# L1b VIIRS-MODIS Matchup Inter-Comparisons

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Deep Blue and Dark Target Aerosol Teams

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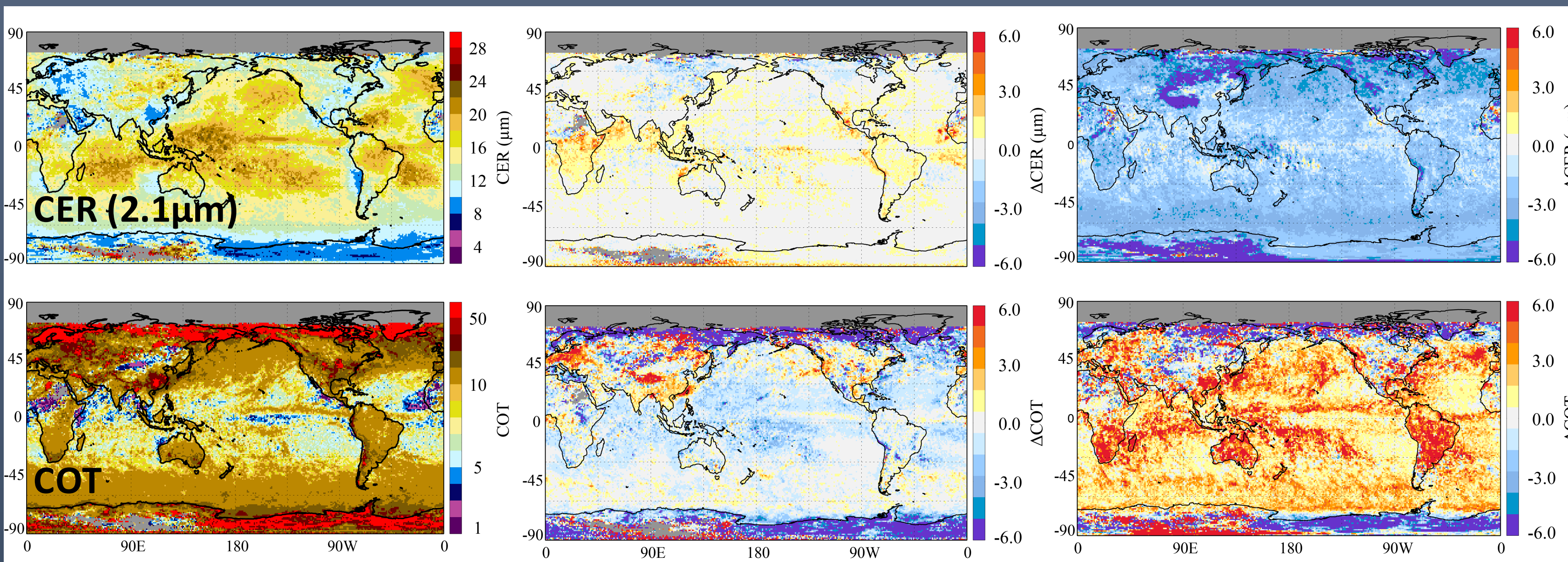
# Background

MYD08 | MODAWG-MODIS - MYD08 | MODAWG-VIIRS - MODAWG-MODIS

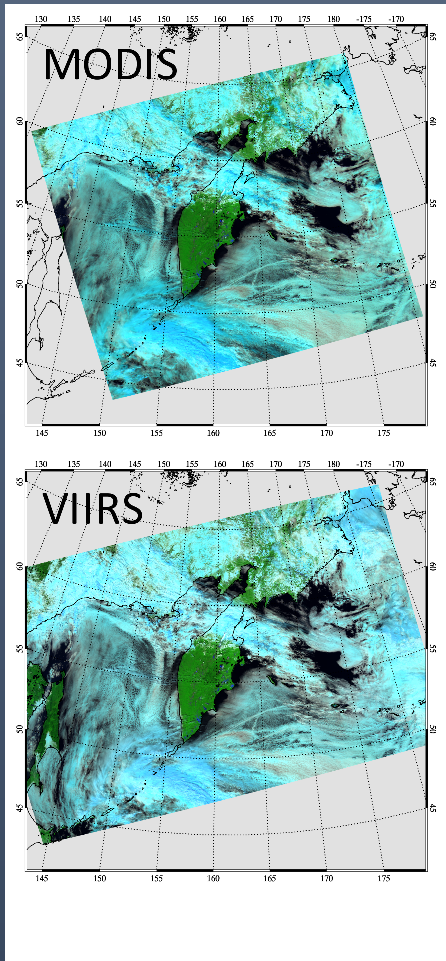



Liquid Phase Clouds, February 2014

Significant cloud optical thickness (COT) and effective particle radius (CER) differences between MODIS and VIIRS (above, right column) using identical algorithm, analogous spectral channel set, and cloud radiative models that account for spectral response differences.

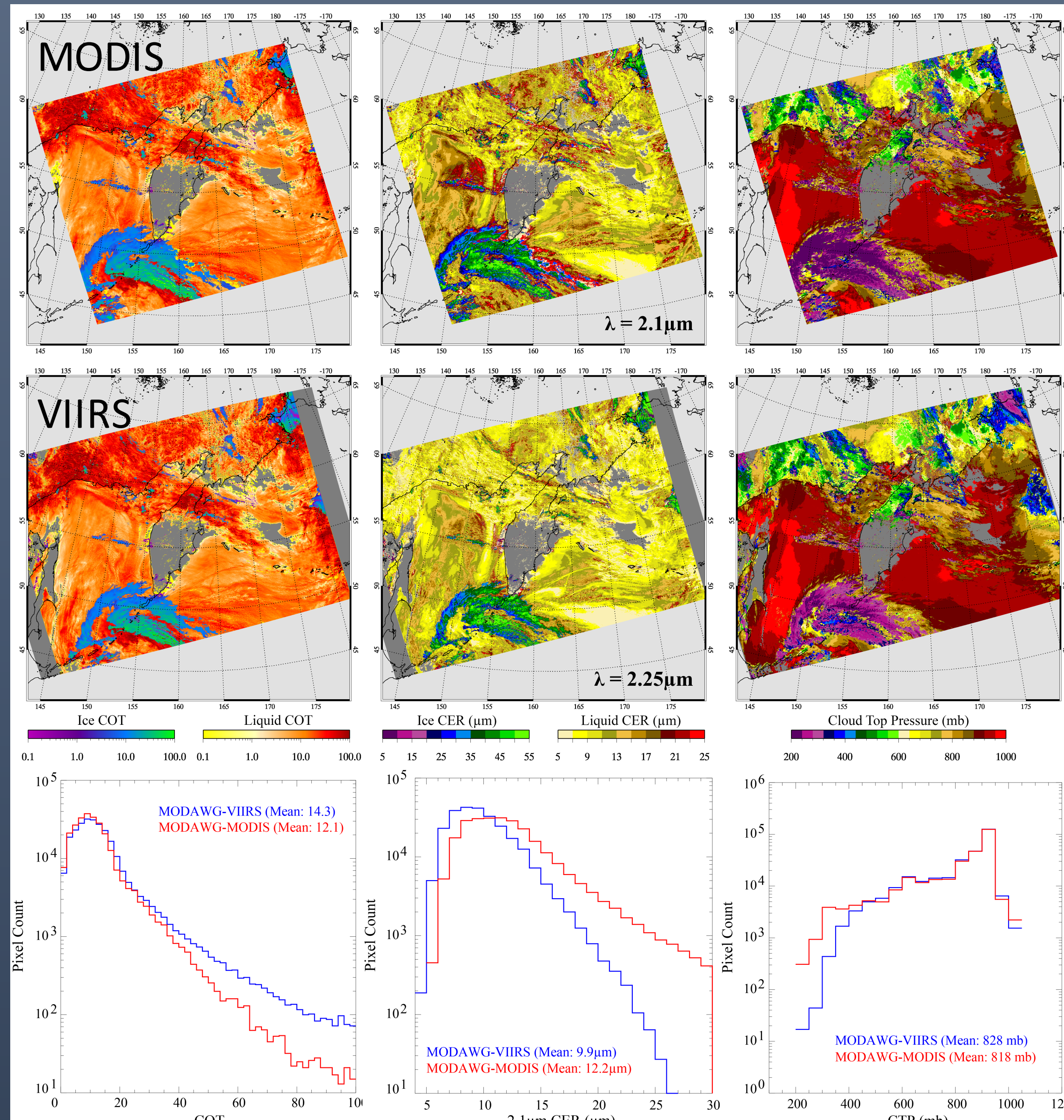
MODAWG = MODIS-VIIRS cloud product continuity algorithm

# Background



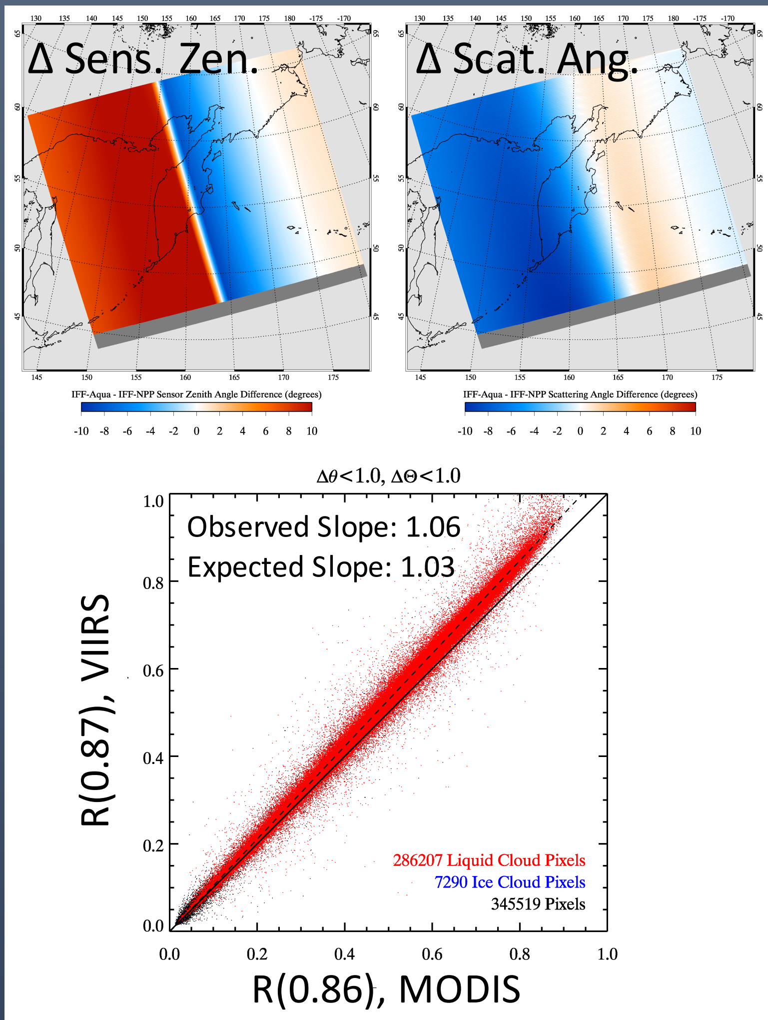

6 July 2014, 0200 UTC
(IFF 5-minute granules)

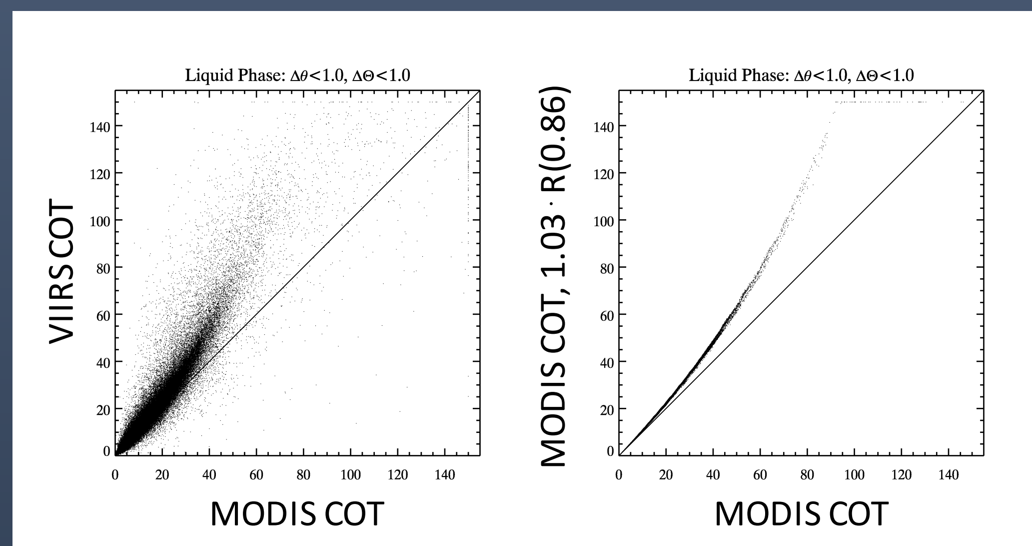
COT CER (2.Xµm) CTP



# Background

- For liquid cloud pixels in this granule (6 July 2014, 0200 UTC) having similar MODIS and VIIRS view geometries, VIIRS R(0.87µm) is roughly 3% brighter than MODIS R(0.86µm) after accounting for expected spectral differences at this view geometry.
- Increasing MODIS R(0.86µm) by 3% yields COT differences (with respect to baseline MODIS COT) similar to VIIRS-MODIS COT differences.



# Inter-Calibration Match Files

- Radiometric differences, evident between MODIS Aqua and SNPP VIIRS, adversely affect inter-sensor climate data record continuity.
- Atmosphere SIPS producing MODIS-VIIRS match files containing key co-located parameters for assessing inter-sensor radiometric calibration:
  - Common angle space and observation time: ±5° threshold for view zenith and scattering angle differences; ±20 minute observation time
  - Geolocation, sun-satellite geometry, solar reflectance, IR radiance, and cloud mask (for scene identification)
  - Entire MODIS-VIIRS concurrent record, through March 2016.
  - Uses NASA VIIRS L1b (Version 1).

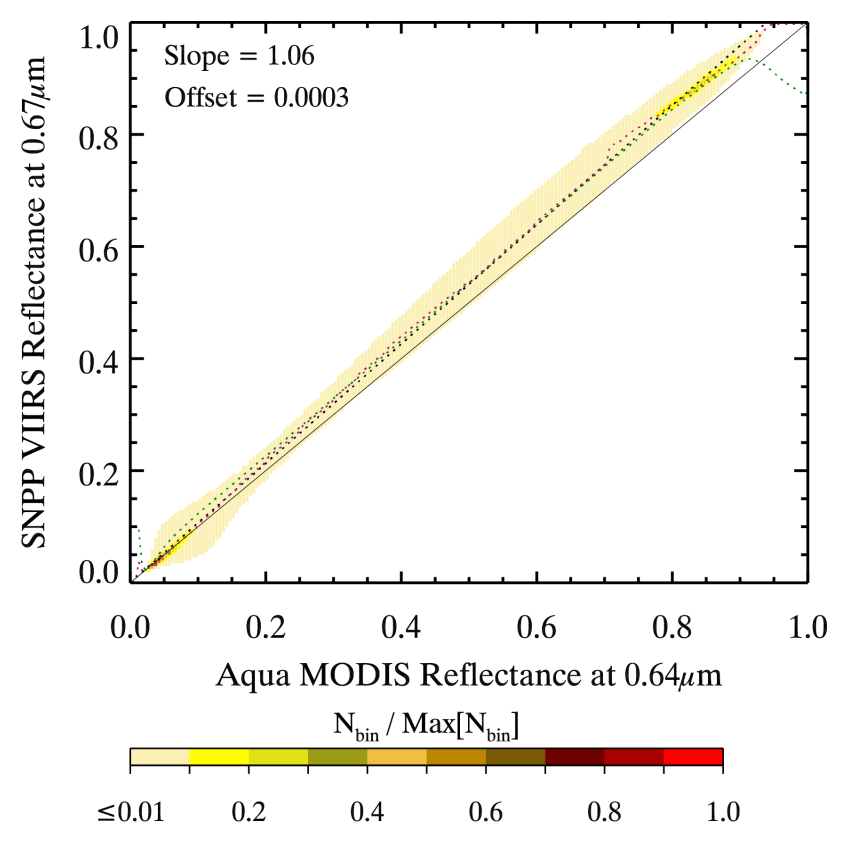
# Cloud Team Efforts

- Efforts focused on liquid phase clouds that are expected to have comparable optical/microphysical retrievals given the spectral response differences of the analogous channel set.
  - Ice cloud absorption quite different between MODIS 2.1 and VIIRS 2.25μm channels.
- More restrictive angle matching: $\pm 1^{o}$ threshold for view zenith and scattering angle differences.
- Additional parameters appended for cloud product team evaluation:
  - Cloud top pressure/temperature/height/emissivity, cloud phase, cloud optical/microphysical properties

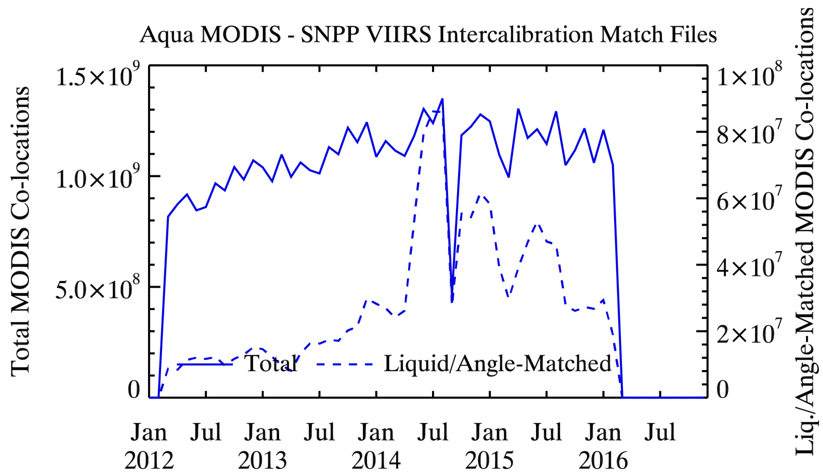
# First Results

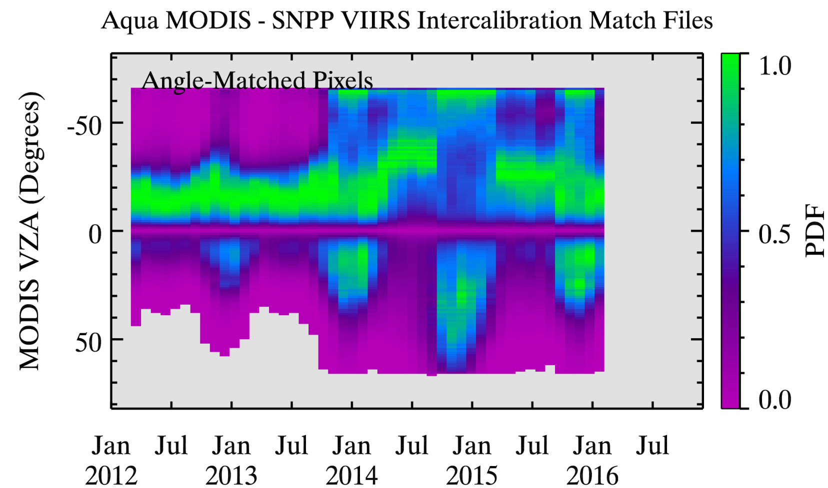
- Monthly reflectance scatter plots (global) for cloud optical retrieval channels plus 0.47, 0.55µm (example at right for 0.66µm) over entire MODIS-VIIRS record through March 2016.
    - Note: VIIRS reflectance from NASA L1b (Version 1).
- Time series plots of monthly co-located pixel counts, co-located sensor view angle distribution, and radiometric slopes/offsets.

January 2014



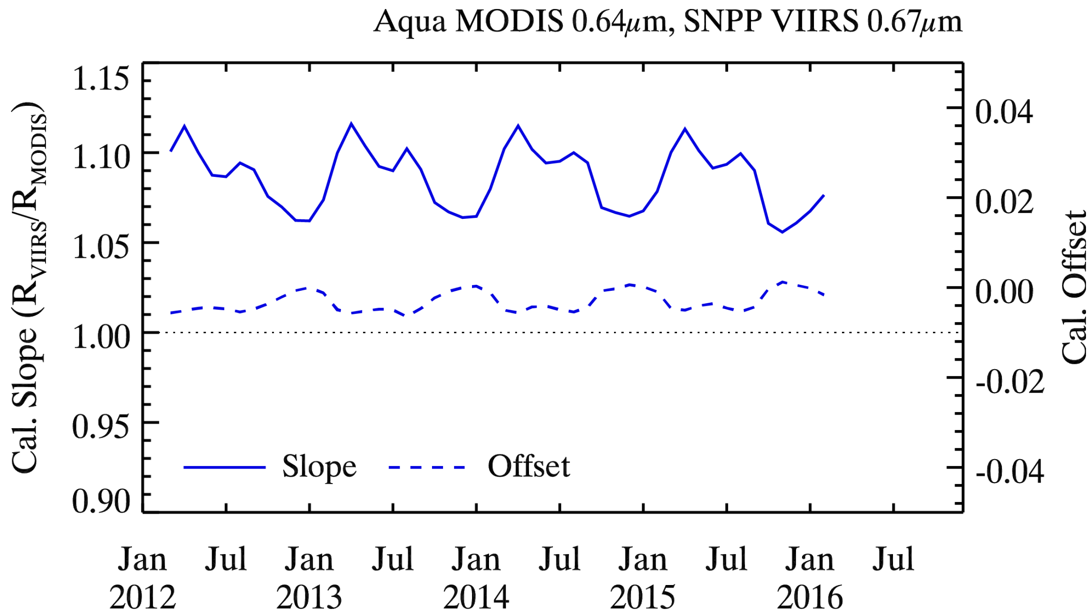
# First Results

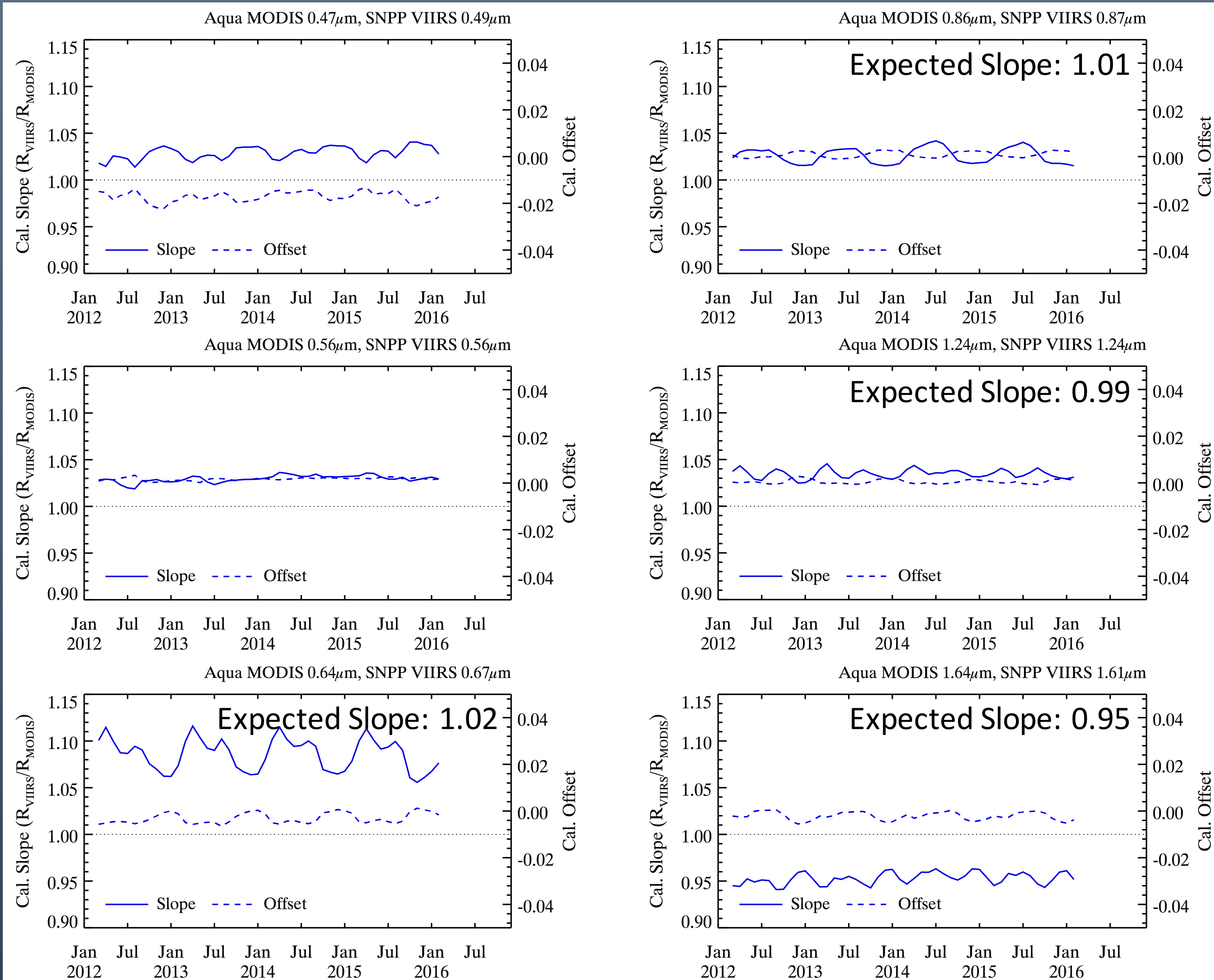



**Liquid/Angle-Matched Filtering:**

- ±1° view zenith & scattering angle difference
- Liquid phase clouds determined by MOD06
- VIIRS reflectance aggregated to MODIS FOV

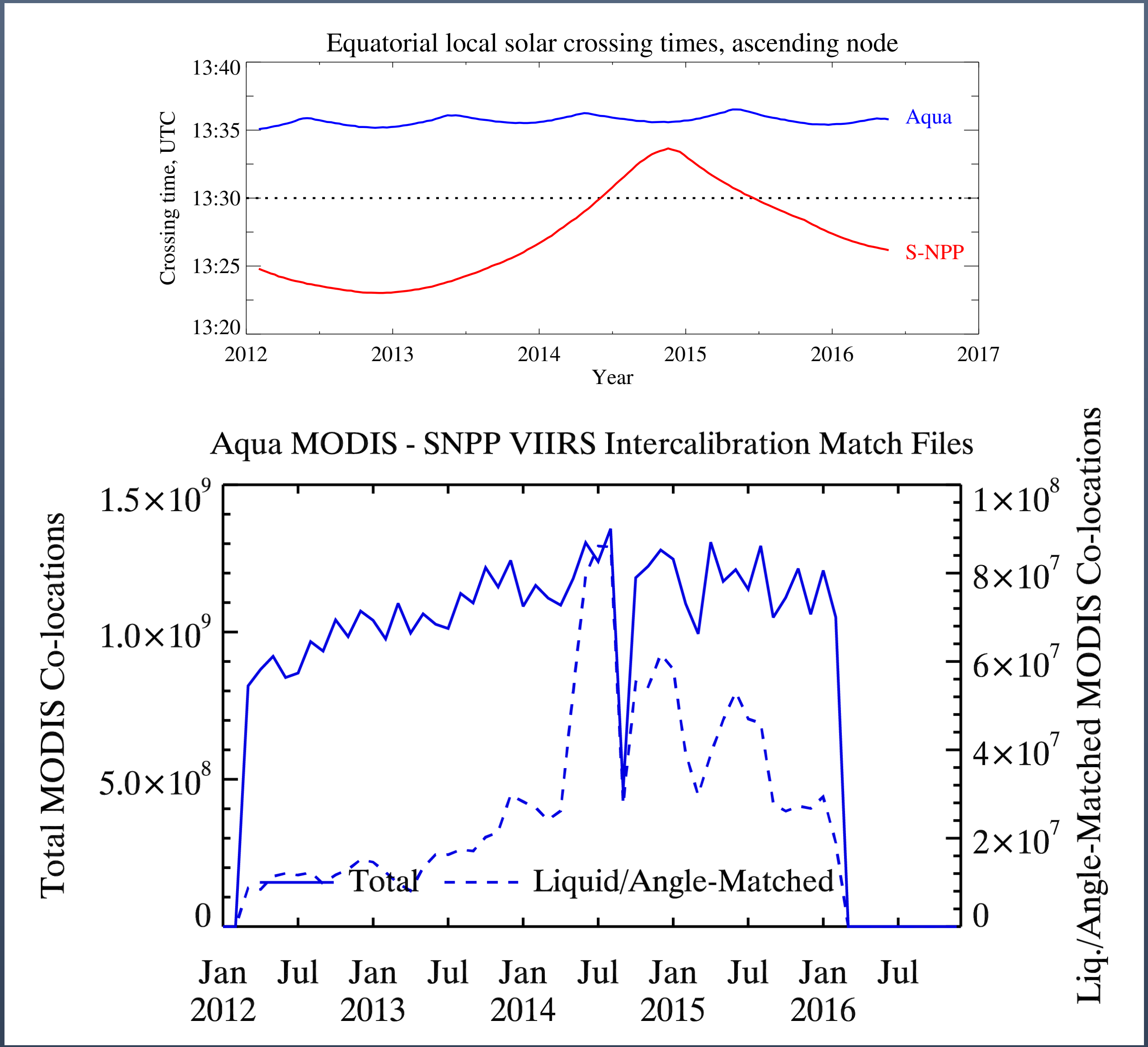



Aqua MODIS 0.47$\mu$m, SNPP VIIRS 0.49$\mu$m
Aqua MODIS 0.86$\mu$m, SNPP VIIRS 0.87$\mu$m
Expected Slope: 1.01
Aqua MODIS 0.56$\mu$m, SNPP VIIRS 0.56$\mu$m
Aqua MODIS 1.24$\mu$m, SNPP VIIRS 1.24$\mu$m
Expected Slope: 0.99
Aqua MODIS 0.64$\mu$m, SNPP VIIRS 0.67$\mu$m
Expected Slope: 1.02
Aqua MODIS 1.64$\mu$m, SNPP VIIRS 1.61$\mu$m
Expected Slope: 0.95
Cal. Slope ($R_{VIIRS}/R_{MODIS}$)
Cal. Offset
Slope
Offset
1.15
1.10
1.05
1.00
0.95
0.90
0.04
0.02
0.00
-0.02
-0.04
Jan 2012
Jul
Jan 2013
Jul
Jan 2014
Jul
Jan 2015
Jul
Jan 2016
Jul

# To do…

- Assess geographic sampling of match files.
- Improve co-located pixel filtering.
  - Add MODAWG-MODIS/VIIRS products to match files for better liquid phase pixel identification.
    - Action Item: Run MODAWG product suite over the entire data record.
  - Possible observation time difference filtering.
- More rigorous characterization of expected radiometric differences.
  - Function of COT, CER, angle space, etc.
  - Action Item: Estimate from forward RT calculations (directly from cloud retrieval LUTs, or additional RT calcs if necessary) and atmospheric correction algorithm.

# VIIRS Orbit Drift



# Retrieval of aerosol properties from MODIS-Terra, MODIS-Aqua, and VIIRS-SNPP: Calibration focus

Robert C. Levy (NASA-GSFC)



Shana Mattoo, Virginia Sawyer* and Richard Kleidman (SSAI/GSFC)
Falguni Patadia and Yaping Zhou* (Morgan State U / GSFC)
Pawan Gupta and Yingxi Shi* (USRA/GSFC)
Lorraine Remer (UMBC/JCET), Robert Holz (SSEC/UWisconsin)

* New people in 2016.

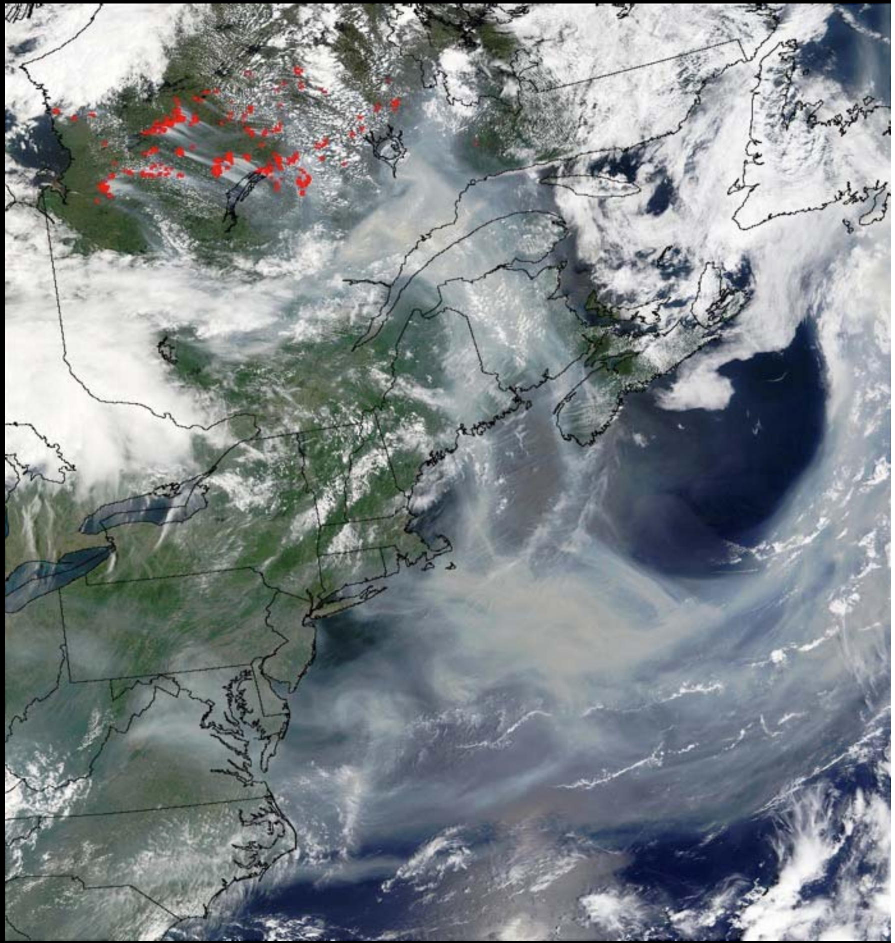
And many, many, many others

MODIS/VIIRS Science Team Meeting: June 2016

# Aerosol from space

- Aerosol optical depth (AOD or $\tau$)
- "Essential Climate Variable" (ECV)
  - Requires accuracy <±0.02
  - Measured over multi-decades
- Yet, mostly a "regional" problem.
- Required uncertainty (per pixel) = <15%.

- A 2% uncertainty in measuring reflectance (low light levels) can lead to 20% uncertainty in AOD



Smoke transported over Eastern Canada/USA (8 July 2002)

http://earthobservatory.nasa.gov/

# Outline

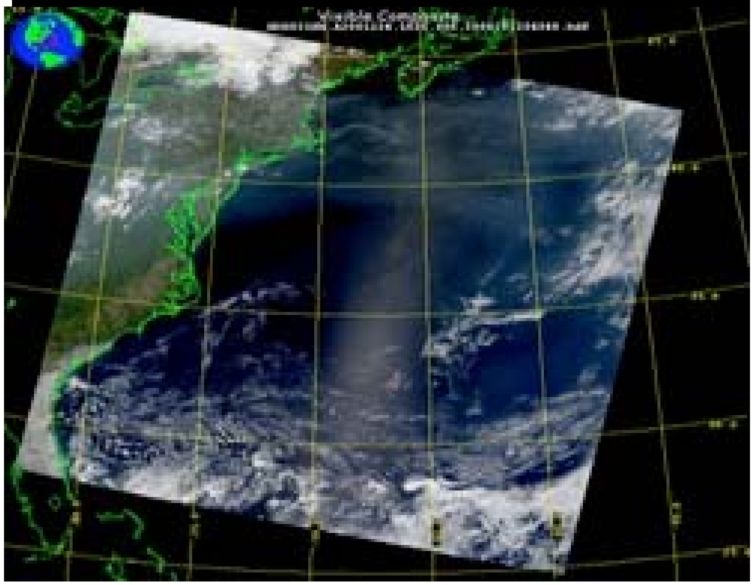
1. “Dark-target” (DT) remote sensing
2. Terra vs Aqua
3. VIIRS vs Aqua (using Wisconsin and IFF)

# Dark Target Aerosol Retrieval

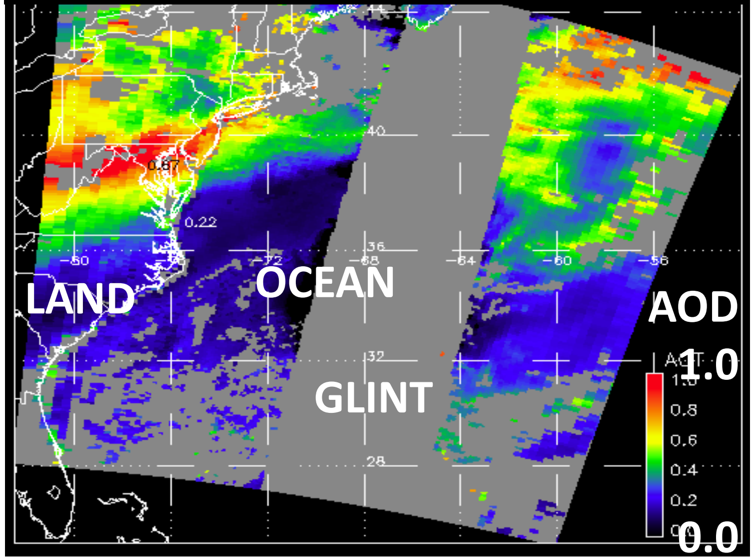
What sensor observes

Attributed to aerosol (AOD)

**May 4, 2001; 13:25 UTC**
**Level 1 "reflectance"**



**May 4, 2001; 13:25 UTC**
**Level 2 "product"**




There are many different "algorithms" to retrieve aerosol

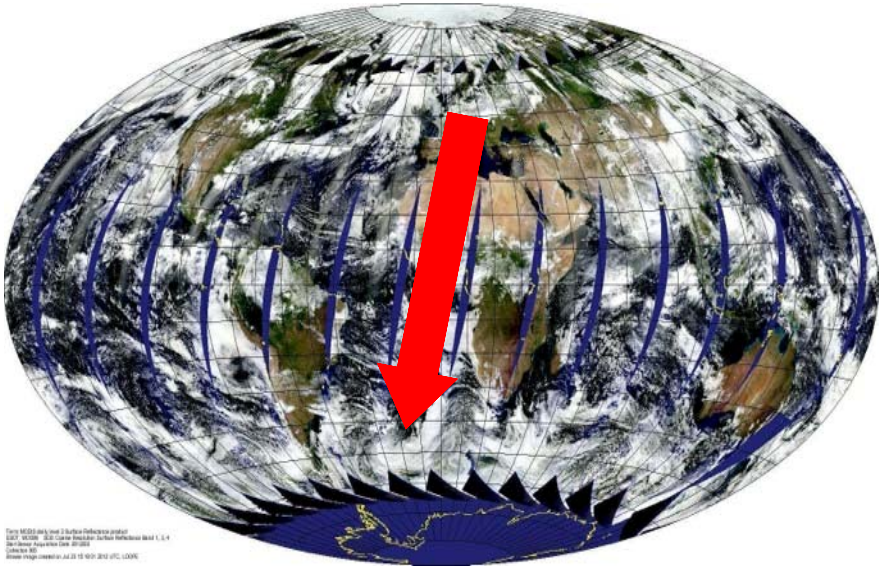
Ours is **Dark Target (DT)**; "Established 1997" by Kaufman, Tanré, Remer, etc)

**Separate algorithms: Ocean and Land**
**Both are multi-channel inversions**
**Products = AOD at 0.55 μm, spectral AOD, diagnostics**

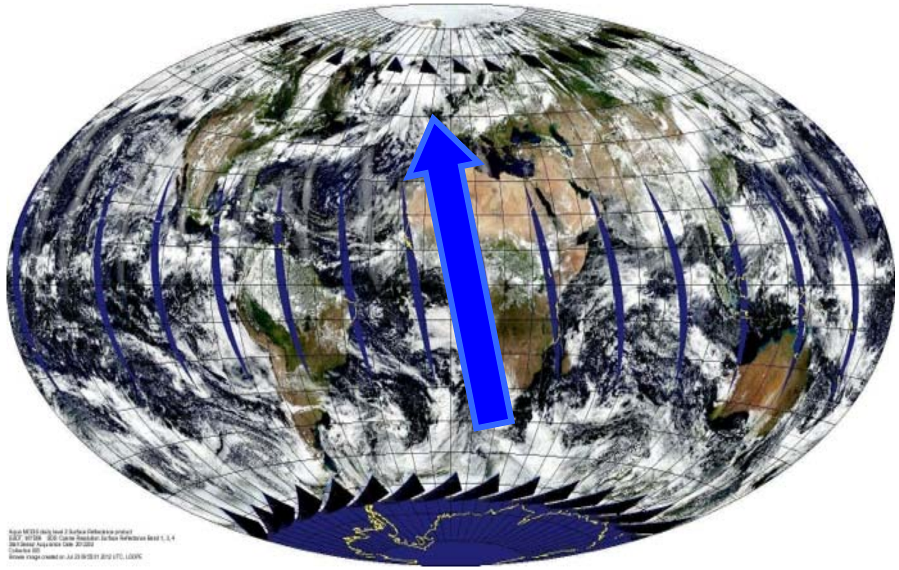
# MODIS on Terra and Aqua
## Do they represent the same world?

- Same instrument hardware (optical design)
- Same spatial and temporal sampling resolution
- Same calibration/processing teams
- Same aerosol retrieval algorithms
- The two MODIS instruments are Identical twins!

Terra (10:30, Descending)



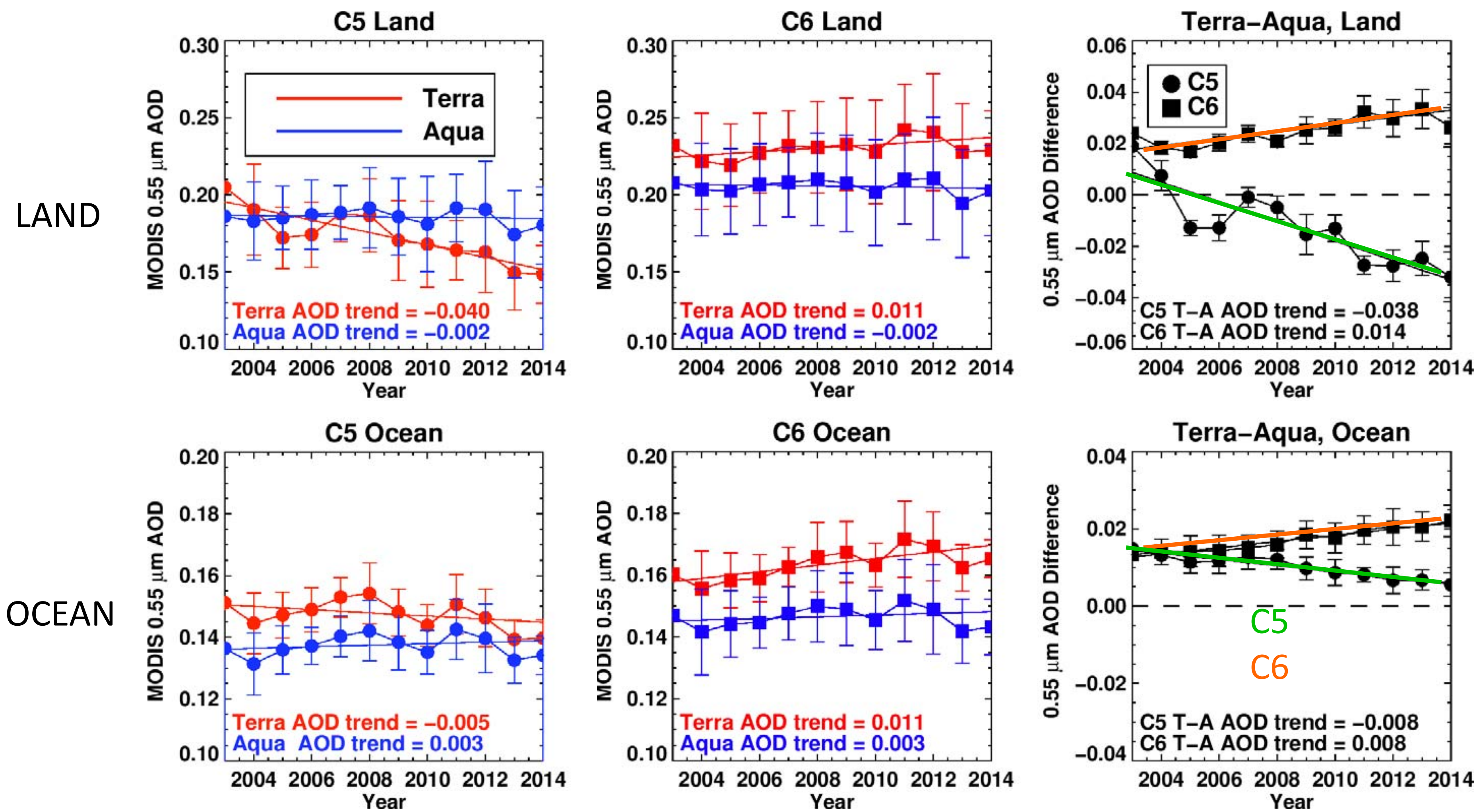
Aqua (13:30, Ascending)



Twins!  And they behave like twins, meaning not exactly the same

# Time series of MODIS-derived AOD

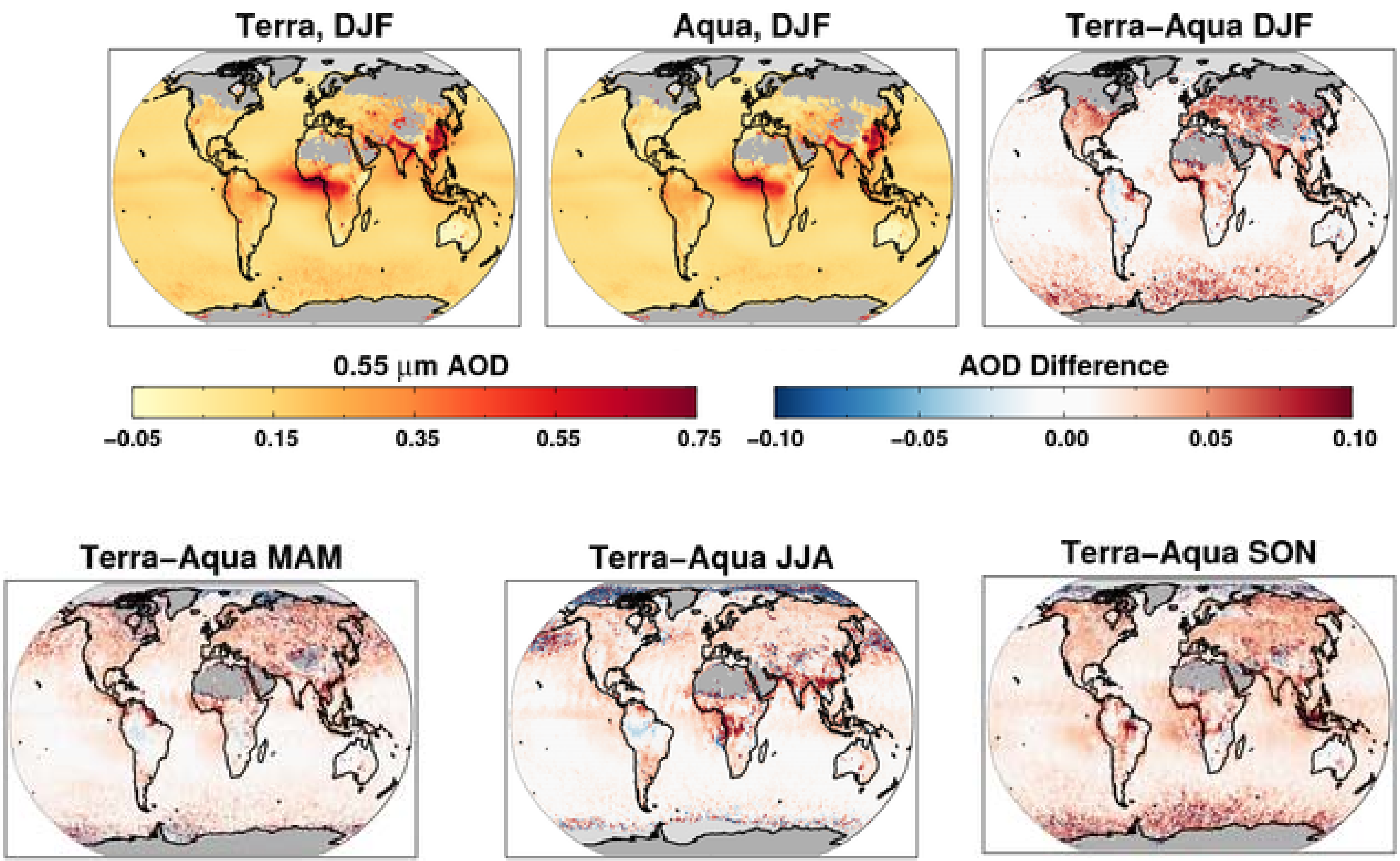
## $\Delta\tau$ = Terra - Aqua




Good news: Strong $\Delta\tau$ negative "trending" is reduced in C6

Bad news: 1) $\Delta\tau$ offset increases, and 2) there is now a positive trend

# $\Delta\tau > 0$: everywhere and for all seasons



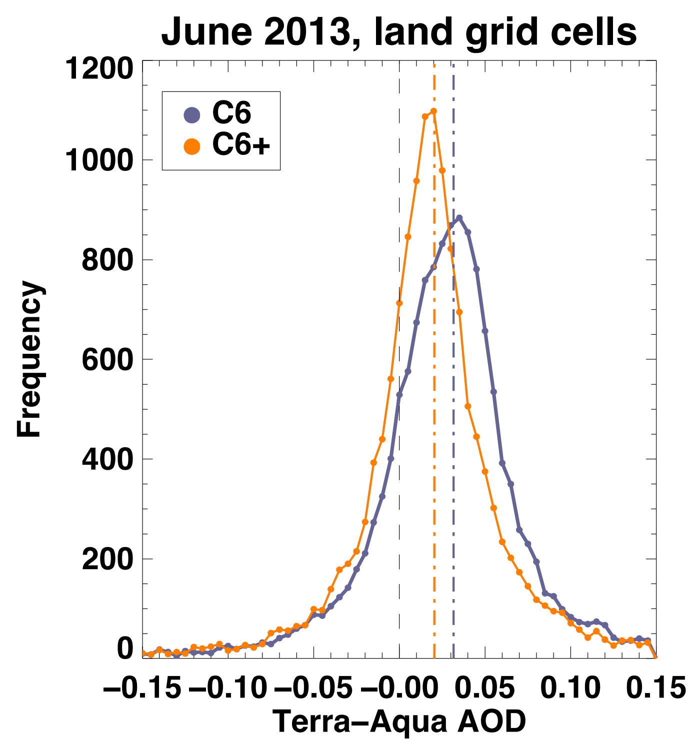

This can't be right…..

