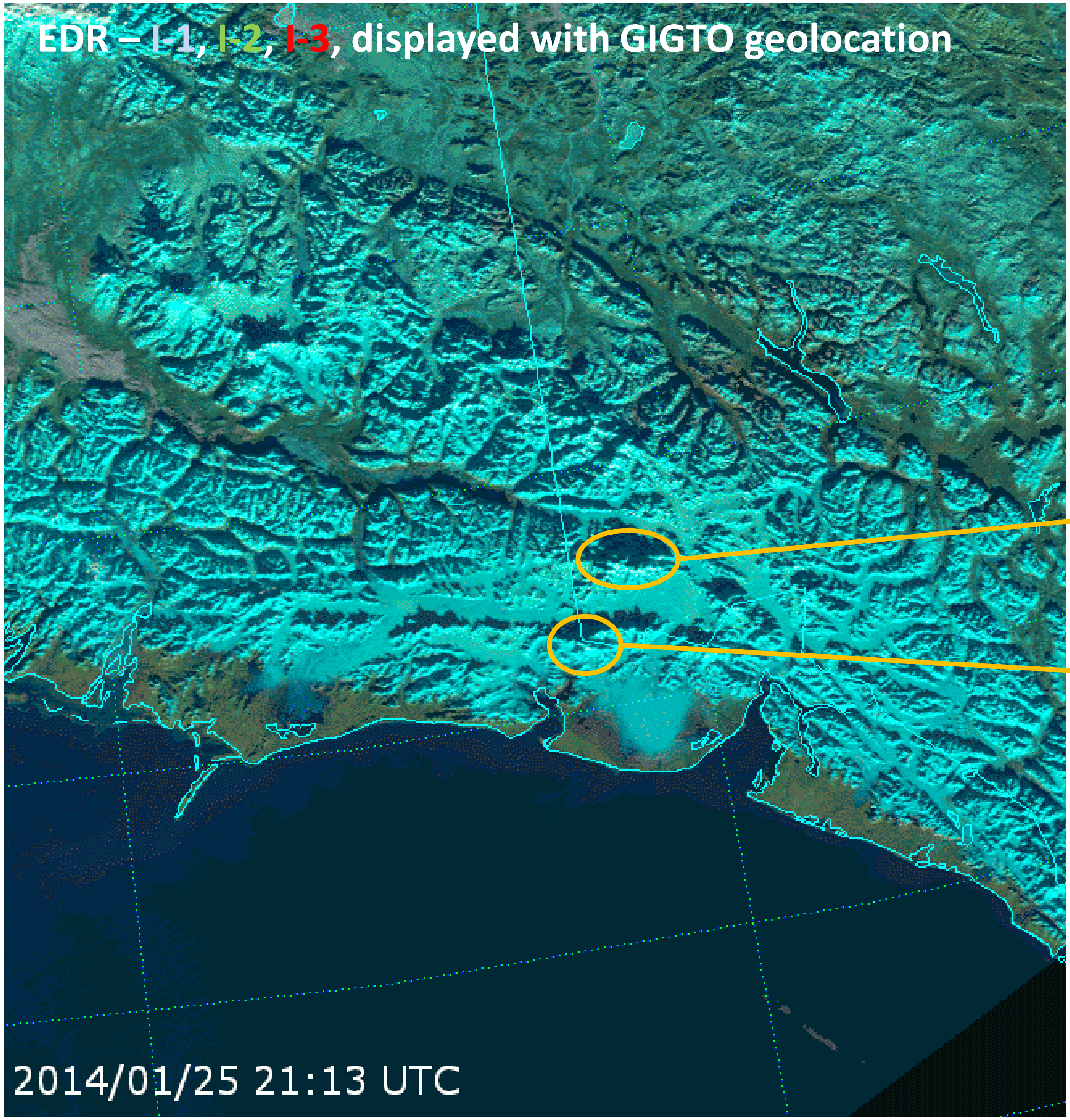


# Terrain Correction Evaluation: SDR

**SDR – I-1, I-2, I-3, displayed with GITCO geolocation**



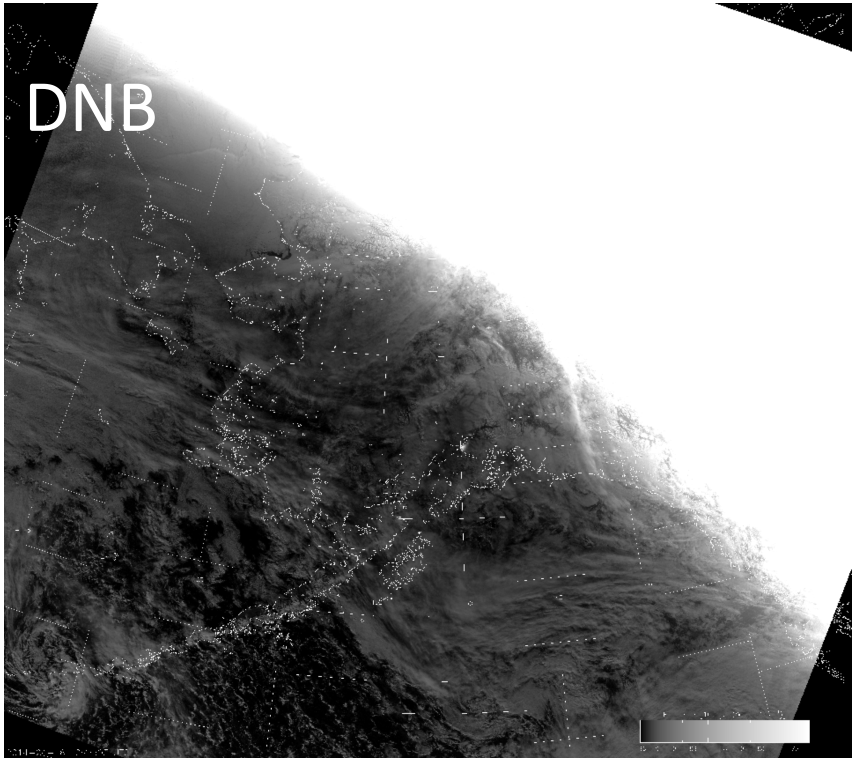
# EDRs are not Terrain Corrected!

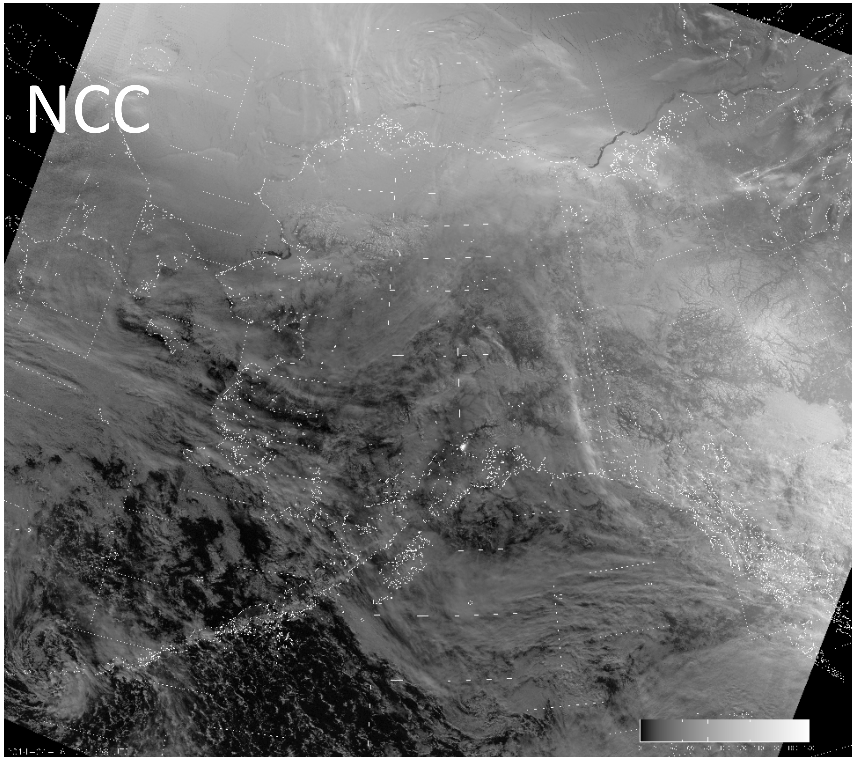



Mt. Logan
(6050 m MSL)

Mt. St. Elias
(5489 m MSL)

# DNB (SDR) vs. NCC (EDR)

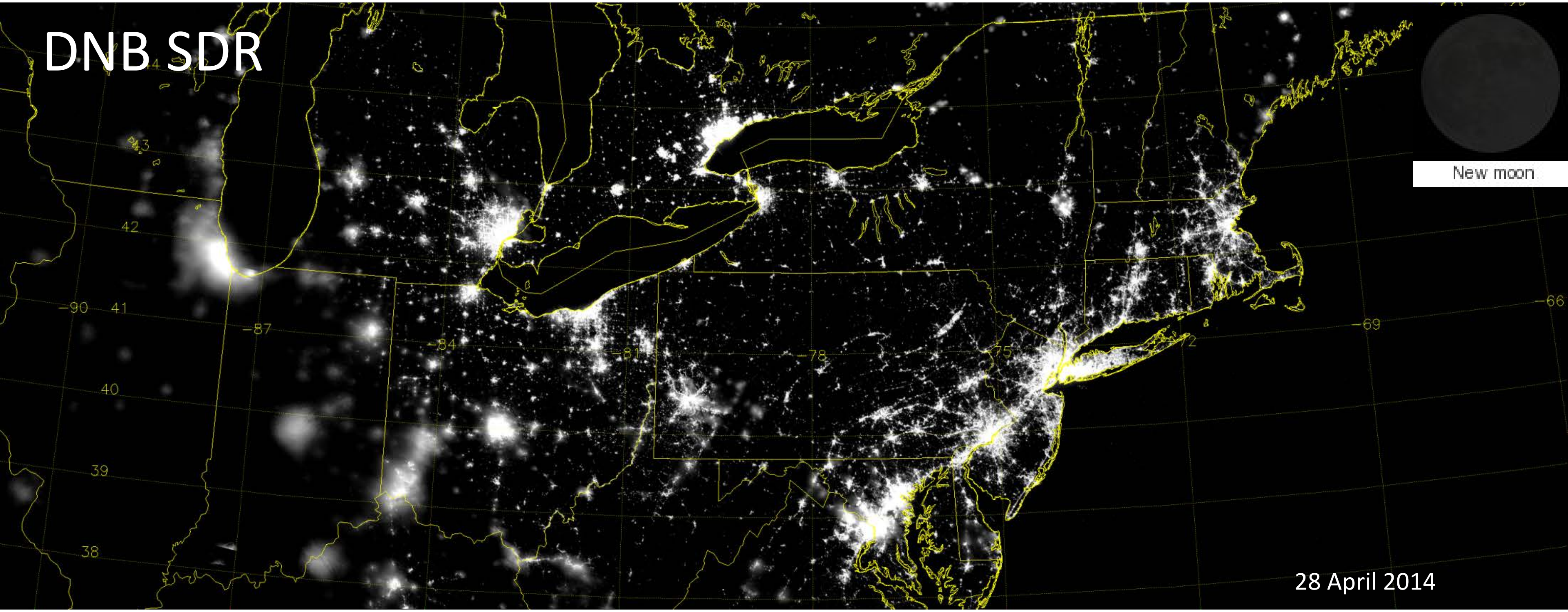



It is difficult to display DNB images near the day/night terminator, as radiance values vary by 7-8 orders of magnitude from day to night, and many displays only have 256 colors.

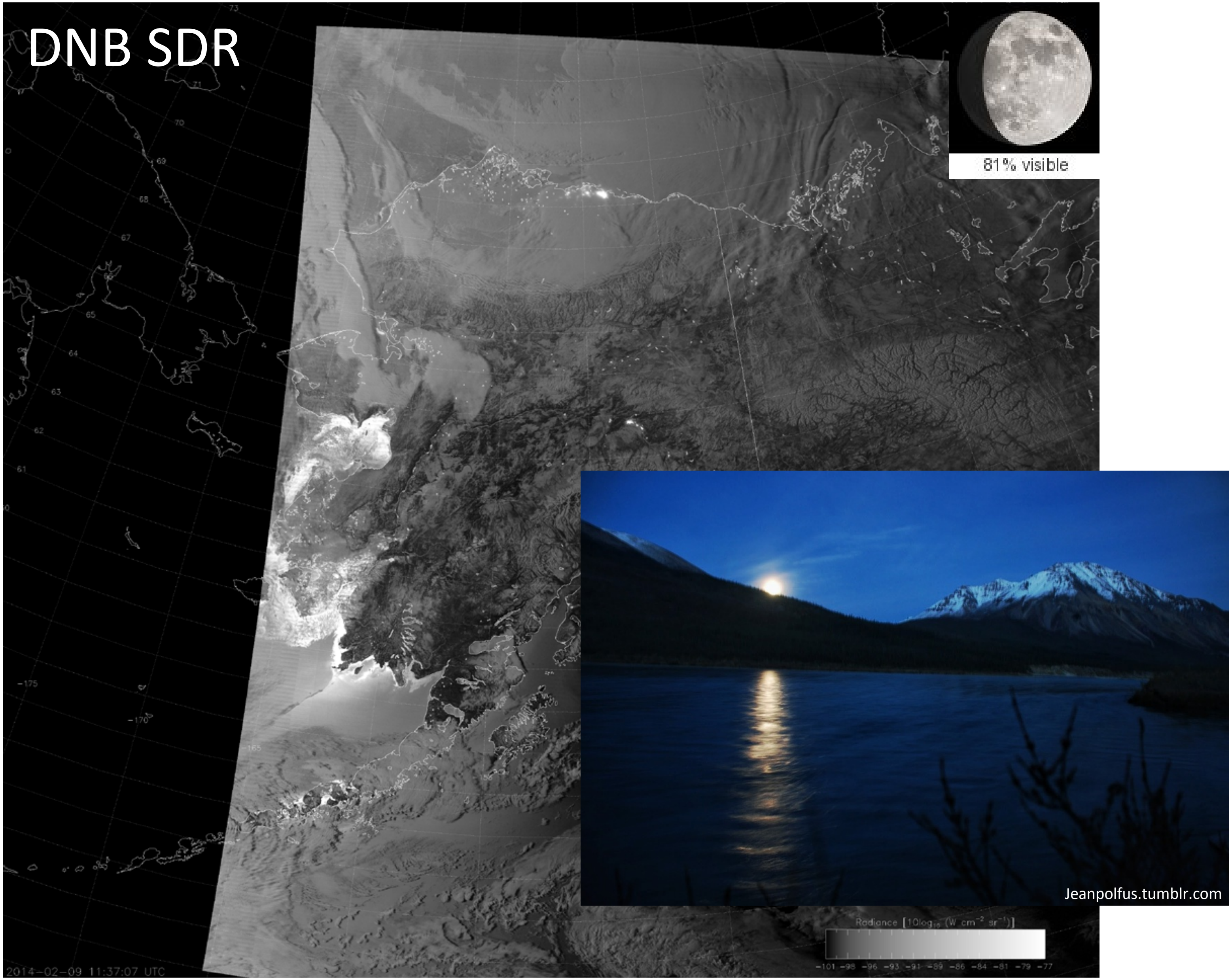
The NCC EDR converts DNB radiance to a "reflectance" to reduce the dynamic range of the data, improving the display across the terminator.

# Stray Light and Striping




Stray light and striping were an issue with DNB and NCC imagery until 20 August 2013, when a correction was applied. Problem solved!

# ~~Bug~~? Or Feature?




Nighttime DNB image of Alaska, 11:37 UTC 9 February 2014

# ~~Bug~~? Or Feature? Part 2

*BAMS Nowcast*, October 2013

NOWCAST

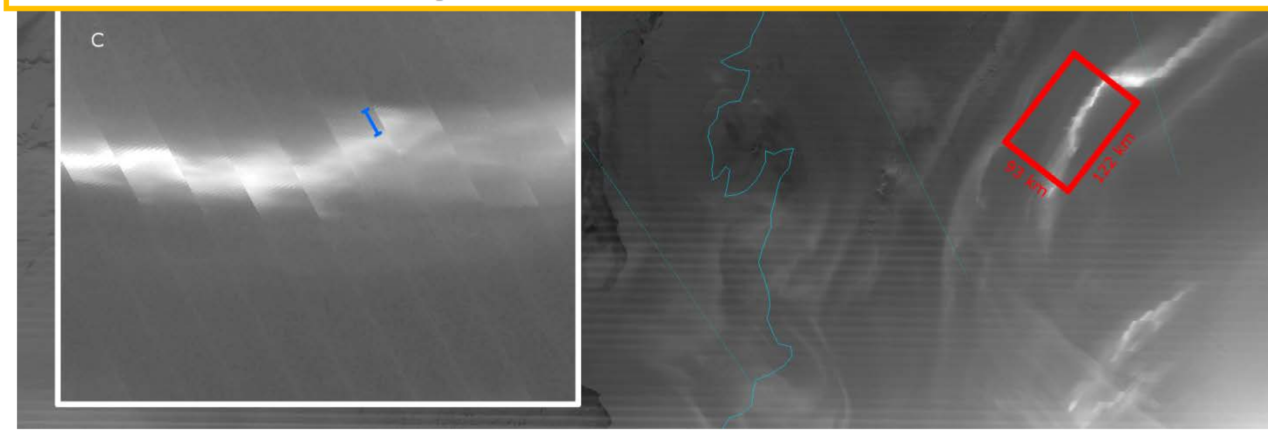
OBSERVATIONS

## VIIRS CAPTURES AURORA MOTIONS

BY CURTIS J. SEAMAN AND STEVEN D. MILLER

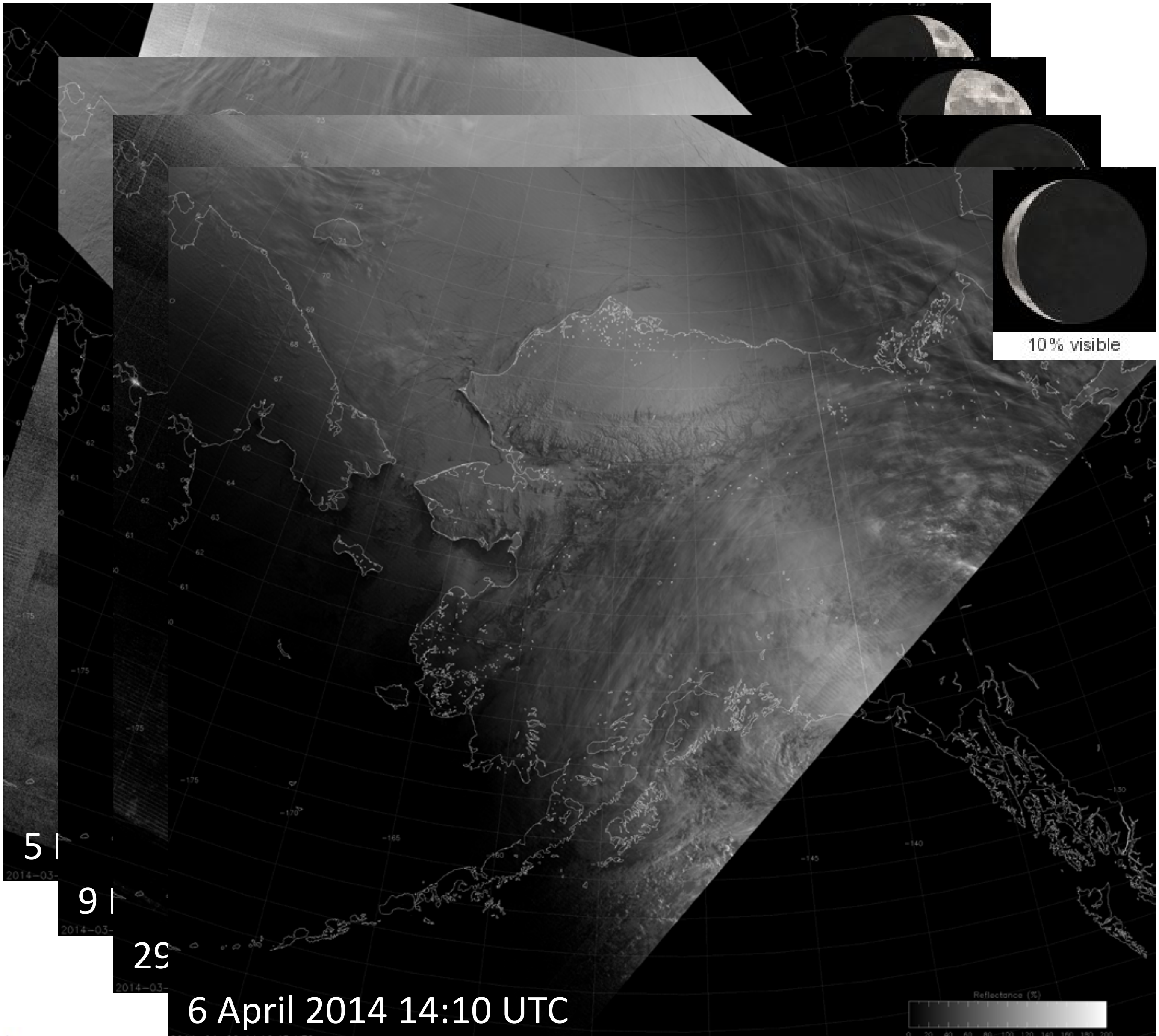
Auroras are the visible manifestation of interactions between the atmospheres of the Sun and the Earth. Massive amounts of high-energy hydrogen and helium atoms, spewed from the so-

The day/night band has captured images of auroras during a new moon (Fig. 1) and near-full moon (Fig. 2). Both of these auroras occurred near the coast of Antarctica, as shown in Figs. 1a and 2a.




Nighttime DNB images of Antarctica with aurora, 00:22 UTC 1 October 2012

# Bug? Or ~~Feature~~? Part 3



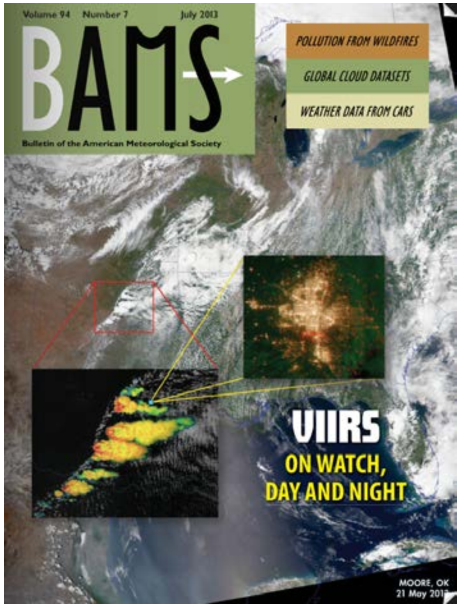

Nighttime NCC images of Alaska, Spring 2014

# Summary

- VIIRS Imagery is alive and well!
  - Geolocation has been accurate and stable since mid-2012
  - "Missing Triangle" problem eliminated (mid-2012)
  - Striping reduced or eliminated (August 2013 for DNB and NCC imagery)
  - Stray Light in DNB reduced or eliminated (August 2013)
  - NCC imagery available at night throughout the lunar cycle
  - All Imagery EDR products have achieved Validation Stage 3 (April 2014)

- Many "bugs" are actually features of the data
  - Moon glint
  - Aurora motions

- Others are attributed to "user error"
  - Incorrect mapping of SDR data by users, e.g.




- For the future:
  - Anomalously dark/light areas in NCC near terminator
  - Terrain correction for the EDR geolocation
  - Make EDRs from all 16 M-bands
  - Make M-band EDRs more readily available

# Resources

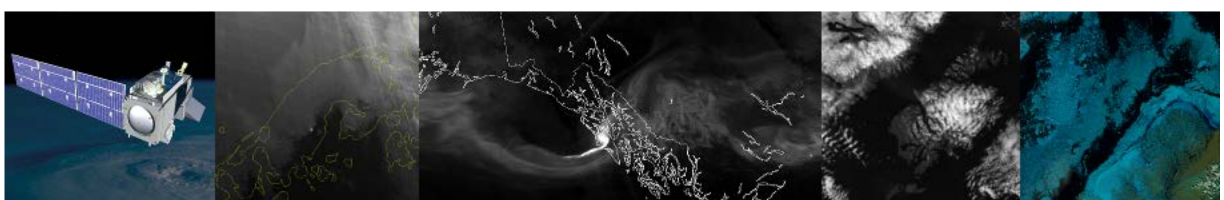
Geolocation evaluation tests:


http://rammb.cira.colostate.edu/projects/npp/calval/

JPSS Imagery and Visualization Team blog:

http://rammb.cira.colostate.edu/projects/npp/blog/

High-latitude applications of VIIRS Imagery:



http://rammb.cira.colostate.edu/projects/alaska/blog/

NOAA • NESDIS JPSS Joint Polar Satellite System

# Nightfire: Using the VIIRS Nighttime M-bands to Detect and Characterize Combustion Sources

May 14, 2014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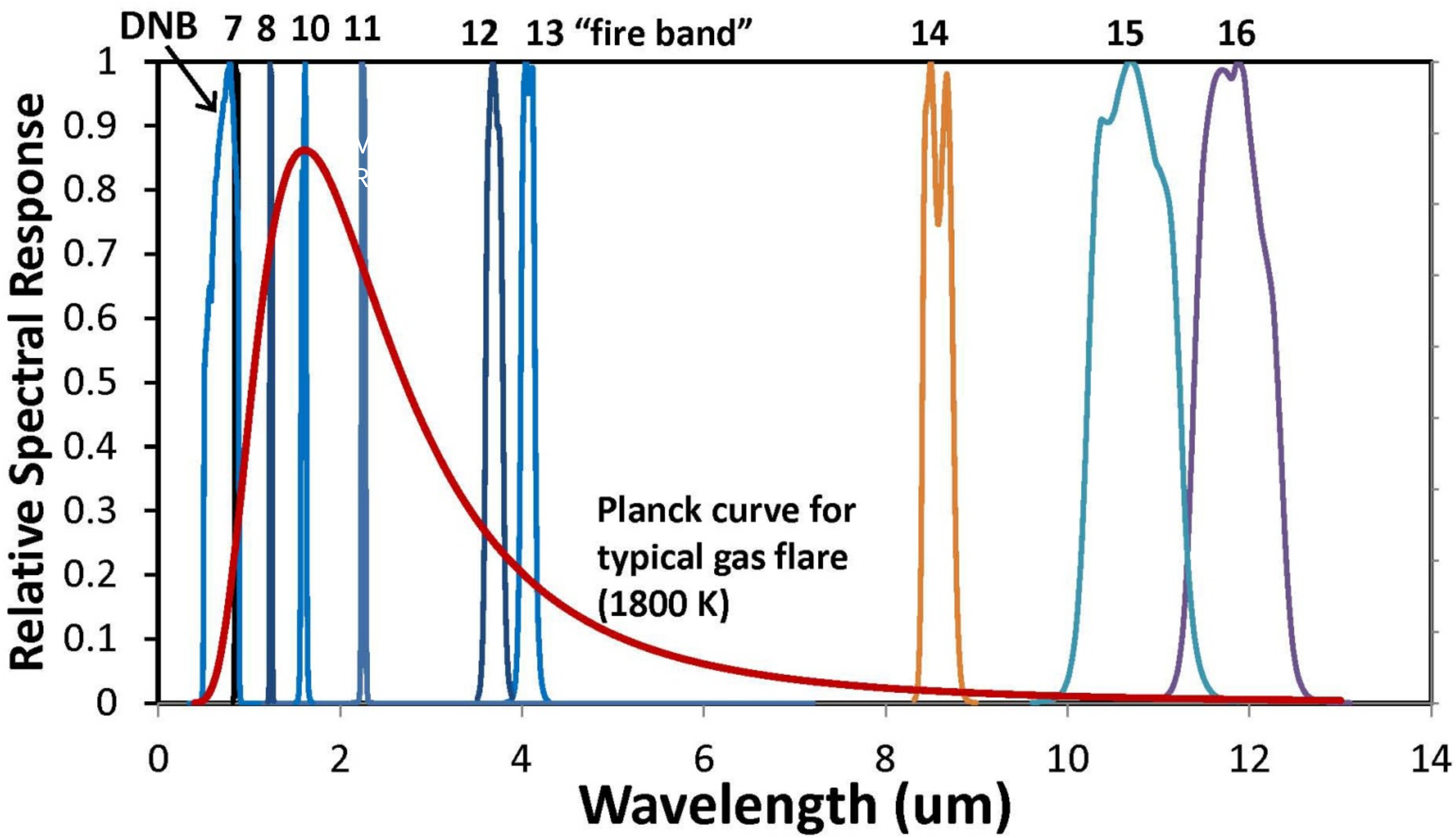
# Gas Flaring

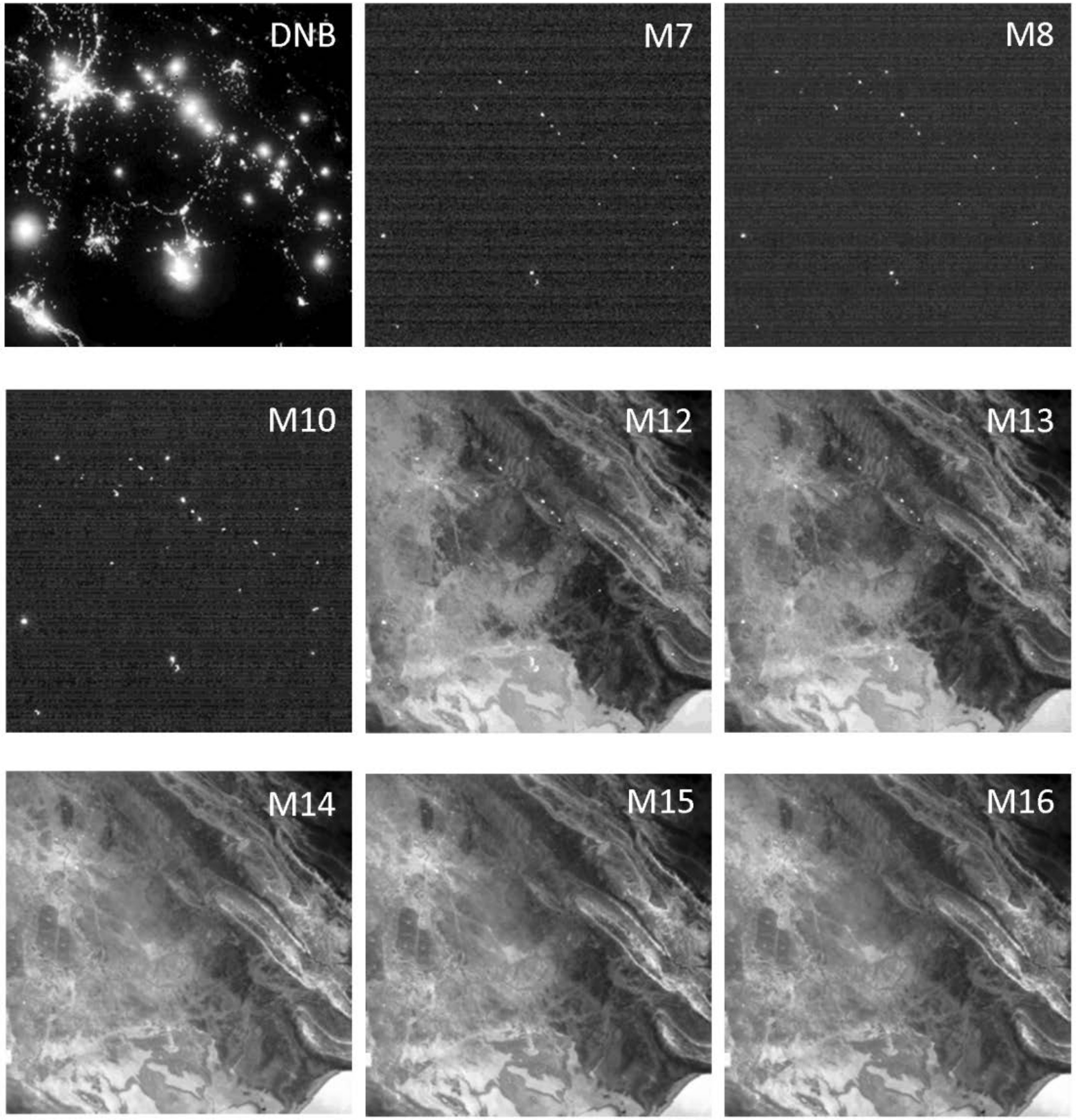
• A widely used practice to dispose of natural gas in oil production areas that lack infrastructure to make productive use of the gas.
• More common in remote locations and in impoverished countries.
• Reporting is poor since this is a waste disposal process.
• Satellite data sources have the potential for global systematic observation of flares and estimation of flared gas volume / $CO_2$ emissions.

# What makes nighttime VIIRS data so great for detection of combustion sources?

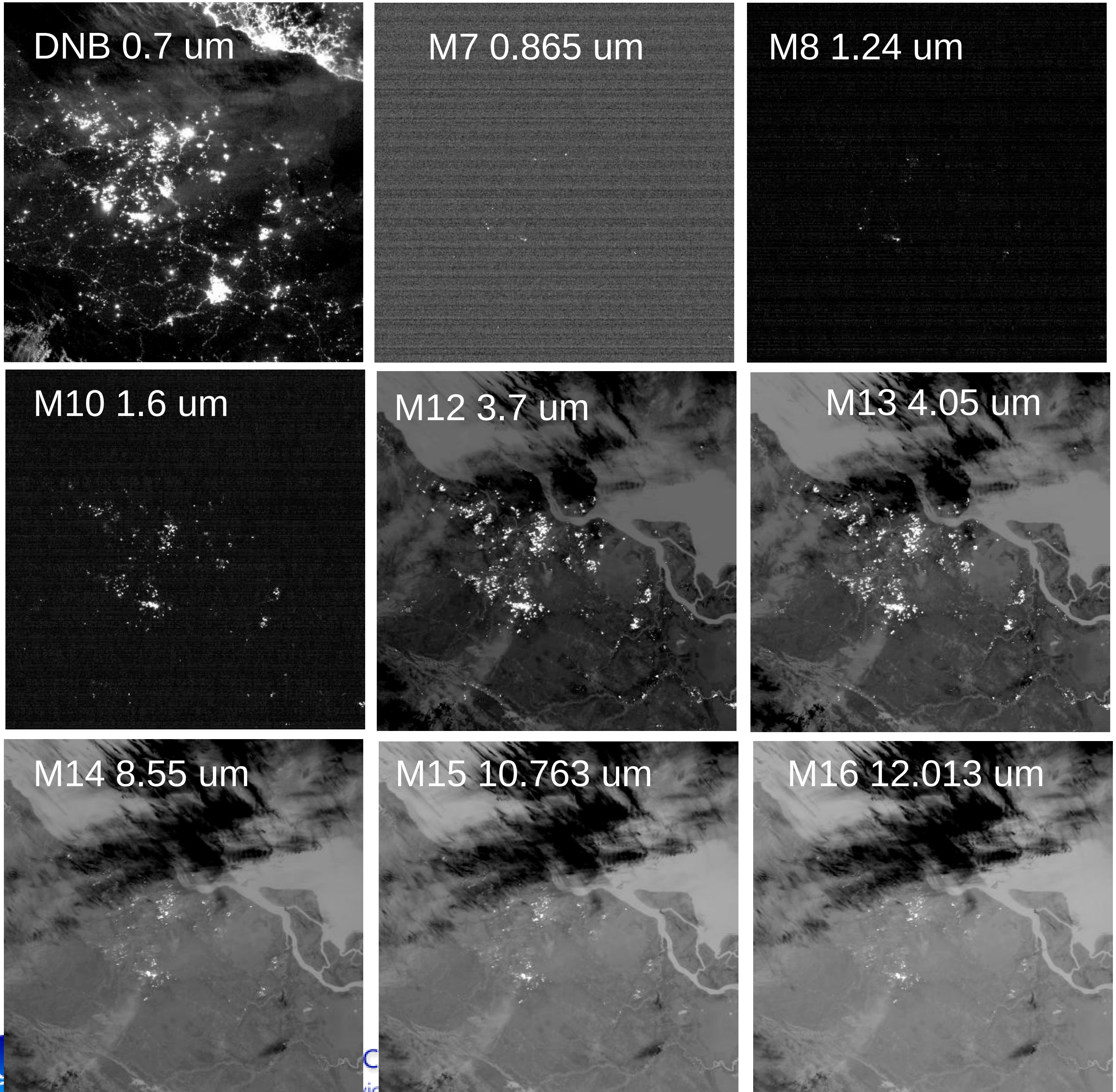



The M7,8,10 spectral bands are well placed to record the peak radiant emissions from flares. During daylight hours the signal is overwhelmed by sunlight. At night combustion sources stand out clearly against the background.

Basra Gas Flares, Iraq - July 17, 2012




Gas flares are readily detected in the VIIRS M10 spectral band

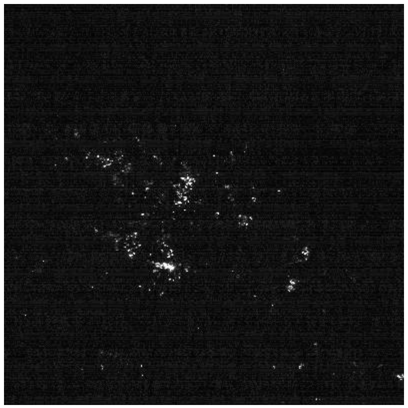



# VIIIRS Nighttime Imagery

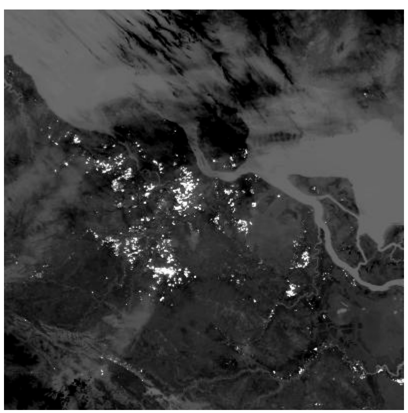
Riau Indonesia

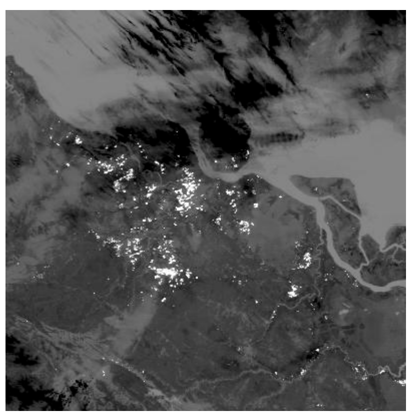
June 19, 2013

# VIIRS Nightfire v2 has two independent hot pixel detection algorithms

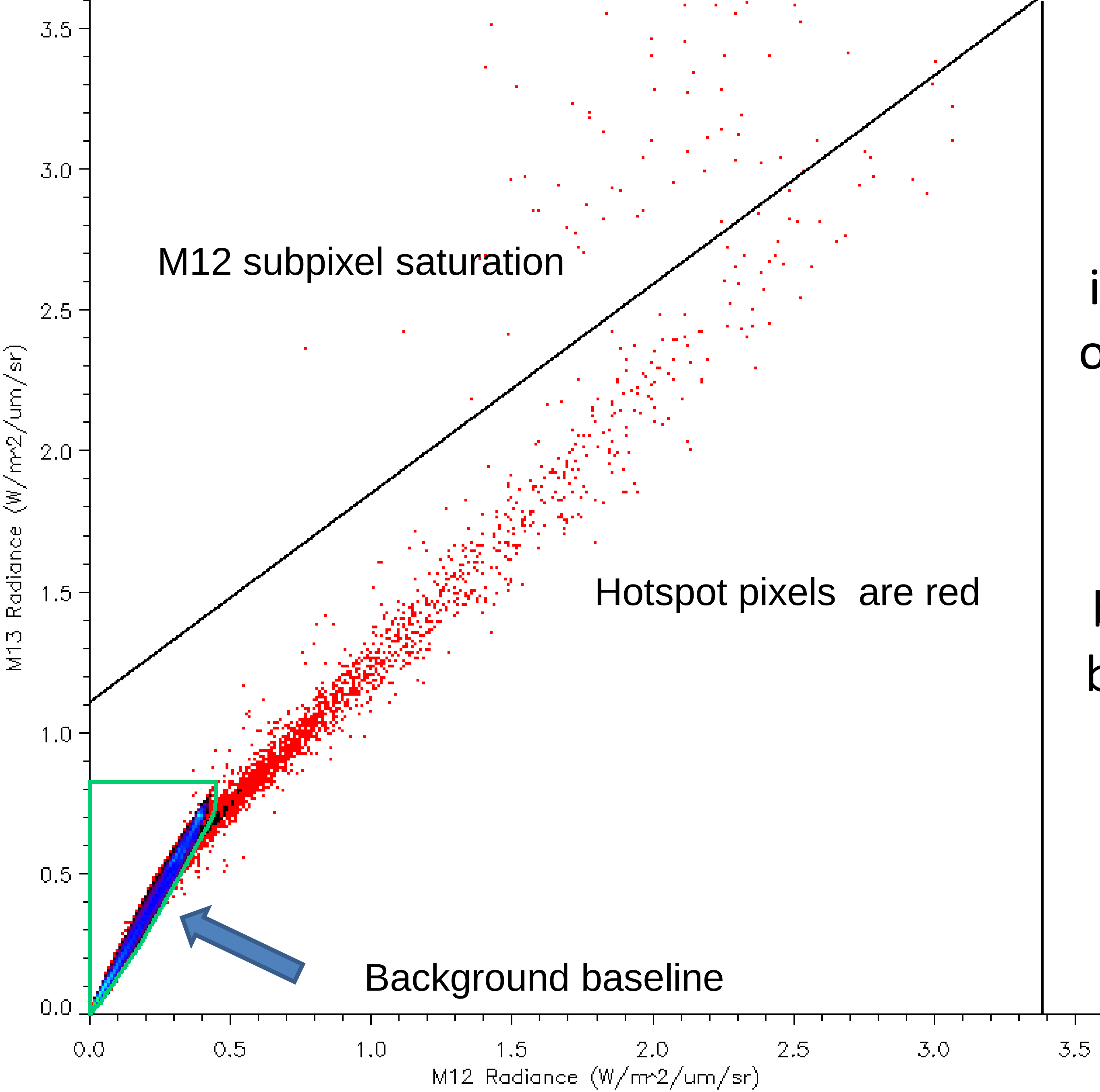


<u>High Temperature Detector</u>
SWIR: M10 (1.6 um) detection threshold set based on background noise – mean plus four standard deviations. The detected pixels are then checked for detection in M7 & M8.





<u>Low Temperature Detector</u>
MWIR: M12-M13 (3.8 and 4 um) scattergram analysis identifies background. Hot pixels are the outliers.




M12 and M13 detection algorithm identifies pixels outside of scene background, which is in the form of a baseline. Local background not used.

# Planck Curve Fitting

- Planck curve fitting uses an iterative simplex algorithm.
- Pixels with M10 detection and no M12-M13 detection are fit with a single hot Planck curve.
- Pixels with M10 plus M12-M13 detection are fit with dual Planck curves (one hot and one background) spanning all nine bands. Observed radiances used as constraints.
- Single curve fitting with insufficient detections
  - Fitting for pixels without M16 detection use zero radiance in M16 as a hot source constraint.
  - Fitting for pixels without M10 detection use zero radiance in M10 as a hot source constraint.

# Planck Curve Calculations

- Peak radiance indicates temperature (K) using Wein's Displacement Law.
- Subpixel sources appear as graybodies. The ratio of the observed curve versus the full pixel curve for that temperature is traditionally referred to as emissivity. We call it emission scaling factor (ESF) to distinguish it from full field of view graybodies. Source area is calculated by multiplying ESF by the size of the pixel footprint.
- Radiant heat (aka heat release) is calculated in MWs using the Stefan-Boltzmann Law.

# Typical Gas Flare Detection

**Combustion parameters:**

ID=VNF_npp_d20140426_t0800568_e0806372_b12924_x0922946W_y196042N_l2716_s2045_v21

Lat=19.604204 Lon=-92.294624 deg.
Time=2014/04/26 08:06:32

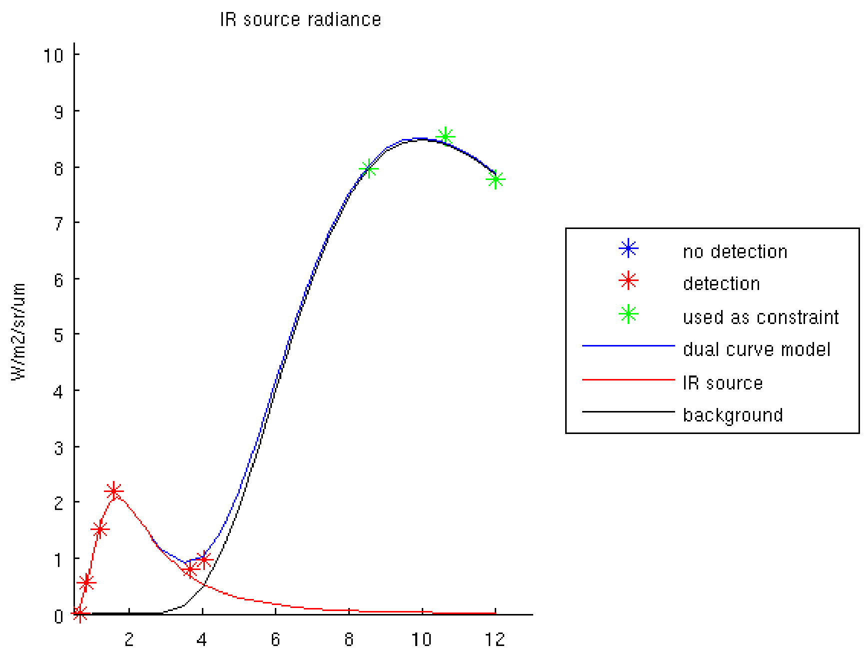
Temperature source=1730 deg. K
Temperature background=291 deg. K

Radiant heat intensity=16.63 W/m2
Radiant heat=13.18 MW

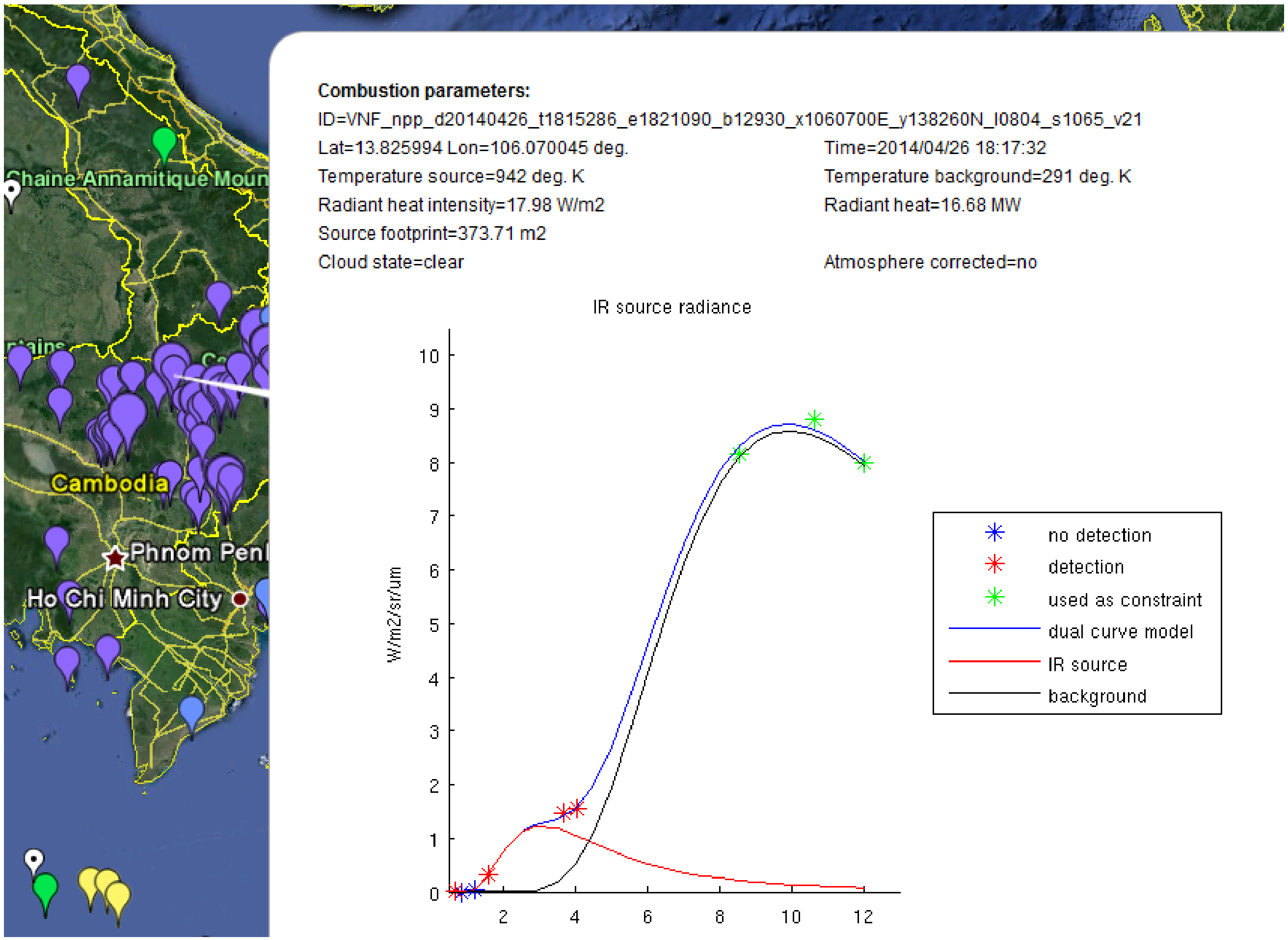
Source footprint=25.96 m2

Methane equivalent=0.356 m3/s
CO2 equivalent=651.983 g/s

Cloud state=clear
Atmosphere corrected=no

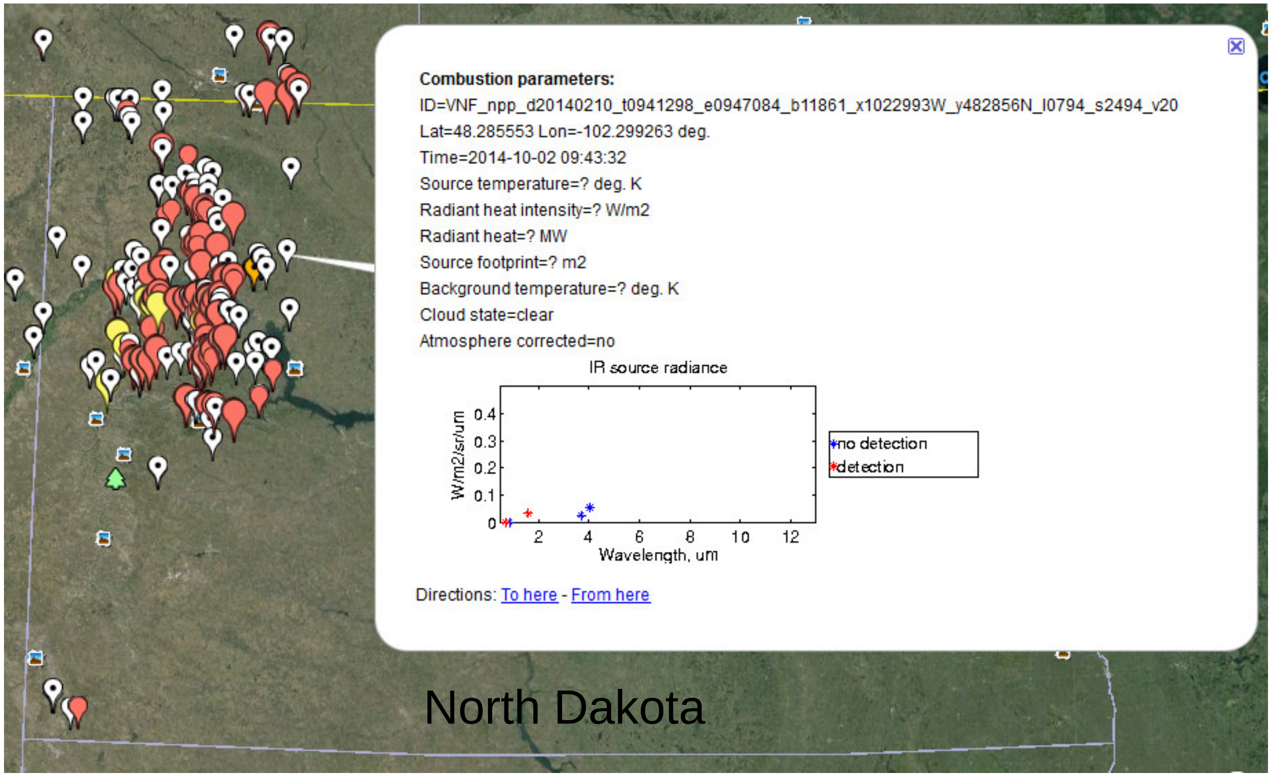


# Typical Biomass Burning Detection



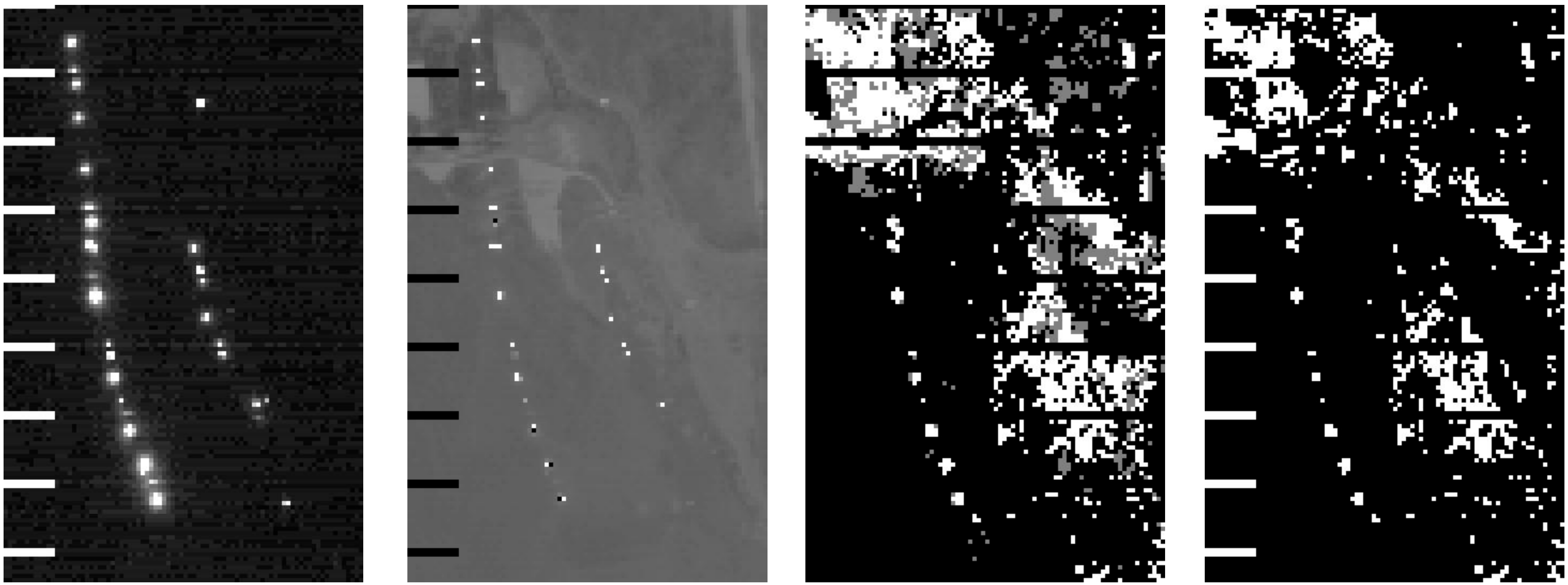

Lower temperature than gas flaring. Often these have larger source size than gas flares.

# Weak Detections




- Approximately 40% of all detections have M10 and DNB detection only.
- The Planck curve fitting fails.
- It is not possible to calculate temperature, radiative heat, and source footprint.

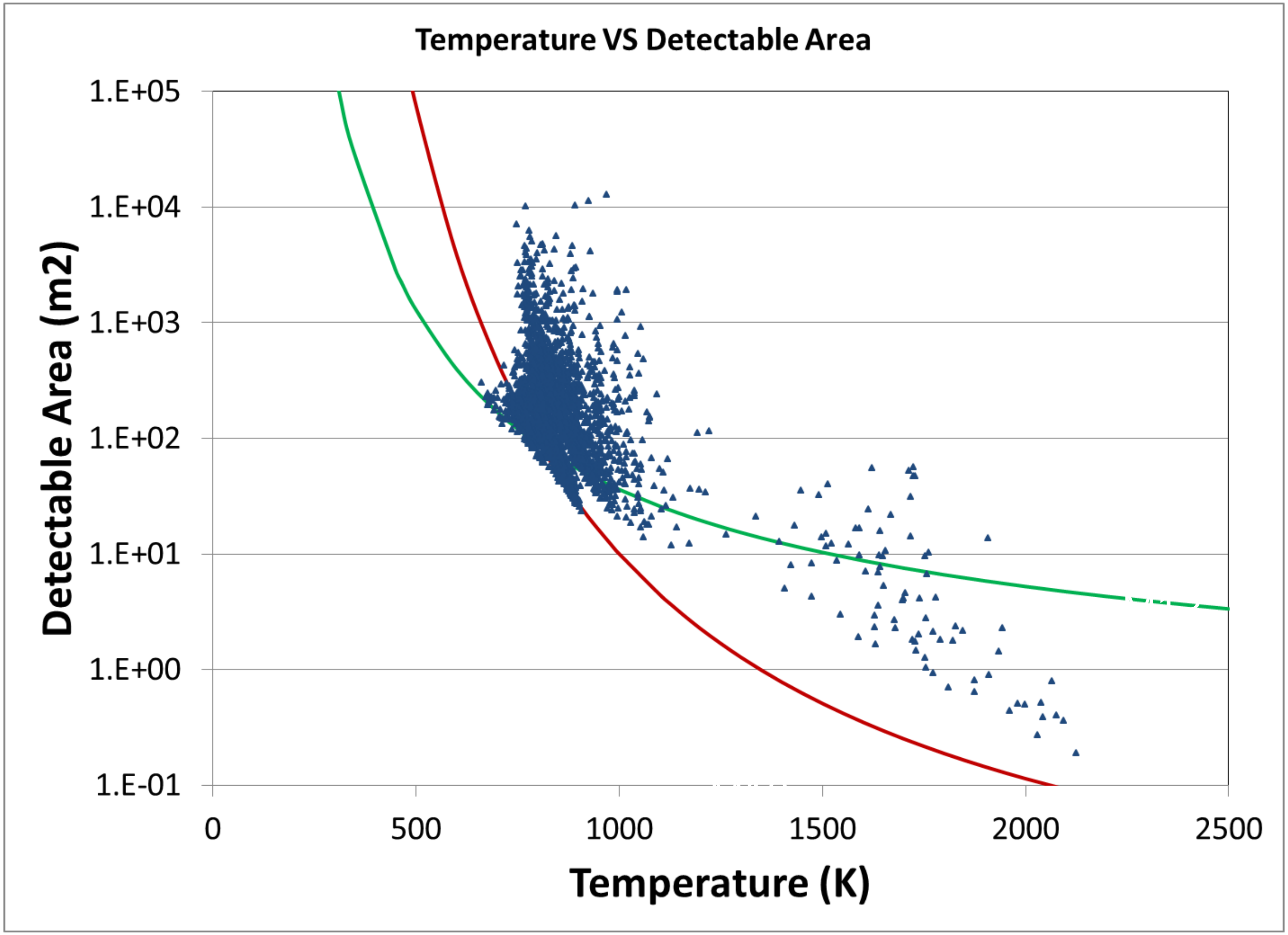
# VIIRS Cloud Mask Algorithm Identifies Flares as Cloud



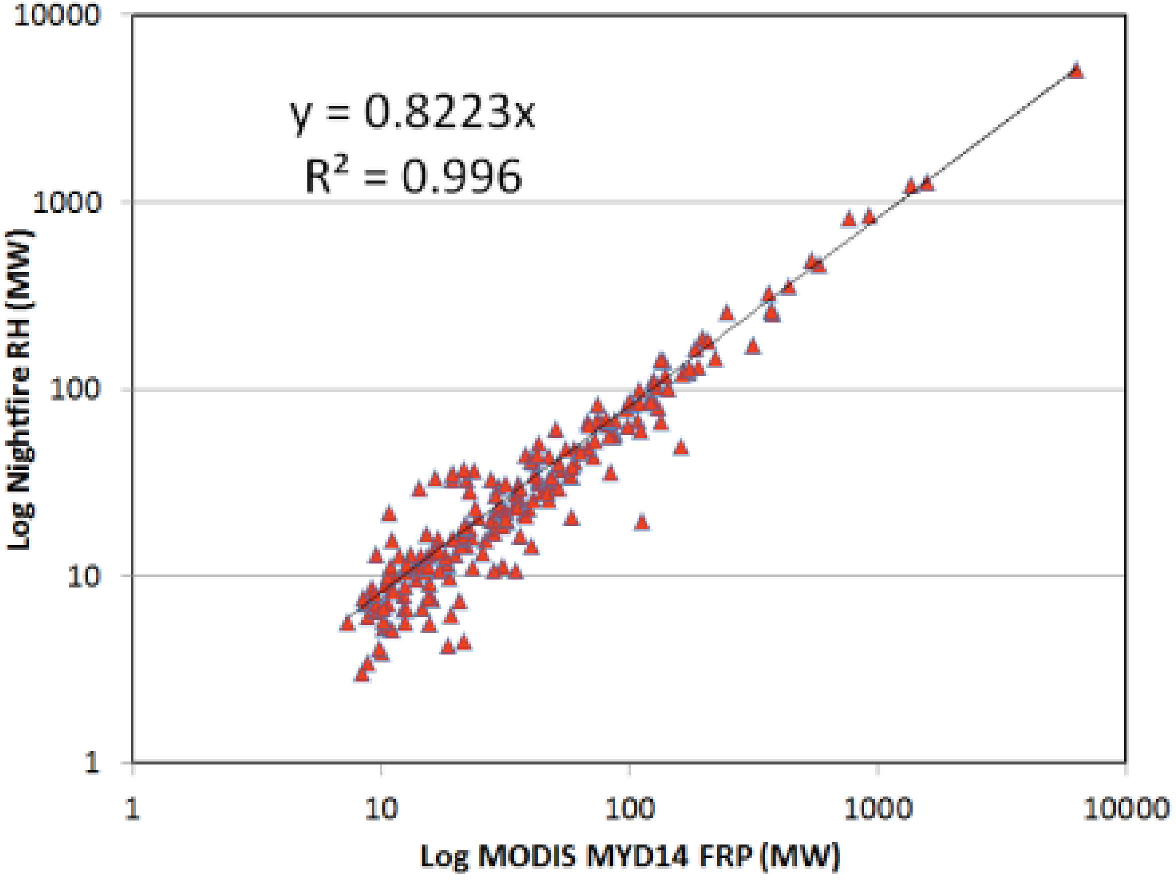
M10 Basra, Iraq | M13 | Cloud mask | Cloud optical thickness

There is likely spectral confusion between clouds and gas flares.

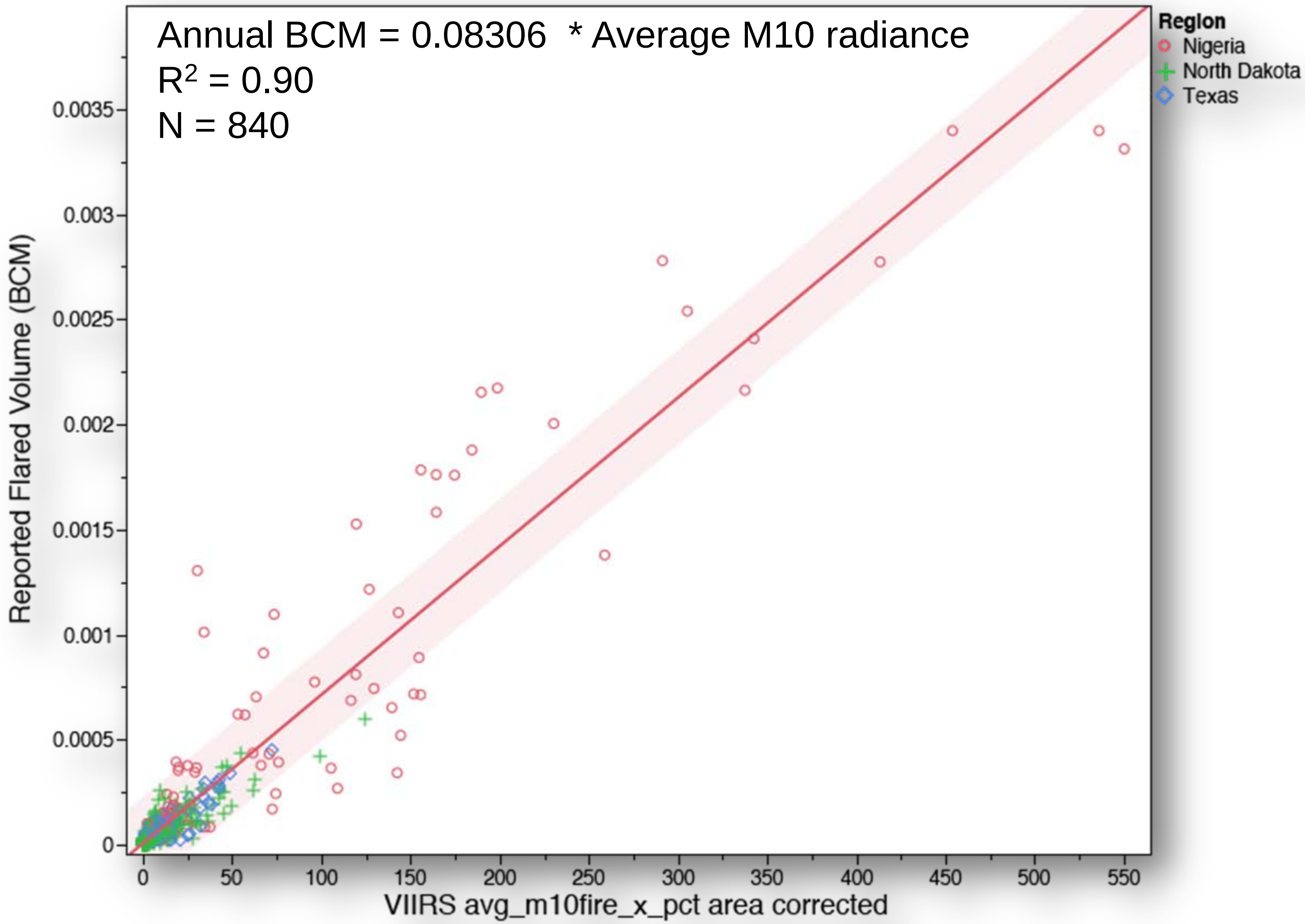
# Nightfire Detection Limits



# Comparison with MODIS



# Initial Flared Gas Volume Calibration Based on Monthly Reported Data



# JPSS Validation System

Robert Holz, Andy Heidinger Fred Nagle, Greg Quinn, Min Oo, and Ralph Kuehn

May 14th 2014

# Outline

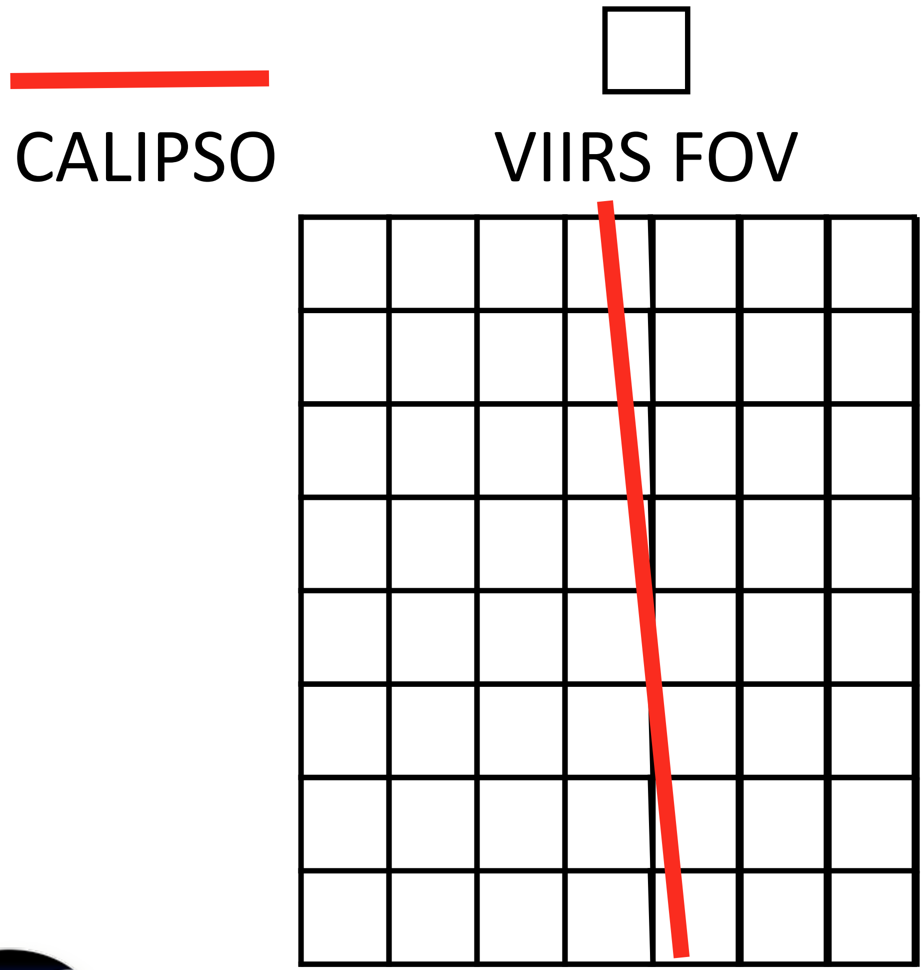
- An overview the processing and validation tools
- Products and data access (Atmospheric PEATE)
- Developing a near realtime monitoring system for cloud products

# Ingested Products at UW SSEC

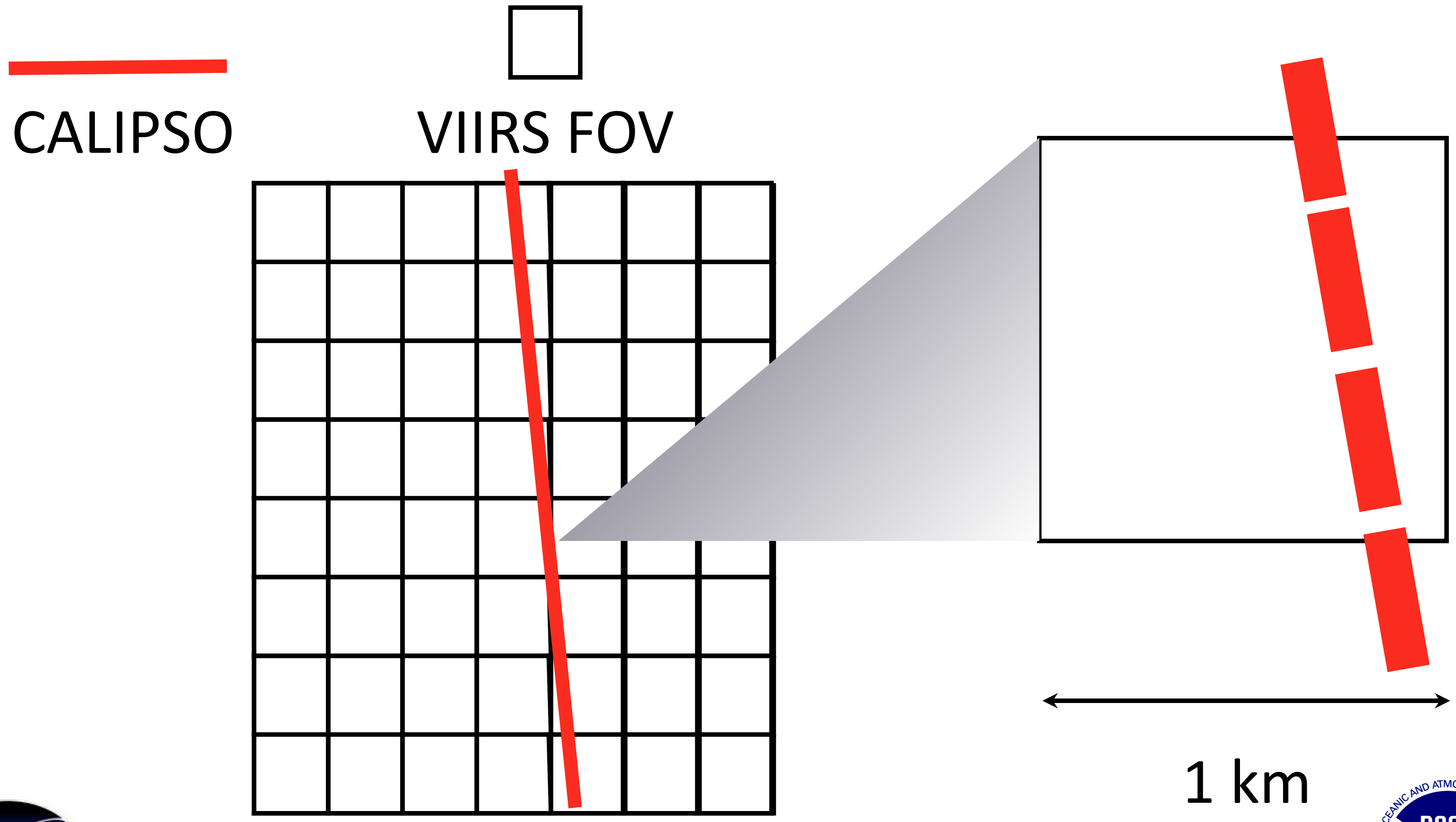
## Ingested Products

- VIIRS RDR, SDR, and EDR (Clouds and Aerosols)
- MODIS Terra and Aqua L1a, L1b, MYD04 (aerosol), MYD06 (Cloud)
- AVHRR L1B
- ATMS RDR and SDR
- CALIPSO V3 L1b, L2 products (aerosol), and IIR
- CloudSat L1 and L2 products
- CrIS SDR and EDR
- Metop-A (IASI) and Metop-B (IASI)

# Collocation and Evaluation



# Collocation and Evaluation



# Collocation and Evaluation

## PEATE multi-satellite sensors collocation

| Master \ Follower | AVHRR | CALIOP | CLOUDSAT | GOES | MODIS | POLDER | SEVIRI | VIIRS |
|---|---|---|---|---|---|---|---|---|
| AIRS | | ✷ | ✷ | ✷ | ✷ | | ✷ | |
| AMSR-E | | | | | ✷ | | | |
| CLOUDSAT | | ✷ | | | | | | ✷ |
| CrIS | | ✷ | | | | | ✷ | ✷ |
| COMS | | ✷ | | | ✷ | | | |
| GOES | | ✷ | | | ✷ | | | |
| HIRS | ✷ | ✷ | | | | | | |
| IASI | | | | | ✷ | | ✷ | |
| MODIS | | ✷ | | | | ✷ | | ✷ |
| SEVIRI | | ✷ | | | ✷ | | | ✷ |
| VIIRS | | ✷ | | | | | | |

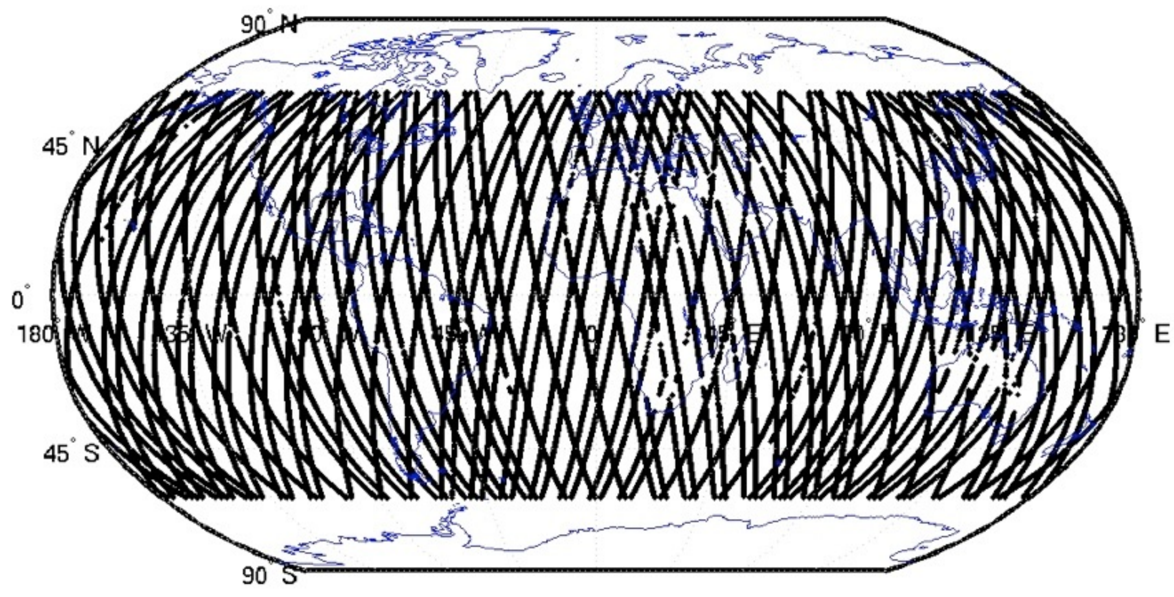
# The Flo Processing System

- Leverages UW Atmospheric PEATE processing system
- Supports forward stream and archival processing
- Geographical and multi-sensor processing via integrated orbital prediction
- An extensible catalog of scientific algorithms; algorithms specify sensor and ancillary input requirements; Flo chains algorithms together as needed to reach output products
- Provides the capability to processes the collocation and algorithms that require multiple instruments platforms (ie VIIRS and CrIS)

# Collocation and Evaluation

## Aqua/CALIPSO Intersections with NPP

May 1 - Aug 11 2012Observations within 20 min



# Collocation and Evaluation

## Match Files Generation

```
CALIPSO_Feature_Classification_Flag_Phase_Fraction_5km: [2704x3 double]
       CALIPSO_Feature_Classification_Flag_Phase_QA_5km: [2704x1 double]
                    CALIPSO_IR_Derived_Cloud_Height_5km: [2704x1 double]
                      Column_Optical_Depth_Aerosols_532: [2704x1 double]
          Column_Optical_Depth_Aerosols_Uncertainty_532: [2704x1 double]
                                       CALIPSO_Pressure: [33x2704 double]
                                  Master_Vertical_Index: [2704x1 double]
                                Master_Horizontal_Index: [2704x1 double]
                                            Slave_Index: [2704x3 double]
                                         Parallax_Table: [677x32 double]
                                    CALIOP_GDAS_Pressure: [2704x33 double]
                                    CALIOP_GDAS_Altitude: [33x1 double]
                   IFF_L1b_BrightnessTemperatureBandCenters: [11x1 double]
                         IFF_L1b_BrightnessTemperatureBands: [2704x11 double]
                                IFF_L1b_EmissiveBandCenters: [11x1 double]
                                      IFF_L1b_EmissiveBands: [2704x11 double]
                                        IFF_L1b_LandSeaMask: [2704x1 double]
                                           IFF_L1b_Latitude: [2704x1 double]
                                          IFF_L1b_Longitude: [2704x1 double]
                              IFF_L1b_ReflectiveBandCenters: [11x1 double]
                               IFF_L1b_ReflectiveSolarBands: [2704x11 double]
                                         IFF_CLX_Cloud_Mask: [2704x1 double]
                                       IFF_CLX_surface_type: [2704x1 double]
                                        IFF_CLX_cloud_phase: [2704x1 double]
                                     IFF_CLX_cld_press_acha: [2704x1 double]
                                      IFF_CLX_cld_temp_acha: [2704x1 double]
                                    IFF_CLX_cld_height_acha: [2704x1 double]
                                IFF_CLX_cld_height_top_acha: [2704x1 double]
                               IFF_CLX_cld_height_base_acha: [2704x1 double]
```

# Collocation and Evaluation

## Current available multi-satellite sensors

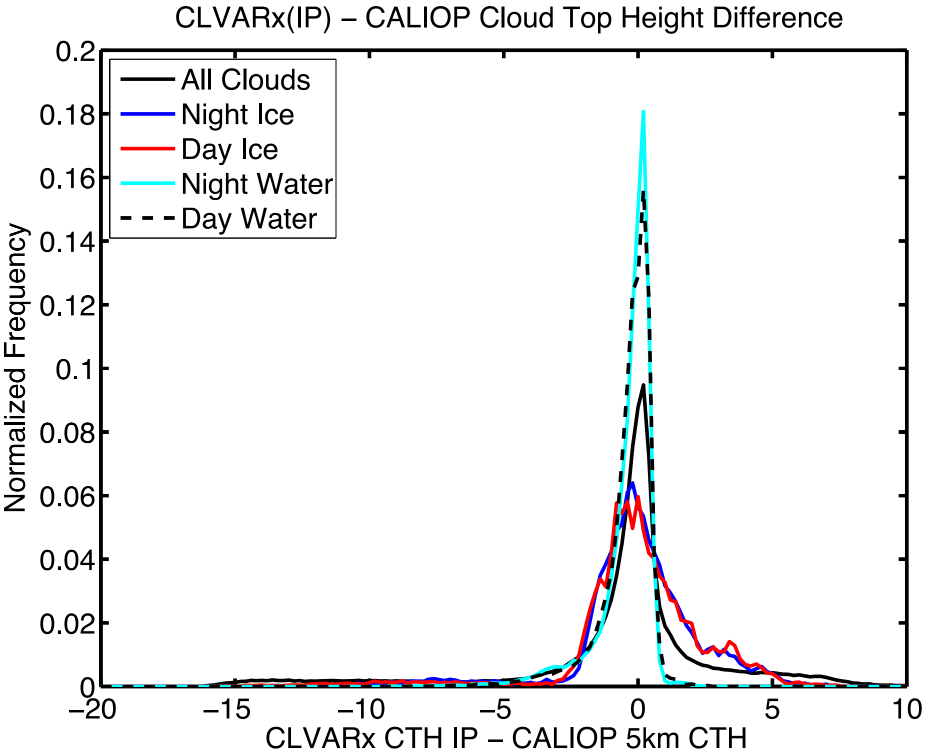
| | Geo-stationary satellites sensors | | Polar-orbiting satellites sensors | | |
|---|---|---|---|---|---|
| | *SEVIRI* | *COMS* | *VIIRS* | *CALIOP* | *MODIS (Aqua)* |
| ***MODIS (Aqua)*** | ✔ (Aerosol) ✔ (Cloud) | ✔ (Aerosol) ✔ (Cloud) | ✔ (Aerosol) ✔ (Cloud) | ✔ (Aerosol) ✔ (Cloud) | |
| ***VIIRS*** | | | | ✔ (Cloud) | ✔ (Aerosol) ✔ (Cloud) |
| ***CALIOP*** | ✔ (Cloud) | ✔ (Aerosol) ✔ (Cloud) | ✔ (Cloud) | | ✔ (Aerosol) ✔ (Cloud) |

✔ Aerosol Products

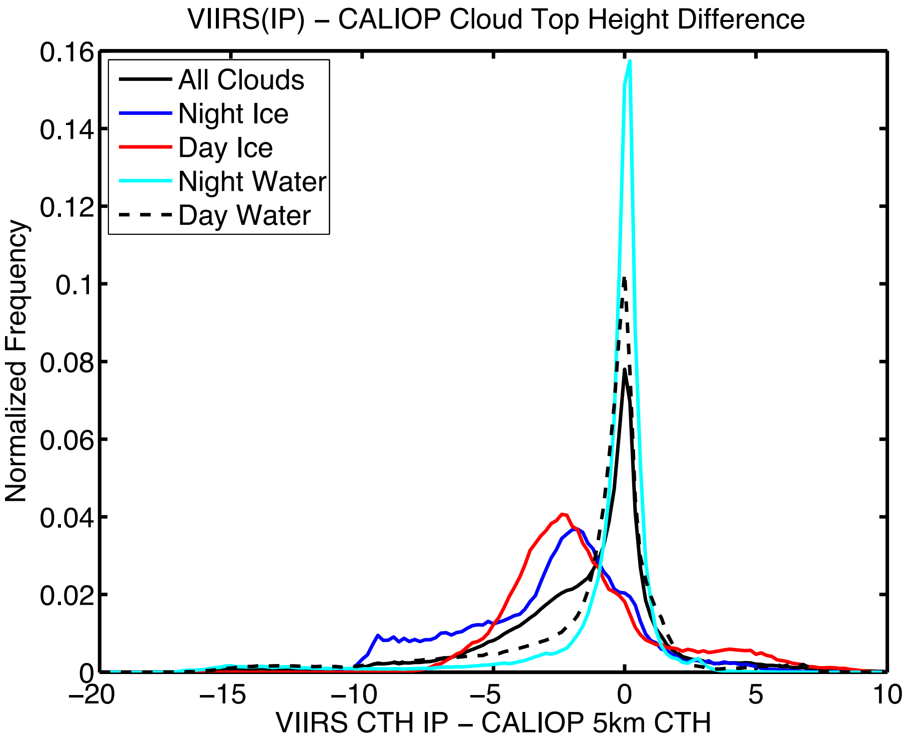
✔ Cloud Products

# Cloud Height Validation

## NDE Applied to VIIRS



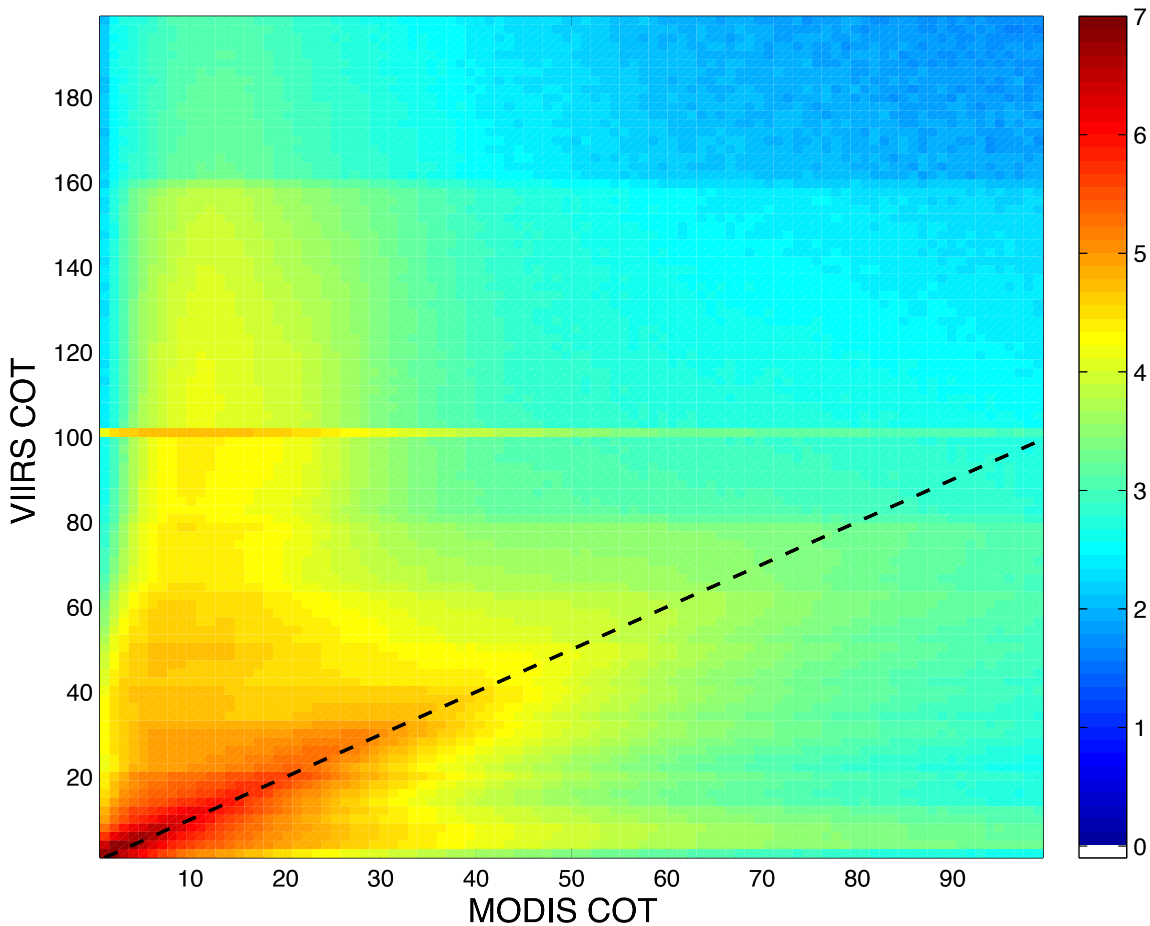

## IDPS IP




| | COT < 1.0 | COT >1.0 |
|---|---|---|
| **Accuracy (mean km) % in spec** | 12 % | 63 % |
| **Precision (STD) (km) % in spec** | 43 % | 49 % |

- 3 Months of data
- IDPS has significant low bias

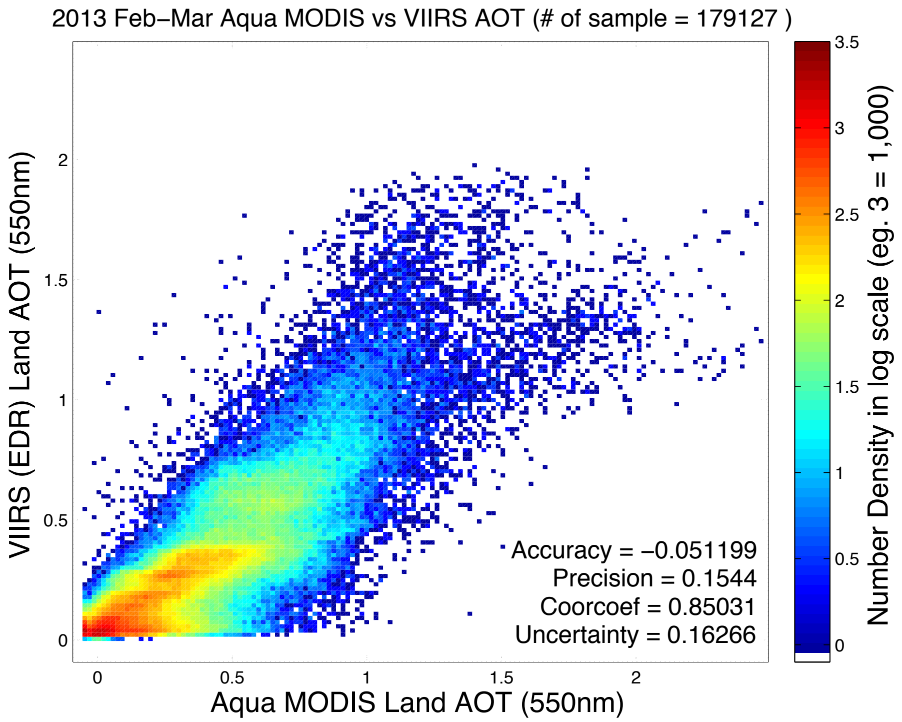
# Cloud Cloud Optical Thickness



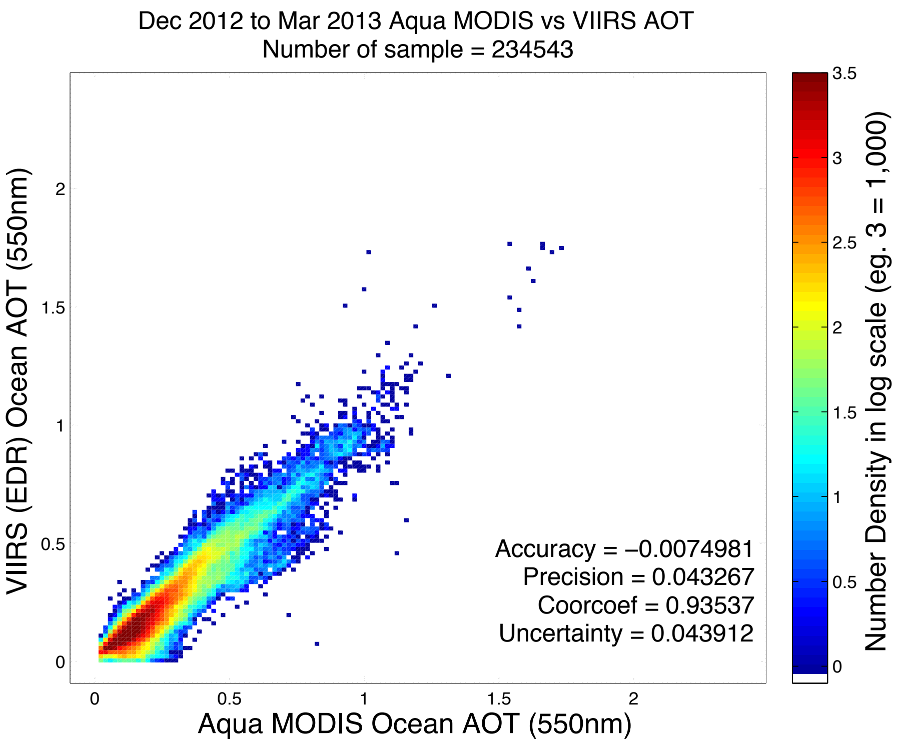

- Number of sample= 234 mills
- Both Ice and water cloud
- Color bar shows number density in log scale ( example: 3 =1,000)

# Aerosol AOD Validation Against MODIS

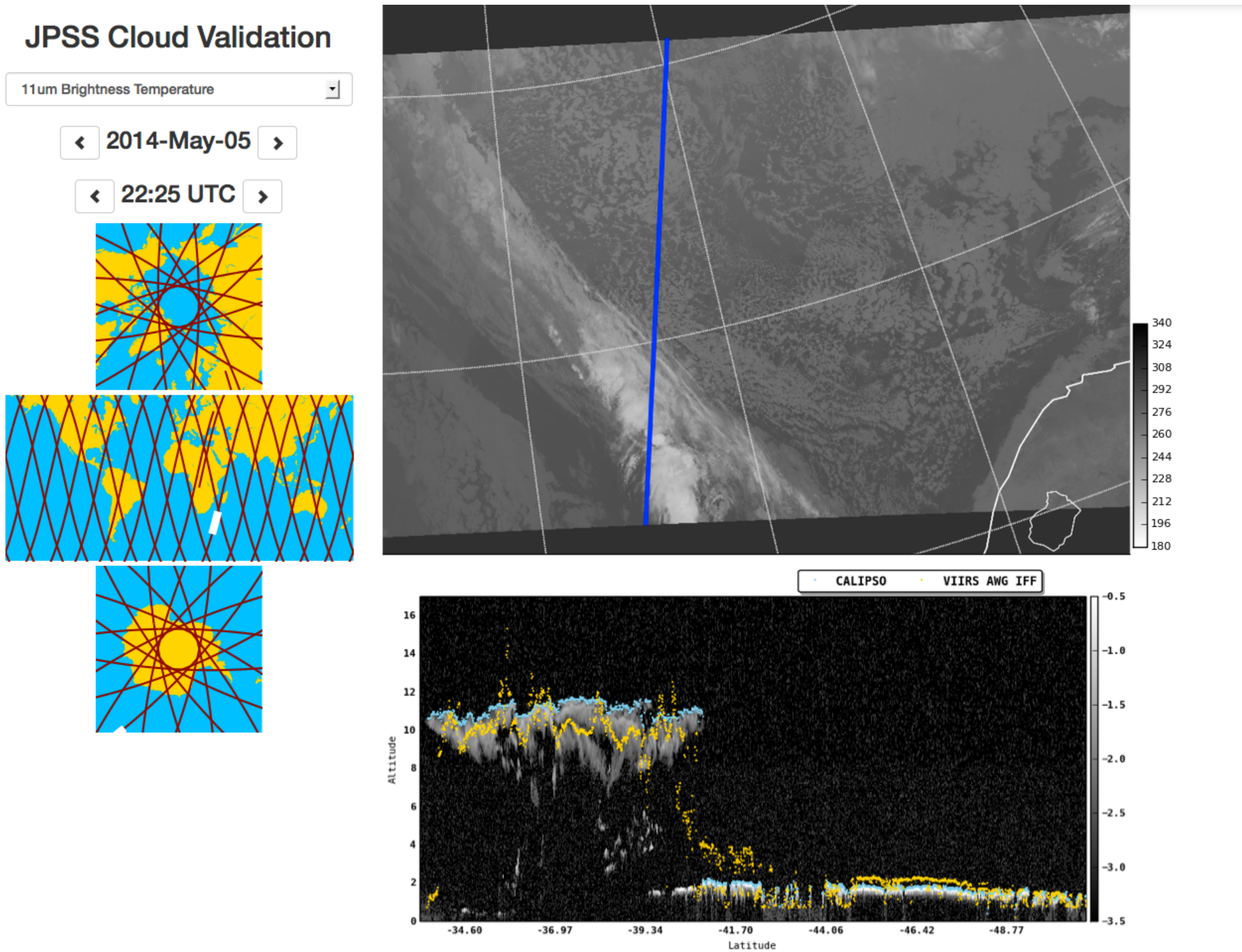
## IDPS EDR Land



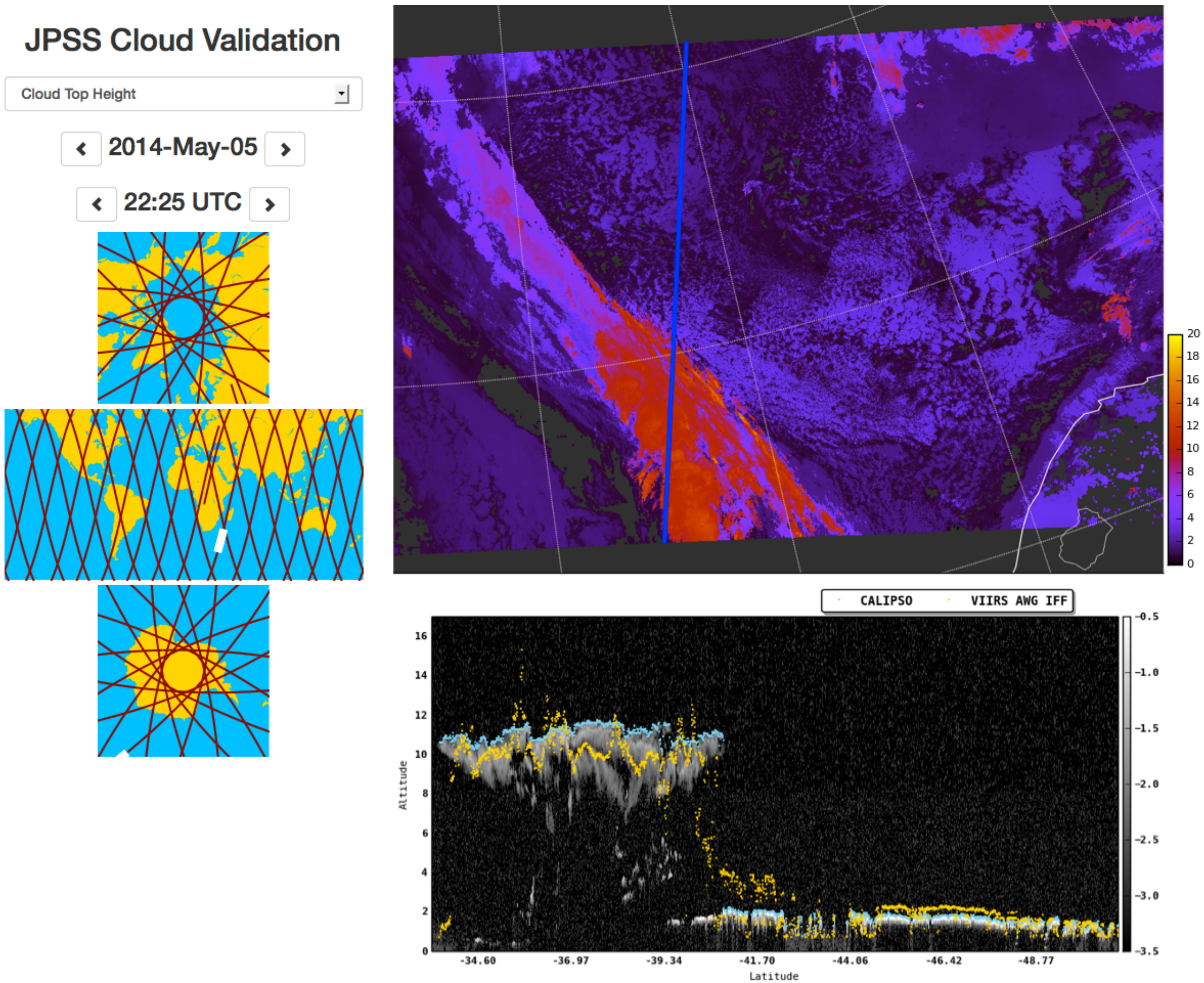

## IDPS EDR Ocean



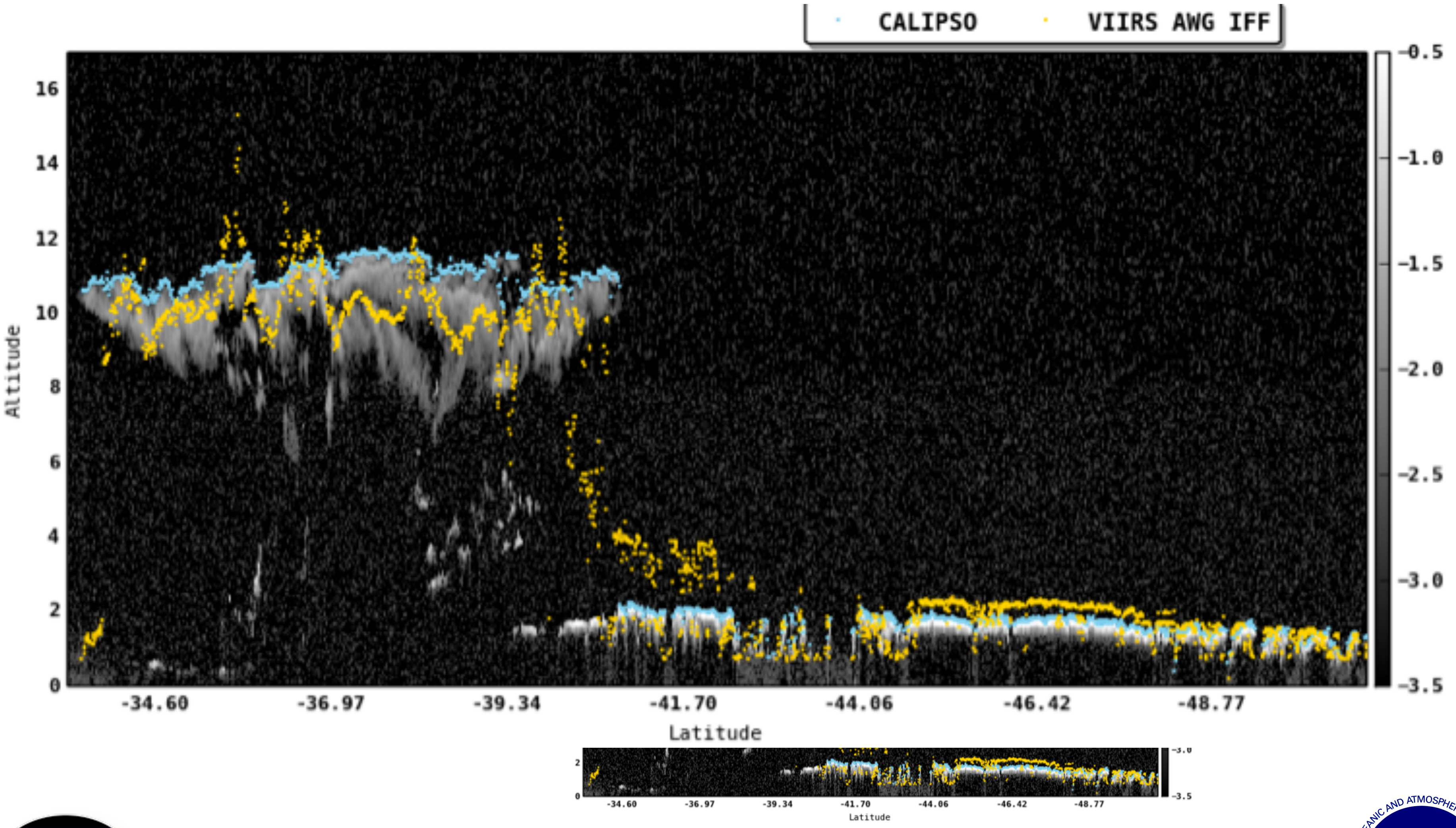
# JPSS Cloud Validation Interface



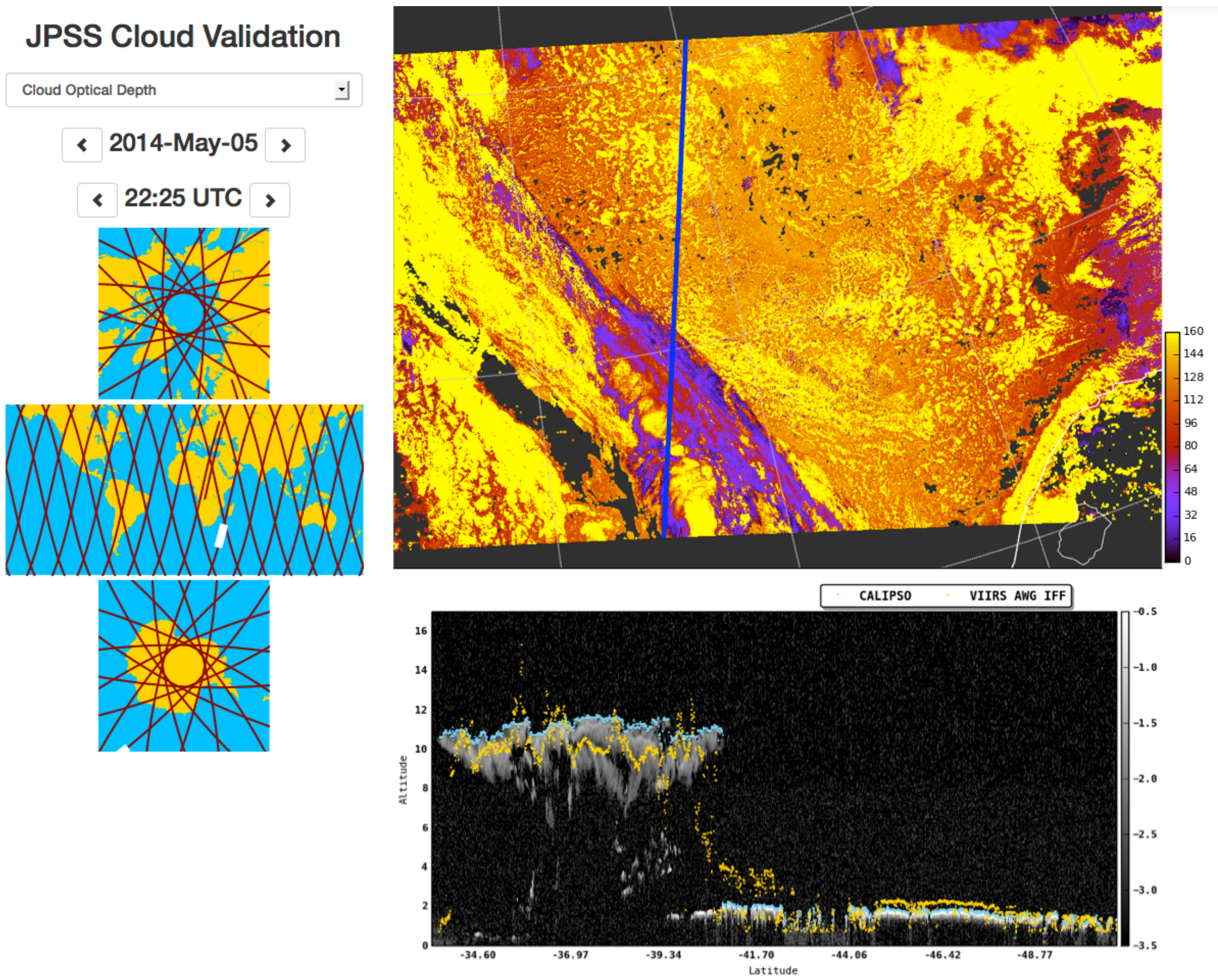
# JPSS Cloud Validation Interface



# JPSS Cloud Validation Interface



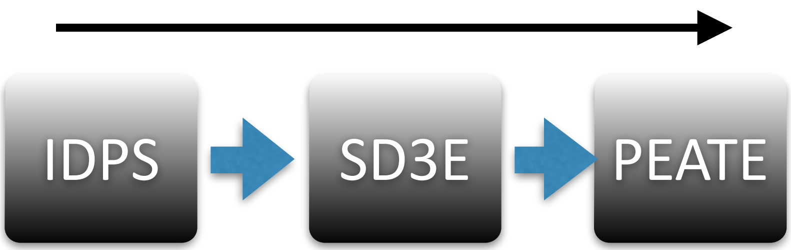
# JPSS Cloud Validation Interface



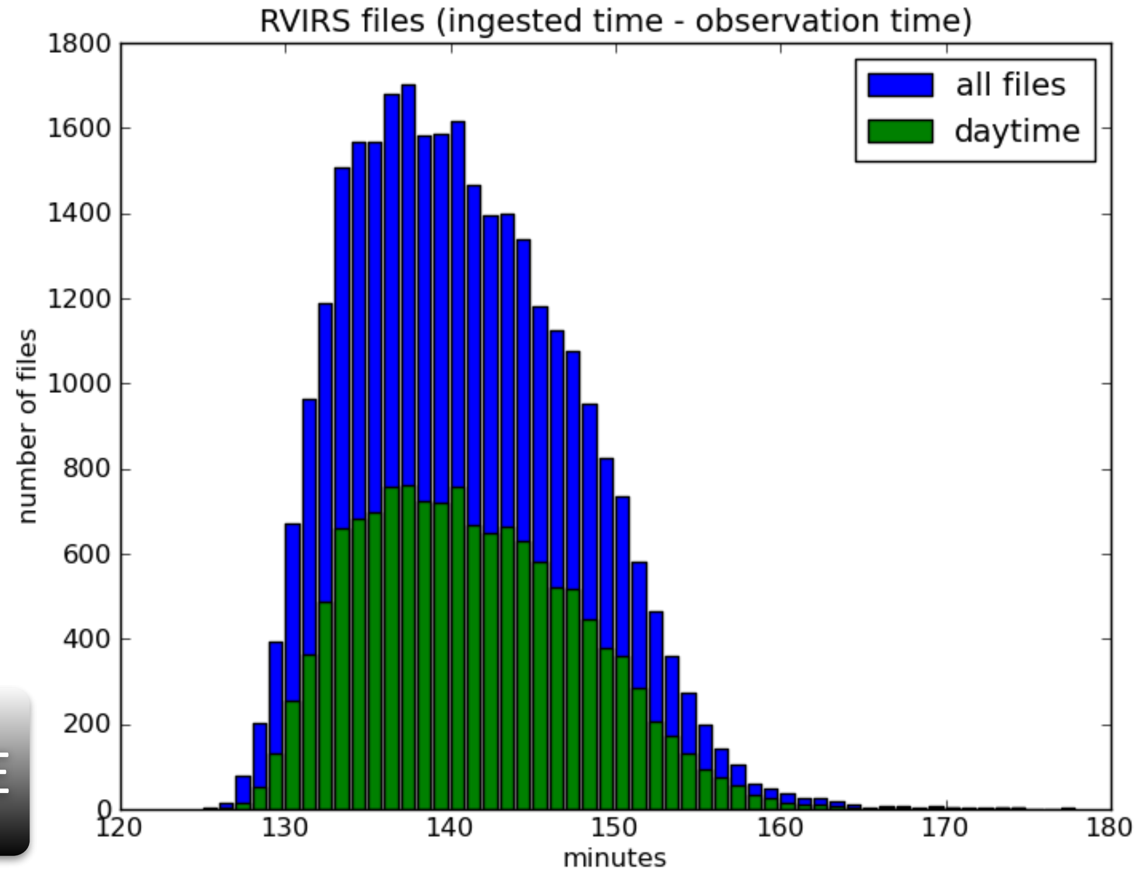
# Near Real Time Processing

- 97% of VIIRS RDR files are created at 118 minutes after observation
- PEATE could ingest VIIRS RDR files within 5 minutes after creation on the IDPS
- Process RDR - IP or EDR within 10 min after being ingested

VIIRS RDR 130 minutes (min)



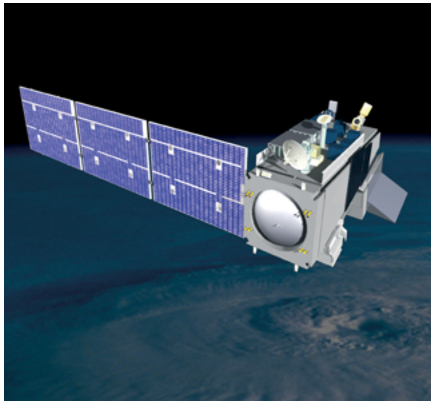

VIIRS RDR Latency Between IDPS and PEATE

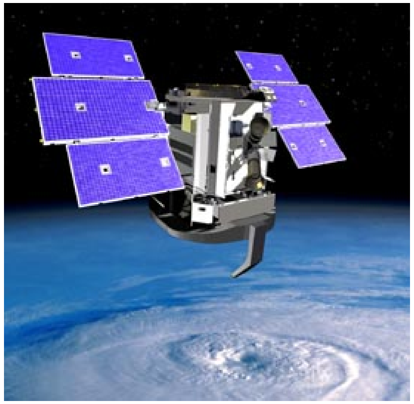


# Take away messages

- UW SSEC is actively supporting the JPSS cloud and aerosol validation
- Leveraging our processing and collocation expertise has allowed long term inter-comparisons of the JPSS products to active (CALIOP) and passive (MODIS) observations
- We are currently developing a near realtime validation interface which will provide monitoring the of the JPSS products
- The system will also have the capability to reprocess selected products (NDE Clouds and ADL Aerosols) for evaluating algorithm changes

# Evaluation of the VIIRS Cloud Base Height (CBH) EDR Using CloudSat





Curtis J. Seaman, Yoo-Jeong Noh, Steven D. Miller

Colorado State University/CIRA

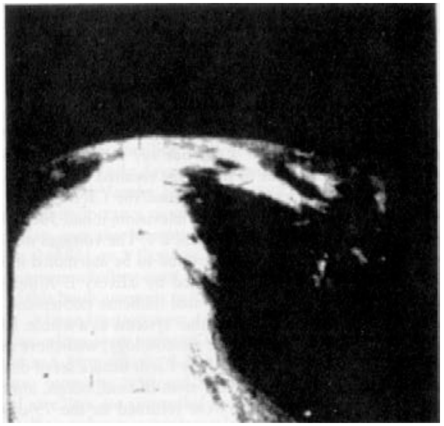
Daniel T. Lindsey, Andrew K. Heidinger

NOAA/NESDIS/Satellite Applications and Research

1st STAR JPSS Annual Science Team Meeting, College Park, MD, May 2014

# Introduction

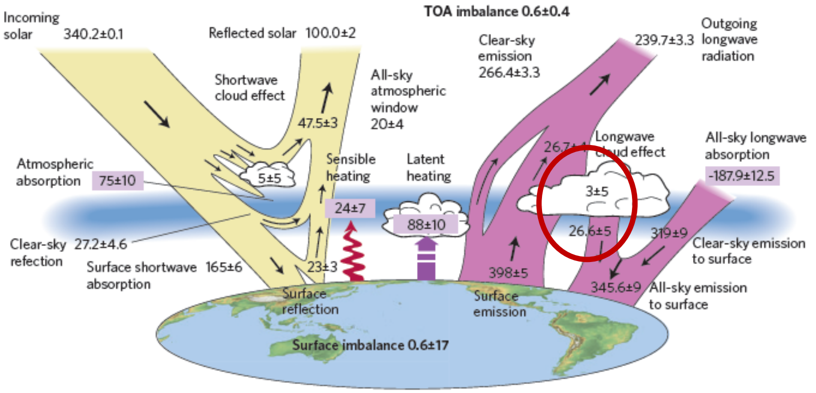
- Satellites have been viewing the tops of clouds for 50+ years
- Hutchison (2002) developed algorithm to determine cloud base height (CBH) from VIS/IR observations from MODIS
- VIIRS (CBH) EDR is the first operational algorithm to determine cloud base height
- CBH is important for aviation
- CBH is also important for closure of the Earth's Radiation Budget



TIROS-1 (1960) [Rao *et al*. (1990)]

VIIRS "Blue Marble" [NASA 2012]

Airport ceilometer [DWD]




[Stephens *et al*. (2012)]

# Cloud Base Height Algorithm

The cloud base height for liquid clouds is defined at right. Cloud base height definition for ice clouds is similar, except the average ice water content is temperature dependent.

CBH requires upstream retrievals of cloud top height (CTH), cloud optical depth ($\tau$), effective particle size ($r_e$) and cloud type, which is used to determine the LWC value to use.

Errors in CBH are directly proportional to errors in each of these values. Issues in upstream retrievals directly impact CBH retrieval.

$\tau$, $r_e$, cloud type ⟷ IVPCP

$CTH$ ⟷ IVPTP

CBH algorithm for liquid clouds:

$$CBH = CTH - \left(\frac{LWP}{LWC}\right)$$

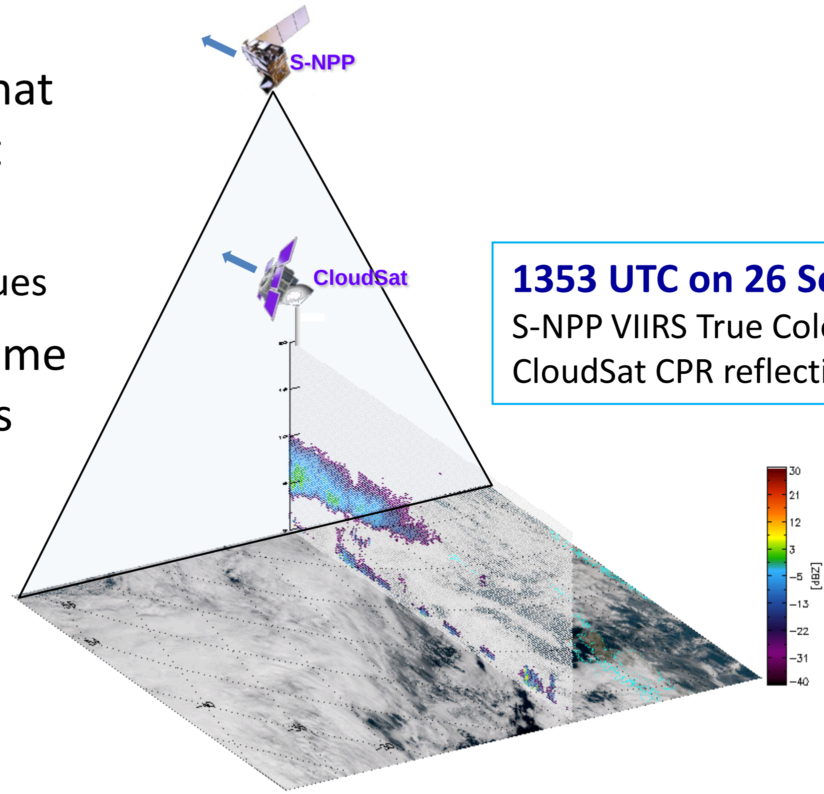
$$LWP = \frac{2\tau\rho r_e}{3}$$

Red variables come from upstream retrievals

LWC is pre-defined average value based on cloud type; cloud type comes from upstream retrieval

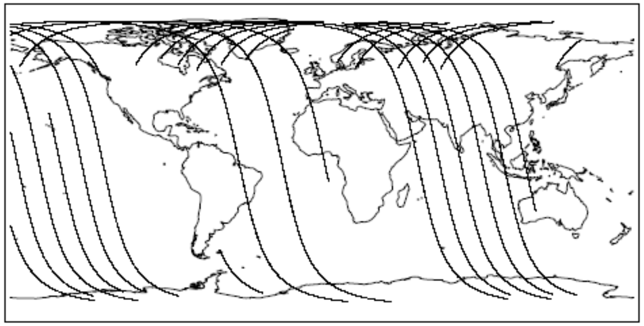
# Matching VIIRS with CloudSat

- CloudSat has a cloud-profiling radar that is well suited to observe CBH for most clouds
  - Ground clutter and precipitation are issues
- Suomi-NPP and CloudSat are in the same orbital plane, but at different altitudes
- CloudSat and VIIRS overlap for ~4.5 hours every 2-3 days
  - 8-9 “matchup periods” per month
- Due to battery issues, CloudSat only operates on the daytime side of the Earth
- Use only the closest non-fill VIIRS pixels that overlap CloudSat and have CBH and CTH above 1 km AGL
- Use only CloudSat profiles where precipitation is not present



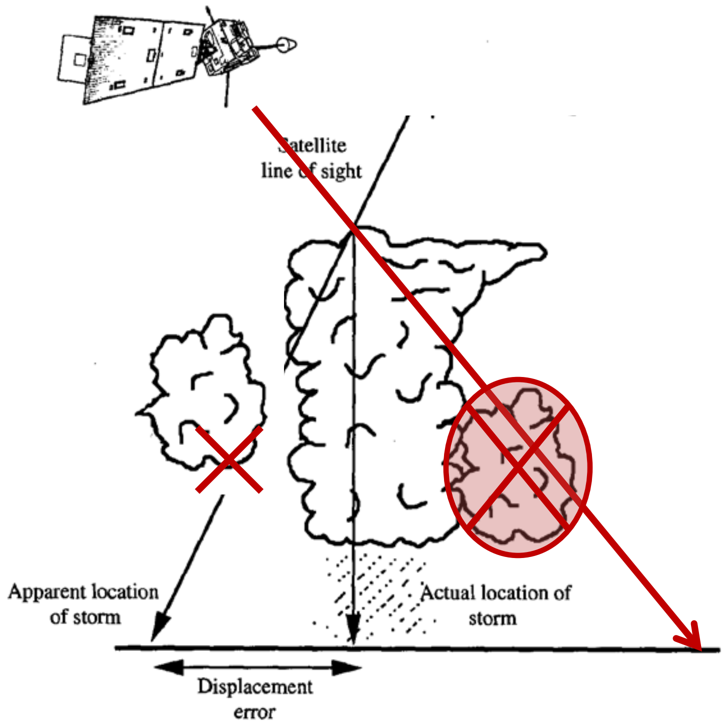

**1353 UTC on 26 Sept 2013**
S-NPP VIIRS True Color image
CloudSat CPR reflectivity

Match-up locations Sept. 2013

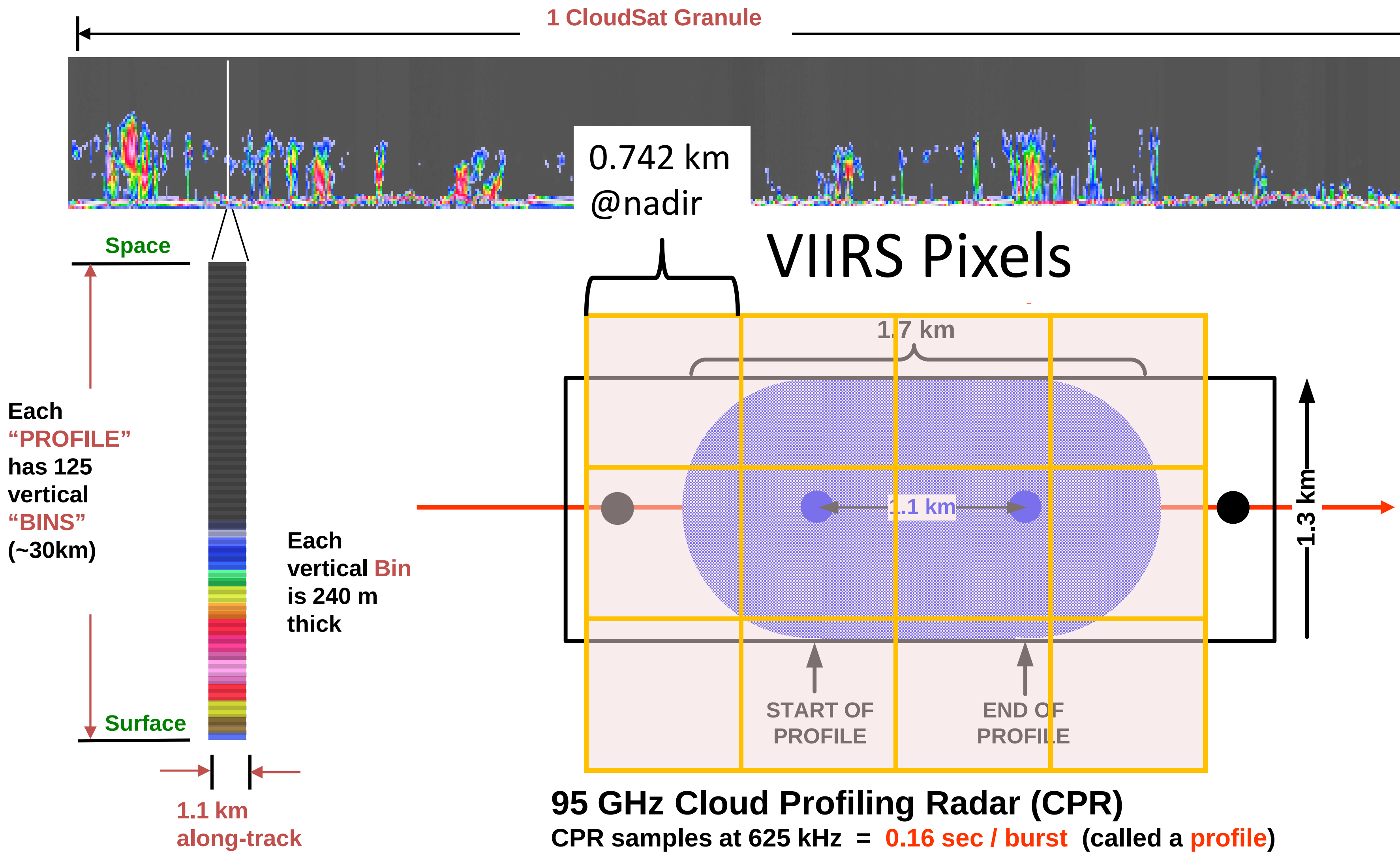


# What VIIRS Sees

- Intermediate Products (IP) have the same resolution as M-band SDRs
- Parallax-corrected cloud products (IVPTP, IVPCP) are required to properly account for line-of-sight issues
- Parallax means some clouds are missed
- VIIRS does not see through optically thick clouds
- Only the top of the top-most layer



# What CloudSat Sees



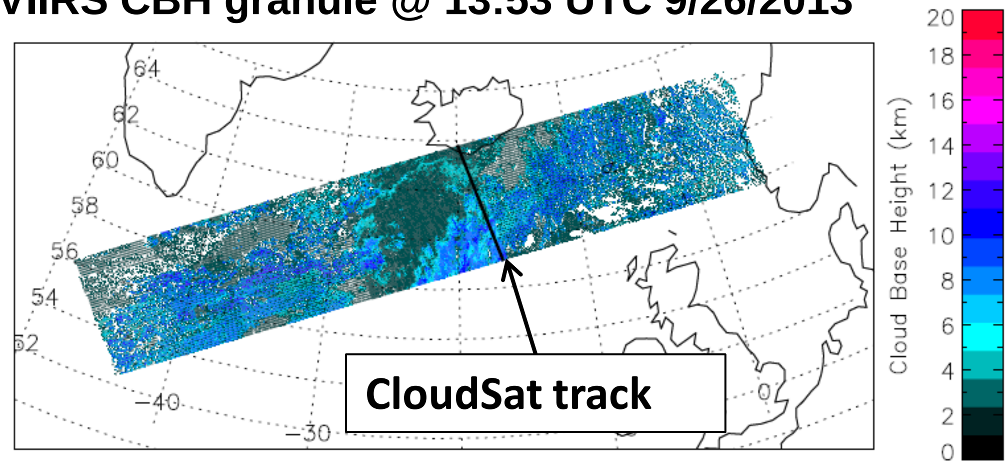

## 95 GHz Cloud Profiling Radar (CPR)

**CPR samples at 625 kHz = 0.16 sec / burst (called a profile)**
**PRF = 4300**
**(4300 pulses / sec) * (0.16 sec/burst) = 688 pulses/profile**

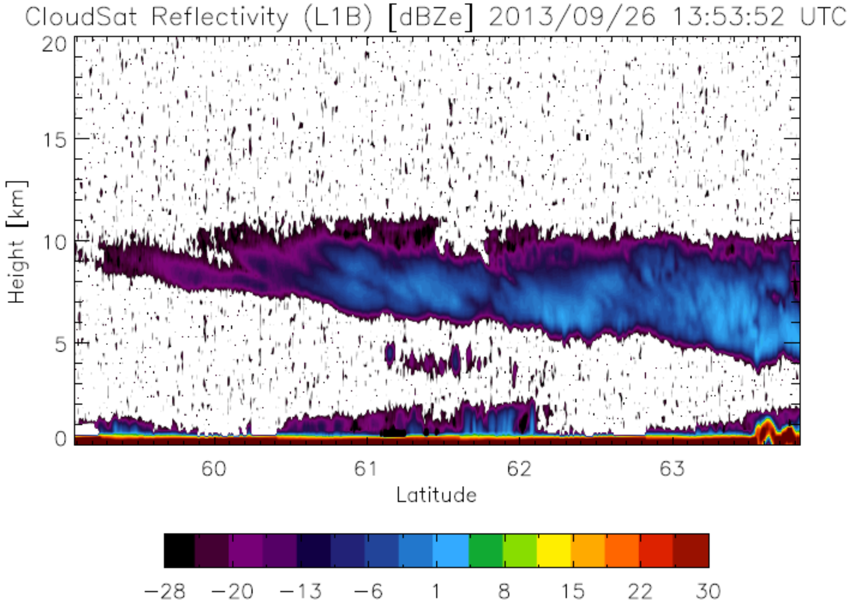
Figures courtesy D. L. Reinke, CIRA

# Matchup Example

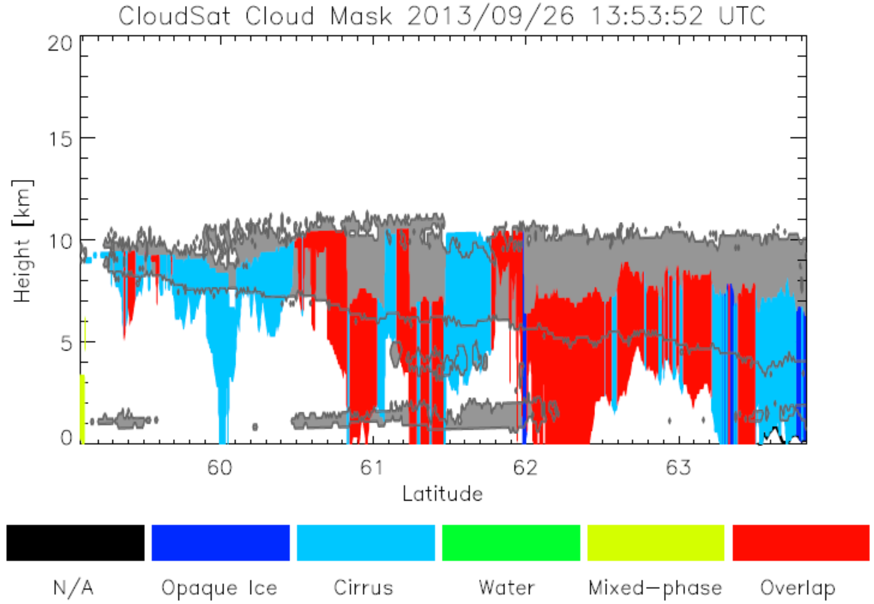
### VIIRS CBH granule @ 13:53 UTC 9/26/2013



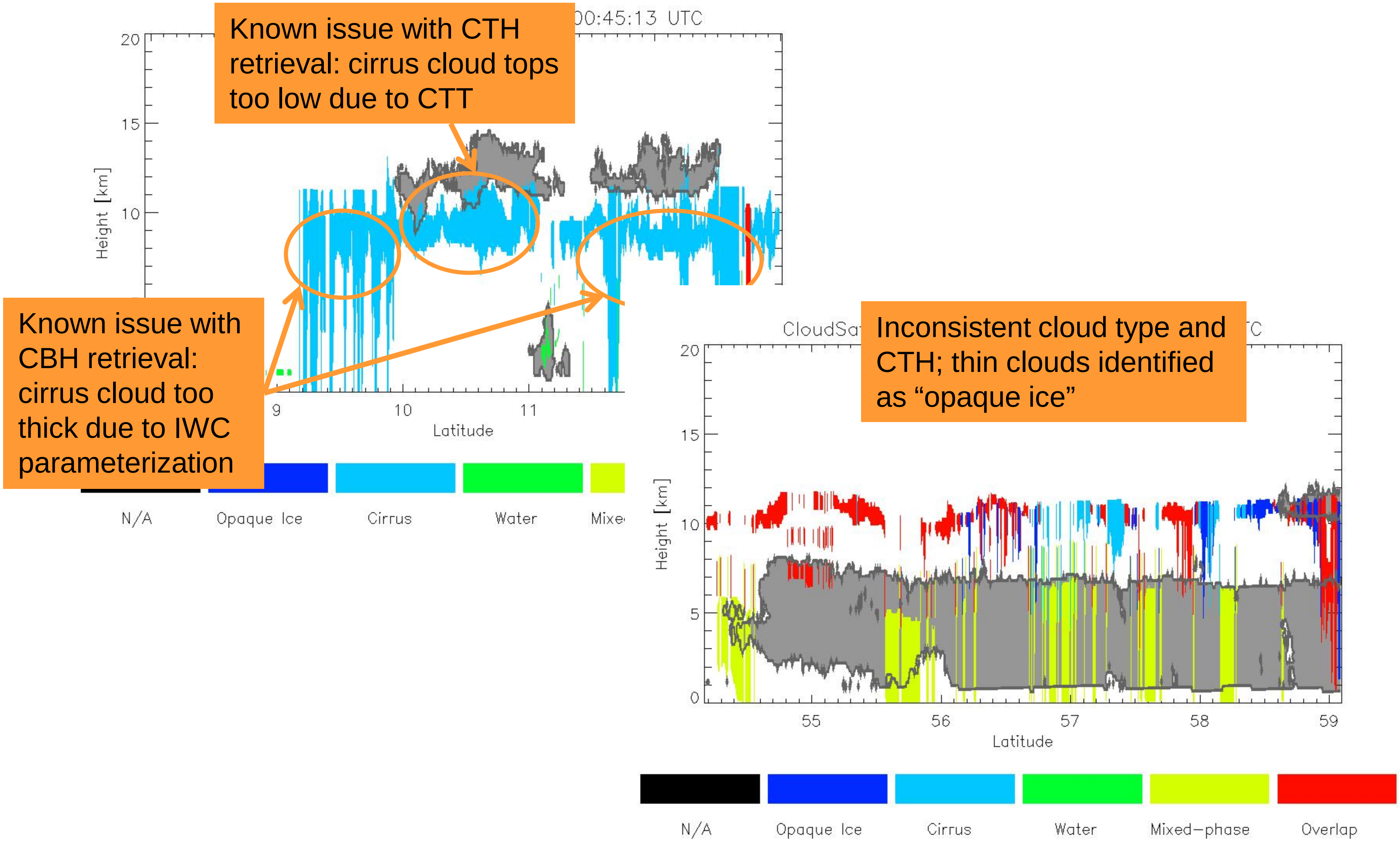

### CloudSat 2B-GEOPROF reflectivity




### CloudSat Cloud Mask with VIIRS overlayed



# Additional Examples



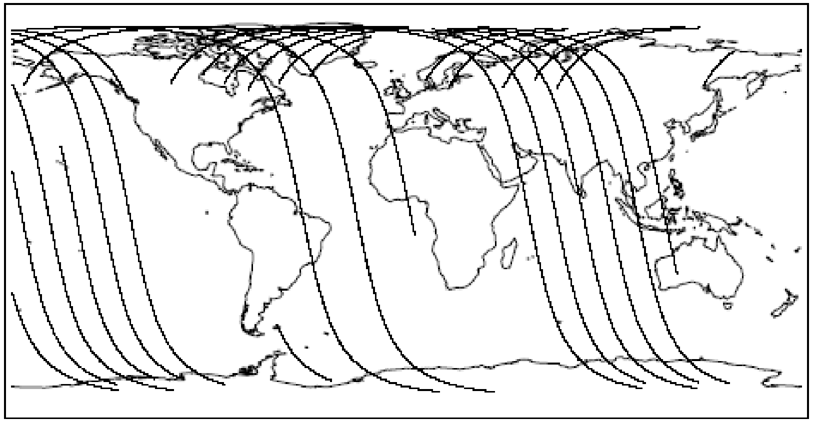

Gray shading represents vertical extent of clouds from CloudSat cloud mask. Colored areas represent vertical extent of clouds from VIIRS CTH and CBH retrievals, sorted by VIIRS cloud type.