# MODIS C6 (and calibration adjustments?)

- Trending issues reduced with C6 product, but:
  - Still significant offsets (13%) and
  - Still residual co-trending (<0.01 / decade)
- Why? Sampling? diurnal cycles? Cloud masking?

- Calibration?
  - Test different options
  - "C6+" of Alexei Lypustin et al.,
  - Ocean vicarious corrections
  - Many others
  - Me, playing on my own.
  - Etc.

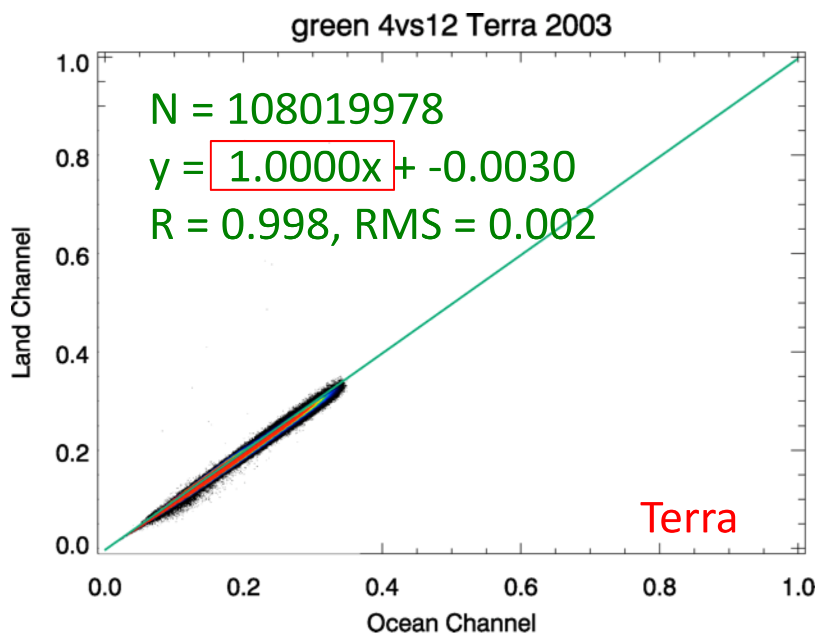
- Still working on problem

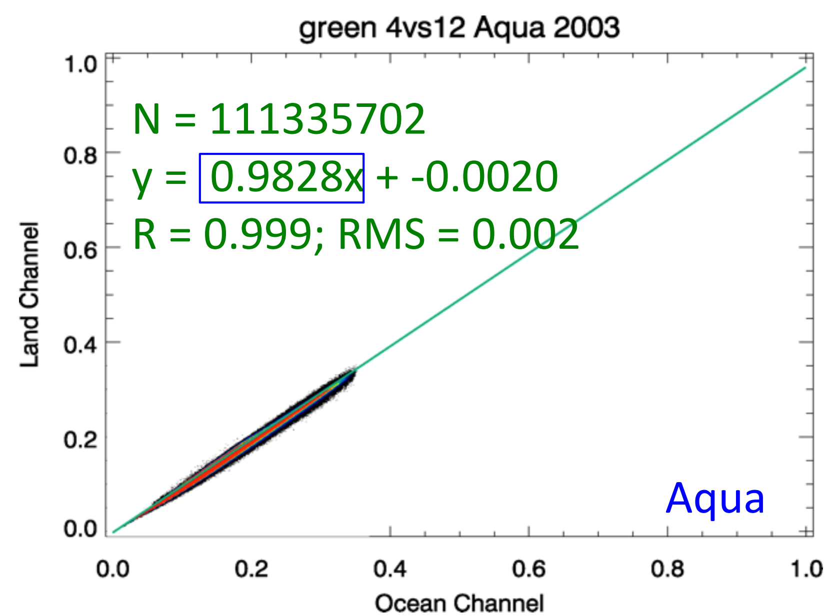



TBD author et al., (in prep)

# Me playing on my own: Land vs Ocean bands

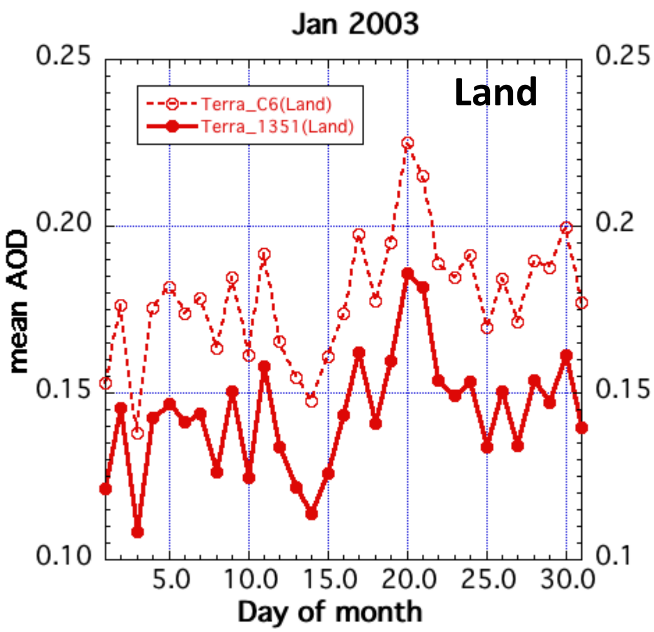
- For aerosol retrieval, we generally operate in the lower reflectance regime (as compared to clouds or ice/snow retrievals)
- Some "land" bands (#3,4,1 & 2 = 0.47, 0.55, 0.65, & 0.86) have counterpart "ocean" bands (#10,12,13 & 16 = 0.48, 0.55, 0.67 & 0.87)
- Make scatterplots of land vs ocean band reflectance, stratified by sensor, and by year. Ignore angle/detector dependencies. Note slope and offset

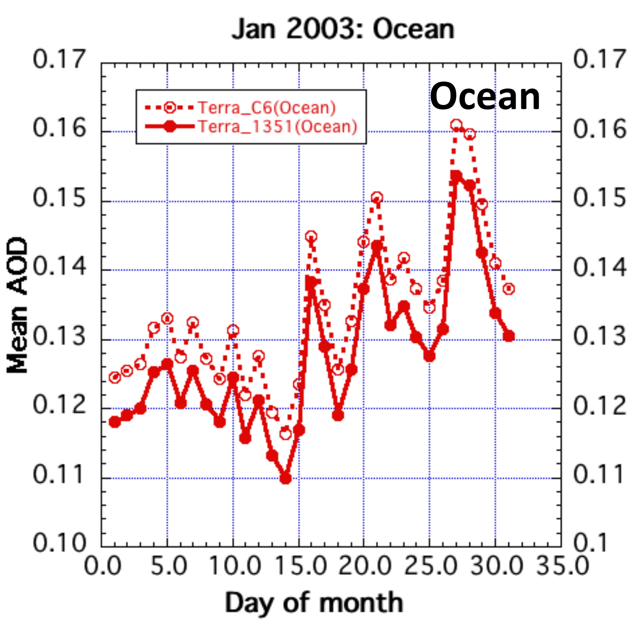


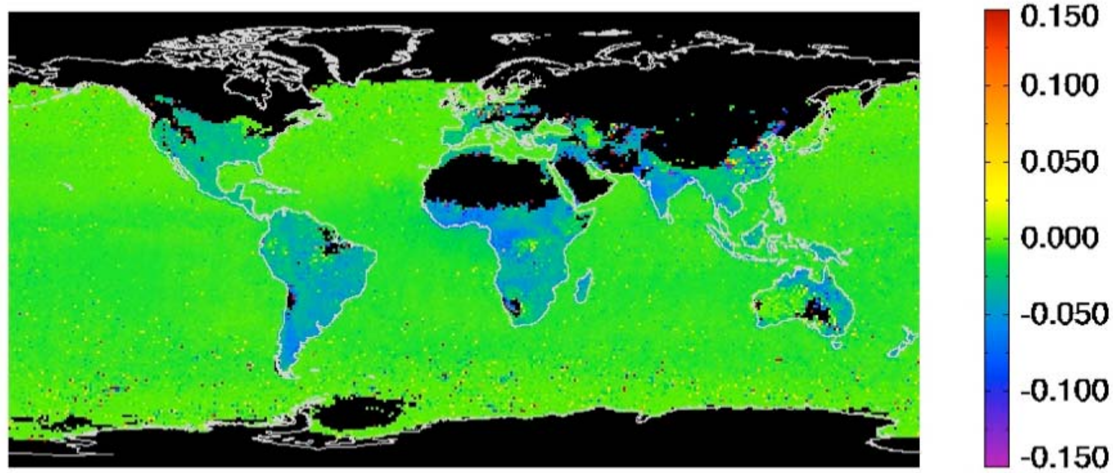

For green, there is a 2% difference in slope! Do same for other pairs.

# Apply “corrections” (e.g. make Terra look like Aqua): Jan 2003; Terra




Jan 2003 Gridded AOD: Test1351 – C6




With the gain correction factors:

Land reduced by 0.027

Ocean reduced by 0.007

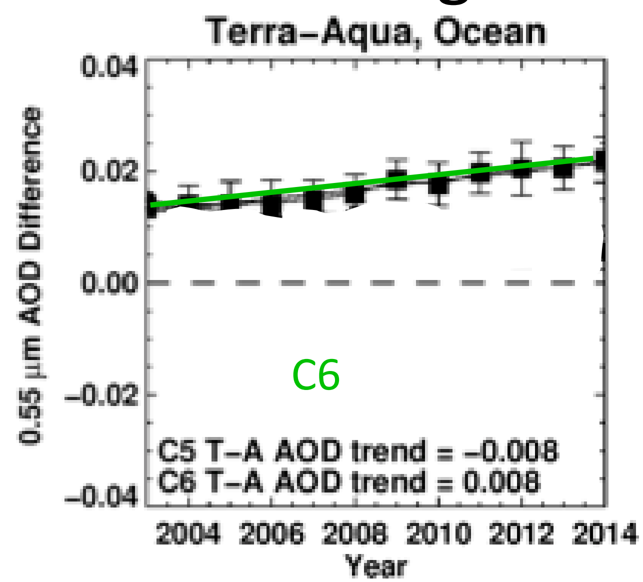
Recall: $\Delta\tau$ = Terra – Aqua in 2003

Land offset by 0.024

Ocean offset by 0.015

# MODIS: Terra vs Aqua

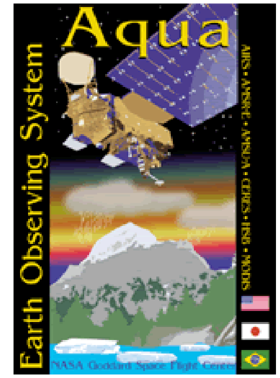
- Trending issues reduced with C6 product, but:
  - Still significant offsets (13%) and
  - Still residual co-trending (<0.01 / decade)
- Why? Sampling? diurnal cycles? Cloud masking?
- Calibration?
  - Test different options




- Aerosols are hard: We retrieve in a range from near black to fairly bright.

TBD author et al., (in prep)

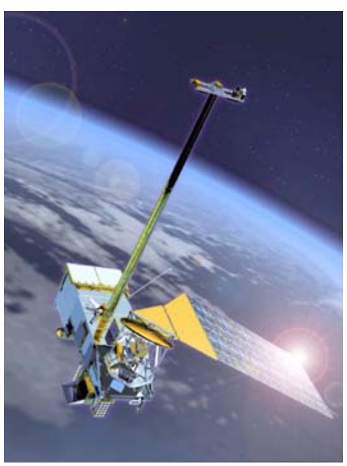
# Beyond **MODIS**





- Terra (16 years old) is driving in Maryland
- Aqua (14) "seems" well behaved, but is a teenager
- Both have well-exceeded their planned mission lifetimes
- Calibration continues to get trickier, and there are end-of-lifetime plans

**How do we make AOD climate data record? (20+ years of global AOD)?**



# **VIIRS?**

Visible-Infrared Imager Radiometer Suite
aboard Suomi-NPP
(and future JPSS)

# VIIRS versus MODIS

**Orbit**: 825 km (vs 705 km), sun-synchronous, over same point every 16 days

Equator crossing: 13:30 on Suomi-NPP, since 2012 (vs on Aqua since 2002)

**Swath**: 3050 km (vs 2030 km)

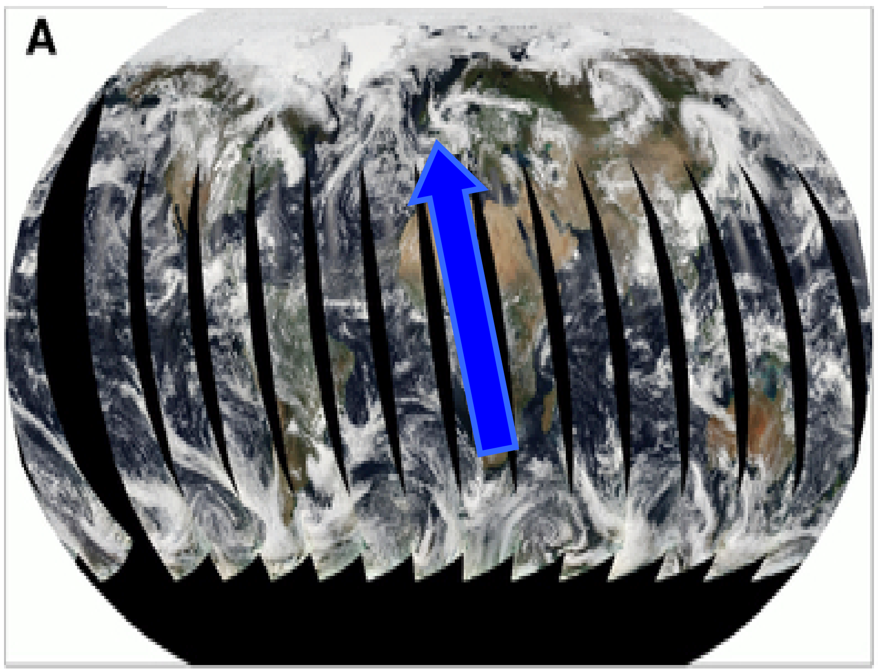
**Spectral Range**: 0.412-12.2µm (22 bands versus 36 bands)

**Spatial Resolution**: 375m (5 bands) 750m (17 bands): versus 250m/500m/1km

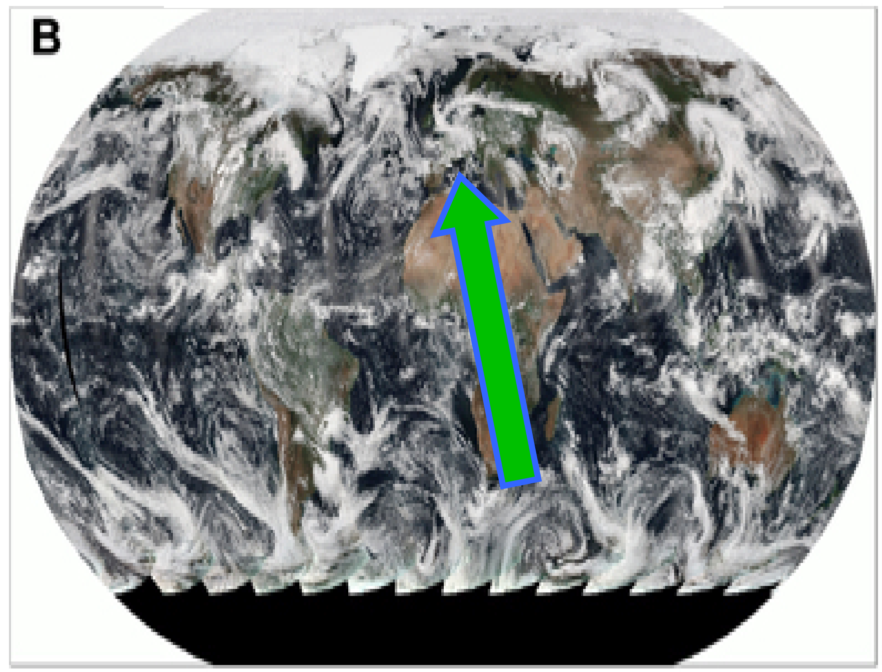
**Aerosol retrieval algorithms:** "Physics" similar, but different strategies

**Wavelength bands (nm) / DT aerosol retrieval**: 482 (466), 551 (553) 671 (645), 861 (855), 2257 (2113) → differences in Rayleigh optical depth, surface optics, gas absorption.

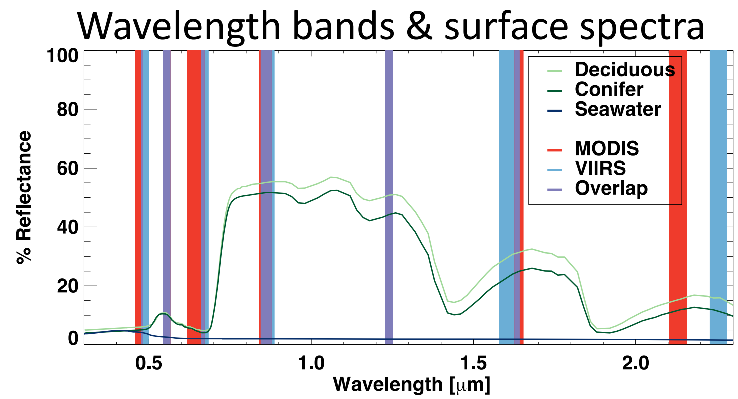
MODIS-Aqua – 29 May 2013



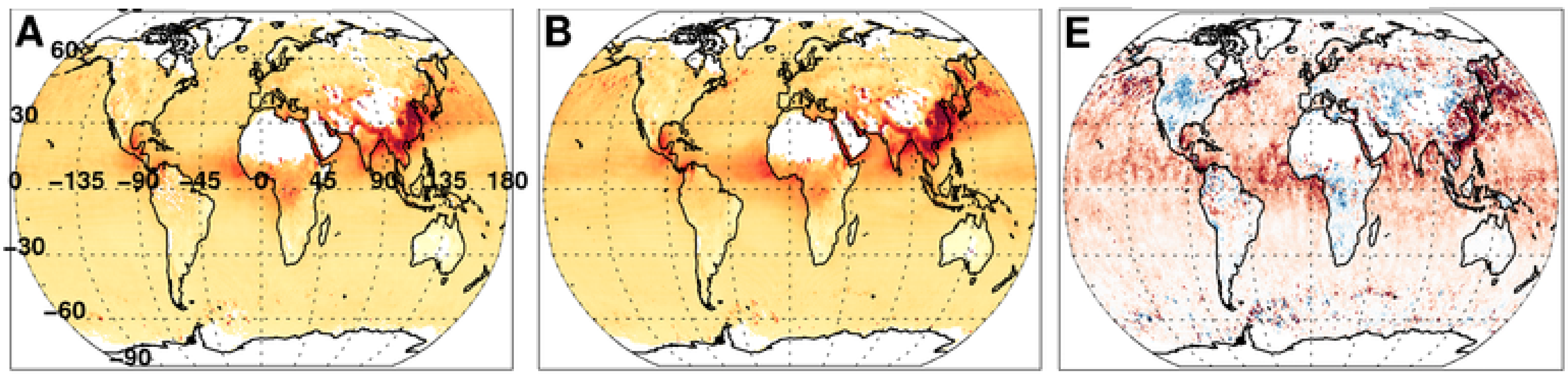

VIIRS-SNPP – 29 May 2013



# We want continuity?
# Port the DT algorithm!




MODIS | MODIS-like on VIIRS | Difference M - V

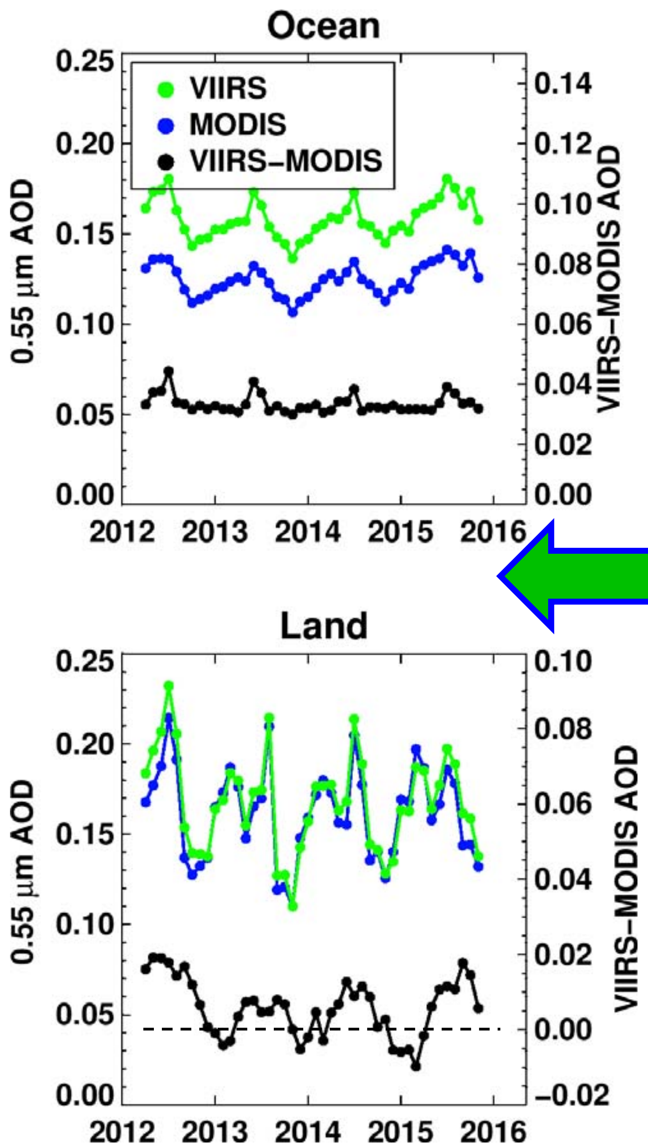



- We use Intermediate File Formats (IFF) and tools developed at the "Atmosphere-SIPS", at the University of Wisconsin
- Results of MODIS-like on VIIRS include:
  - Reduced global AOD differences and more similar global sampling
  - Now a systematic bias over ocean (VIIRS high by 20%).
  - Déjà vu? Terra versus Aqua? (Terra high by 13%)
  - → VIIRS also needs calibration study?



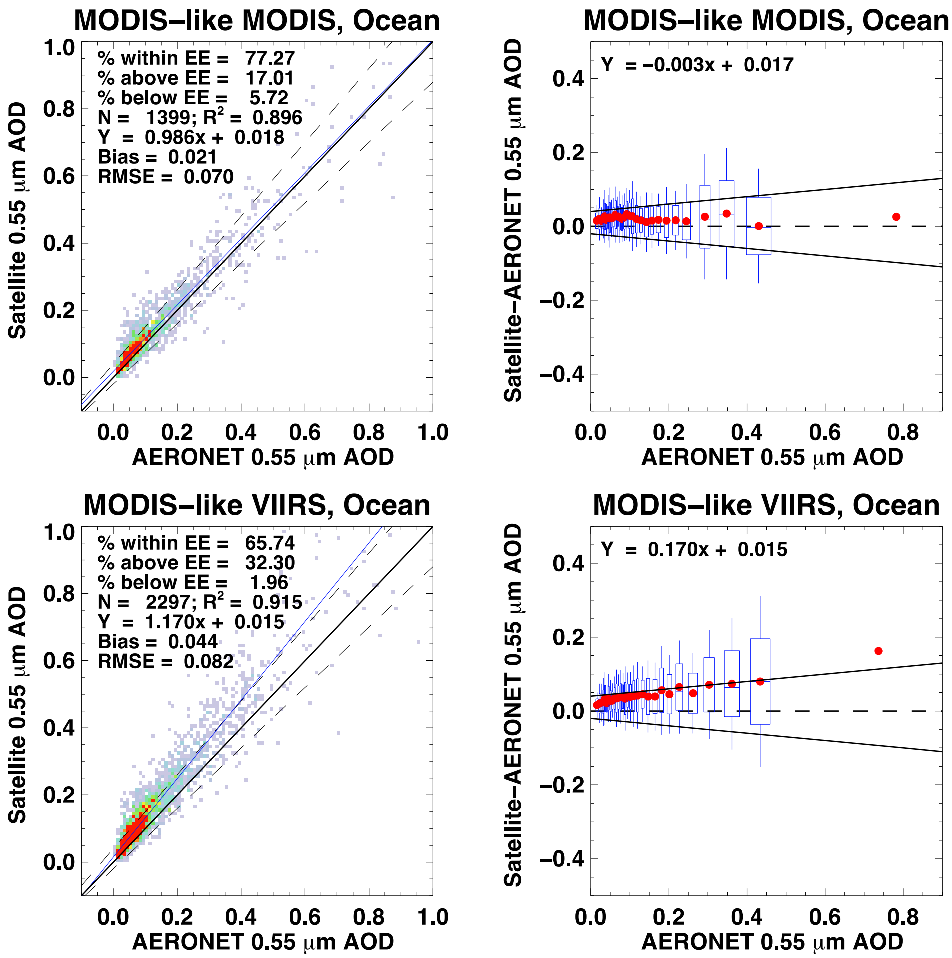
Levy et al., 2015

# MODIS – VIIRS overlap with the IFF




- 2012-2015.
- Ocean: Consistent offset = 0.03 (20%) with spikes in summer
- Land: Average offset is near zero, but seasonal dependence

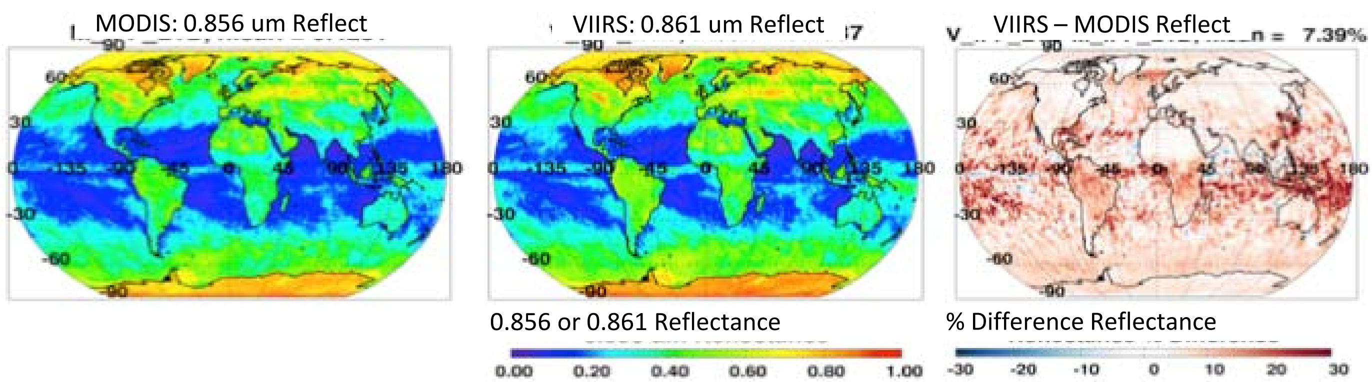
# Comparing to AERONET and calibration




MODIS-like on VIIRS has great correlation but 1.17 slope!

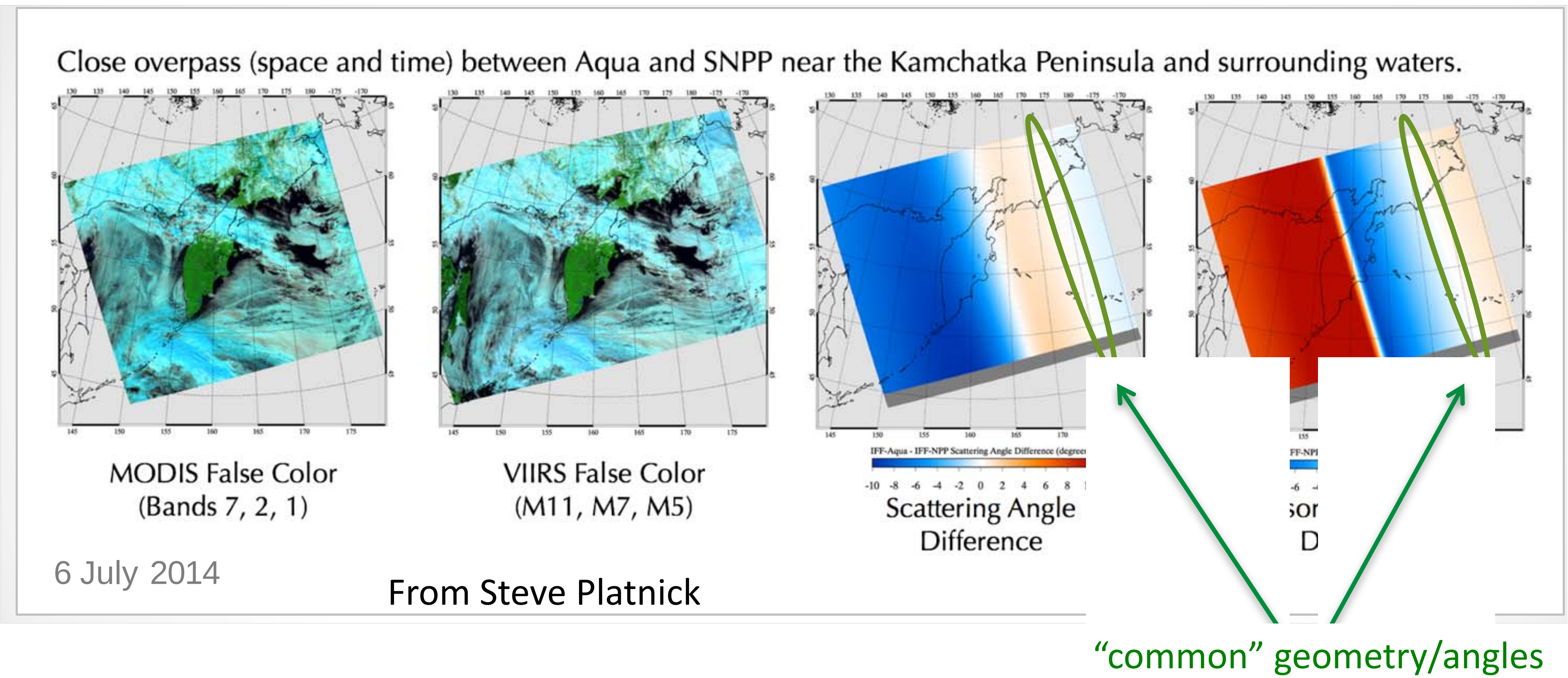
Studies such as Uprety et al., (2013) do radiometric comparisons between VIIRS and MODIS and find that VIIRS may be 2% high in some bands.

2% high bias is sufficient to give a 1.17 slope over ocean without the adding same bias to land.



# Calibration: Match files

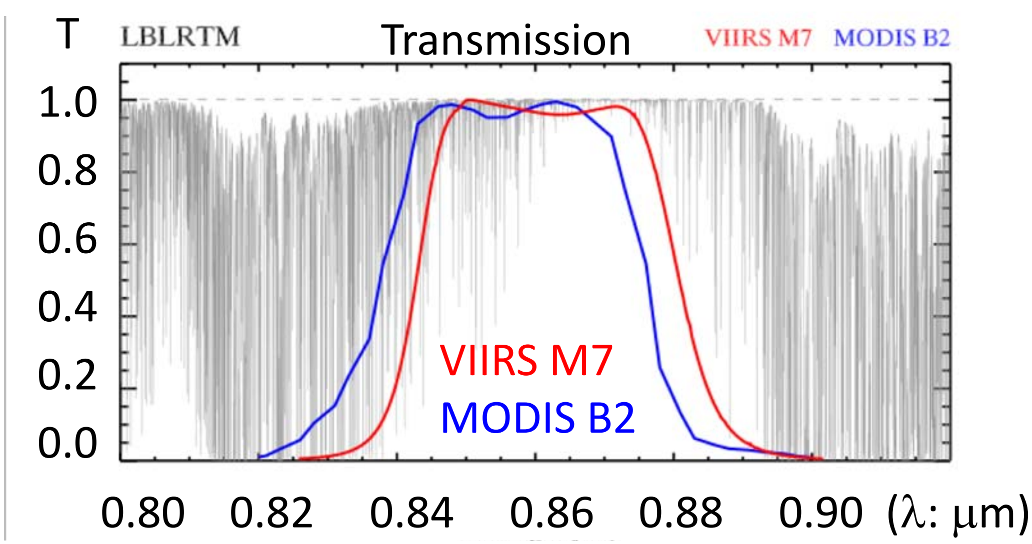
- Can we "prove" calibration differences? It's hard!
  - Slight differences in orbit → no true matches inside ±70° latitude
  - Common geometry is very limited
  - University of Wisconsin is creating "match" files for us to look at



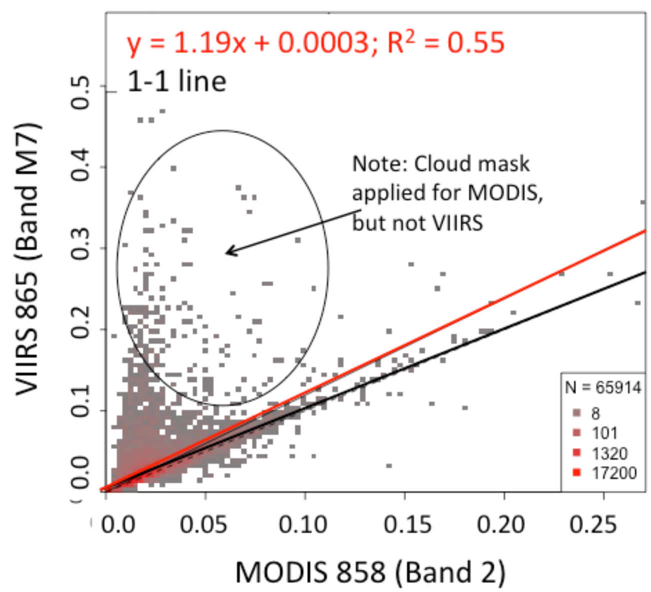
# Calibration: Wavelength issues

- Slight differences in wavelength → no true matches
- Slight differences in Rayleigh optical depths,
- Sometimes major differences in gas absorptions
- With of lack of spatial overlap, hard to find mutual cloud free.
- And so far, both datasets are not cloud-masked equally.

Example: 0.86 μm channel over "clear" sky



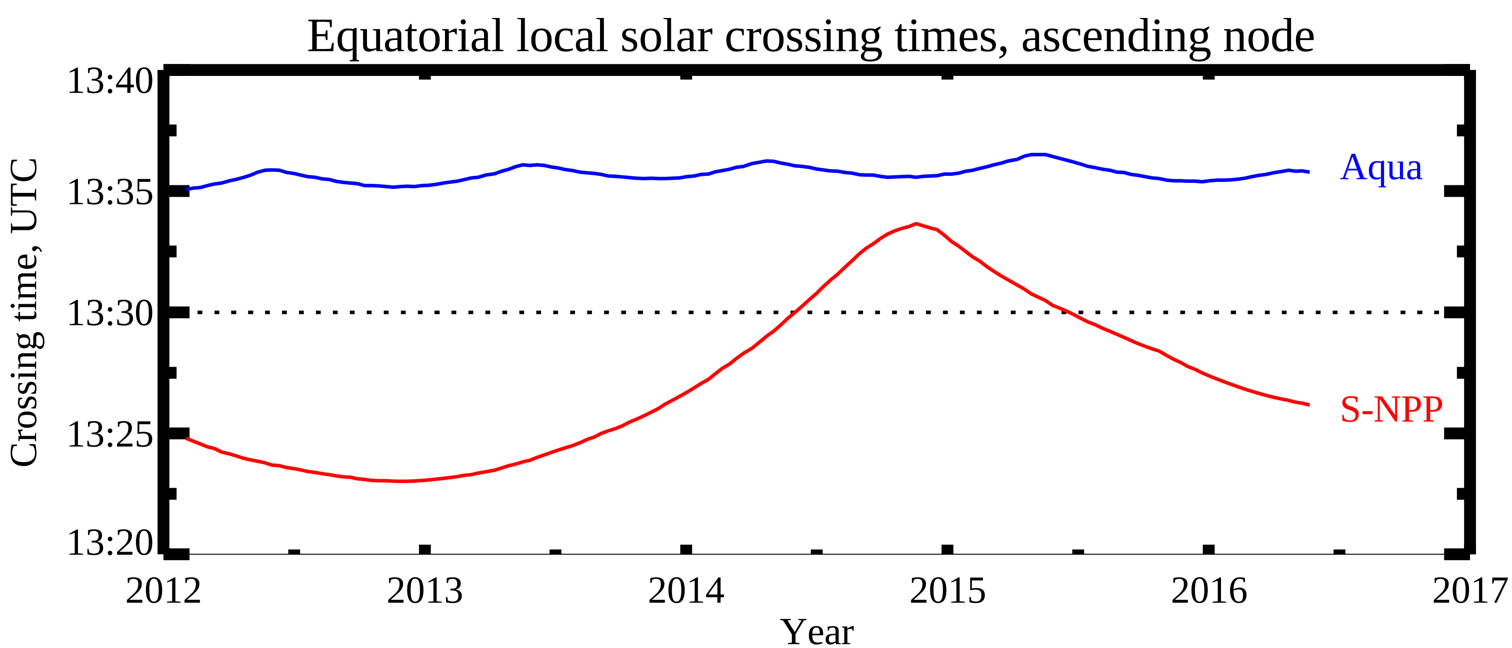

Reflectance: VIIRS vs MODIS
"Matched" data from 2014-2015




See Virginia Sawyer poster:

# Calibration: Timing issues

- Drifting orbits: varying equatorial overpasses
- Defining a max time difference (e.g. 10 mins) may not work

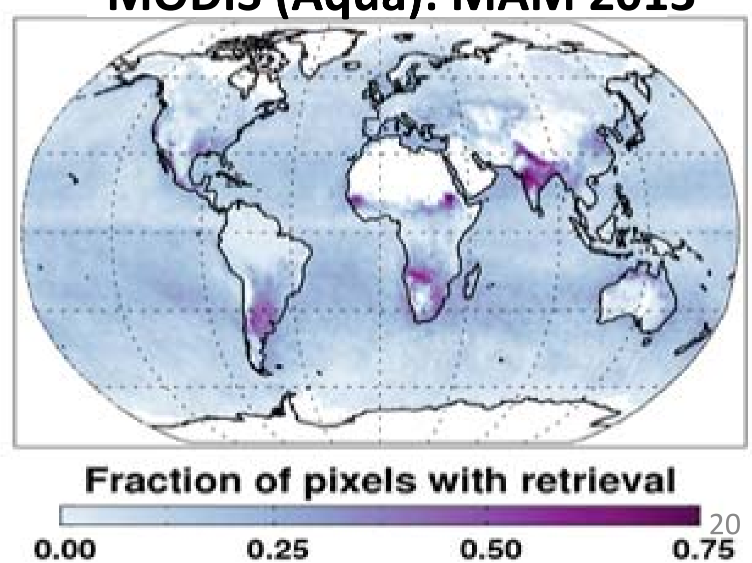



Plot drawn by Andy Sayer (GSFC), source data from Greg Quinn at SSEC Wisconsin.

# What is good enough?

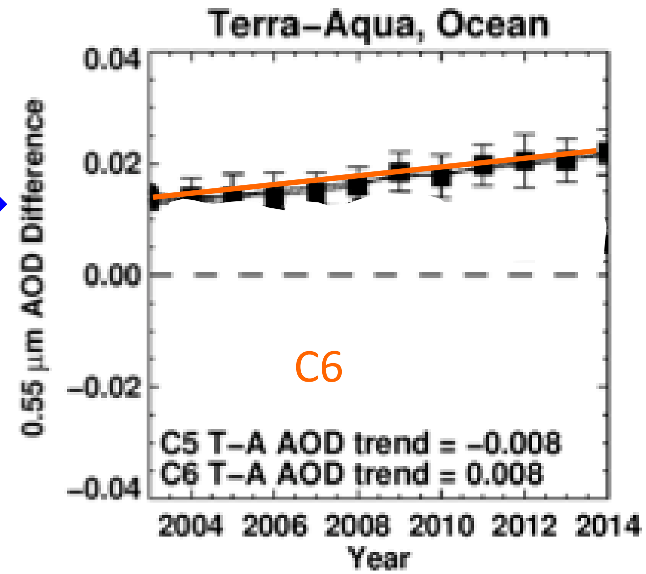
- Convergence: of gridded (Level 3 –like) data
  - For a day? A month? A season?
  - What % of grid boxes must be different by less than X?
    - in AOD? In Angstrom Exponent? Size parameters?
- Validation: Comparison with AERONET, etc?
- "Retrievability": Do algorithms make same choices under same conditions?
- Other metrics?

**MODIS (Aqua): MAM 2013**

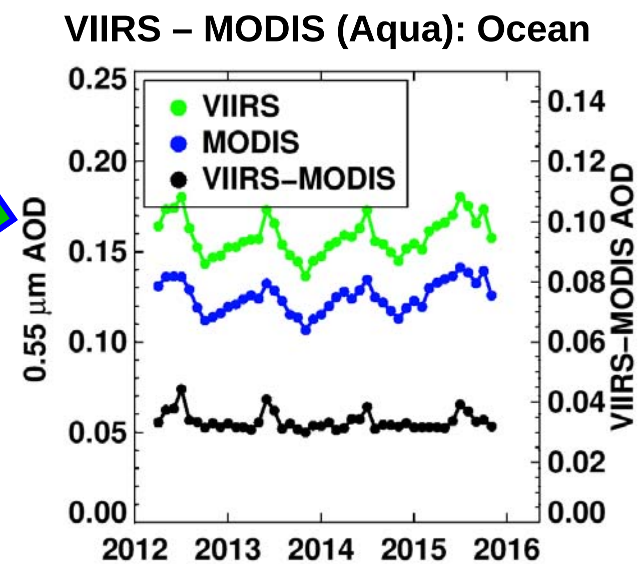


# Summary (MODIS →VIIRS)

- MODIS-DT Collection 6
  - Aqua/Terra level 2, 3; entire record processed
  - “Trending” issues reduced
  - Still a 15% or 0.02 Terra vs Aqua offset.
  - Terra/Aqua convergence improved with C6+, but bias remains.
  - Other calibration efforts yield mixed results




- VIIRS-DT in development
  - VIIRS is similar, yet different then MODIS
  - With 50% wider swath, VIIRS has daily coverage
  - Ensures *algorithm* consistency with MODIS.
  - Currently: 20% NPP vs Aqua offset over ocean.
  - Only small bias (%) over land (2012-2016)
  - Can VIIRS/MODIS create aerosol CDR?




- Calibration for MODIS – VIIRS continues to fundamentally important.
- It’s not just Terra, or just Aqua, or just NPP-VIIRS, I really want to push synergistic calibration.