# “All Clouds” vs. “Within Spec”

- The VIIRS CBH algorithm has been evaluated for two groups:
  - All clouds observed by CloudSat and VIIRS
  - Only those clouds where the VIIRS CTH retrieval is within the error specifications (aka “Within Spec”)
    - Error specifications: CTH must be within 1 km if the COT is greater than 1, or within 2 km if the COT is less than 1
- Thus, “**All Clouds**” results show the general performance of the CBH retrieval, “**Within Spec**” results show the performance of the CBH retrieval when the CTH retrieval is accurate
  - CBH accuracy is very closely related to CTH accuracy
  - CBH is within the error specifications if CBH error is less than 2 km

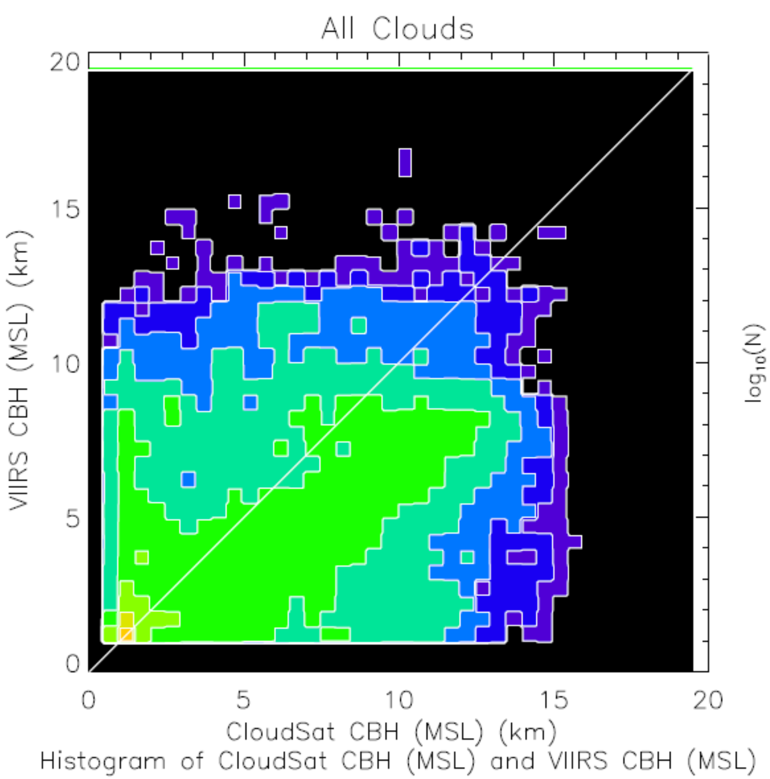
# From a Month of Matchups

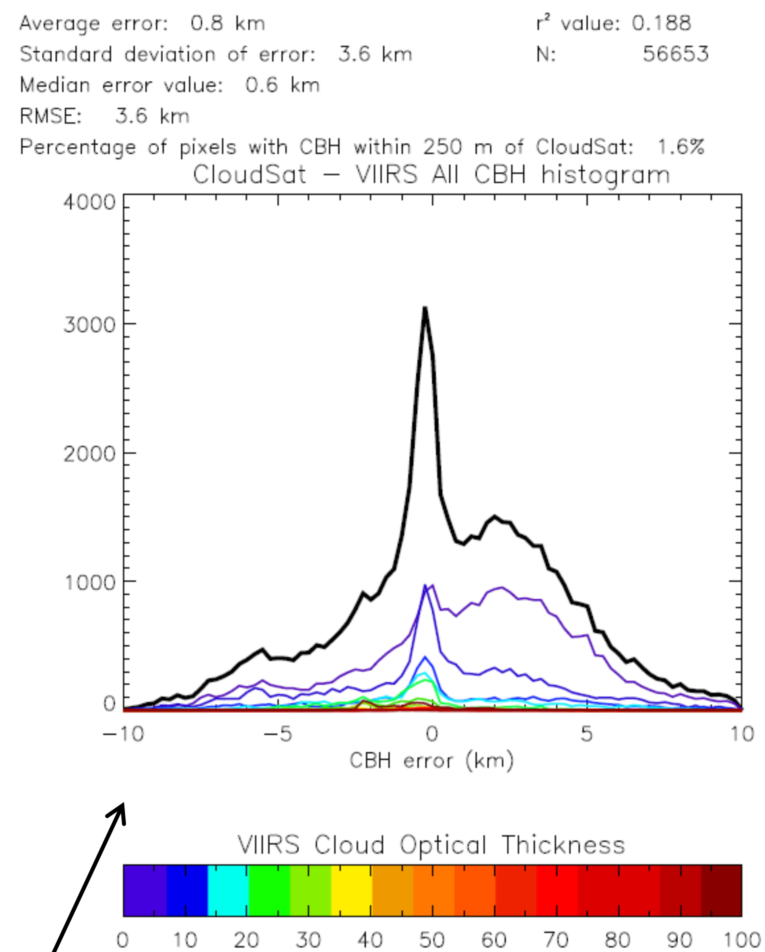
Match-up locations (Sept. 2013)



| | September 2013 |
|---|---|
| Matchup periods examined | 9 |
| Total matchup profile-pixel pairs | 363,499 |
| Valid matchup points | 56,655 |
| Percentage of valid points where CTH is “within spec” | 37.6% |
| Percentage of valid points where CBH error < 2 km | 44.6% |

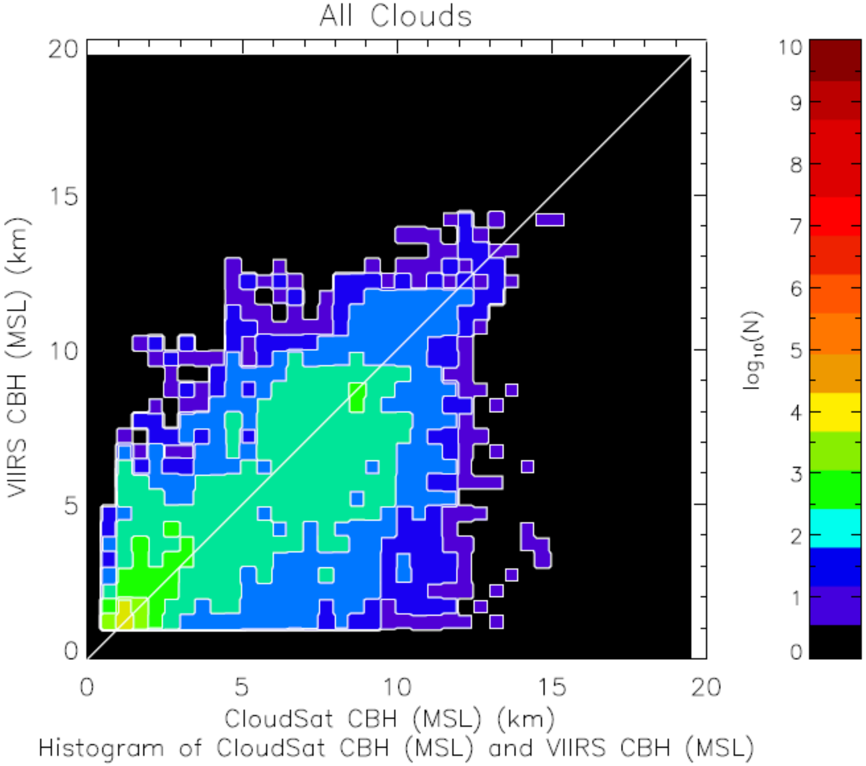
# All "Valid Matchups"

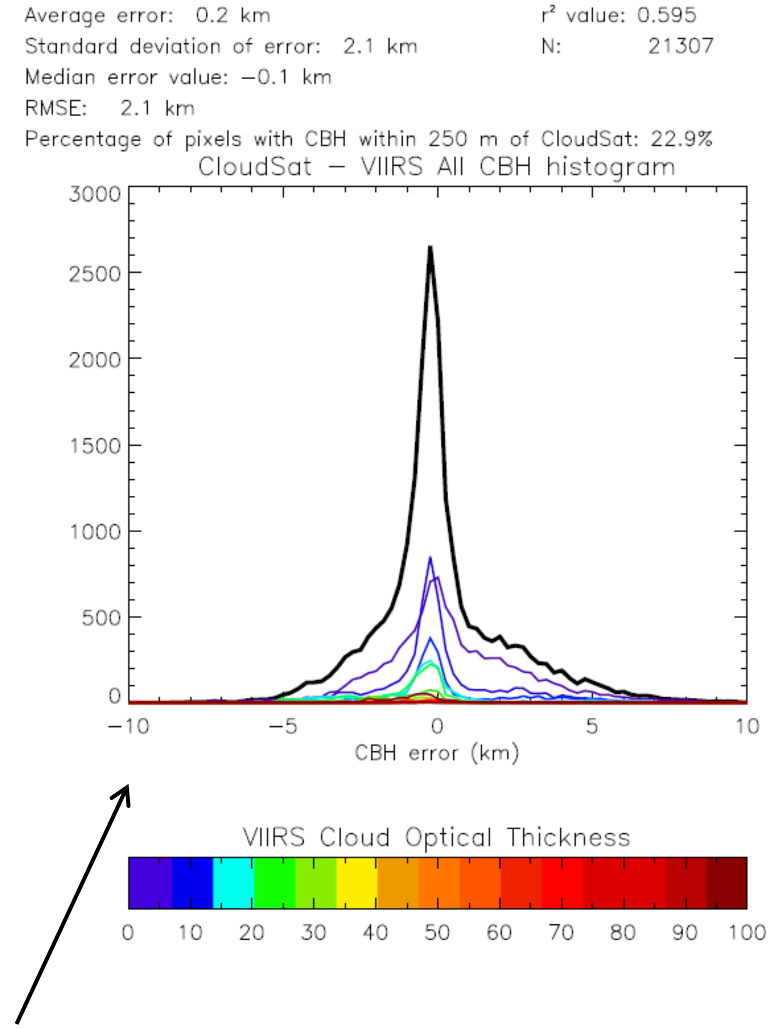



Negative errors indicate CloudSat CBH was lower than VIIRS CBH
(VIIRS biased high relative to CloudSat)

# "Within Spec" Matchups




Negative errors indicate CloudSat CBH was lower than VIIRS CBH
(VIIRS biased high relative to CloudSat)

# Cloud-type Statistics

**When the CTH retrieval is within the error specifications, the CBH retrieval performs better.**

CBH retrieval performs best on clouds classified as **liquid water**. The retrieval performs the worst for cirrus and overlap clouds.

## All valid matchups

| | All Clouds | Opaque Ice | Cirrus | Water | Mixed-phase | Overlap |
|---|---|---|---|---|---|---|
| Percentage of valid points (%) | 100 | 5.5 | 36.6 | 18.9 | 14.4 | 24.6 |
| Average Error (km) | 0.8 | -1.1 | 1.7 | 0.9 | -0.2 | 0.6 |
| Median Error (km) | 0.6 | -1.0 | 2.2 | 0.0 | -0.3 | 1.2 |
| Standard Deviation (km) | 3.6 | 3.4 | 3.5 | 2.9 | 2.5 | 4.2 |
| RMSE (km) | 3.6 | 3.6 | 3.9 | 3.0 | 2.5 | 4.3 |
| Percentage within 250 m (%) | 1.6 | 0.9 | 1.6 | 4.3 | 1.9 | 1.4 |
| R-squared correlation (-) | 0.188 | 0.030 | 0.093 | 0.124 | 0.066 | 0.000 |

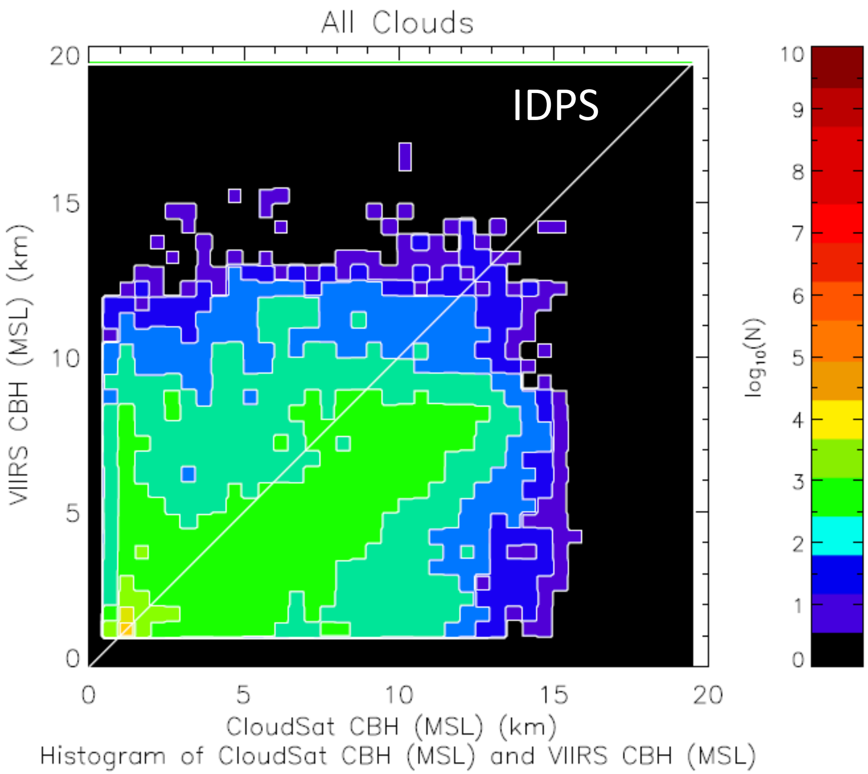
## Within Spec matchups

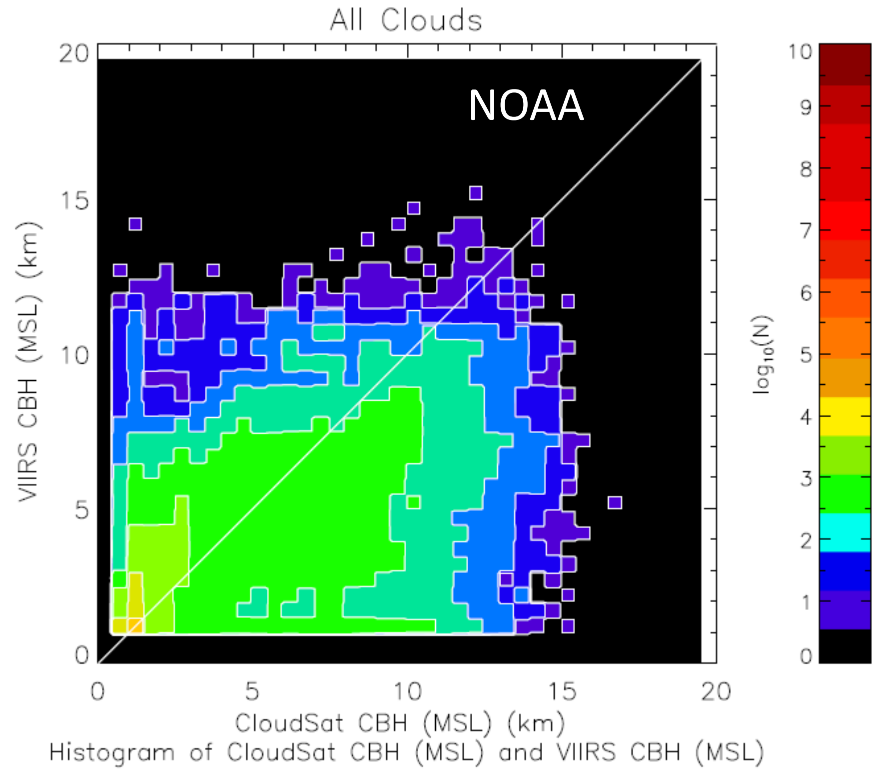
| | All Clouds | Opaque Ice | Cirrus | Water | Mixed-phase | Overlap |
|---|---|---|---|---|---|---|
| Percentage of valid points (%) | 100 | 4.2 | 28.6 | 31.1 | 19.3 | 16.6 |
| Average Error (km) | 0.2 | 0.5 | 1.0 | -0.2 | -0.7 | 0.8 |
| Median Error (km) | -0.1 | 0.2 | 0.9 | -0.2 | -0.4 | 0.5 |
| Standard Deviation (km) | 2.1 | 2.4 | 2.7 | 0.6 | 1.5 | 2.8 |
| RMSE (km) | 2.1 | 2.4 | 2.8 | 0.7 | 1.6 | 2.9 |
| Percentage within 250 m (%) | 22.9 | 10.9 | 7.3 | 44.4 | 26.5 | 8.1 |
| R-squared correlation (-) | 0.595 | 0.190 | 0.208 | 0.814 | 0.224 | 0.181 |

**Green values** indicate best performer

**Red values** indicate worst performer

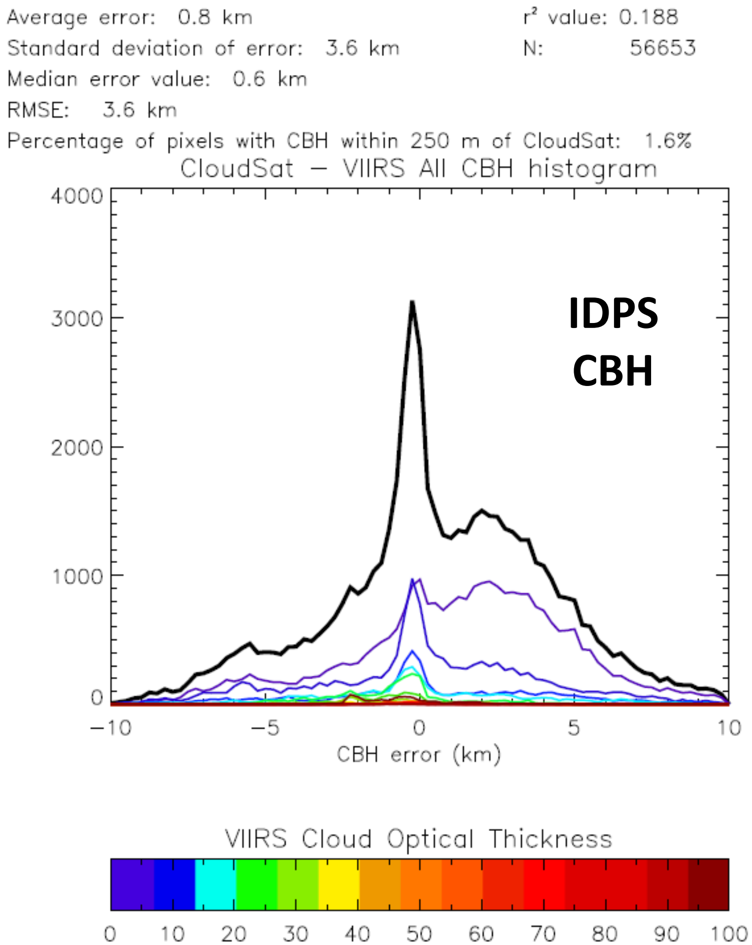
# Investigating a Switch of Algorithms

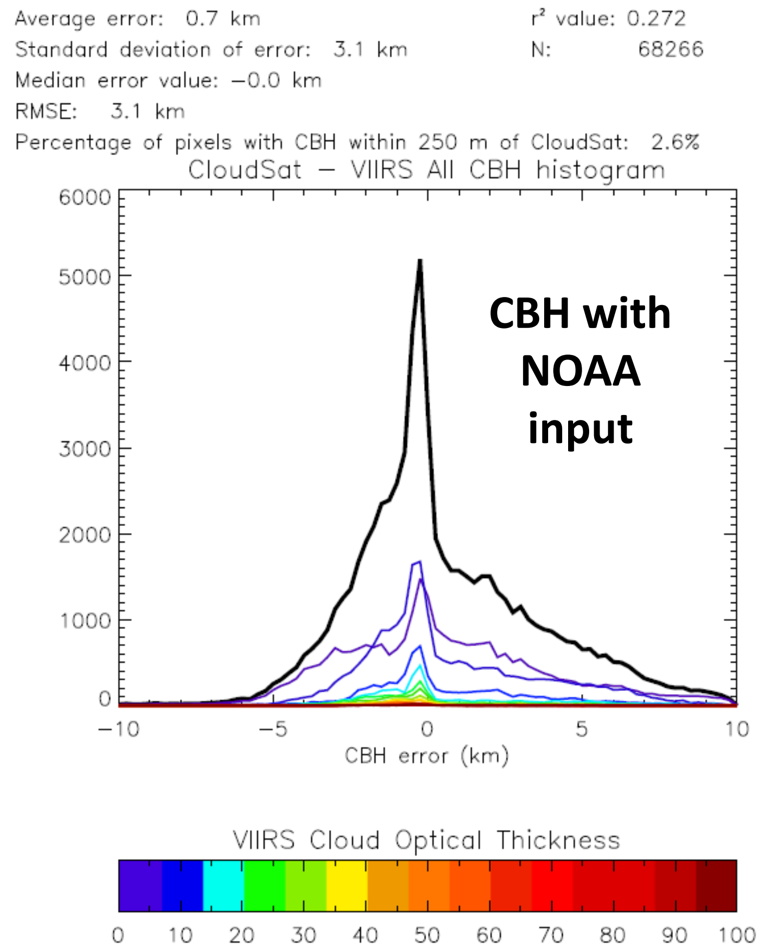



| September 2013 | IDPS | NOAA |
|---|---|---|
| Matchup periods examined | 9 | 9 |
| Valid matchup points | 56,653 | 68,266 |
| Percentage of valid points where CTH is "within spec" | 37.6% | 52.1% |
| Percentage of valid points where CBH error < 2 km | 44.6% | 56.3% |

# IDPS vs NOAA: **All Valid Matchups**



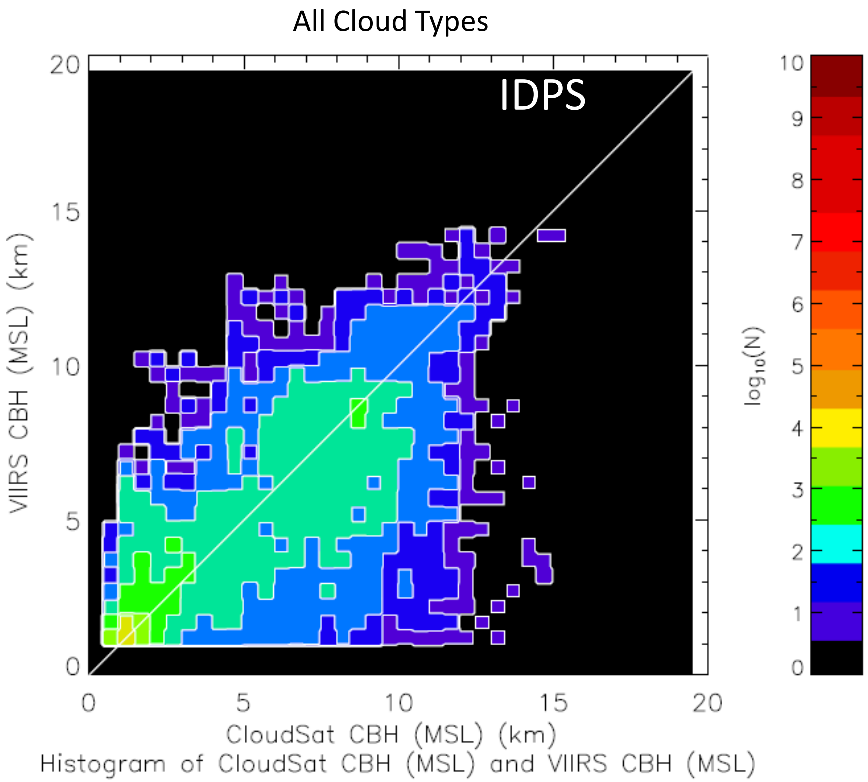



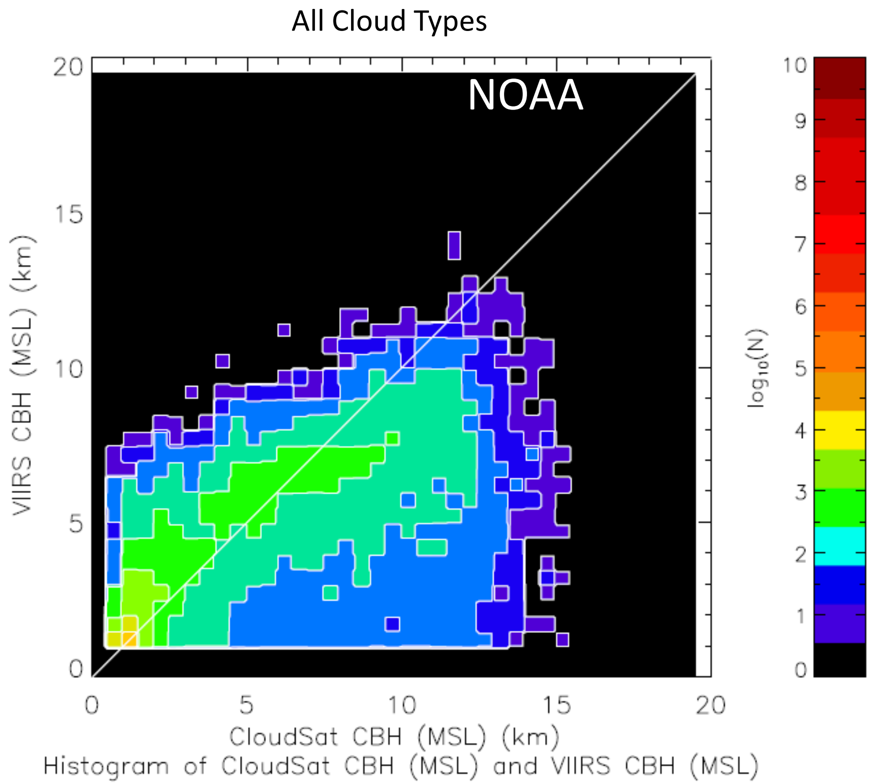

**$R^2$= 0.188, RMSE= 3.6 km, Avg error= 0.8 km**
**CBHs within 250 m of CloudSat = 1.6 %**

**$R^2$= 0.272, RMSE= 3.1 km, Avg error= 0.7 km**
**CBHs within 250 m of CloudSat = 2.6 %**

Negative errors indicate CloudSat CBH was lower than VIIRS CBH
(VIIRS biased high relative to CloudSat)

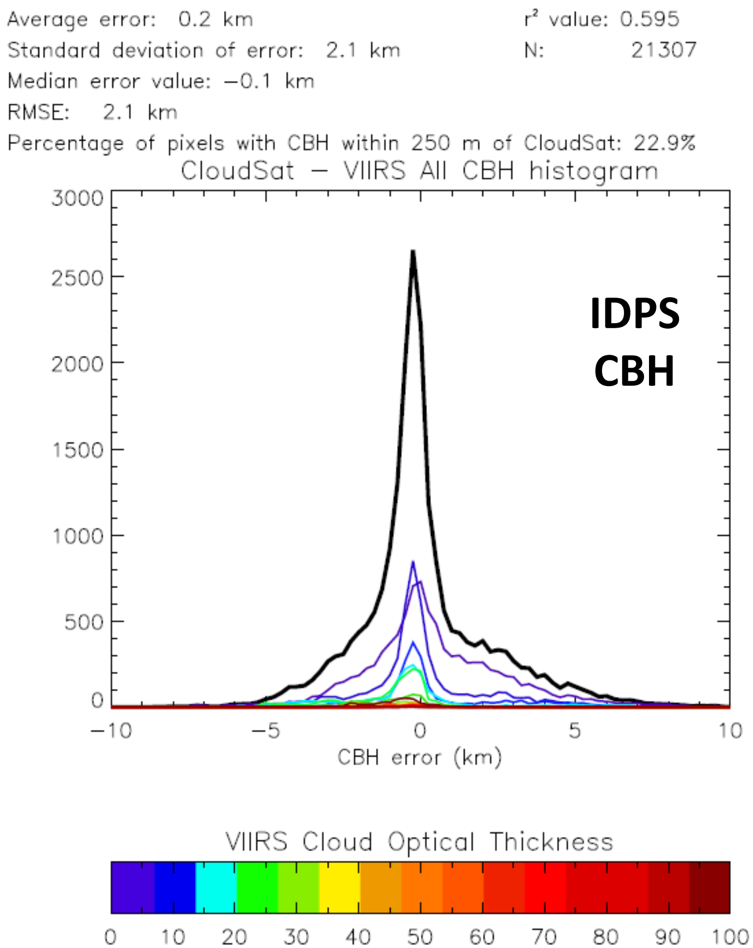
# IDPS vs. NOAA: **"Within Spec"**

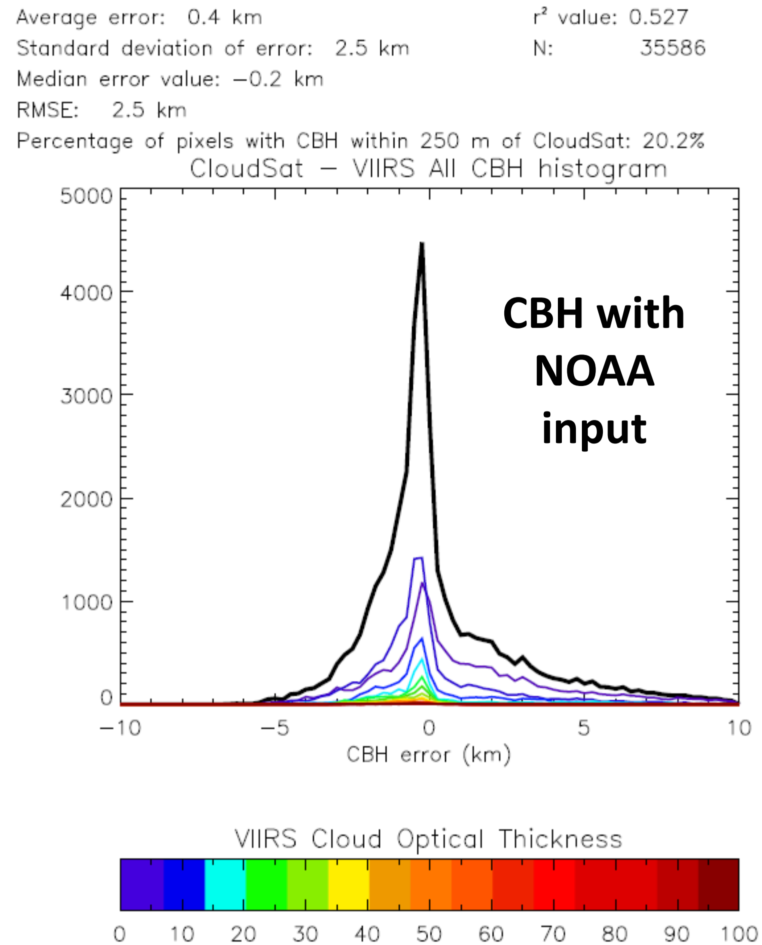



*CBH calculations with NOAA upstream input are ongoing.*

# IDPS vs. NOAA: **"Within Spec"**




**$R^2$= 0.595, RMSE= 2.1 km, Avg error= 0.2 km**
**CBHs within 250 m of CloudSat = 22.9 %**

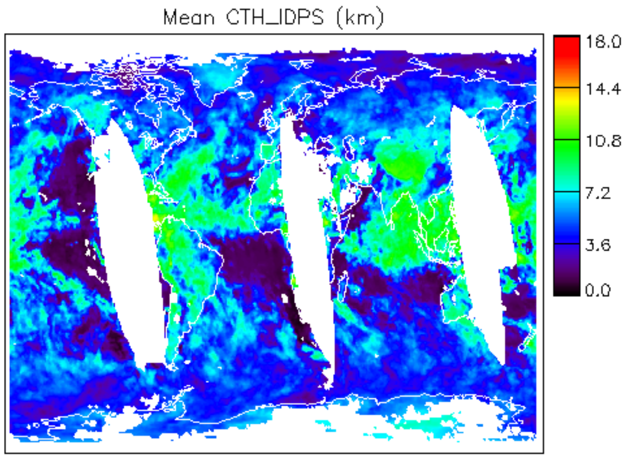
**$R^2$= 0.527, RMSE= 2.5 km, Avg error= 0.4 km**
**CBHs within 250 m of CloudSat = 20.2 %**

Negative errors indicate CloudSat CBH was lower than VIIRS CBH
(VIIRS biased high relative to CloudSat)

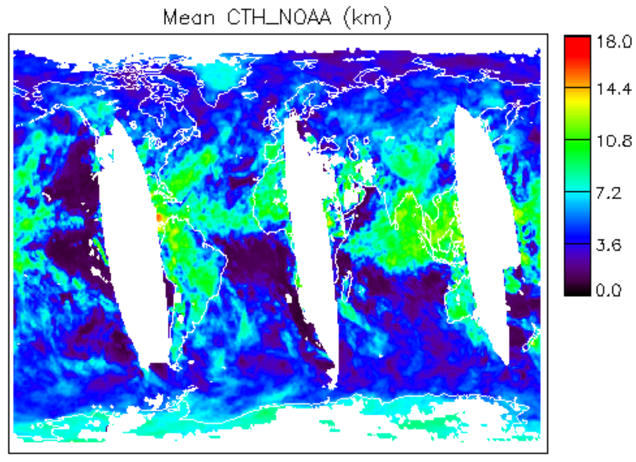
# Mean CTH & CBH of Sept-Oct 2013 VIIRS-CloudSat matchups ($1^o$ x $1^o$)

## CLAVR-x Supercooled cloud type as <u>water</u> phase to CBH calculation

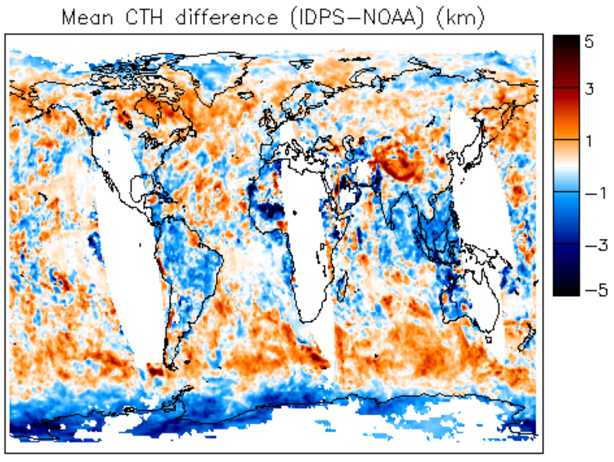
VIIRS IDPS CTH



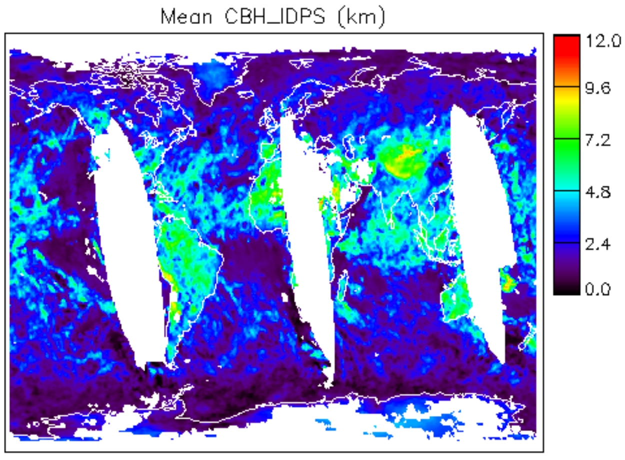

NOAA CTH



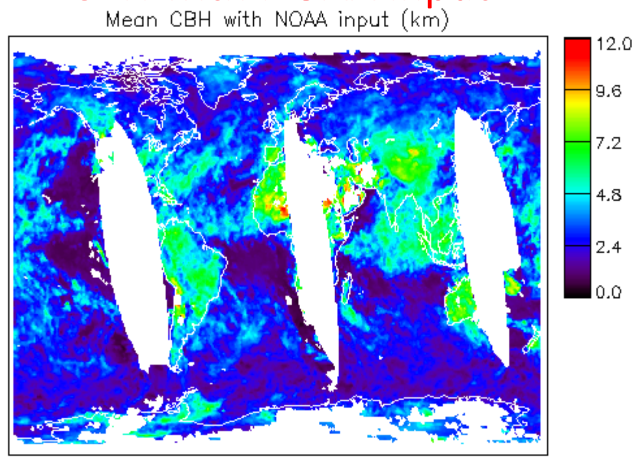

Δ CTH



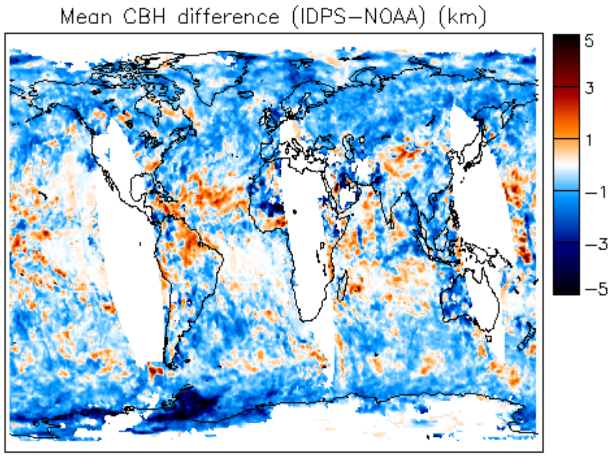

VIIRS IDPS CBH




CBH with NOAA input

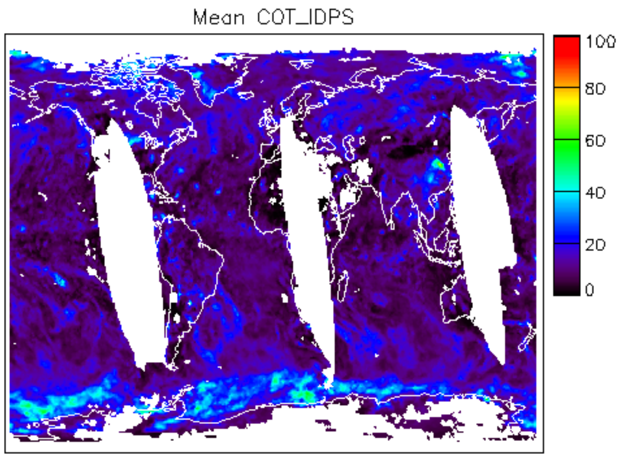



Δ CBH

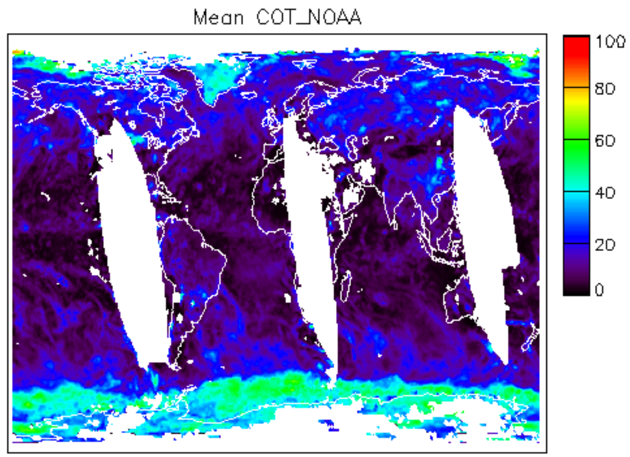


# Mean COT and EPS of Sept-Oct 2013 VIIRS-CloudSat matchups (1º x 1º)

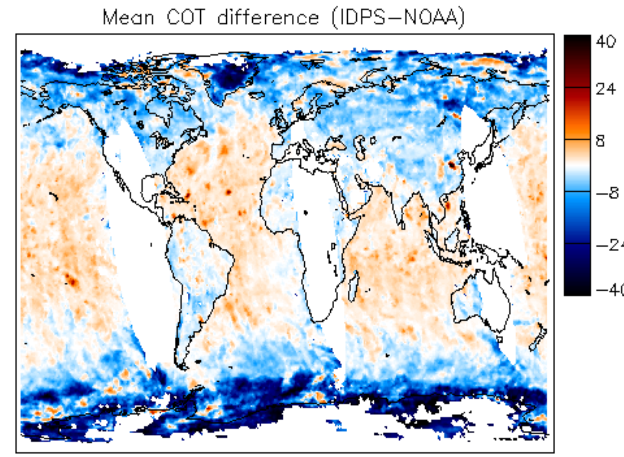
VIIRS IDPS COT



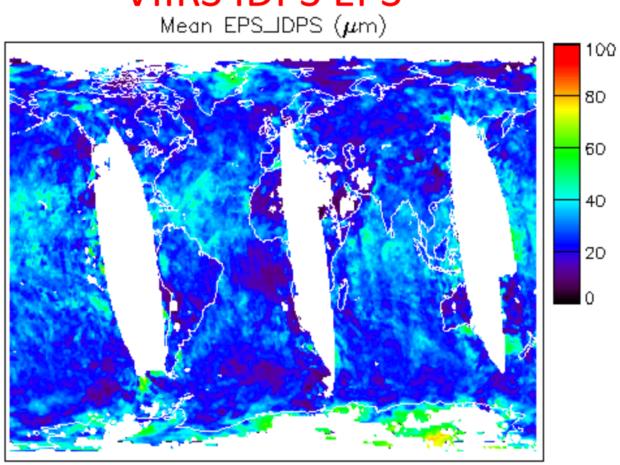

NOAA COT



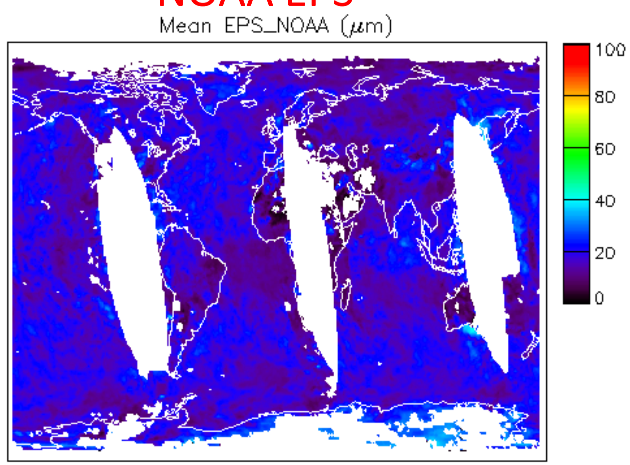

Δ COT



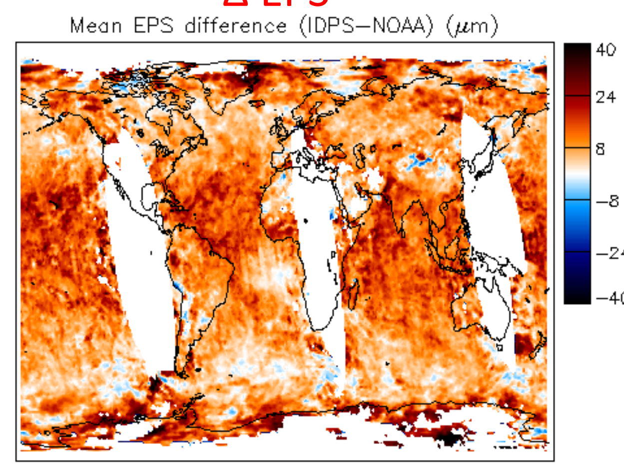

VIIRS IDPS EPS




NOAA EPS




Δ EPS



# Summary

- Retrieving CBH from VIS/IR information is difficult
  - VIIRS CBH EDR is the first to attempt this on a large scale
- Errors in upstream retrievals all directly impact CBH
  - IWC parameterization results in very low CBH values for high clouds
  - Cloud type errors impact CBH
  - Very low effective particle size and optical depths observed
  - Difficult to retrieve CTH for optically thin ice clouds
- VIIRS and CloudSat do not always agree on where the upper-most cloud layer is
  - Results in large CBH errors
- CBH has some skill when CTH is "within spec"
- In general, the NOAA algorithms perform better than IDPS when compared to CloudSat for all valid matchups
  - Similar performance for "within spec" matchups
- CBH retrieval performs best for low, liquid water clouds; worst on thin cirrus and overlap
- Large differences in EPS and COT between IDPS and NOAA algorithms - This feeds back into CBH

# For the Future

- Errors in CTH, COT and EPS need to be fixed
- Average LWC values used by CBH algorithm are constant across the globe
  - Use latitude/temperature dependent LWC
- Investigate fix for poor IWC parameterization
  - Eliminate cirrus CBH at ground level
- Different cloud types form under different dynamic conditions
  - Use lifted condensation level for convective cloud CBH, e.g.
- Use 5+ years of CloudSat statistics on cloud thickness to improve CBH

# Backup Slides

# September 2013 Matchups

Total number of CloudSat granules included in this matchup: 26
Total number of VIIRS granules included in this matchup: 716
Number of matchup profiles examined: 363499

Number of profiles with VIIRS N/A fill value: 3468 ( 1.0%) ← Clouds obscured by parallax effect
Number of profiles with VIIRS missing fill value: 205 ( 0.1%)
Number of profiles with VIIRS pixel trim fill value: 12171 ( 3.3%) ← Cloud-free pixels
Number of profiles with VIIRS error fill value: 101824 (28.0%) ← Cloud-free pixels
Number of profiles with VIIRS VDNE fill value: 0 ( 0.0%)
Number of profiles with VIIRS flagged as out-of-range: 1 ( 0.0%)
Number of profiles with valid CBH retrieval and invalid CTH retrieval: 14849 ( 4.1%)

CloudSat profiles removed due to ground clutter: 120954 (33.3%)
CloudSat profiles removed due to precipitation: 31379 ( 8.6%)

Profiles where CloudSat detected cloud VIIRS did not: 18866 ( 5.2%)
Profiles where VIIRS detected cloud CloudSat did not: 53374 (14.7%)
Profiles where CloudSat and VIIRS both detected cloud: 56653 (15.6%) ← "Valid matchup" pixels
Profiles where CloudSat and VIIRS did not detect cloud: 234606 (64.5%)

**CTH Error specifications: CTH must be within 1 km if the COT is greater than 1, or within 2 km if the COT is less than 1**

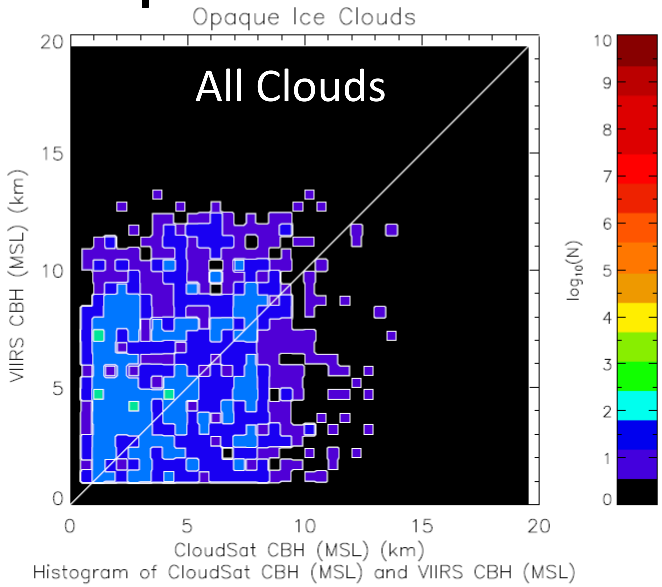
Profiles where VIIRS is within spec: (CTH) 21308 ( 5.9%) ← "Within Spec" pixels
Percentage of pixels where both detected cloud and VIIRS was within spec: 37.6%

**CBH Error specifications: CBH must be within 2 km**

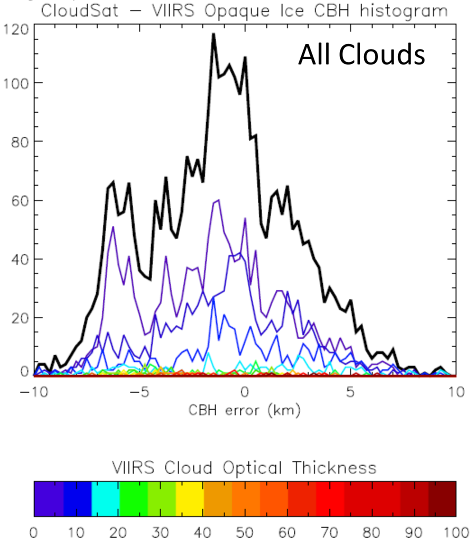
Profiles where VIIRS is within spec: (CBH) 25266 ( 7.0%)
Percentage of pixels where both detected cloud and VIIRS was within spec: 44.6%

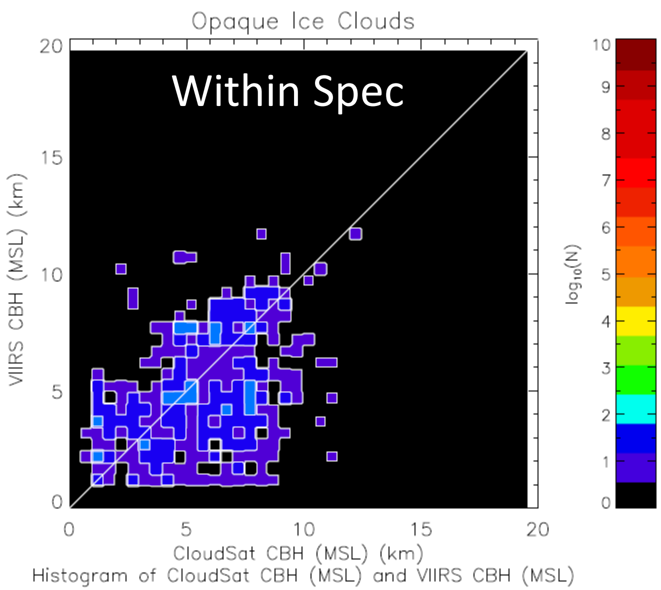
# CBH performance – Opaque Ice

## September 2013

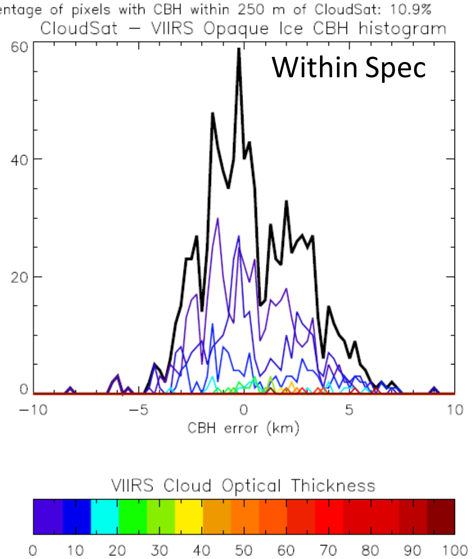



Average error: −1.1 km
Standard deviation of error: 3.4 km
Median error value: −1.0 km
RMSE: 3.6 km
Percentage of pixels with CBH within 250 m of CloudSat: 0.9%
$r^2$ value: 0.030
N: 3092



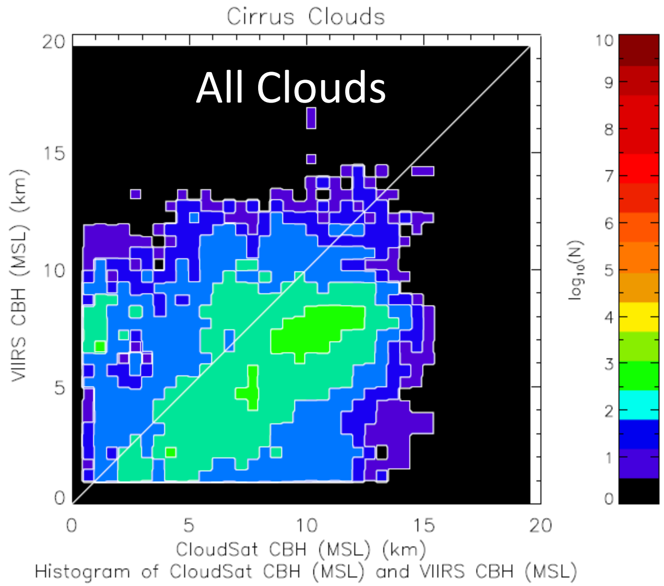



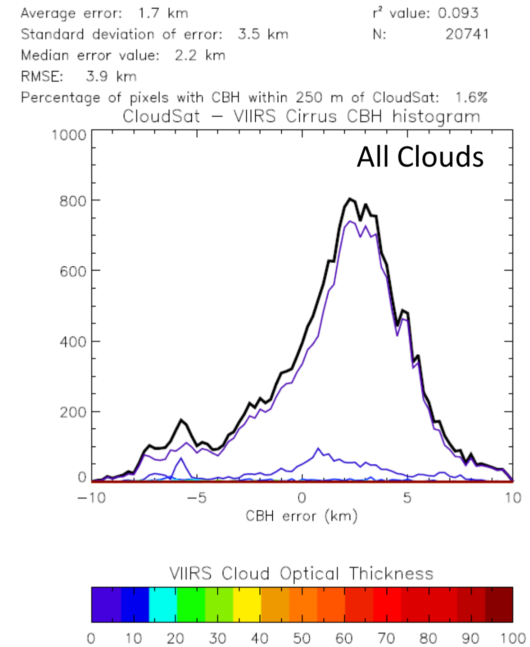

Average error: 0.5 km
Standard deviation of error: 2.4 km
Median error value: 0.2 km
RMSE: 2.4 km
Percentage of pixels with CBH within 250 m of CloudSat: 10.9%
$r^2$ value: 0.190
N: 911