# Biases in VIIRS aerosol optical depth arising from solar band calibration biases

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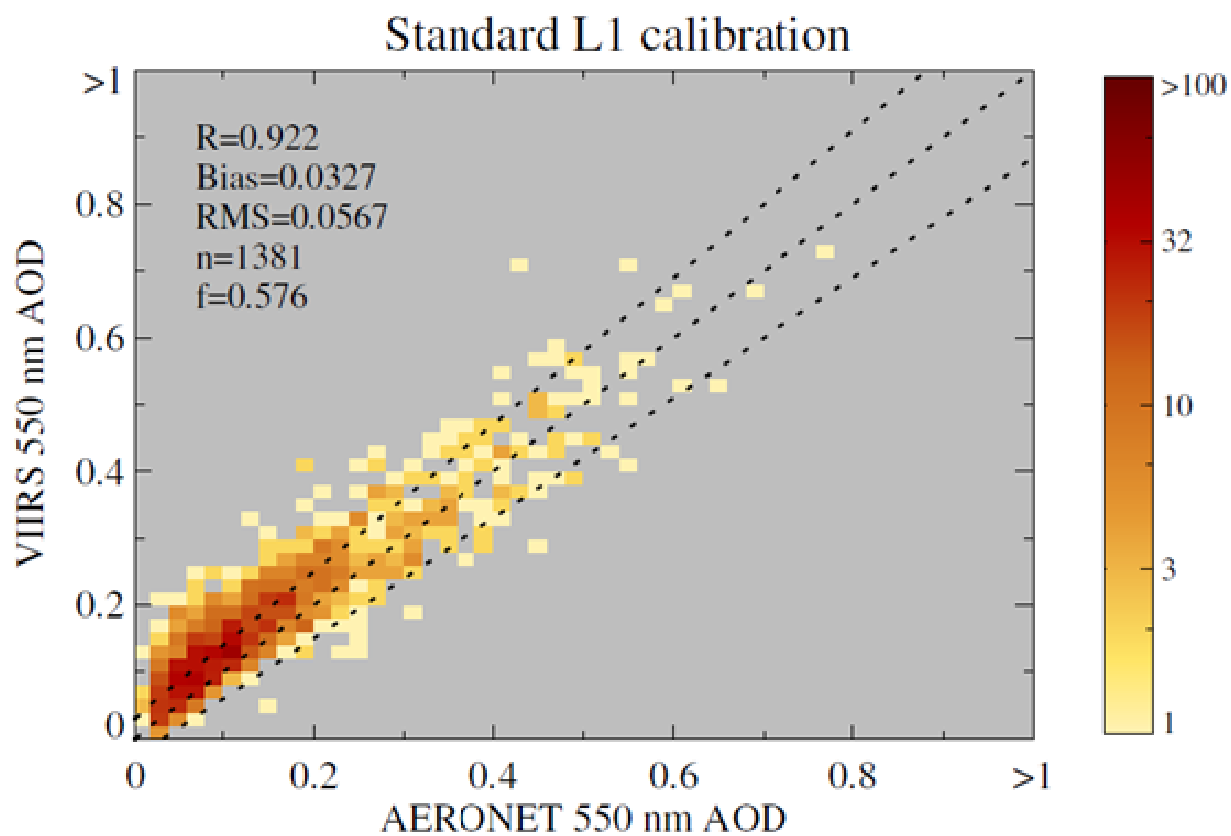
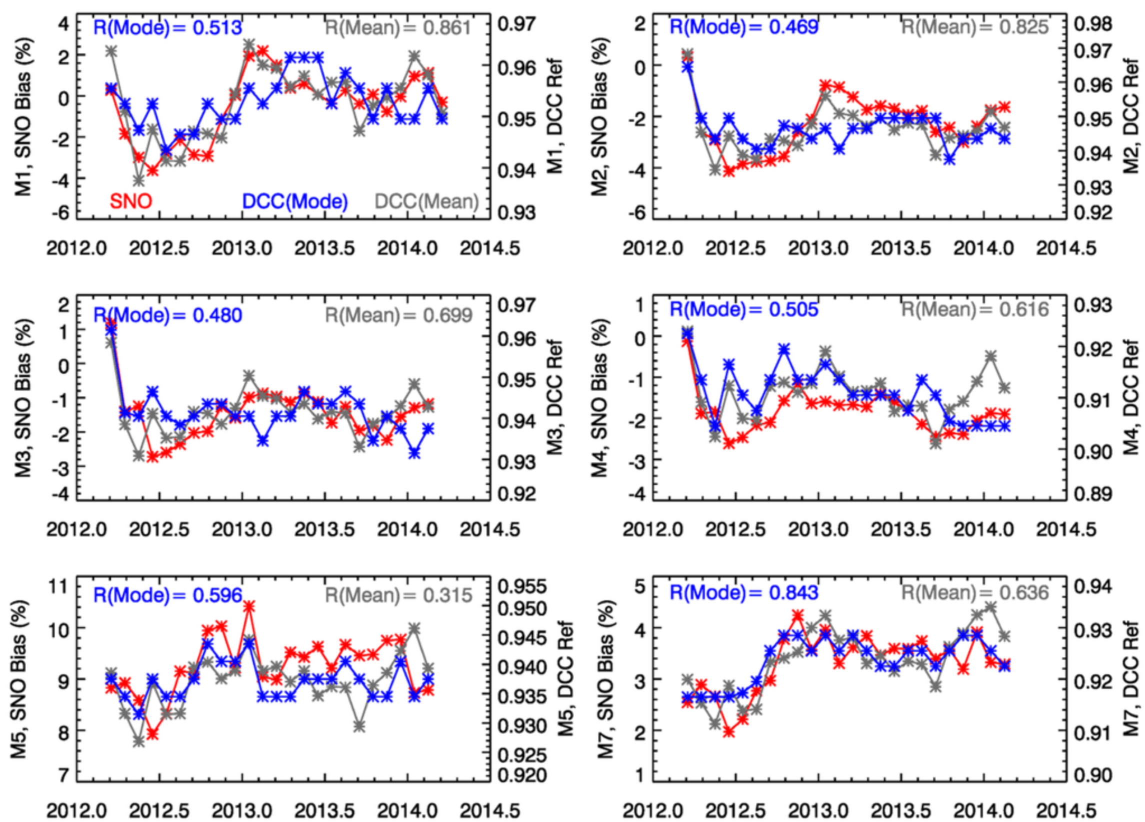
With acknowledgements to the MODIS/VIIRS Characterization Support Team, AERONET, Wisconsin SIPS, and the Ocean Biology Processing Group

# Aerosol optical depth (AOD) biases over ocean scenes are larger than expected



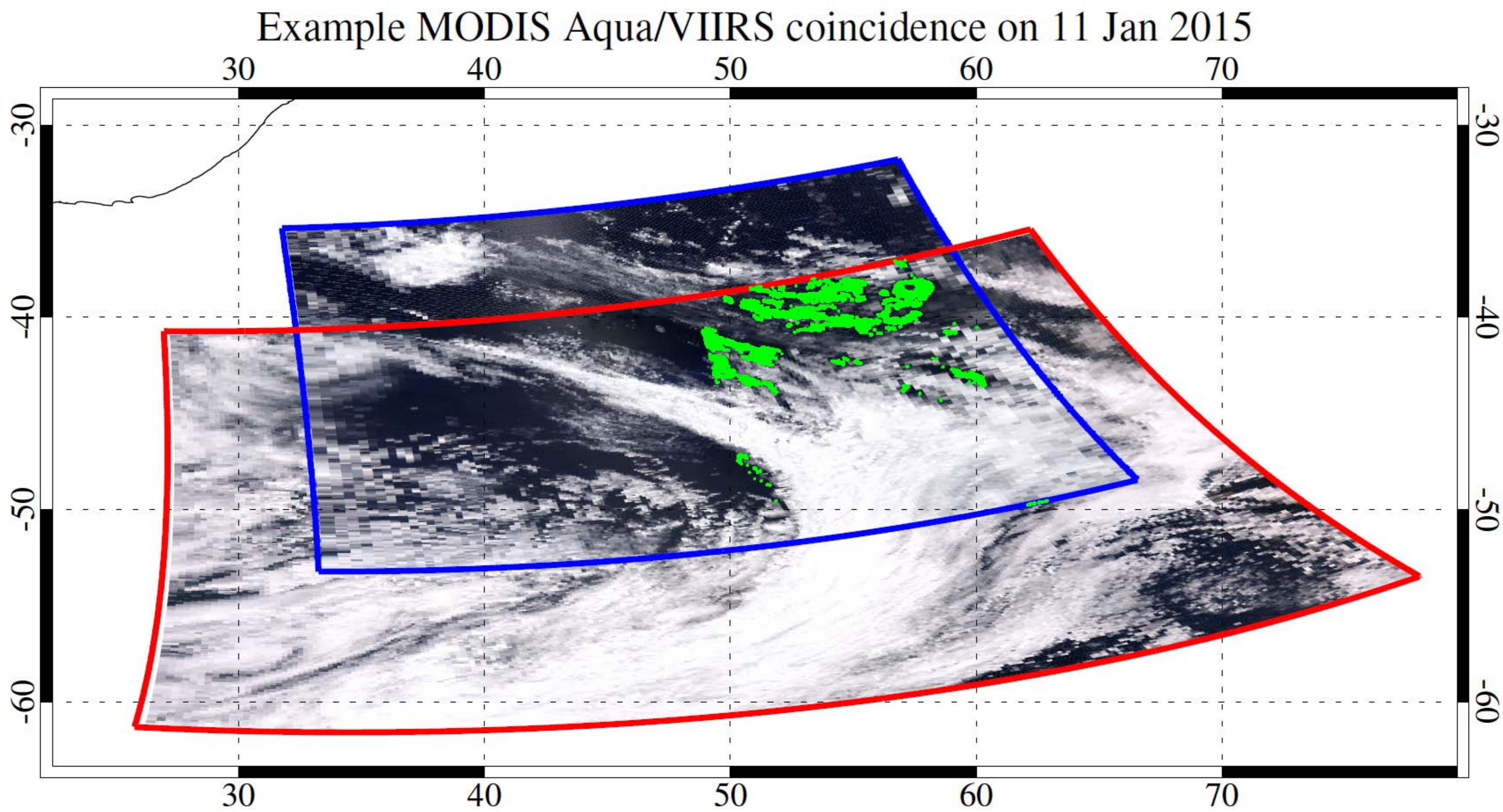

- Median bias =0.0327; expected < 0.015

# Several prior studies suggest some VIIRS solar bands are too bright

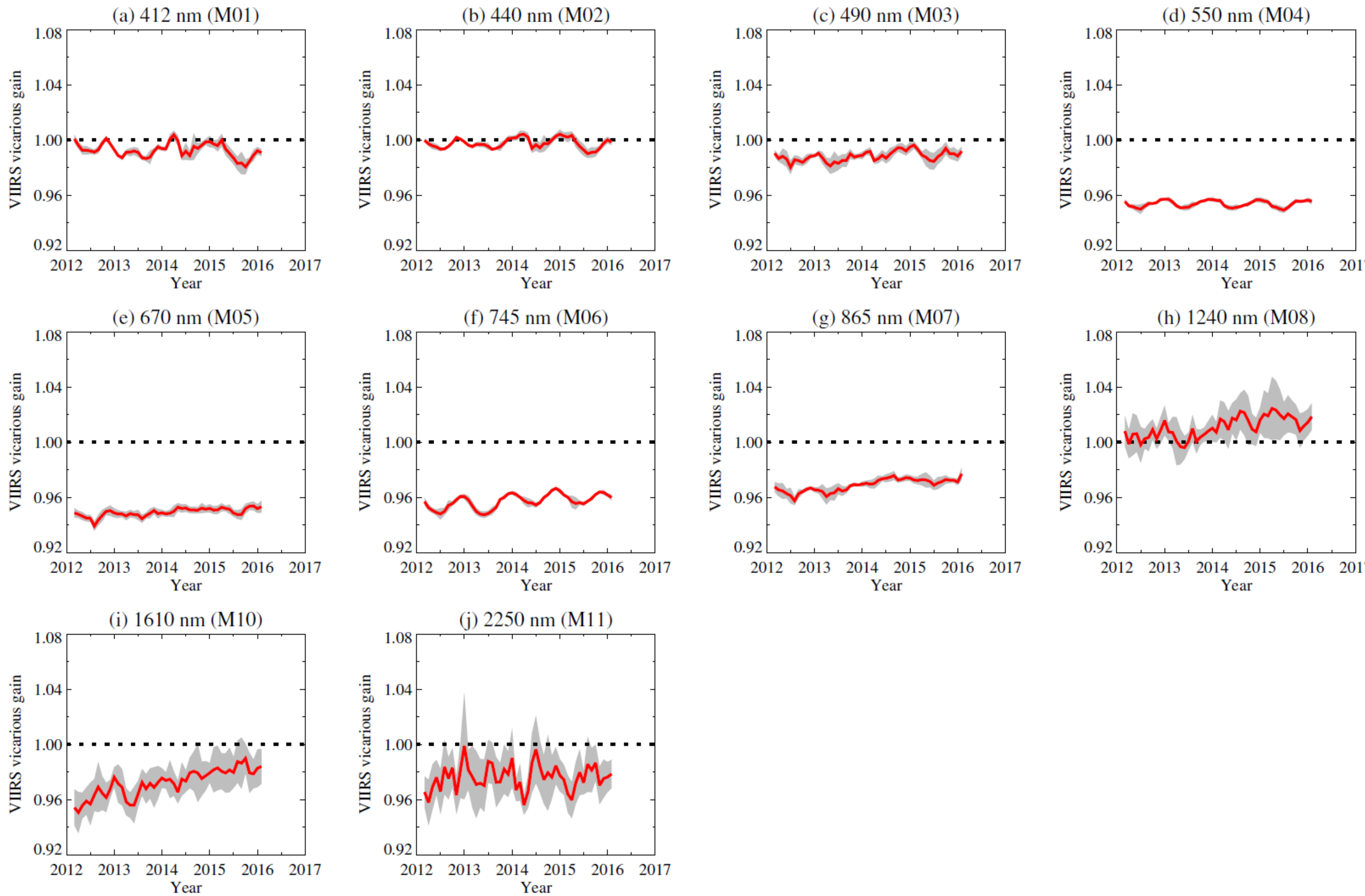



- Wang and Cao (2016), Monitoring the NOAA Operational VIIRS RSB and DNB Calibration Stability Using Monthly and Semi-Monthly Deep Convective Clouds Time Series, *Remote Sens.*, **8**(32), doi:10.3390/rs8010032.

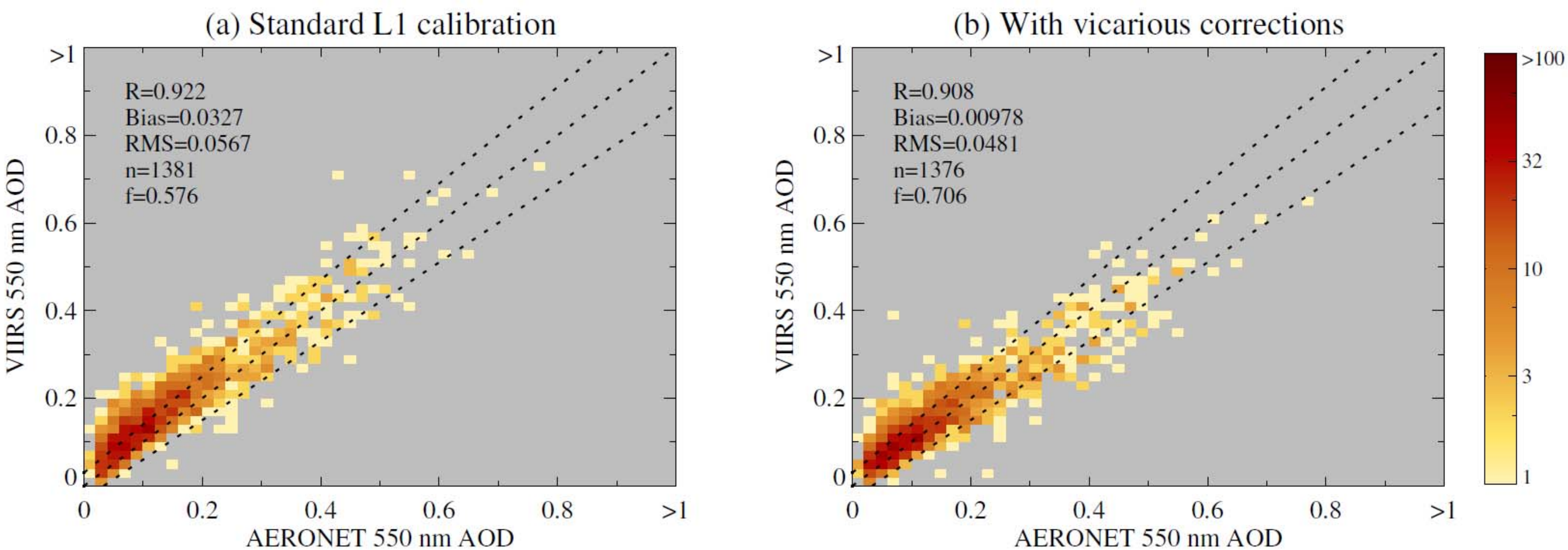
# The Atmos SIPS have created 'matchfiles' to aid MODIS-VIIRS cross-calibration



# We cross-calibrated VIIRS against MODIS Aqua for open-ocean scenes

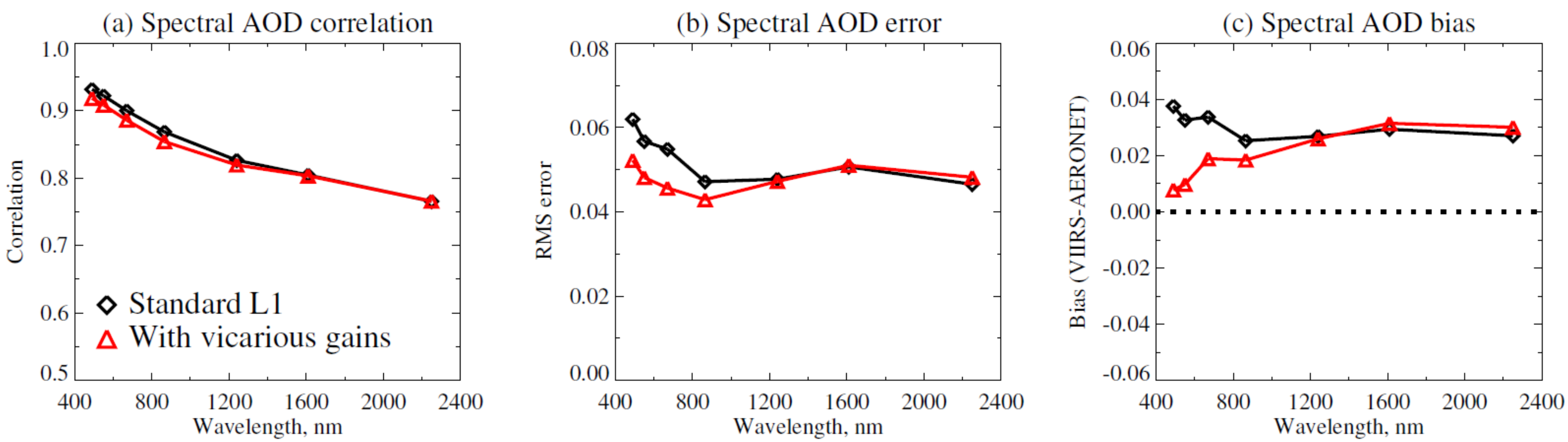


# Applying these gains removes the bulk of the AOD bias




- Suggests MODIS absolute calibration is closer to the truth than VIIRS
- See my poster in the Atmospheres session for more information

# Results for swIR wavelengths are not as settled




- AOD bias at swIR wavelengths remains ~0.03
- How much is due to retrieval biases, and how much is due to MODIS swIR calibration uncertainty?

# OBPG update on MODIS Terra gain and polarization sensitivity trending

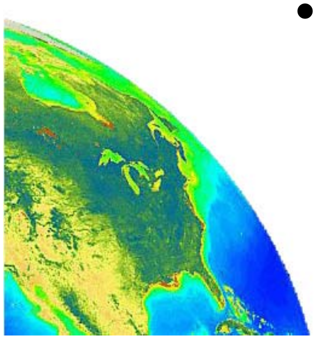
**Gerhard Meister**
OBPG (Ocean Biology Processing Group)
NASA Code 616, Ocean Ecology Laboratory

6/6/2016

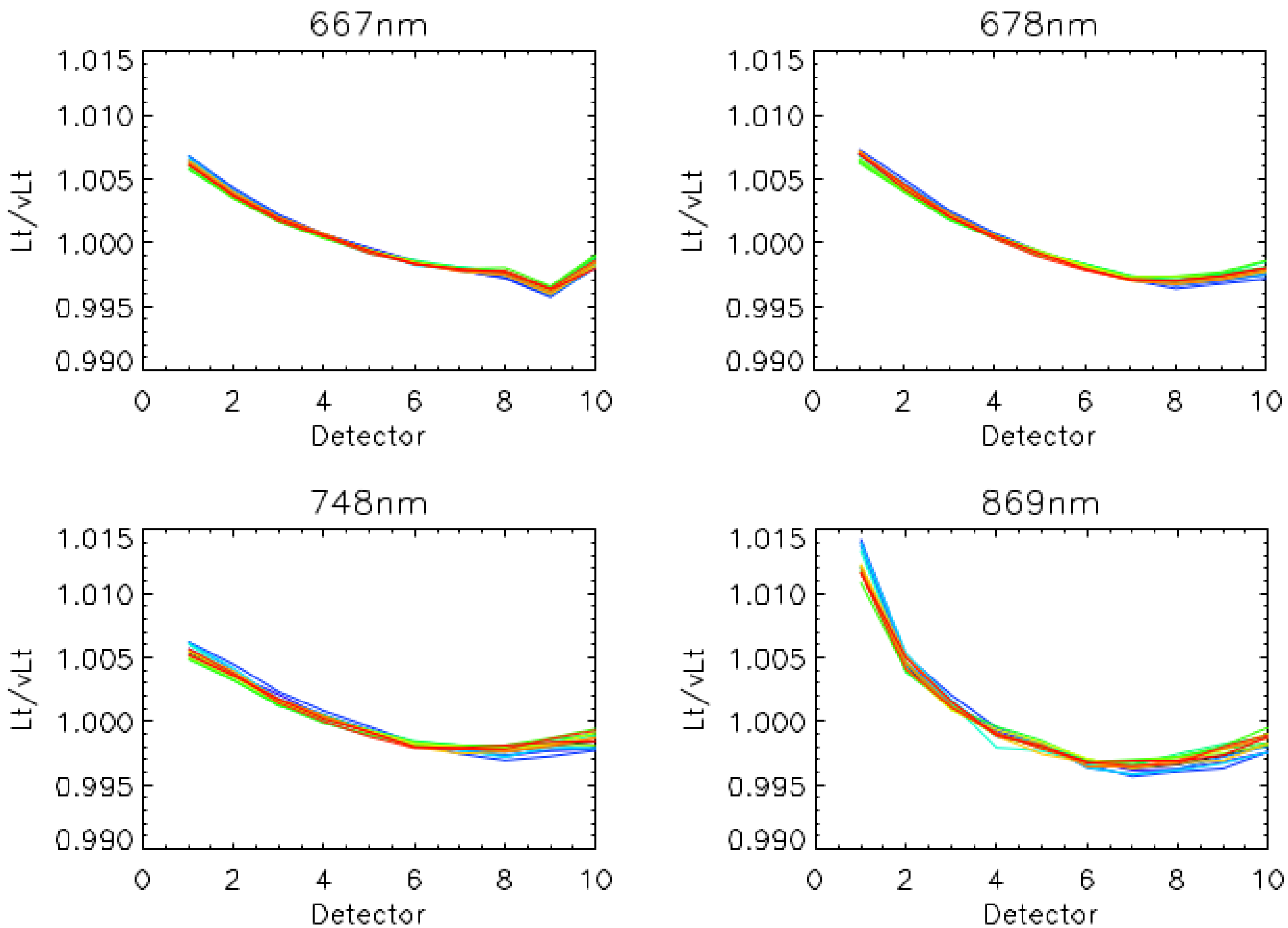
**Presentation to MODIS Calibration Workshop**
**MODIS/VIIRS Science Team Meeting, Silver Spring, MD**

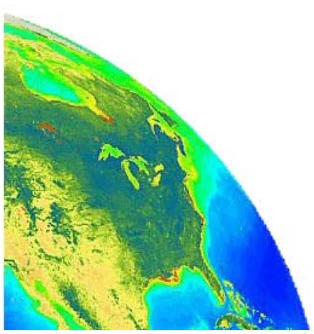
# Overview:

- Same basic approach as before: use SeaWiFS and MODISA to crosscalibrate MODIST
- Individual steps needed:
  - residual detector corrections for NIR bands (TDET01, done, verified)
  - Crosscalibration to SeaWiFS (TXC17)
  - Crosscalibration to MODISA (TXC16)
  - Merging of xcal results from SeaWiFS and MODISA, verification with TT and TV tests (done)
- All xcal results are relative to MCST LUT V6.1.20.8. We used V6.1.20.13 for reprocessing
- The new xcal LUTs are named txc16c, same format as before



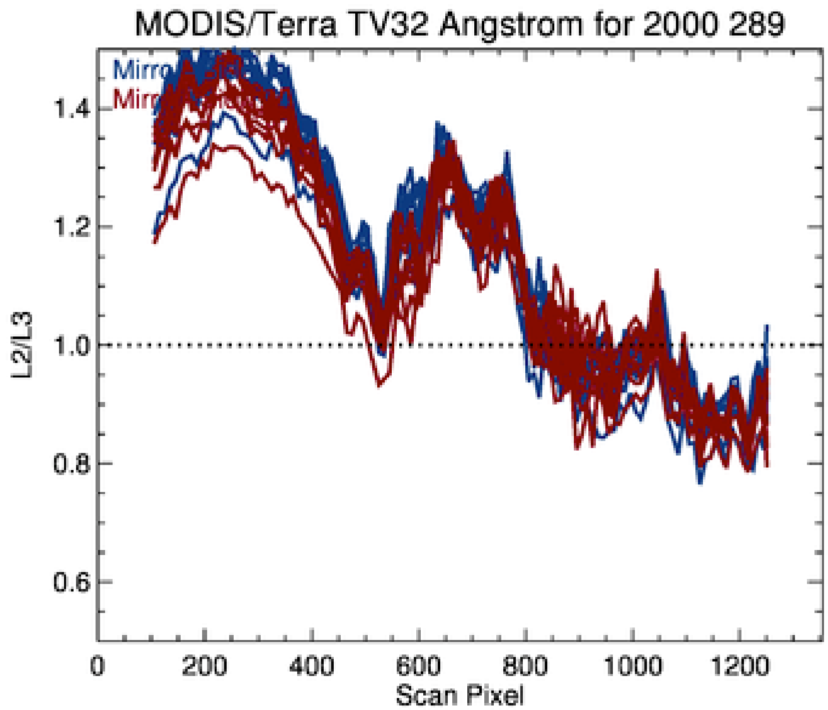
# TDET01 results

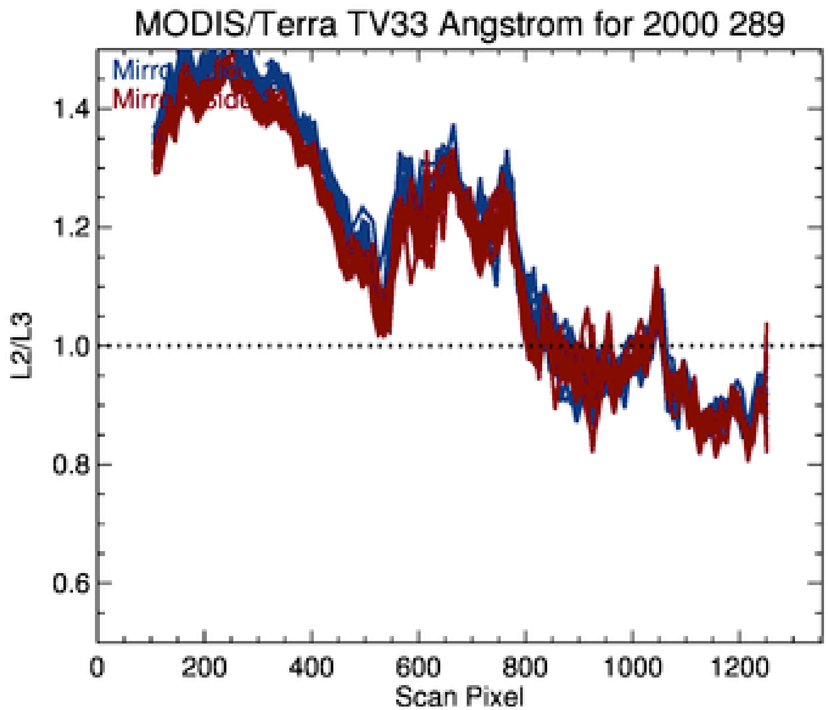


Gain of MODIST detector 10 is 1.5% too high relative to detector 1 at 869nm (MCST has similar results)

# TDET01 validation: xcal applied in TV33




Angstrom striping at the beginning of scan eliminated in TV33; no change in AOT (did not have striping anyway); TV32 is operational (no correction to NIR bands)

# Crosscalibration coefficients (Mueller matrix):

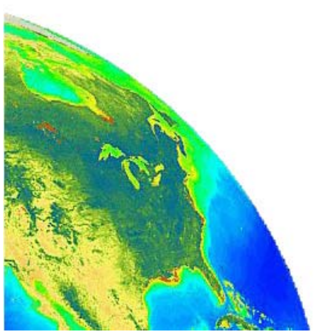
$$L_m/M_{11} = L_t + m_{12}*Q + m_{13}*U$$

$L_m$: measured TOA radiance (MODIST)

$L_t$: true TOA radiance (from SeaWiFS/MODISA)

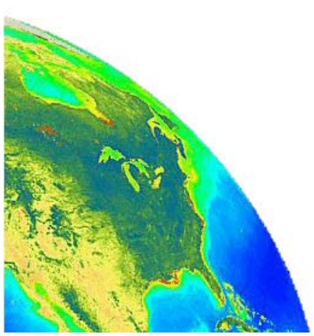
Q, U : linear Stokes vector components, modeled from Rayleigh and glint

$M_{11}$, $m_{12}$, $m_{13}$ : fitted instrument characterization parameters. They depend on band, MS, detector, scan angle (polynomial $4^{th}$ order for M11, $2^{nd}$ for $m_{12}$ and $m_{13}$). Total of 2*10*5 + 2*10*3 = 160 coefficients per band per day.

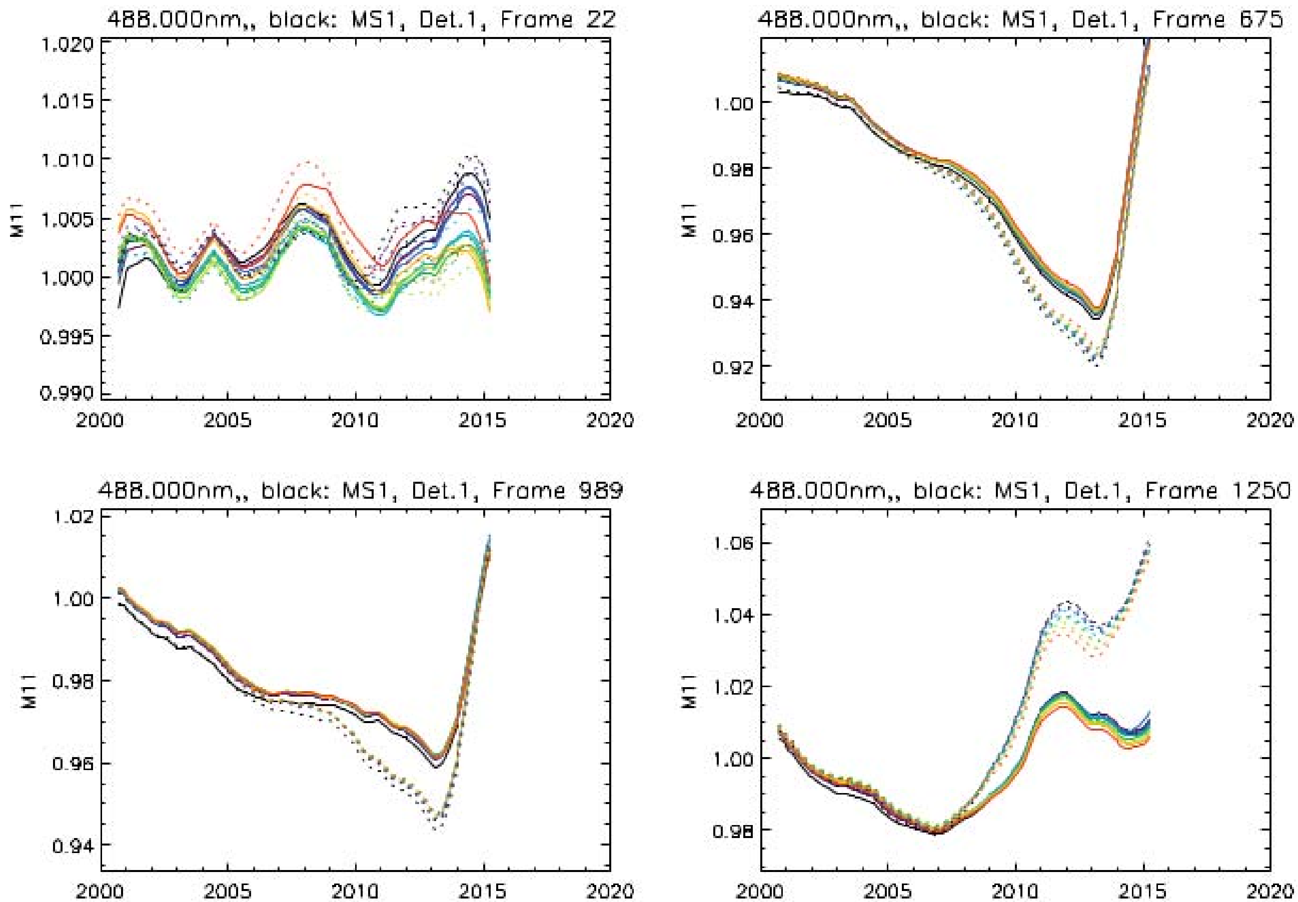


# Main results:

- SeaWiFS used until January 2004, then MODIS Aqua (known MODISA issue in early mission, blue bands are too high by ~0.5%)
  - one year transition period, SeaWiFS coefficients adjusted to match MODIS
- Using VIIRS after 2012 was discussed, but rejected (but potentially in the future)
- Sensitivity to U component of Stokes vector (m13) is now modeled as a function of time, really significant only in bands 13 and 14
- Polarization sensitivity hasn’t changed much in the last three years for most bands

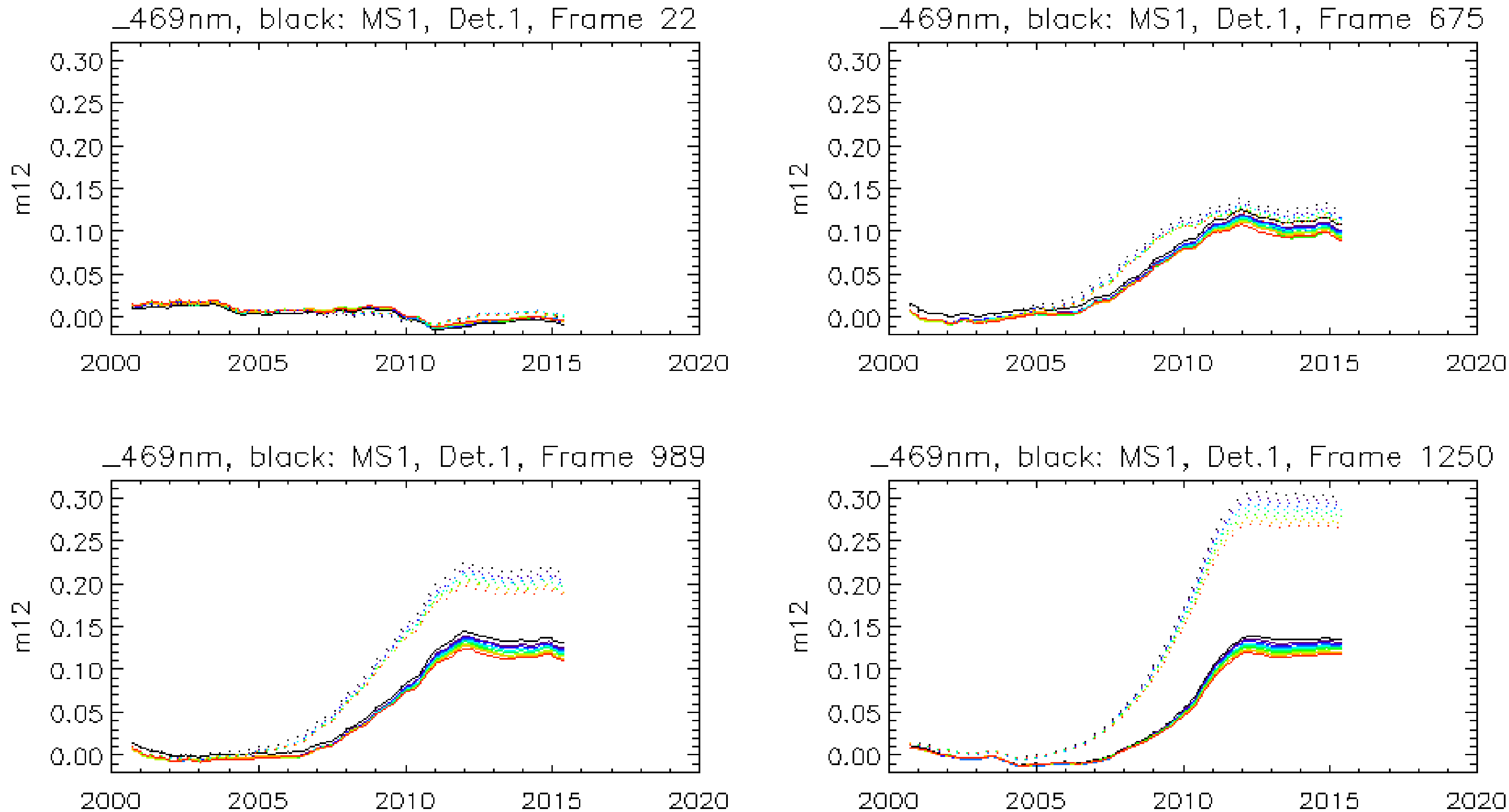


# M11: Switching to operational LUT for 488nm



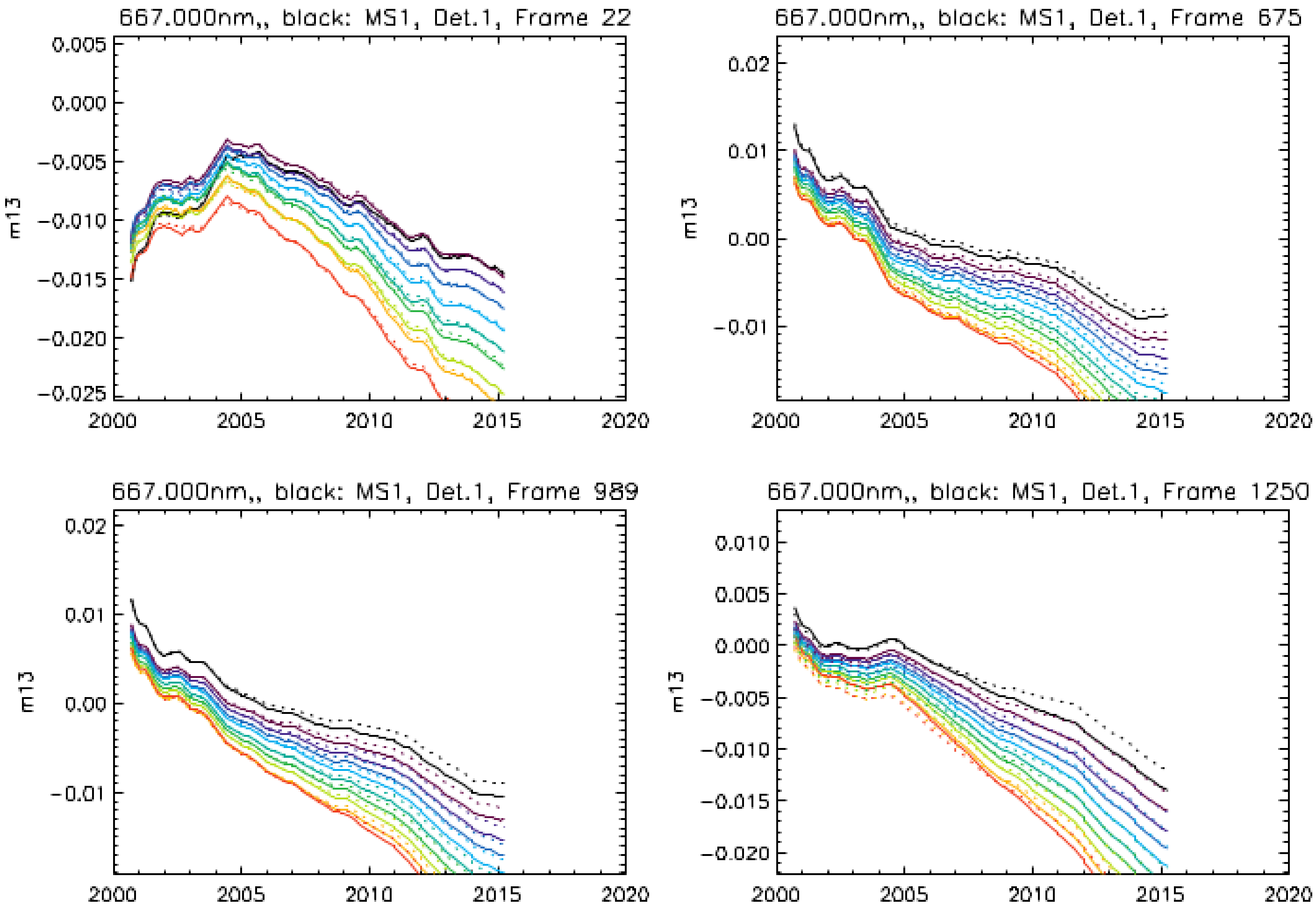

MCST switched to desert trending in 2013 for band 10, large impact on M11, but not for lunar trending, as expected

# m12 (Q-component) for 469nm



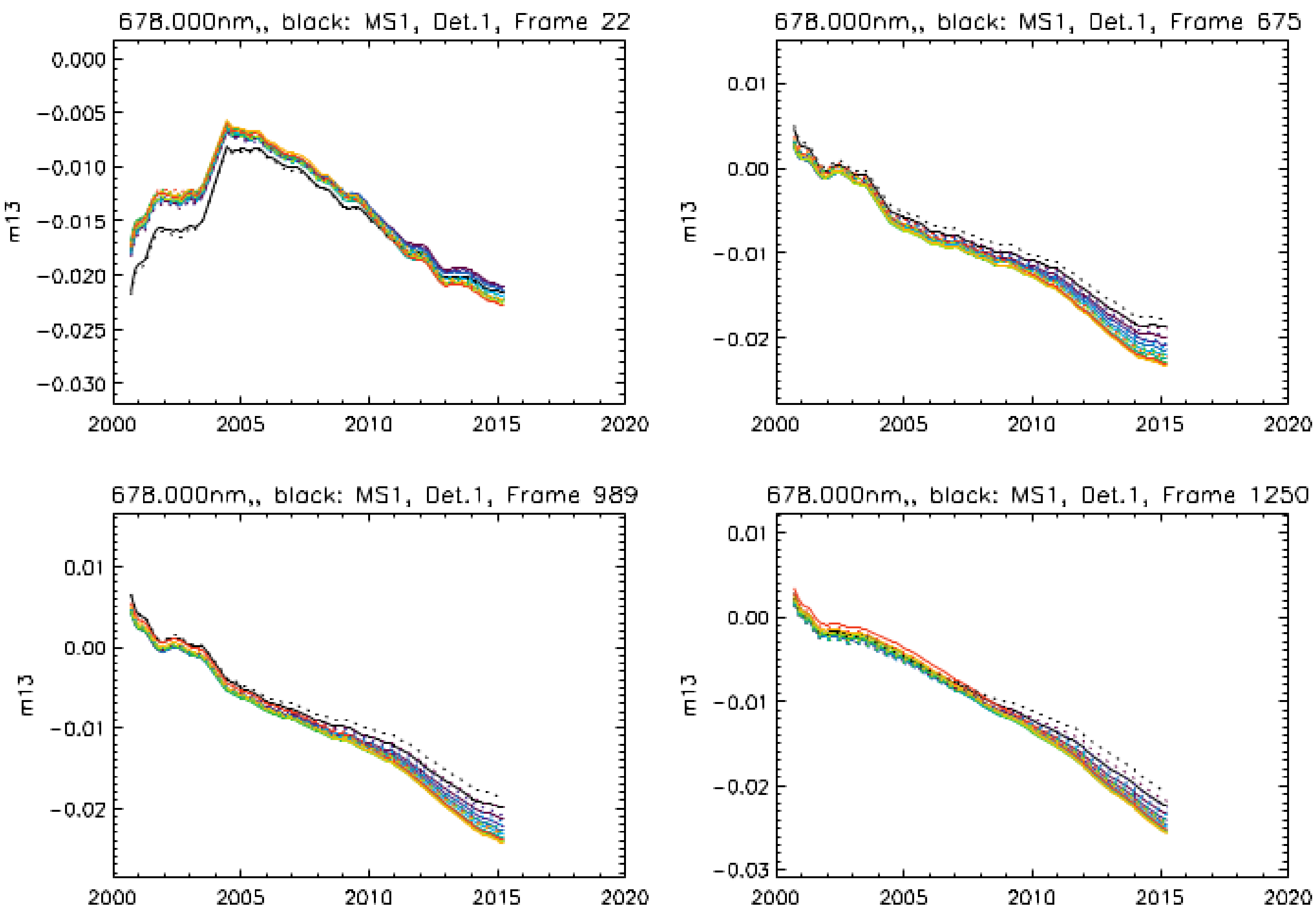

Detectors are color coded, dashed/solid for mirror side 1/2
Plateau reached in 2012, similar for other bands

# New m13 (U-component) for 667nm



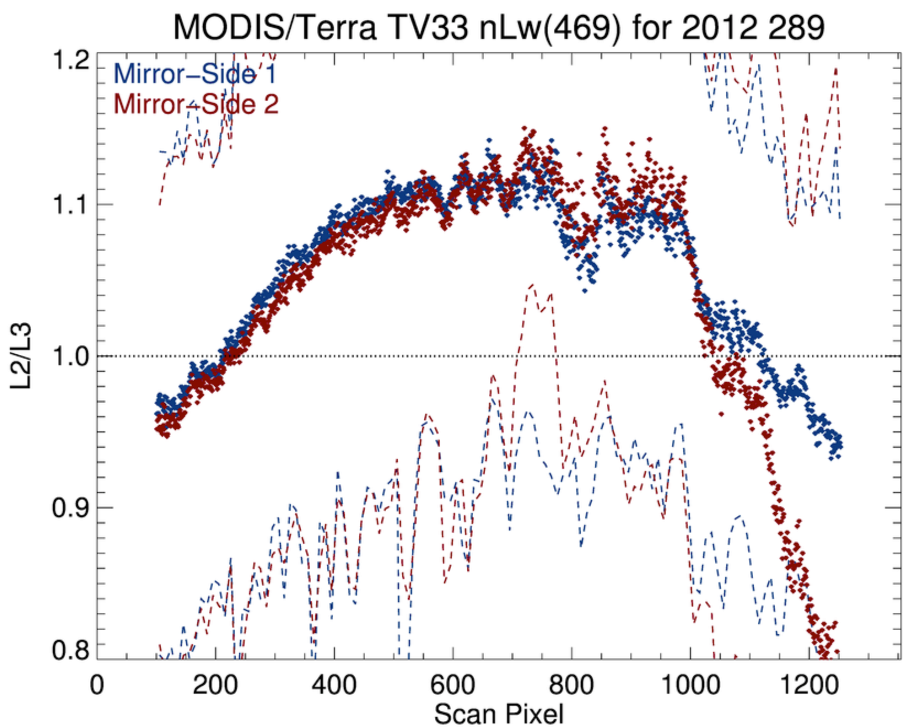

- Before, we set m13 to prelaunch because it is too noisy
- Enough data now to conclude that m13 is decreasing for 667nm