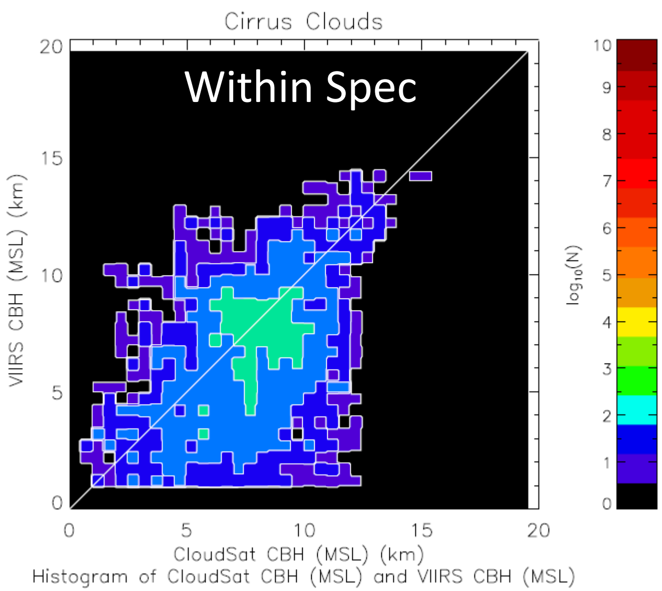


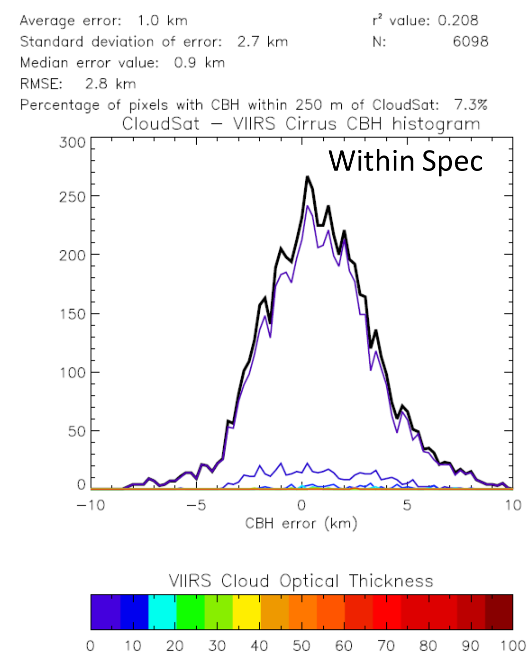
# CBH performance – Cirrus

## September 2013



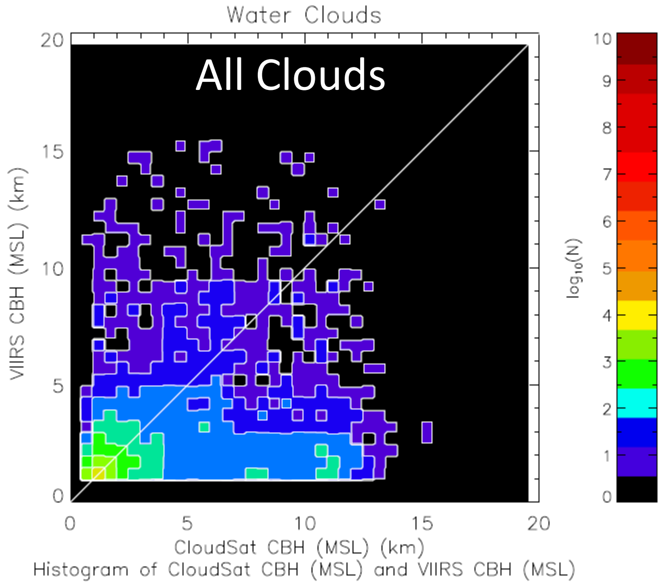



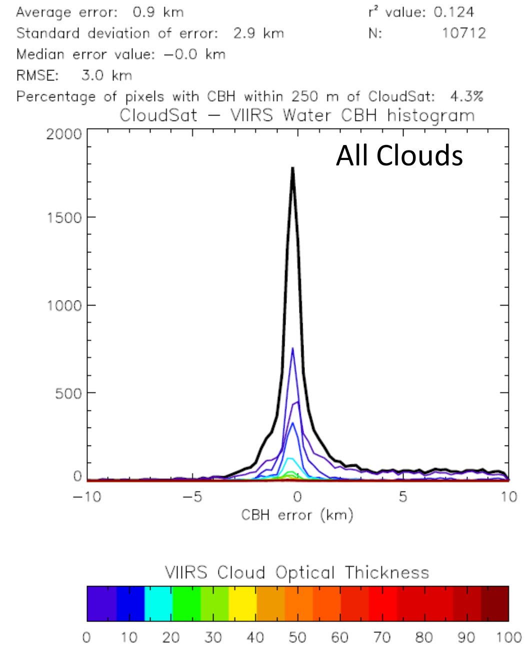



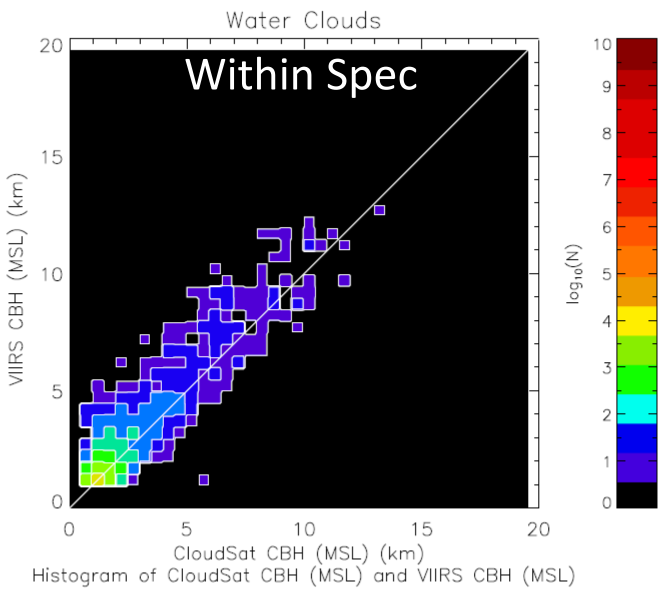



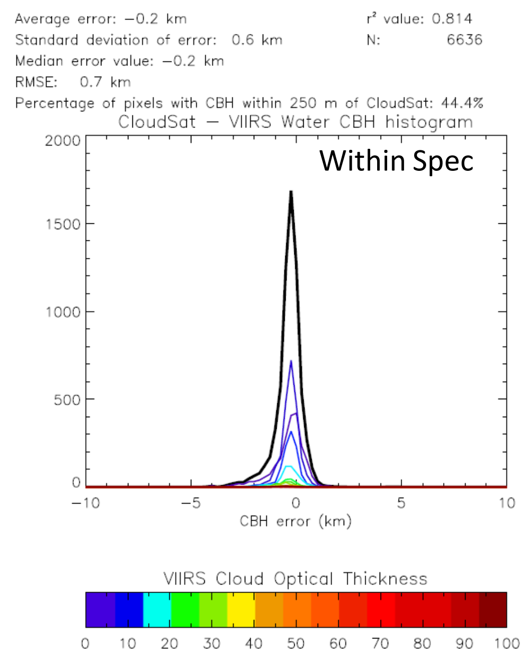
# CBH performance – Water

## September 2013



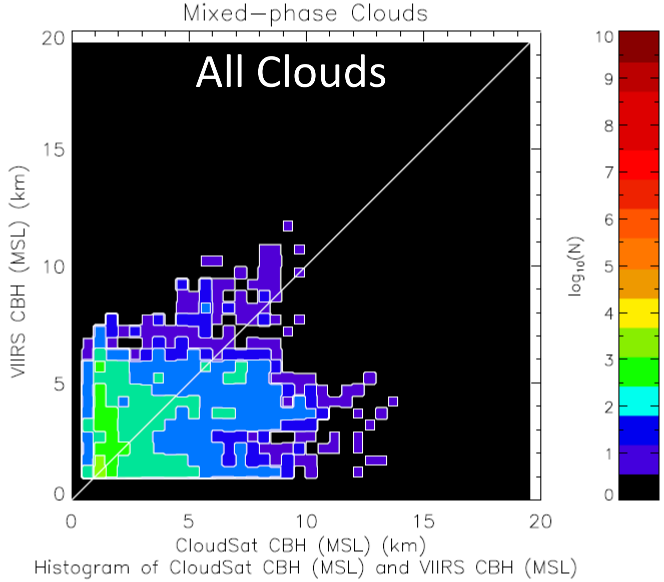



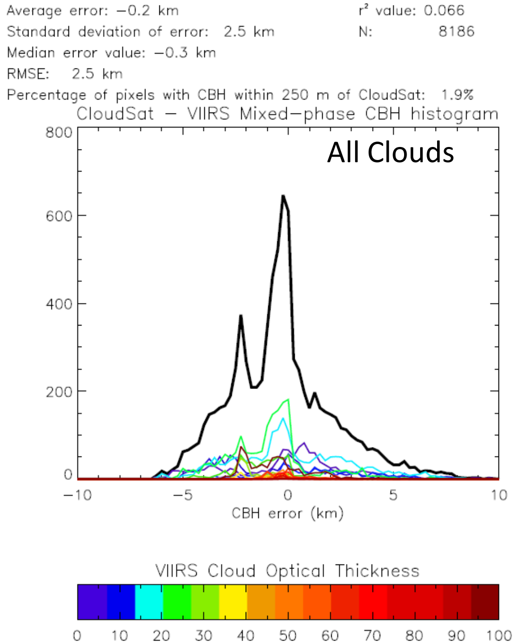



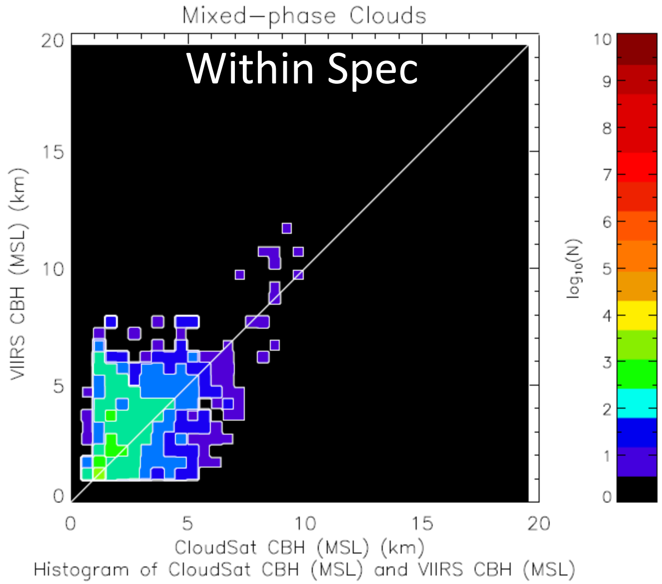



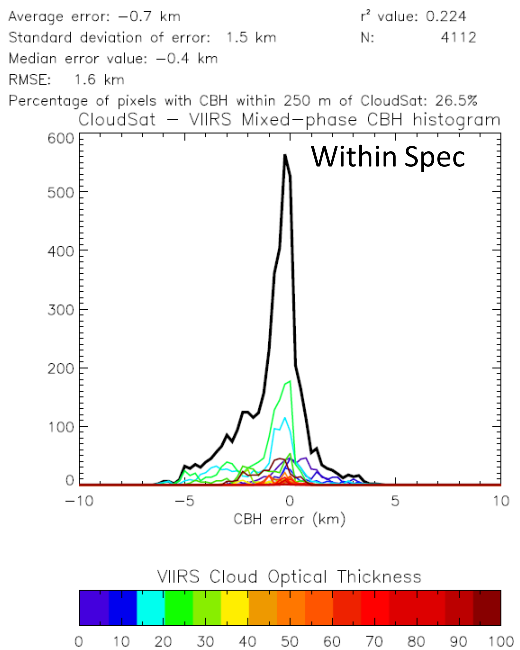
# CBH performance – Mixed-phase

## September 2013



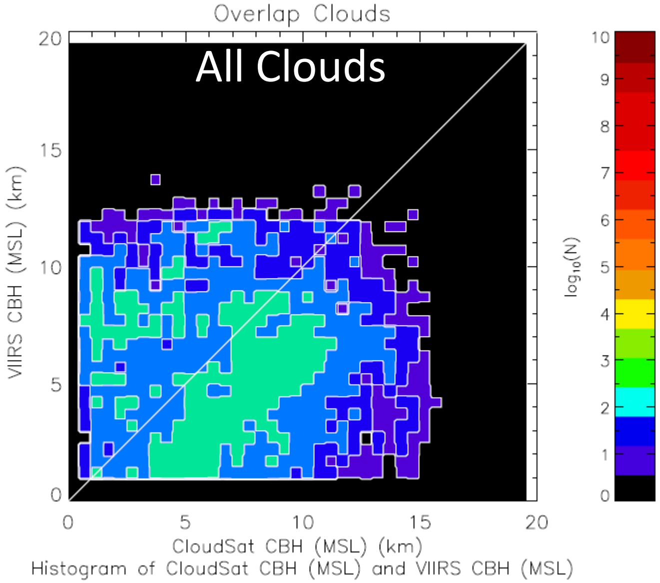



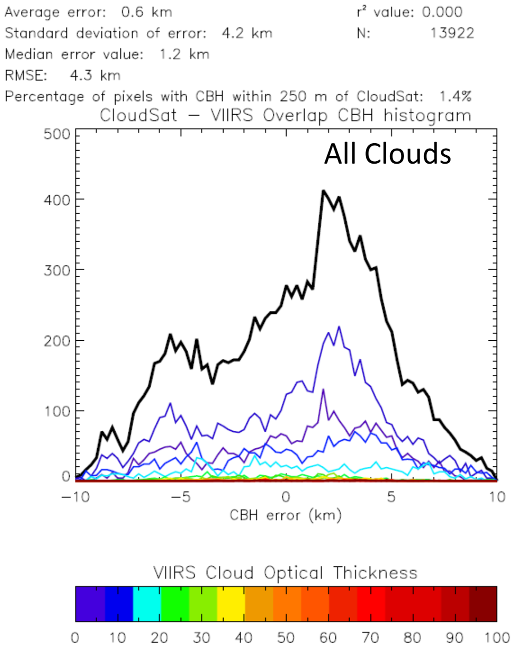



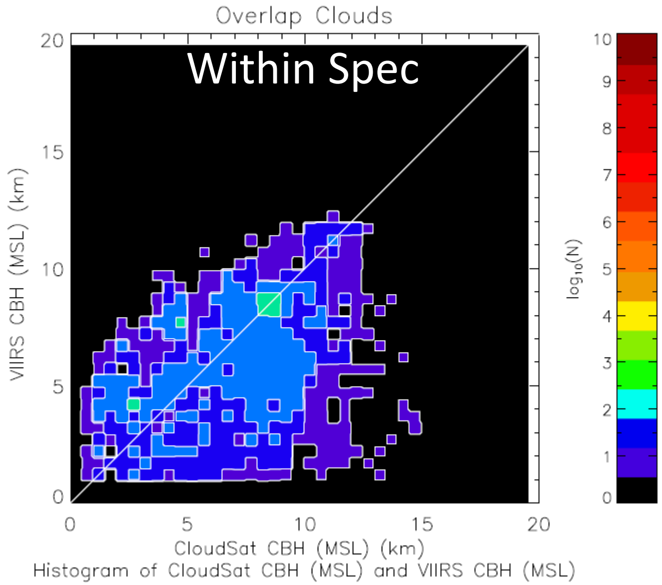



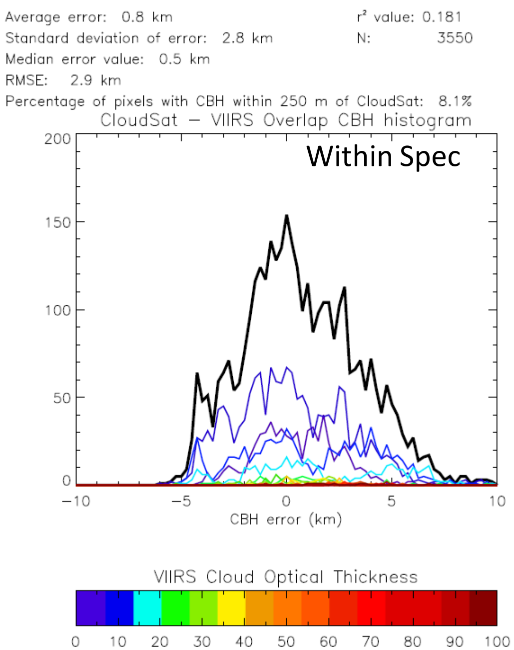
# CBH performance – Overlap

## September 2013

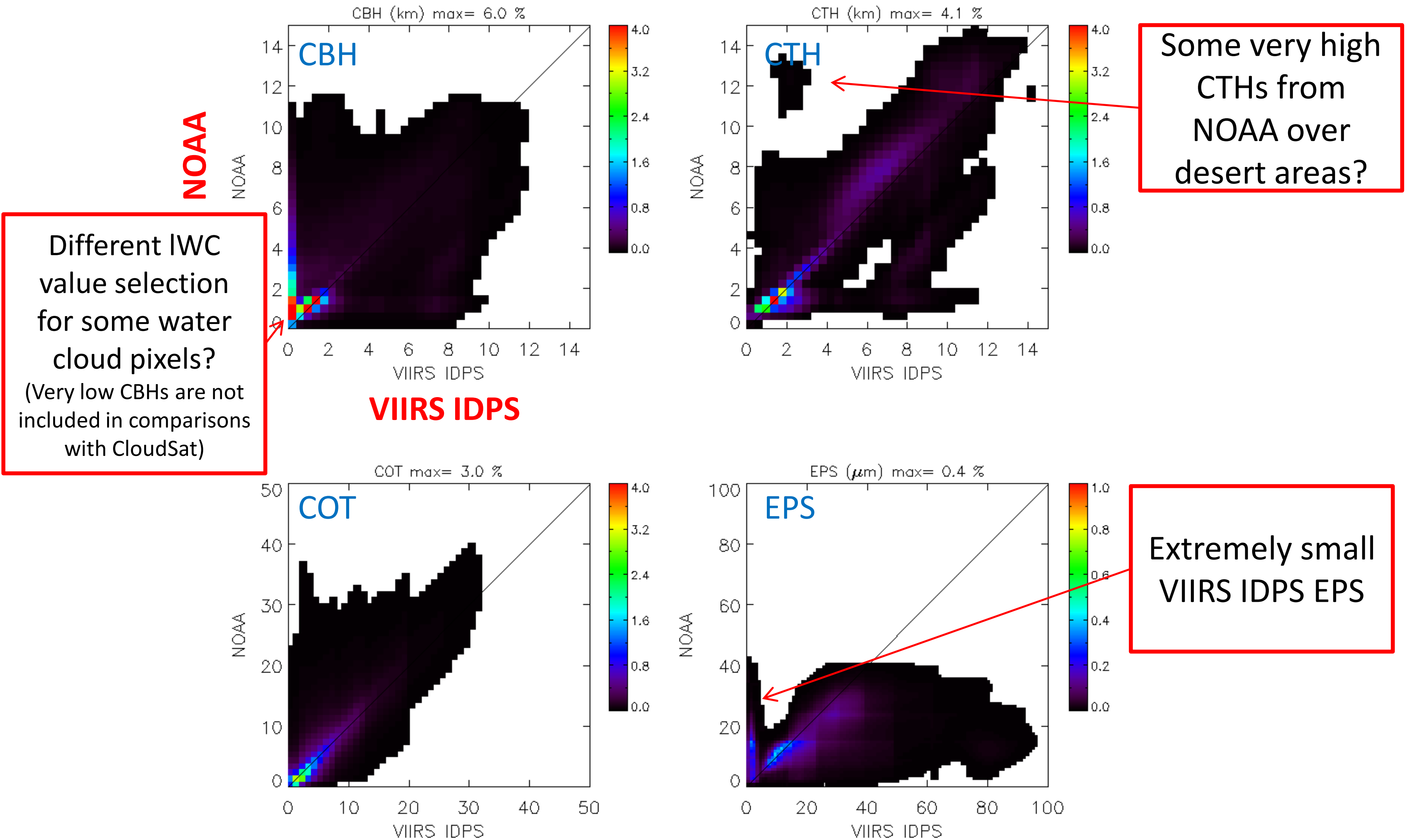


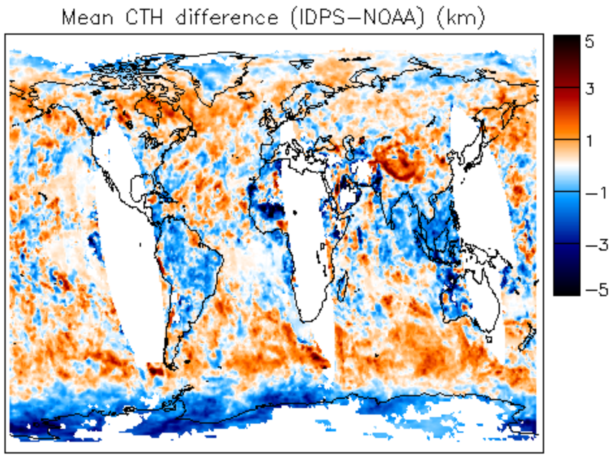
# Comparisons between IDPS and NOAA (%) over the globe



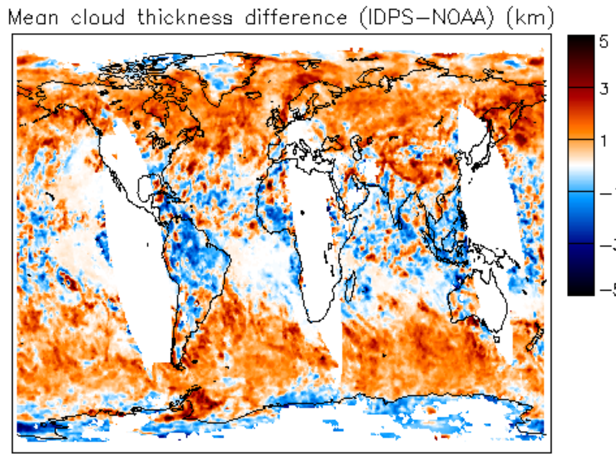

Sept-Oct 2013 matchup cases (daytime granules only)

# Differences between **IDPS** and **NOAA** mean cloud properties

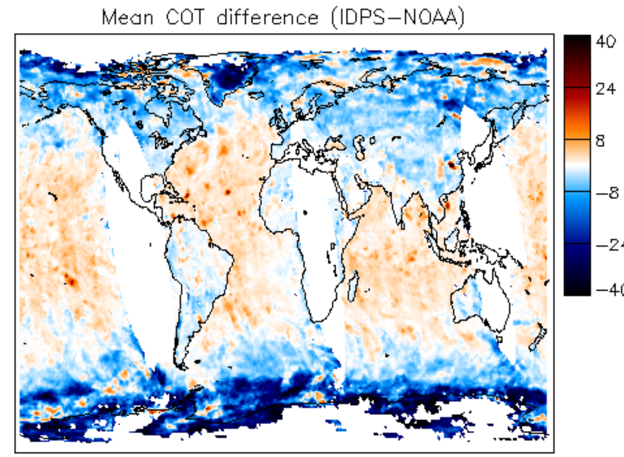
Δ CTH



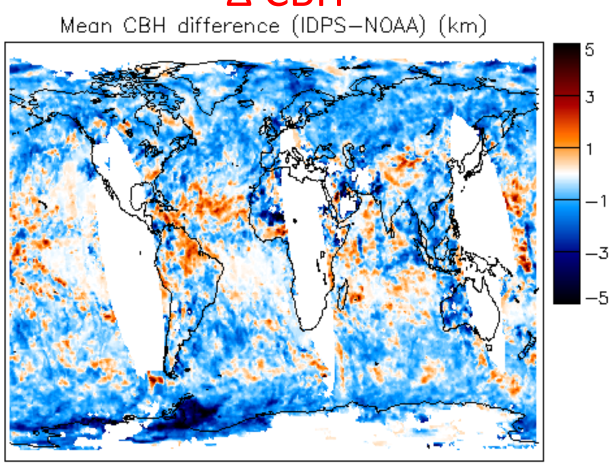

Δ Geometric Thickness



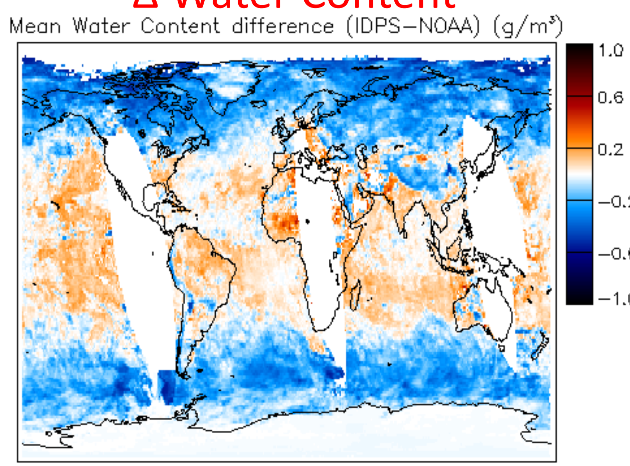

Δ COT



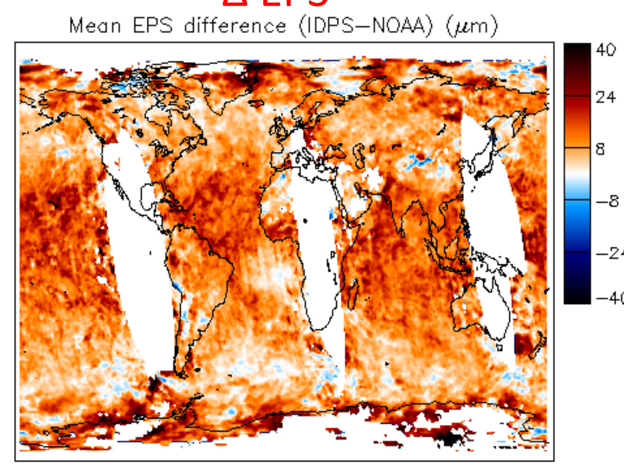

Δ CBH




Δ Water Content




Δ EPS



# Summary of Comparisons Between SNPP VIIRS and Calipso/PATMOS-X Cloud Properties and Progress in Addressing the Discrepancies

THE VALUE OF PERFORMANCE.

NORTHROP GRUMMAN

NOAA STAR JPSS 2014 Annual Science Team Meeting, May 12-16, 2014
NCWCP, College Park, MD

Eric Wong

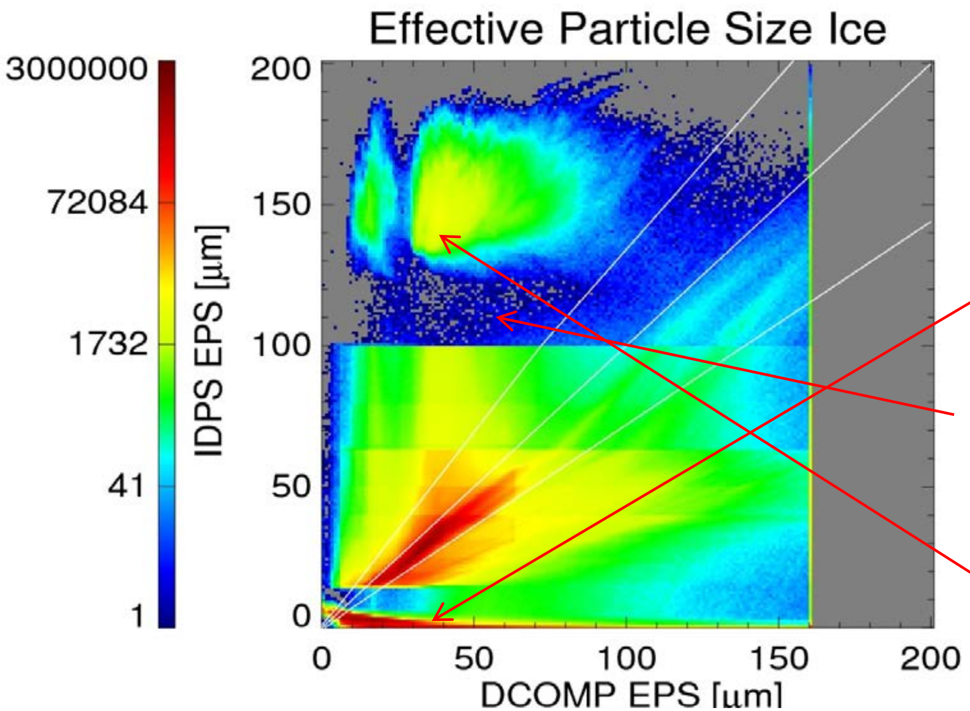
# Outline Of the Presentation

- Description of the 2 major issues affecting performance of IDPS Cloud Properties Products
- Work completed in addressing the day COT/EPS retrieval discrepancies issue
- Progress in addressing the ice cloud low bias issue
- Concluding Remarks

# Provisional Effective Particle Size Ice Phase – Discrepancy Issue Identified Below

Requirements:

– Precision & Accuracy: 28% for Ice ( or 1 µm whichever larger)




58.6% of pixels meets the specs. (similar to Beta Analysis)

Distinctive disagreement features in scatterplot density plot: (belong to un-converged pixels)

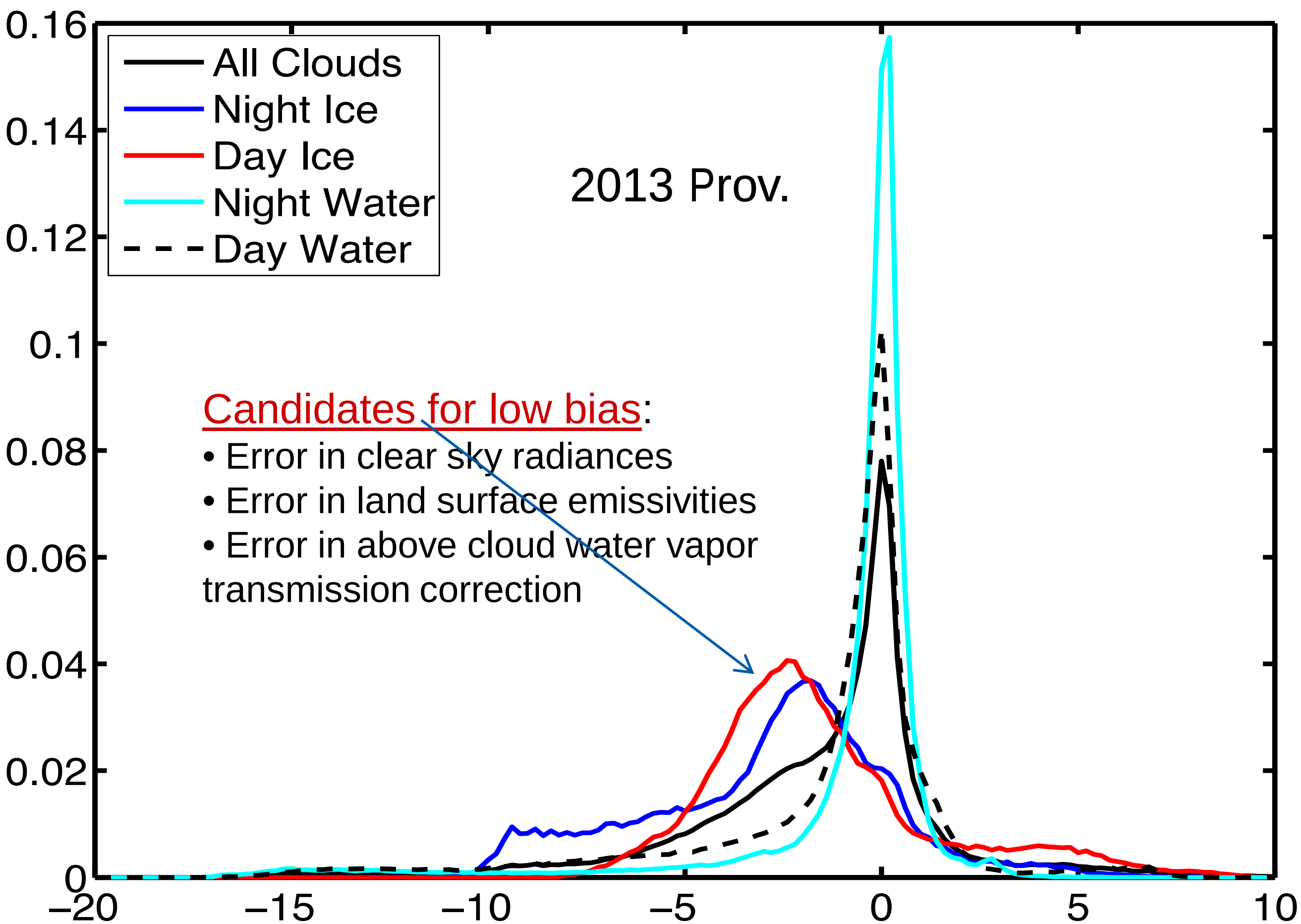
- Pattern of very low EPS values
- Density gap between 5µm and 15µm
- High EPS values where DCOMP has values between 40 and 80µm. (belong to un-converged pixels)

- Issue remains: the wide scatter in comparison
- Hints: scatter points mainly land pixels; un-converged data mostly are land pixels
- Leading candidate for discrepancies – differences in land surface albedos used

# Global CALIPSO/CALIOP Cloud Top Height Evaluation of the VIIRS IP CTH – Low Bias Issue Identified

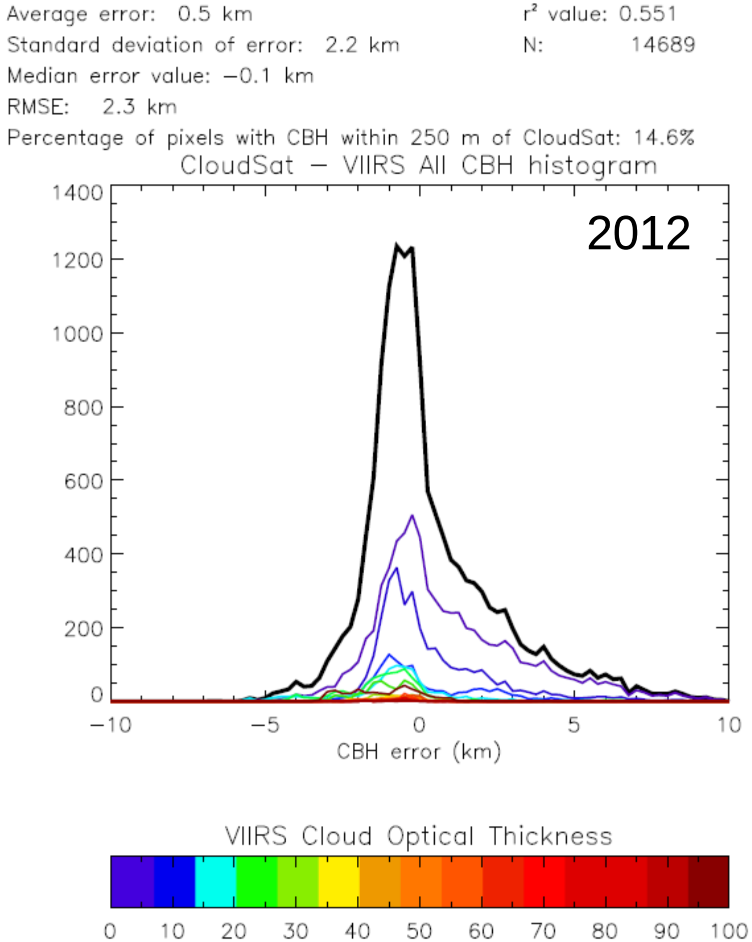
NORTHROP GRUMMAN

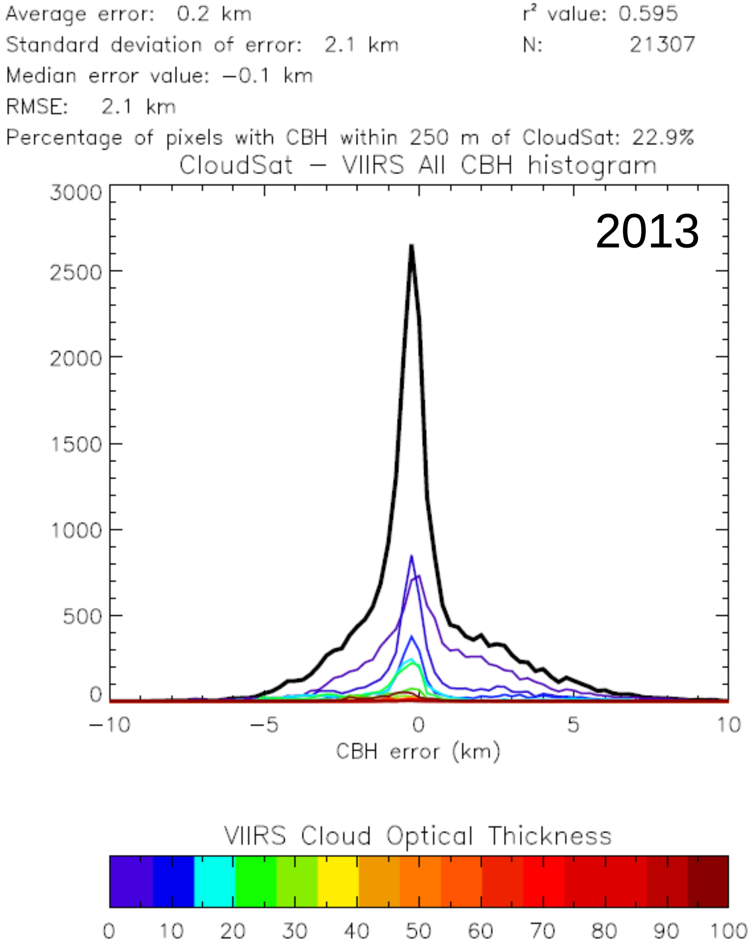
Results at Provisional Presentation (before low cloud inversion logic)




- 4 months of collocated CALIOP (lidar) comparisons with the VIIRS IP CTH product
- 20 minute maximum time separation
- Poles (>60deg lat) excluded.
- **Results show positive bias for water clouds has been largely removed.**
- High cloud bias remains.

# CBH Statistics When CTH Is “within spec”




VIIRS CBH biased high relative to CloudSat

Candidates for improvement:

- Improvement in CTH from upstream CTH will improve CBH performance
- A DR submitted to investigate performance due to LWC of different cloud types

# Assessment Of The Impact Of Land Surface Albedo On COT/EPS Performance

**Diagnosis:**

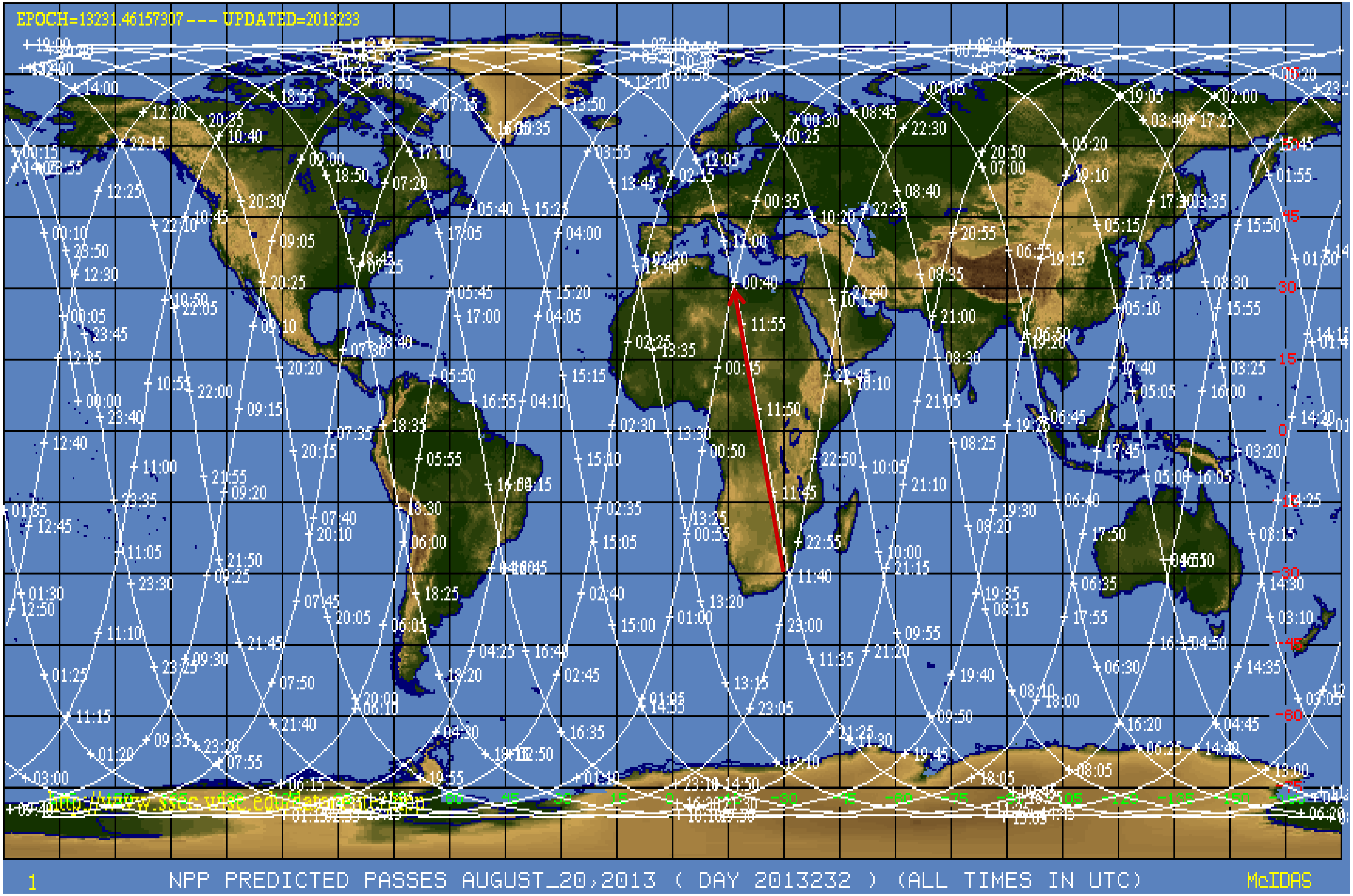
- Current NPP COP algorithms use a static database for land surface albedos
- There are only 3 land surface type in database: desert, land and forest - one single value is used to represent each land type
- Land surface albedos are highly non-uniform

**Expected utcome**

- Constant land surface albedo introduces large error in COT/EPS for thin and semi-transparent clouds

**Method for assessing the land surface albedo effects on COT/EPS Retrievals**

- IDPS VIIRS Operational System generates Granulated Land Surface Albedo based on years of MCD43C1 white sky land surface albedo product (years of data since 2002)
- Replace Static Database with input of VIIRS Granulated Land Surface Albedo files
- Assess improvement by comparing with CLAVRX-PATMOS COT/EPS



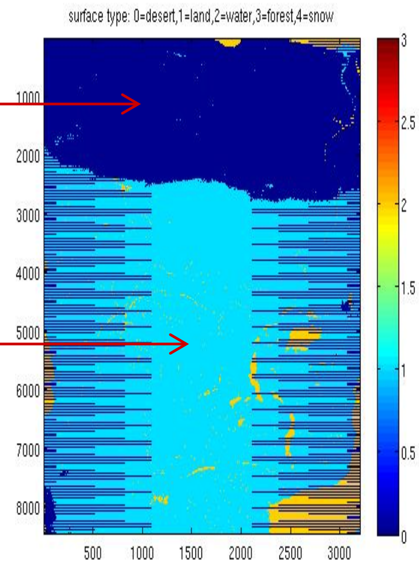

Region selected for testing and assessing effect of land surface albedo on COT/EPS performance

# Comparison of Land Surface Albedo Between COP Static Database and VIIRS Granulated Products – Scene Of Africa 08/20/13, 11:41-11:57

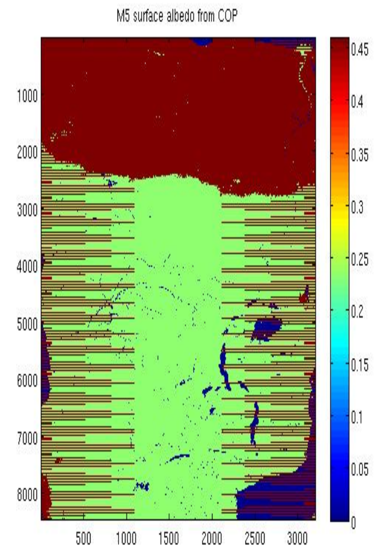
VIIRS Surf. Type

Sahara Desert

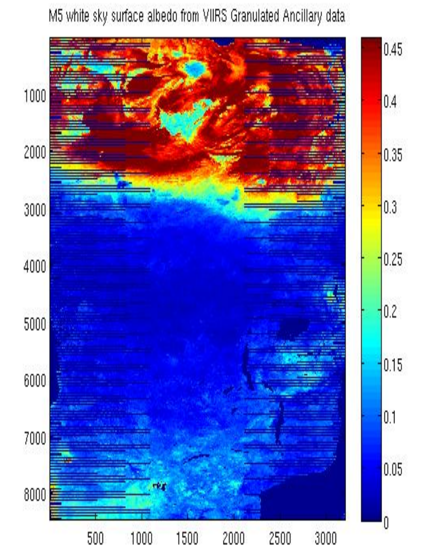
Africa Land

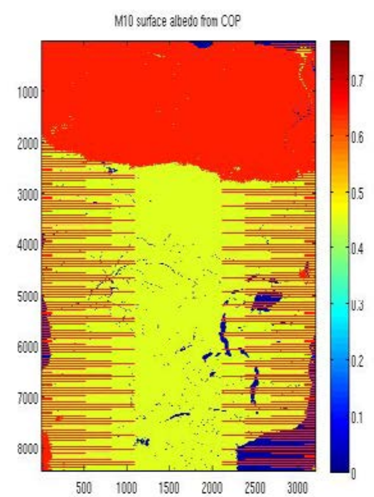


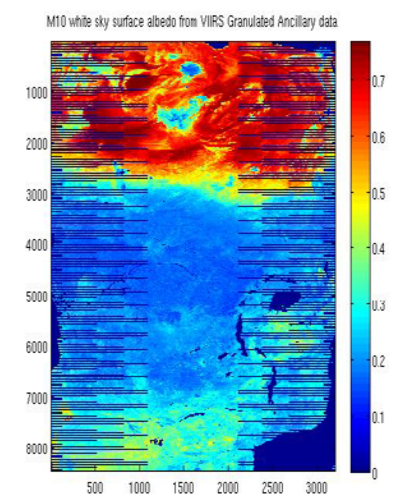

Static Database




VIIRS Granulated LSA



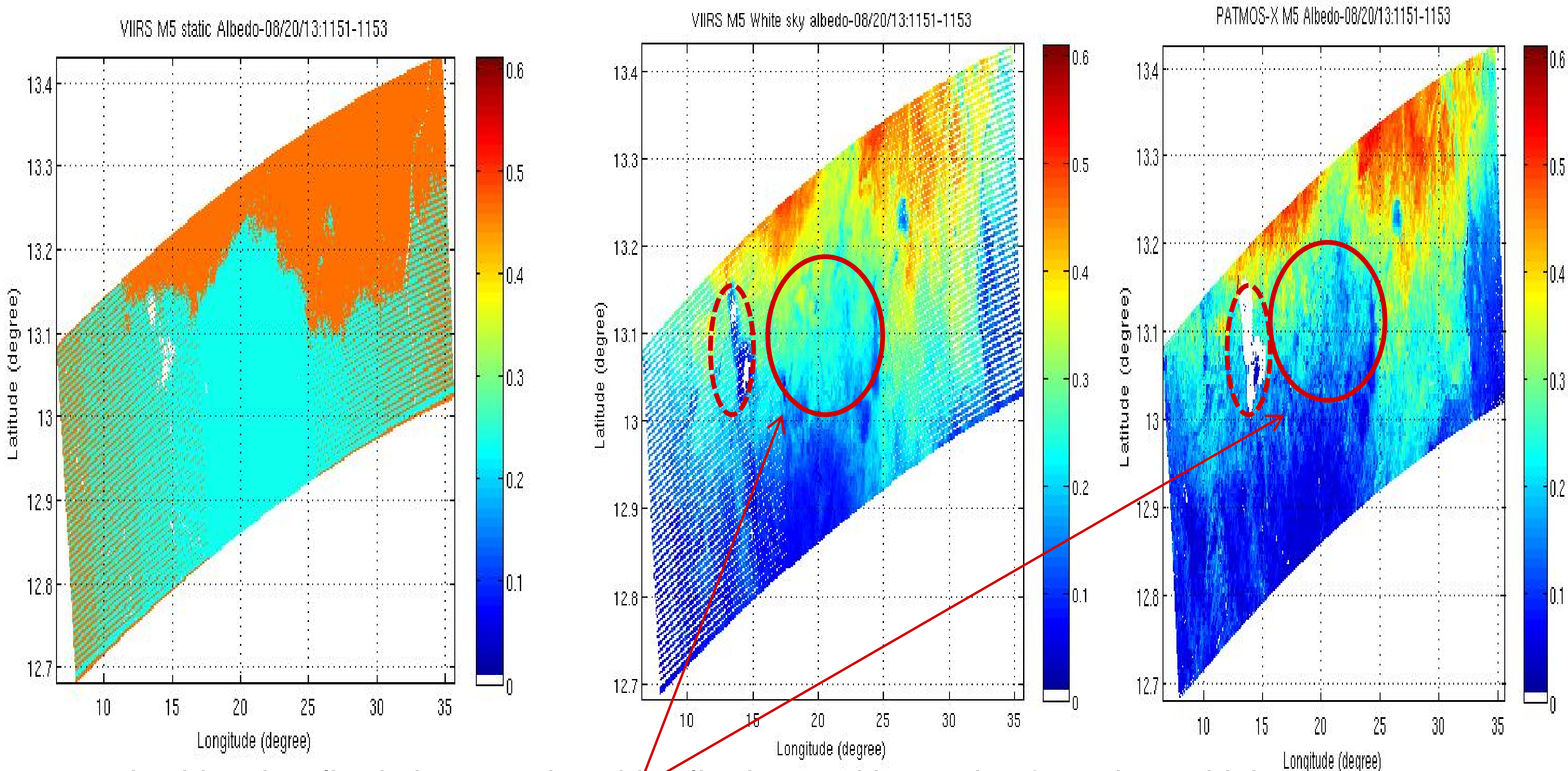




- Significant differences between static database and white sky albedo values
- Albedo values are highly non-uniform under the same land type
- Albedo value differences within the land type exceed 50%
- Albedo value differences within the desert type can also vary greatly

# Comparison of M5 Surface Albedo Between VIIRS Granulated White sky Albedo And PATMOS-X Based On MODIS Moody Dataset

NORTHROP GRUMMAN

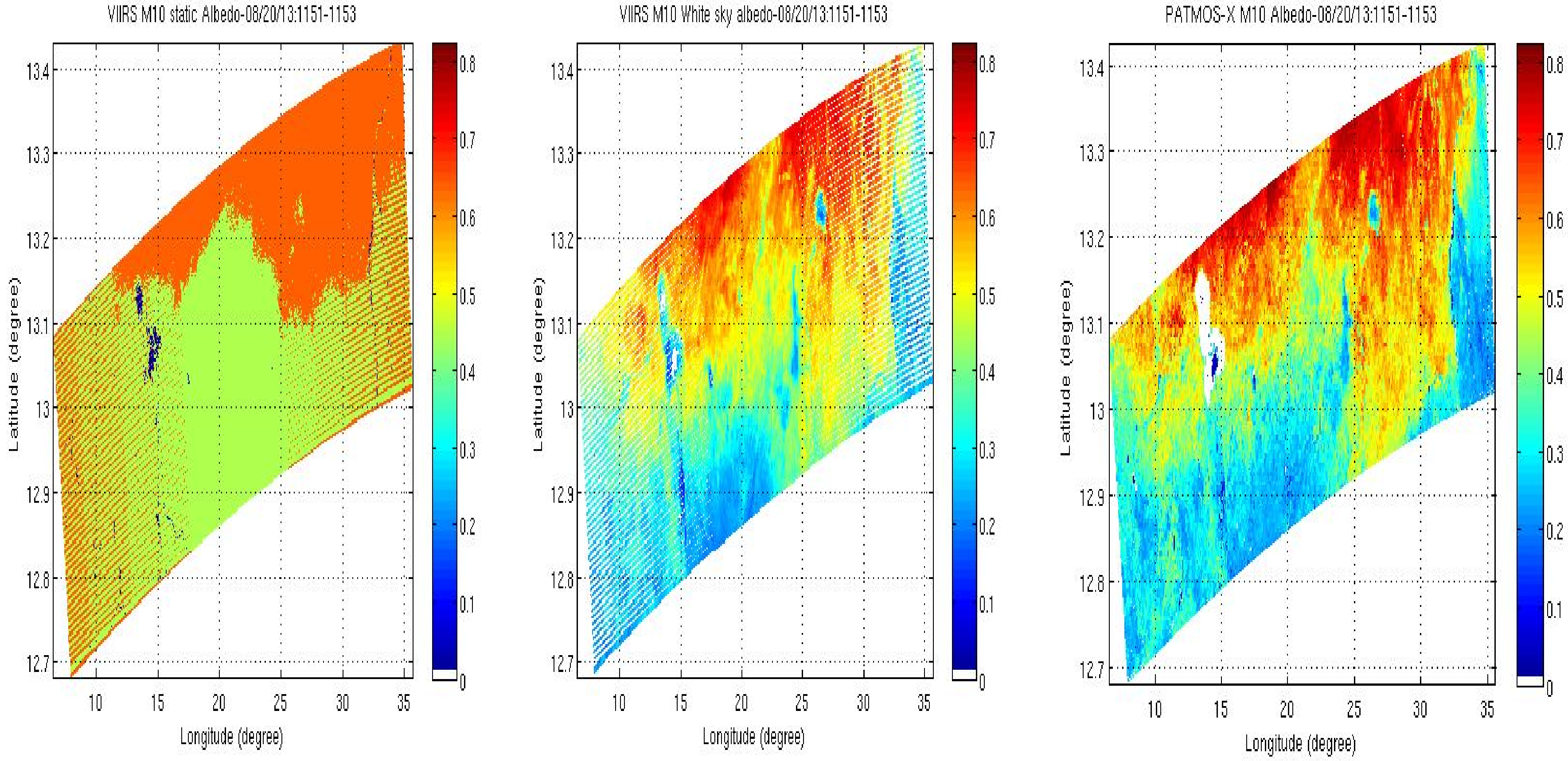



•Both white sky albedo images show big albedo transition region from desert high to land low values, while static database shows a jump

•While the 2 sources of white sky albedo look similar there are regions of significant difference

•Such differences will undoubtedly contribute to differences in COT/EPS retrievals

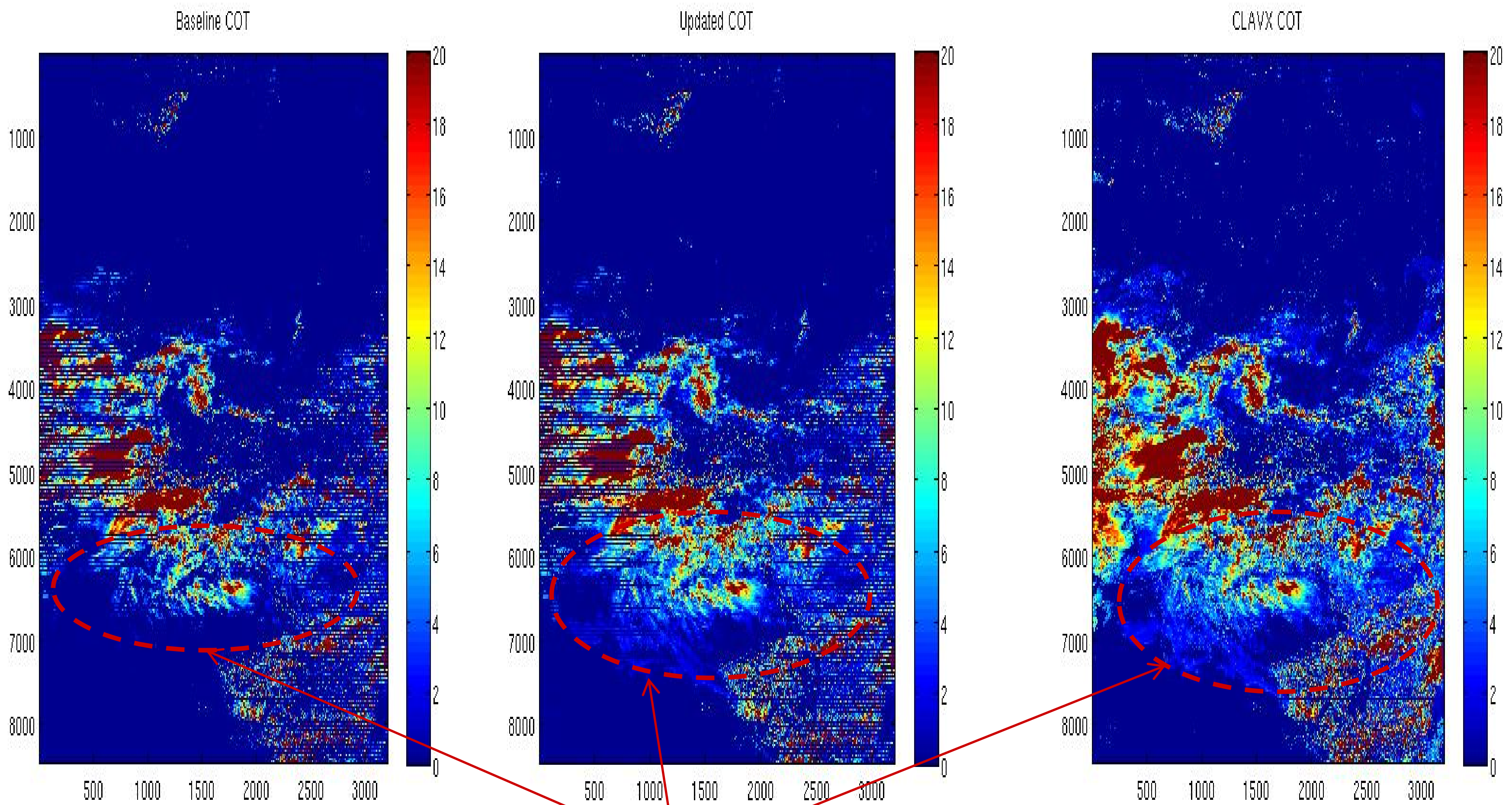
# Comparison of M10 Surface Albedo Between VIIRS Granulated White sky Albedo And PATMOS-X Based On MODIS Moody Dataset




Similar behaviors as shown in the previous slide on M5 albedo comparison

# Comparison of Cloud Optical Thickness Between Baseline, Updated VIIRS COP And CLAVRX – Scene Of Africa 08/20/13, 11:41-11:57

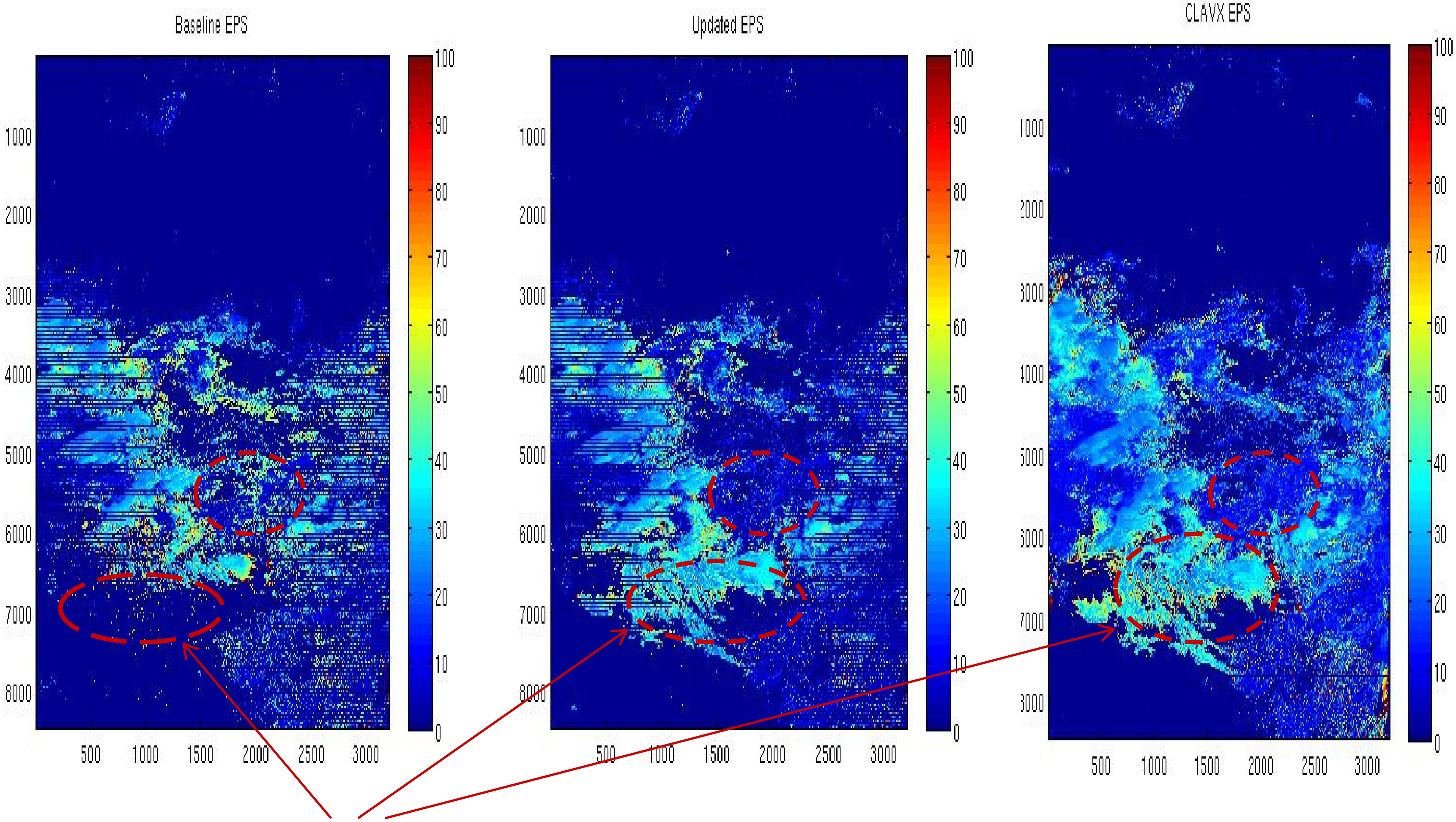
NORTHROP GRUMMAN




•Updated COT image looks much closer to that of PATMOS-X

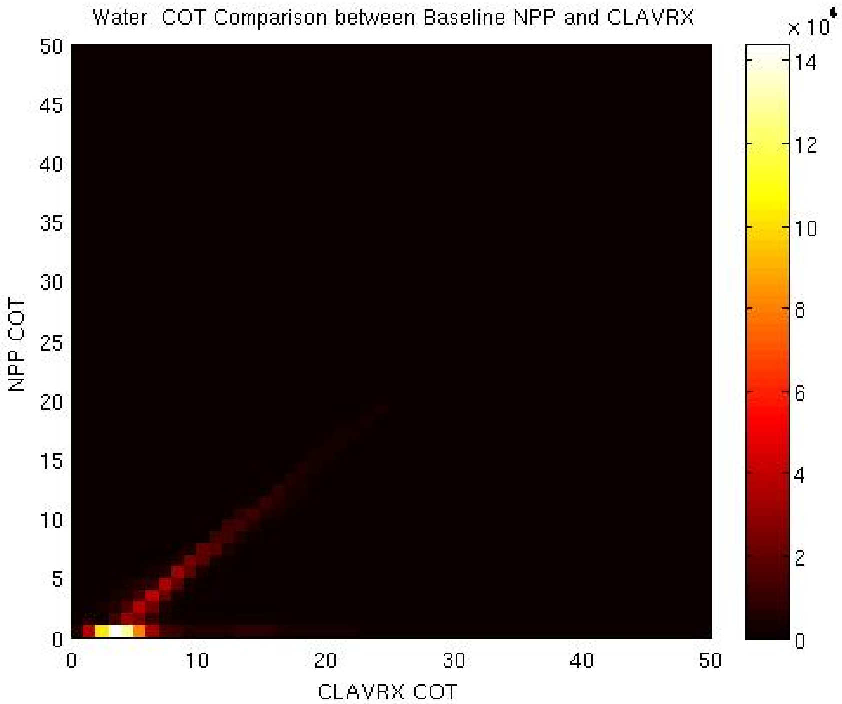
•Updated COT has more converged retrievals than that of Baseline

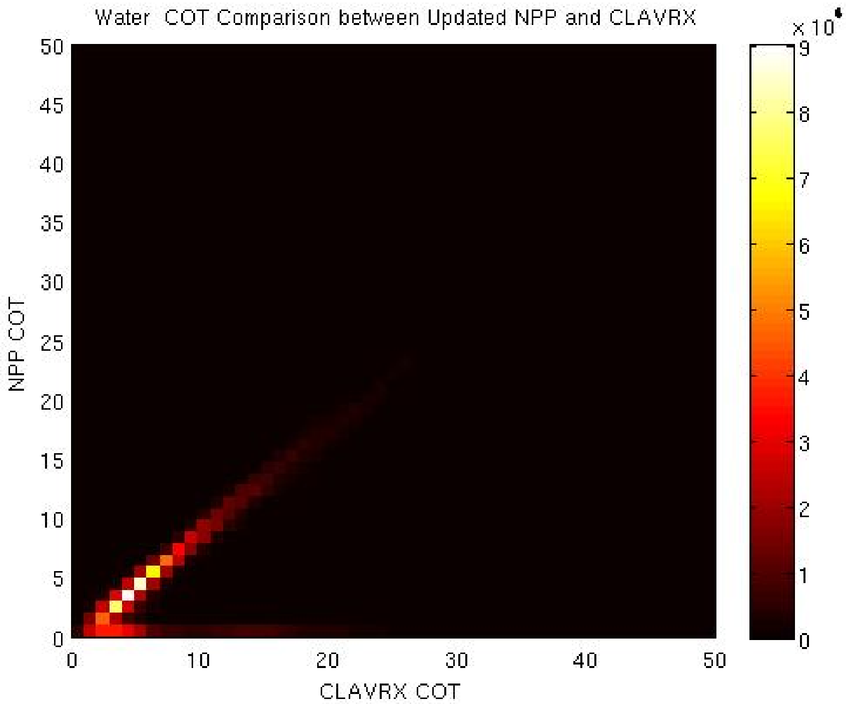
# Comparison of Cloud Effective Particle Size Between Baseline, Updated VIIRS COP and CLAVRX – Scene of Africa 08/20/13, 11:41-11:57




•Updated EPS shows noticeable improvement in these 2 regions
•Updated VIIRS EPS are smoother at cloud edge than in PATMOS-X

# Statistics On The Comparison Of Water Cloud COT Between Baseline, Updated VIIRS COP and CLAVRX – Scene Of Africa 08/20/13, 11:41-11:57

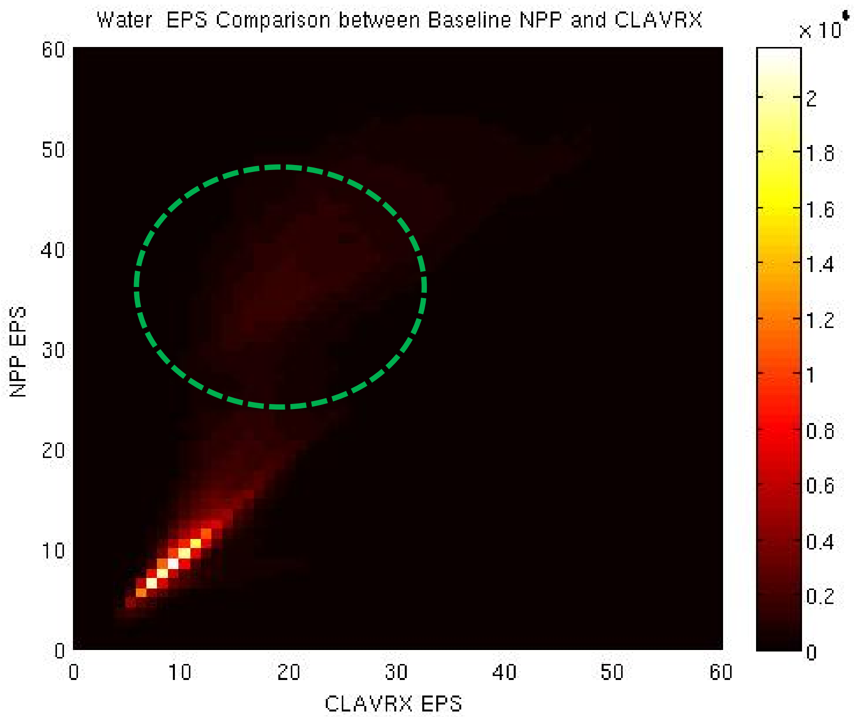


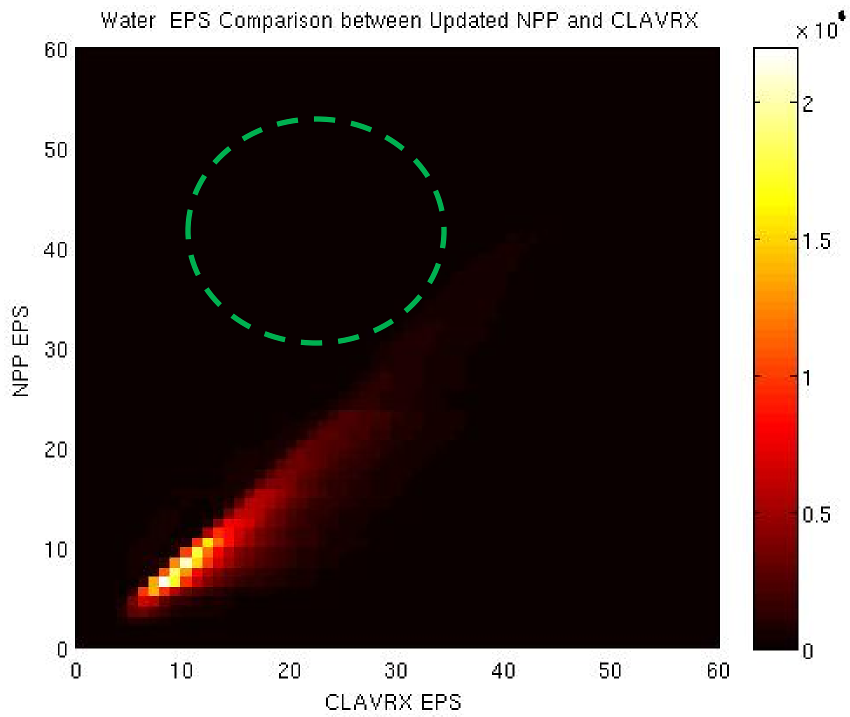




- Updated COT shows better performance than Baseline
- Updated COT has significantly less number of optically thin clouds predicted than in the Baseline
- Discrepancies between Updated and PATMOS-X are un-avoidable due to differences in surface albedo values, particularly for optically thin clouds