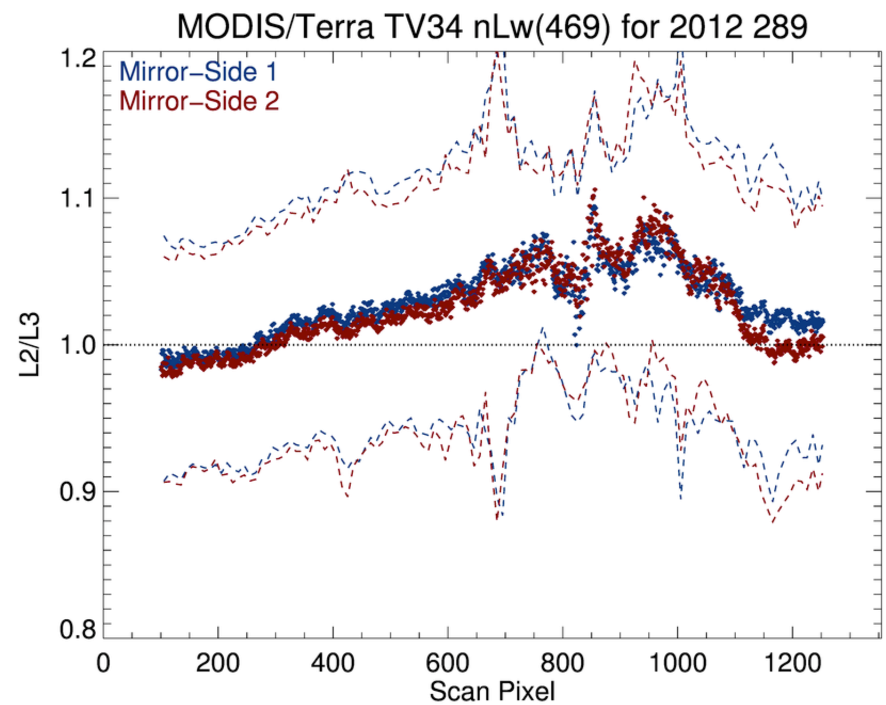
# New m13 (U-component) for 678nm




- Enough data now to conclude that m13 is decreasing for 678nm
- Detectors much more consistent than for 667nm

# Scan angle validation for 469nm band

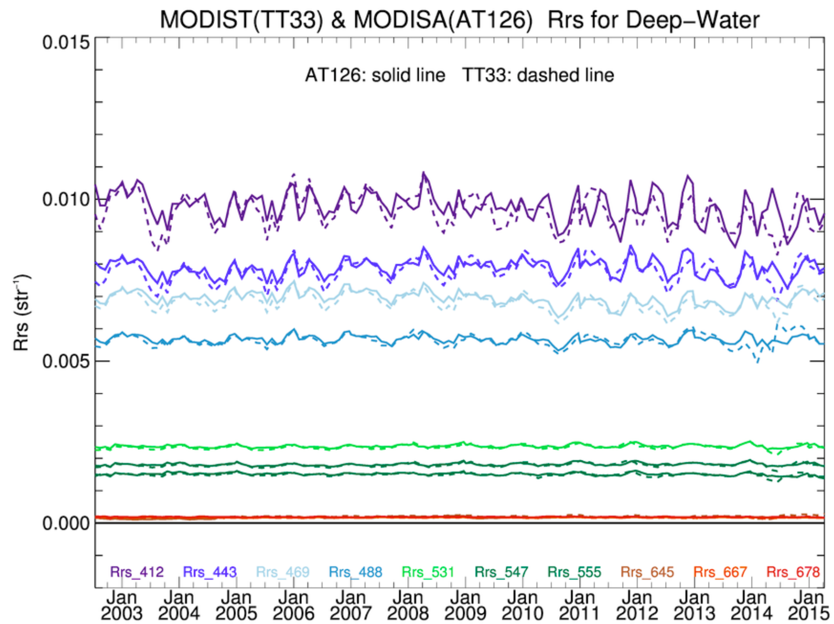


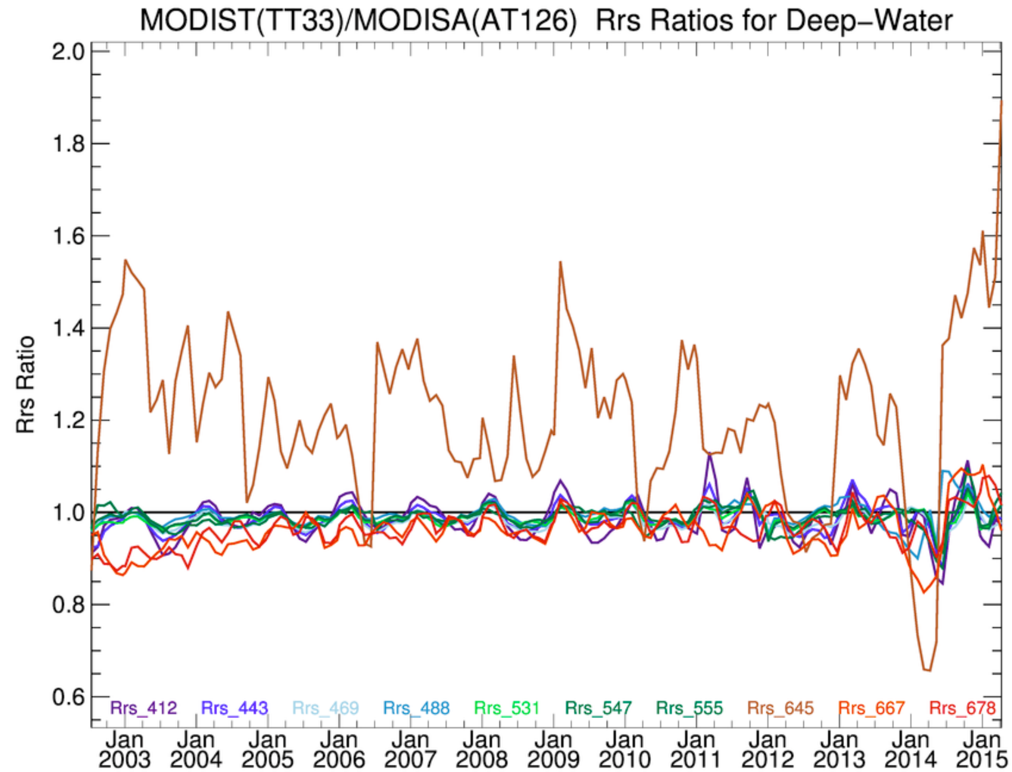




TV33 (left): TDET01 detector correction only
TV34 (right): application of new xcal coefficients (txc16c)

Water-leaving radiance at 469nm is now flat vs scan angle (glint area still elevated)

# Temporal validation: comparison to MODISA



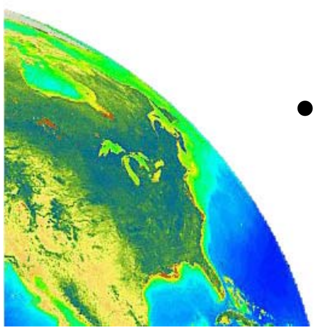

Left: Global deep water average water-leaving radiances for MODISA (solid line) and MODIST (dashed line)

Right: Ratio of data on the left

Very good overall agreement, except for 645nm (noisy, vicarious calibration challenging, and questionable MODISA trend)

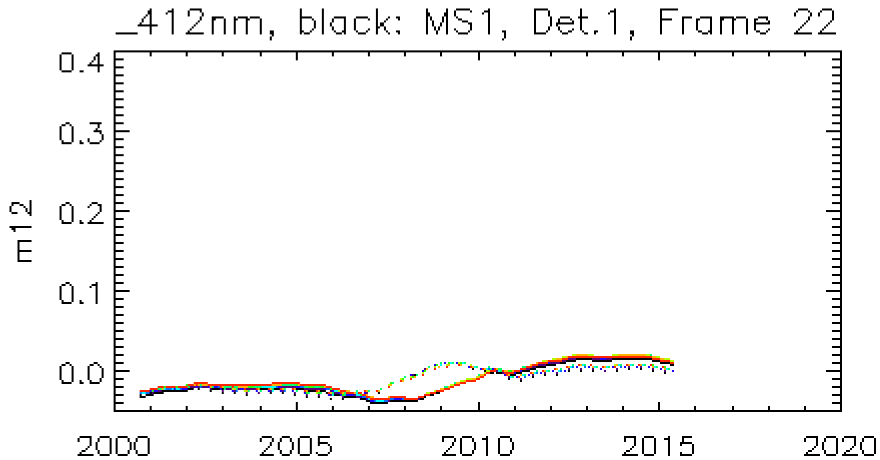
# Summary:

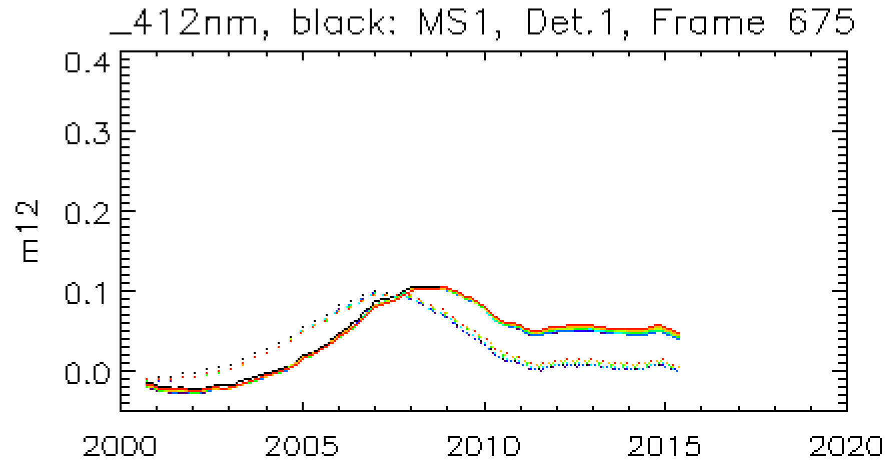
- MODIS Terra Ocean Color products have been reprocessed (announced last week)
- Crosscalibration approach: SeaWiFS used as truth field until January 2004, then MODIS Aqua
- Comparisons of long term trends  to MODIS Aqua and SeaWiFS look good
- Using VIIRS after 2012 was discussed, but rejected (but potentially in the future)
- Sensitivity to U component of Stokes vector (m13) is now modeled as a function of time, really significant only in bands 13 and 14
- Polarization sensitivity hasn't changed much in the last three years for most bands

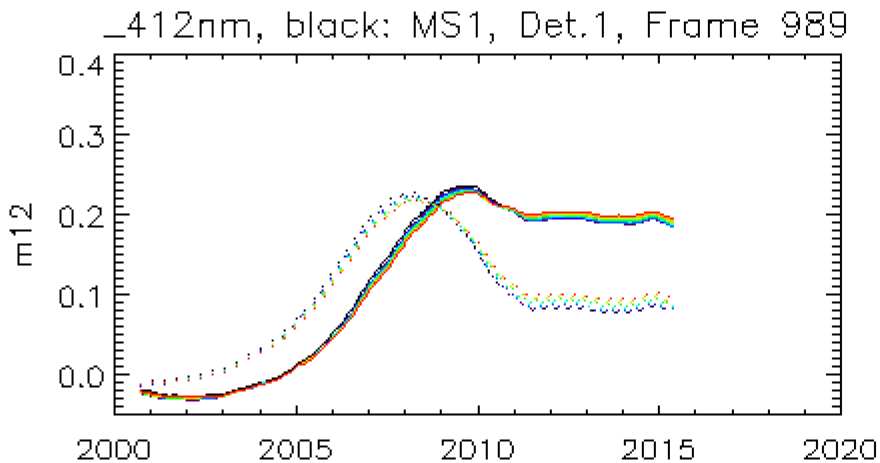


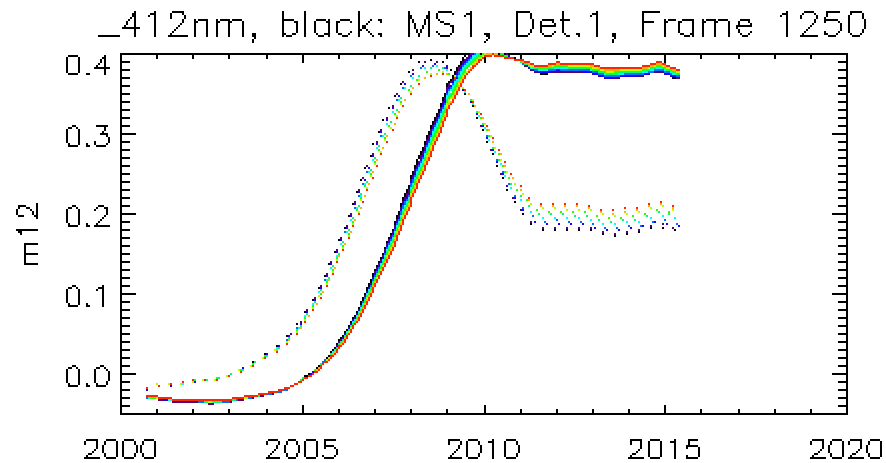
# Backup

# 412nm: m12

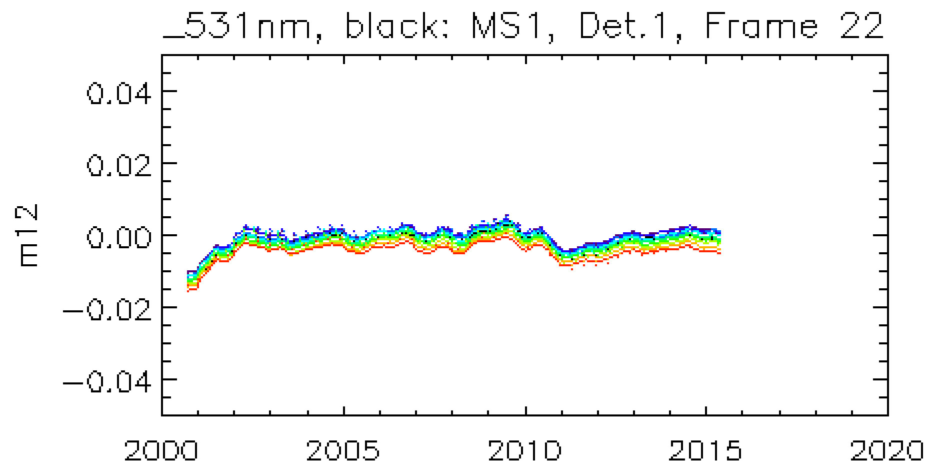

_412nm, black: MS1, Det.1, Frame 22
m12
0.4
0.3
0.2
0.1
0.0
2000
2005
2010
2015
2020

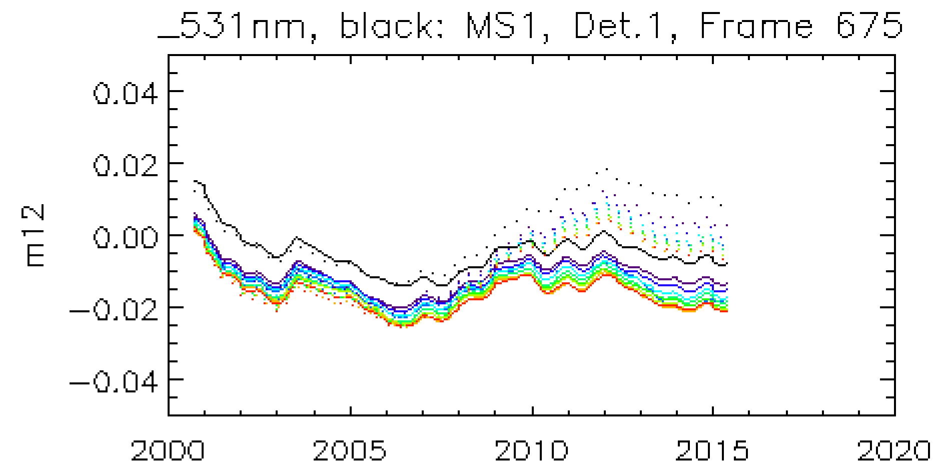

_412nm, black: MS1, Det.1, Frame 675
m12
0.4
0.3
0.2
0.1
0.0
2000
2005
2010
2015
2020

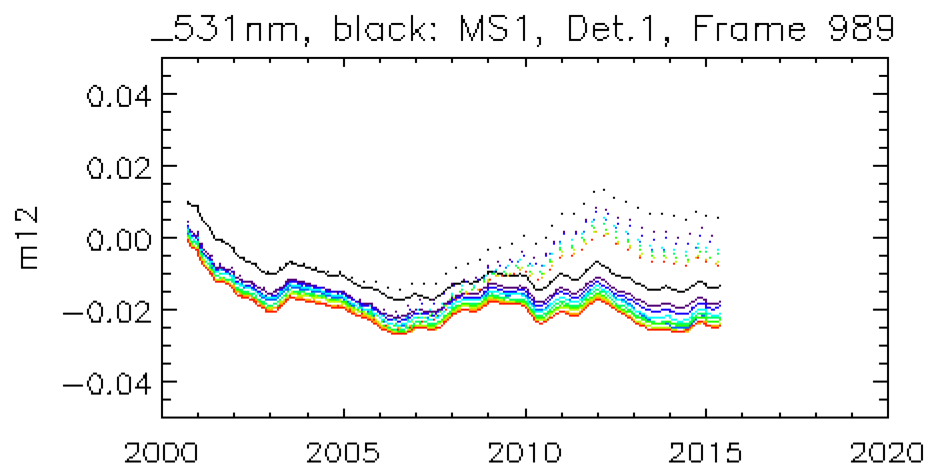

_412nm, black: MS1, Det.1, Frame 989
m12
0.4
0.3
0.2
0.1
0.0
2000
2005
2010
2015
2020

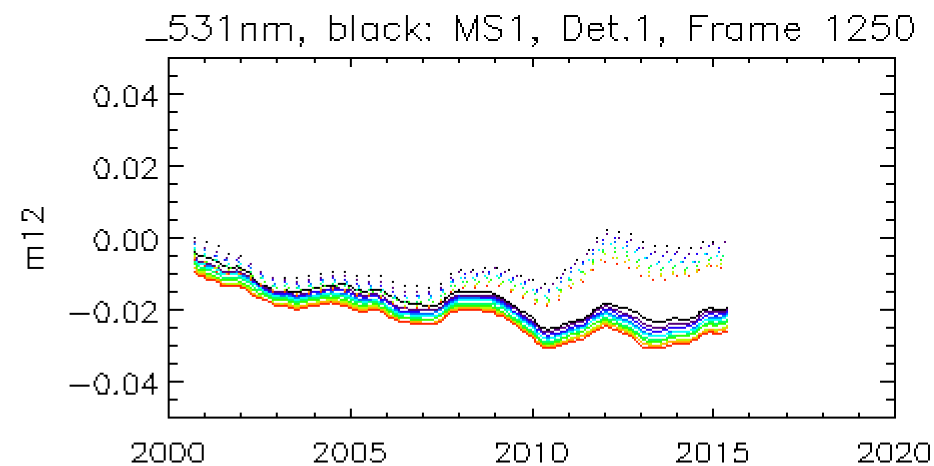

_412nm, black: MS1, Det.1, Frame 1250
m12
0.4
0.3
0.2
0.1
0.0
2000
2005
2010
2015
2020

# 531nm: m12


_531nm, black: MS1, Det.1, Frame 22
m12
0.04
0.02
0.00
−0.02
−0.04
2000
2005
2010
2015
2020


_531nm, black: MS1, Det.1, Frame 675
m12
0.04
0.02
0.00
−0.02
−0.04
2000
2005
2010
2015
2020


_531nm, black: MS1, Det.1, Frame 989
m12
0.04
0.02
0.00
−0.02
−0.04
2000
2005
2010
2015
2020


_531nm, black: MS1, Det.1, Frame 1250
m12
0.04
0.02
0.00
−0.02
−0.04
2000
2005
2010
2015
2020

# MODIS optical throughput degradation and its impacts on calibration

**Shihyan Lee**

NASA OBPG
Code 616
2016/06/06

# Content

•Relative Spectral Response (RSRs) is a key component in radiometric calibration and science algorithm

•During on-orbit operation, the wavelength dependency in optical throughput degradation will change RSR (modulated RSR)

•Lesson from VIIRS RSR change due to optical throughput degradation

•Long-term trend in MODIS calibration coefficients (m1) indicate wavelength dependency in optical throughput degradation

**Objective: Optical degradation → Modulated RSRs → Science products**

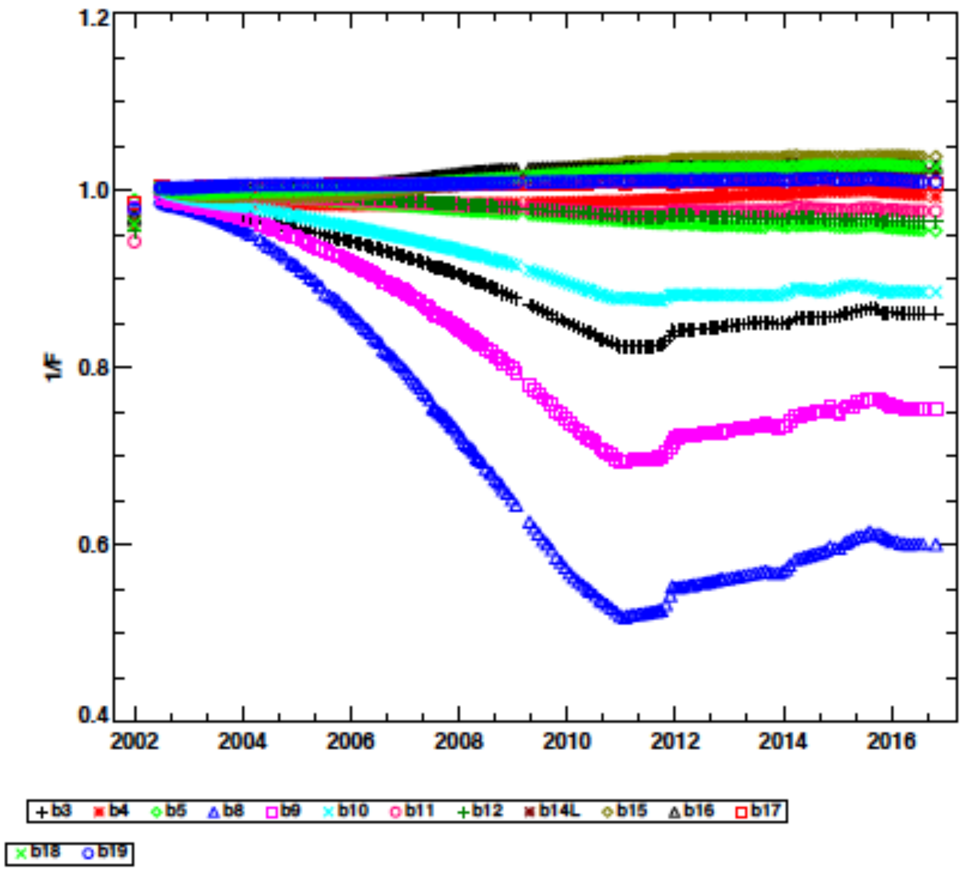
•Estimate RSR modulation over time.

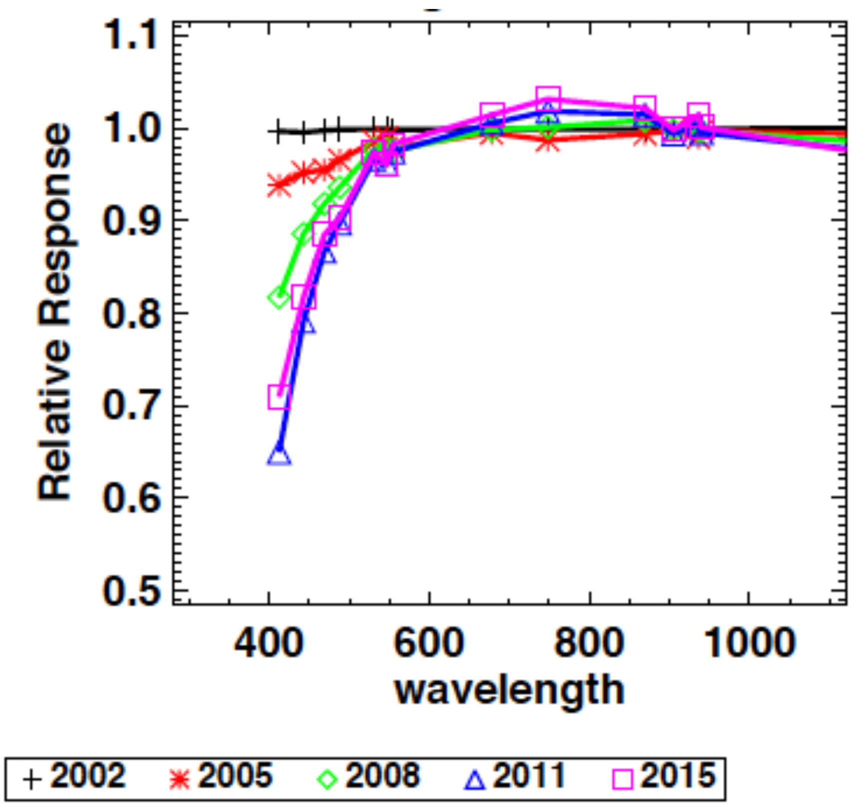
•Impact on radiometric calibration

•Scan angle dependency

•Show Analysis in Aqua MODIS

# MODIS Aqua Optical Degradation



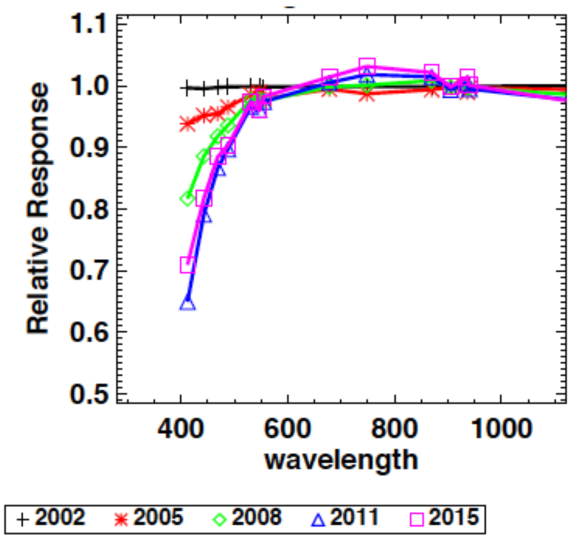

L: MODIS degradation (1/m1 (MCST)) vs. time (normalized to first on-orbit measurement)

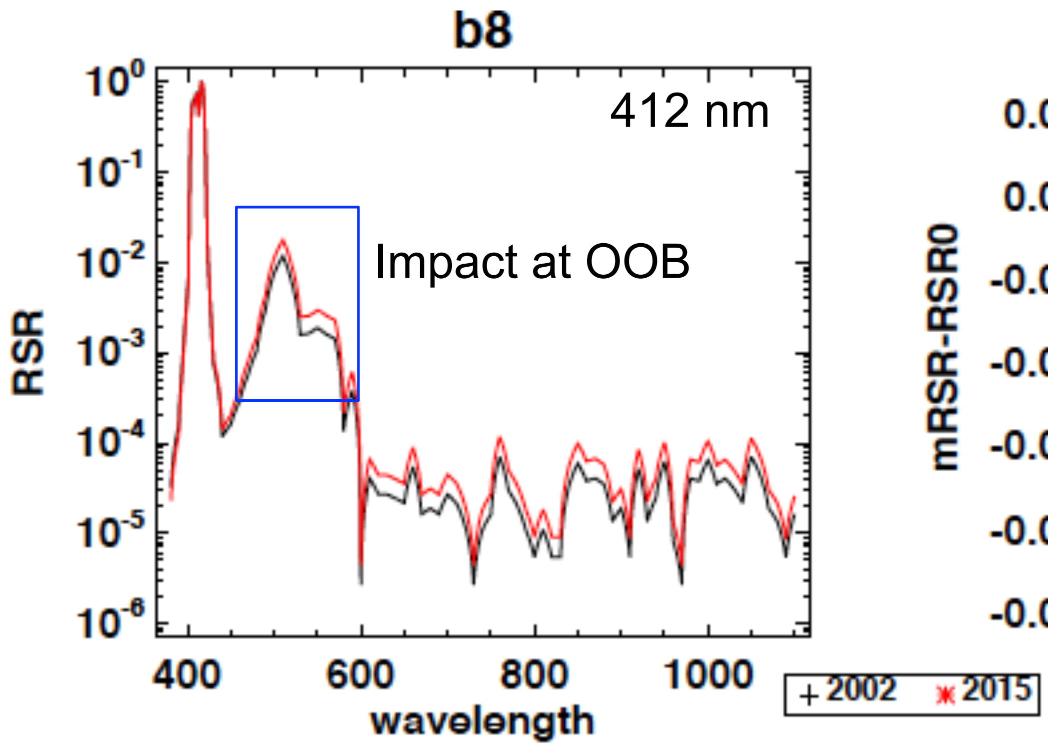
R: throughput degradation vs. wavelength over time.

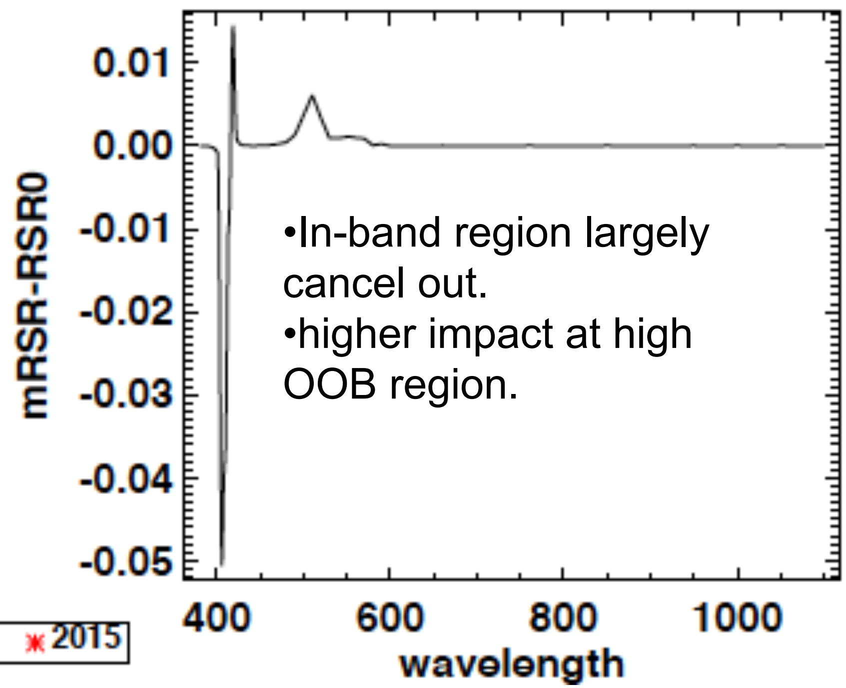
# Modulated RSRs

$$RSR_{\text{modulated}}(\lambda,t) = \frac{RSR_{original}(\lambda)D(\lambda,t)}{\max\left(RSR_{original}(\lambda)D(\lambda,t)\right)}$$

D(λ,t) = degradation at wavelength λ at time t

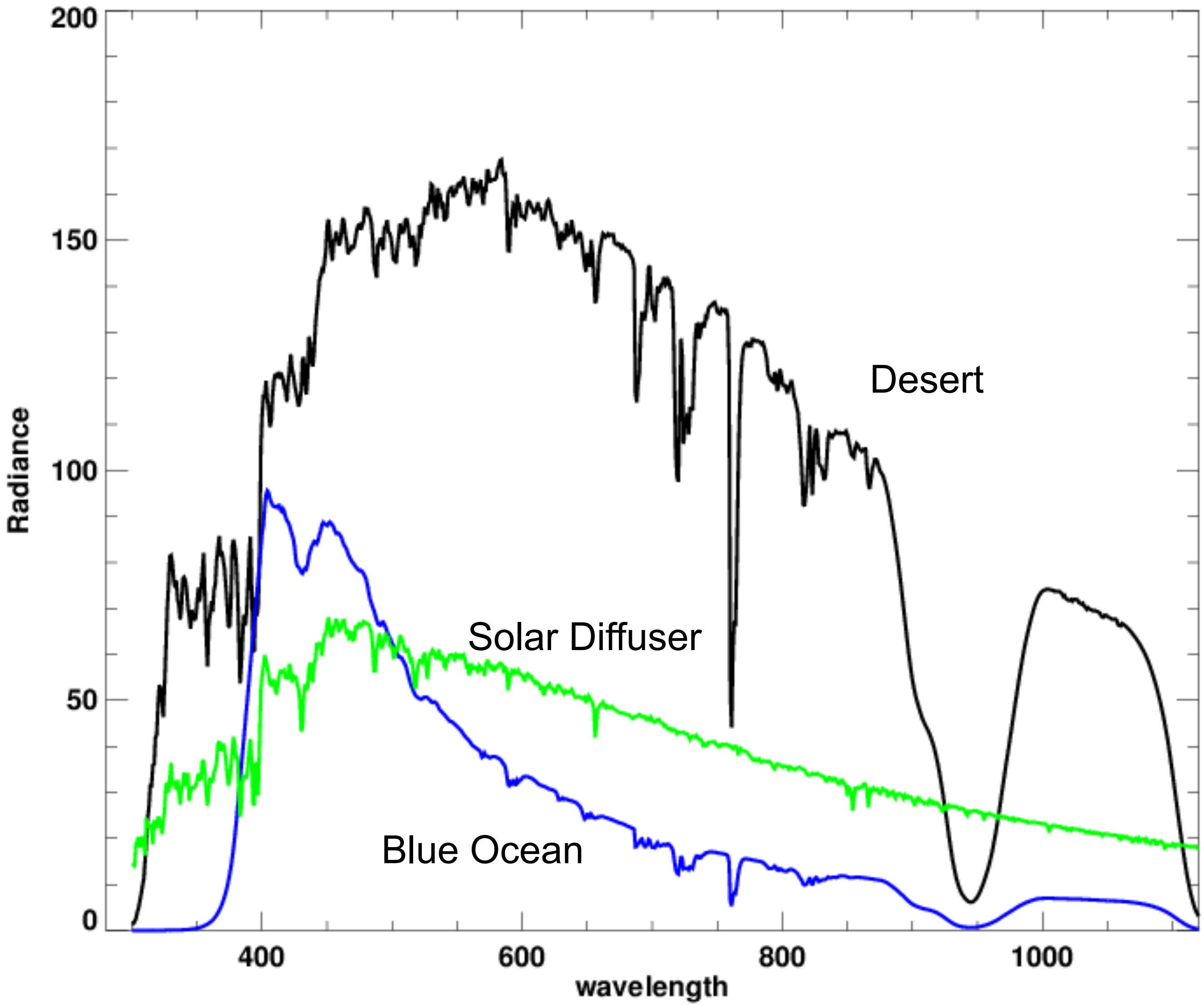



•In-band region largely cancel out.
•higher impact at high OOB region.

# Target Spectra



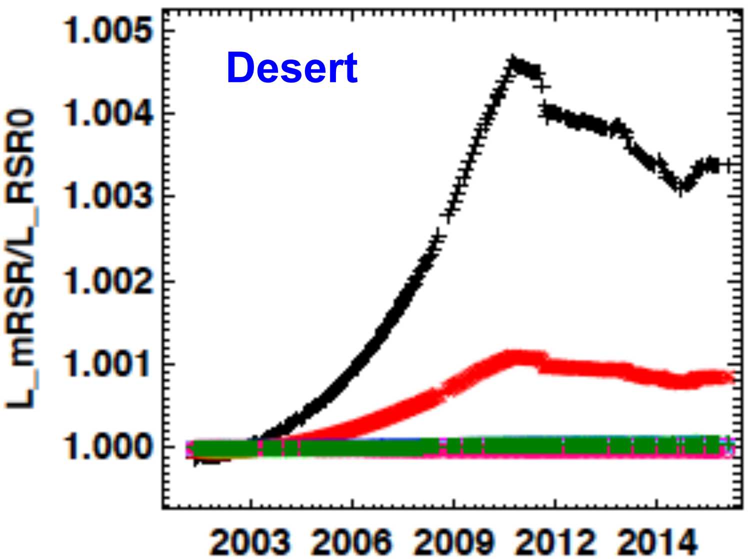

Calibration target:

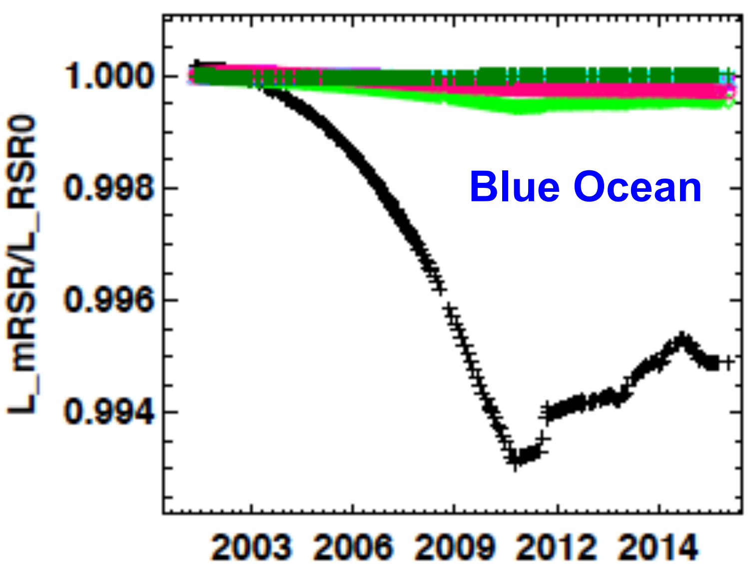
desert / SD

Scene: blue ocean

•Modulated RSR impact due to spectrum differences between calibration targets and scene.

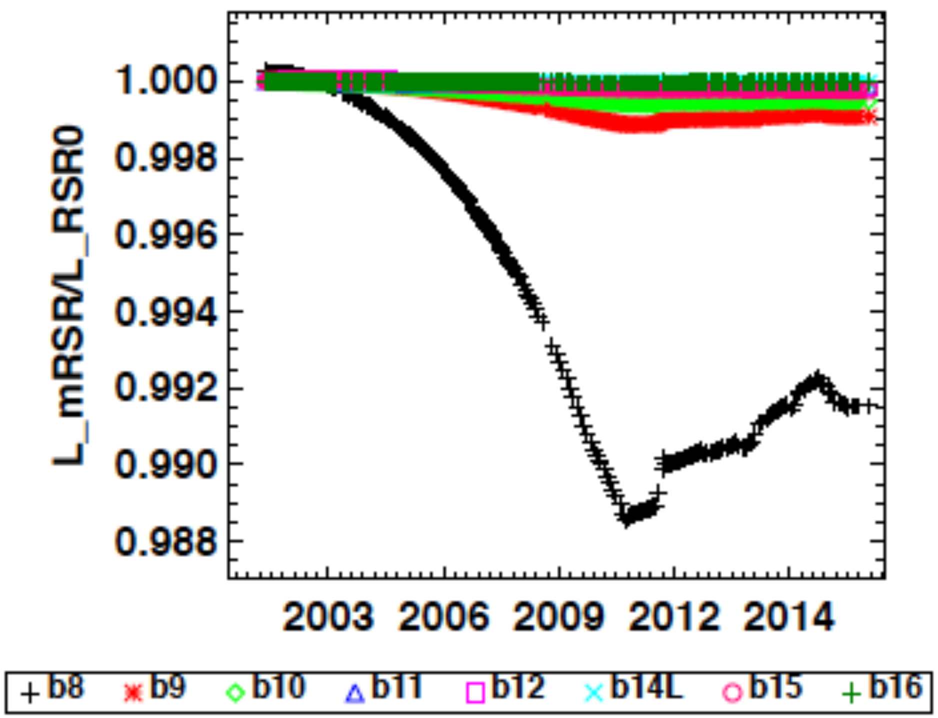
# Modulated RSR Effects



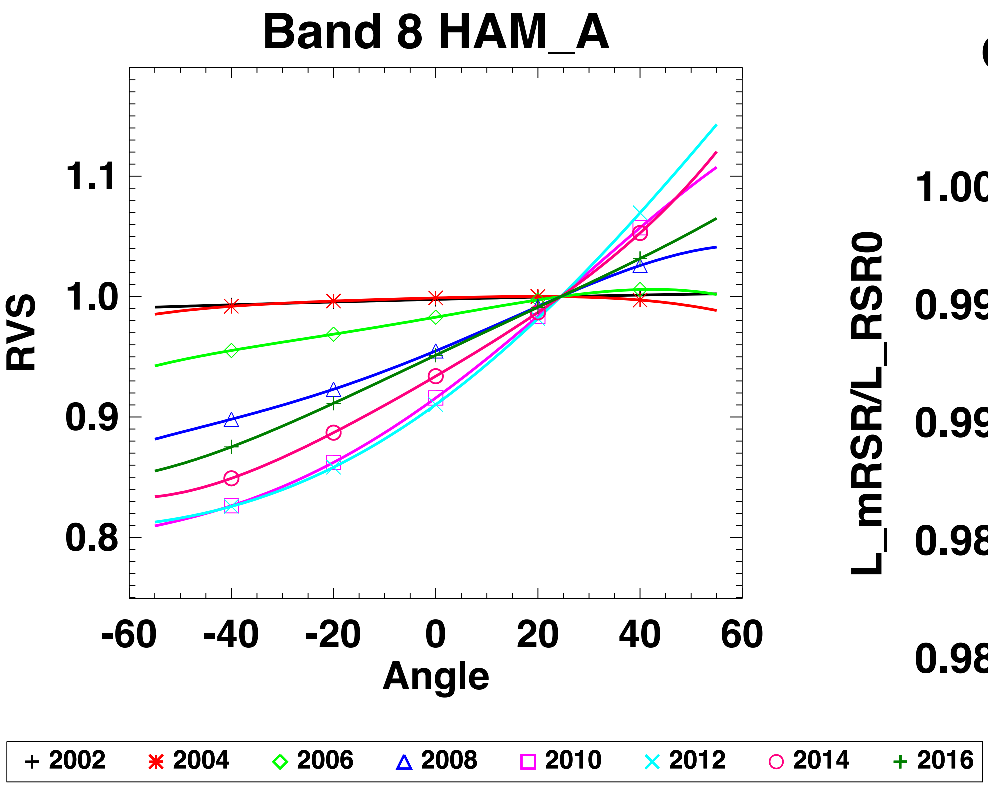



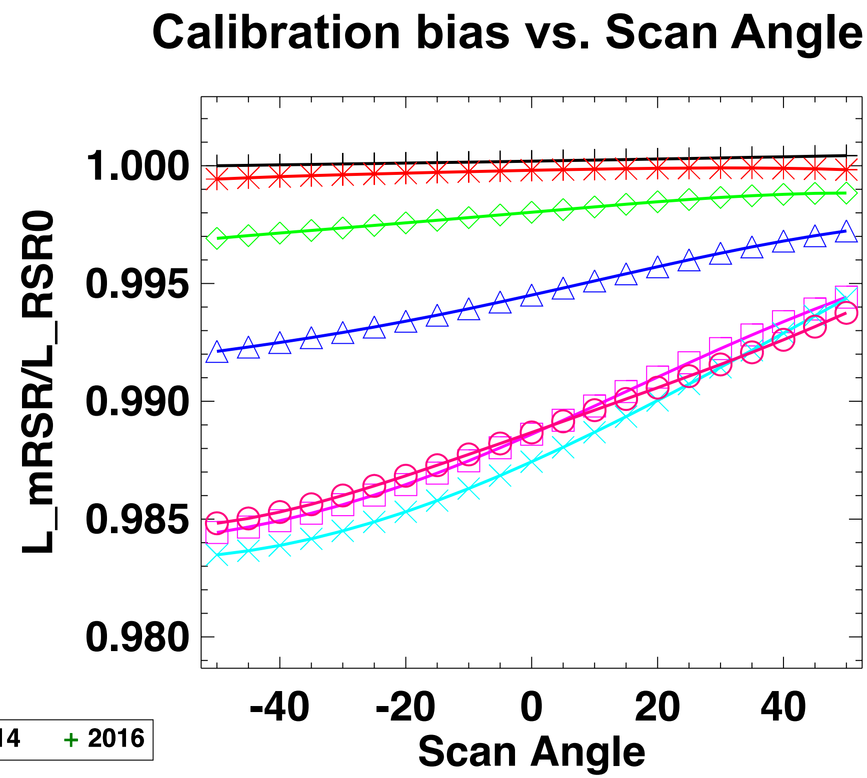

- •Ratios of target radiances computed using pre-launch and modulated RSRs.
- •Large impact (>1%) on band 8 (412nm)

**Cal: Desert, scene: Blue Ocean**



# Modulated RSR Effects



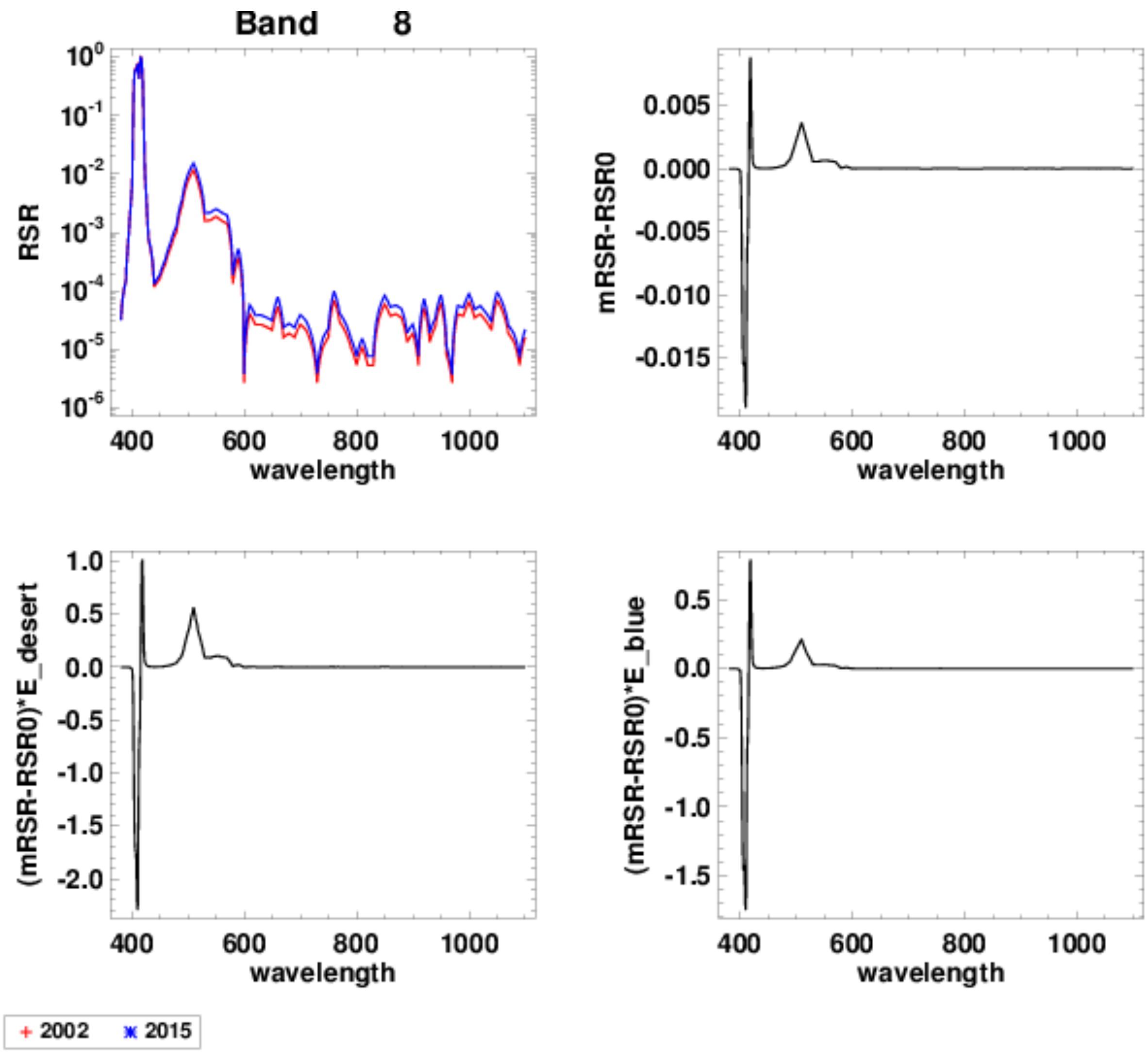

- •Aqua MODIS scan mirror RVS has large change over time
- •Optical throughput angular dependent

- •Scan angle dependent RSR modulation and impacts on calibration

# Summary

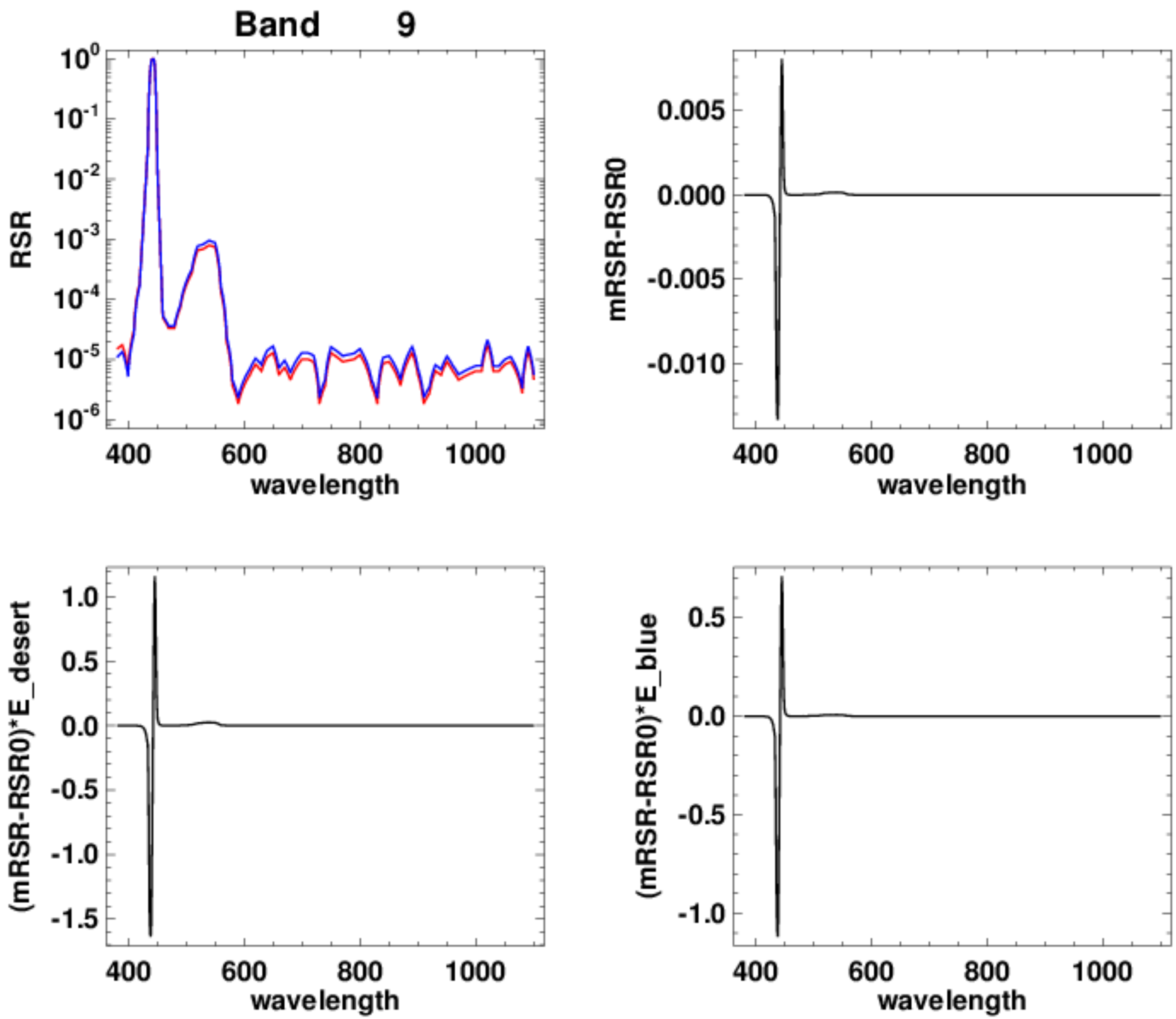
- Temporal trending in Aqua MODIS gain indicates wavelength dependency in its optical throughput degradation
- The wavelength dependent degradation will reshape the relative spectral response (RSR) function.
- The RSR change is also scan angle dependent due to large RVS change over time.
- The calibration impact due to RSR modulation is most significant on band 8 (up to 1.5% at typical ocean scene).
- The calibration impact for the rest of the ocean bands are less then 0.15%.
- The RSR modulation impact on calibration are mainly due to out-of-band response and minimized this will minimized similar issue in future missions.