# Statistics On The Comparison of Water Cloud EPS Between Baseline, Updated VIIRS COP and CLAVRX – Scene of Africa 08/20/13, 11:41-11:57

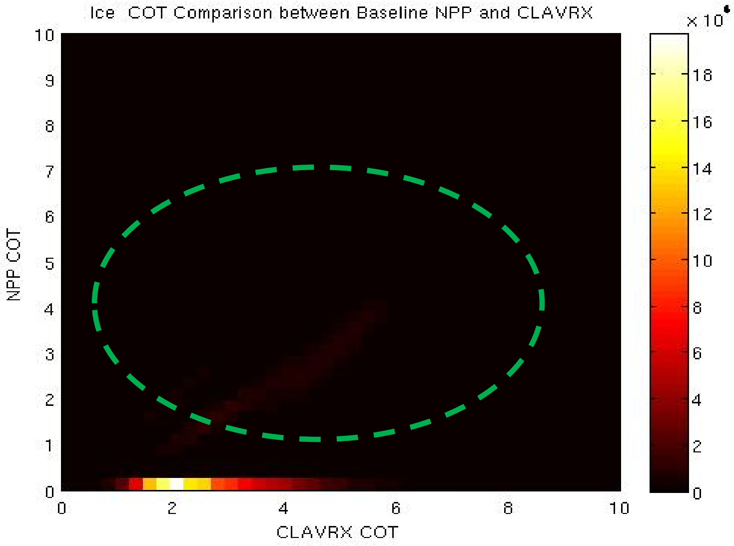
NORTHROP GRUMMAN

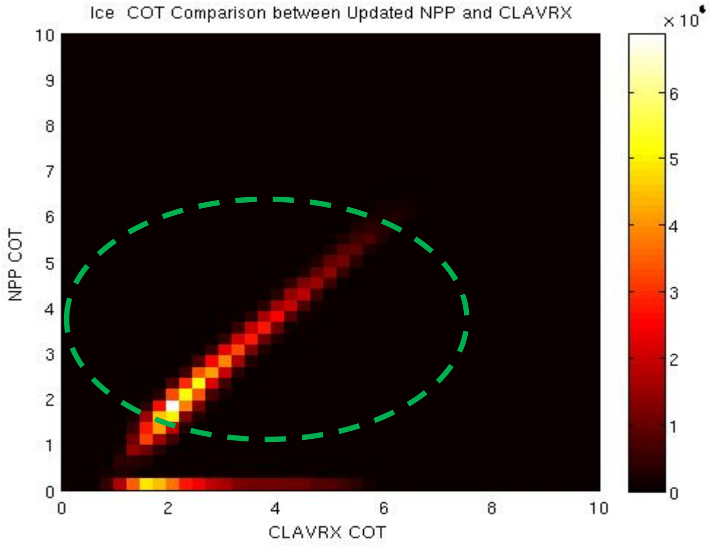



- Updated EPS shows better performance
- Large number of off diagonal pixels are no longer in the Updated retrievals

# Statistics On The Comparison of Ice Cloud COT Between Baseline, Updated VIIRS COP and CLAVRX – Scene Of Africa 08/20/13, 11:41-11:57

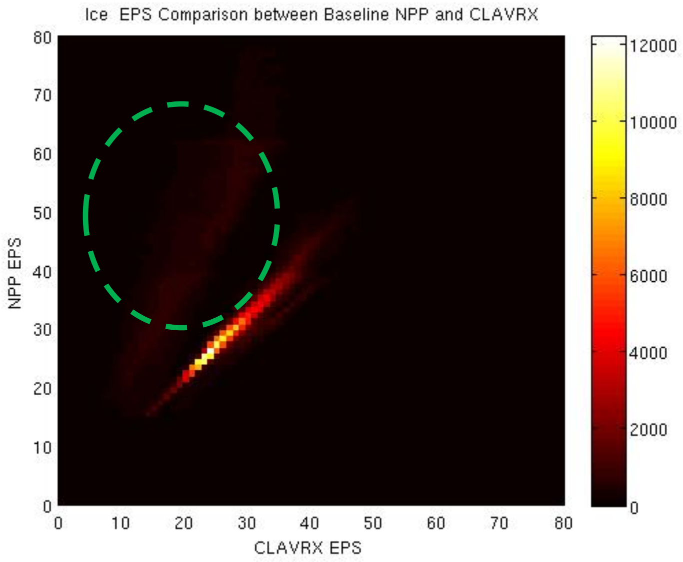


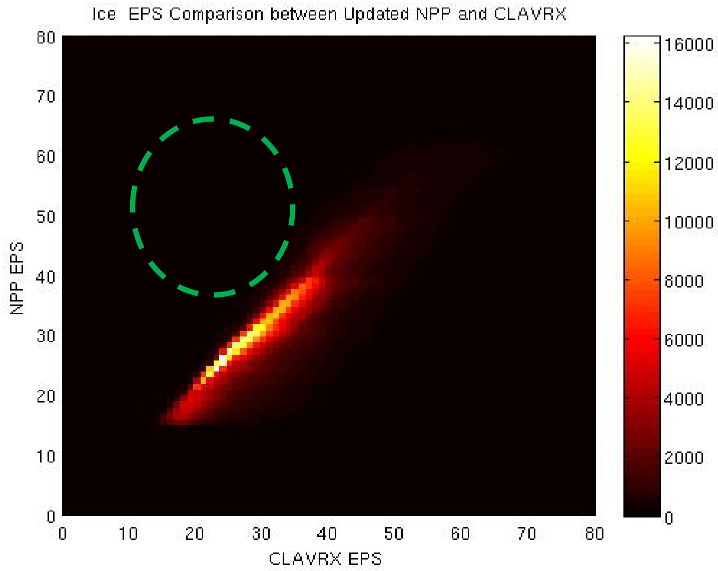




- Updated COT shows better performance than Baseline
- Updated COT has significantly less number of optically thin clouds predicted than in the Baseline
- Discrepancies between Updated and PATMOS-X are un-avoidable due to differences in surface albedo values, particularly for usually optically thin ice clouds

# Statistics On The Comparison of Ice Cloud EPS Between Baseline, Updated VIIRS COP and CLAVRX – Scene of Africa 08/20/13, 11:41-11:57

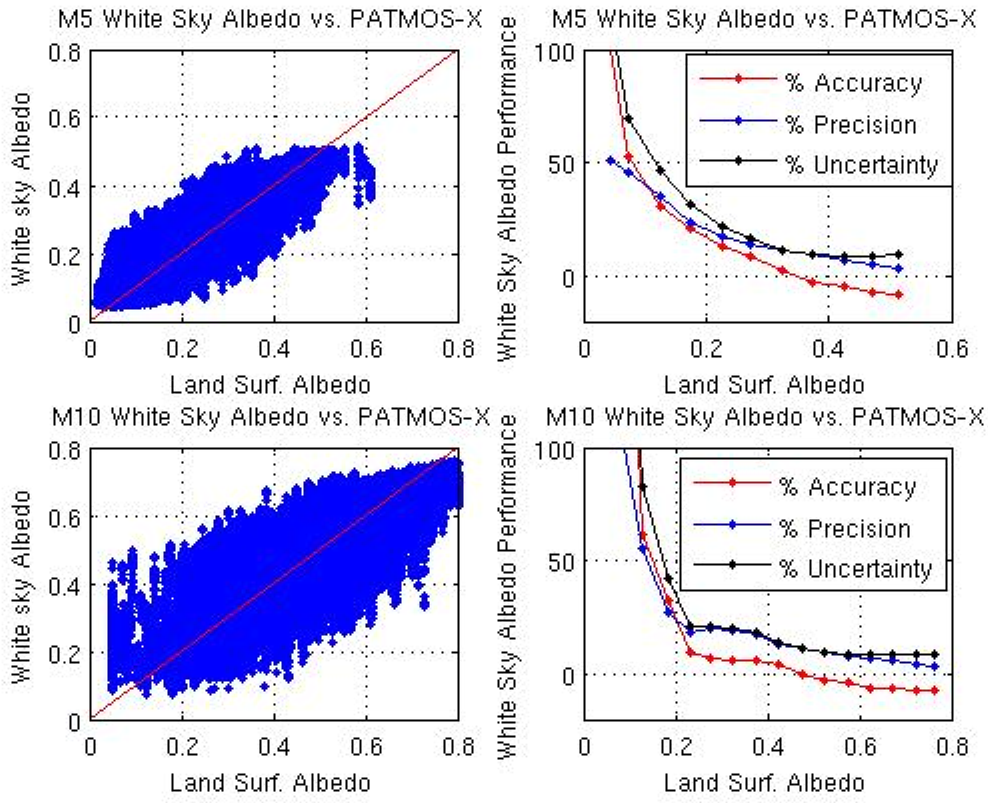





- Updated EPS shows better performance
- Large number of off diagonal pixels are no longer in the Updated retrievals

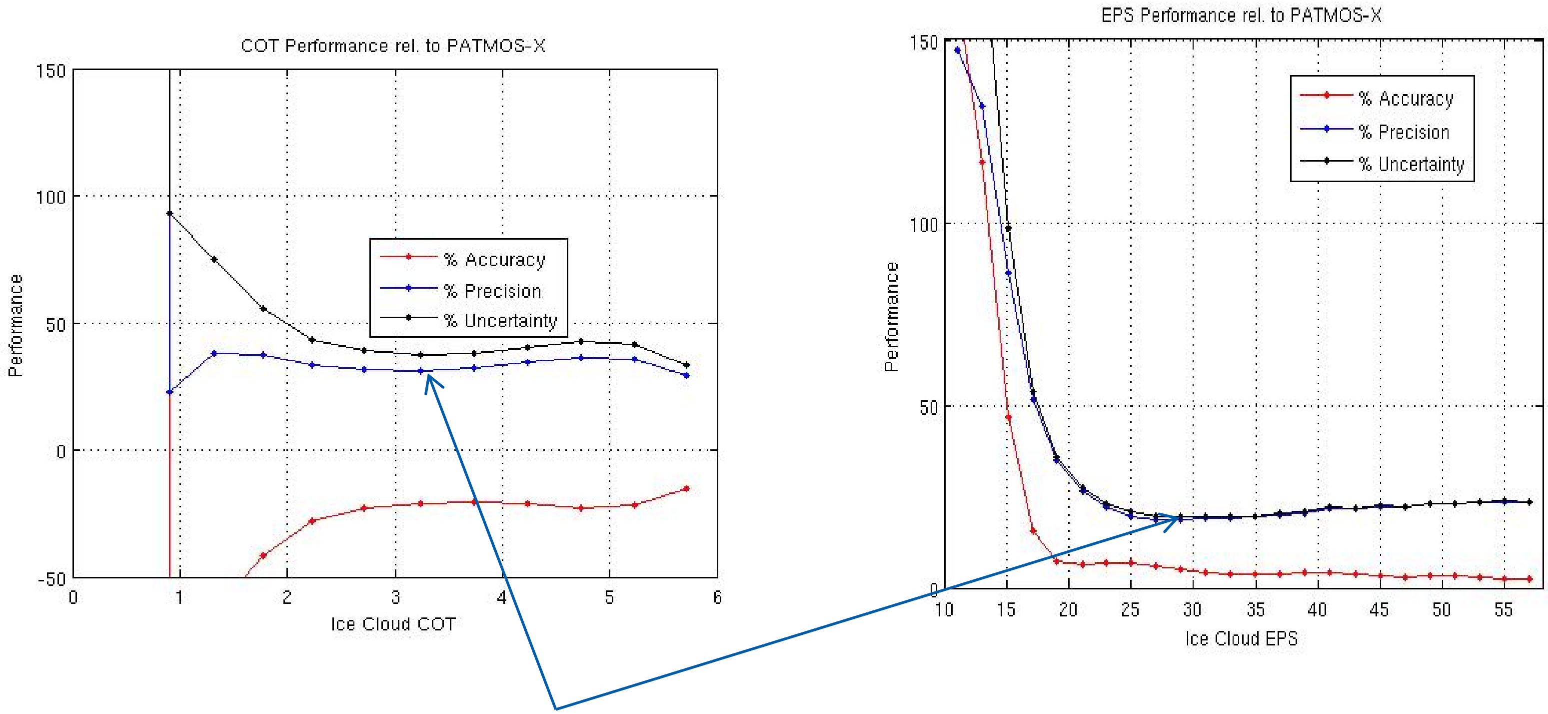
# Statistics Of VIIRS Granulated And PATMOS-X Land Surface Albedo




- Precision error dominates the overall uncertainty
- This albedo precision error will translate into precision errors in COT/EPS performance statistics

# Statistics of IDPS COT/EPS Performance Relative To PATMOS-X, Due To Differences In Land Surface Albedo

NORTHROP GRUMMAN




- Precision error dominates the overall uncertainty in COT/EPS performance
- These COT/EPS precision errors are direct results of precision errors in albedo noted above

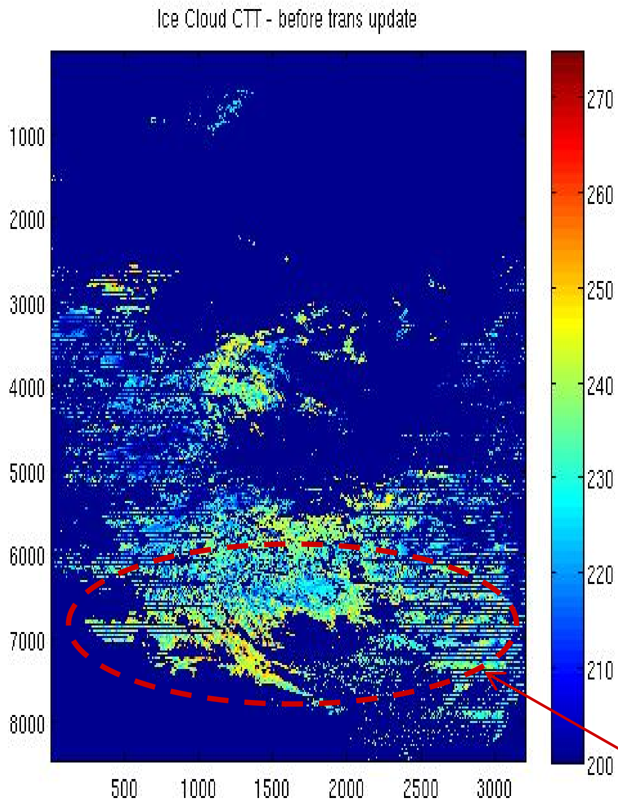
# Focus Areas Contributing To The Low Bias In Ice Cloud Top Height

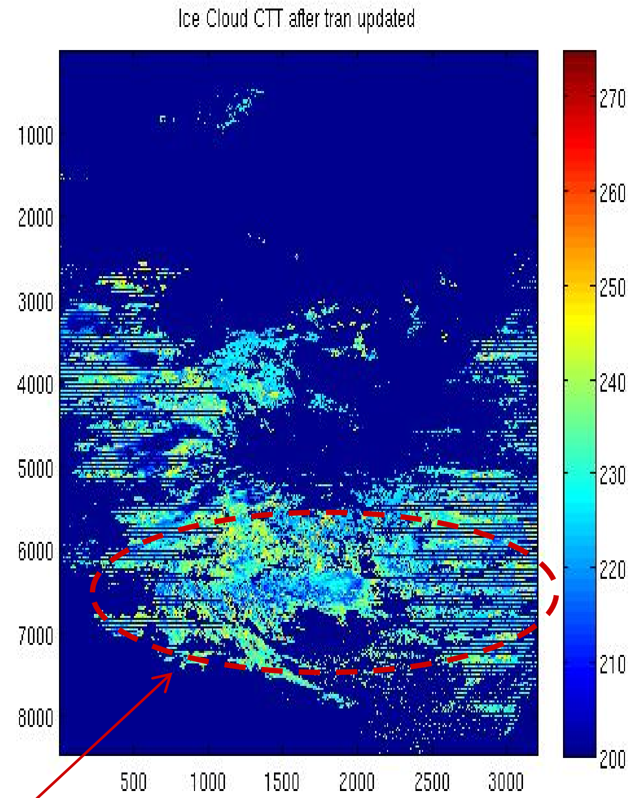
- Error in clear sky radiances due to Non-VIIRS RSR used in Pfaast RTM – DR to be submitted to correct for the discrepancies

- Error in land surface emissivities – to be investigated along with the above

- Error in the above cloud water vapor transmission effect – Correcting an error in transmission effect for ice clouds, preliminary results were obtained and presented here

# Comparison In Ice Cloud CTT Between the Baseline and COP Code Updated To Remove Error In Above Cloud Transmission Correction – Scene Of Africa, 08/20/13 11:41-11:57

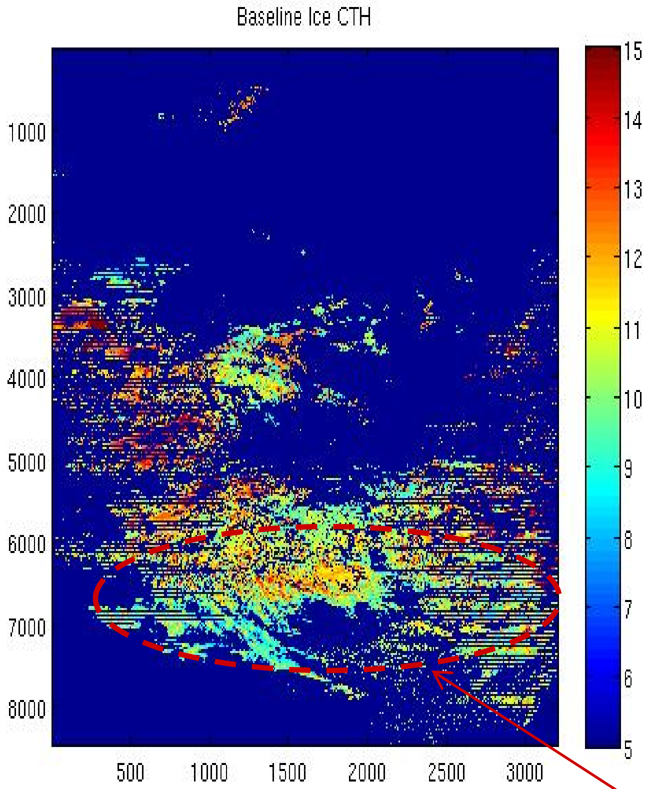


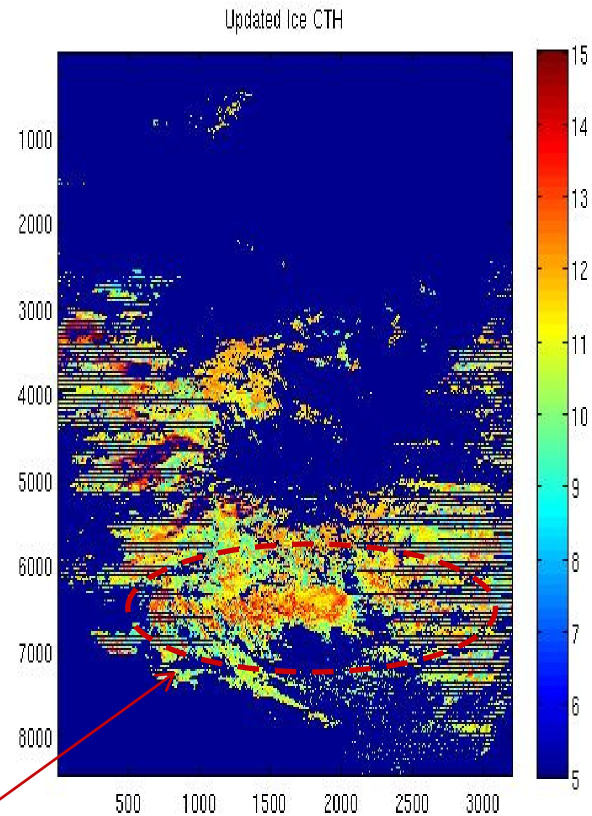




- After code update ice cloud CTT is noticeably colder thus raising CTH
- Removing the error in transmission correction will reduce the low CTH bias seen in Calipso data comparisons

# Comparison In Ice Cloud CTH Between the Baseline and COP Code Updated To Remove Error In Above Cloud Transmission Correction – Scene Of Africa, 08/20/13 11:41-11:57

NORTHROP GRUMMAN




Correcting the transmission error raised the CTH, therefore reducing the low bias

# Concluding Remarks

NORTHROP GRUMMAN

**Summary**

- 2 major issues derived from the Provisional Cloud Properties Review are discussed here : (1) Discrepancies in COT/EPS comparisons; (2) low bias in ice cloud CTH
- Approached are identified to address these 2 major issues affecting the performance of the cloud properties products
- From preliminary results it was found that the discrepancies in COT/EPS are caused by the differences in land surface albedo used between the VIIRS and PATMOS-X code
- The COT/EPS issue can be completely resolved once the VIIRS COP code is updated with the Granulated surface albedo
- For the reduction of the low bias in ice cloud CTH 3 candidates: errors in clear sky radiance derived from MODIS Pfaast RTM, surface emissivities and above cloud transmission were identified
- With preliminary testing results it was demonstrated that correction to the above cloud transmission error reduces the low bias
- With updates to Pfaast and perhaps including surface emissivities the ice cloud CTH low bias issue will be completely resolved

**Conclusion**

- With completion of these 2 DR updates to COP it is expected all IDPS cloud properties products will meet the JPSS L1RD requirements, thus advancing the products to Validated stage1 Maturity

THE VALUE OF PERFORMANCE.

NORTHROP GRUMMAN

# Preparation for assimilation of aerosol optical depth data from NPP VIIRS in a global aerosol model

Edward J. Hyer[1]
Peng Lynch[2]
Jeffrey S. Reid[1]
Douglas L. Westphal[1]

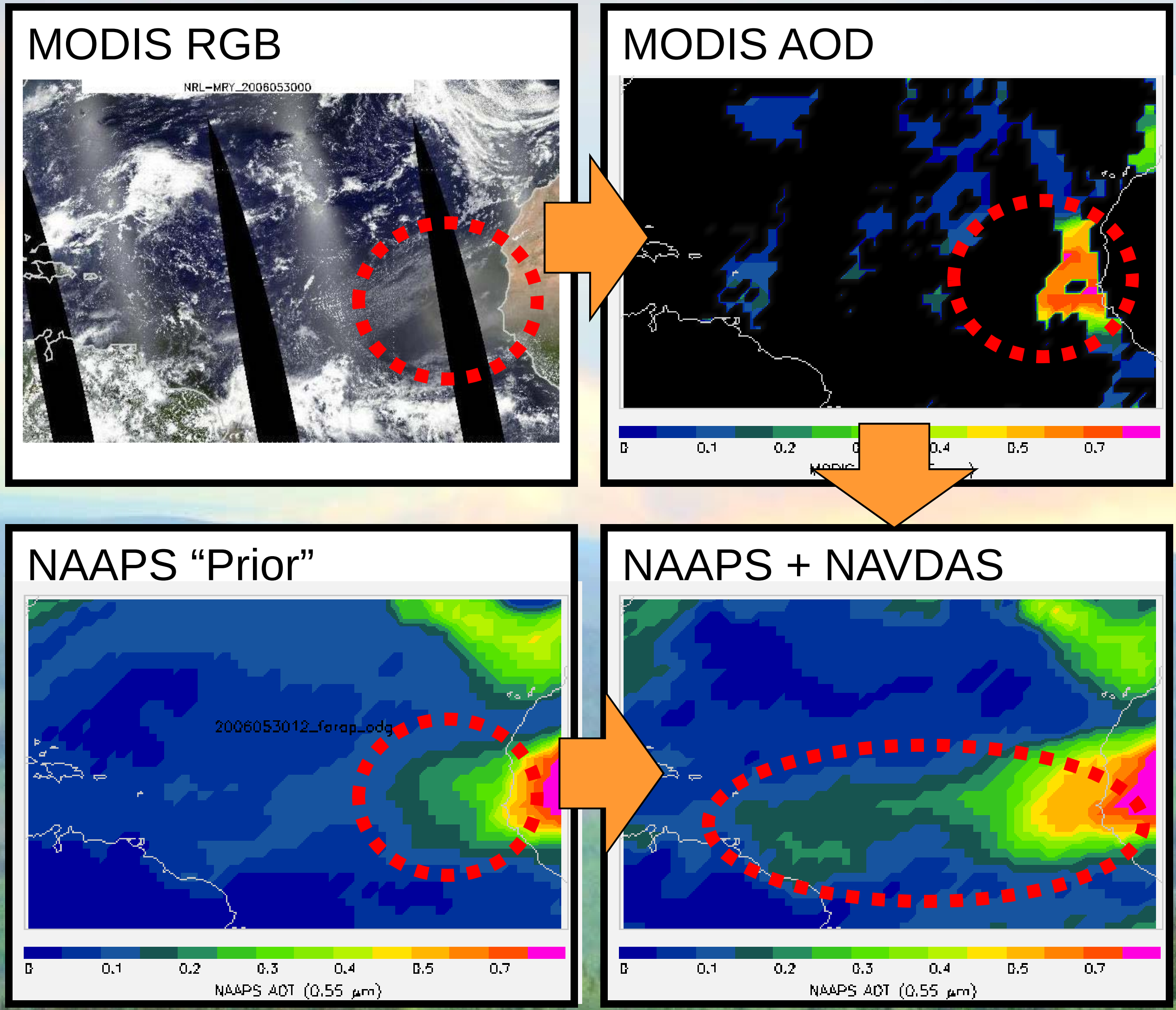
1. NRL, Monterey, CA
2. Computer Science Corporation

***And the JPSS Aerosol Cal/Val Team***

# In This Talk

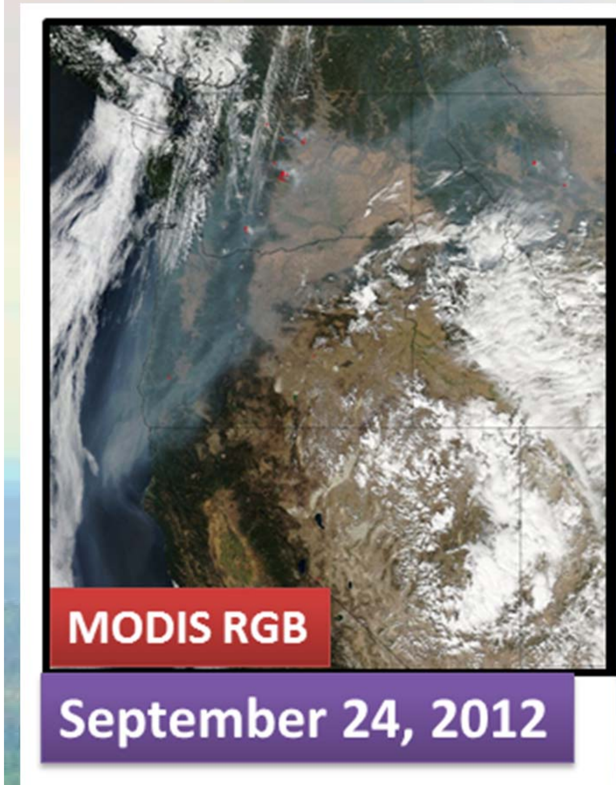
- Data Requirements for Aerosol Assimilation
- Preparation of NPP VIIRS products for assimilation
- Observations of processed VIIRS data
- Conclusions / Prospects

# Navy Global Aerosol Forecasting

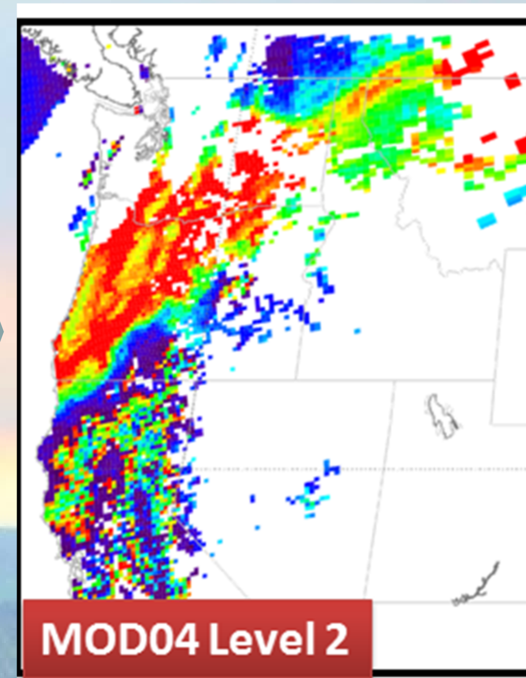



- **Navy Aerosol Analysis and Prediction System (NAAPS) operational since 2005**
- **Navy Variational Data Assimilation System for AOD (NAVDAS-AOD) Operational at FNMOC from September 2009 (MODIS over ocean)**
- **Global MODIS is assimilated operationally as of February 2012**
- **J.L. Zhang et al., "A System for Operational Aerosol Optical Depth Data Assimilation over Global Oceans", JGR 2008.**

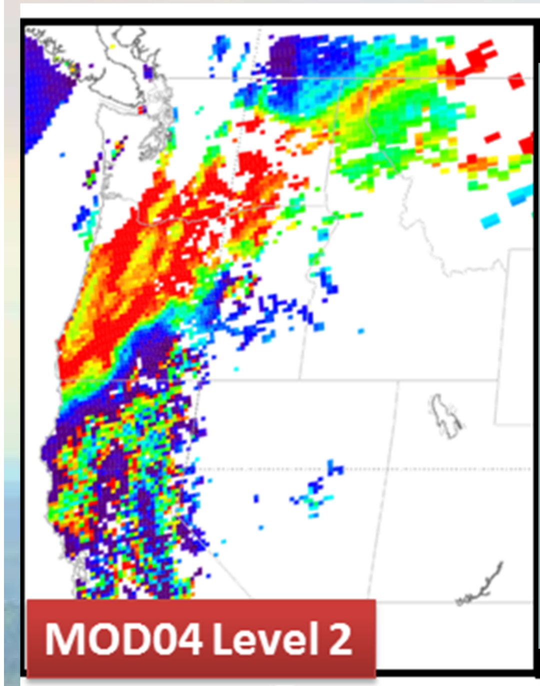
# Preparation of Satellite Data for Assimilation




**Level 2 MOD04 (NASA) or VAOOO EDR (JPSS) data is generated by upstream data centers – spatial resolutions of a few km**



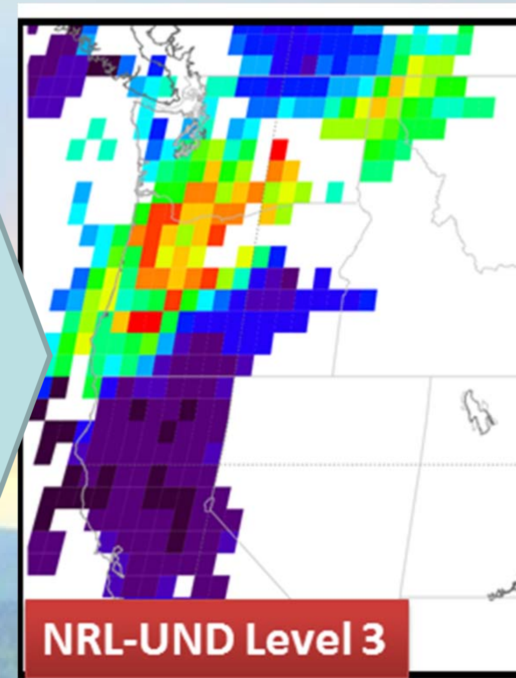
# Preparation of Satellite Data for Assimilation




AOD data process developed by NRL and UND, includes

- Aggressive cloud filtering
- Ocean wind speed correction
- Land albedo correction
- land surface and snow filters
- Microphysical AOD bias correction

0.5 degree product distributed to public via NASA LANCE (MxDAODHD)



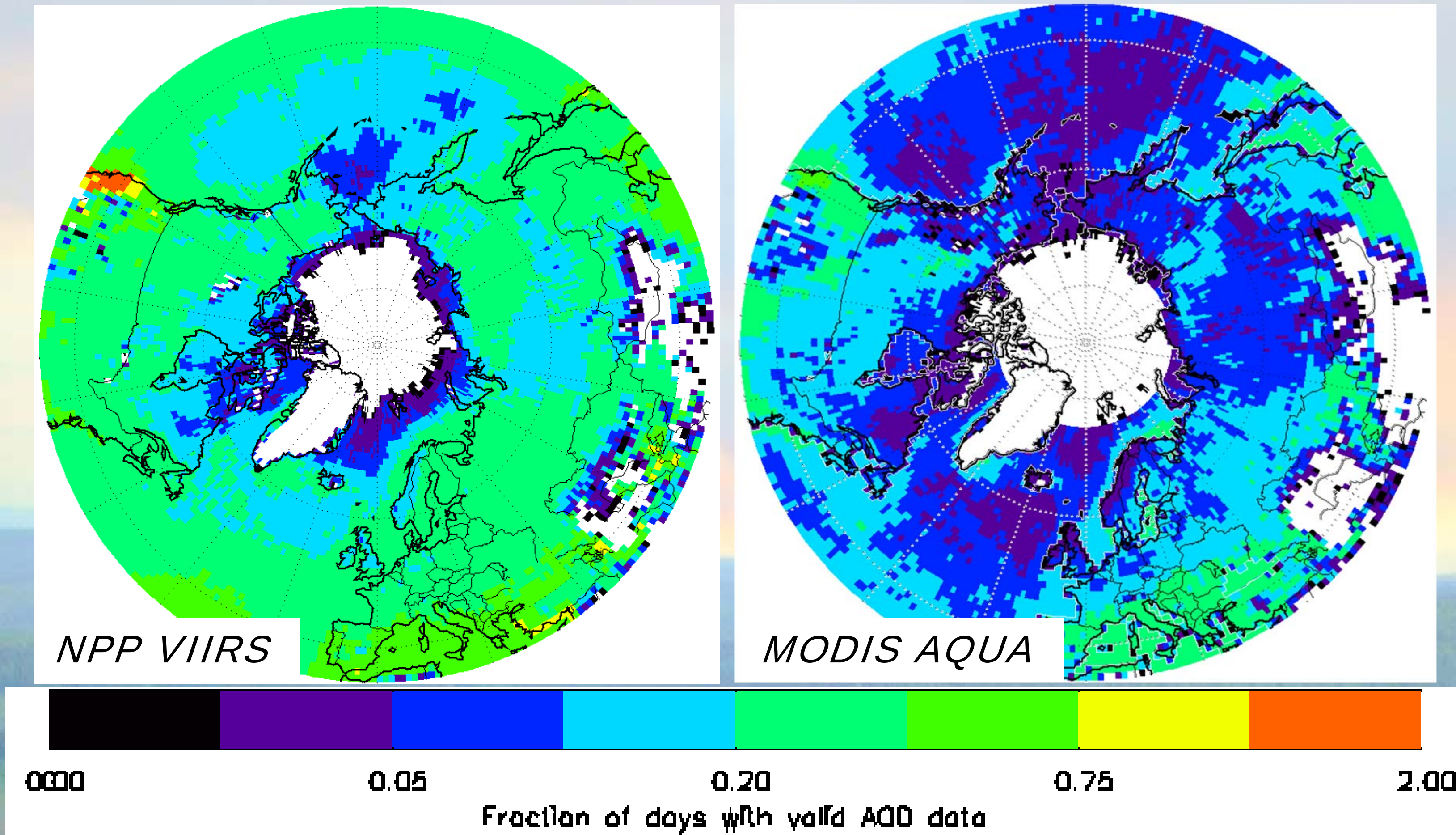

This is the process developed for MODIS Collection 4&5

How much pre-processing will be required for Suomi NPP VIIRS?

# NPP VIIRS pre-processor

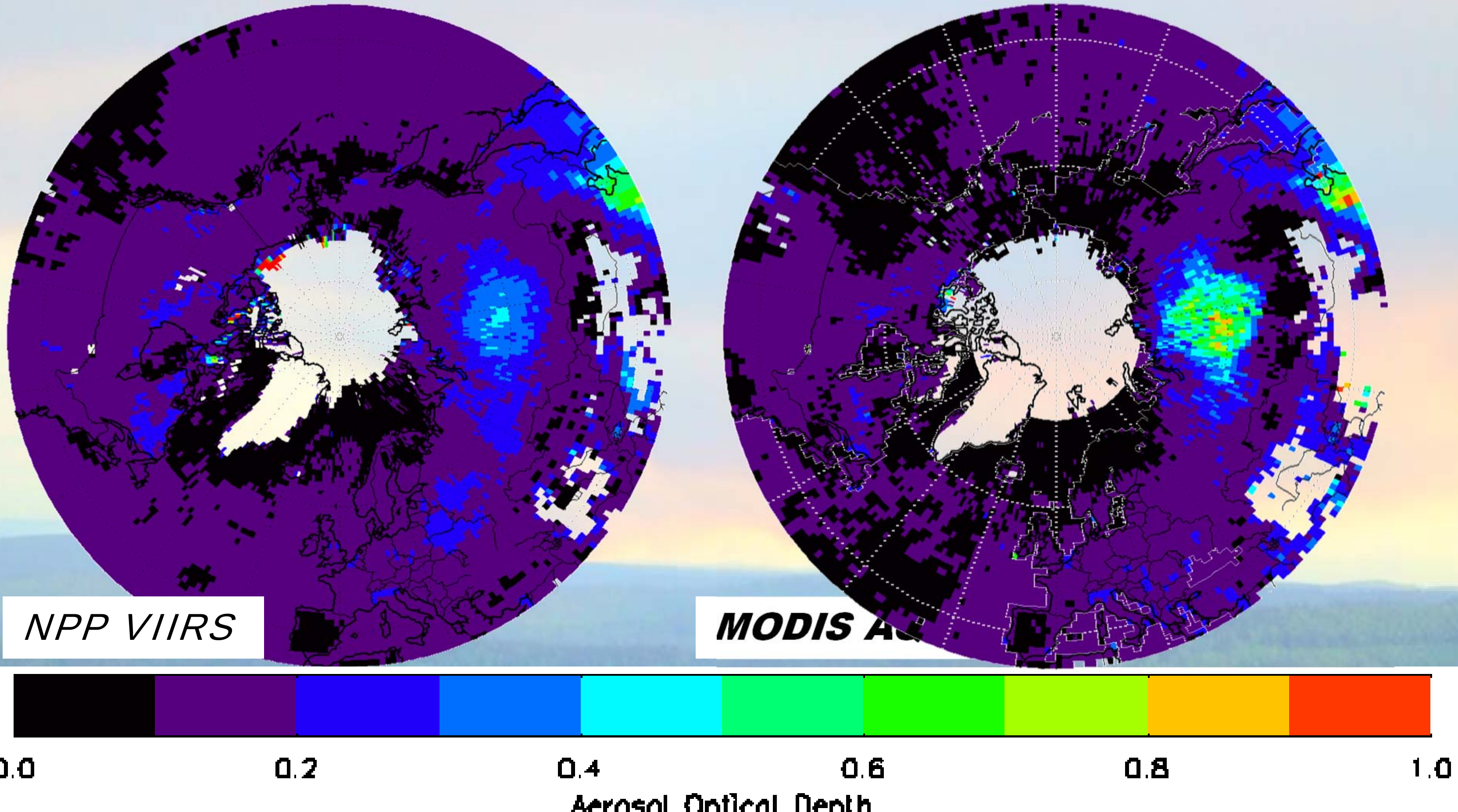
- 1-degree, 6-hour
  - **Operational NAAPS now 1/3°**, 1° used for testing
- “fullQA” uses information packaged with EDR granules
  - QA = ‘High’ (highest EDR QA value)
  - Cloud mask, cloud proximity, snow flags, glint flags
  - No textural filtering (this is a cal/val experiment, not an operational candidate)
- Results shown using 12 months of data
  - 2013.01.24.00 to 2014.01.12.00

# VIIRS ‘fullQA’ coverage vs NRL-UND Level 3 MODIS-- Land



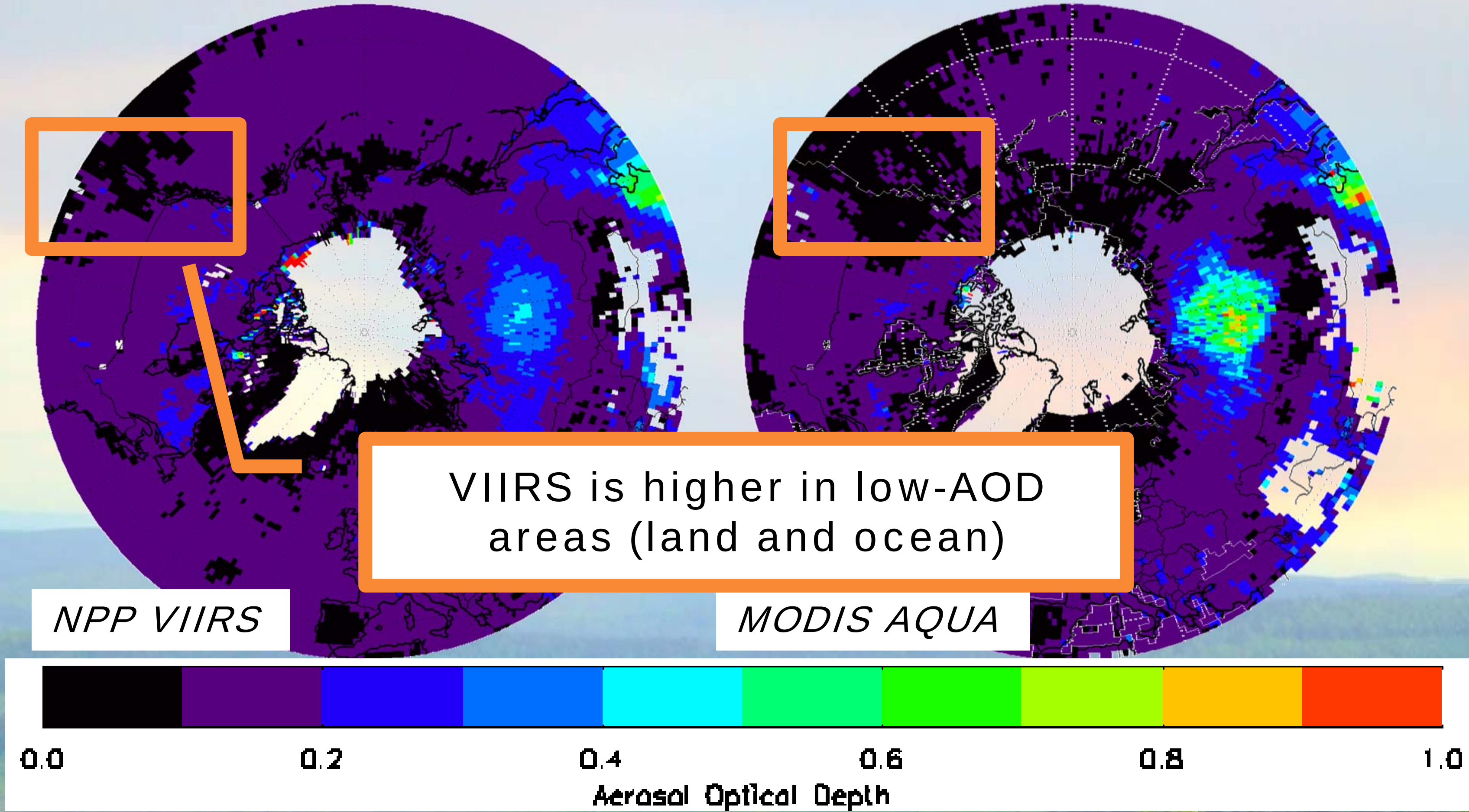

- NRL/UND Level 3 MODIS is stringently filtered
- **VIIRS potentially delivers much more data vs 1 MODIS**
  - **Almost as much as 2 MODIS**

# VIIRS ‘fullQA’ AOD vs NRL-UND Level 3 MODIS-- Ocean




Global patterns match very well
VIIRS has smaller excluded area, greater coverage

# VIIRS ‘fullQA’ AOD vs NRL-UND Level 3 MODIS-- Ocean



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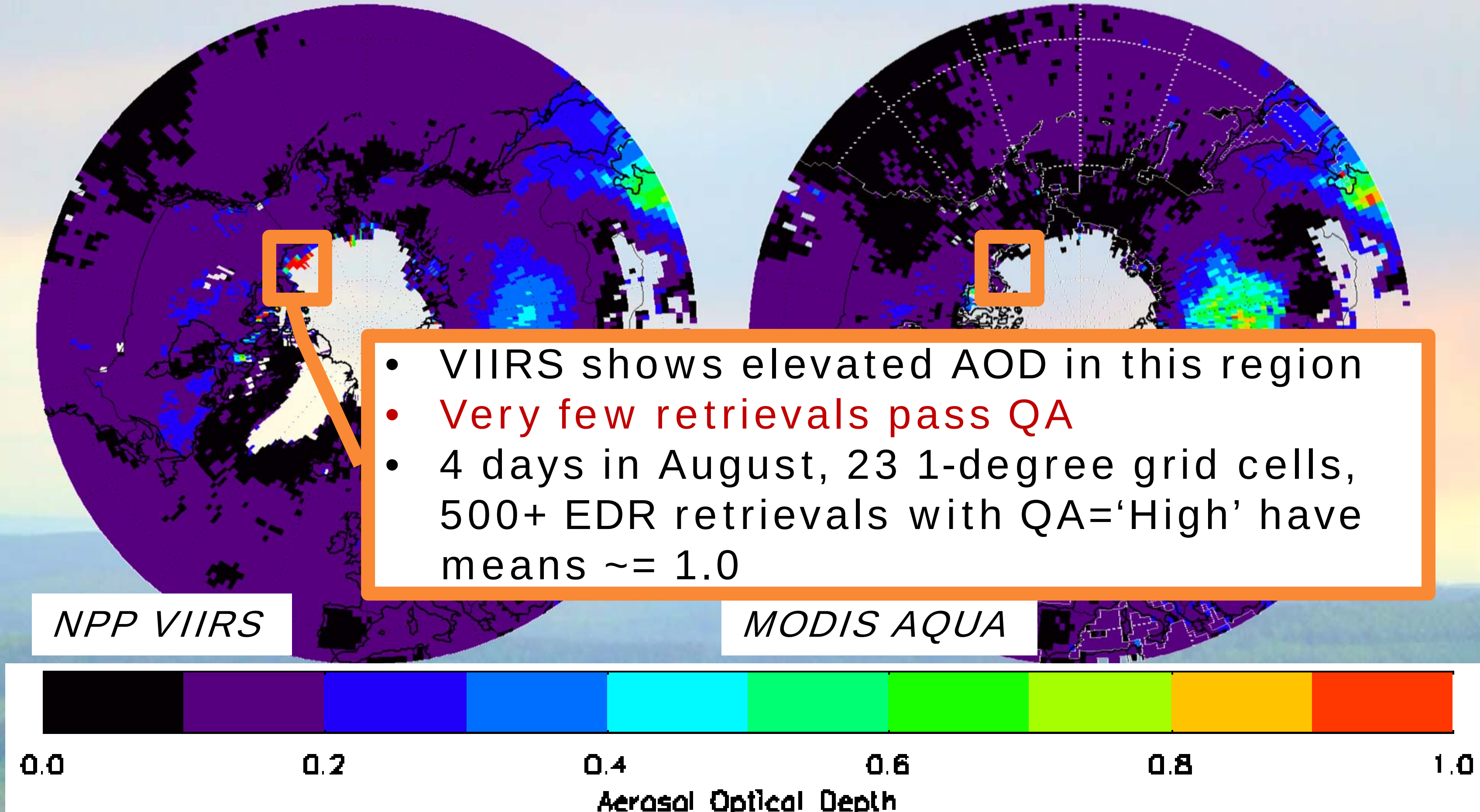
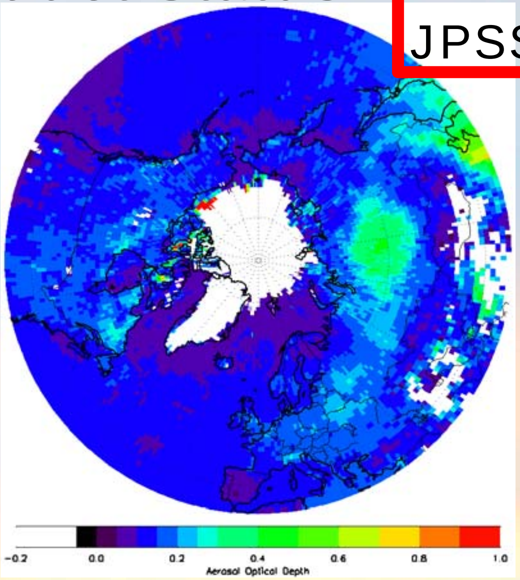



- VIIRS shows elevated AOD in this region
- Very few retrievals pass QA
- 4 days in August, 23 1-degree grid cells, 500+ EDR retrievals with QA=‘High’ have means ~= 1.0

# Attempt at DA-ready VIIRS AOD

## NPP VIIRS Aerosol Product Status

VIIRS with JPSS QA only




- We are testing a heavily filtered VIIRS aerosol dataset based on IDPS products
- All data:
  - Best QA
  - All granule ancillary data used to filter
    - (cloud adjacency, etc.)
  - Textural filtering for clouds (limit on local variability of AOD)
- Over-land:
  - MCD43 snow filter used
  - (adapted from NRL/UND MODIS processing)
- Over-ocean
  - Excluded above 65N
- **Products have been generated at UW PEATE, assimilation testing is now underway at NRL**

# Attempt at DA-ready VIIRS AOD

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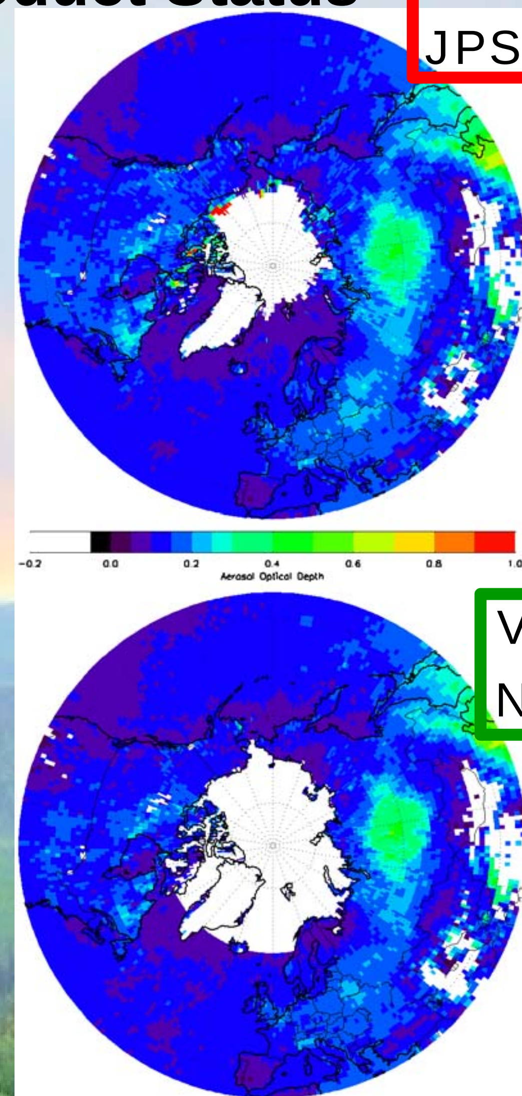

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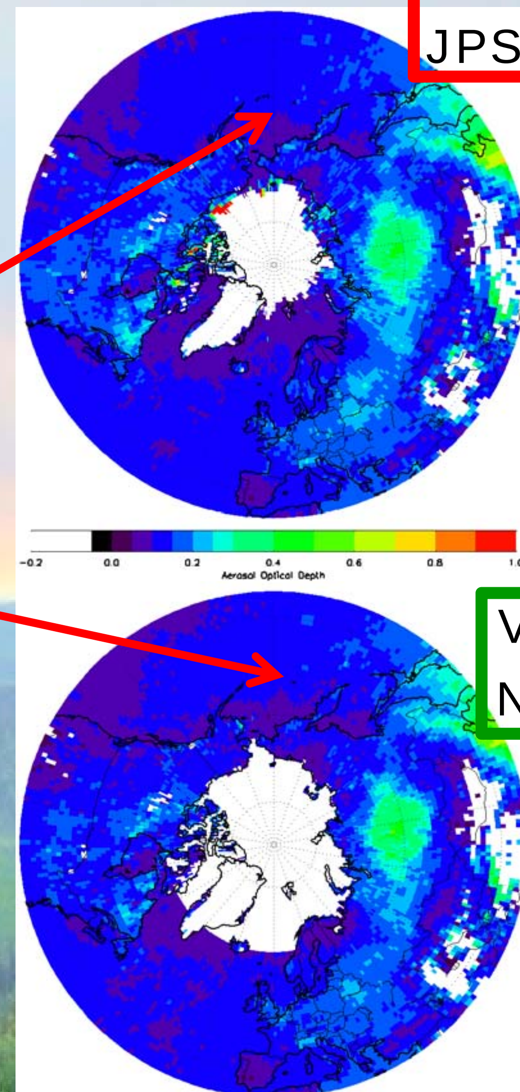
VIIRS with JPSS QA only




VIIRS with NRL filters

# Attempt at DA-ready VIIRS AOD

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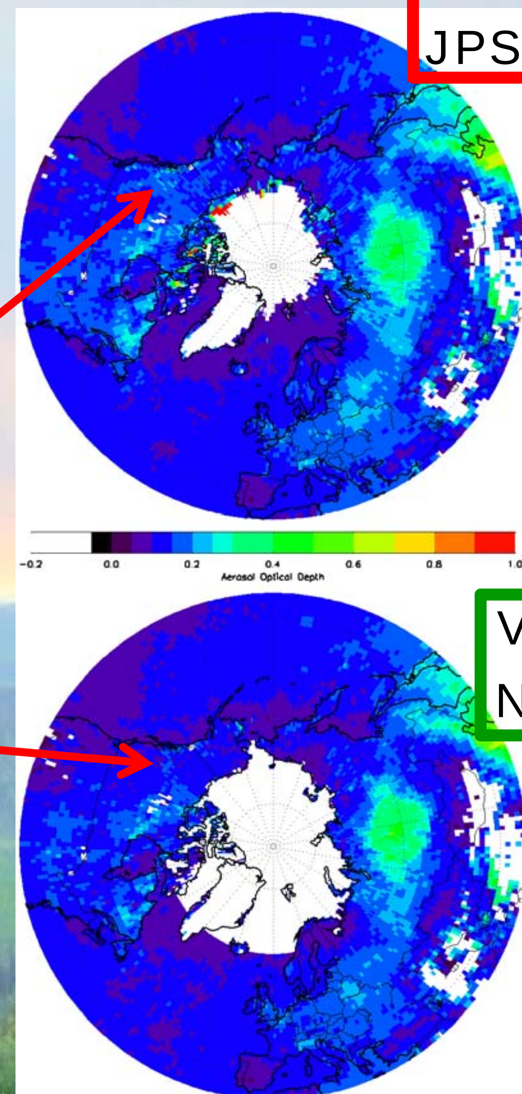

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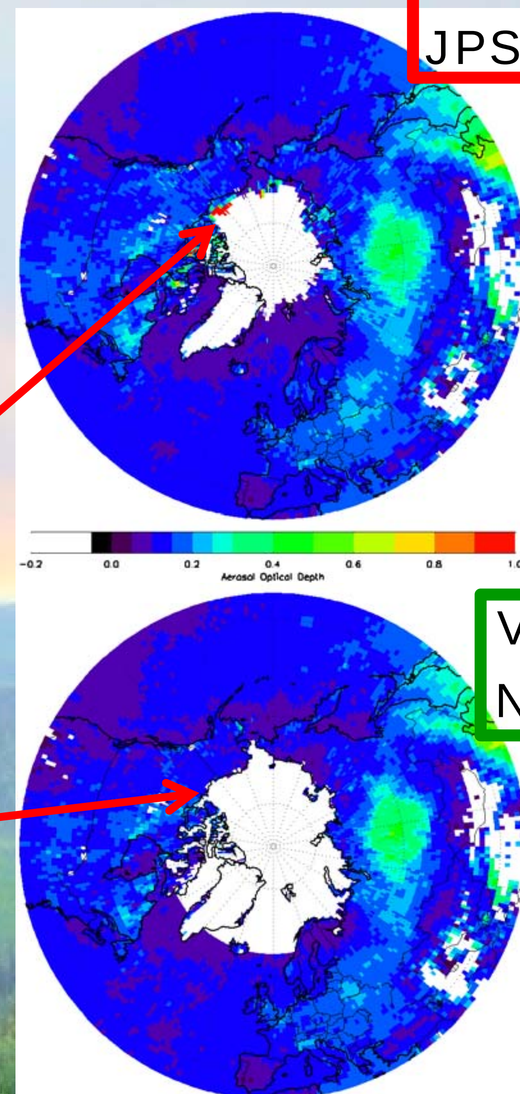
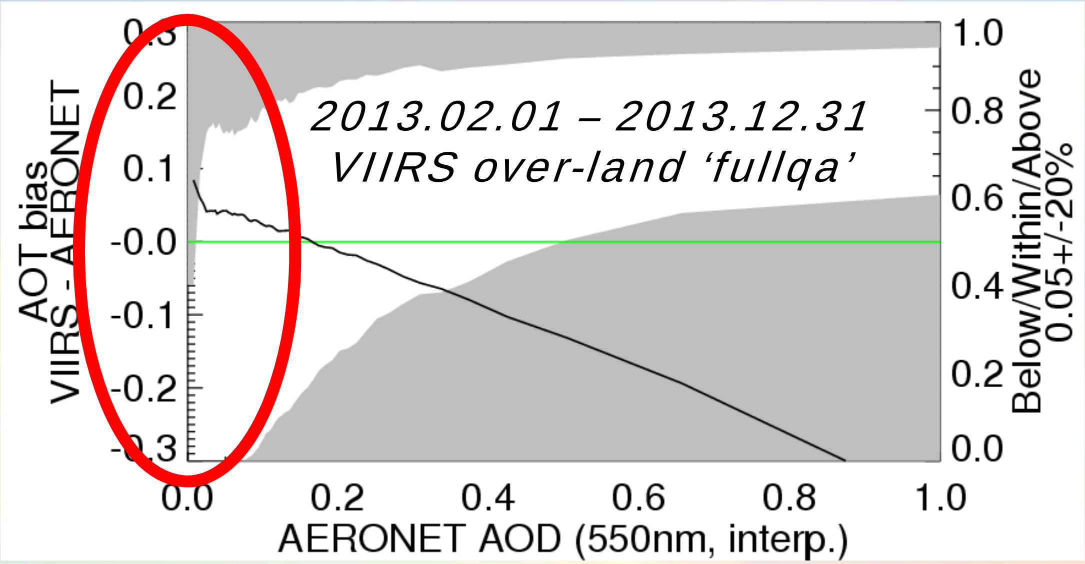
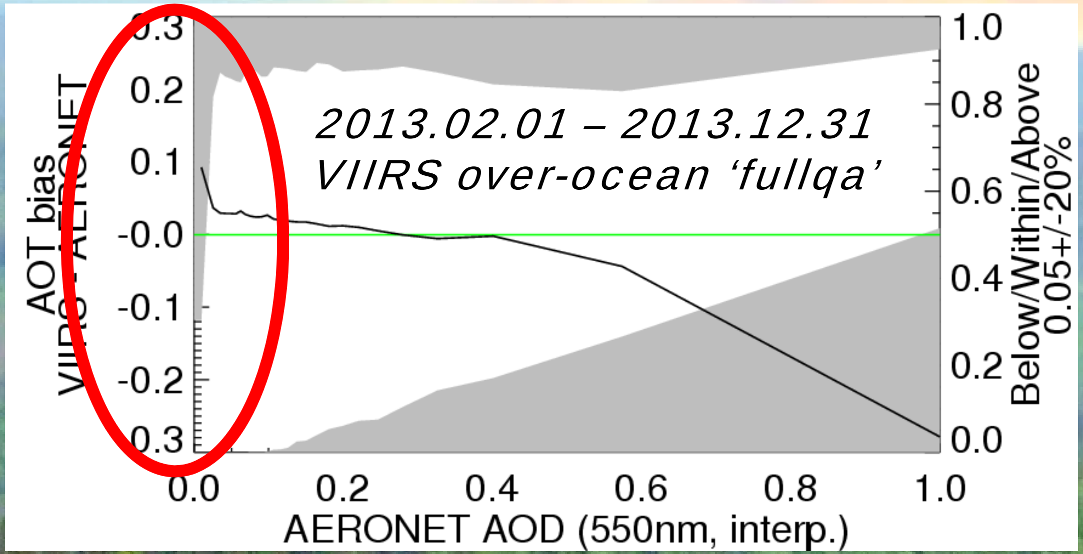


# 1-degree products vs AERONET



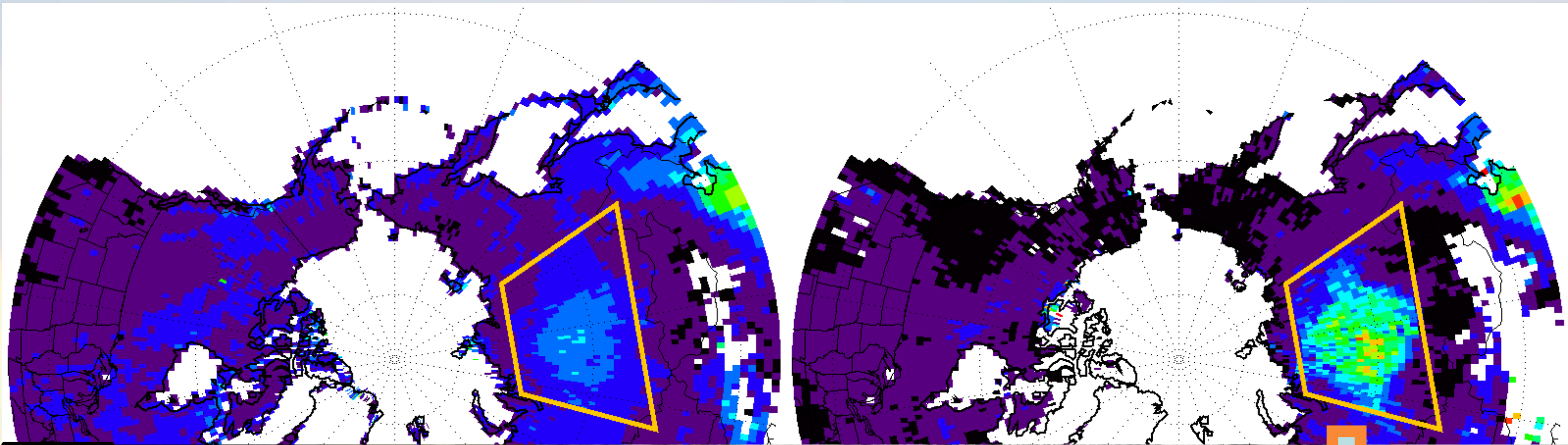

**(left) White bar indicates % of data within 0.05+/-20%, gray bars indicate % above or below. At low AOD, positive errors dominate.**

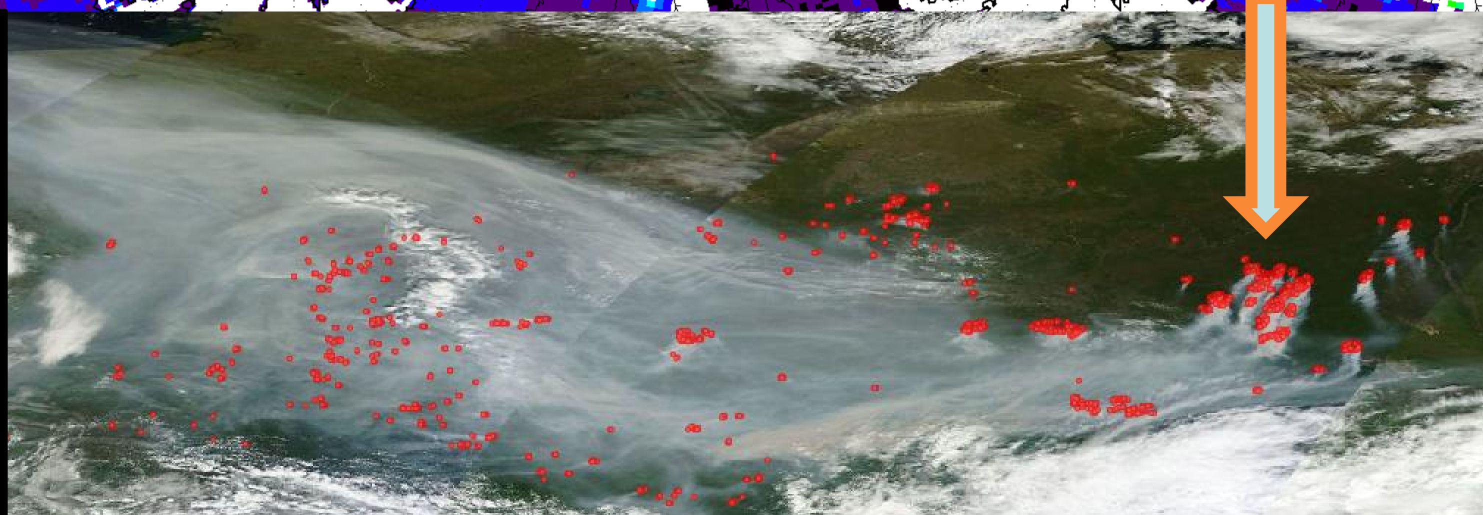
VIIRS product from JPSS has truncation problem at low AOD

- AOD retrieval is uncertain: MODIS permits negative AOD values
- When aggregated, zero truncation results in positive bias

- We'll get to high optical depths momentarily
- **This is not a problem that can be fixed with filtering**

# Comparison for high-AOD case



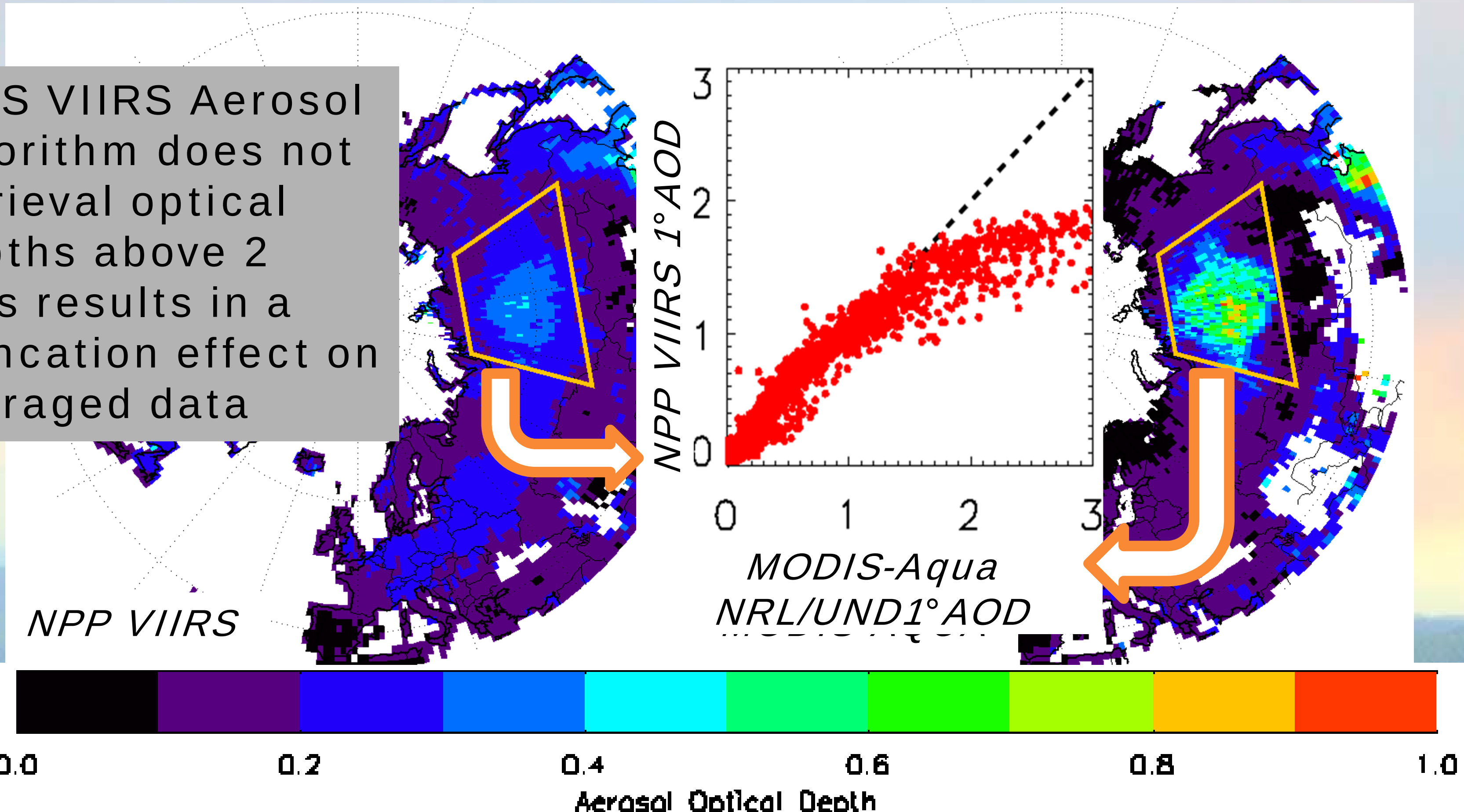


NASA LANCE Worldview
MODIS Aqua 3 August 2013

- **Massive midsummer Siberian fires**
- **Episodic, intense plumes**
- **Signal in VIIRS is much lower than MODIS**

# Comparison for high-AOD case

- IDPS VIIRS Aerosol algorithm does not retrieval optical depths above 2
- This results in a truncation effect on averaged data




- Data in region shown from 2013.07.23 to 2013.08.23
- Suomi NPP VIIRS ‘fullqa’ vs MODIS-Aqua C5 NRL/UND L3

**JPSS Cal/Val team is discussing a fix that would extend valid range of AOD to match MODIS (-0.05 to 5.0). This would mitigate this problem.**

# Results and Next Steps

- NPP VIIRS AOD requires additional filtering of EDR to improve analysis and forecast
- Cal/Val Team has further improvements to over-land AOD data underway
- Additional analysis of over-ocean VIIRS AOD data is needed
- Assimilation testing of candidate DA-ready VIIRS AOD products is underway
- Thank you to sponsors: JPSS, NASA AQAST, NRL

2014 STAR JPSS Science Team Annual Meeting

# The JPSS Risk Reduction Aerosol Algorithm

Hongqing Liu and Istvan Laszlo

May 14, 2014

I.M. Systems Group, Inc.