# Backup Slides




Kept degradation below 412 nm constant

# Modulated RSRs

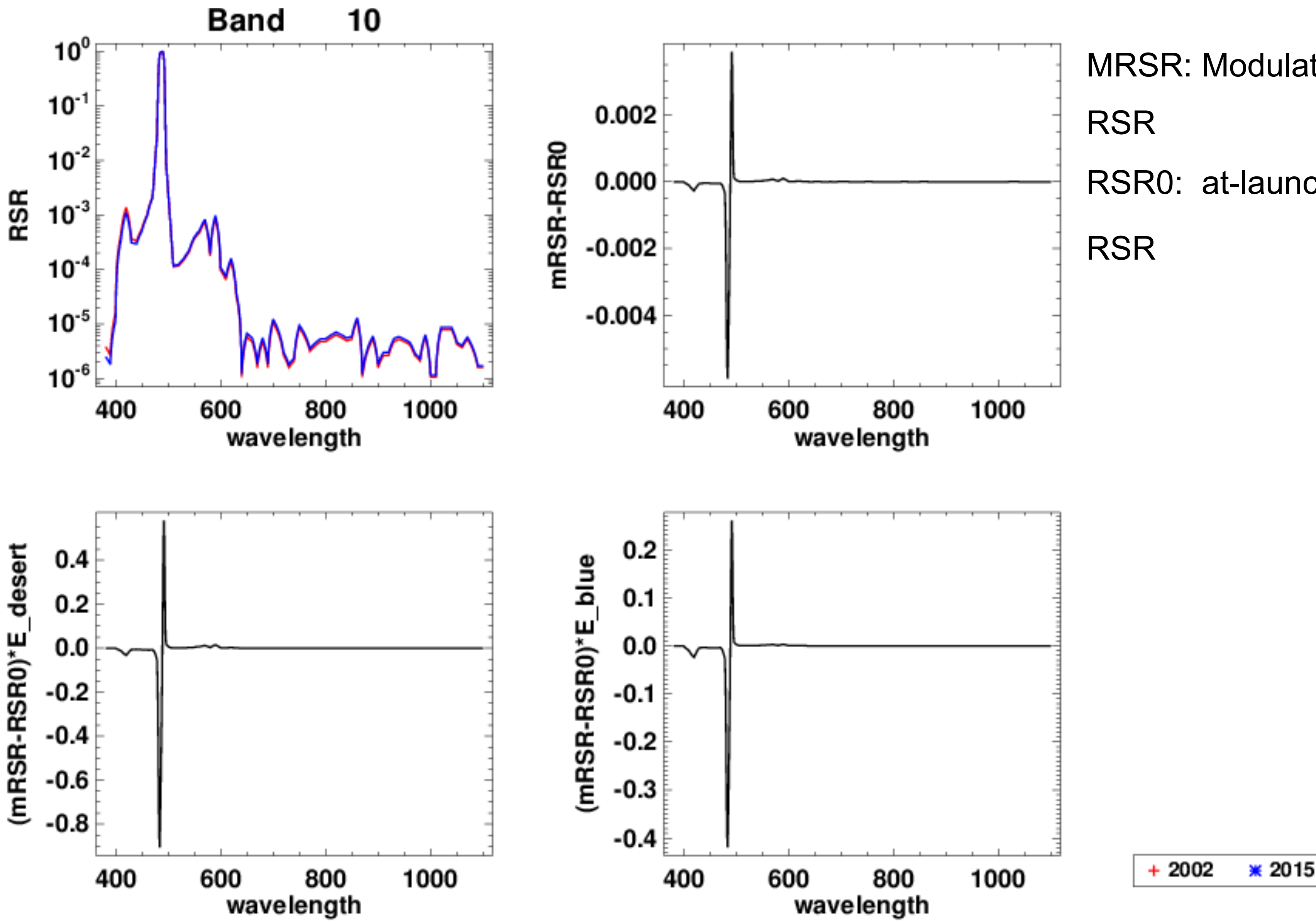



MRSR: Modulated RSR

RSR0: at-launch RSR

+ 2002 ✱ 2015

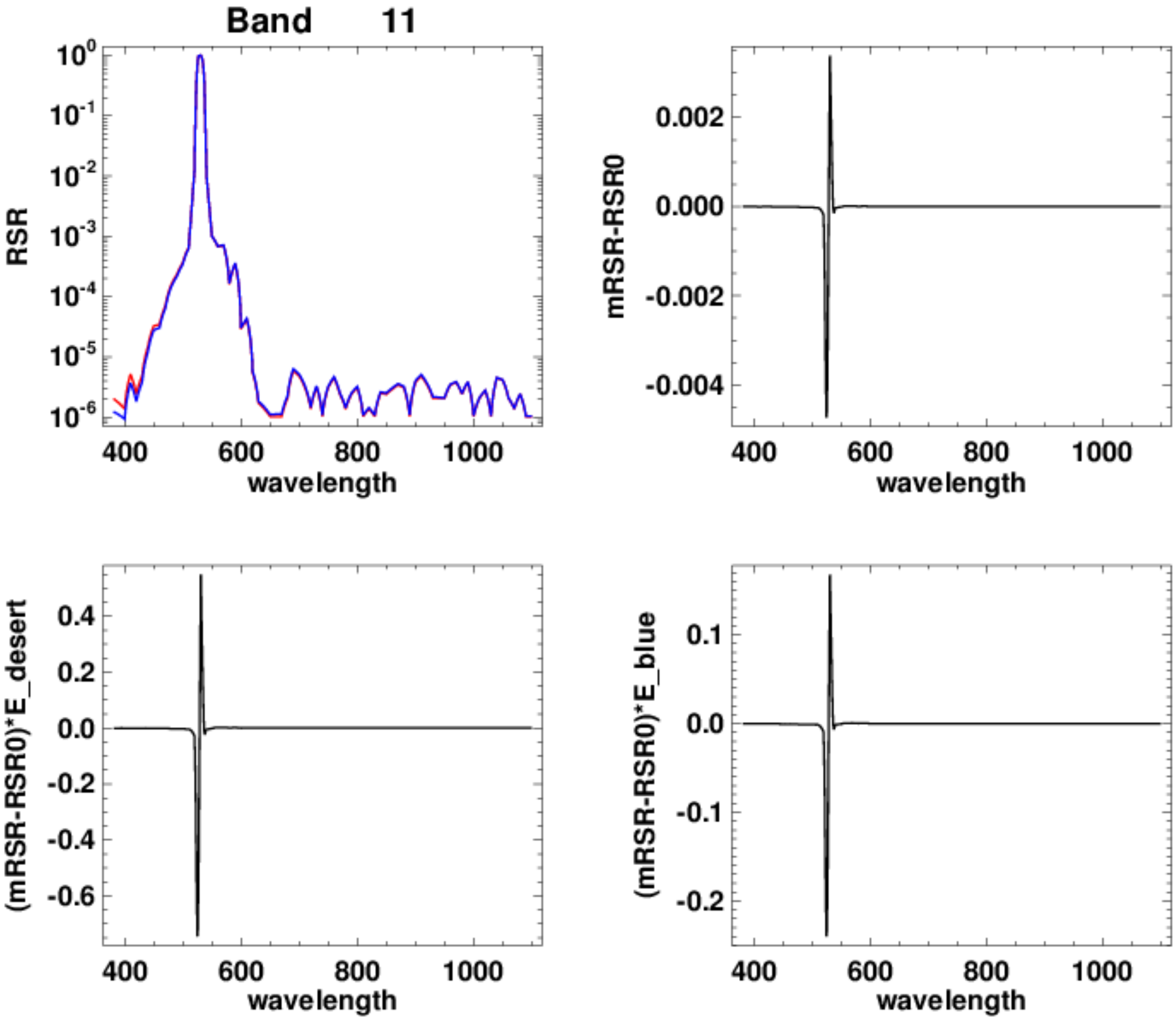
# Modulated RSRs




MRSR: Modulated RSR

RSR0: at-launch RSR

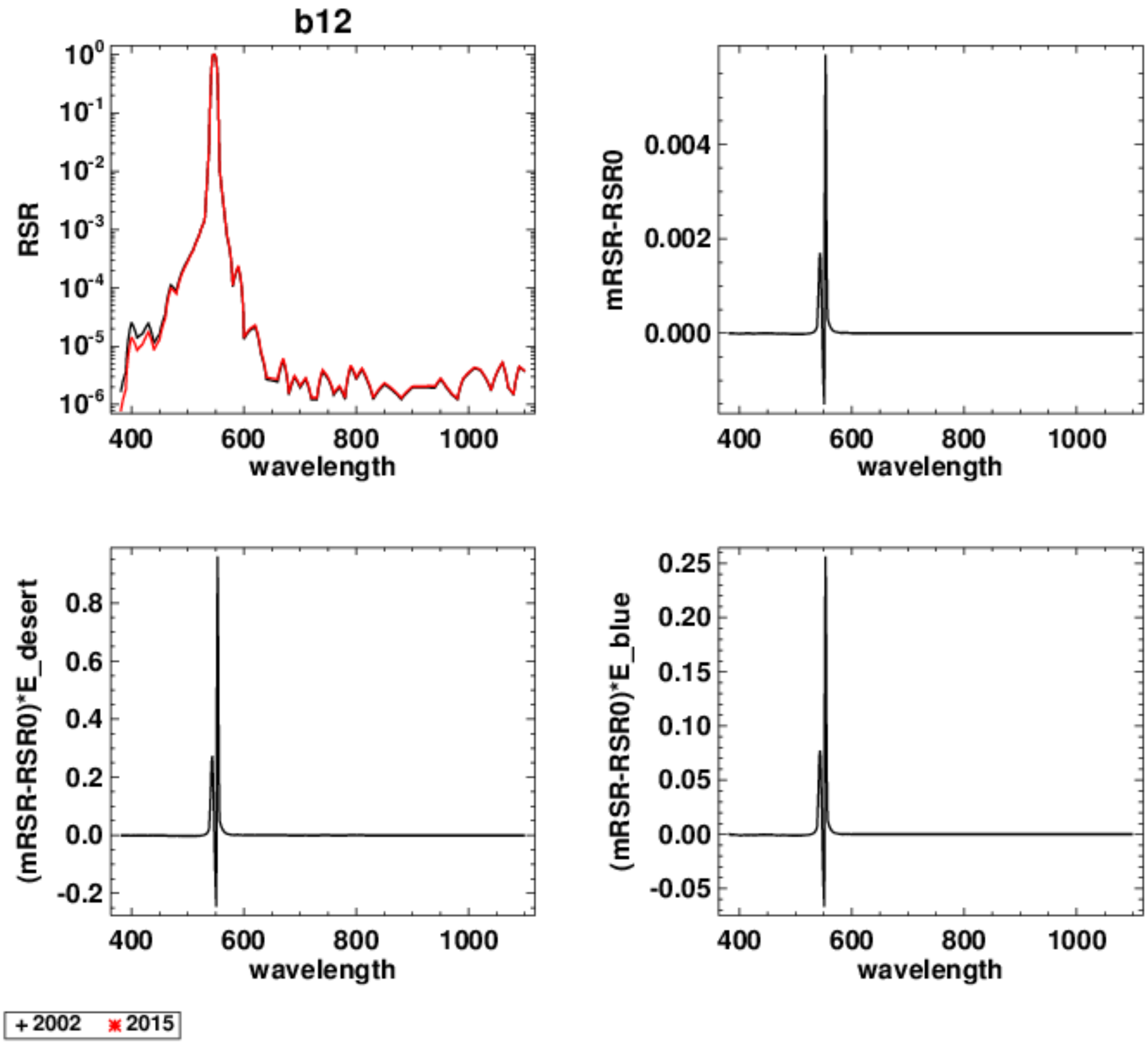
# Modulated RSRs




MRSR: Modulated RSR

RSR0: at-launch RSR

# Modulated RSRs

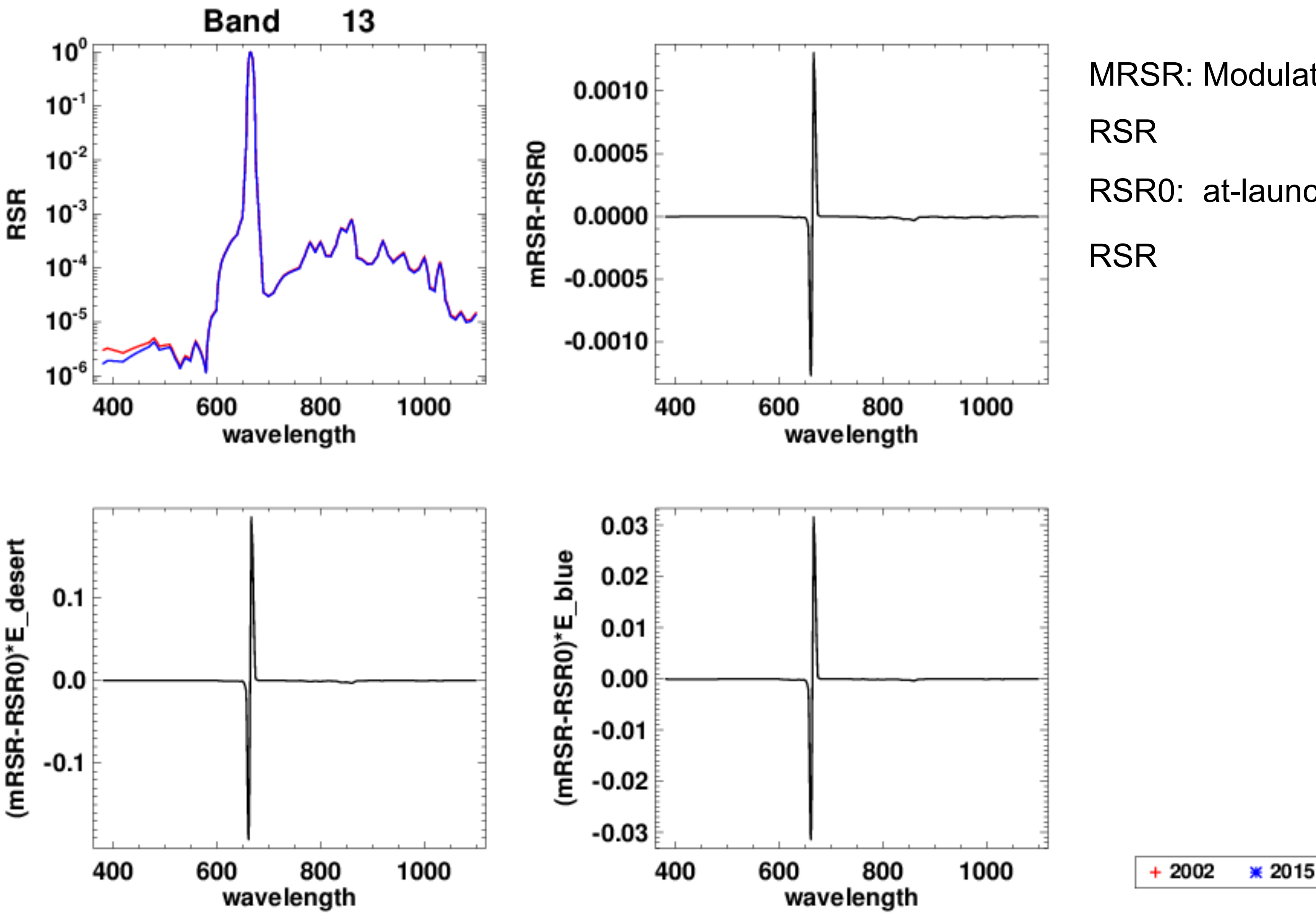



MRSR: Modulated RSR

RSR0: at-launch RSR

+ 2002 ✳ 2015

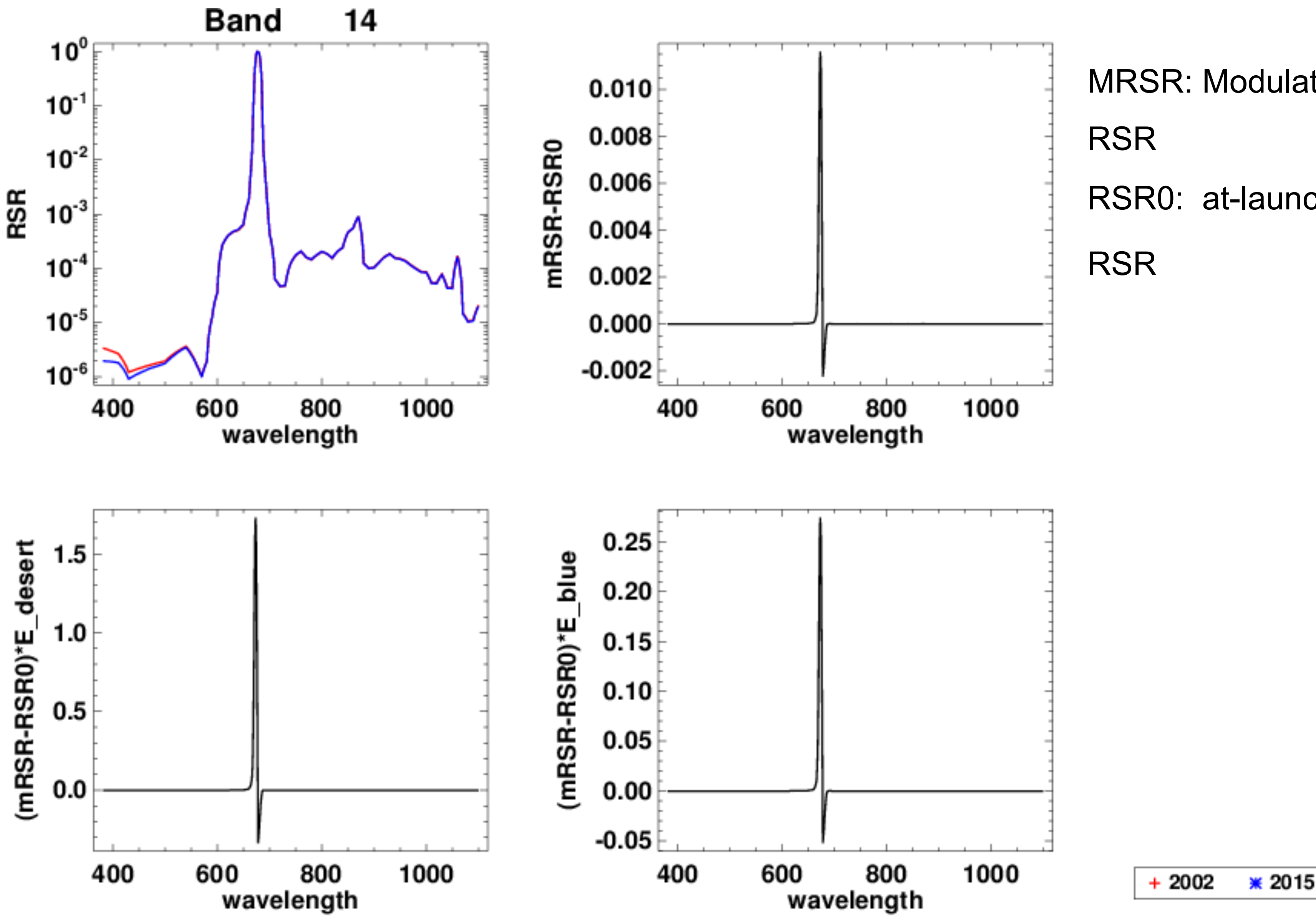
# Modulated RSRs




MRSR: Modulated RSR

RSR0: at-launch RSR

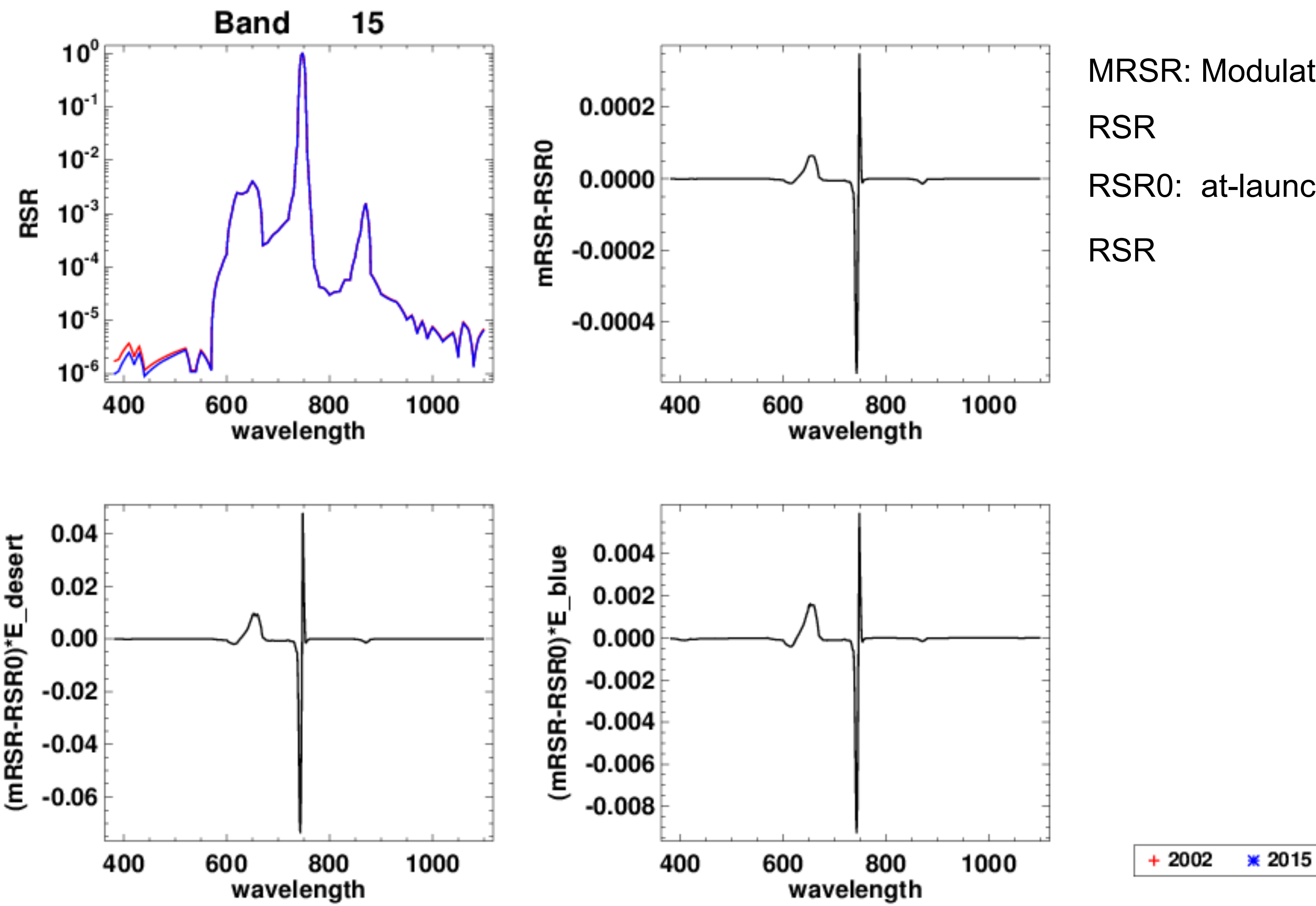
# Modulated RSRs




MRSR: Modulated RSR

RSR0: at-launch RSR

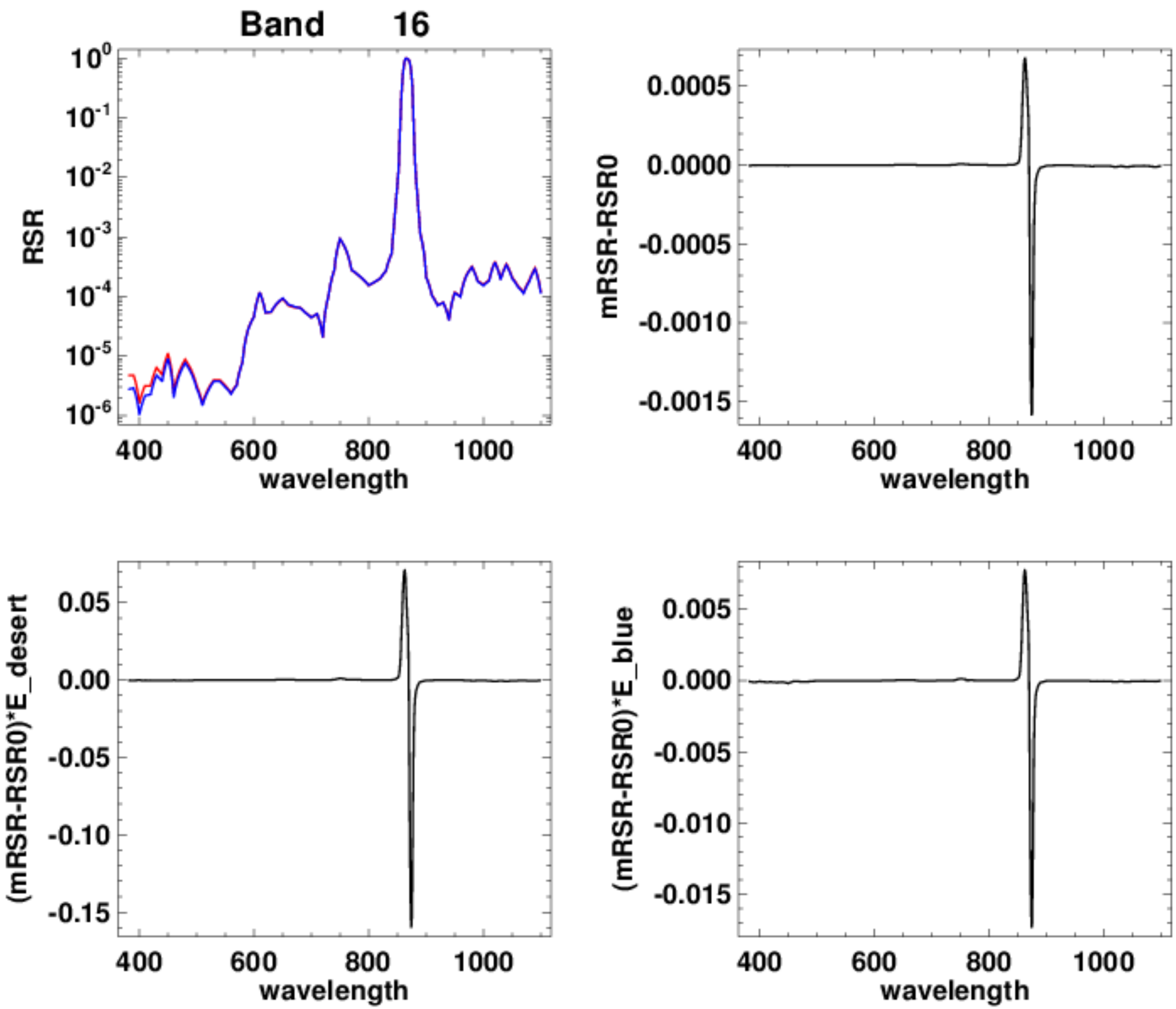
# Modulated RSRs




MRSR: Modulated RSR

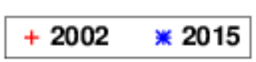
RSR0: at-launch RSR

# Modulated RSRs




MRSR: Modulated RSR

RSR0: at-launch RSR



# Modulated RSR effects

Ratios of band-averaged target radiances
computed using pre-launch and 2015 modulated RSRs.
(cap degradation at 412 nm)

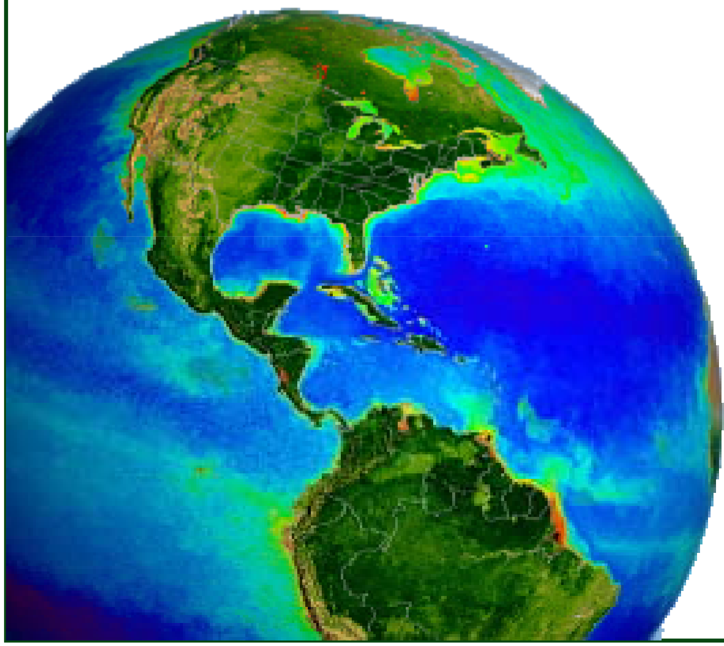
| Band | Wave | Dessert (%) | Blue (%) | Blue + Dessert (%) |
|---|---|---|---|---|
| 8 | 412.5 | 0.2822 | -0.4472 | -0.7273 |
| 9 | 443 | 0.0788 | -0.0071 | -0.0858 |
| 10 | 488 | 0.0068 | -0.0440 | -0.0507 |
| 11 | 531 | 0.0050 | -0.0081 | -0.0131 |
| 12 | 551 | 0.0009 | -0.0090 | -0.0099 |
| 13 | 667 | 0.0121 | 0.0116 | -0.0005 |
| 14 | 678 | 0.0114 | 0.0142 | 0.0028 |
| 15 | 748 | 0.0029 | 0.0182 | 0.0154 |
| 16 | 869.5 | 0.0014 | -0.0027 | -0.0042 |

# Modulated RSR effects

Ratios of band-averaged target radiances
computed using pre-launch and 2015 modulated RSRs.

| Band | Wave | Dessert (%) | Blue (%) | Blue + Dessert (%) |
|---|---|---|---|---|
| 8 | 412.5 | 0.3128 | -0.4717 | -0.7821 |
| 9 | 443 | 0.0790 | -0.0070 | -0.0858 |
| 10 | 488 | 0.0069 | -0.0441 | -0.0510 |
| 11 | 531 | 0.0050 | -0.0081 | -0.0132 |
| 12 | 551 | -0.0007 | -0.0526 | -0.0520 |
| 13 | 667 | 0.0125 | 0.0179 | 0.0053 |
| 14 | 678 | 0.0083 | 0.0184 | 0.0101 |
| 15 | 748 | 0.0027 | 0.0050 | 0.0023 |
| 16 | 869.5 | 0.0047 | 0.0023 | -0.0024 |

# Updates to the On-Orbit Calibration of SNPP VIIRS for Ocean Color Applications



Gene Eplee, Kevin Turpie,
Fred Patt, Gerhard Meister,
and Bryan Franz

NASA Ocean Biology
Processing Group

MODIS / VIIRS Science Team Meeting
June 6, 2016

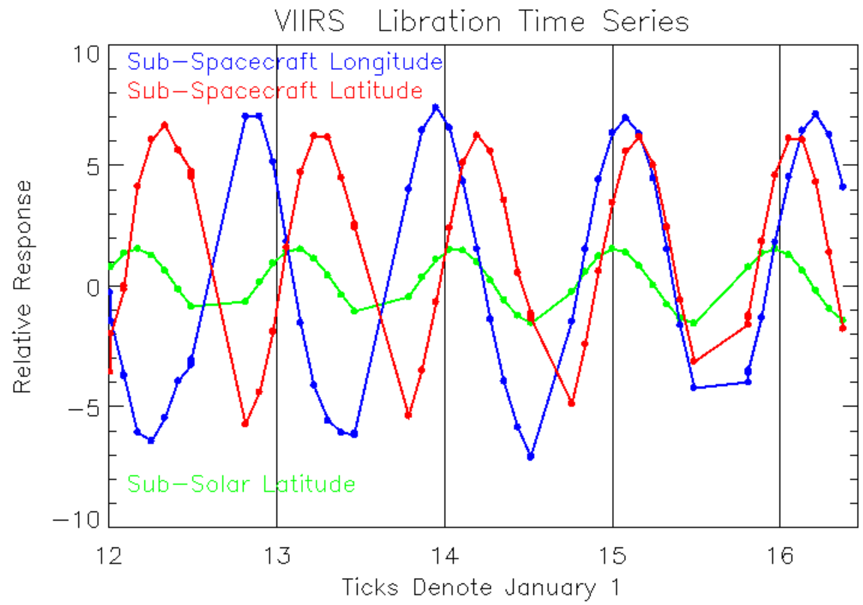
# OBPG On-Orbit Calibration Analysis Updates

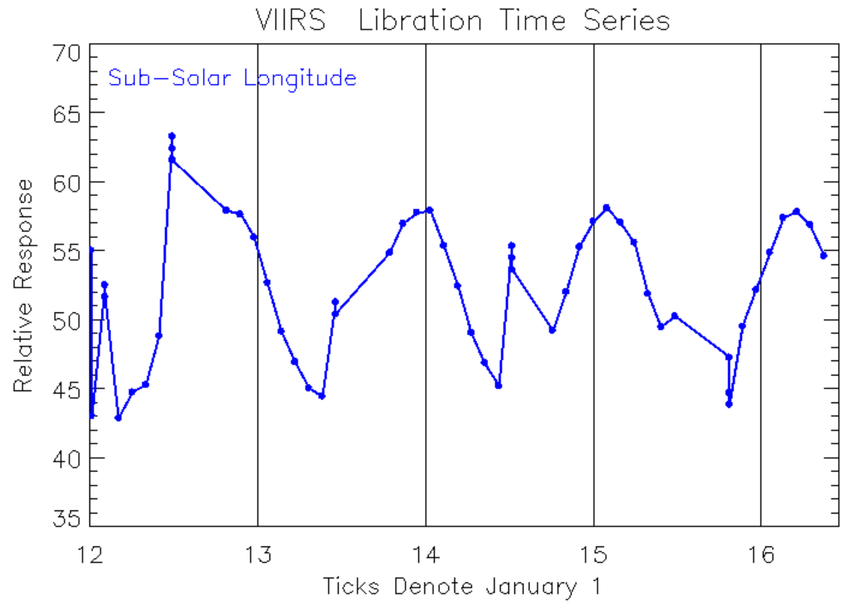
- Current corrections to lunar/solar observations:
  - Lunar calibration data processed using modulated RSRs.
  - Empirical libration corrections applied to lunar calibration time series.
  - SDSM H-factors normalized by detrended channel 8.
  - Solar F-factor BRDF corrected by spline-interpolated SDSM H-factors.

- Lunar/solar time series differences fit by exponential functions of time.
  - Trend differences depart from linear functions of time.
  - Bands M1-M4 fit by 400 day exponential + linear function of time
  - Bands M5-M11 fit by 120 day and 800 day exponentials of time.

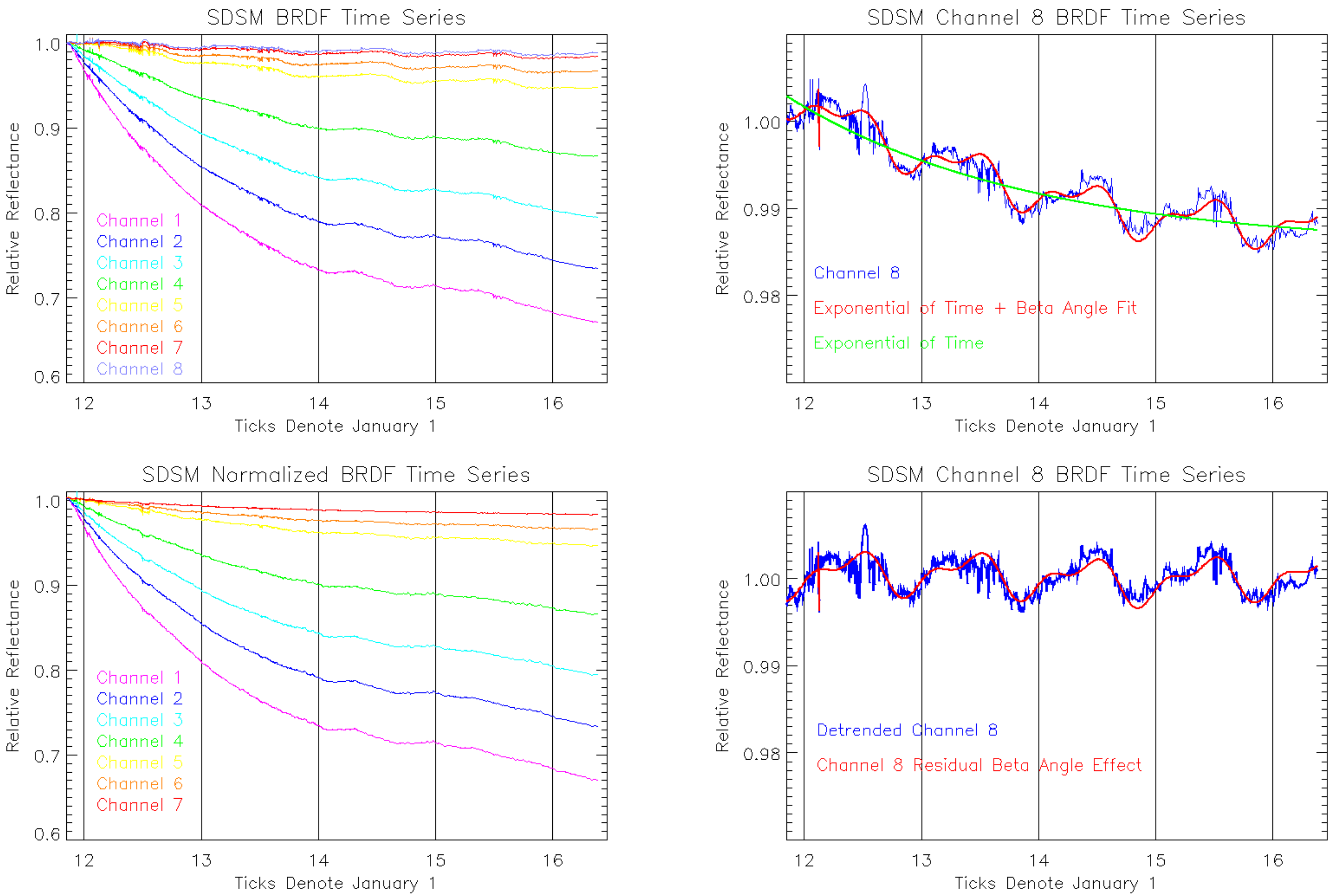
- Periodic signal in red bands (M5-M11) apparent in both solar and lunar time series, with period of 14-15 months.
  - Wavelength-dependent effect strongest for band M7
  - Currently, best ocean data retrievals are obtained by fitting through periodic signal.