# Objectives

- Cross-platform consistency
  - Apply a single algorithm on JPSS and GOES-R
- Extensive internal tests
  - Minimize the dependence on external cloud mask
- Extending the range of aerosol optical thickness
  - Extend the retrievals for episodic aerosol events
- Address known issues in IDPS algorithm
  - Snow/ice contamination
  - Positive bias of Ångström Exponent over water
  - Globally constant land spectral reflectance ratios
  - Degraded or no retrievals over soil-dominated area
  - Negative bias for high AOT over land

# Algorithm Comparison (Over Water)

| | IDPS | NOAA |
|---|---|---|
| **Internal Tests** | Turbid water; Sun glint; Sea ice | Bright cloud; Cirrus; Sea ice; Spatial homogeneity; Turbid/shallow water; Heavy aerosol |
| **Aerosol Models** | MODIS C4 | MODIS C5 |
| **Surface Reflectance** | $R_f+R_u+R_s$ | $R_f+(1-R_f)R_u+(1-W)R_s$ [Koepke, 1984] |
| **AOT Range** | [0.0, 2.0] | [-0.05, 5.0] |
| **Channel Used** | 0.67, 0.74(saturation), 0.86, 1.24, 1.61, 2.25 µm | **0.55**, 0.67, 0.74(saturation), 0.86, 1.24, 1.61, 2.25 µm |
| **Residual** | $\sum_{\lambda=1}^{n}\left(\rho_\lambda^m-\rho_\lambda^{LUT}\right)^2$ | $\sqrt{\sum_{\lambda=1}^{n}\left(\frac{\rho_\lambda^m-\rho_\lambda^{LUT}}{\rho_\lambda^m-\rho_\lambda^{Ray}+0.01}\right)^2 \Big/ n}$ |
| **Ångström Exponent** | 0.86 vs. 1.61 µm | 0.55 vs. 0.86 µm<br>0.86 vs. 1.61 µm |
| **Inland Lakes** | No retrievals | Included |

# Algorithm Comparison (Over Land)

| | IDPS | NOAA |
|---|---|---|
| **Internal Tests** | Cirrus; Sunglint; Fire; Snow; Ephemeral water | Cloud; Cirrus; Snow; Spatial homogeneity; Ephemeral water; Heavy aerosol |
| **Aerosol Models** | AERONET | MODIS C5 |
| **Surface Reflectance Spectral Relationship** | Constant ratios | Linear relationship as functions of $NDVI_{SWIR}$ and scene redness |
| **AOT Range** | [0.0, 2.0] | [-0.05, 5.0] |
| **Reference Channels** | 0.48 and 0.67 µm | 0.48 and 0.67 µm (SW scheme)<br>0.48 and 2.25 µm (SWIR scheme) |
| **Residual** | $\sum_{\lambda=1}^{n}\left(\alpha_{\lambda}^{corr}-\alpha_{\lambda}^{est}\right)^{2}$ | $\sqrt{\sum_{\lambda=1}^{n}\left(\frac{\rho_{\lambda}^{m}-\rho_{\lambda}^{LUT}}{\rho_{\lambda}^{m}-\rho_{\lambda}^{Ray}+0.01}\right)^{2}/n}$ |
| **Ångström Exponent** | Dictated by selected aerosol model | Independent channel retrieval |

# Land Aerosol Algorithm

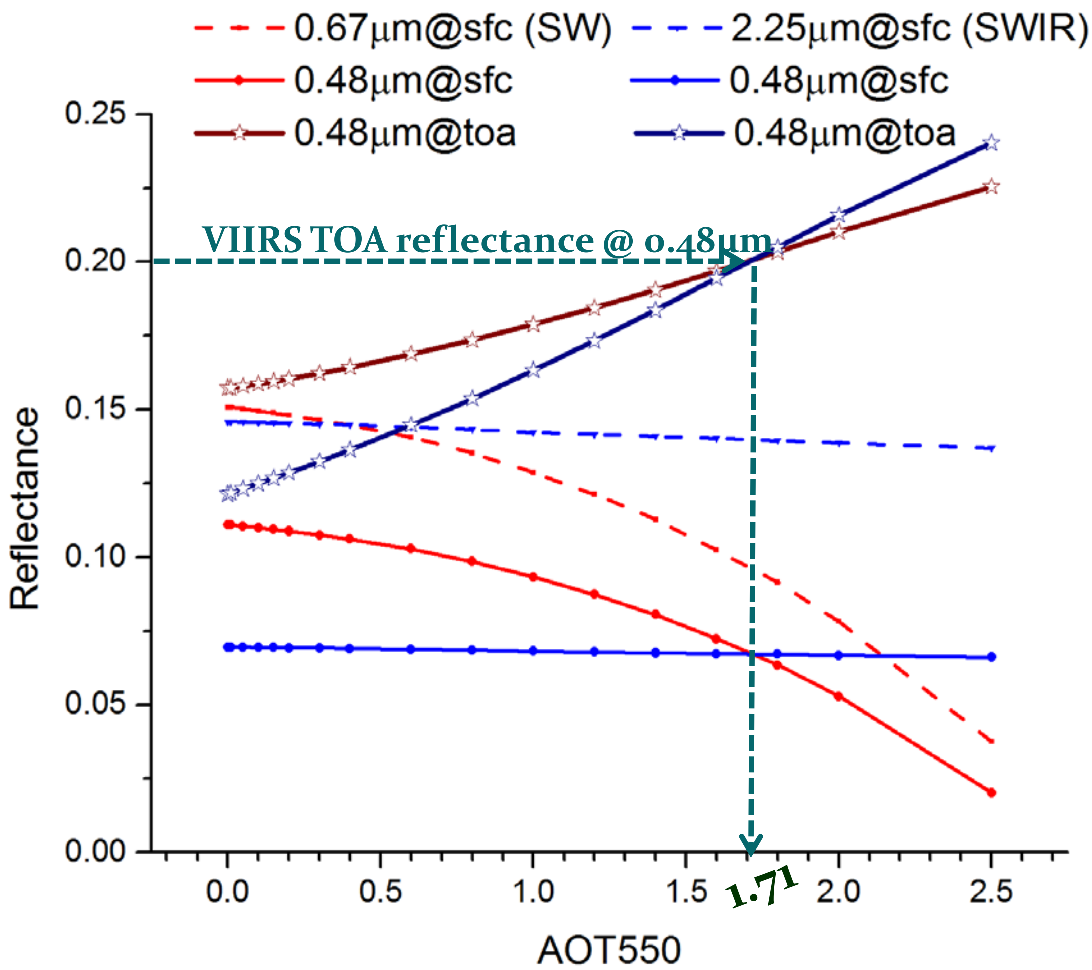
- IDPS VIIRS (SW scheme)
  - Surface reflectance at 0.48μm is estimated from 0.67μm
  - Pros: robust spectral surface reflectance relationship
  - Cons: strong atmospheric effect
  - Better performance at low AOTs

- MODIS/ABI (SWIR scheme)
  - Surface reflectance at 0.48μm is estimated from 2.25μm
  - Pros: transparent atmosphere at 2.25μm
  - Cons: uncertain spectral surface reflectance relationship
  - Better performance at high AOTs

- JPSS Risk Reduction Aerosol Algorithm (NOAA VIIRS)
  - SW scheme as the first choice
  - Apply SWIR algorithm if
    - Invalid retrievals from SW scheme
    - Surface reflectance at 0.48μm is out of uncertainty range
  - Surface spectral reflectance relationship are linear functions of redness ratio (TOA M5/M4 reflectance ratio) and $NDVI_{SWIR}$ (TOA M8-M11/M8+M11)

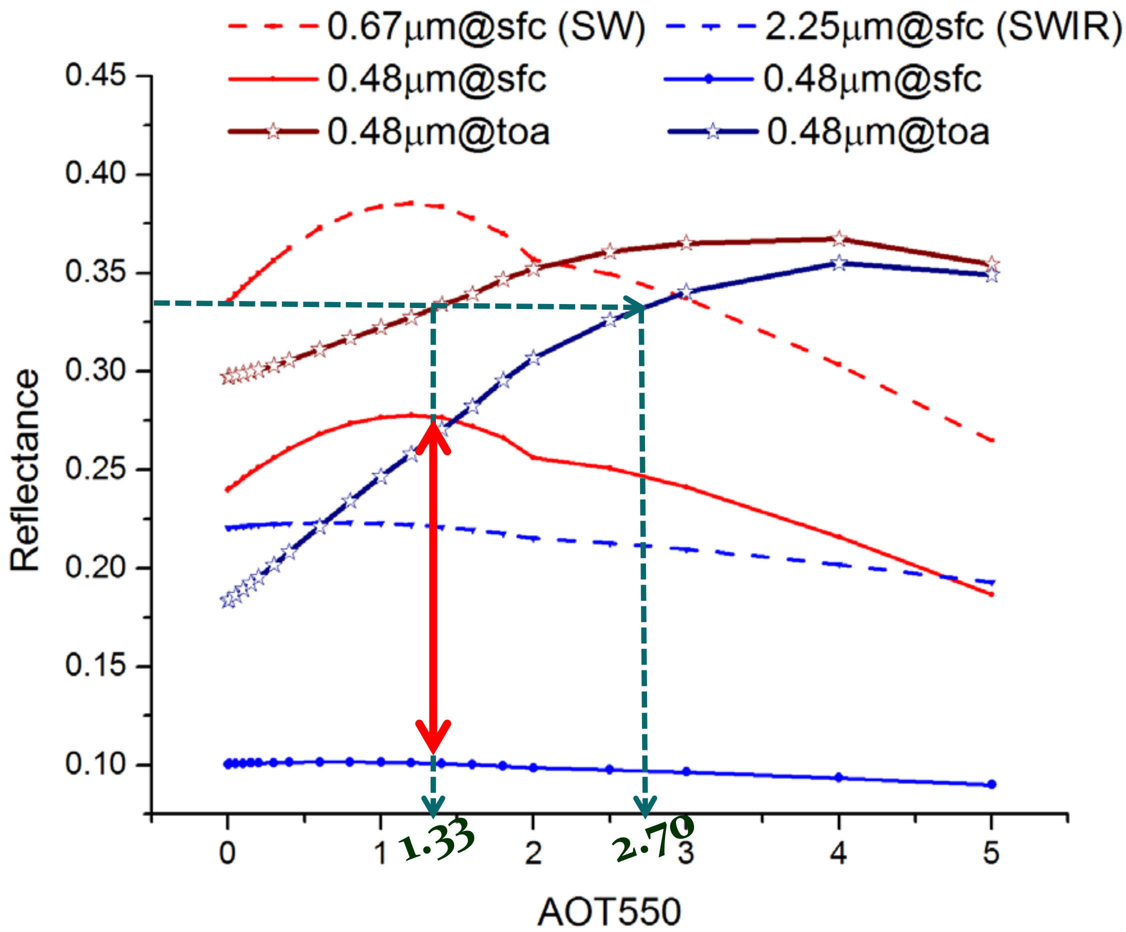
$$Y = (c_1+c_2*Redness+c_3*NDVI_{SWIR}) + (c_4+c_5*Redness+c_6*NDVI_{SWIR})*X$$

# Land Aerosol Algorithm (Cont.)



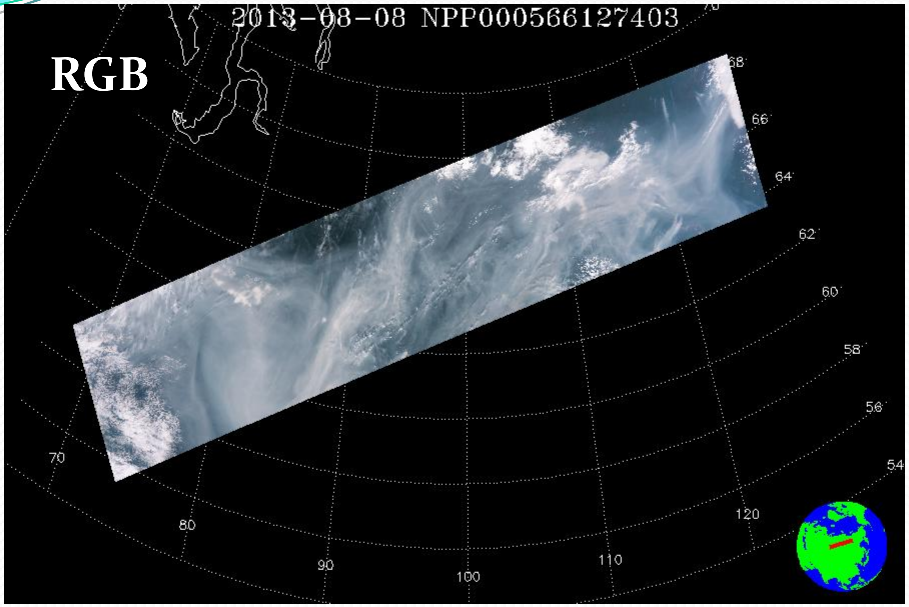

- Measurement
  - AERONET station: Taihu (China)
  - June 9, 2012
  - $\tau_{550}$ =1.71
- Retrieval
  - Urban aerosol model
  - $\tau_{550}$ =1.71 from both SW and SWIR schemes

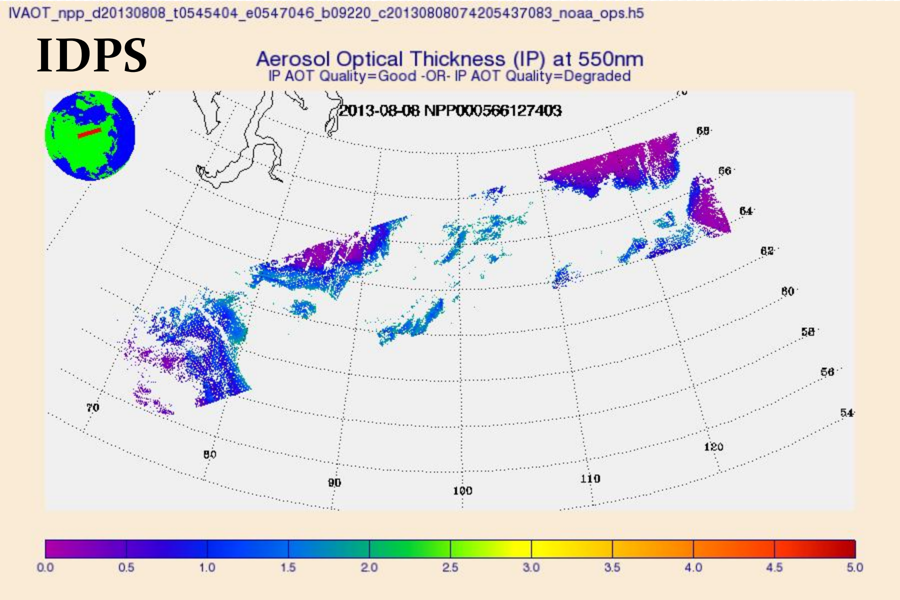
# Land Aerosol Algorithm (Cont.)

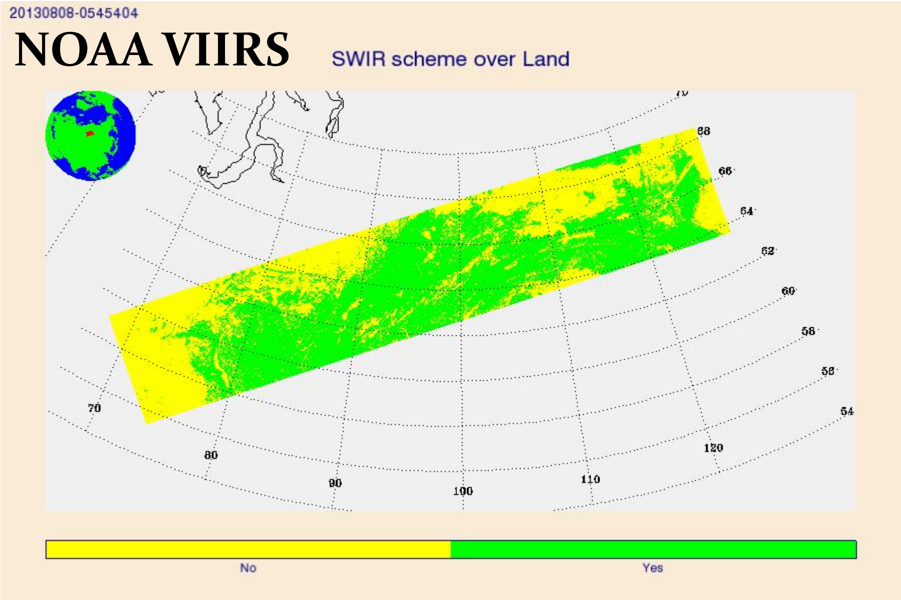


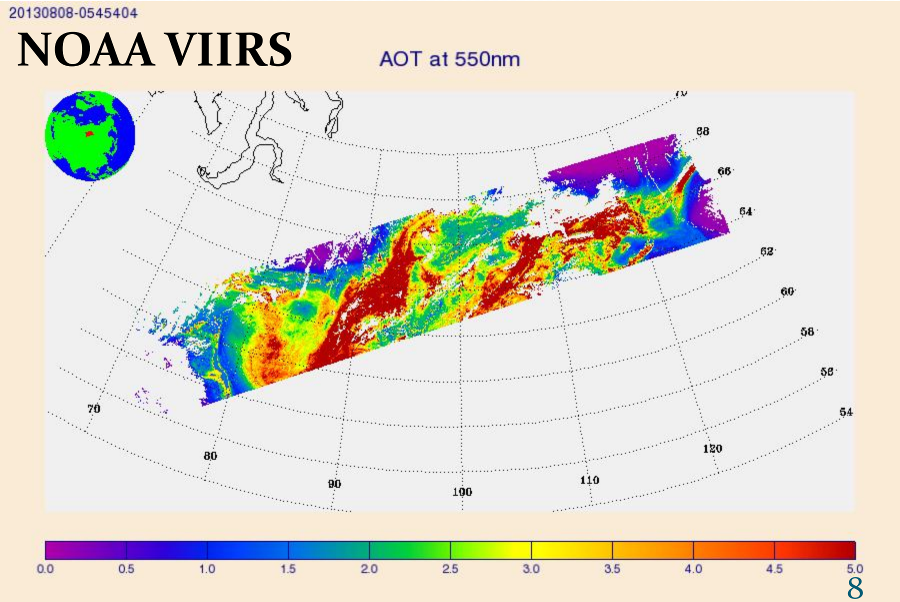

- Measurement
  - AERONET station: Karachi (Pakistan)
  - June 6, 2012
  - $\tau_{550}$ =2.70
- Retrieval
  - Generic aerosol model
  - $\tau_{550}$ =1.33 from SW scheme
  - $\tau_{550}$ =2.70 from SWIR scheme

# Land Aerosol Algorithm (Example)



# Local Retrievals

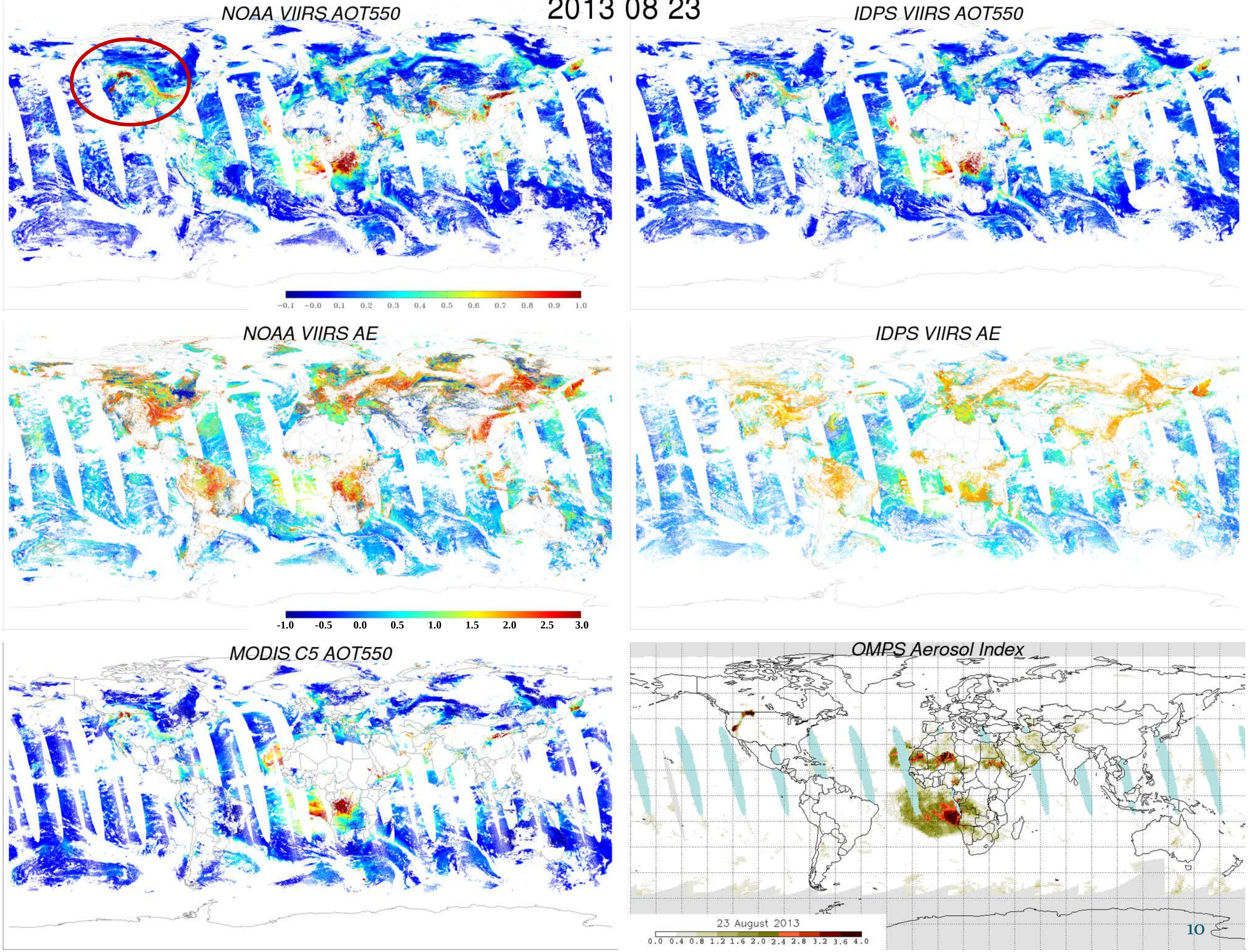
- Local retrievals with JPSS Risk Reduction Aerosol Algorithm
  - Global retrievals (74 days)
    - 03/01/2013 – 03/01/2014; every 5 days
    - Wider spatial coverage from RR algorithm

| Spatial Coverage | $N_{NOAA}/N_{IDPS}$ | $N_{NOAA}/N_{MODIS}$ |
|---|---|---|
| **Over Land** | 1.62±0.13 | 4.79±0.49 |
| **Over Ocean** | 1.04±0.08 | 2.73±0.17 |

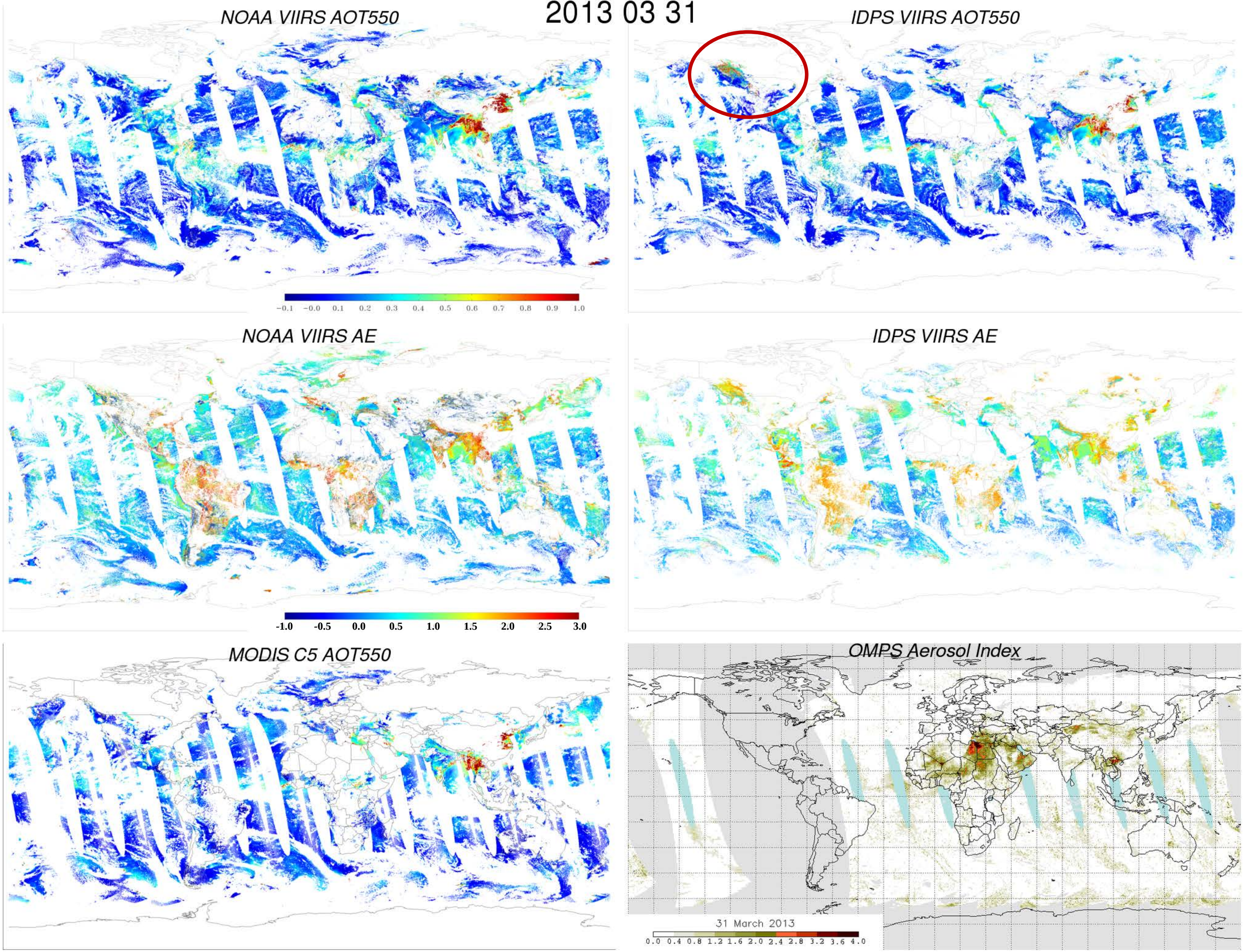
Spatial coverage is evaluated by counting the number of 0.1° grids containing retrievals

  - Retrievals over AERONET match-ups
    - 05/02/2012 – 03/31/2014
    - Satellite retrievals within 20km-radius circle (centered on stations)
    - AERONET measurements within one-hour window (centered on satellite overpass time)

# 2013 08 23

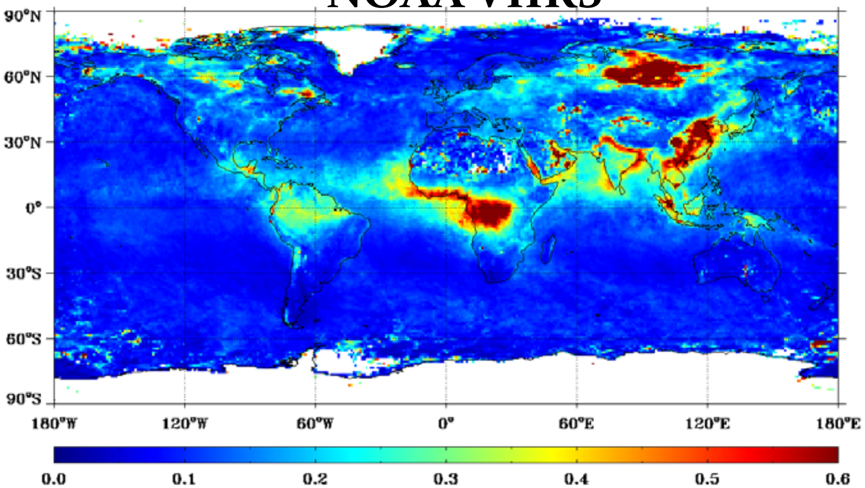


NOAA VIIRS AOT550
IDPS VIIRS AOT550
-0.1 -0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
NOAA VIIRS AE
IDPS VIIRS AE
-1.0 -0.5 0.0 0.5 1.0 1.5 2.0 2.5 3.0
MODIS C5 AOT550
OMPS Aerosol Index
23 August 2013
0.0 0.4 0.8 1.2 1.6 2.0 2.4 2.8 3.2 3.6 4.0

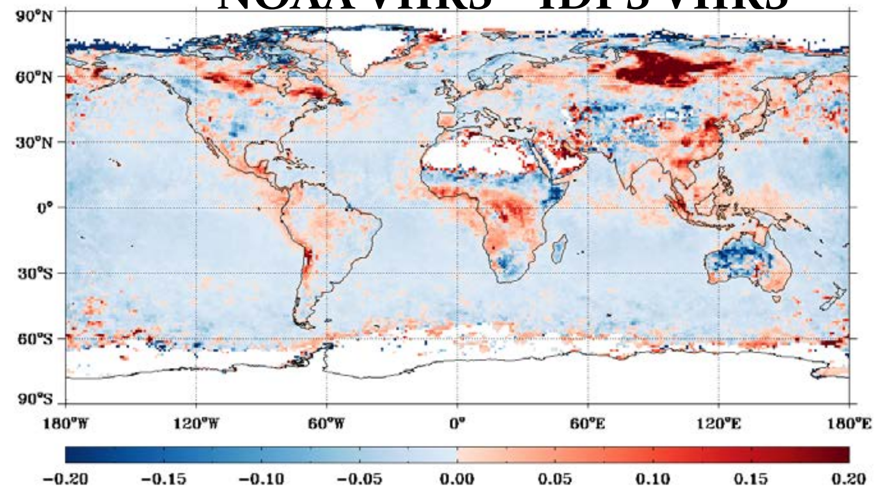

2013 03 31
NOAA VIIRS AOT550
IDPS VIIRS AOT550
−0.1 −0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
NOAA VIIRS AE
IDPS VIIRS AE
-1.0 -0.5 0.0 0.5 1.0 1.5 2.0 2.5 3.0
MODIS C5 AOT550
OMPS Aerosol Index
31 March 2013
0.0 0.4 0.8 1.2 1.6 2.0 2.4 2.8 3.2 3.6 4.0

# Global 1° Gridded

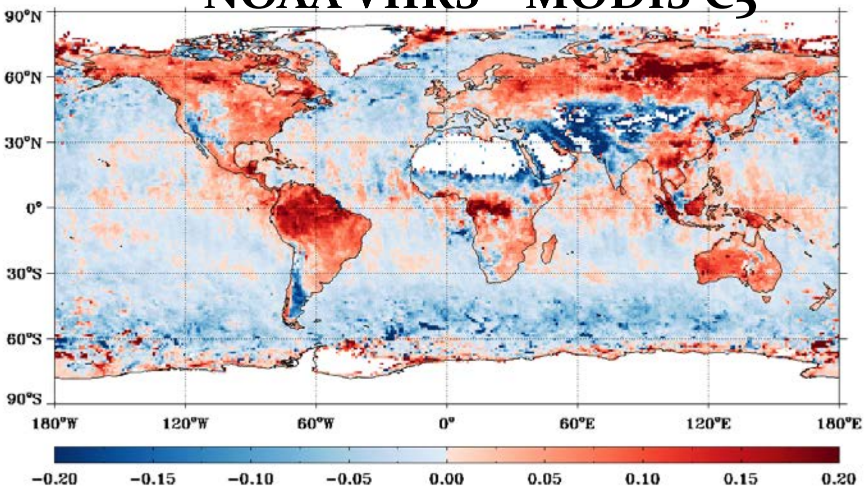
**NOAA VIIRS**



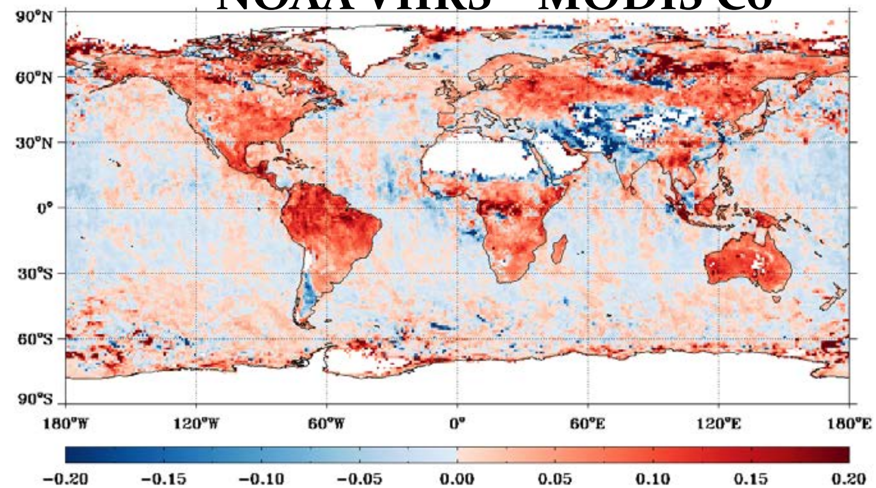

**NOAA VIIRS – IDPS VIIRS**



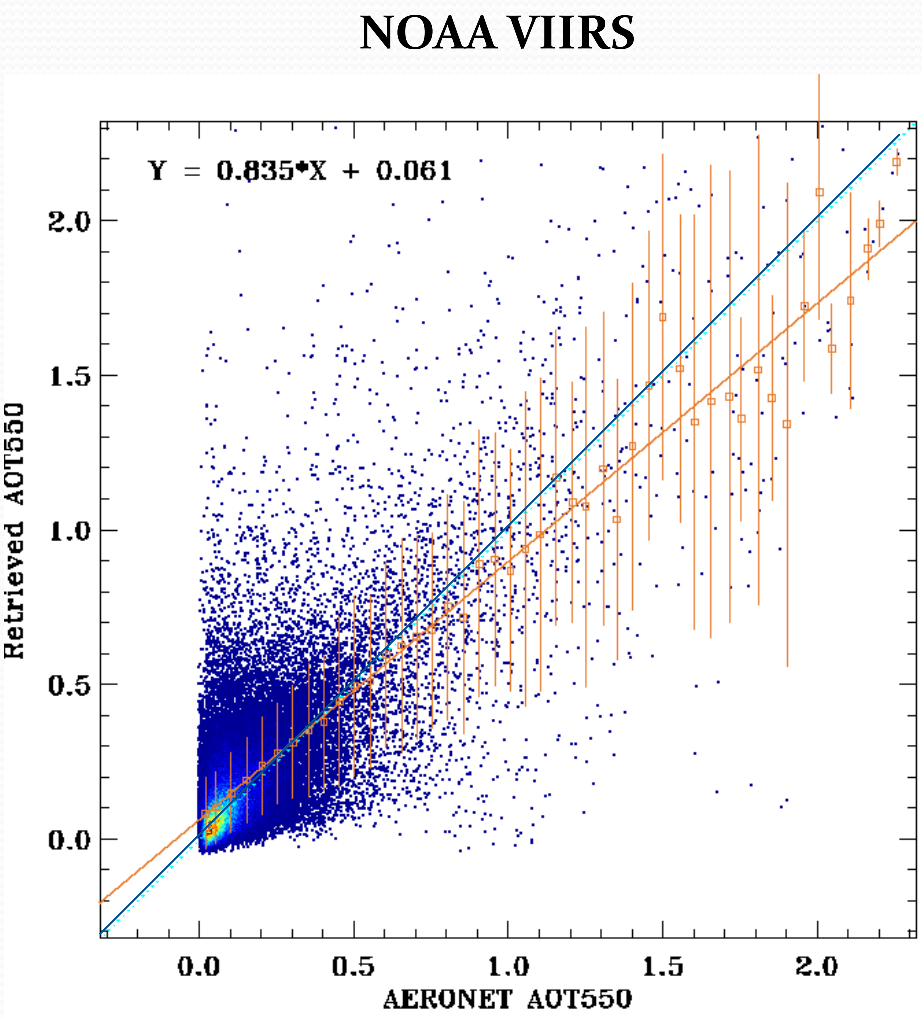

**NOAA VIIRS – MODIS C5**

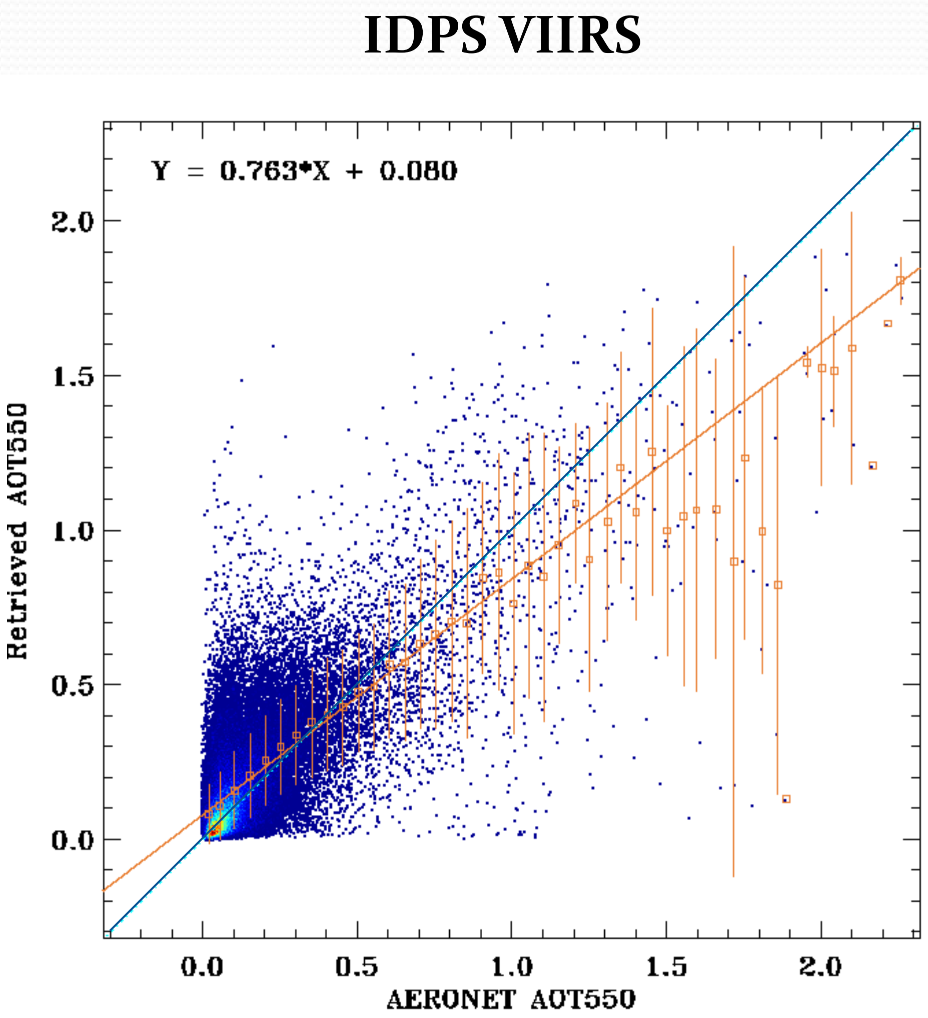



**NOAA VIIRS – MODIS C6**



# Validation Over Land

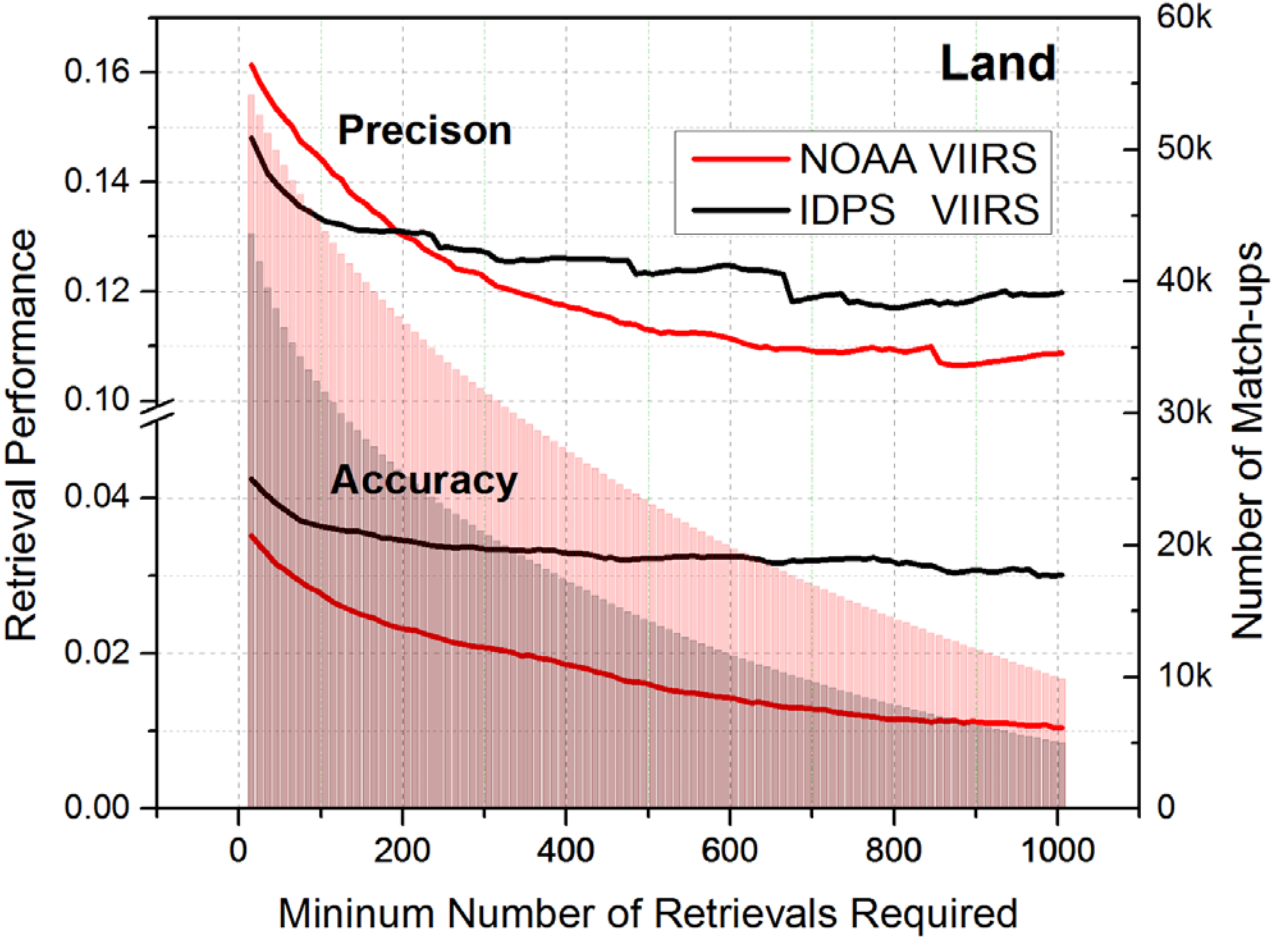


# Statistics

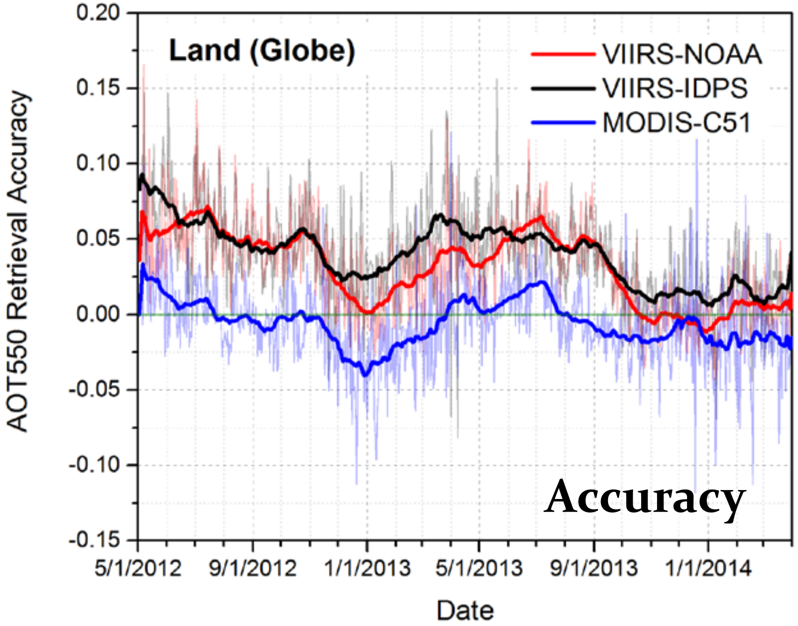
| LAND | | NOAA-VIIRS | IDPS-VIIRS | Requirement |
|---|---|---|---|---|
| <0.1 | Accuracy | 0.05 | 0.05 | 0.06 |
| | Precision | 0.12 | 0.11 | 0.15 |
| | Number | 27,174 | 21,107 | |
| [0.1, 0.8] | Accuracy | 0.03 | 0.04 | 0.05 |
| | Precision | 0.17 | 0.15 | 0.25 |
| | Number | 26,079 | 21,861 | |
| >0.8 | Accuracy | -0.12 | ***-0.22*** | 0.20 |
| | Precision | ***0.49*** | ***0.46*** | 0.45 |
| | Number | 887 | 666 | |
| All | Accuracy | 0.04 | 0.04 | |
| | Precision | 0.16 | 0.15 | |
| | Number | 54,140 | 43,634 | |

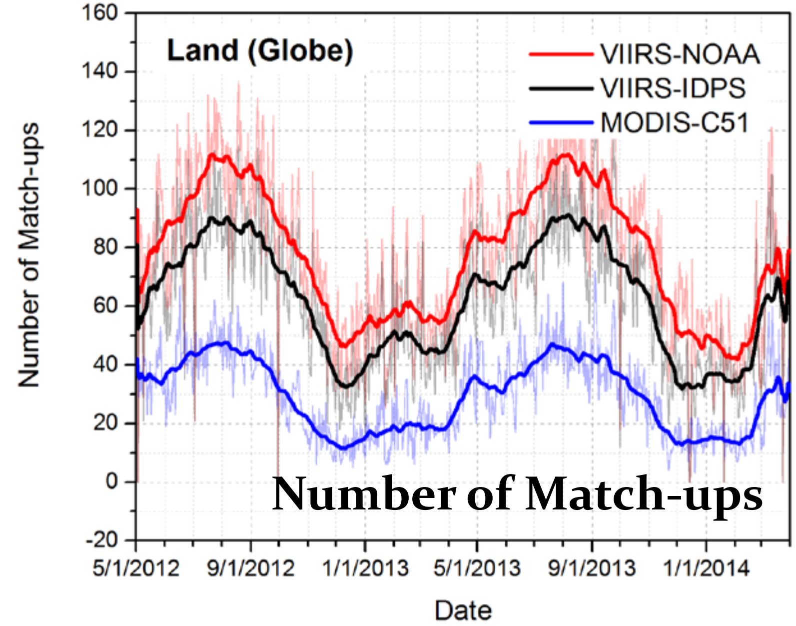
# Sampling Issue in Validation

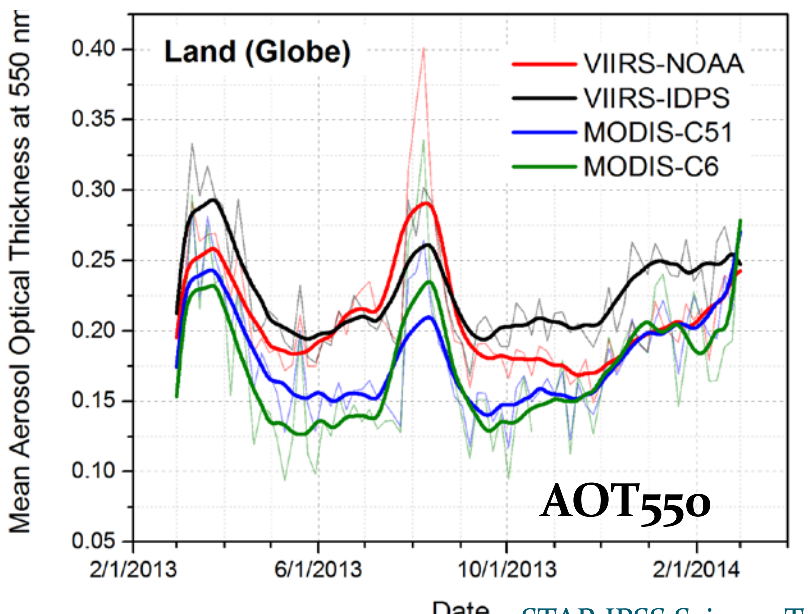


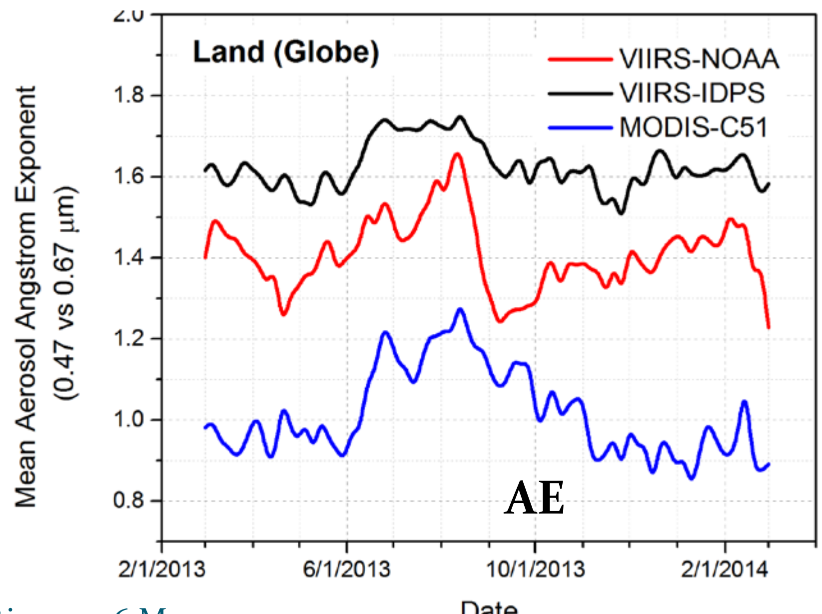

- As many as ~2100 pixels within the 20km-radius-circle matching domain.
- Validation requires at least **15** satellite retrievals (<1%).
- Statistics improve as the required minimum number of retrieval increases.
- RR algorithm outperforms the IDPS if minimum number of retrievals is higher than 200.

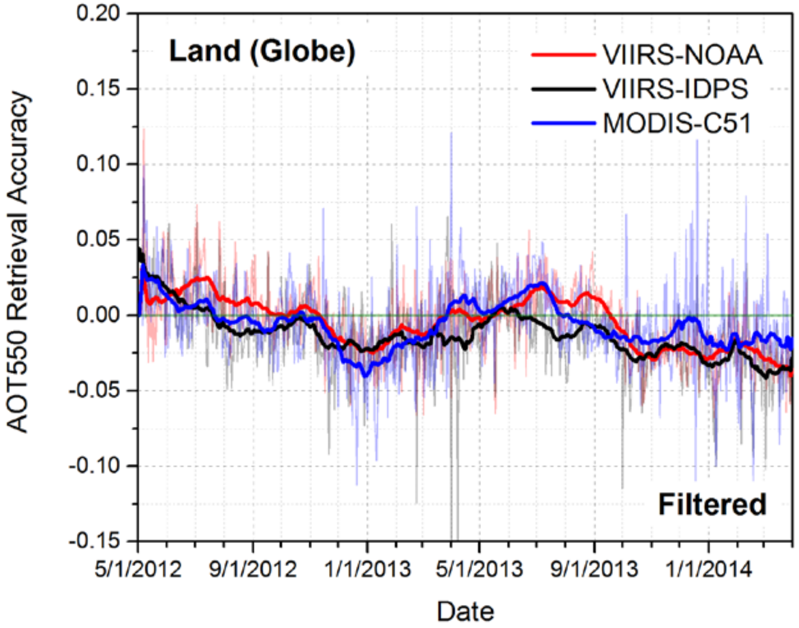
# Time Series

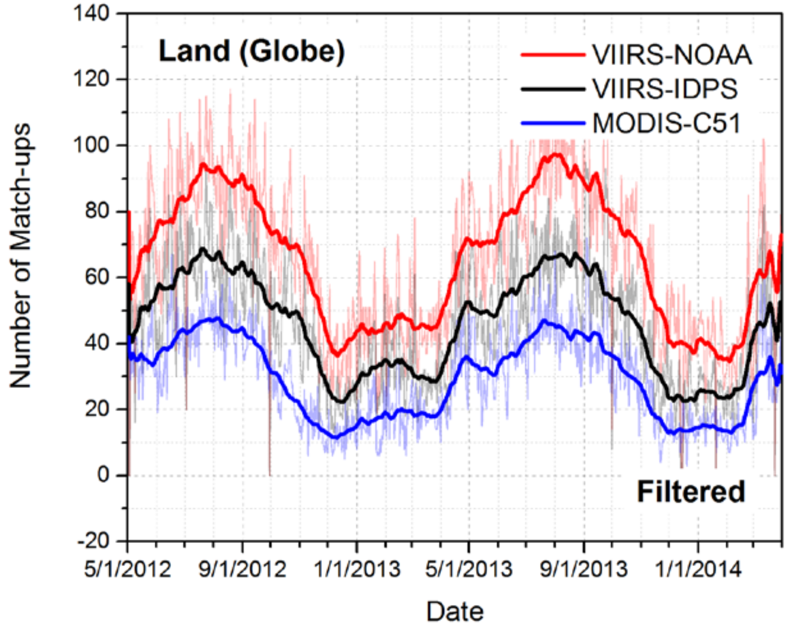

Land (Globe)
VIIRS-NOAA
VIIRS-IDPS
MODIS-C51
AOT550 Retrieval Accuracy
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
-0.15
5/1/2012
9/1/2012
1/1/2013
5/1/2013
9/1/2013
1/1/2014
Date
Accuracy


Land (Globe)
VIIRS-NOAA
VIIRS-IDPS
MODIS-C51
Number of Match-ups
160
140
120
100
80
60
40
20
0
-20
5/1/2012
9/1/2012
1/1/2013
5/1/2013
9/1/2013
1/1/2014
Date
Number of Match-ups


Land (Globe)
VIIRS-NOAA
VIIRS-IDPS
MODIS-C51
MODIS-C6
Mean Aerosol Optical Thickness at 550 nm
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
2/1/2013
6/1/2013
10/1/2013
2/1/2014
Date
AOT550


Land (Globe)
VIIRS-NOAA
VIIRS-IDPS
MODIS-C51
Mean Aerosol Angstrom Exponent
(0.47 vs 0.67 μm)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
2/1/2013
6/1/2013
10/1/2013
2/1/2014
Date
AE



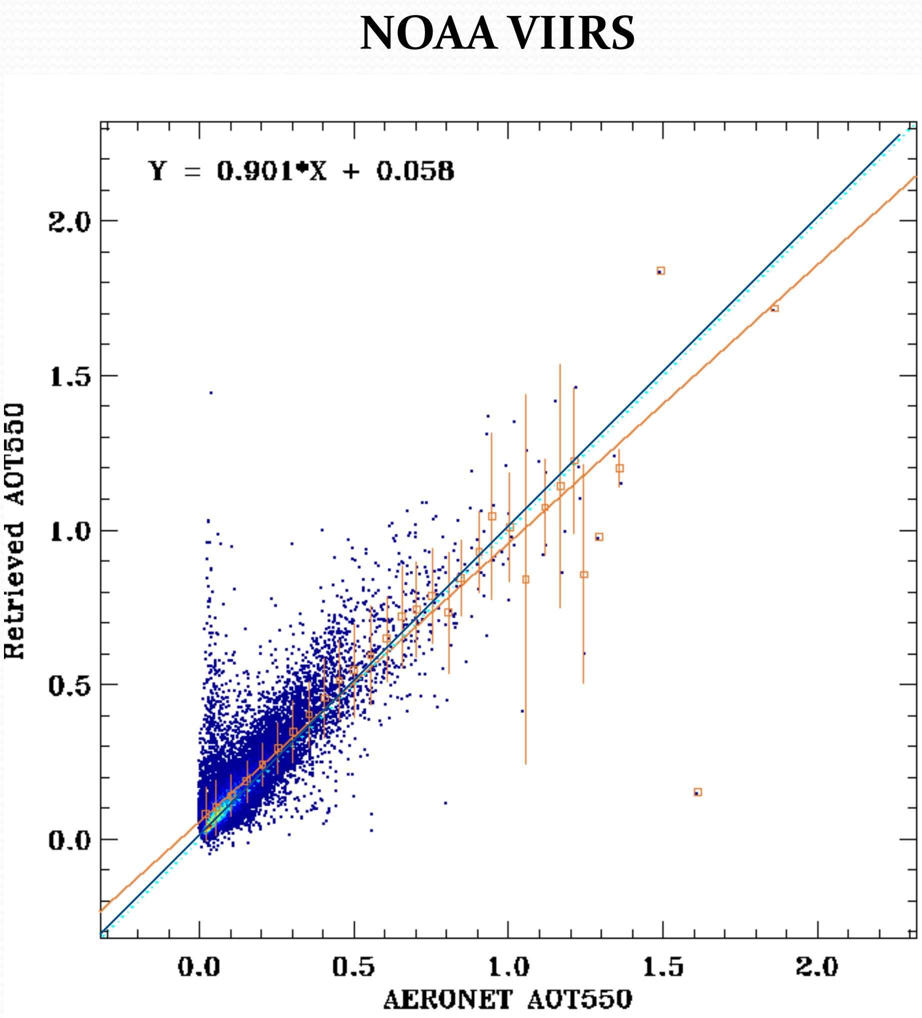



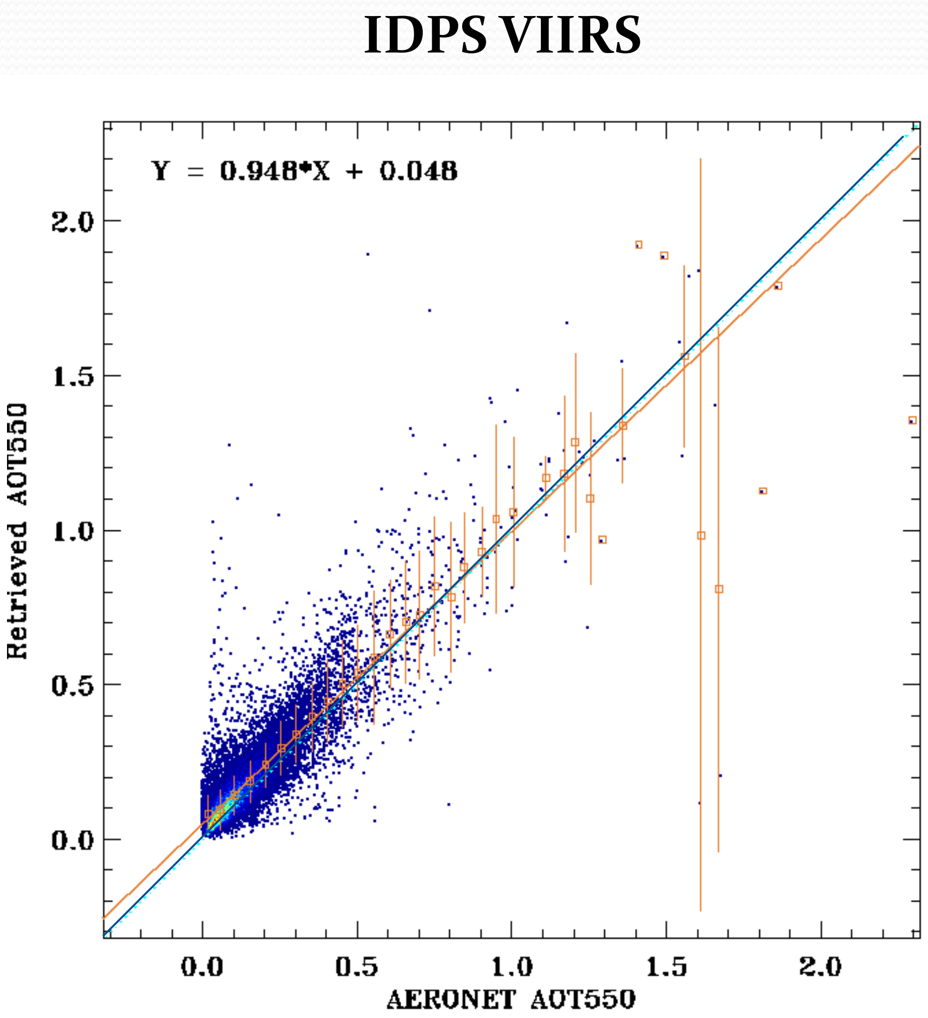

VIIRS pixel level retrievals are filtered before averaging in order to be comparable with MODIS products:

- Requiring at least 100 pixel retrievals within 20km-radius-circle matching domain.
- Discarding the highest 40% and lowest 20% AOTs in spatial averaging.
- Number of match-ups:

  VIIRS-NOAA: 45,855
  VIIRS-IDPS: 31,889
  MODIS-C51: 20,422

# Validation Over Ocean

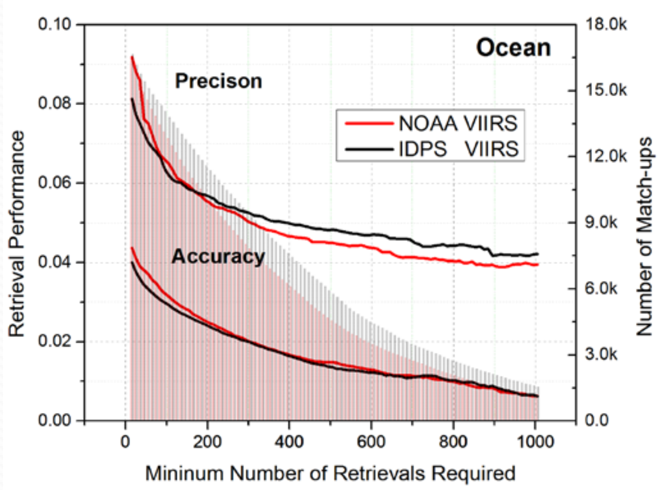


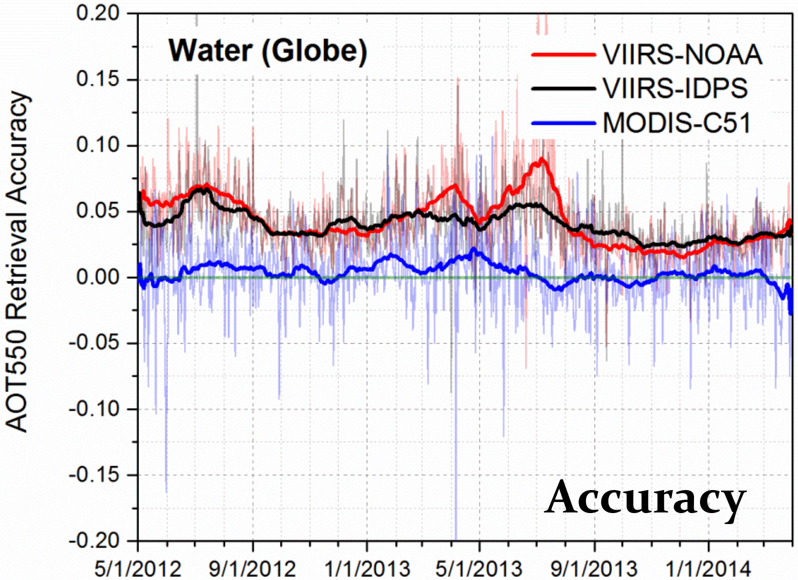
# Statistics

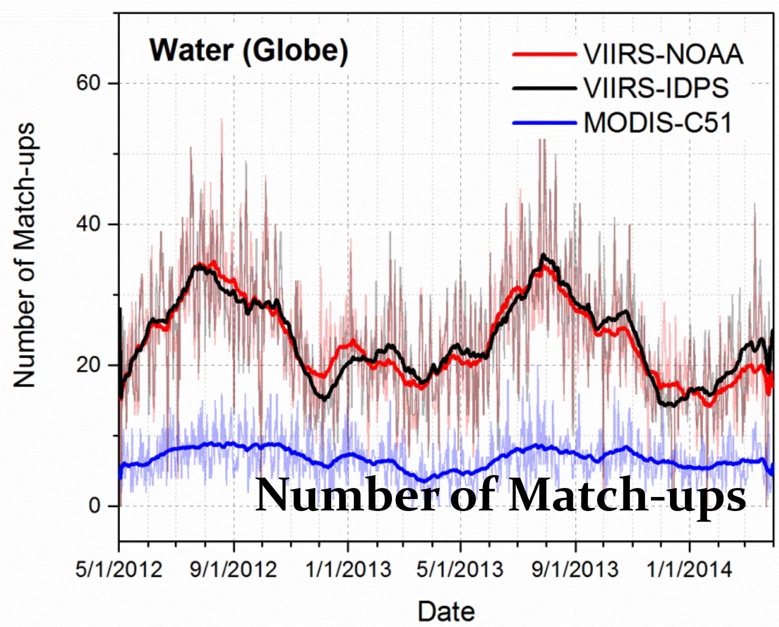
| Ocean | | NOAA-VIIRS | IDPS-VIIRS | Requirement |
|---|---|---|---|---|
| <0.3 | Accuracy | 0.04 | 0.04 | 0.08 |
| | Precision | 0.08 | 0.07 | 0.15 |
| | Number | 14,851 | 14,939 | |
| >=0.3 | Accuracy | 0.04 | 0.04 | 0.15 |
| | Precision | 0.18 | 0.16 | 0.35 |
| | Number | 1,603 | 1,722 | |
| All | Accuracy | 0.04 | 0.04 | |
| | Precision | 0.09 | 0.08 | |
| | Number | 16,454 | 16,661 | |

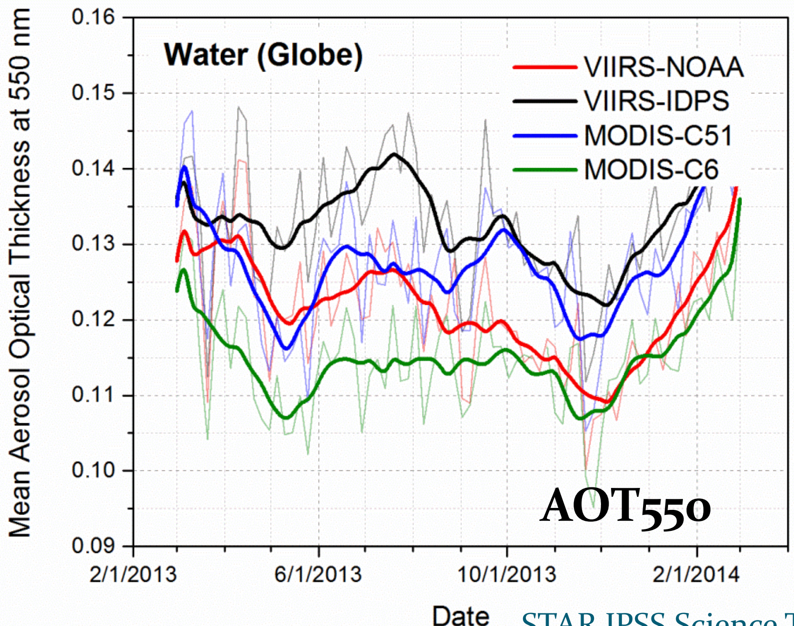
- Statistics can be a function of minimum number of retrievals (MN) required for matching.
- RR algorithm has a slightly higher precision if MN>200

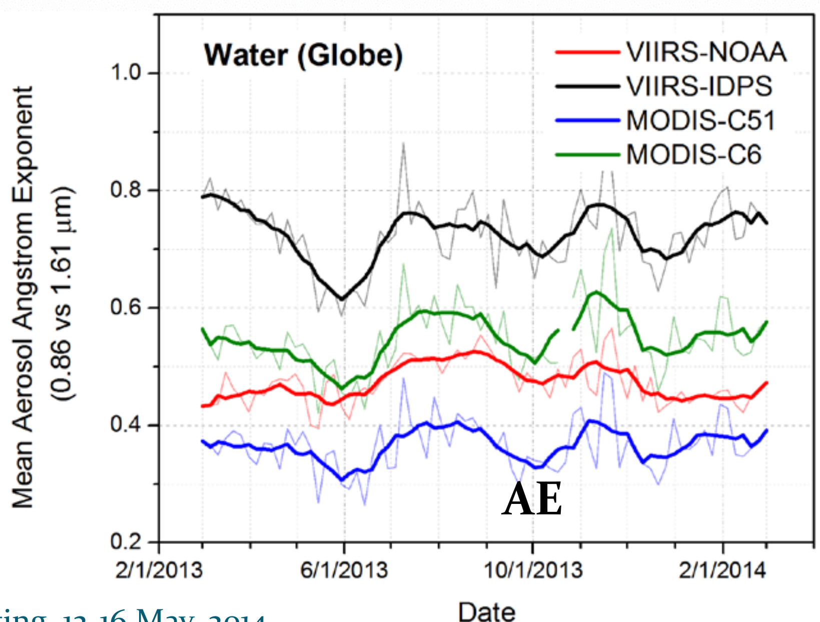


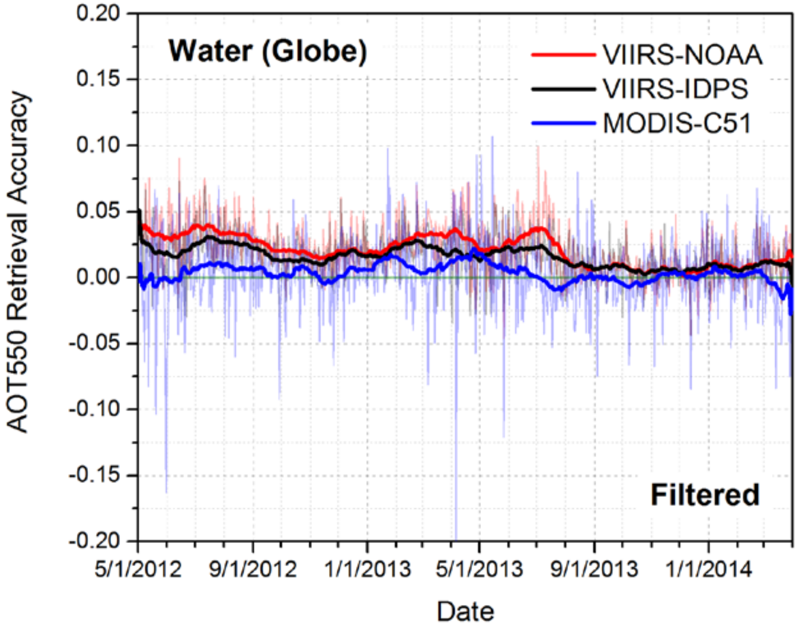
# Time Series

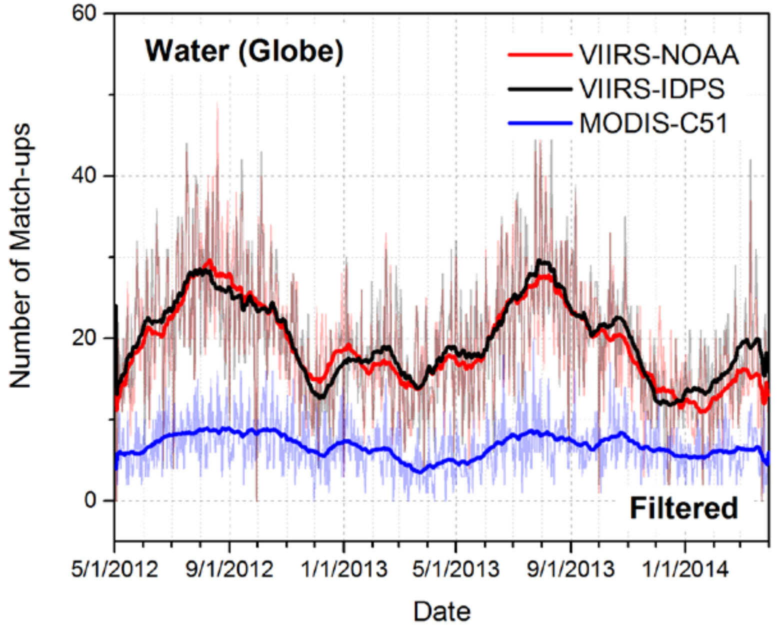

Water (Globe)
VIIRS-NOAA
VIIRS-IDPS
MODIS-C51
Accuracy
AOT550 Retrieval Accuracy
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
-0.15
-0.20
5/1/2012
9/1/2012
1/1/2013
5/1/2013
9/1/2013
1/1/2014


Water (Globe)
VIIRS-NOAA
VIIRS-IDPS
MODIS-C51
Number of Match-ups
Number of Match-ups
60
40
20
0
5/1/2012
9/1/2012
1/1/2013
5/1/2013
9/1/2013
1/1/2014
Date


Water (Globe)
VIIRS-NOAA
VIIRS-IDPS
MODIS-C51
MODIS-C6
AOT550
Mean Aerosol Optical Thickness at 550 nm
0.16
0.15
0.14
0.13
0.12
0.11
0.10
0.09
2/1/2013
6/1/2013
10/1/2013
2/1/2014
Date


Water (Globe)
VIIRS-NOAA
VIIRS-IDPS
MODIS-C51
MODIS-C6
AE
Mean Aerosol Angstrom Exponent
(0.86 vs 1.61 μm)
1.0
0.8
0.6
0.4
0.2
2/1/2013
6/1/2013
10/1/2013
2/1/2014
Date




- Requiring at least 100 pixel retrievals with 20km-radius-circle matching domain.
- Discarding the highest 40% and lowest 20% AOTs in spatial averaging.
- Number of match-ups:

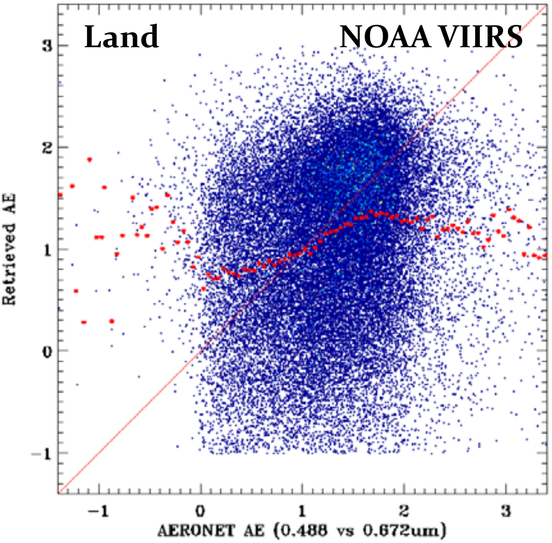
  VIIRS-NOAA: 13496

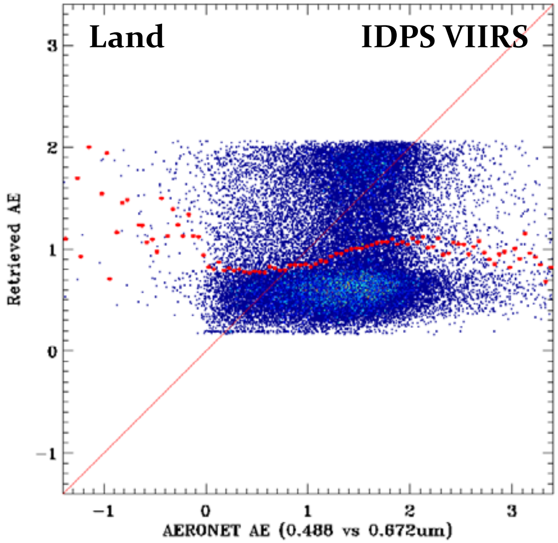
  VIIRS-IDPS: 13905

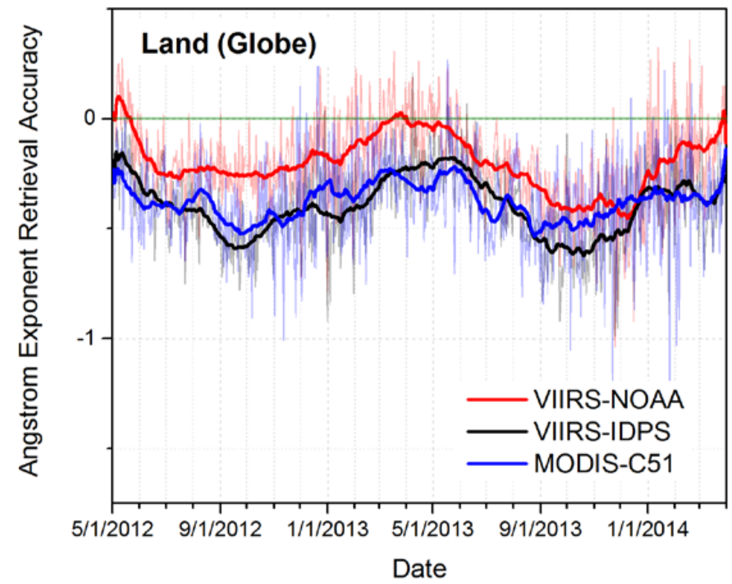
  MODIS-C51: 4745

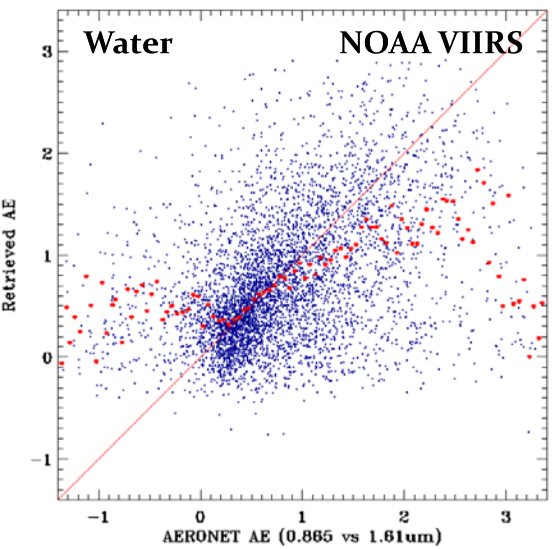
# Aerosol Ångström Exponent

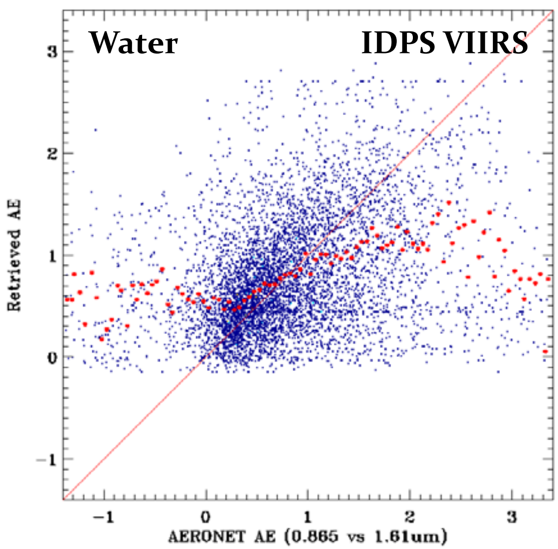
- Independent channel retrieval
  - Spectral AOTs are retrieved from corresponding channels
  - Assign aerosol model as the one selected from the AOT550 retrieval
- Output the spectral AOTs at VIIRS channels calculated from the retrieved AOT550 and selected aerosol model
  - Can be used to calculate Ångström Exponent

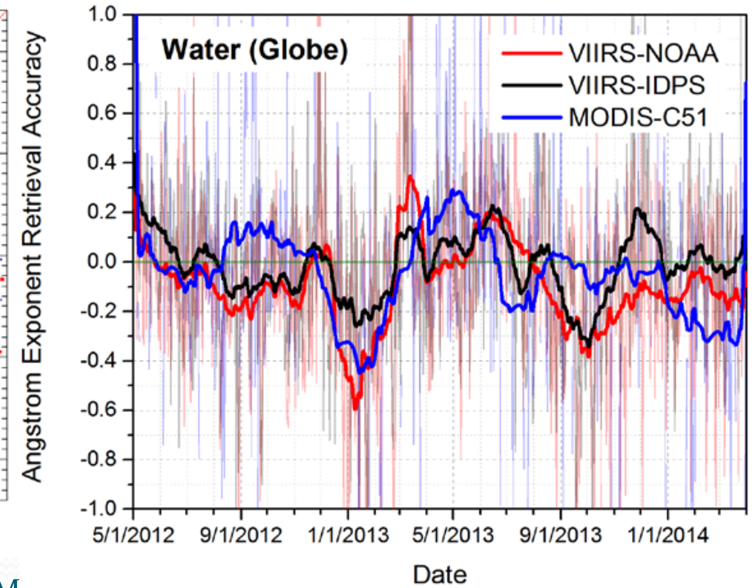

Land
NOAA VIIRS
Retrieved AE
AERONET AE (0.488 vs 0.672um)


Land
IDPS VIIRS
Retrieved AE
AERONET AE (0.488 vs 0.672um)


Land (Globe)
Angstrom Exponent Retrieval Accuracy
VIIRS-NOAA
VIIRS-IDPS
MODIS-C51
5/1/2012
9/1/2012
1/1/2013
5/1/2013
9/1/2013
1/1/2014
Date


Water
NOAA VIIRS
Retrieved AE
AERONET AE (0.865 vs 1.61um)

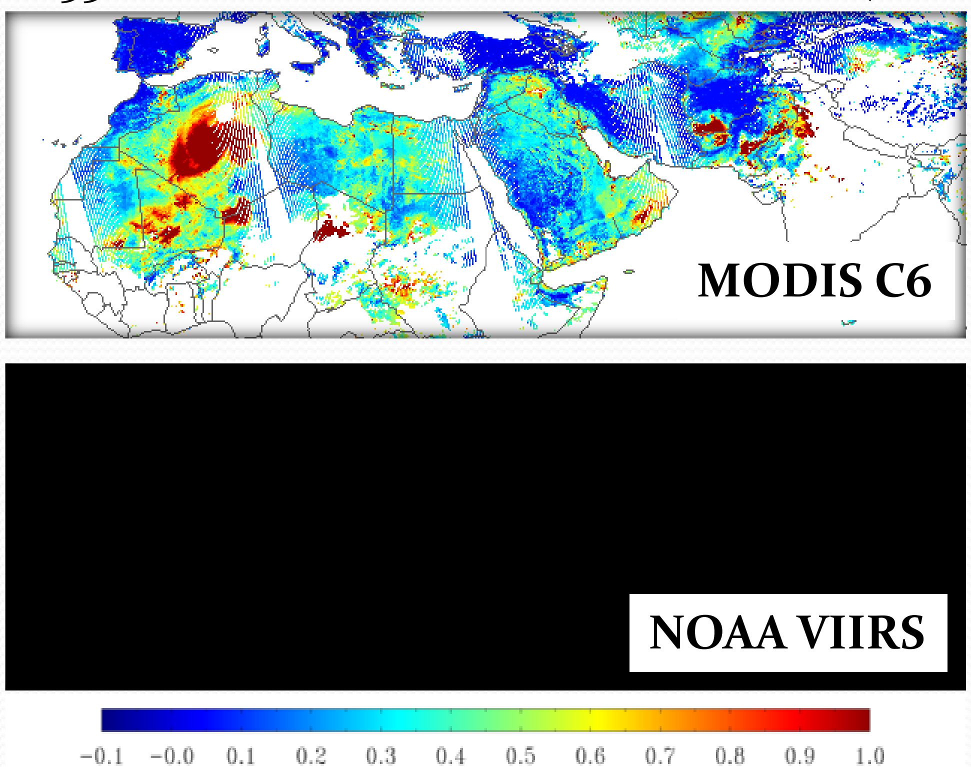

Water
IDPS VIIRS
Retrieved AE
AERONET AE (0.865 vs 1.61um)


Water (Globe)
Angstrom Exponent Retrieval Accuracy
VIIRS-NOAA
VIIRS-IDPS
MODIS-C51
5/1/2012
9/1/2012
1/1/2013
5/1/2013
9/1/2013
1/1/2014
Date

# Retrieval over Bright Surface

- Attempting to retrieve aerosol over bright surface with deep-blue channels (M1 and M2)
- Establish spectral surface reflectance relationship between M1 and M2
- Assign aerosol model (generic or dust/smoke)

AOT550 over North Africa and Middle East (06/24/2013 )



# Summary

- JPSS Risk Reduction Aerosol Algorithm was developed.
  - Single algorithm applied to both VIIRS and ABI
  - More functionalities with less number of line of code than the IDPS algorithm (~3500 vs. ~5600)
- RR algorithm is tested with global retrievals
  - Wider spatial coverage than IDPS
  - More retrievals over significant aerosol events
  - Wider AOT range [-0.05, 5.0]
- Evaluation with AERONET shows slight improvement over IDPS for cases dominated by clear-sky.
- Evaluation with MODIS shows better consistency of retrievals over water.

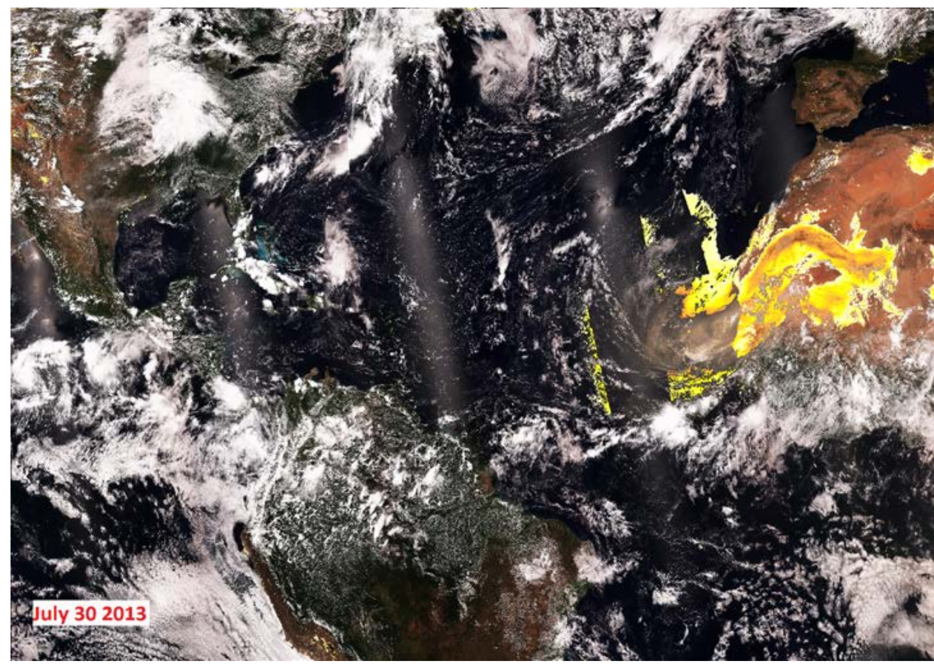
# Summary (Cont.)

- Some IDPS retrieval issues have been addressed:
  - Snow/ice contamination in the Spring season is reduced
  - Ångström Exponent over water is decreased
  - Land spectral reflectance relationship depends on $NDVI_{SWIR}$ and redness
  - More retrievals over arid area
  - Alternative scheme is available for high AOT cases
- Experiment with independent-channel AE retrieval and retrieval over bright land surface using deep-blue channels.
- Future plans
  - Evaluate and improve internal tests
  - Deep-dive evaluation
  - Improve the surface reflectance estimation

# Application of DAI-based smoke/dust detection algorithm to VIIRS observations

Pubu Ciren[1,2] and Shobha Kondragunta[1]

[1]NOAA/NESDIS
[2]IMSG



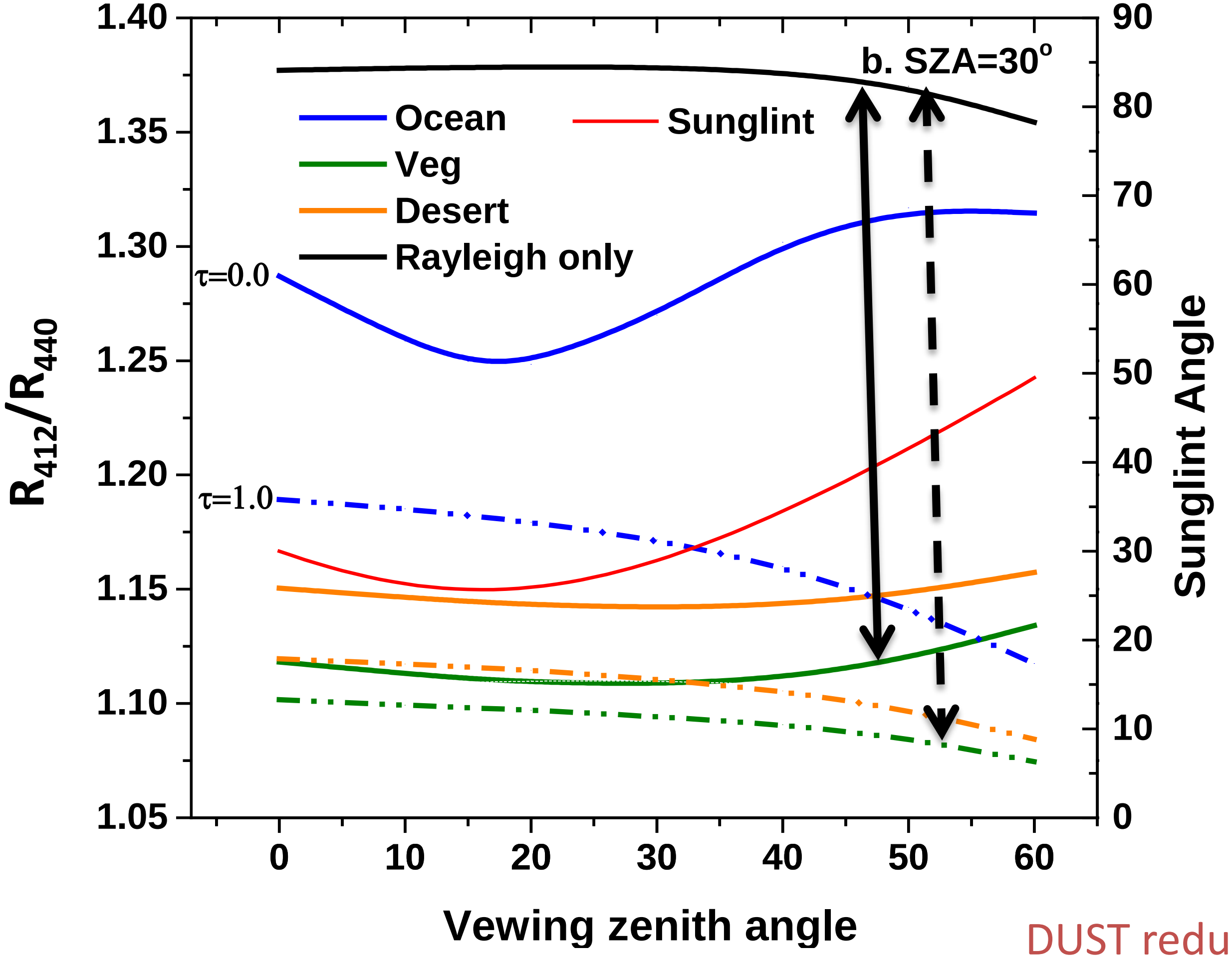
# JPSS Risk Reduction Algorithm for VIIRS Dust and Smoke Detection

- Adapt GOES-R Advanced Baseline Imager (ABI) aerosol (dust and smoke) detection algorithm
  - For dust, take advantage of deep-blue channels on VIIRS and adapt MODIS dust detection algorithm developed by STAR*
- Simple, fast, and easy to be implemented operationally
- Detects most plumes with good accuracy

***Dust Aerosol Index (DAI) Algorithm for MODIS**
Pubu Ciren and Shobha Kondragunta
*Journal of Geophysical Research: Atmospheres*
03/2014 DOI:10.1002/2013JD020855

- Spectral dependence of three processes allows the dust detection
  - Surface reflectance
  - Rayleigh scattering
  - Dust absorption

# 6S Radiative Transfer Simulations

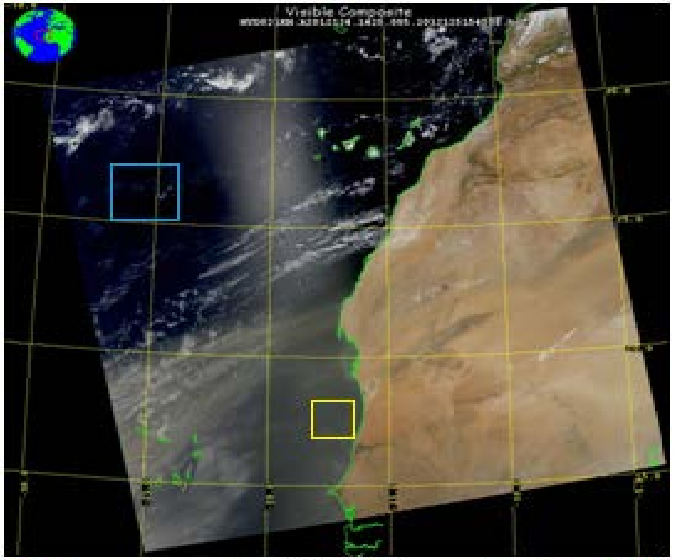


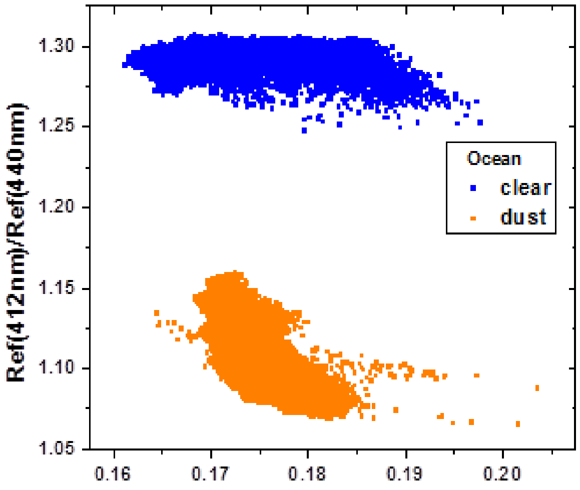

6S Simulations:

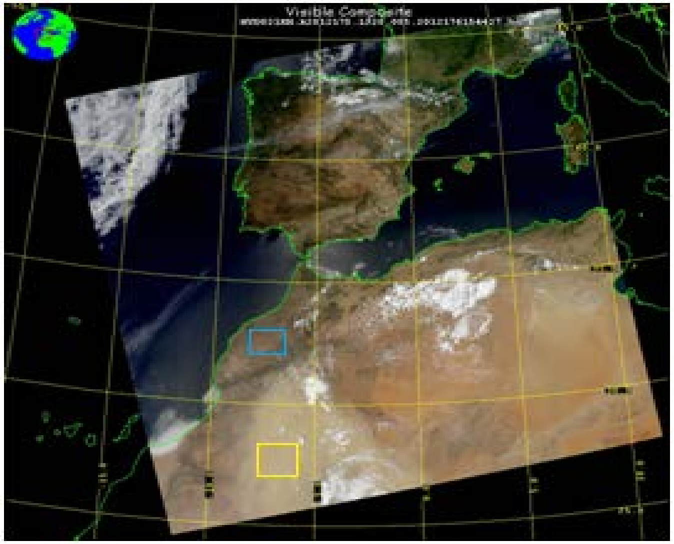
1. MODIS C5 dust aerosol model used
2. Desert, vegetation, ocean BRDF with easterly wind speed of 6 m/s are used to represent surfaces in 6S

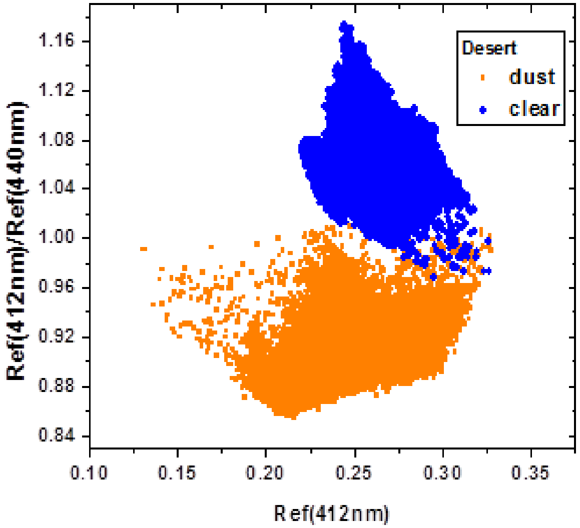
DUST reduces the contrast between 412nm and 440 nm as a result of increasing absorption by dust with decreasing wavelength

# MODIS Observations: Dust vs. Clear Sky

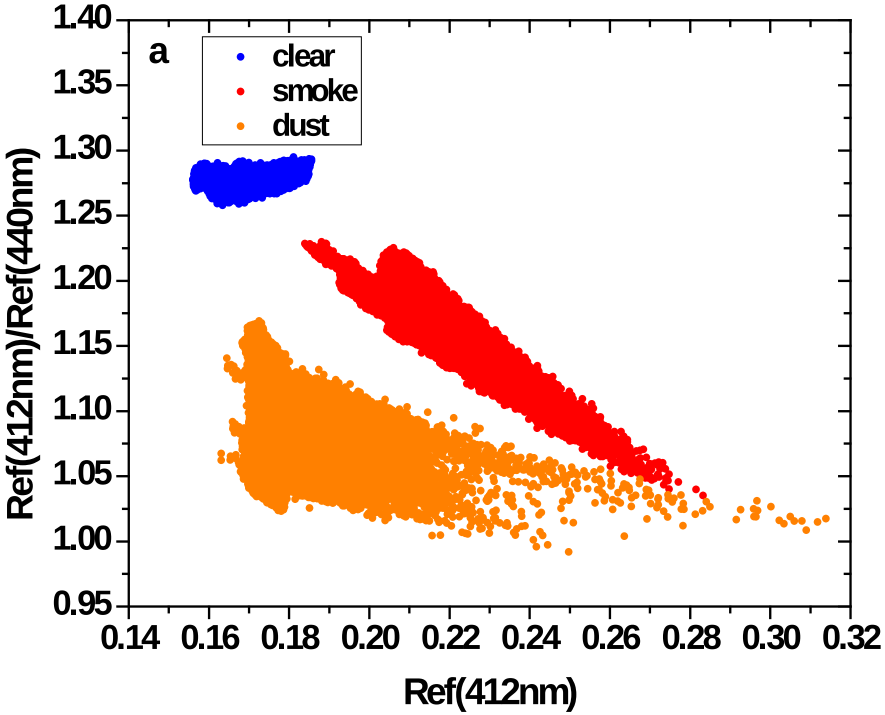


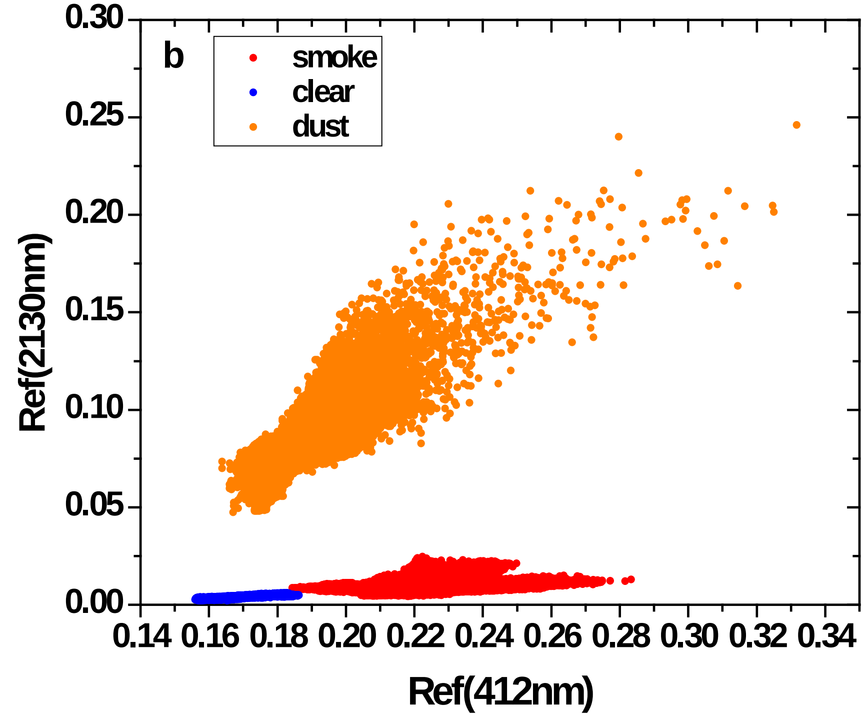



# Smoke and dust vs. Clear Sky

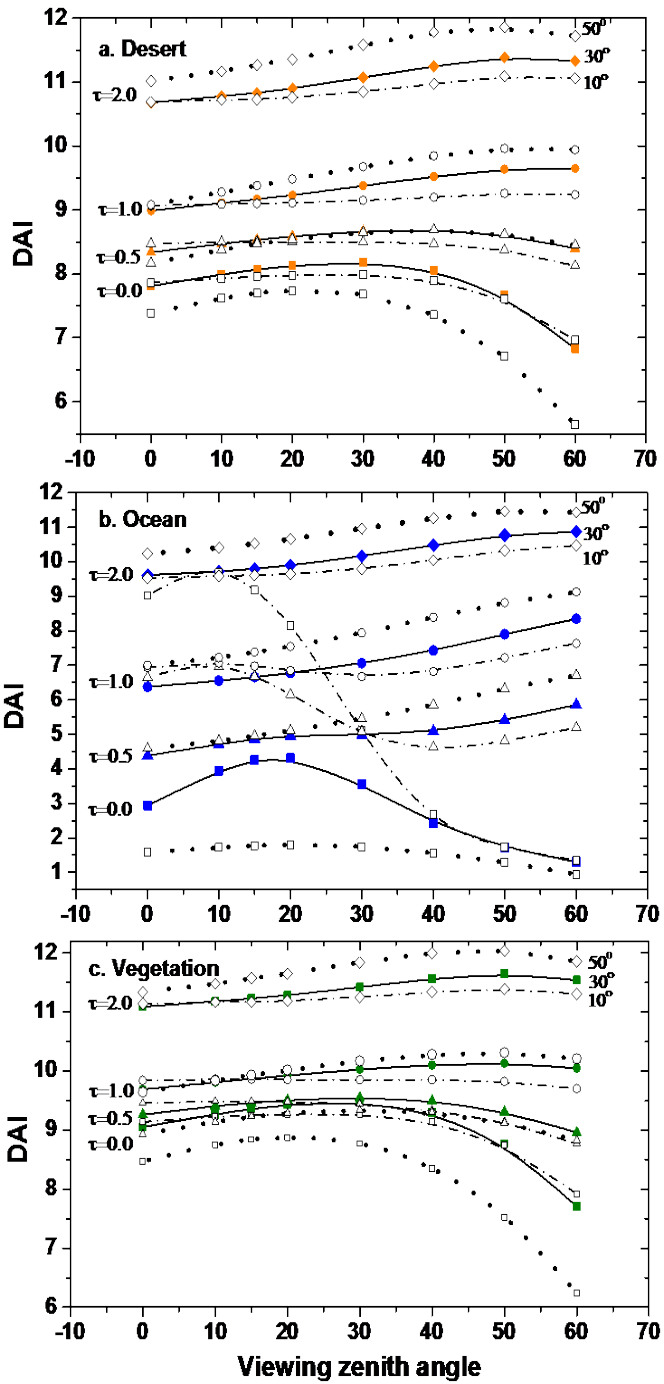



Smoke:

- Has the same effect as dust in terms of reduction of the contrast between 412nm to 440nm
- Difference in particle size enables us to pick-out the smoke by introducing short-wave IR channel (2.13 µm)

# Dust Aerosol Index



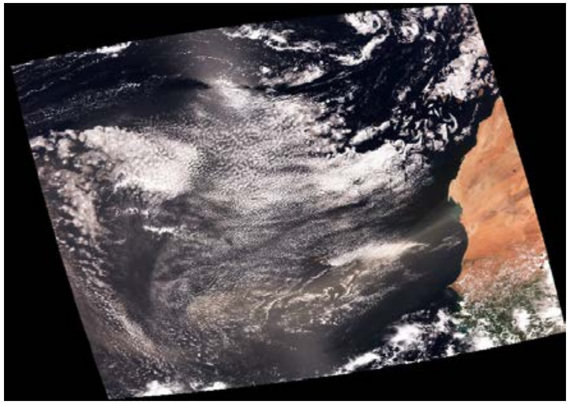

$$DAI = 100*[\log_{10}(R_{412nm}/R_{445nm})-\log10(R'_{412nm}/R'_{445nm})]$$

$$NDAI = -10*[\log_{10}(R_{412nm}/R_{2.25um})]$$

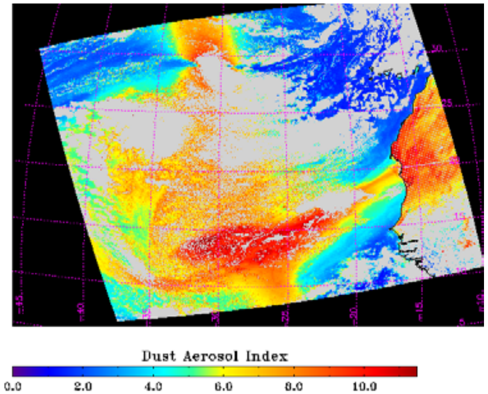
R' -- reflectance from Rayleigh scattering

- Clouds are first screened by using $R_{0.42um}$
- Residual Clouds over water are screened using 0.86 μm spatial variability test. Over land, residual clouds are screened by 412 nm spatial variability test. Cirrus clouds are screened using 1.38 μm test.
- Bright desert surfaces are screened for by bright pixel index (normalized difference of 1.24 μm and 2.25 μm).
- Turbid water test based on Shi and Wang, 2007 uses 0.746 um and 1.24 μm measurements.
- Sunglint, snow/ice, fire hot spots are also screened based on different tests (geometry, spectral etc.)
- DAI and NDAI are computed for pixels that pass these tests:
  - Water: DAI ≥ 4 and NDAI ≥ -10
  - Land: DAI ≥ 11.5 and NDAI ≥ 0

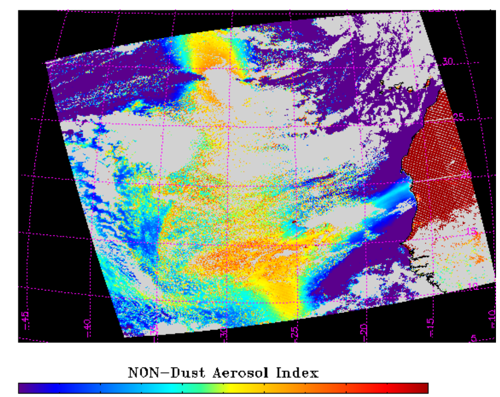
# JPSS RR dust/Smoke Detection



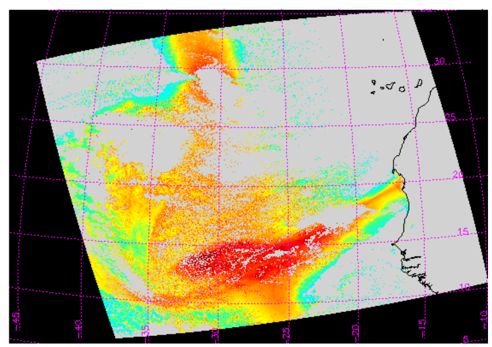
DAI after cloud screening




NDAI after cloud screening

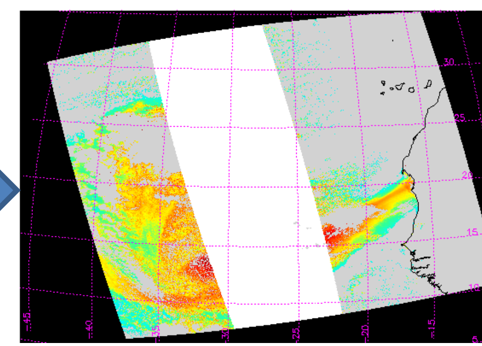



Dust flag



Sunglint flag

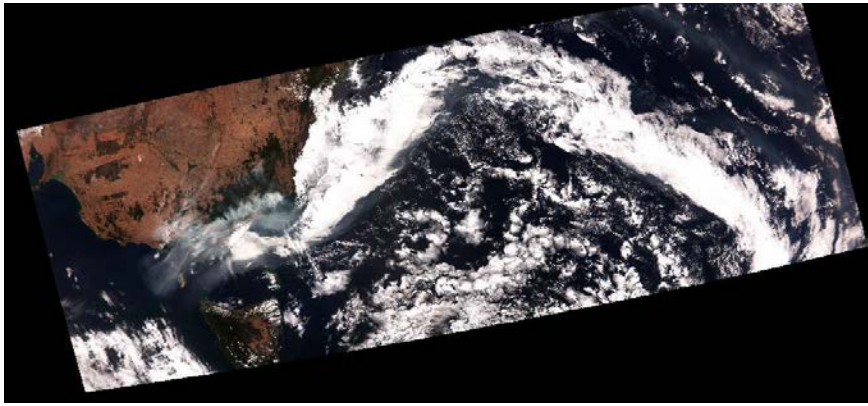
Final dust flag

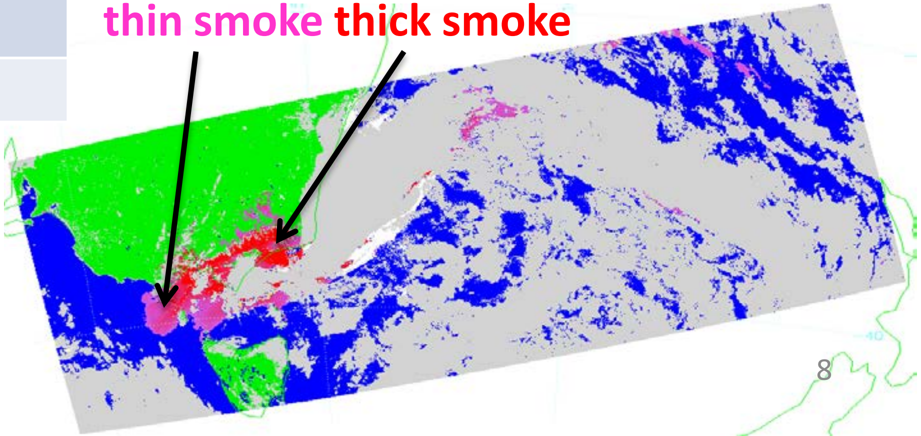


# VIIRS Smoke Detection

- The NDAI in the dust algorithm can also indicate the presence of smoke and/or haze mixed in with smoke

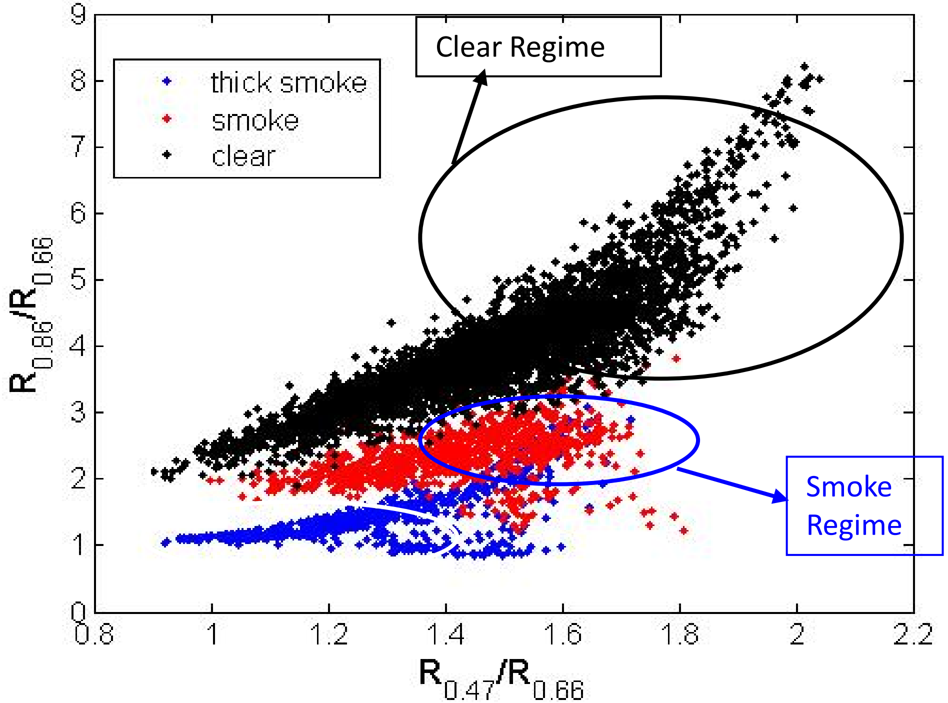
| Surface | Condition | Smoke Detection |
| --- | --- | --- |
| Land | DAI ≥ 5.0 and NDAI ≤ -2.0 | Thin Smoke |
| | DAI ≥ 9.0 and NDAI ≤ -2.0 | Thick Smoke |
| Water | DAI ≥ 4.0 and NDAI ≤ -10.0<br>$R_{410} < 0.1$ | Thin Smoke |
| | DAI ≥ 9.0 and NDAI ≤ -4.0 | Thick Smoke |

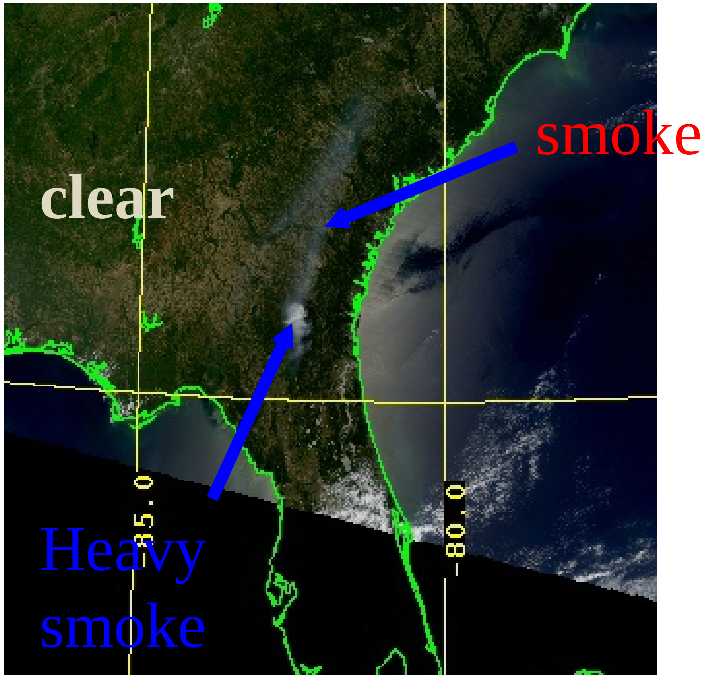




# JPSS RR Algorithm for Smoke Detection

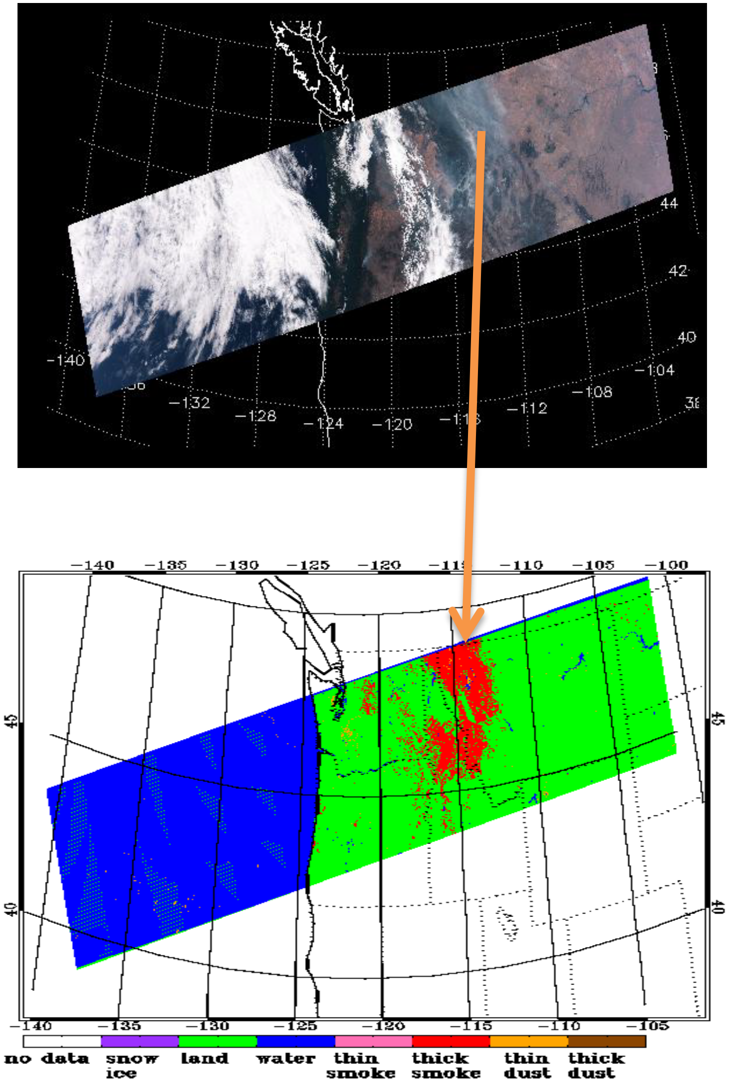
- **Spectral (wavelength dependent) thresholds can separate thick smoke, light smoke, and clear sky conditions**



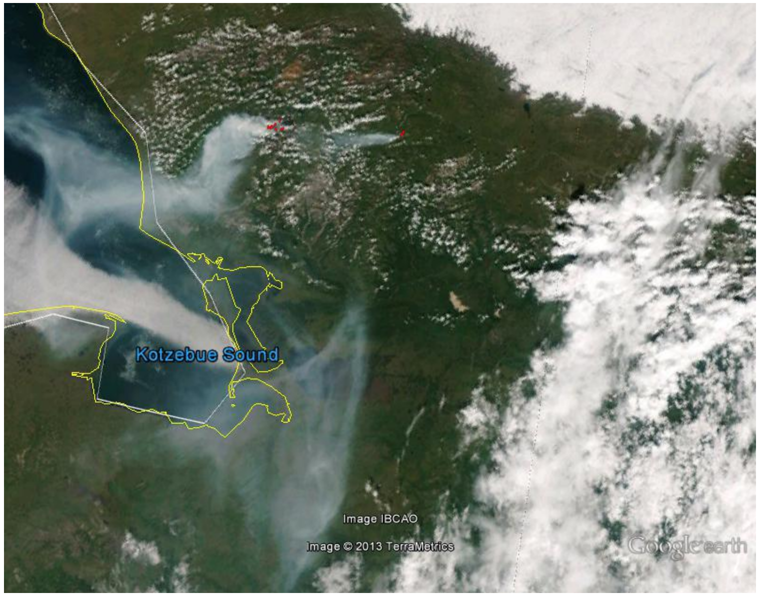



# JPSS RR Dust and Smoke Detection Examples

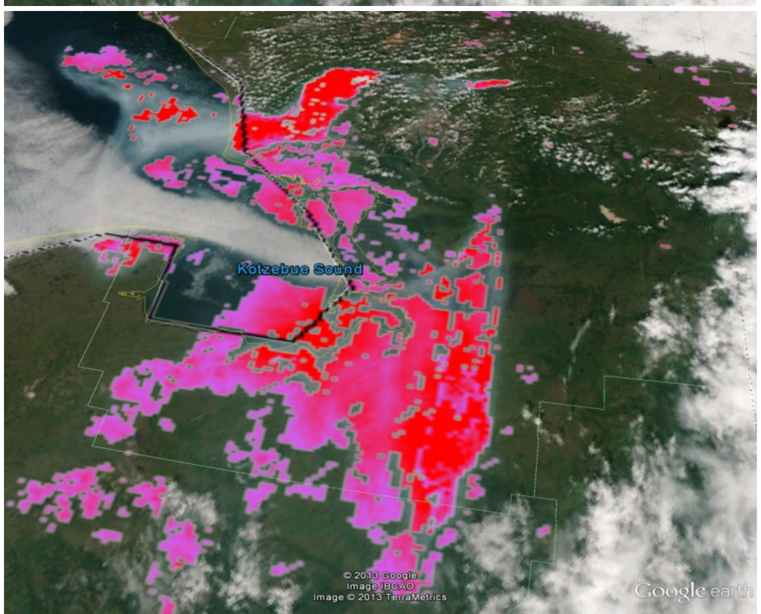
Smoke over West Coast of United States on September 22, 2012