# Lunar Libration Time Series

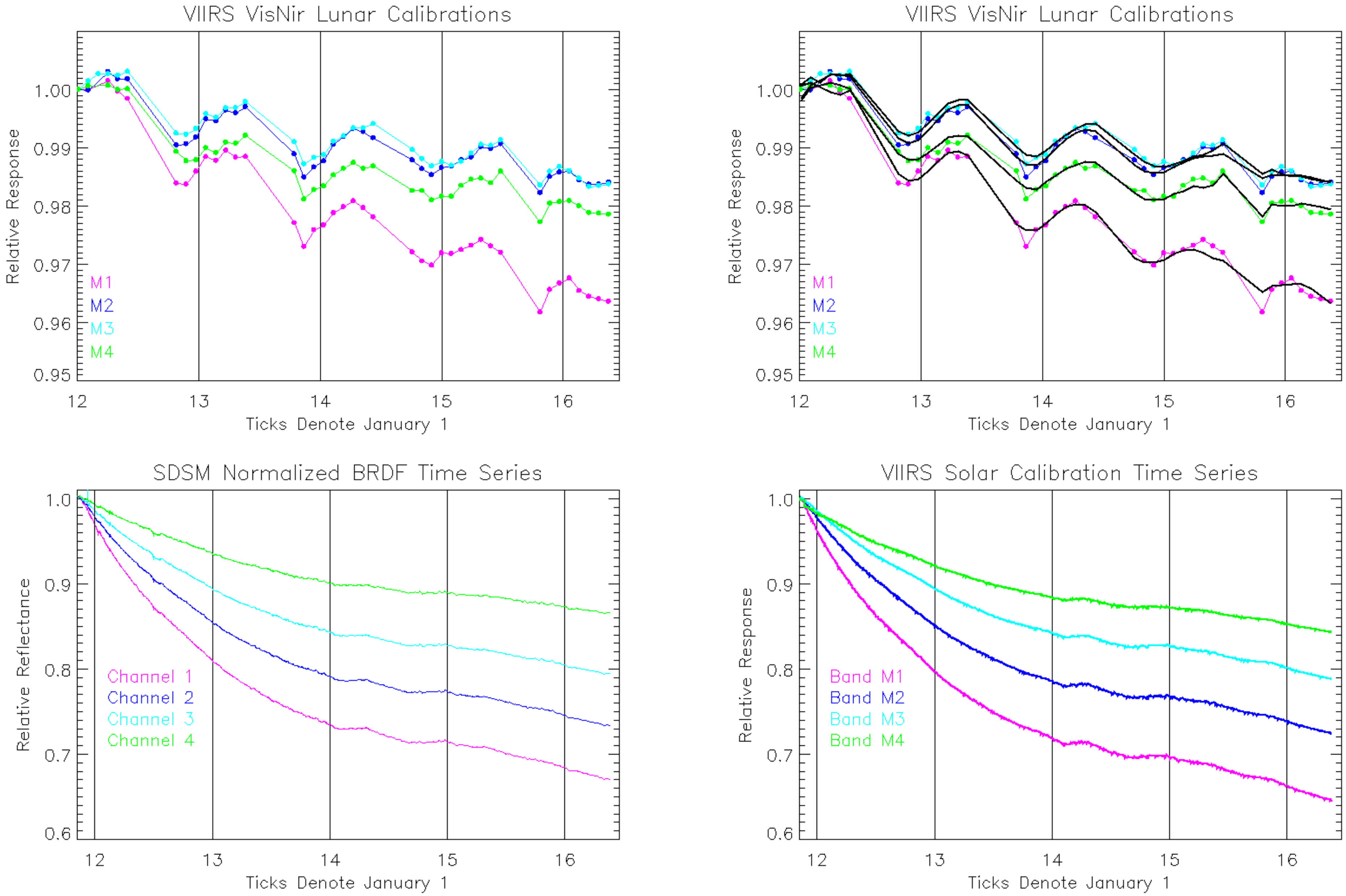


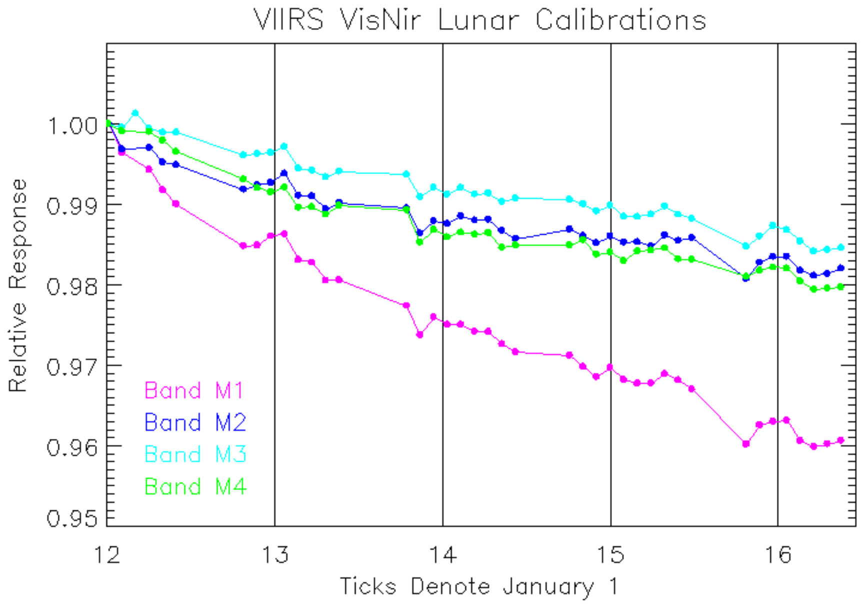
# SDSM H-Factor Time Series

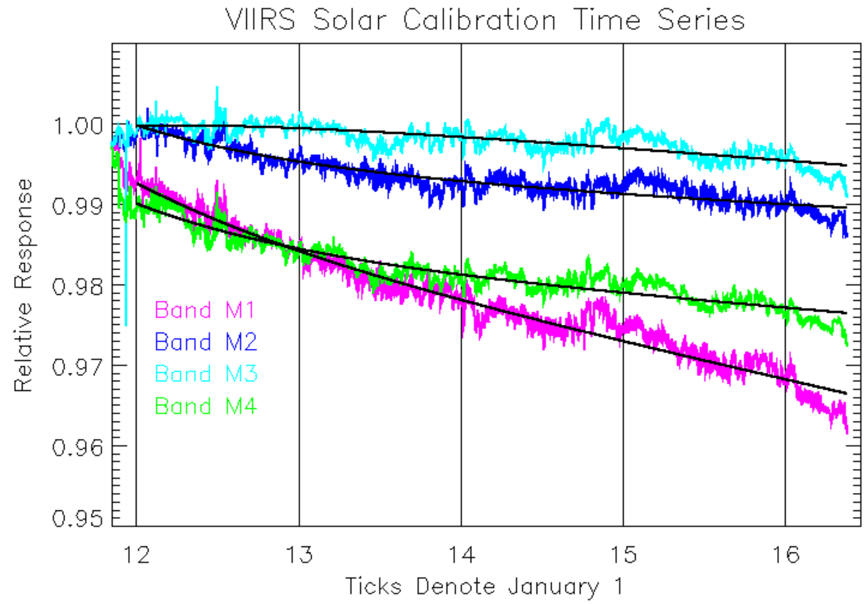


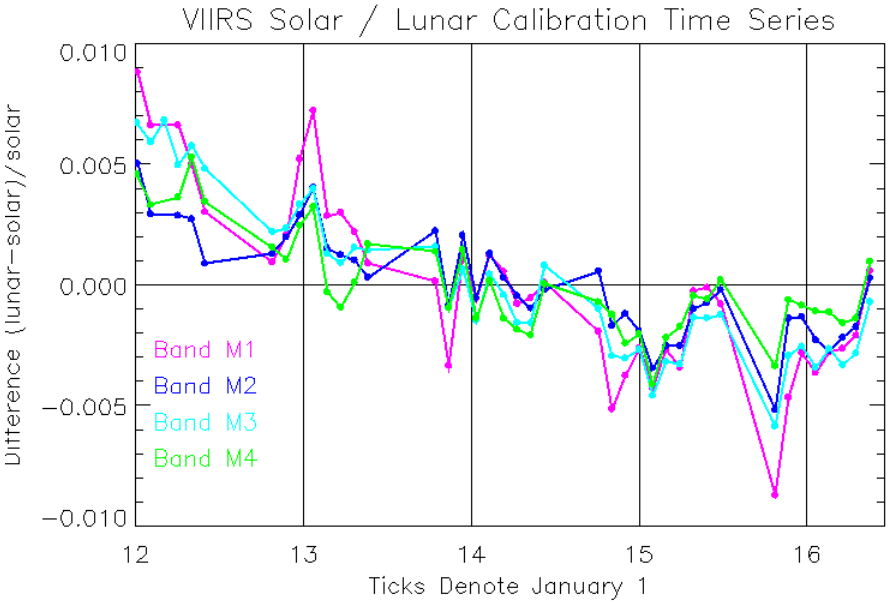
# Band M1-M4 Calibration Time Series

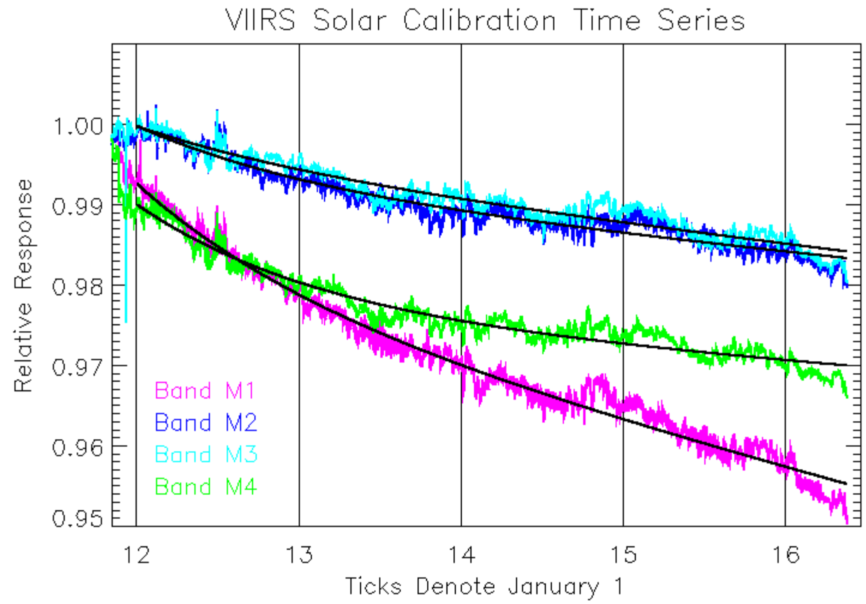


# Band M1-M4 Calibration Time Series

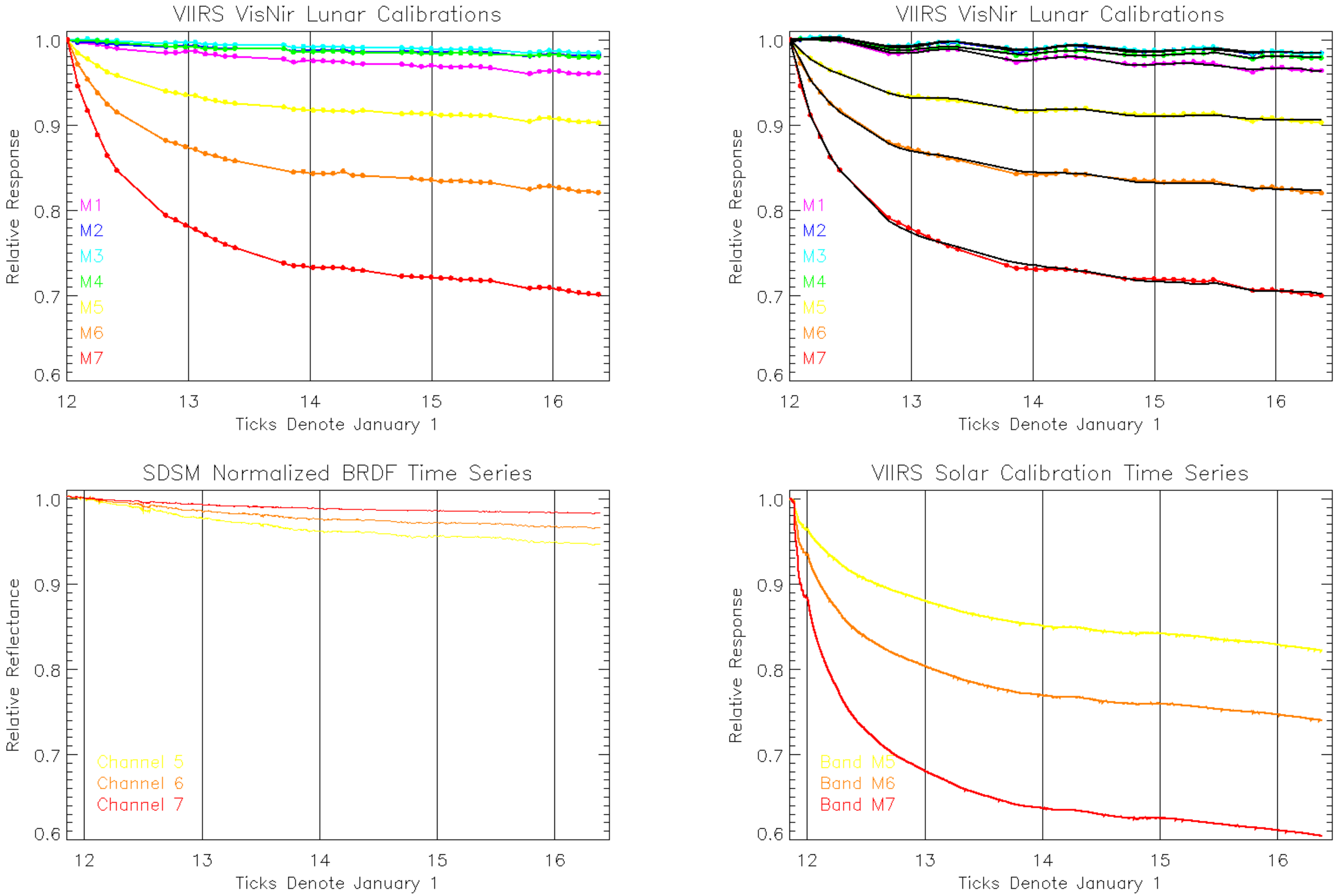


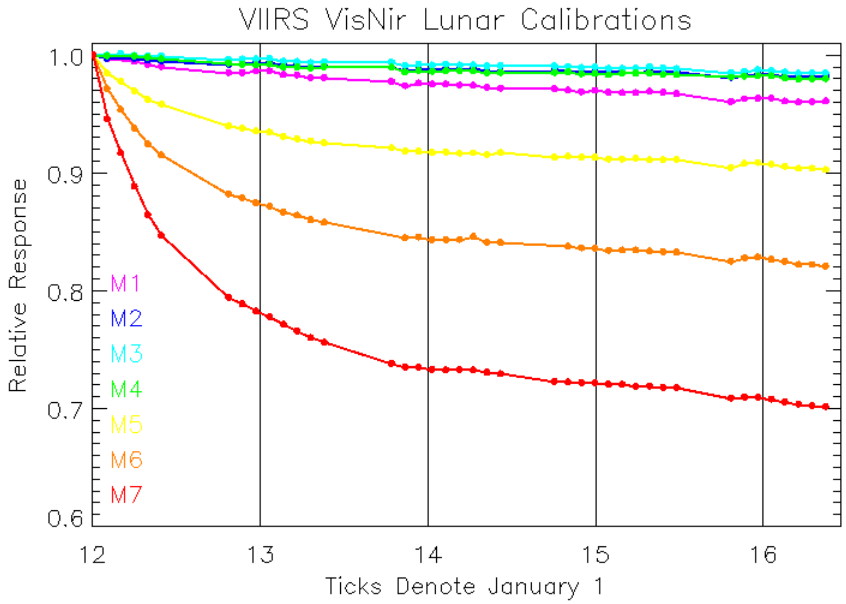



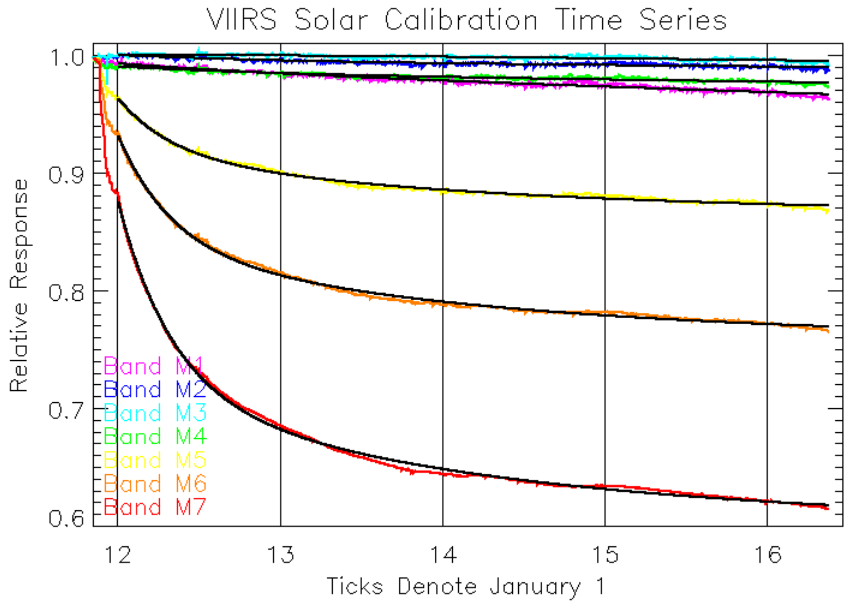



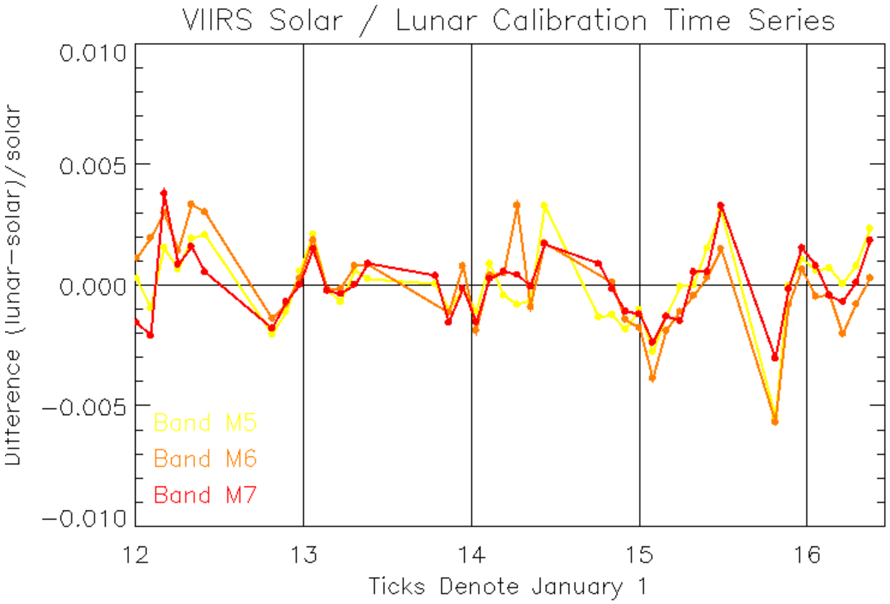
# Band M5-M7 Calibration Time Series

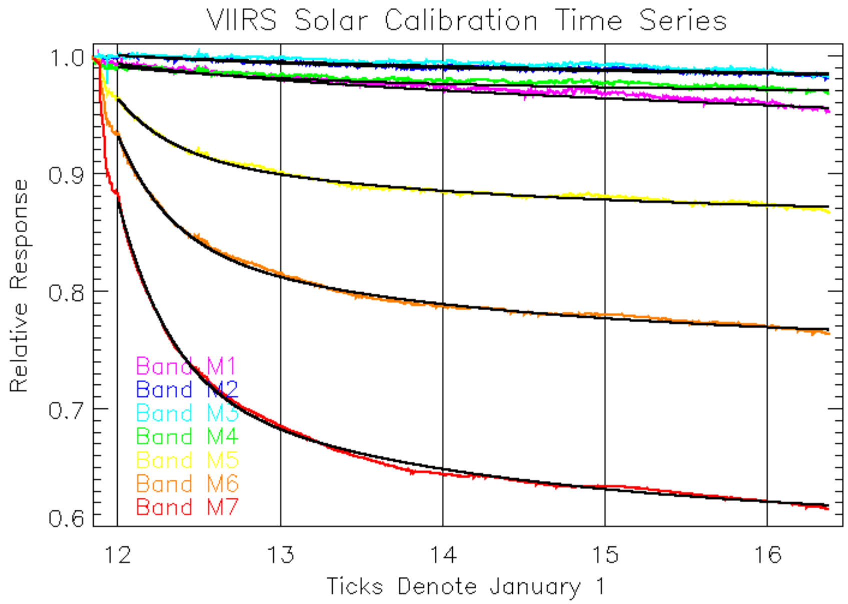


# Band M5-M7 Calibration Time Series

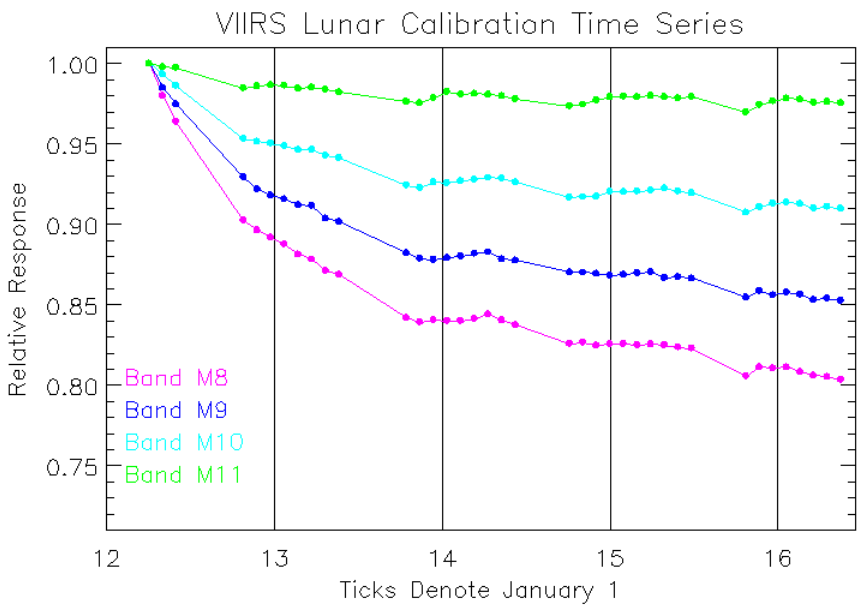


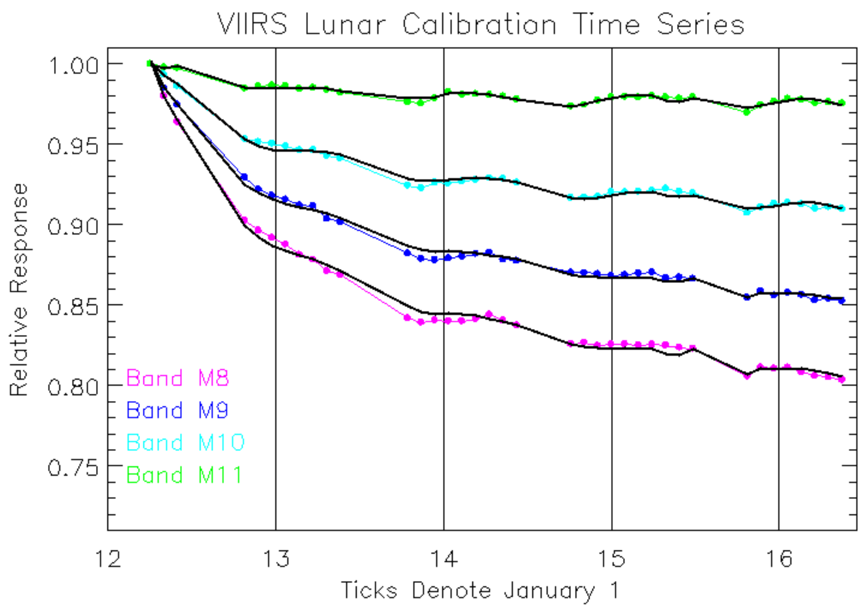



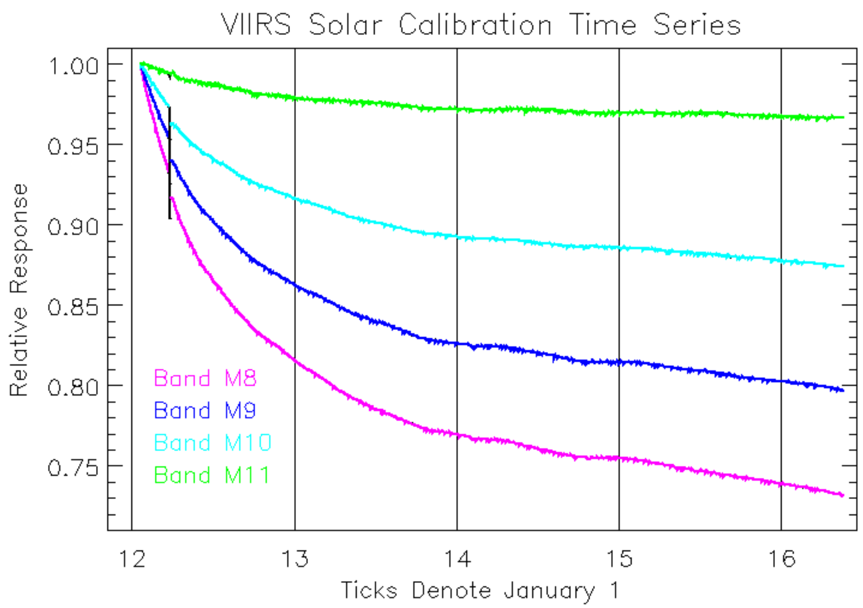



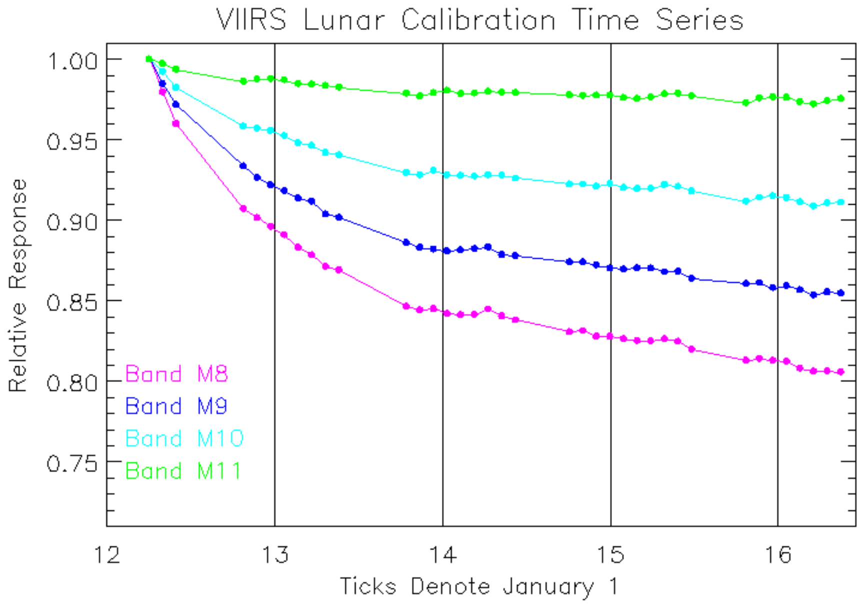
# Band M8-M11 Calibration Time Series

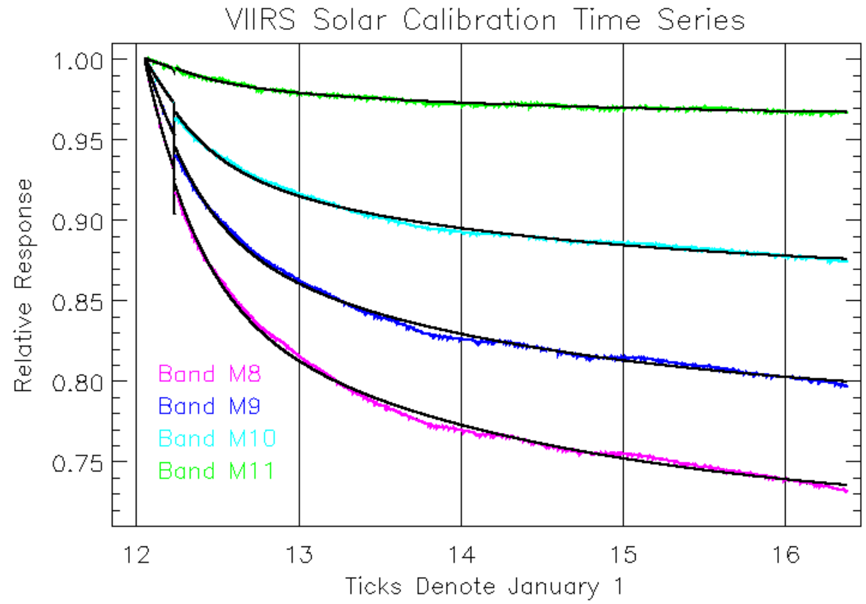


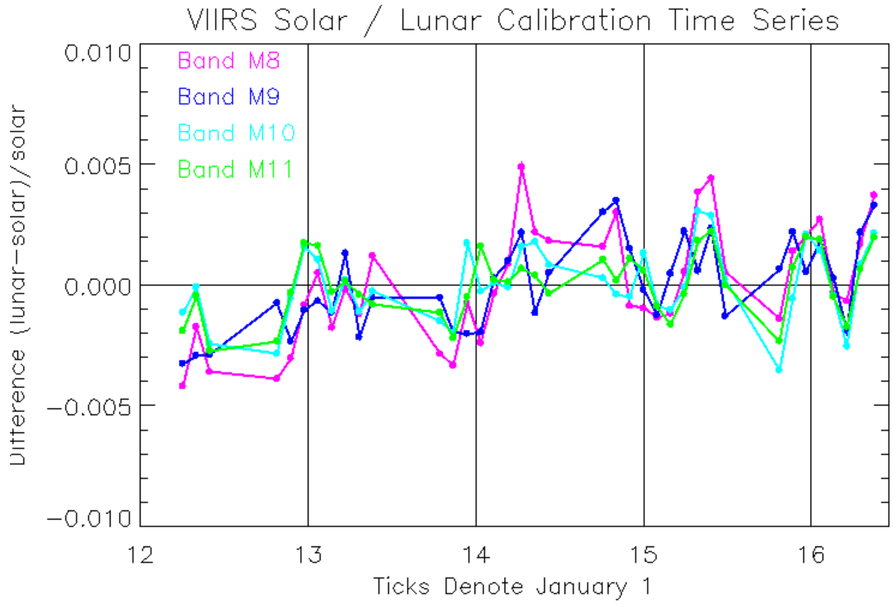



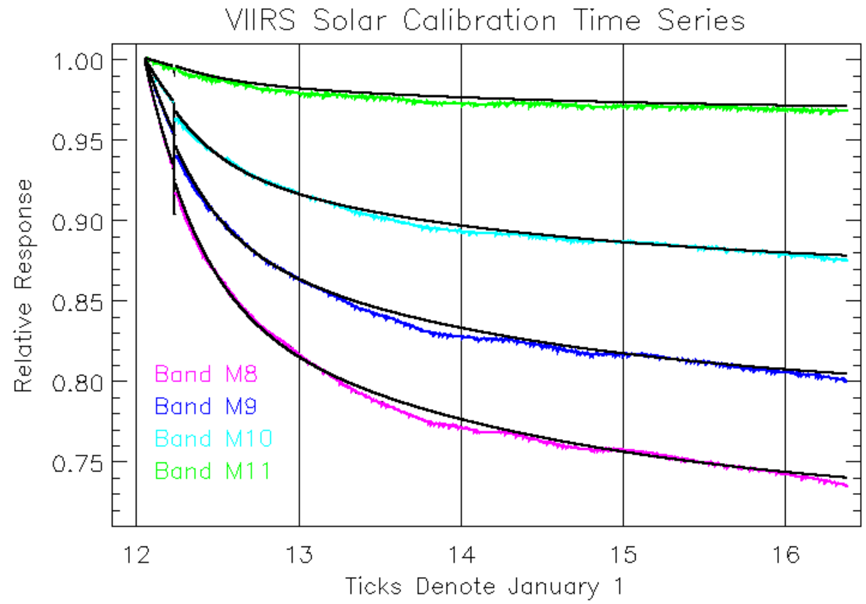



# Band M8-M11 Calibration Time Series

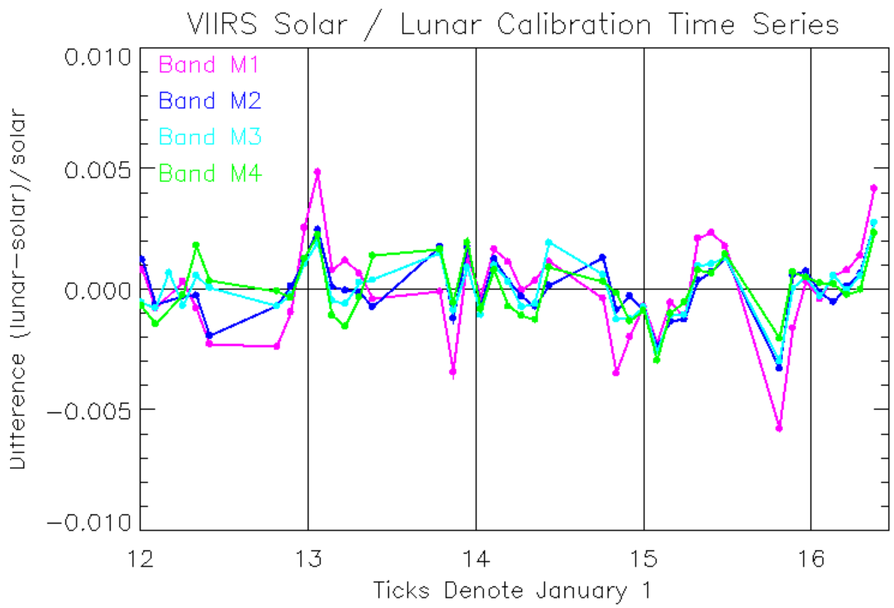


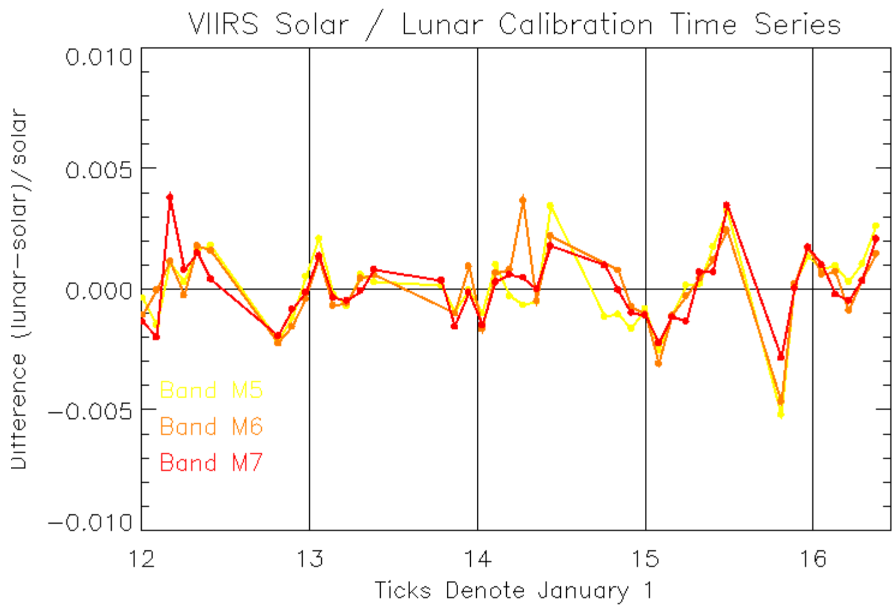



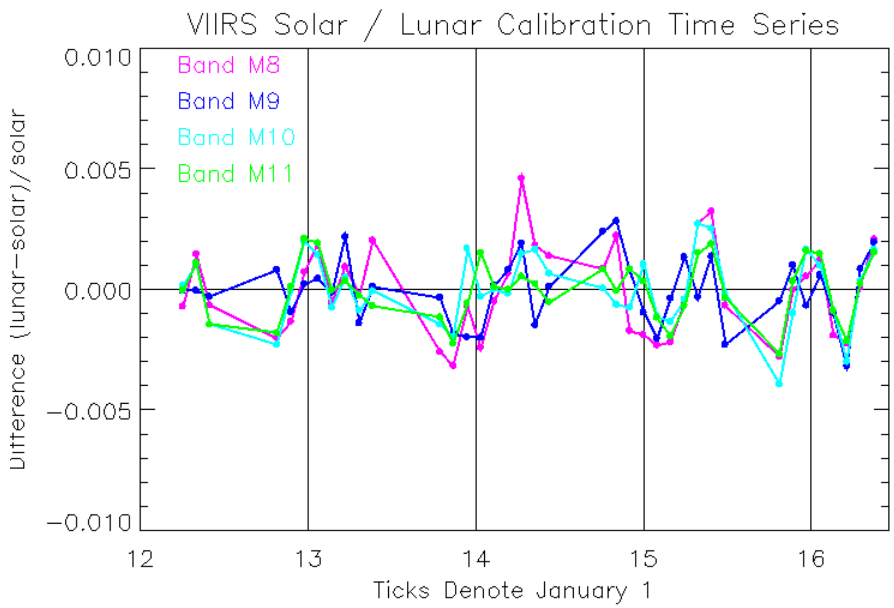



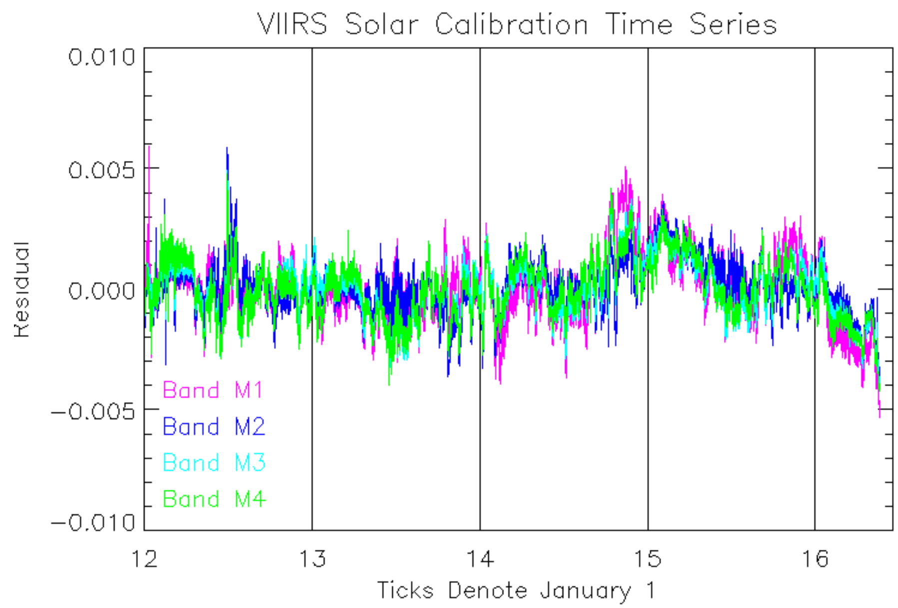
# Lunar / Adjusted Solar Time Series Differences

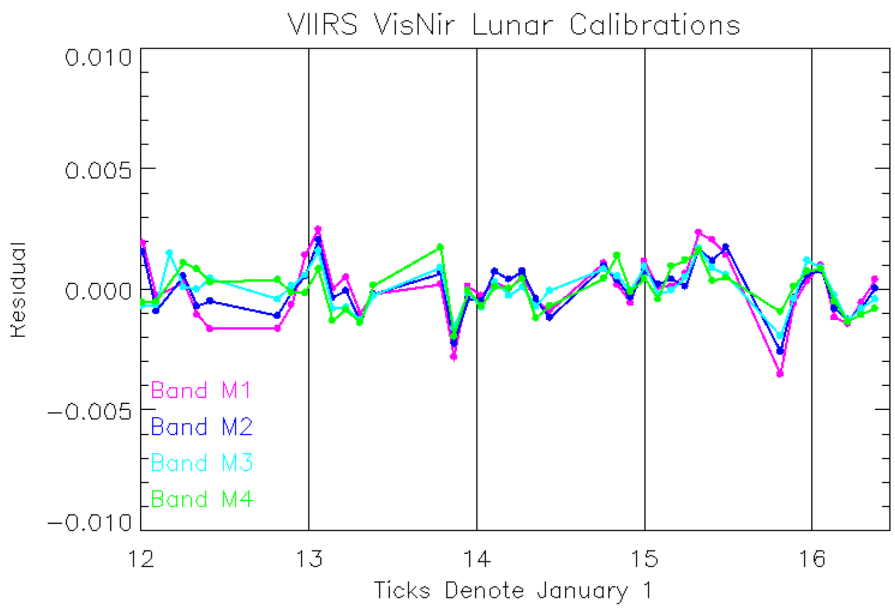


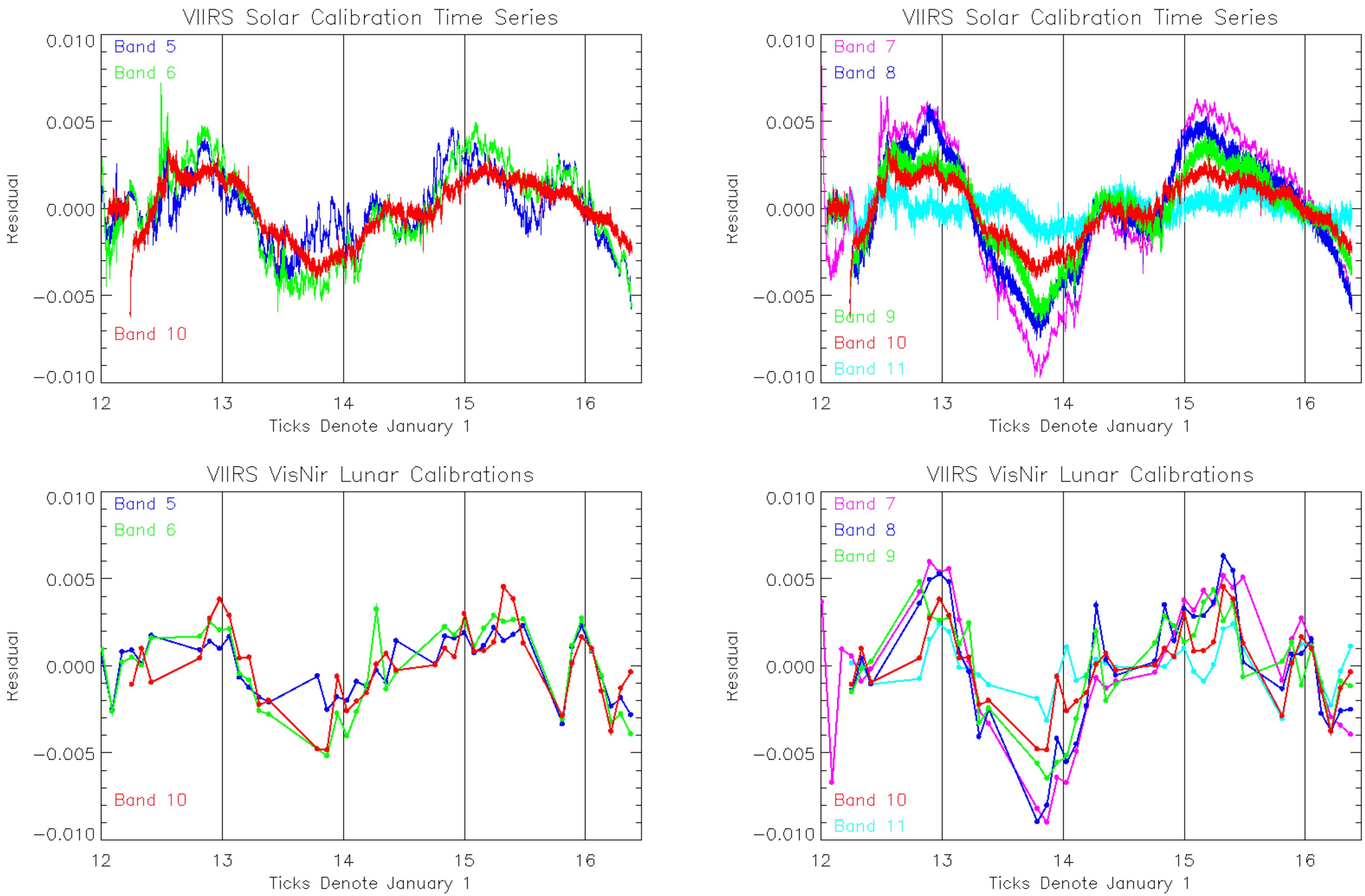



# Solar / Lunar Fit Residuals Bands M1-M4



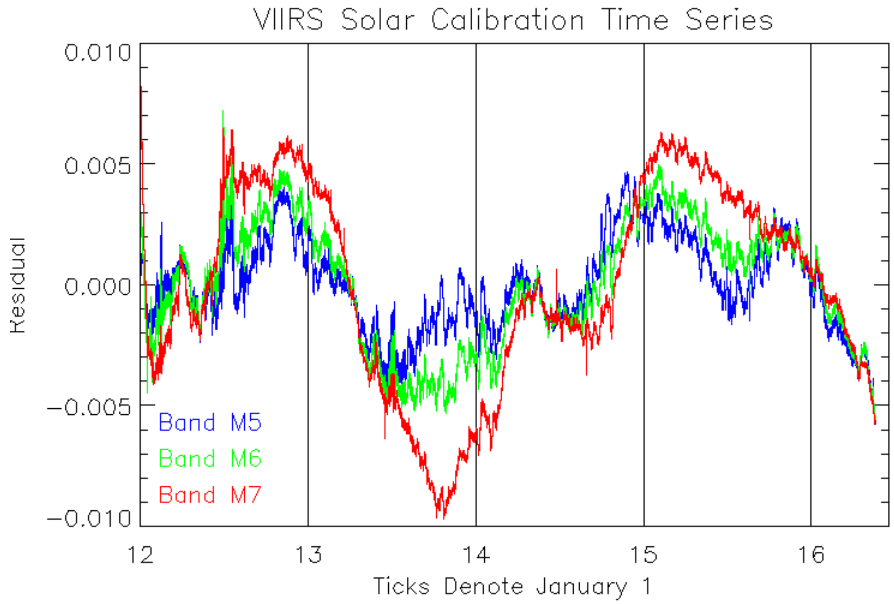
# Solar / Lunar Fit Residuals Bands M5-M11

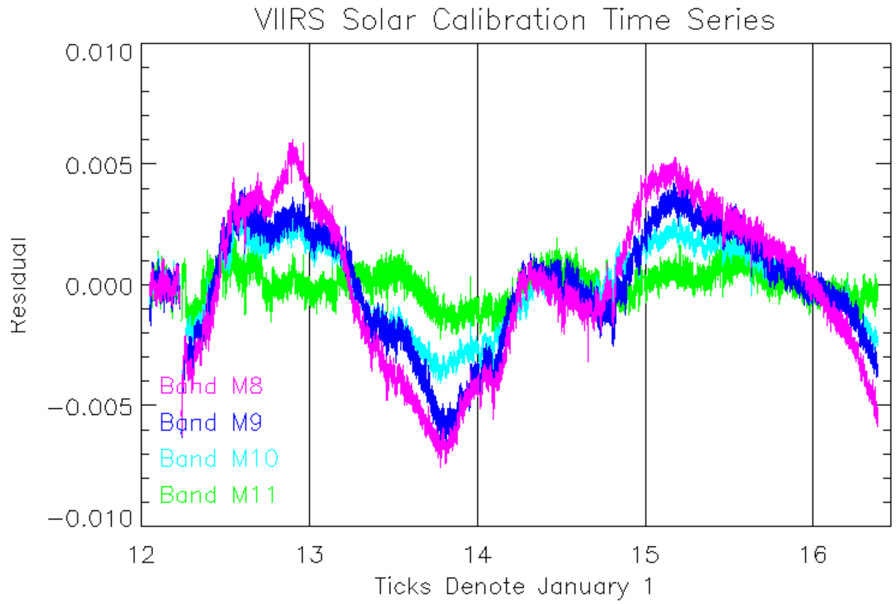


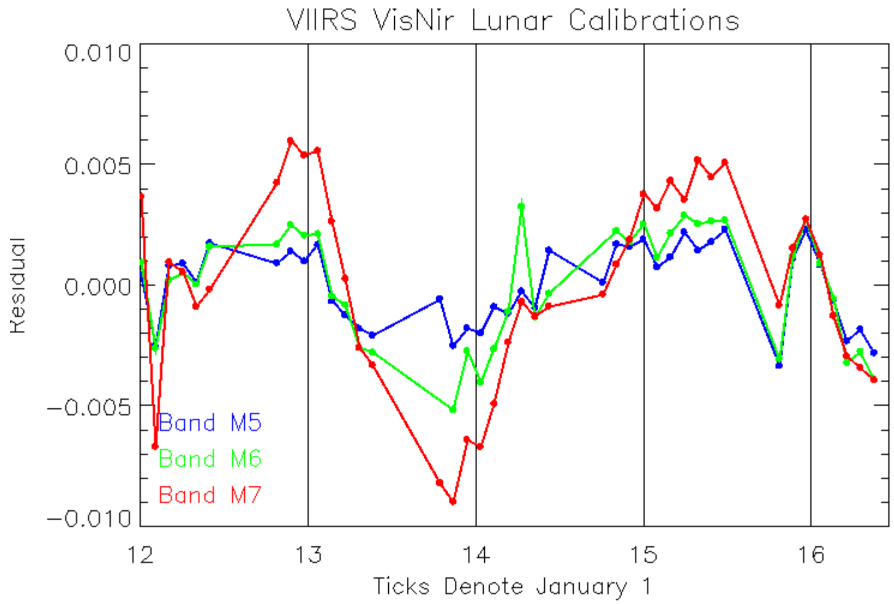
# OBPG SNPP VIIRS On-Orbit Calibration Summary

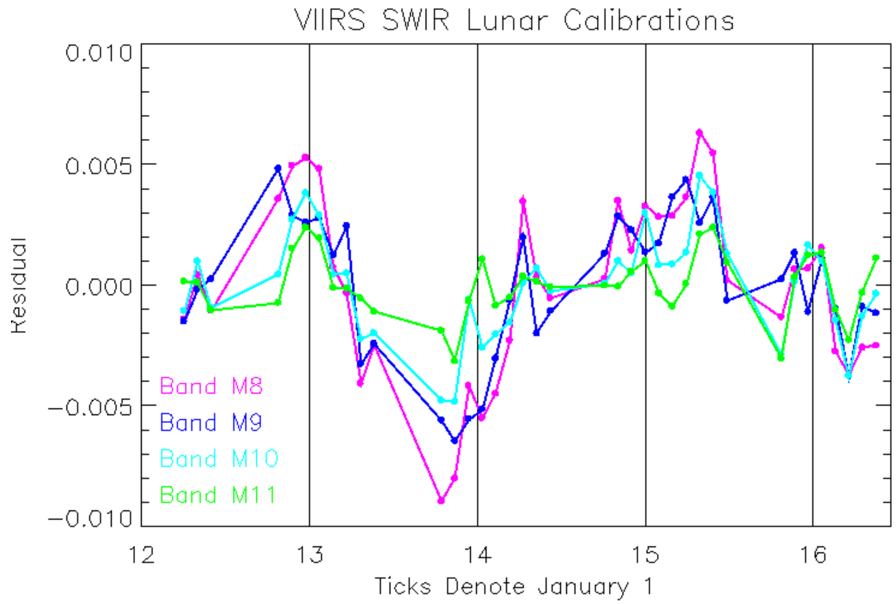
- Blue band (M1-M4) radiometric drift is primarily due to solar diffuser BRDF
  - Lunar / solar calibration comparison shows greatest differences in blue bands
  - Inadequacy of SDSM H-Factor BRDF Correction
  - Large lunar-derived solar trend adjustment
- Red band (M5-M11) radiometric drift is primarily due to Near-Infrared Degradation Anomaly of Rotating Telescope Assembly
  - Small lunar-derived solar trend adjustment
  - Radiometric artifacts in fit residuals appear in both solar and lunar time series
  - Artifacts have wavelength-dependent amplitude consistent with NIRDA
  - Radiometric artifacts have apparent periodicity
  - Current best ocean color data is achieved by fitting through periodic artifacts
- Lunar / Solar time series differences are comparable in magnitude to fit residuals

# Solar / Lunar Fit Residuals Bands M5-M11



# Update on MODIS De-Trending and X-Calibration Analysis

*A. Lyapustin,* Y. Wang, S. Korkin.

# MODIS De-trending and X-calibration

1. MCST: Trending Moon (1 angle) and Earth Targets (EV views - ***Deserts***) to get changing RVS;

2. OBPG - Polarization Correction: use Aqua L3 retrievals (as true) to compute expected TOA radiances for Terra view geometry (over open **Ocean**);

   Based on that, compute $M_{11}$, $m_{12}$, $m_{13}$;

$$L_m/M_{11} = L_t + m_{12}*Q + m_{13}*U$$

   $L_m$: measured TOA radiance (Terra)

   $L_t$: expected TOA radiance (from L3 Aqua)

   Q, U : linear Stokes vector components, modeled from Rayleigh and glint

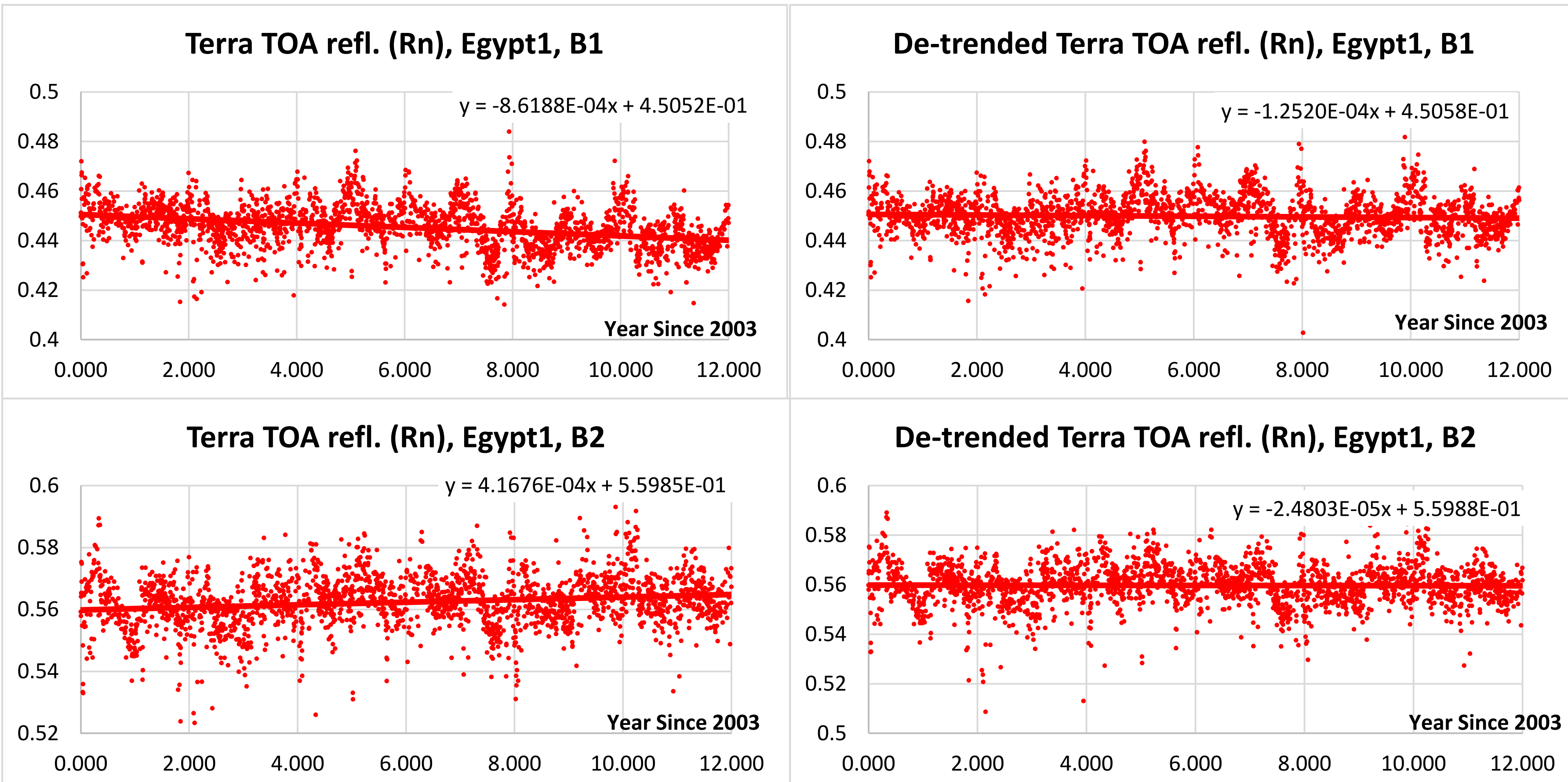
   $M_{11}$, $m_{12}$, $m_{13}$ : fitted instrument characterization parameters (depend on band, MS, detector, scan angle)

3. LWK: Apply PC and do residual de-trending and X-cal (gain adjustment).

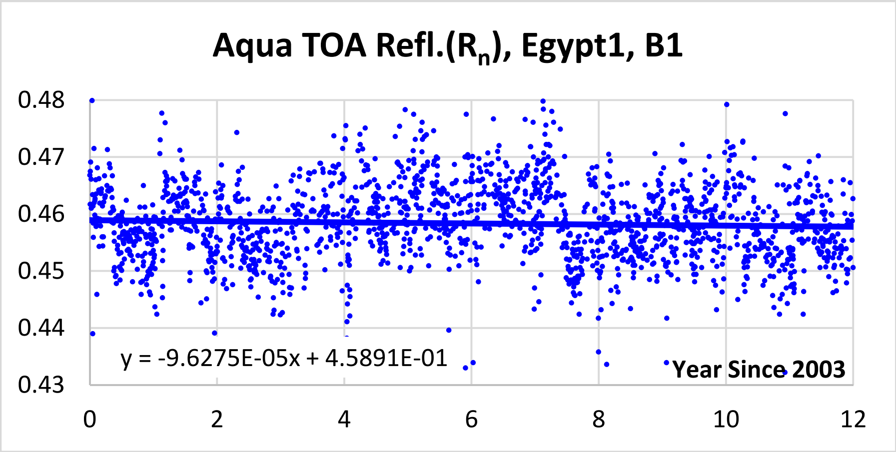
# MODIS de-trending

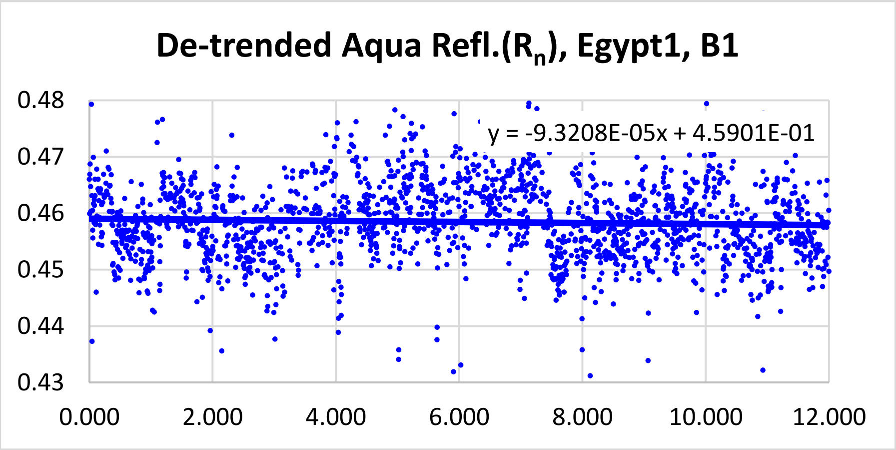
- New MCST RVS characterization for Aqua → new OBPG Terra Polarization Correction (PC) coefficients → MODAPS generated 50km L1B subsets for CEOS desert cal. sites;
- Method: a) run MAIAC retrievals (AOT, BRDF etc.); 2) compute TOA reflectance ($R_n$) for fixed geometry (VZA=0°, SZA=45°) and evaluate trends in both Terra and Aqua; 3) Apply de-trending and compute T-A X-calibration factor (gain correction for T)

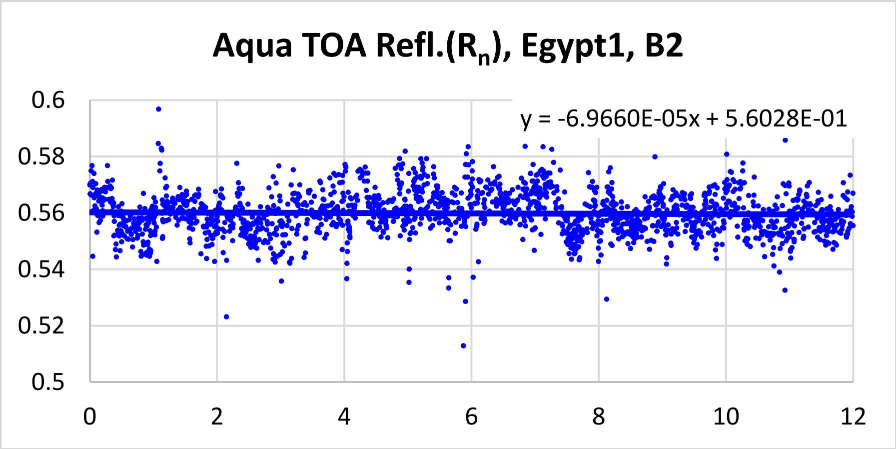
Lyapustin, A., Y. Wang, X. Xiong, G. Meister, S. Platnick, R. Levy et al, **Science Impact of MODIS C5 Calibration Degradation and C6+ Improvements**, *AMT*, 7, 7281-7319, 2014.

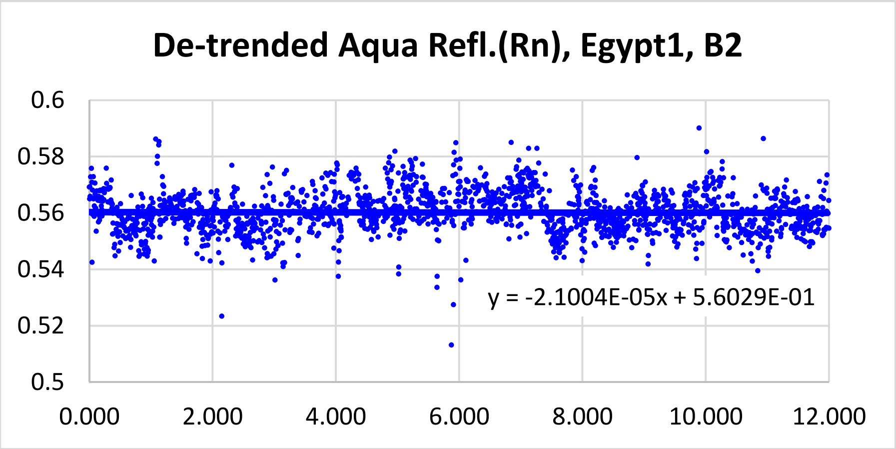


# MODIS de-trending (cont.)



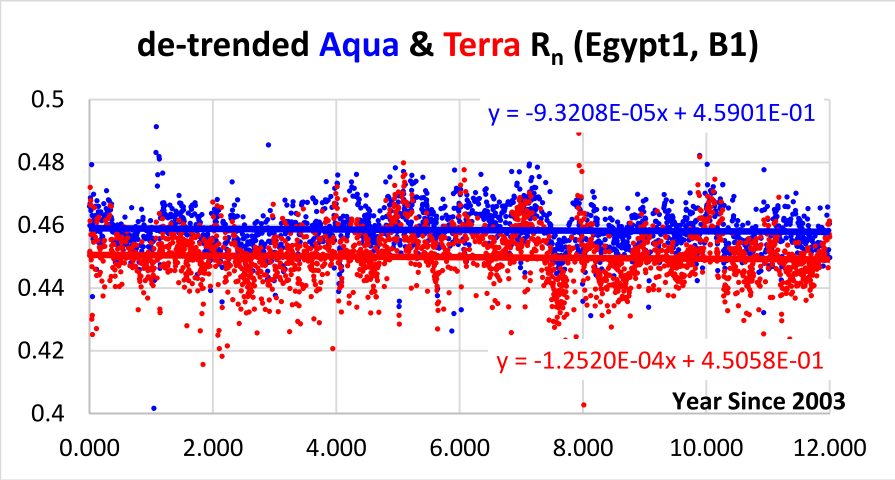



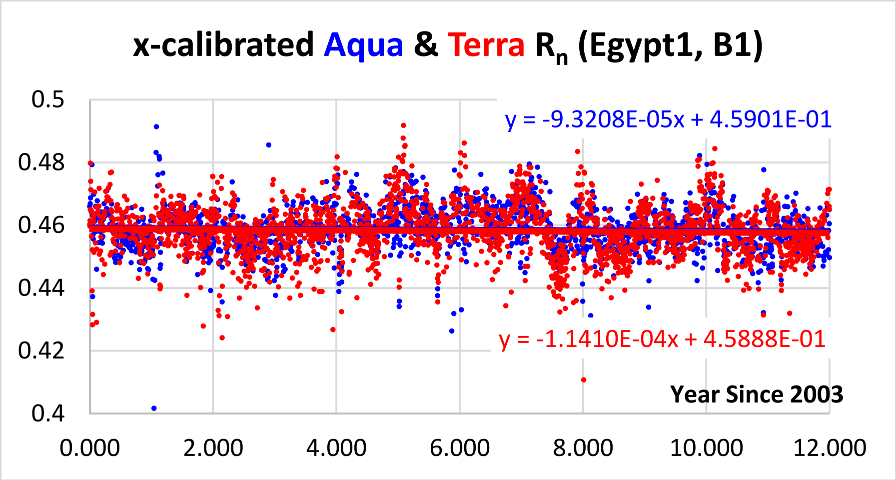



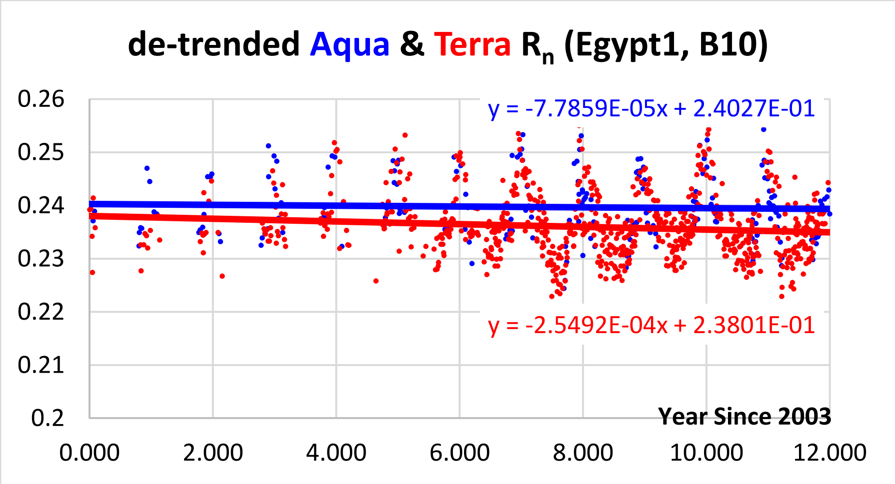



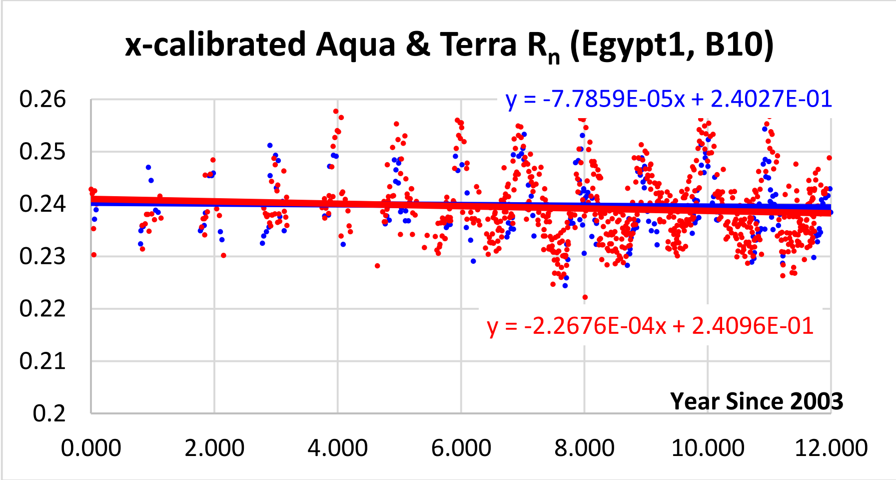
# MODIS X-calibration

After MCST RVS de-trending for Aqua, we see trend reduction (a factor of 12 in B1 and a factor of 2 in B3) compared to our previous analysis.



# Summary

*Average trend/year/unit_refl.*

| | $\Delta_{Terra}$ | $\sigma_{Terra}$ | $\Delta_{Aqua}$ | $\sigma_{Aqua}$ |
|---|---|---|---|---|
| **TOA_B01** | -1.6884E-03 | 2.6114E-04 | 1.5848E-06 | 3.9377E-04 |
| **TOA_B02** | 7.7780E-04 | 2.4303E-04 | -6.5120E-05 | 3.5583E-04 |
| **TOA_B03** | -8.8922E-04 | 4.5314E-04 | -3.1763E-04 | 2.8486E-04 |
| **TOA_B04** | -5.6629E-04 | 3.2829E-04 | -3.9831E-05 | 5.0202E-04 |
| **TOA_B05** | 1.9477E-04 | 3.3019E-04 | 4.5784E-06 | 3.3528E-04 |
| **TOA_B06** | -3.9516E-04 | 3.0211E-04 | -3.1194E-04 | 2.8191E-04 |
| **TOA_B07** | 2.0259E-04 | 2.4491E-04 | -5.8419E-04 | 3.2705E-04 |
| **TOA_B08** | -1.2627E-03 | 1.0018E-03 | -5.5178E-04 | 1.0915E-04 |
| **TOA_B09** | -3.9874E-04 | 5.2176E-04 | 1.3724E-04 | 2.1120E-04 |
| **TOA_B10** | -7.2800E-04 | 8.2601E-04 | -3.0632E-04 | 7.1498E-04 |

*Average X-gain for Terra*

| | Average | Stdev |
|---|---|---|
| **TOA_B01** | 1.018776 | 0.000949 |
| **TOA_B02** | 1.000523 | 0.001054 |
| **TOA_B03** | 0.989436 | 0.001268 |
| **TOA_B04** | 1.00109 | 0.001448 |
| **TOA_B05** | 0.98862 | 0.001855 |
| **TOA_B06** | 0.997128 | 0.000898 |
| **TOA_B07** | 0.999368 | 0.000373 |
| **TOA_B08** | 1.003774 | 0.000948 |
| **TOA_B09** | 1.0014 | 0.001488 |
| **TOA_B10** | 1.014141 | 0.002077 |

## Conclusions

- Largest residual trends in Terra B1 and B8 (>0.01 per decade);
- Largest Terra gain adjustment in B1 (~2%);
- Expanded analysis and added B5-B7 and B9-B10 (unsaturated).

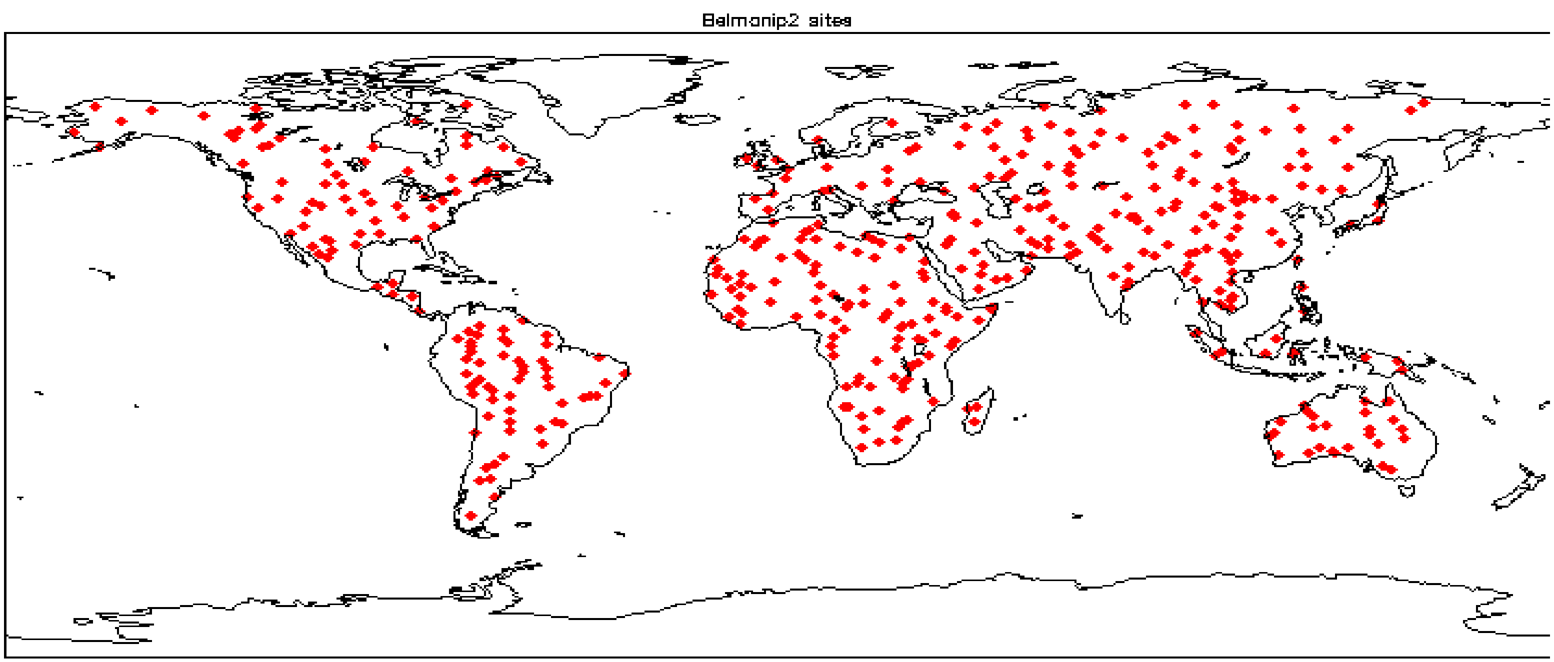
# Cross-Calibration of Aqua/Terra with VIIRS over BELMANIP2 site

Eric Vermote NASA/GSFC 619

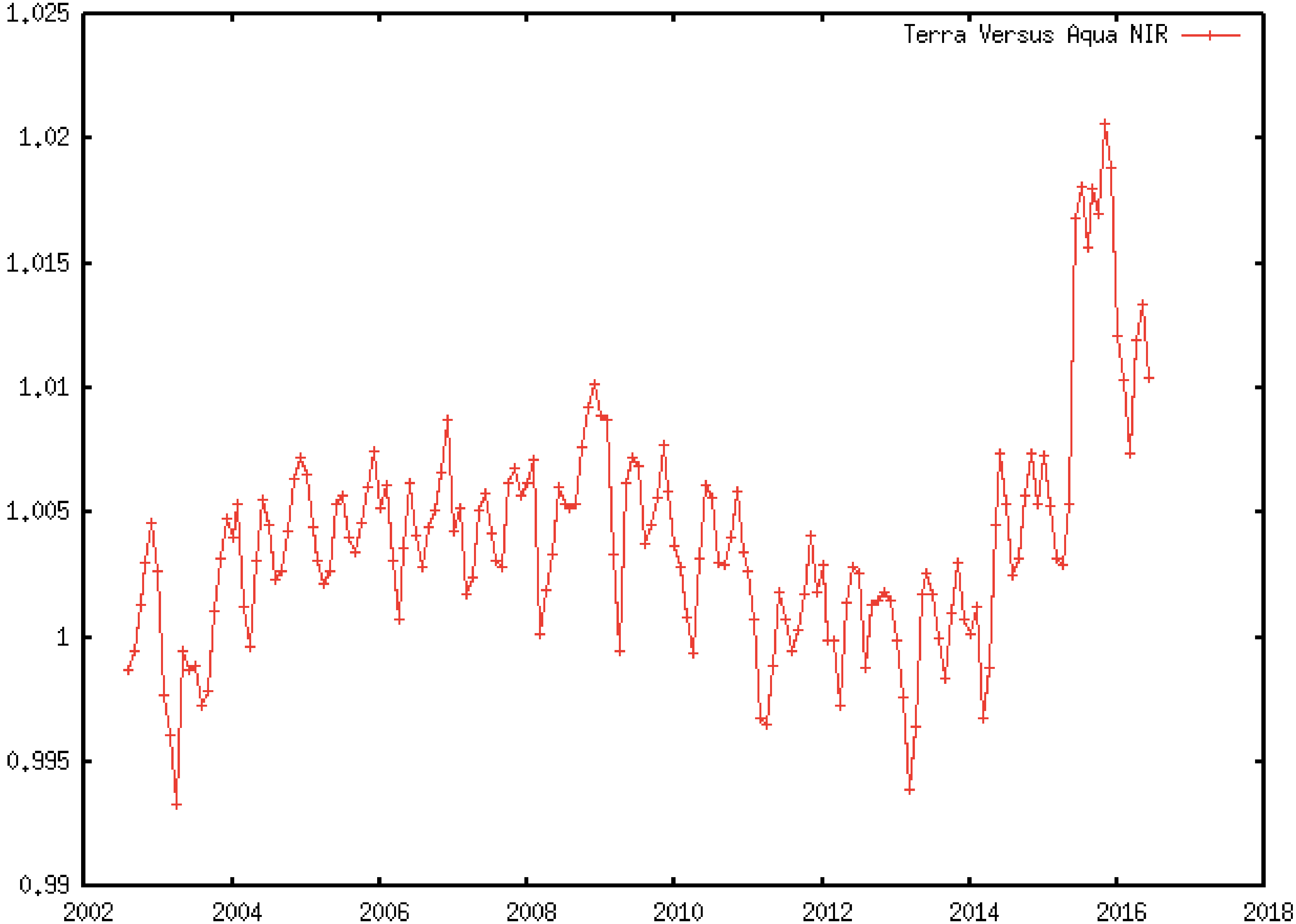
eric.f.vermote@nasa.gov

# Method

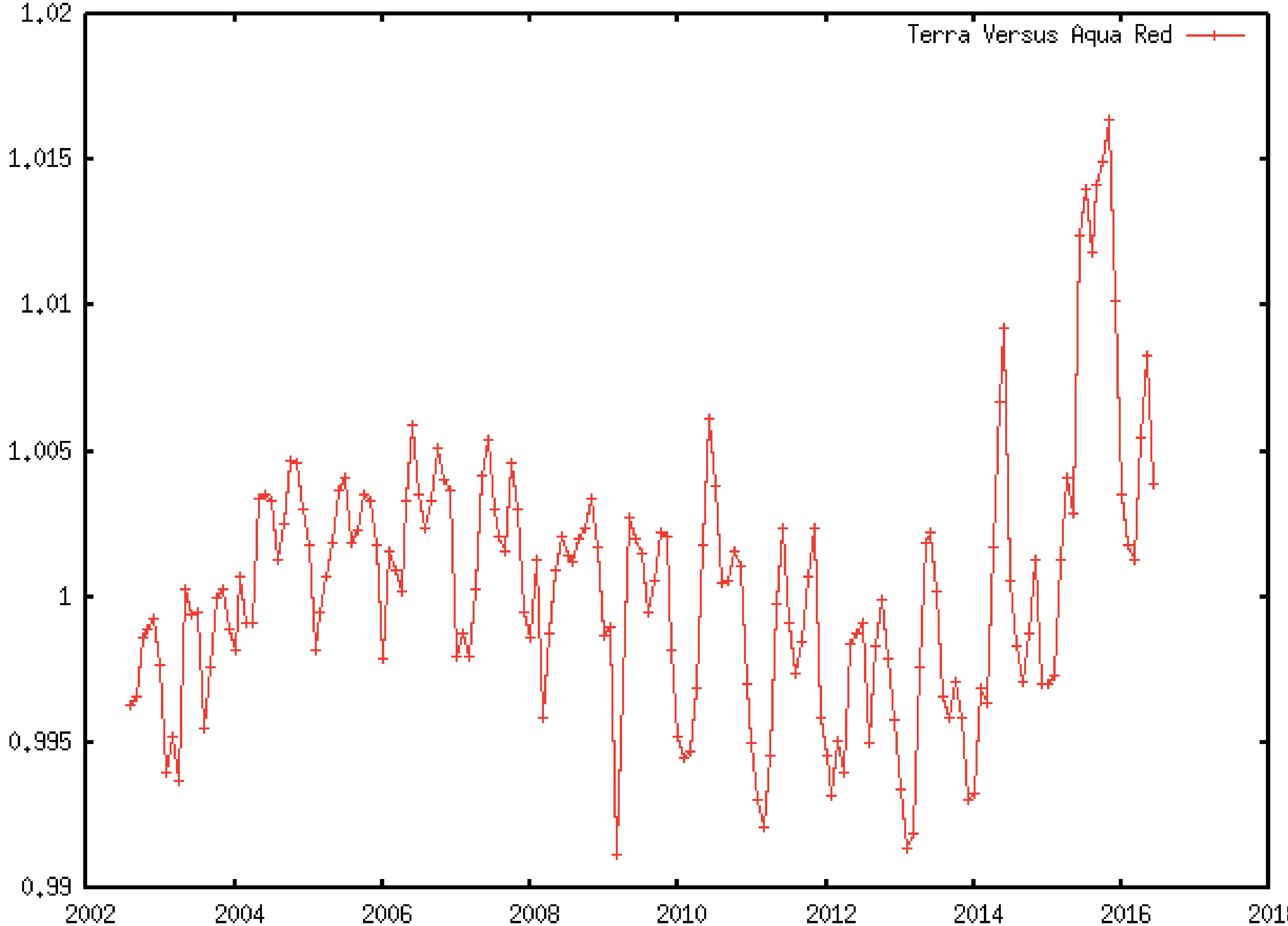
- Using quality screened surface reflectance products corrected for directional effects, cross comparison between sensors is achieved on a monthly basis over 445 globally distributed. In the following slides Aqua and Terra are compared to VIIRS. AS6 is the collection 6 reprocessing, AS 1387 is the new Aqua lookup table, with Alexei polarization correction with de-trending applied/ and no de-trending applied.



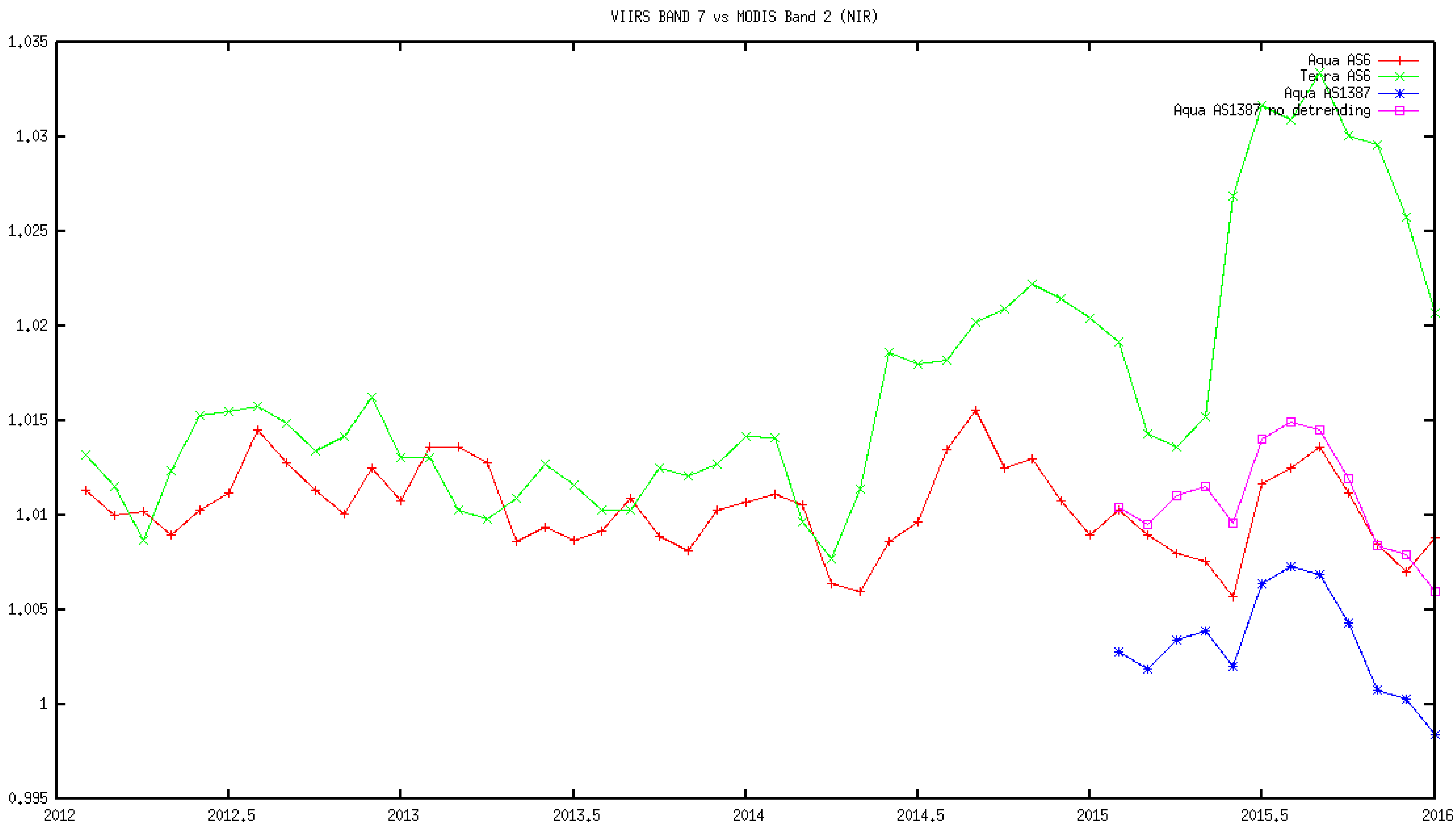
# Terra/Aqua NIR Collection 6



# Terra/Aqua Red Collection 6

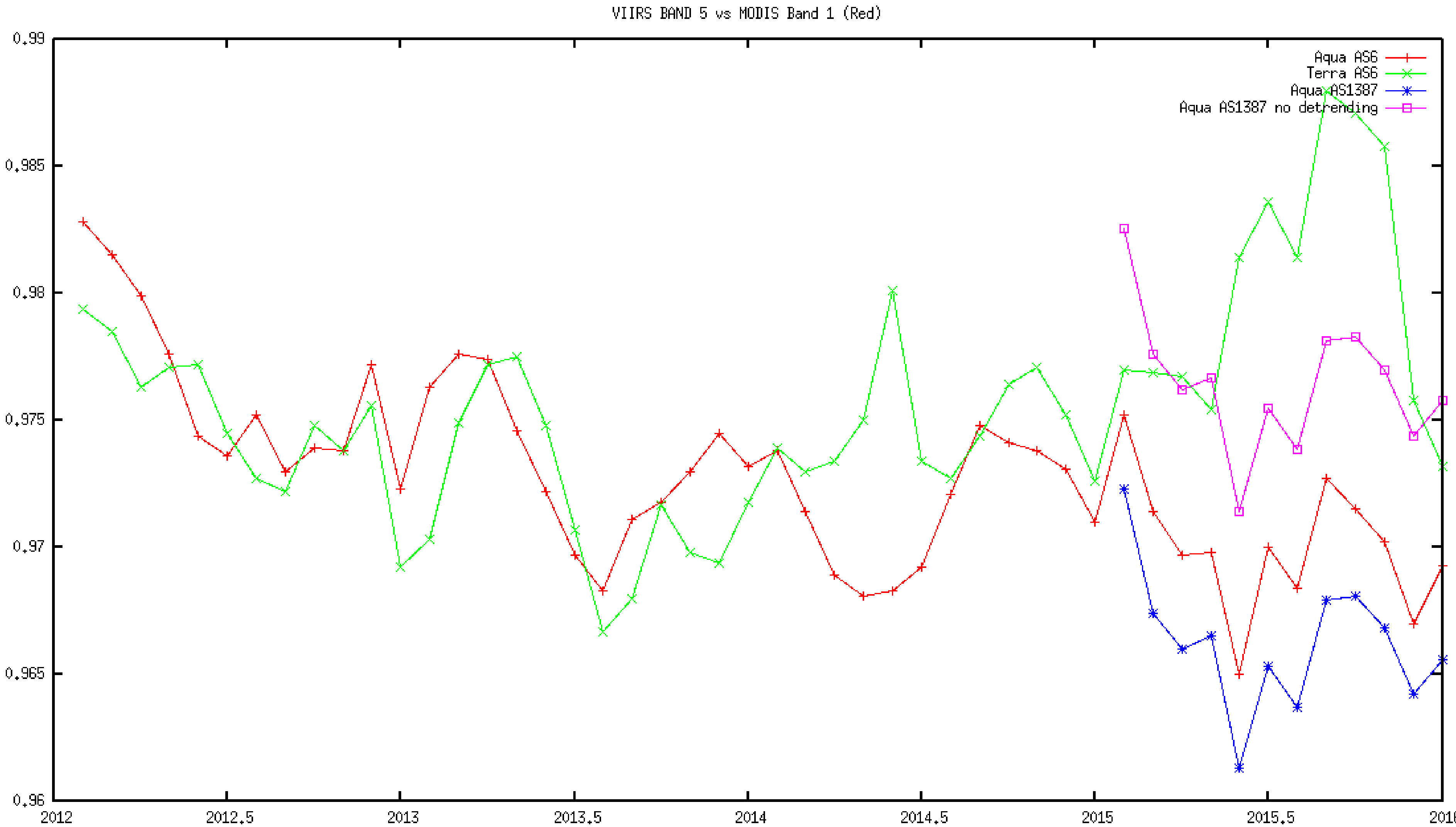


# Results NIR



VIIRS BAND 7 vs MODIS Band 2 (NIR)
Aqua AS6
Terra AS6
Aqua AS1387
Aqua AS1387 no detrending
1.035
1.03
1.025
1.02
1.015
1.01
1.005
1
0.995
2012
2012.5
2013
2013.5
2014
2014.5
2015
2015.5
2016

# Results Red


VIIRS BAND 5 vs MODIS Band 1 (Red)
Aqua AS6
Terra AS6
Aqua AS1387
Aqua AS1387 no detrending
0.99
0.985
0.98
0.975
0.97
0.965
0.96
2012
2012.5
2013
2013.5
2014
2014.5
2015
2015.5
2016

# Conclusions

- Good news for Aqua where both bands are stable when compared to VIIRS with the new look up table and no de-trending applied, that is what we were expecting.
- Terra shows unstable behavior in the NIR starting around 2015 with a marked drifted (~2%) and substantial yearly oscillations, the red band also show a drift in 2016 (~1%)
- Cross-comparison is optimal in NIR, maybe other data (clouds) needs to be analyzed to further assess the red channel.

# MODIS/VIIRS Items

Chris Moeller
Univ. Wisconsin
MODIS/VIIRS Calibration Workshop
June 6, 2016

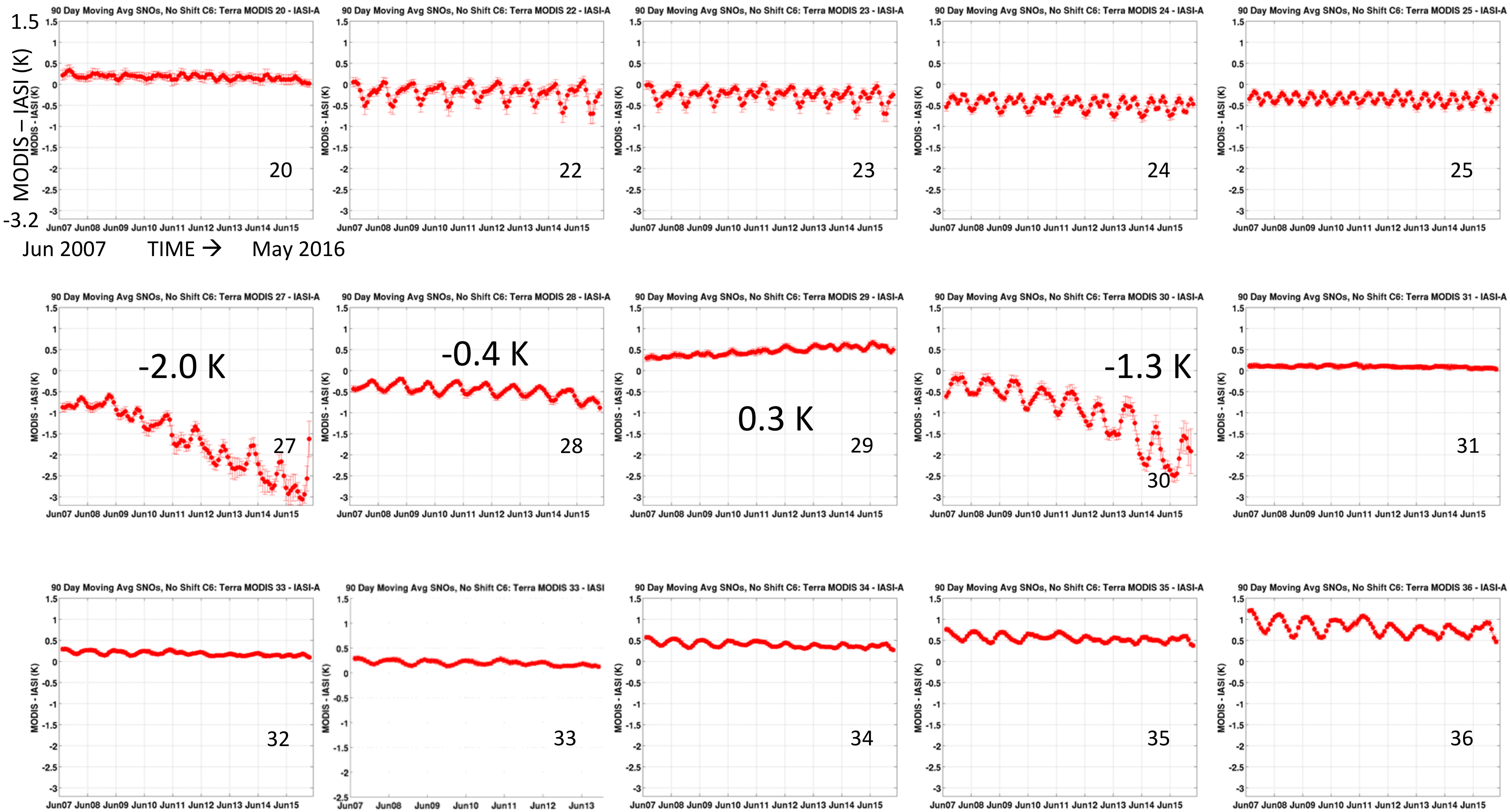
# Topics

- PVLWIR crosstalk impact on L1B
- JPSS-1 RSR Versions

# Terra MODIS – MetOpA IASI Long Term Trends

## (SNOs from June 2007 – May 2016; Collect 6)

**Long term trends very small except bands 27 - 30**

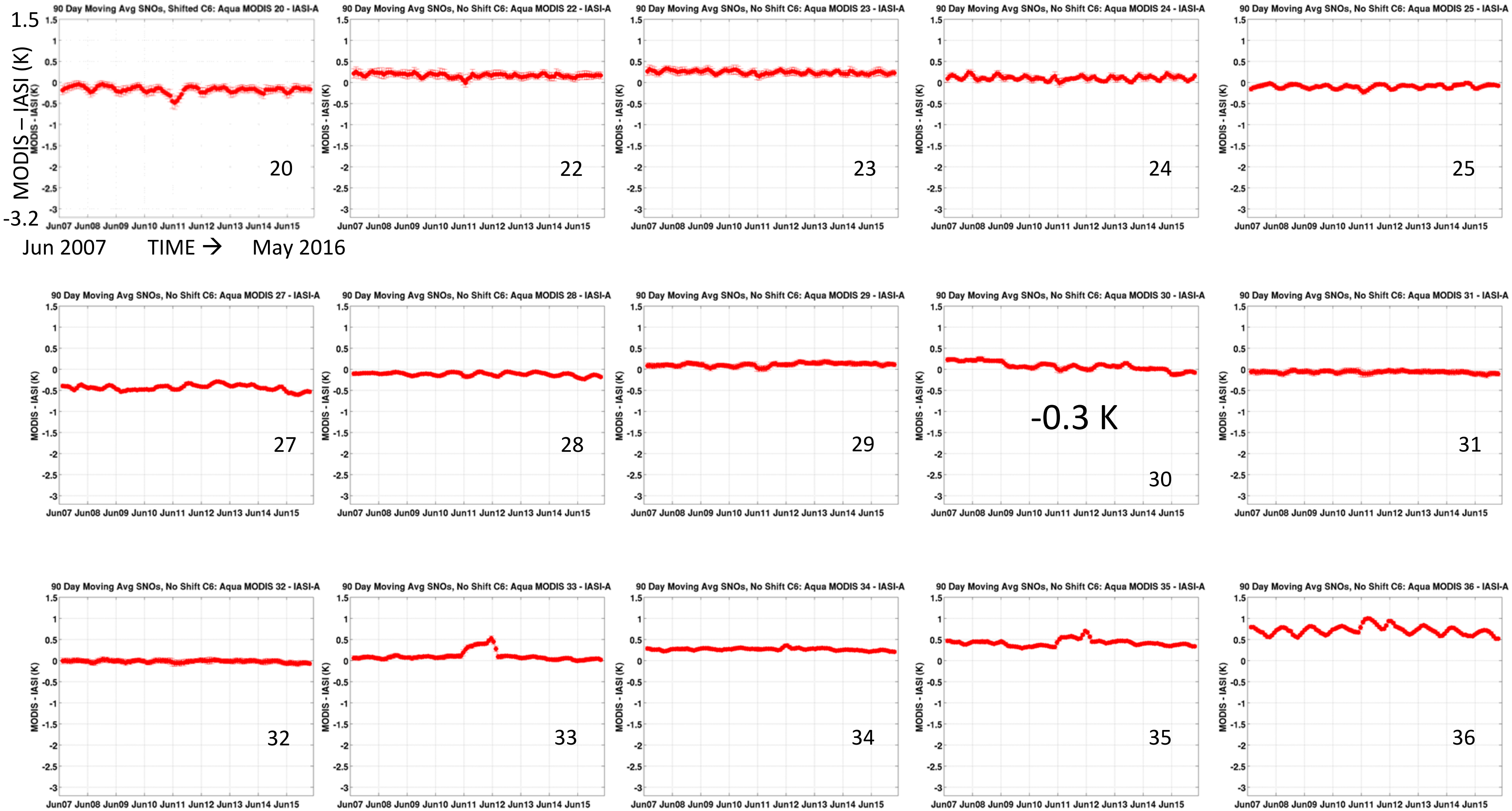



90 Day Moving Window Average Computed at 30 Day Interval

# Aqua MODIS – MetOpA IASI Long Term Trends

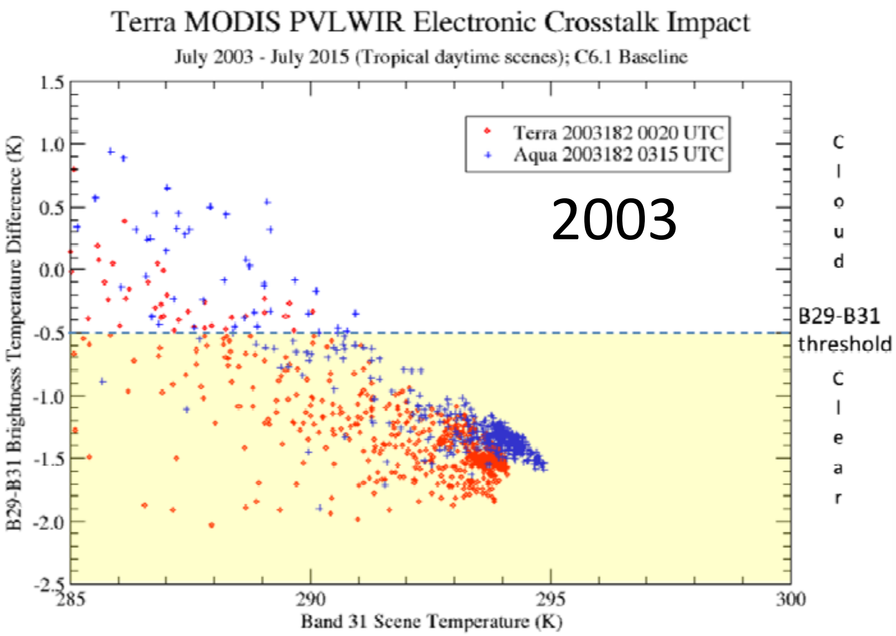
## (SNOs from June 2007 – May 2016; Collect 6)