# JPSS RR Dust and Smoke Detection Examples



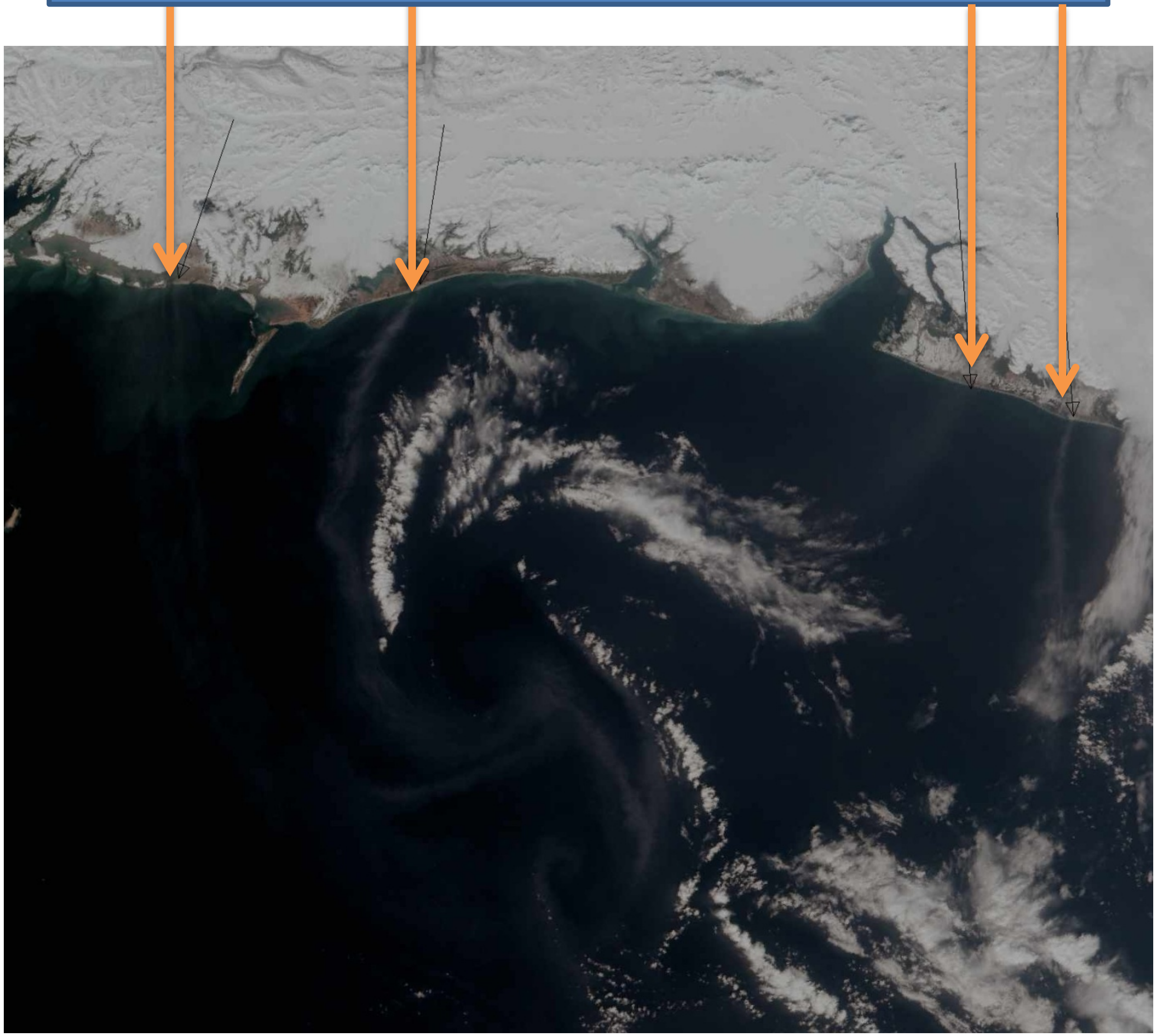

VIIRS fire hot spots and visible smoke in the RGB image on July 8, 2012

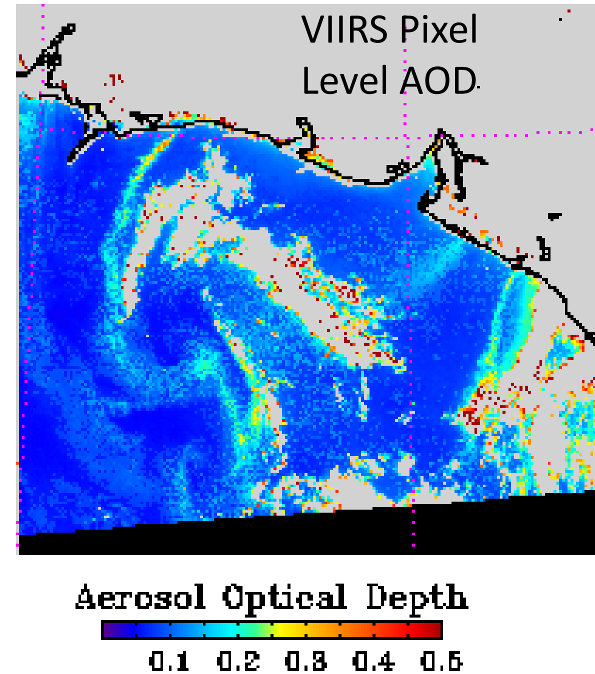


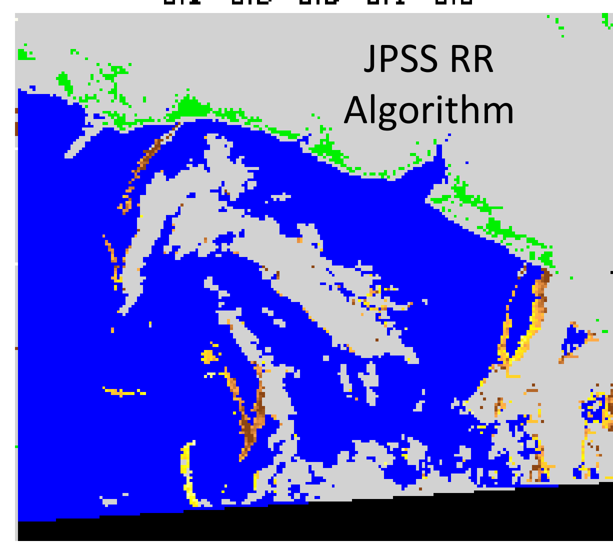

JPSS RR smoke detection algorithm identifies the smoke plumes including the one removed from fire hot spots

# JPSS RR Dust and Smoke Detection Examples

**VIIRS true color image of blowing dust from different sources in Alaska on April 28, 2013**





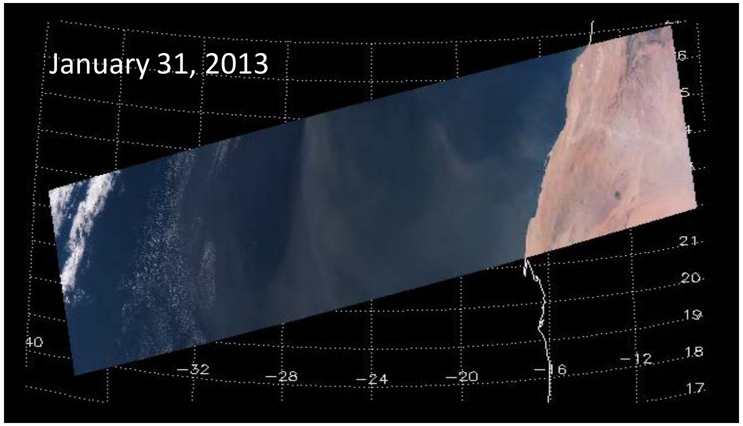
# Validation

- JPSS RR dust detection algorithm run on VIIRS observation for the entire year of 2013.
  - VIIRS smoke/dust frequency vs. CALIPSO and MISR
  - VIIRS smoke and dust detection matchups with CALIPSO and AERONET
- Derive performance metrics
  - Accuracy
  - Probability of Correct Detection (POCD)
  - Probability of False Detection (POFD)

**TRUTH DATA**

| **VIIRS** | **Yes** | **No** |
|---|---|---|
| Yes | A | B |
| No | C | D |

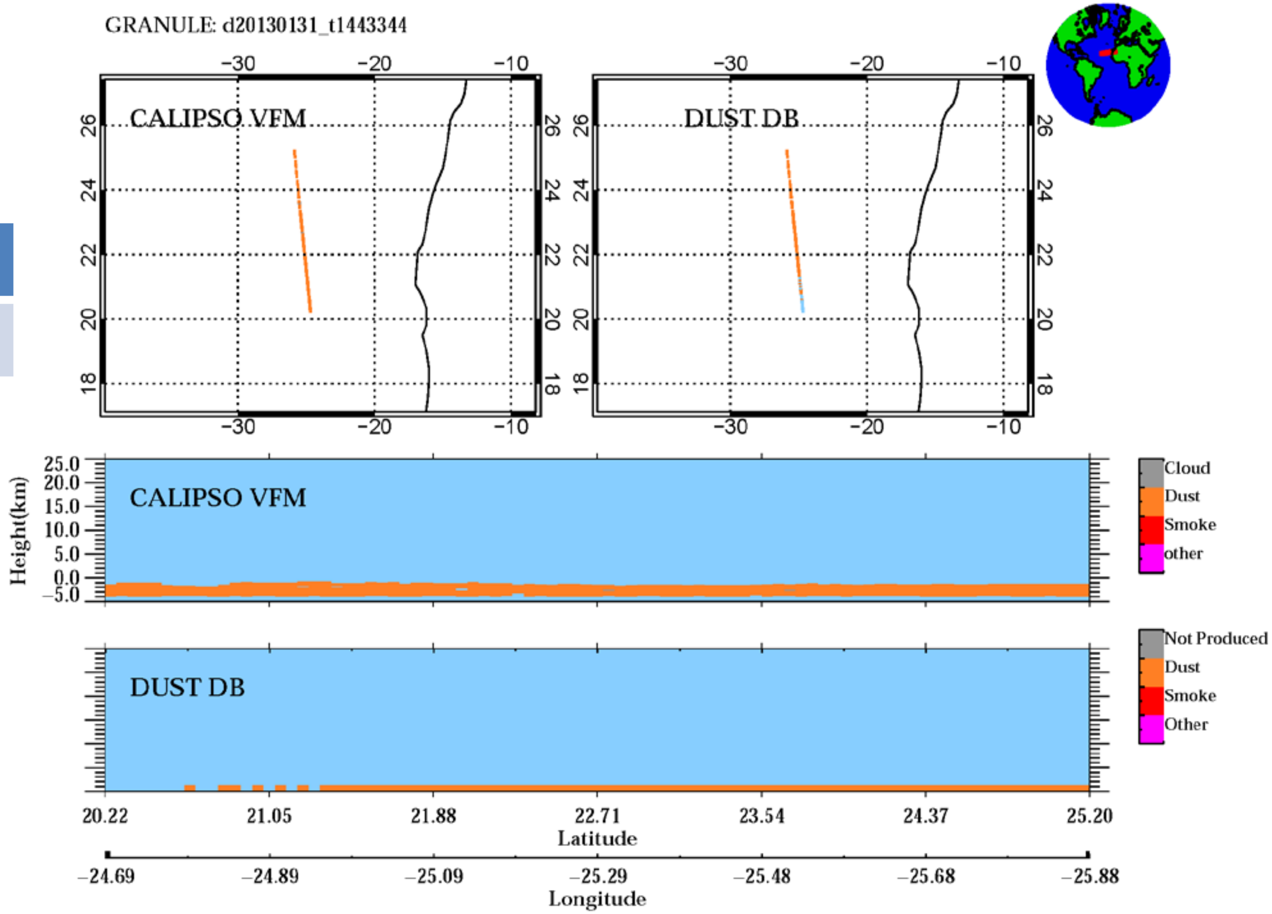
**POCD = A/(A+C)**
**POFD = B/(A+B)**
**Accuracy* = (A+D)/(A+B+C+D)**




# VIIRS vs. CALIPSO

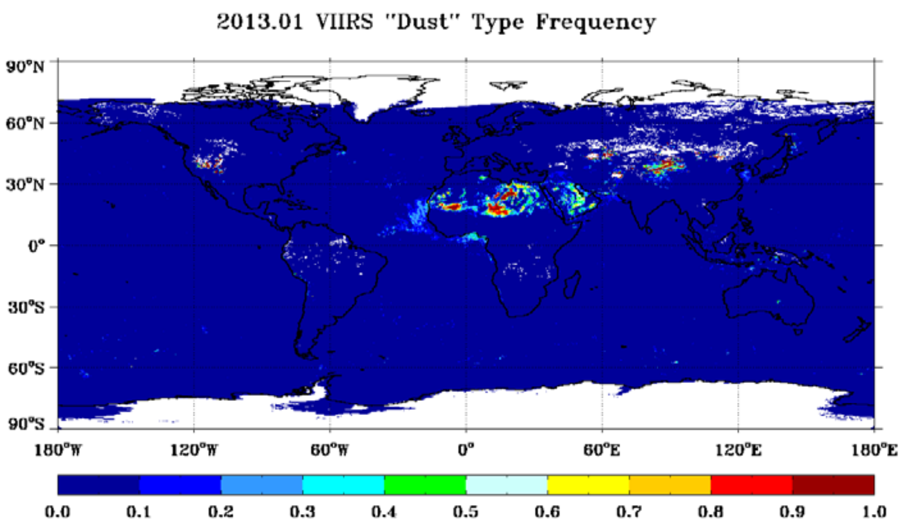
SM DAI

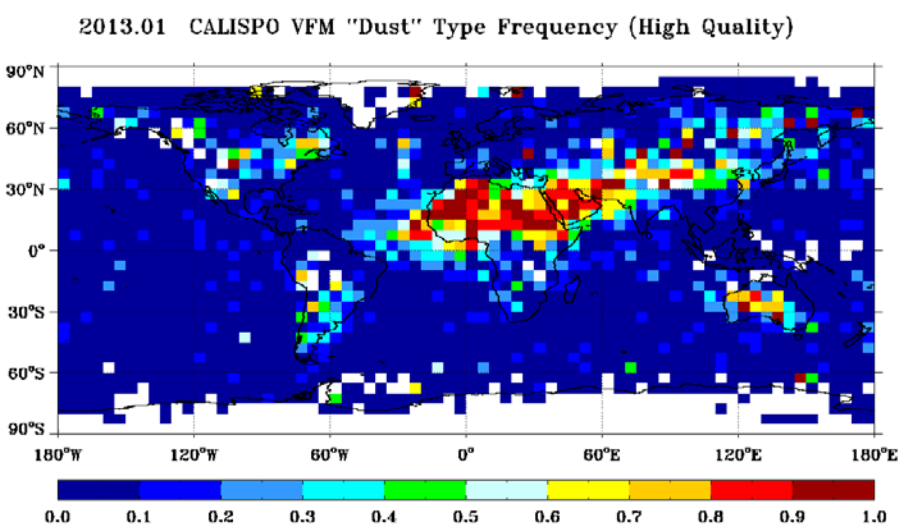
| | |
|---|---|
| Accuracy | 83% |
| POCD | 85% |



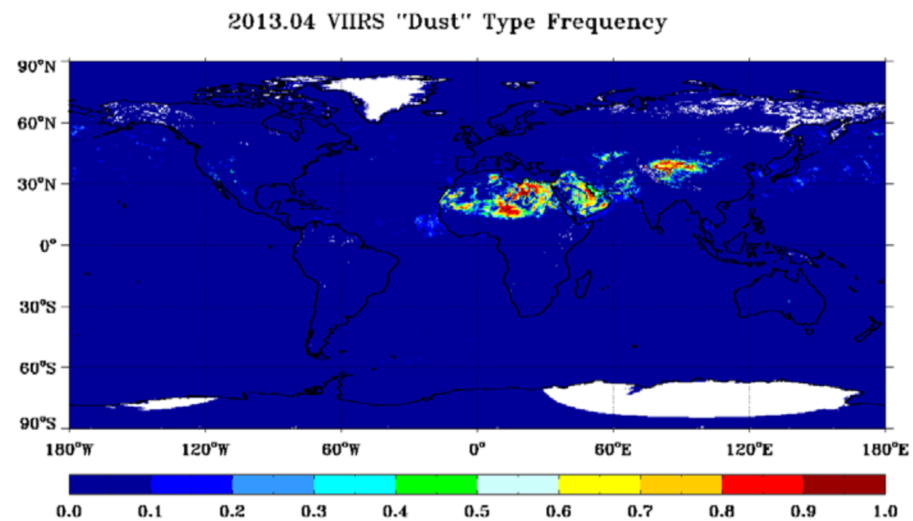
# DUST

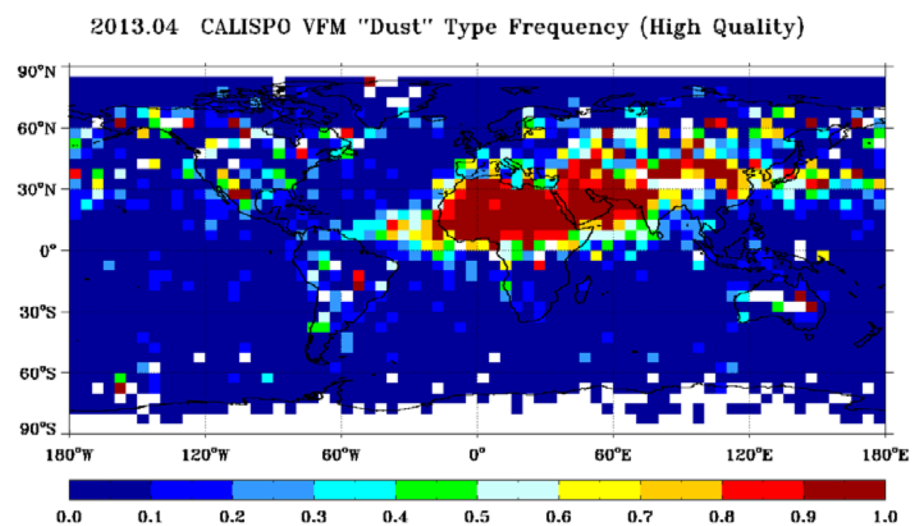
## January




## April

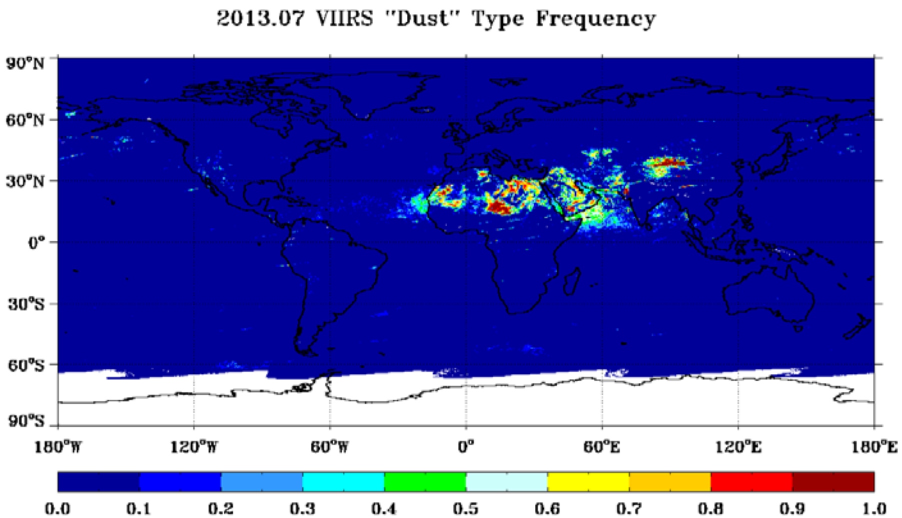


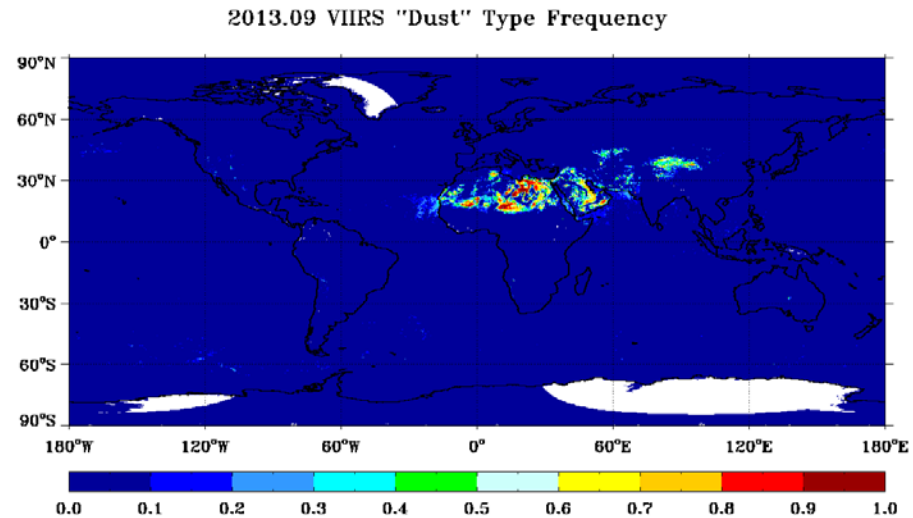



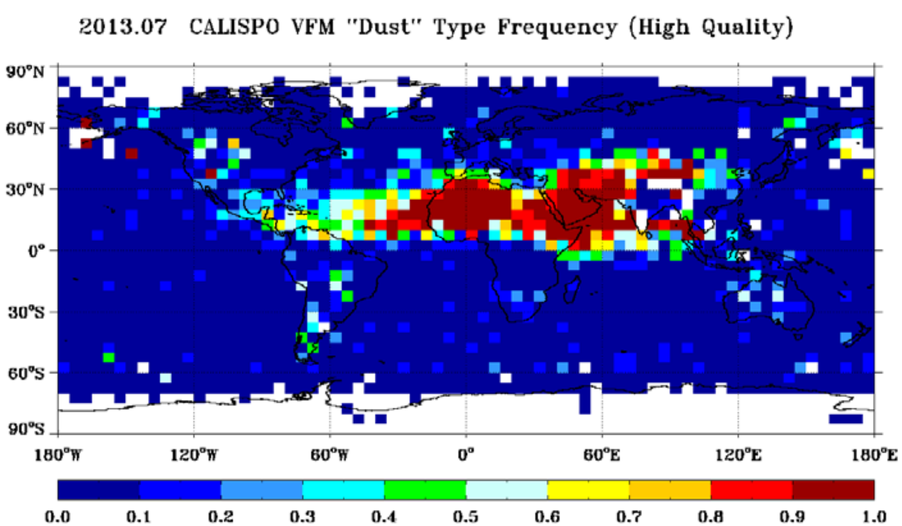
# DUST

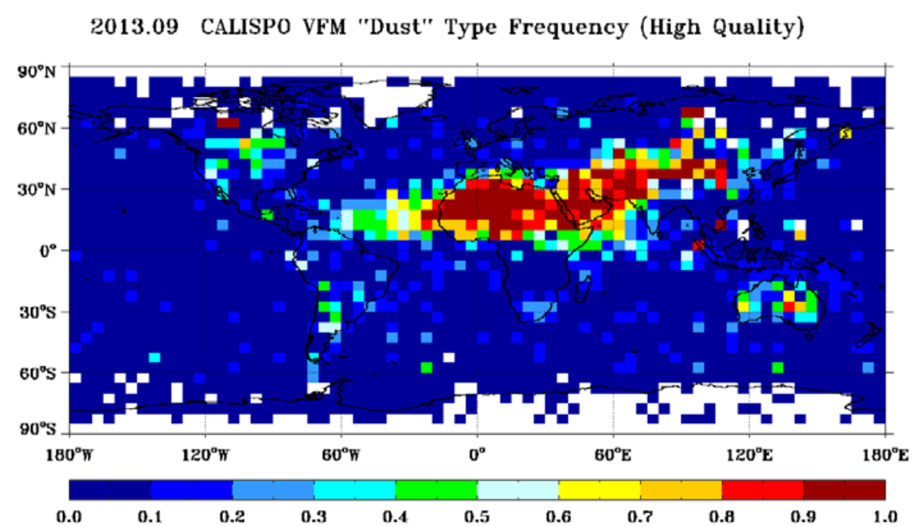
## July

## September



# JPSS RR Dust Detection Over Land: VIIRS vs. CALIPSO

| | Month (2013) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11* | 12 |
| **Accuracy** | 100.0 | 99.4 | 99.9 | 99.9 | 98.4 | 99.4 | 99.6 | 98.7 | 100.0 | 100.0 | - | 100.0 |
| **POCD** | N/A | 71.4 | 77.8 | 80.0 | 75.3 | 73.4 | 97.9 | 76.5 | N/A | N/A | - | N/A |
| **POFD** | N/A | 50.0 | 8.7 | 42.8 | 13.5 | 53.4 | 39.4 | 35.3 | N/A | N/A | - | N/A |

* CALIPSO data not available

# JPSS RR Dust Detection Over Water: VIIRS vs. CALIPSO

| | Month (2013) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| **Accuracy** | 99.8 | 99.8 | 99.9 | 99.9 | 99.8 | 99.6 | 99.7 | 99.8 | 100.0 | 100.0 | - | 100.0 |
| **POCD** | 54.2 | N/A | N/A | N/A | N/A | 80.0 | 94.8 | 91.8 | N/A | N/A | - | N/A |
| **POFD** | 56.6 | N/A | N/A | N/A | N/A | 46.1 | 49.5 | 47.6 | N/A | N/A | - | N/A |

* CALIPSO data not available

# JPSS RR Dust Detection : VIIRS vs. AERONET

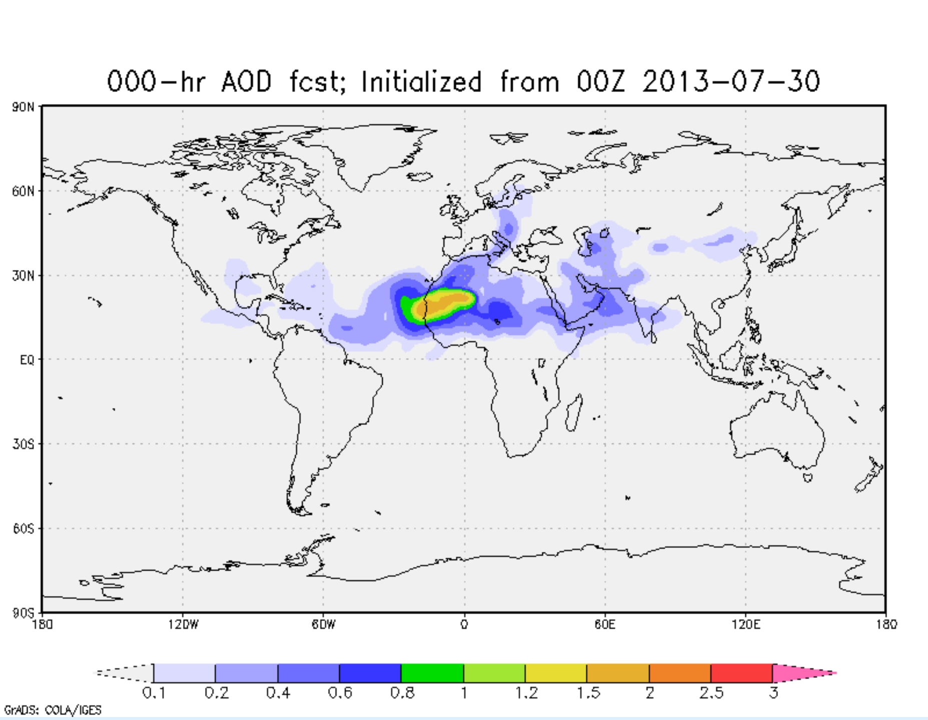
| Stations | True positive | False positive | True negative | False negative | Accuracy | POCD | POFD |
|---|---|---|---|---|---|---|---|
| Banizoumbou | 10 | 1 | 65 | 12 | 85.2 | 45.4 | 9.0 |
| Darkar | 1 | 0 | 25 | 1 | 96.3 | 50.0 | 0.0 |
| IER_Cinzana | 2 | 0 | 23 | 1 | 96.2 | 66.6 | 0.0 |
| Solar_Village | 6 | 5 | 29 | 4 | 79.5 | 60.0 | 45.4 |
| Capo_Verde | 2 | 1 | 9 | 0 | 91.6 | 100.0 | 33.3 |
| Cape_San_Juan | 1 | 2 | 18 | 0 | 90.4 | 100.0 | 66.6 |

| Over 401 AERONET stations | Accuracy | POCD | POFD |
|---|---|---|---|
| Year of 2013 | 99.8 | 86.9 | 39.3 |

# Summary

- An algorithm based on observations from deep-blue and shortwave-IR developed for MODIS has been adapted for VIIRS.
  - Algorithm is simple, fast, and easy to be implemented operationally.
- Dust and smoke detections meet L1RD requirements
- Additional validation on smoke detection is needed
- Additional investigation of data artifacts (false detections) is required to enhance product accuracy

# Toward Improving NCEP Global Aerosol Forecasting System using VIIRS Aerosol Observations





Sarah Lu (NOAA/NWS/NCEP/EMC; IMSG)
Shobha Kondragunta (NESDIS/STAR)
Arlindo da Silva (NASA/GSFC)
Xiaoyang Zhang (South Dakota State University)


*2014 JPSS Science Teams Annual Meeting*

# Why Include Aerosols in the Predictive Systems?

- Improve weather forecasts and climate predictions by taking into account of aerosol effects on radiation and clouds
- Improve the handling of satellite observations by properly accounting for aerosol effects during the assimilation procedure
- Provide aerosol (lateral and upper) boundary conditions for regional air quality predictions
- Account for the aerosol impact on climate, human health, ecosystem, and visibility.
- Meet NWS and WMO global dust forecasting goals

# Presentation Outline

- **Current Operational Configuration**
- Future operational requirements and applications

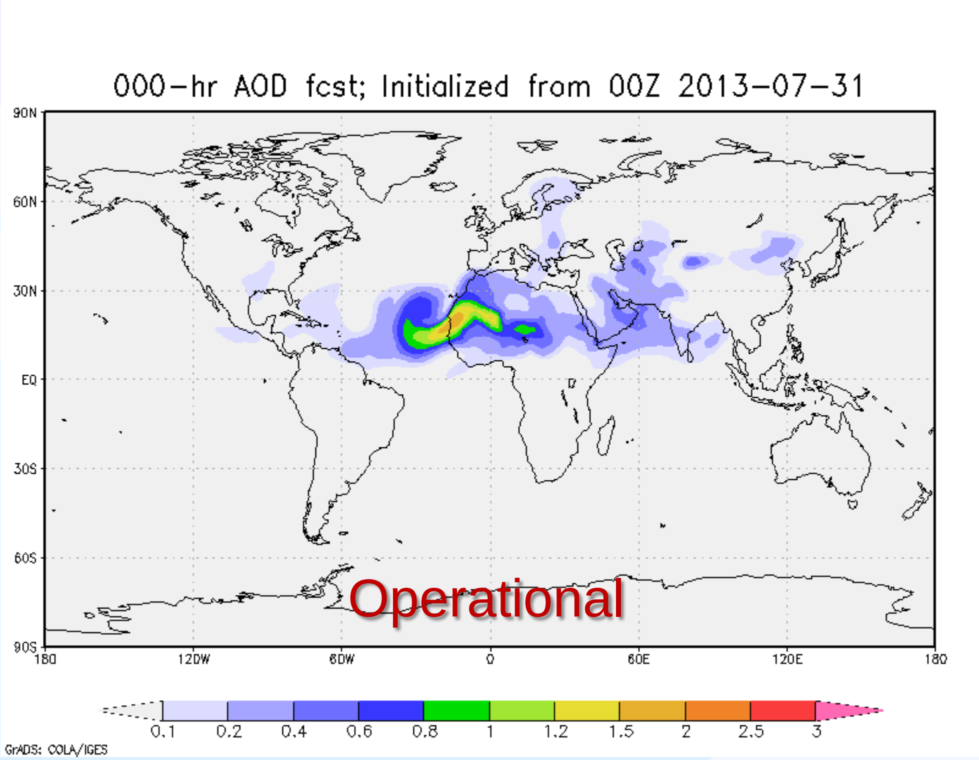
# Near-Real-Time Global Aerosol Forecasting

**In-line chemistry advantage**

- Consistency: no spatial-temporal interpolation, same physics parameterization
- Efficiency: lower overall CPU costs and easier data management
- Interaction: Allows for feedback to meteorology

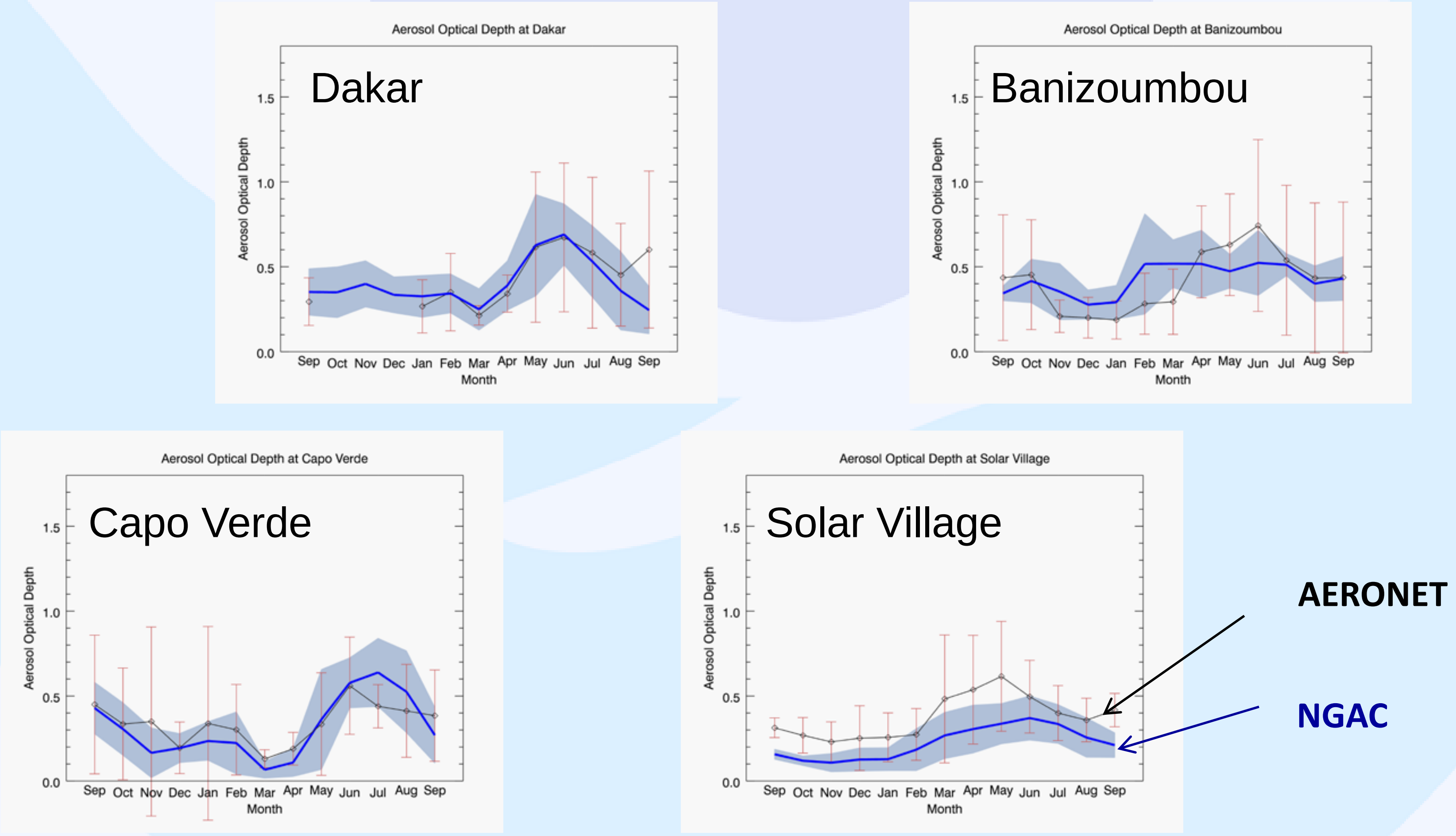
## Current State

- Near-real-time operational system. implemented into NCEP Production Suite in Sept 2012
- The first global in-line aerosol forecast system at NWS
- Model Configuration:
  - Resolution: T126 (~ 1°x1°) L64
  - AGCM: NCEP's NEMS GFS
  - Aerosol: GSFC's GOCART
- 120-hr dust-only forecast once per day (00Z), output every 3-hr
- ICs: Aerosols from previous day forecast and meteorology from operational GDAS
- Leverages the expertise in GSFC, NESDIS, the ICAP working group (NRL, ECMWF, JMA, UKMO, GMAO, BSC), and WMO SDS-WAS program.



# Near-Real-Time Global Aerosol Forecasting

- NGAC forecasts are routinely evaluated using AOD observations from AERONET and MODIS as well as aerosol analysis from other models
- Results of 1-year operational NGAC forecast (09/2012-09/2013) are shown here
- NCEP is yet to extend forecast verification system to include VIIRS aerosol products



# Near-Real-Time Global Aerosol Forecasting

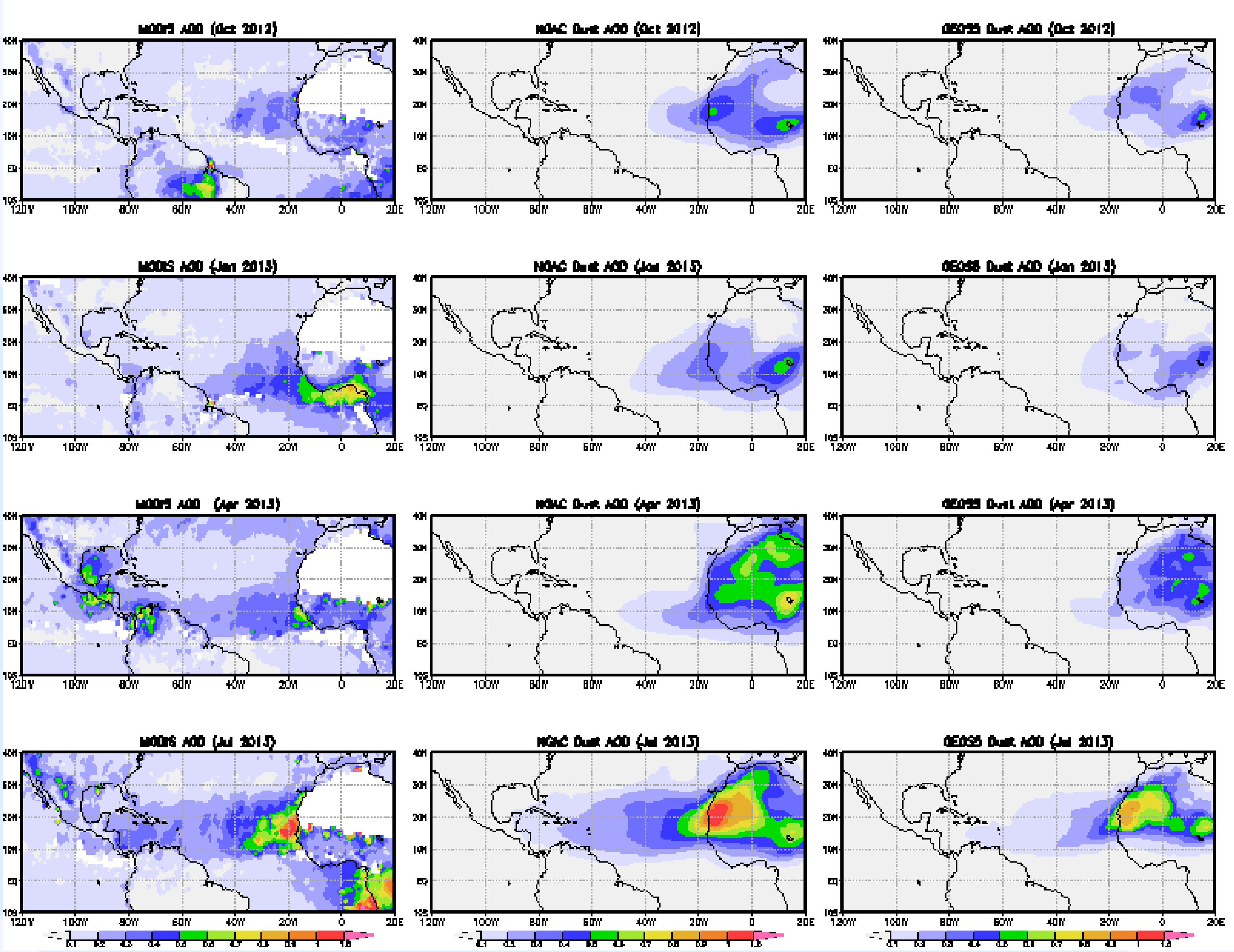
MODIS AOD | NGAC dust AOD | GEOS-5 dust AOD

Oct 2012

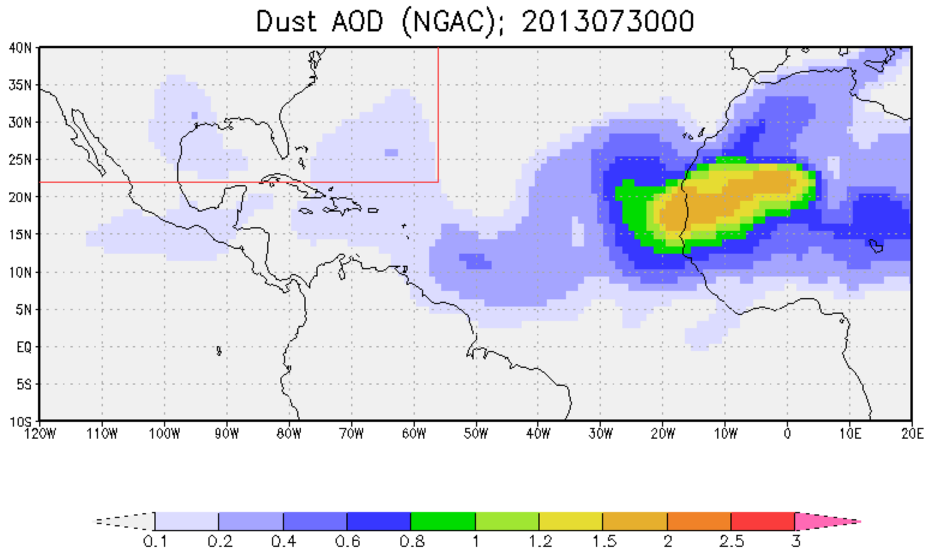
Jan 2013

Apr 2013

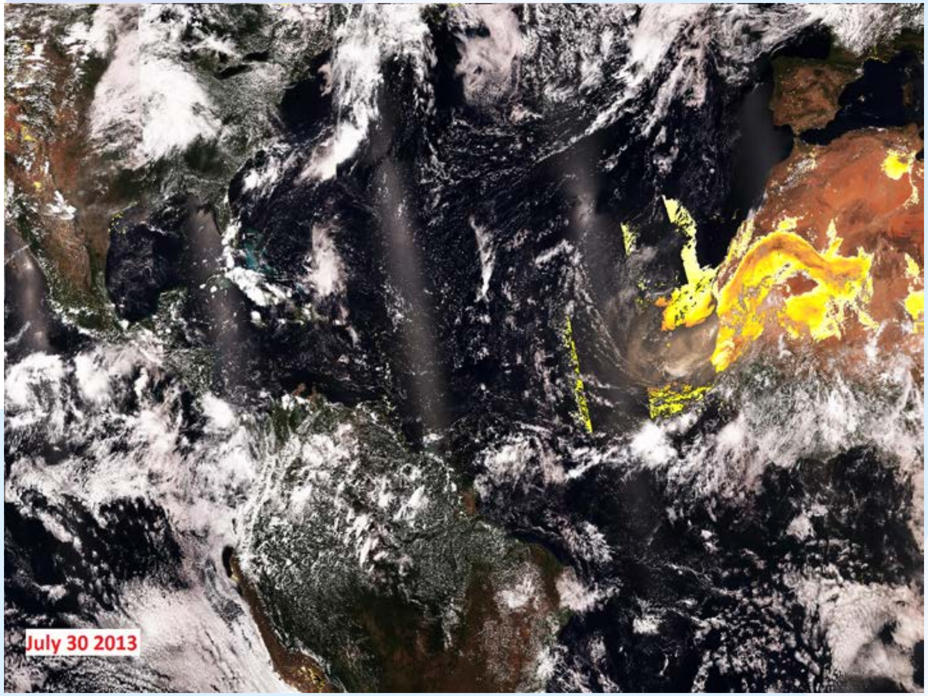
Jul 2013



## Saharan Dust Transport by NGAC forecasts




**VIIRS Dust Aerosol Index: MODIS dust mask algorithm applied to VIIRS globally**

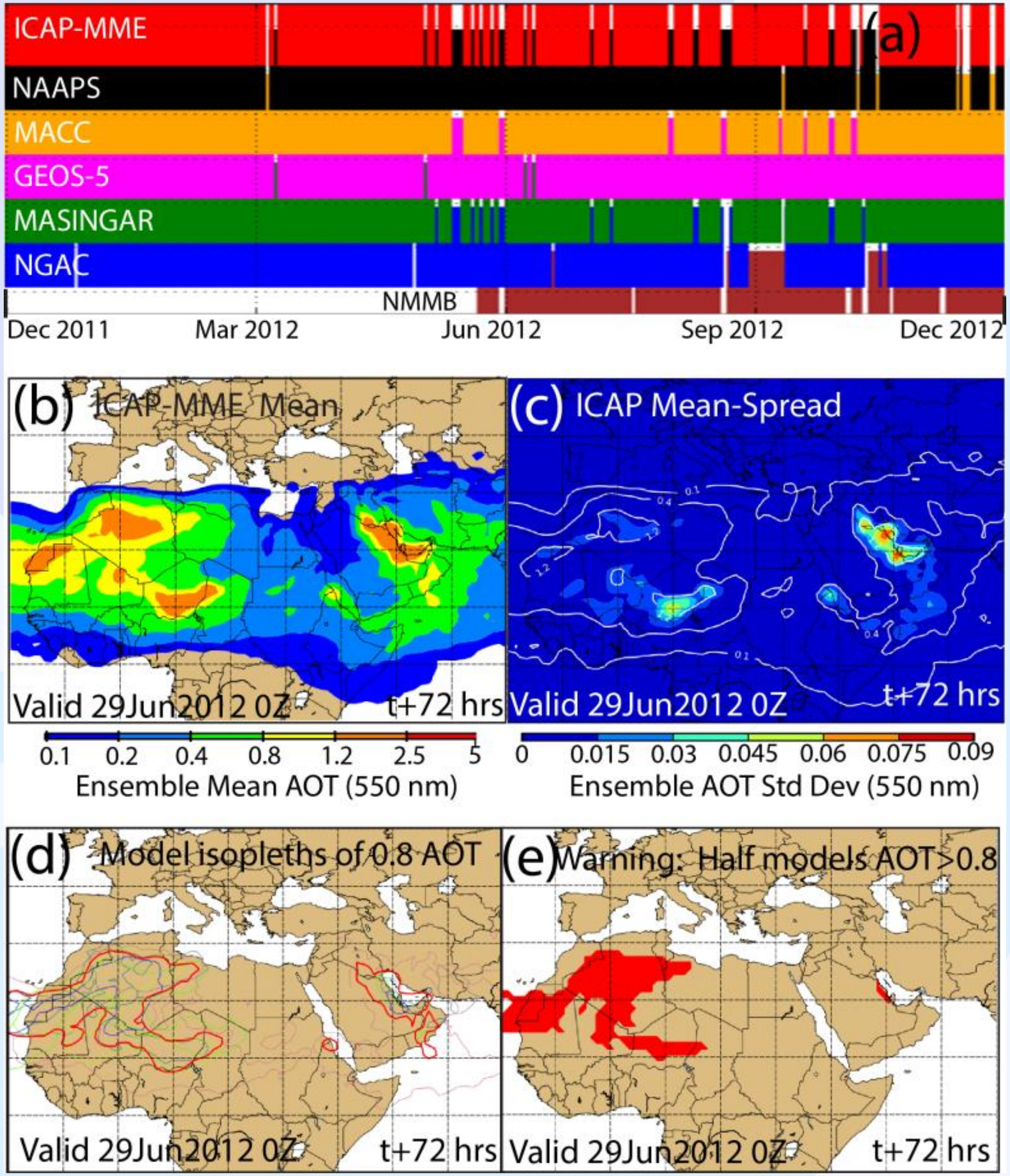



*Pubu Ciren and Shobha Kondragunta (NESDIS/STAR)*

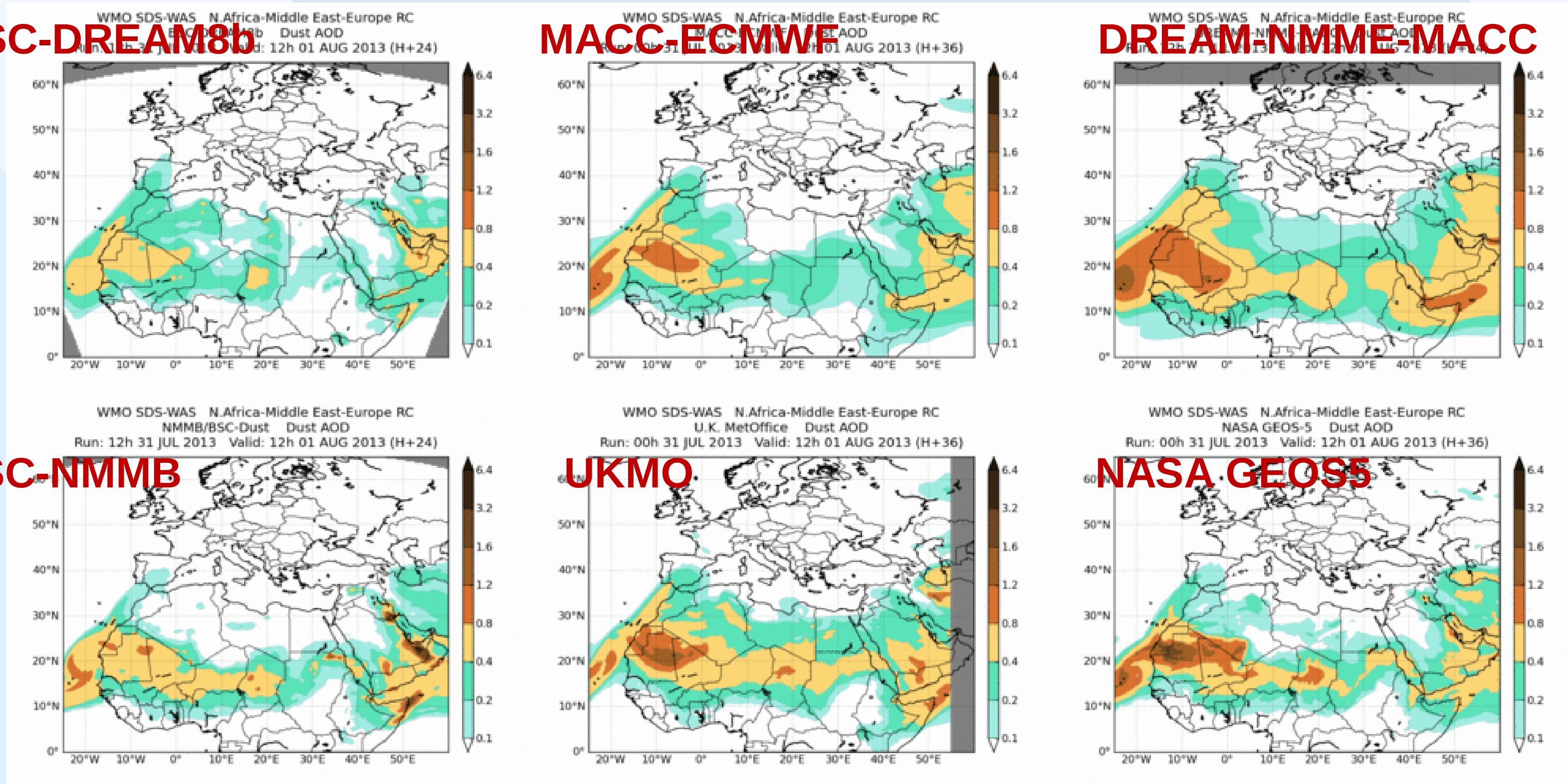
# Near-Real-Time Global Aerosol Forecasting

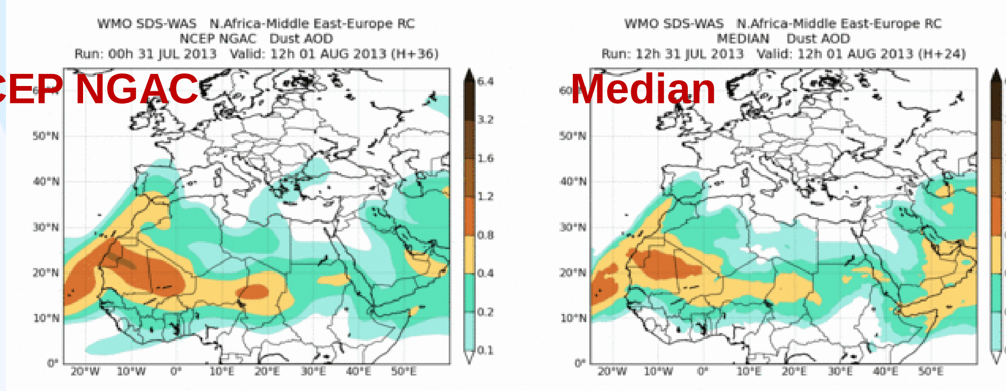
- NGAC dust products contribute global multi-model ensemble (by International Cooperative for Aerosol Prediction, ICAP) and regional multi-model ensemble (by WMO Sand and Dust Storm Warning Advisory and Assessment System, SDS-WAS)

- NGAC forecasts are independently evaluated by the ICAP and SDS-WAS programs



# Near-Real-Time Global Aerosol Forecasting




- SDS-WAS Africa node, conducts daily inter comparison for dust AOD and dust surface concentration
- Regional multi-model ensemble, including 5 global models (NCEP, ECMWF, GMAO, UKMO, BSC)

# Presentation Outline

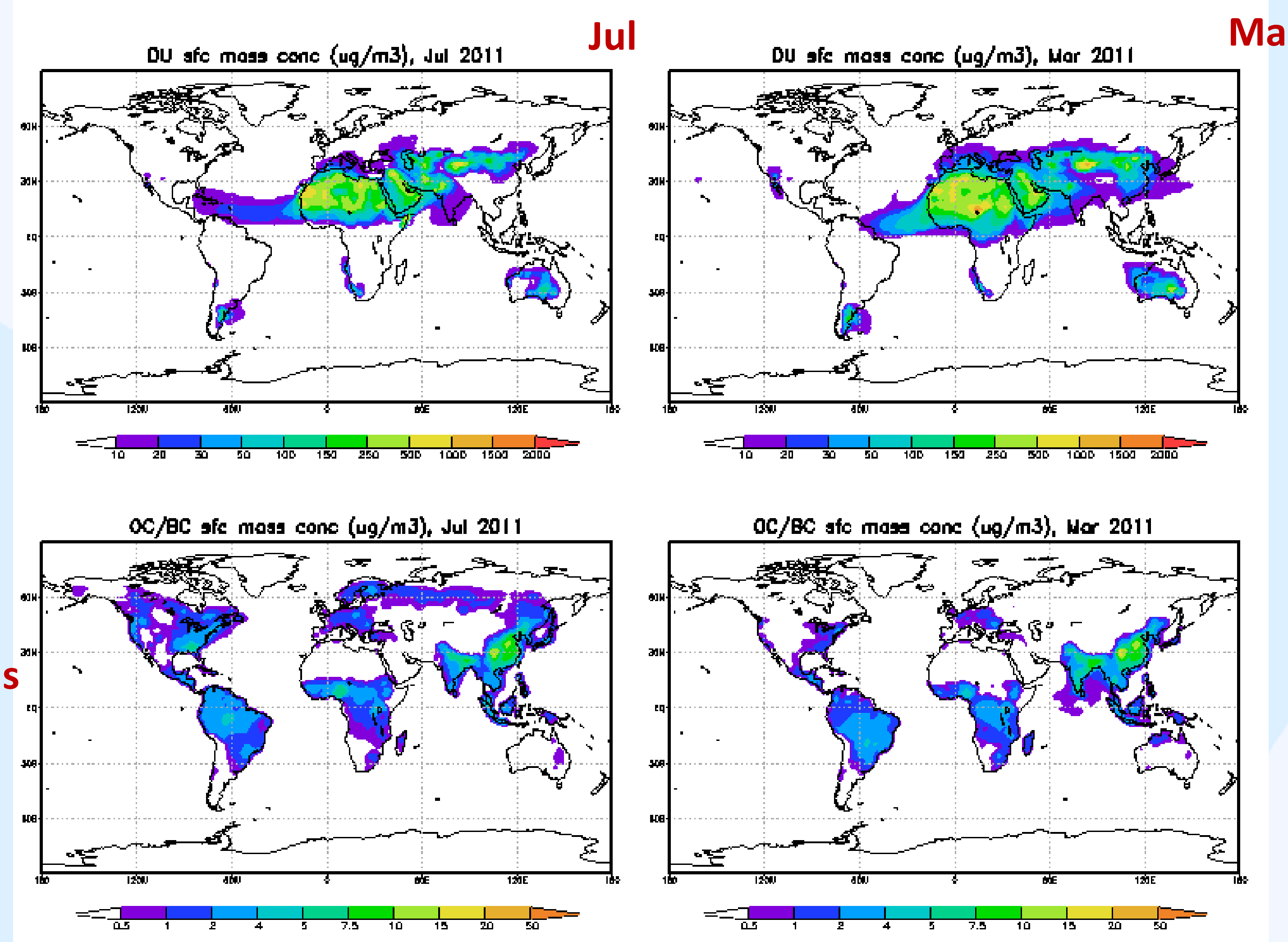
- Current Operational Configuration
- **Future operational requirements and applications**

# NGAC aerosol forecasts

- NGAC has the capability to simulate dust, sulfate, sea salt, and carbonaceous aerosols.
- NGAC using NESDIS's NRT smoke emissions is slated for operation implementation in FY15
- An example is given here where NGAC experiments for 2011 are conducted

**Dust aerosols**

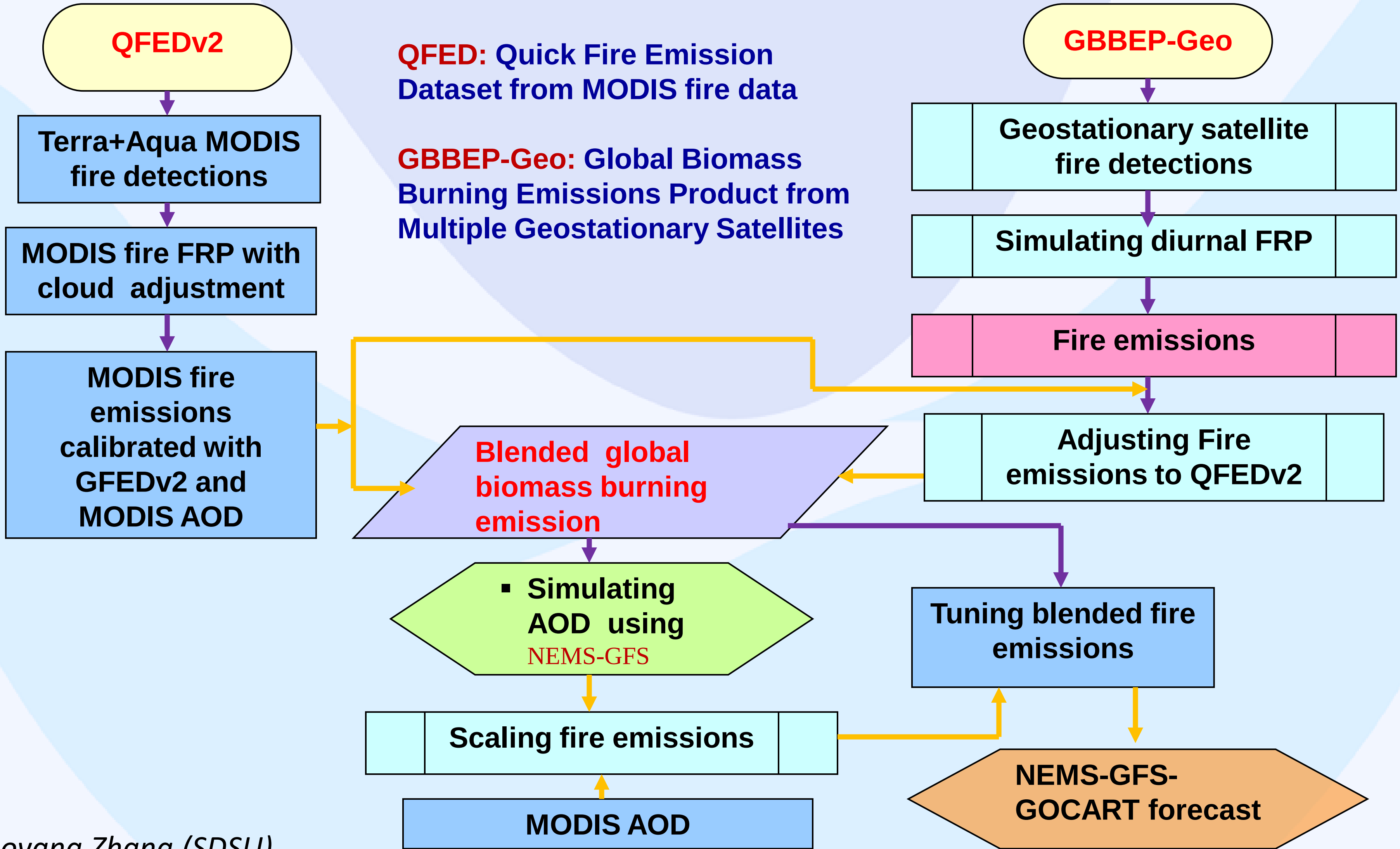
**Carbonaceous aerosols**



# Flowchart of Blending QFED and GBBEP-Geo

**QFED:** Quick Fire Emission Dataset from MODIS fire data

**GBBEP-Geo:** Global Biomass Burning Emissions Product from Multiple Geostationary Satellites




*Xiaoyang Zhang (SDSU)*

# FY15 Planned Implementation

- Extend the dust-only system to include sulfate, sea salt, and carbonaceous aerosols
  - NESDIS  - GSFC - NCEP collaboration to develop and test near-real-time biomass burning emissions (GBBEPx)
- Link low-resolution NGAC with high-resolution GDAS Hybrid EnKF and GFS

# NGAC Product Suite and Applications

NGAC provides 1x1 degree products in GRIB2 format once per day.
Product files and their contents include:

UV index forecasts → AOD assimilation → AVHRR SST → AIRS retrievals

- **ngac.t00z.aod_$CH, CH=340nm, 440nm, 550nm, 660nm, 860nm, 1p63um, 11p1um**
  - Aerosol Optical Depth (AOD) at specified wavelength from 0 to 120 hour

- **ngac.t00z.a2df$FH, FH=00, 03, 06, ….120**
  - AOD at 0.55 micron
  - Dust emission, sedimentation, dry deposition, and wet deposition fluxes ← **Budget, ocean productivity**
  - Dust fine mode and coarse mode surface mass concentration ← **Air quality**
  - Dust fine mode and coarse mode column mass density ← **Budget**

- **ngac.t00z.a3df$FH, FH=00, 03, 06, ….120** ← **Atmospheric correction**
  - Pressure, temperature, relative humidity at model levels
  - Mixing ratios for 5 dust bins (0.1-1, 1-1.8, 1.8-3, 3-6, 6-10 micron) at model levels

***Potential applications for NGAC products are highlighted in red.***

# Priority System Enhancements

- **Long-term goal**
  - Allow aerosol impacts on weather forecasts and climate predictions to be considered
  - Enable NCEP to provide **quality atmospheric constituent products** serving wide-range of stakeholders, such as health professionals, aviation authorities, policy makers, climate scientists, and solar energy plant managers

- **Phased implementation**
  - Phase 1: Dust-only forecasts (operational)
  - Phase 2: Forecasts for dust, sulfate, sea salt, and carbonaceous aerosols using NESDIS's GBBPEx smoke emissions (planned FY15 implementation)
  - Phase 3: Aerosol analysis using VIIRS AOD (well-defined R2O building upon existing NCEP-NESDIS-GSFC collaboration)

# Why VIIRS AOD Data Assimilation?

- While development work remains, ground work has been laid for building a global aerosol data assimilation capability within NGAC and Hybrid EnKF-GSI
  - Prognostic aerosol capability has been established
  - Infrastructure development (CRTM supports GOCART, GSI code development for AOD DA*)
  - Near-real-time smoke emissions have been developed, slated for operational in FY15
  - Community aerosol modeling/assimilation efforts (ICAP, GSI)

- Other centers (e.g., NRL, ECMWF, GMAO) are assimilating MODIS AOD, and are currently assessing the VIIRS aerosol products. NCEP is yet to develop the AOD data assimilation capability and will be focused on VIIRS products (instead of the "MODIS then VIIRS" approach).

* GSI AOD data assimilation: (1) Development work at NCEP is temporarily suspended due to budgetary constraint (2) Extensive development work conducted by other centers (NCAR, ESRL)

| Future Operational Benefits Associated with NEMS GFS Aerosol Component | Status |
|---|---|
| Provides a first step toward an operational aerosol data assimilation capability at NOAA | VIIRS AOD data assimilation (pending support) |
| Allows aerosol impacts on medium range weather forecasts (GFS/GDAS) to be considered | Ongoing work at EMC |
| Allows NOAA to explore aerosol-chemistry-climate interaction in the Climate Forecast System (CFS) as GFS is the atmospheric model of CFS | CPO MAPP-CTB funded project |
| Provides global aerosol information for various applications (e.g., satellite radiance data assimilation, satellite retrievals, SST analysis, UV-index forecasts, solar electricity production) | Ongoing NCEP-NESDIS-Howard collaboration on aerosol-SST |
| Provides lateral aerosol boundary conditions for regional aerosol forecast system | Benchmark study completed |

# Conclusions

**NCEP is developing global aerosol forecasting/assimilation capability**

- The aerosol project builds upon extensive collaboration with NOAA labs/centers (NESDIS) and external research community (GSFC, the ICAP working group, WMO SDS-WAS program)

- Phased implementation
    - Phase 1: Dust-only forecasts (operational)
    - Phase 2: Forecasts for dust, sulfate, sea salt, and carbonaceous aerosols using NESDIS's GBBPEx smoke emissions (planned FY15 implementation)
    - Phase 3: Aerosol analysis using VIIRS AOD (well-defined R2O building upon existing NCEP-NESDIS-GSFC collaboration)

***Thanks.***

***Questions and Comments?***