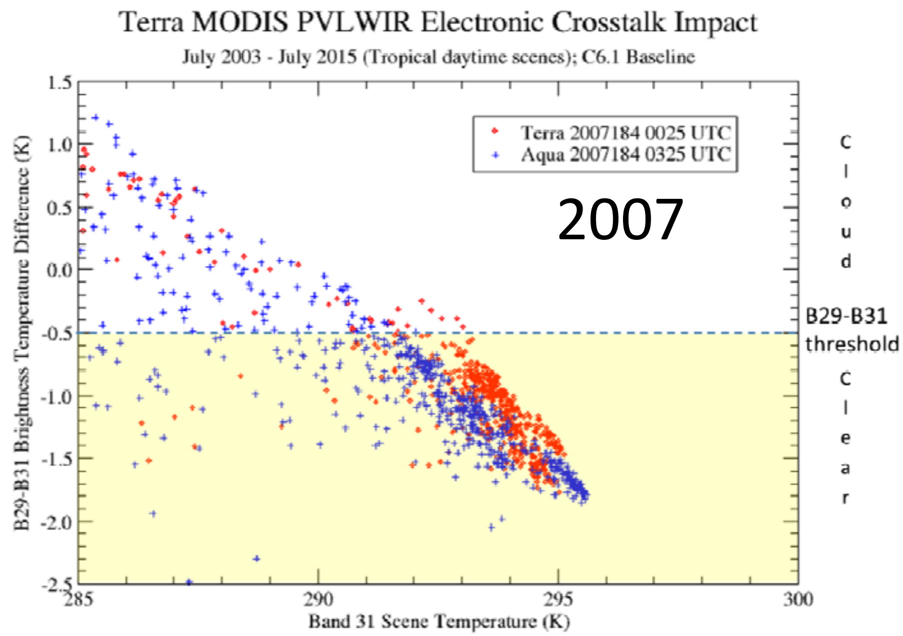
**Long term trends very small except band 30**

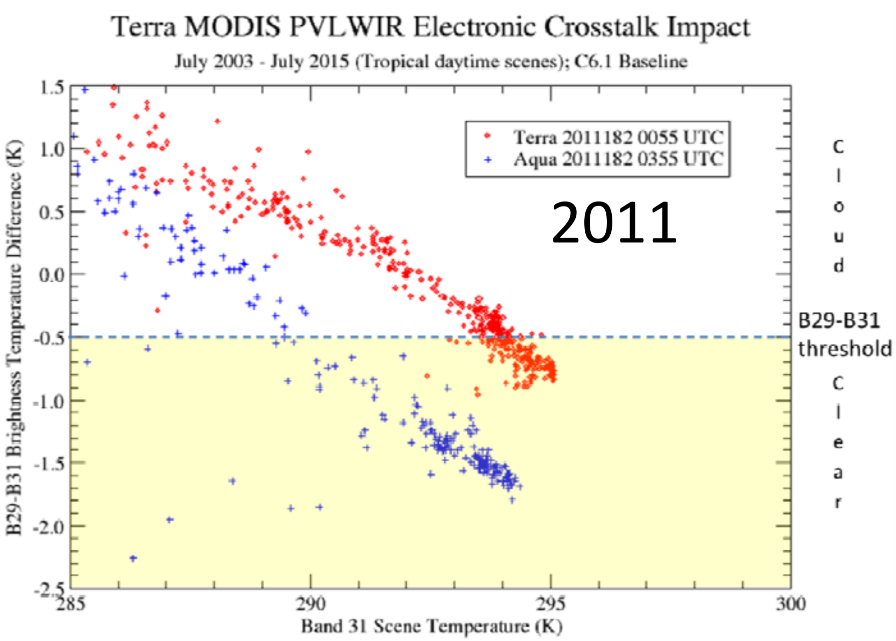


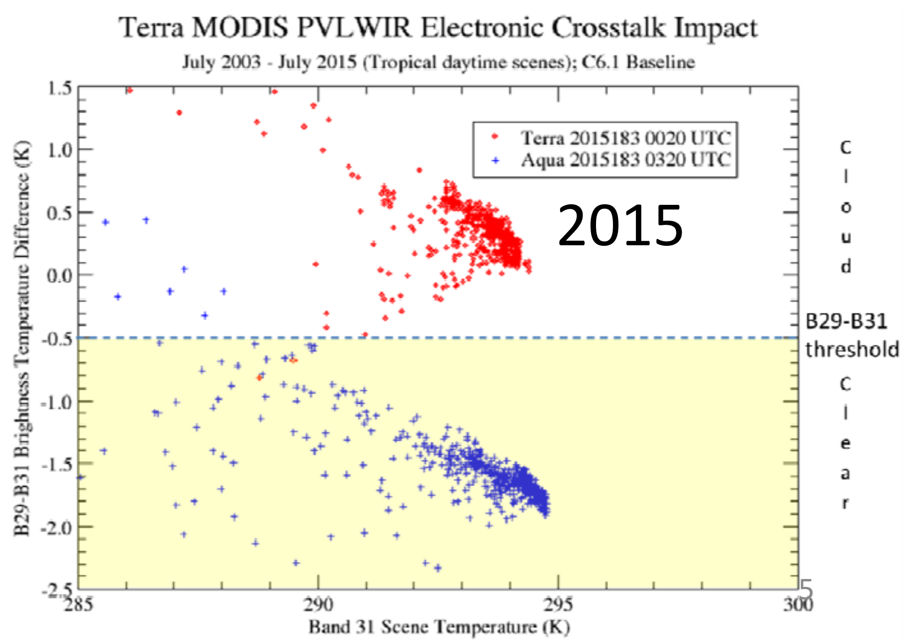

90 Day Moving Window Average Computed at 30 Day Interval

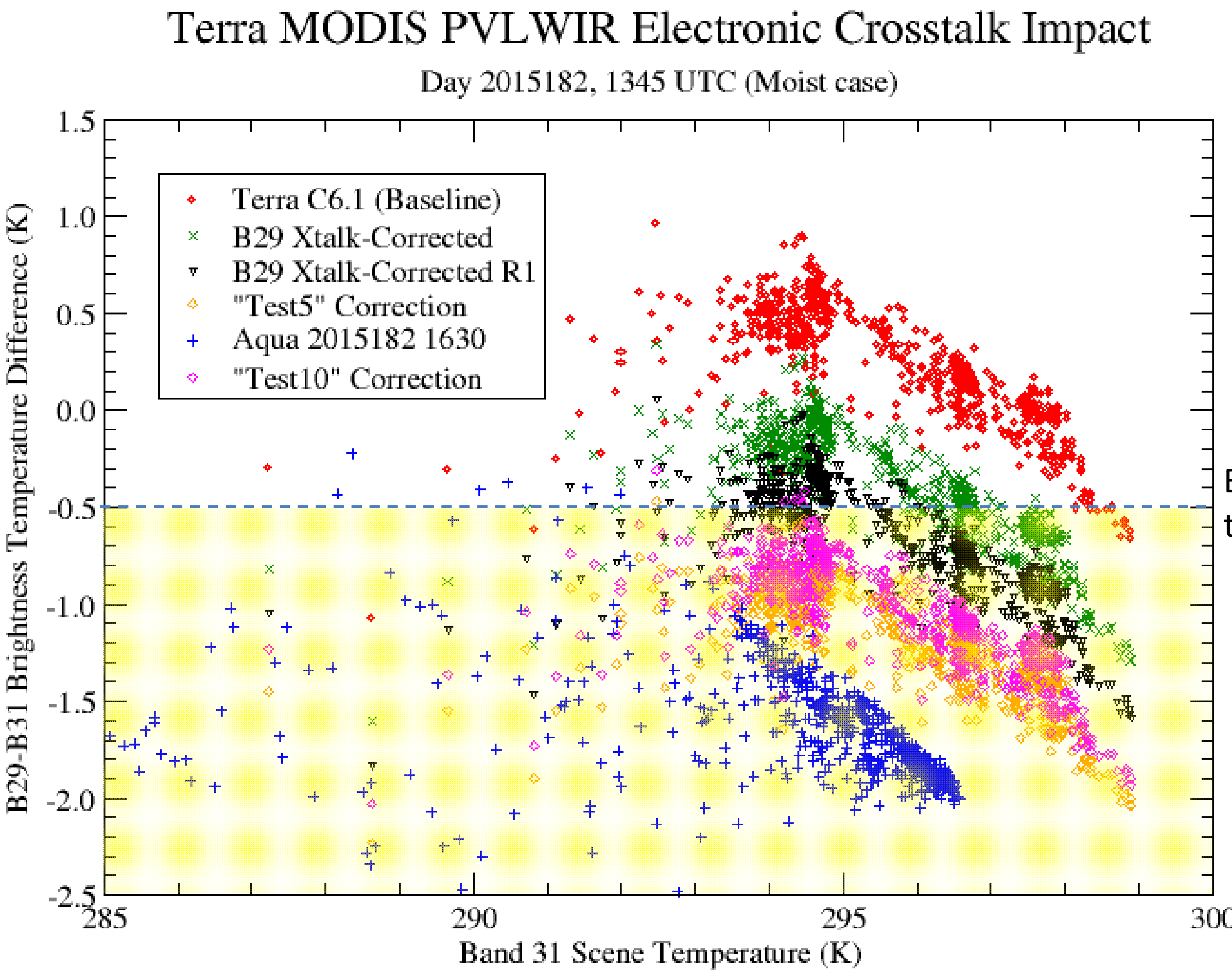
# MODIS PVLWIR Crosstalk Impact



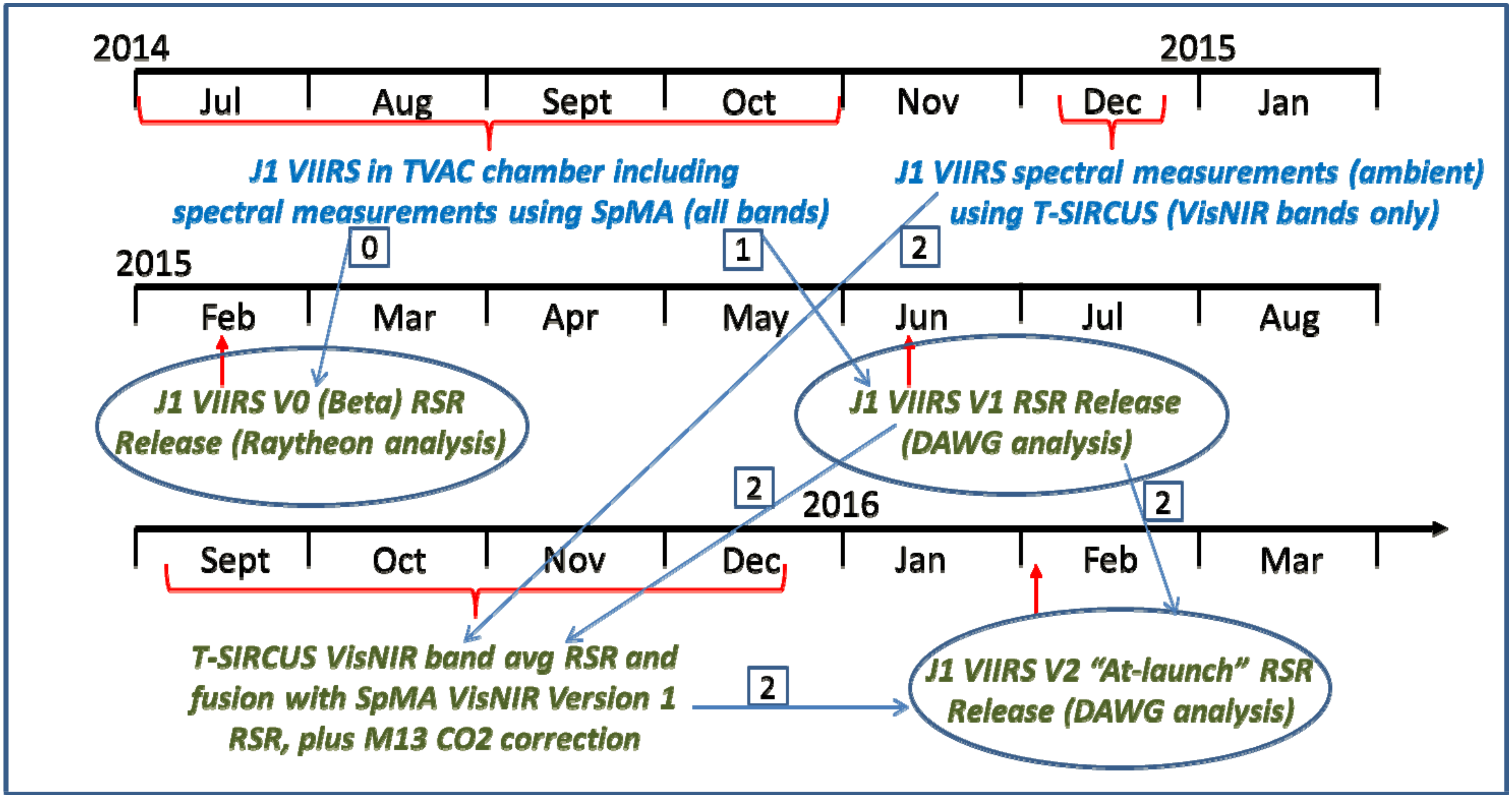


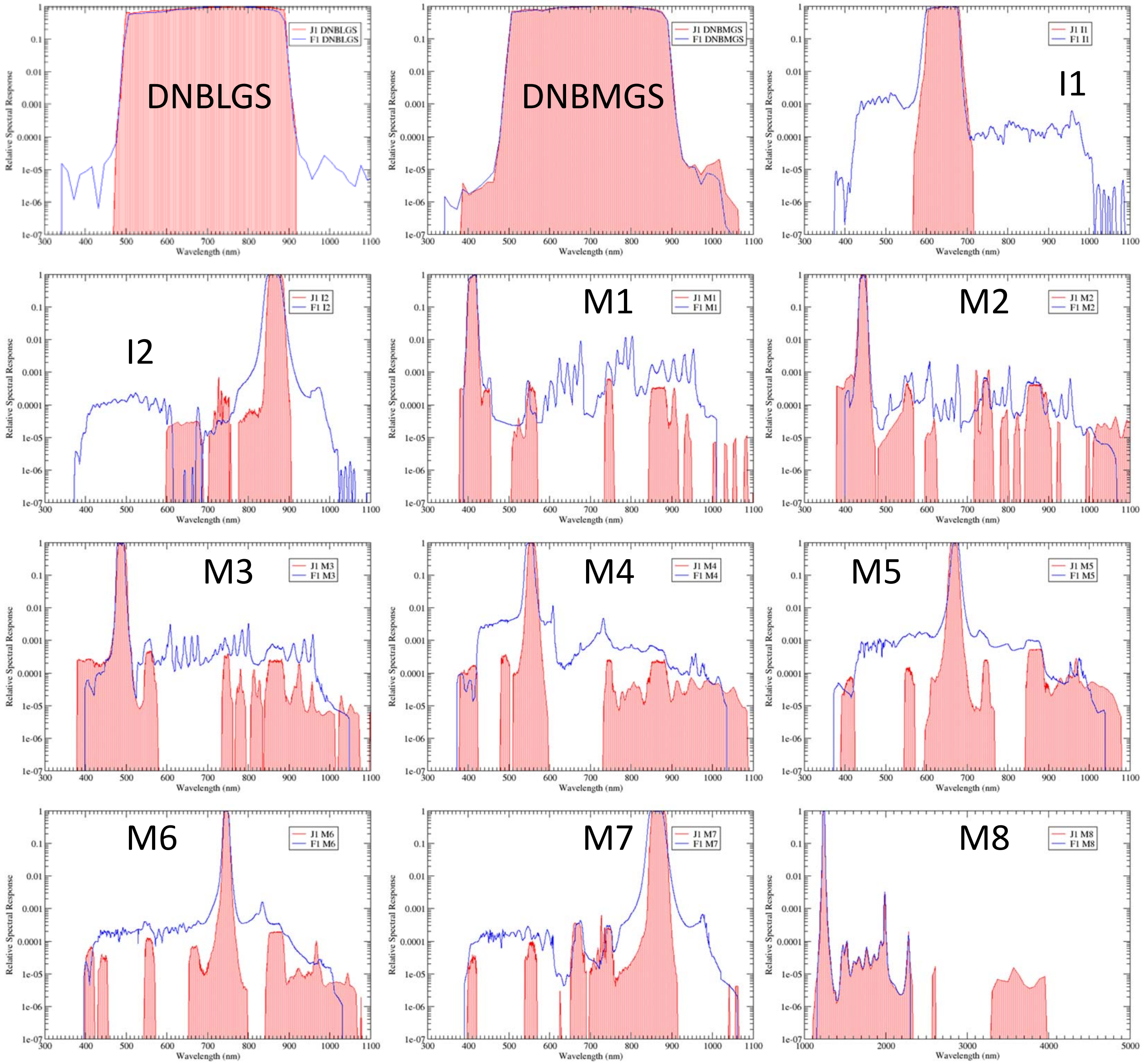

Cloud

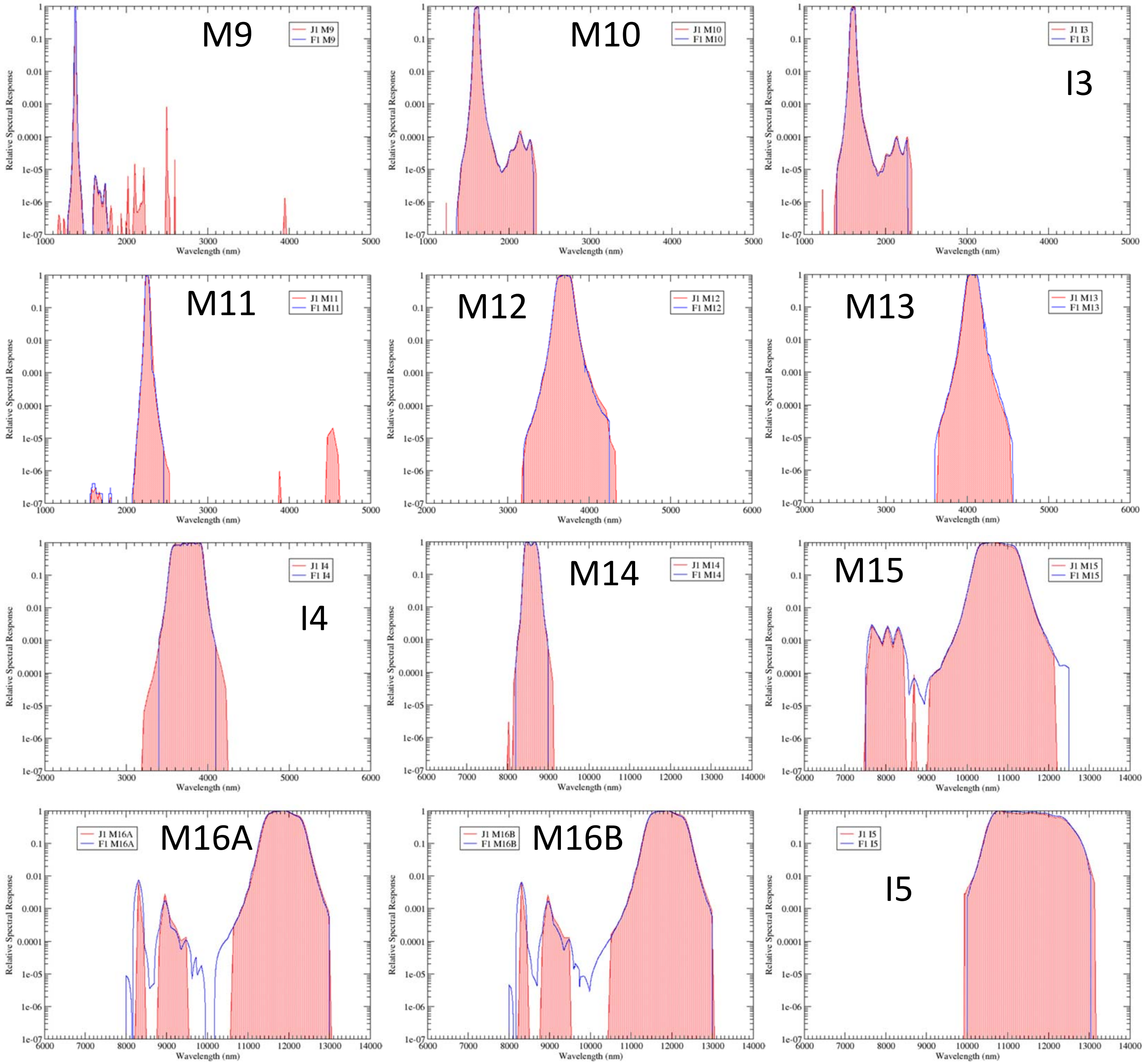
B29-B31 threshold

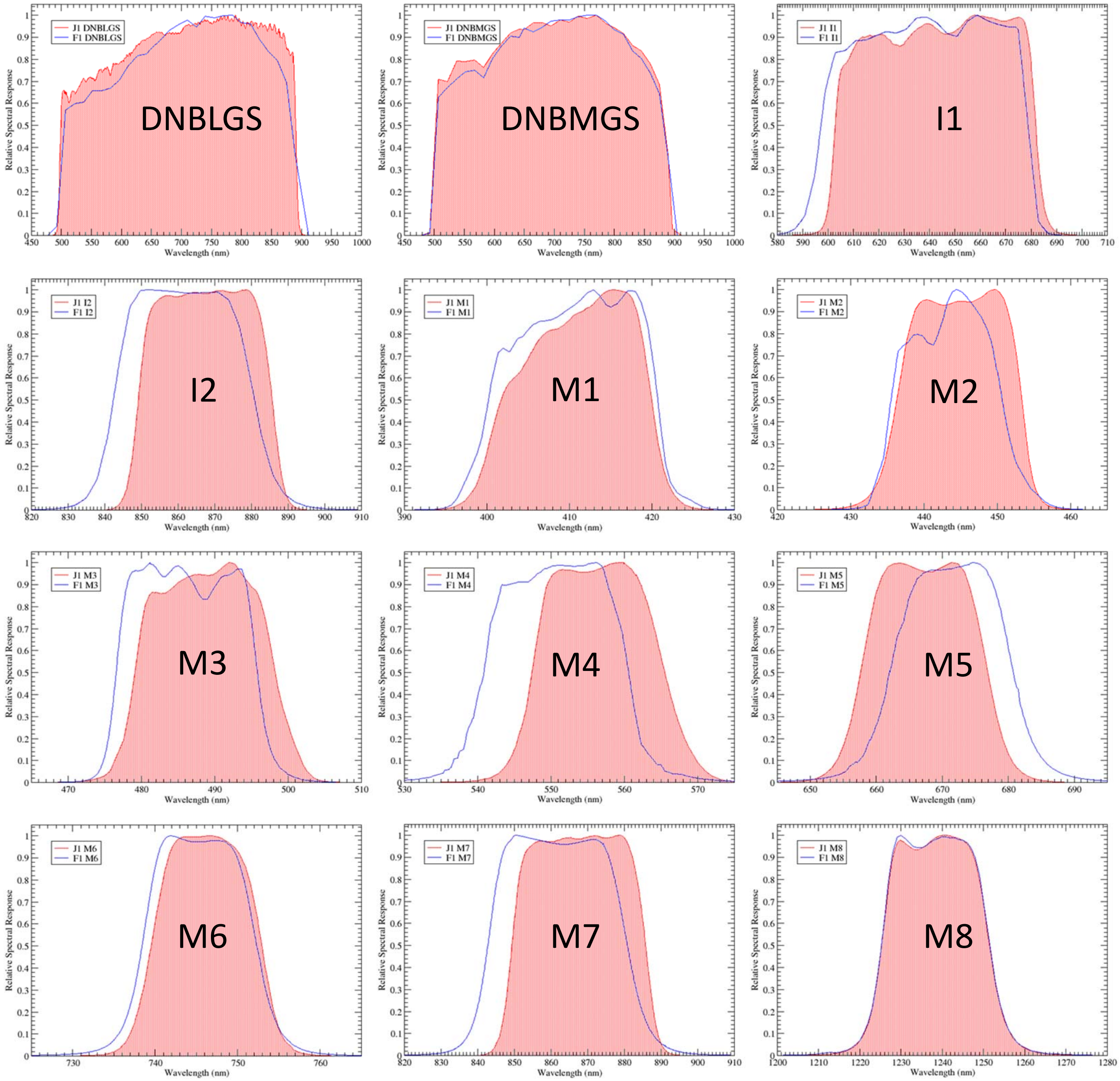
Clear

# JPSS-1 VIIRS RSR Version History




DNBLGS
J1 DNBLGS
F1 DNBLGS
DNBMGS
J1 DNBMGS
F1 DNBMGS
I1
J1 I1
F1 I1
I2
J1 I2
F1 I2
M1
J1 M1
F1 M1
M2
J1 M2
F1 M2
M3
J1 M3
F1 M3
M4
J1 M4
F1 M4
M5
J1 M5
F1 M5
M6
J1 M6
F1 M6
M7
J1 M7
F1 M7
M8
J1 M8
F1 M8
Relative Spectral Response
Wavelength (nm)


M9
J1 M9
F1 M9
M10
J1 M10
F1 M10
I3
J1 I3
F1 I3
M11
J1 M11
F1 M11
M12
J1 M12
F1 M12
M13
J1 M13
F1 M13
I4
J1 I4
F1 I4
M14
J1 M14
F1 M14
M15
J1 M15
F1 M15
M16A
J1 M16A
F1 M16A
M16B
J1 M16B
F1 M16B
I5
J1 I5
F1 I5
Relative Spectral Response
Wavelength (nm)


DNBLGS
J1 DNBLGS
F1 DNBLGS
DNBMGS
J1 DNBMGS
F1 DNBMGS
I1
J1 I1
F1 I1
I2
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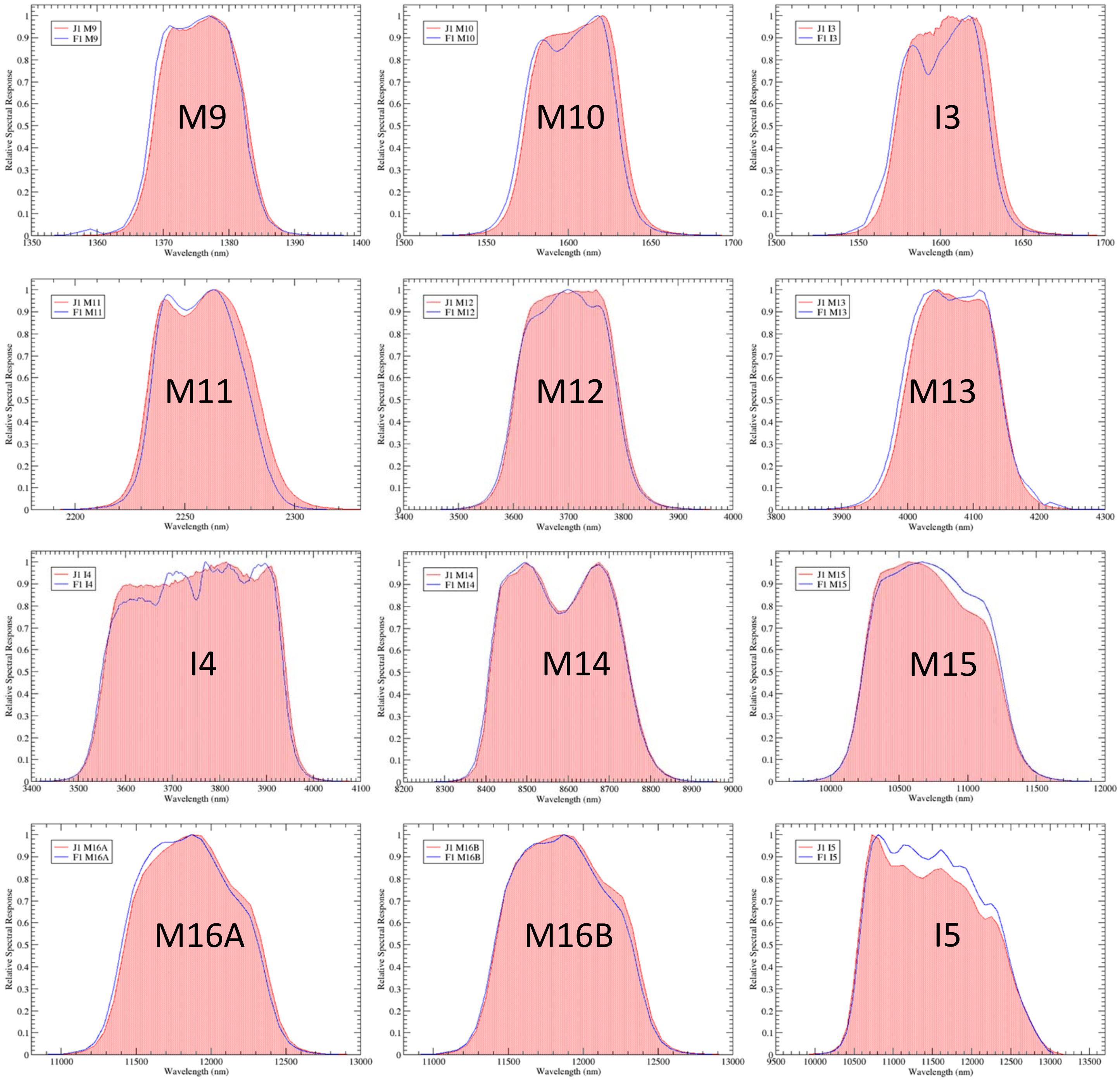
F1 I2
M1
J1 M1
F1 M1
M2
J1 M2
F1 M2
M3
J1 M3
F1 M3
M4
J1 M4
F1 M4
M5
J1 M5
F1 M5
M6
J1 M6
F1 M6
M7
J1 M7
F1 M7
M8
J1 M8
F1 M8
Relative Spectral Response
Wavelength (nm)


J1 M9
F1 M9
M9
J1 M10
F1 M10
M10
J1 I3
F1 I3
I3
J1 M11
F1 M11
M11
J1 M12
F1 M12
M12
J1 M13
F1 M13
M13
J1 I4
F1 I4
I4
J1 M14
F1 M14
M14
J1 M15
F1 M15
M15
J1 M16A
F1 M16A
M16A
J1 M16B
F1 M16B
M16B
J1 I5
F1 I5
I5
Relative Spectral Response
Wavelength (nm)

# Take-Away

- Assessment of MODIS PVLWIR crosstalk impact on L1B is ongoing. Wisconsin encouraged by progress in B29 correction algorithm.
- JPSS-1 VIIRS Version 2 RSR are available at: http://ncc.nesdis.noaa.gov/J1VIIRS/J1VIIRSSpectralResponseFunctions.php


# MODIS and VIIRS Lunar Image Quantitative Analysis — An Update

Thomas C. Stone
U.S. Geological Survey, Flagstaff, Arizona

MODIS/VIIRS Science Team Meeting
Silver Spring, MD
06–10 June 2016

# Brief Background

An explanation of the USGS lunar calibration system was presented at last year's MODIS/VIIRS Calibration Workshop.

Radiometric calibration using the Moon involves comparisons of lunar brightness measurements from images against reference values generated specifically for the instrument's acquisitions of the Moon.

The USGS system works with the spatially integrated quantity of lunar spectral irradiance.

Irradiance measurement from Moon images involves spatial integration of radiance pixels:

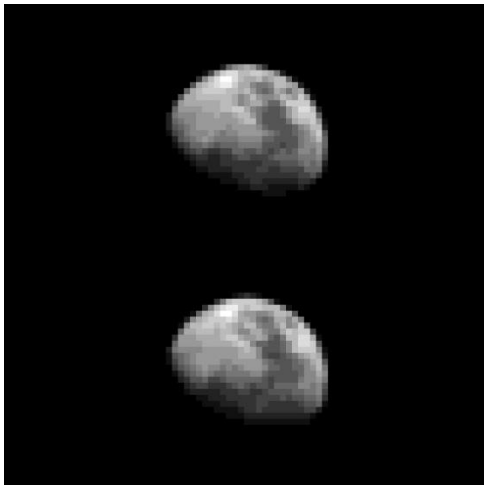
$$I = \Omega_{\mathrm{p}} \sum_{i=1}^{N_{\mathrm{p}}} L_i$$

$L_i$ = pixel radiance
$\Omega_{\mathrm{p}}$ = pixel solid angle
$N_{\mathrm{p}}$ = # of pixels on Moon

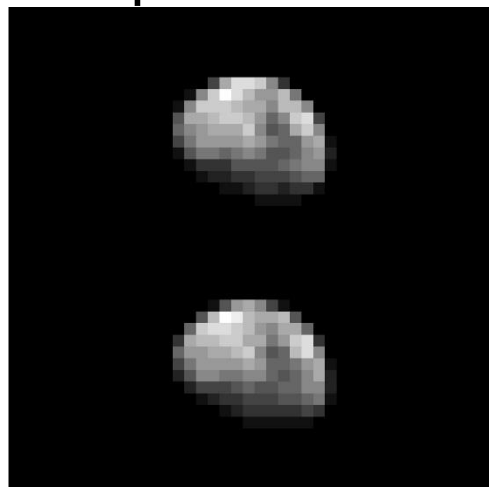
Reference irradiances are computed using a model for the disk-equivalent reflectance, to correspond to the time and location of Moon observations and to the sensor's spectral bands.

# MODIS and VIIRS Lunar Images

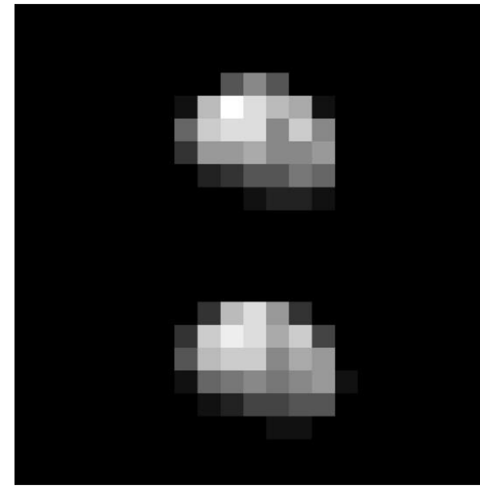
## Aqua MODIS



Band 1  250 m

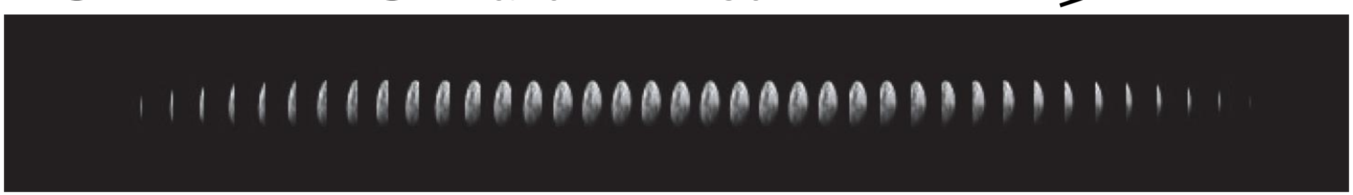


Band 4  500 m



Band 12  1 km

## SNPP VIIRS  Band M7   750 m



images appear elongated due
to non-square detectors

USGS

# Quality of lunar calibrations

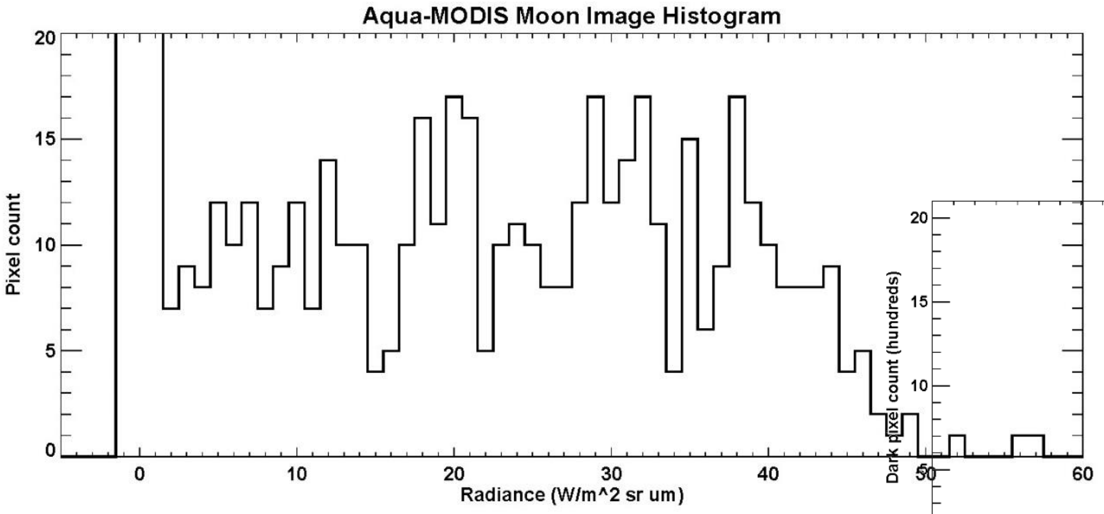
There are dependencies on: (1) the accuracy of lunar irradiance measurements from images; and (2) the specification of the lunar brightness represented in the model (*i.e.* the reference).

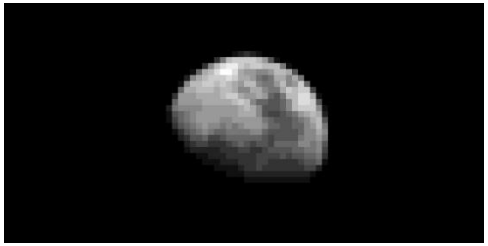
For accuracy of measurements from radiance images, the primary dependencies are:

- Reflectance calibration factor
- Detector linearity correction
  - the Moon is a relatively dark target: average reflectivity ~0.11 at 500 nm
- Consistent spatial sampling
  - the Moon is a spatially non-uniform target; variations in sampling will affect irradiance summations
- Dark level evaluation and subtraction
  - space-viewing regions should register zero mean radiance

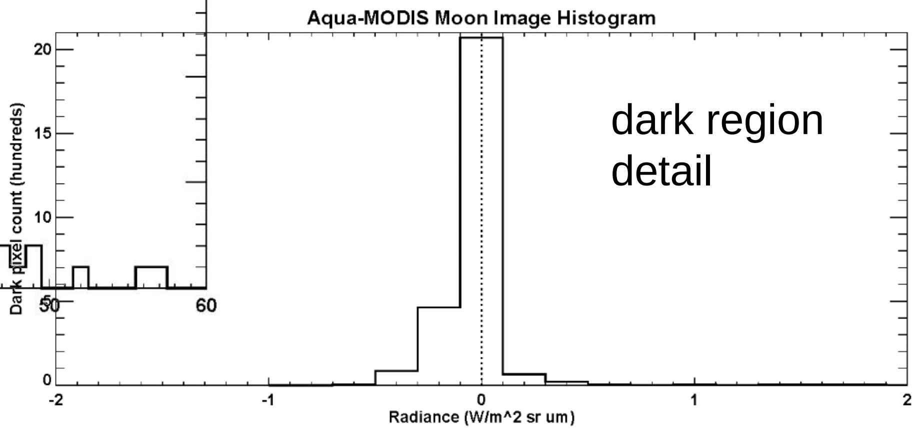
# Aqua-MODIS lunar image analysis

Radiance distribution — histograms:



2014-11-02 19:24:30  Band 1

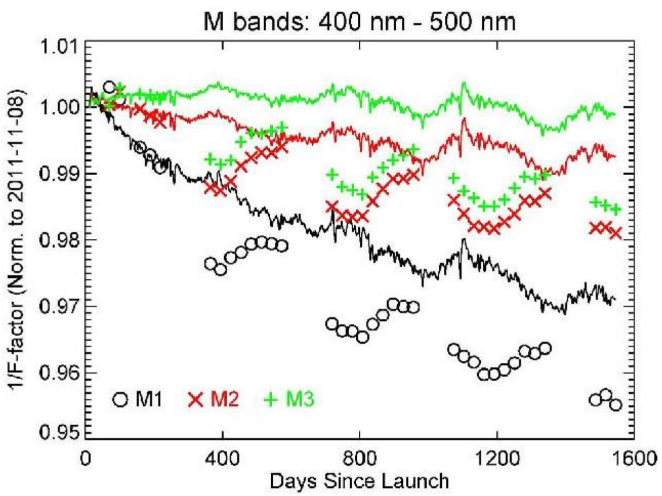


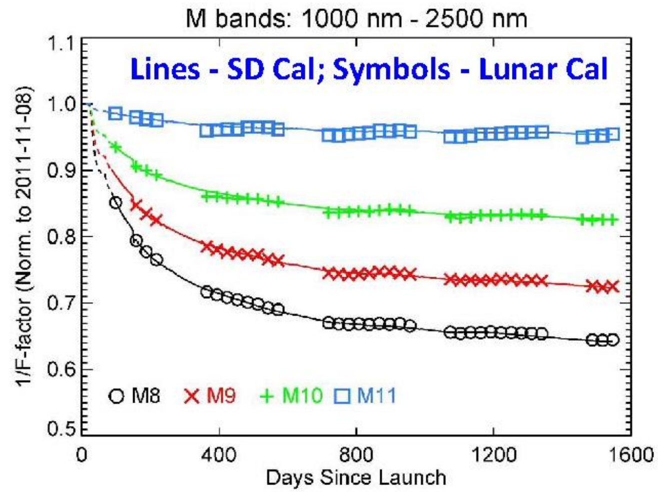

Deconstructing Level-1A images for radiometric analysis requires customizing the Level-0 (or RDR) data processing software.

- for MODIS, used an implementation of MCST code: Reflective_Cal.c
- for VIIRS, using ADL version 4.2.8; code mods are ongoing work
  - SDR processing cannot handle Moon views — geolocation fails

# VIIRS lunar calibration analysis

Irradiance measurements for VIIRS Moon observations are computed by VCST, reference values generated by USGS, leading to “lunar f-factors”

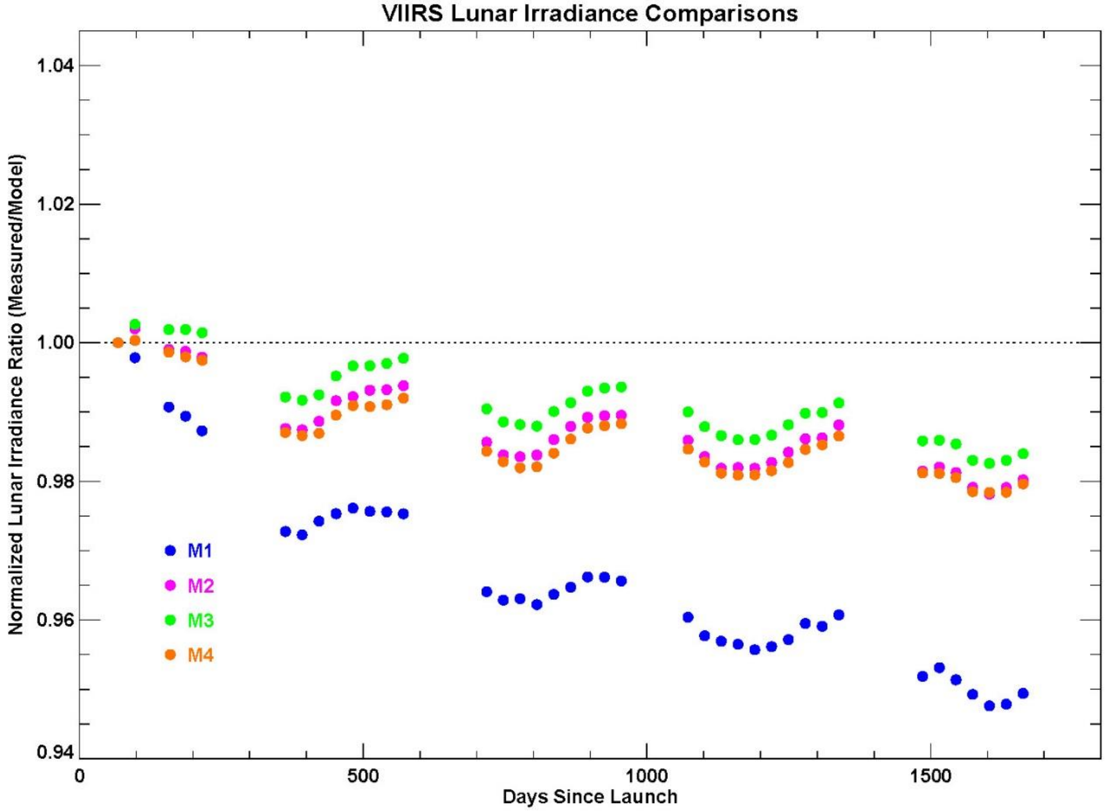



two figures: X. Xiong NASA-GSFC

- lunar results follow solar diffuser temporal trends (NIR degradation)
- differences between lunar and solar cals show oscillatory deviation behavior, correlated among all bands

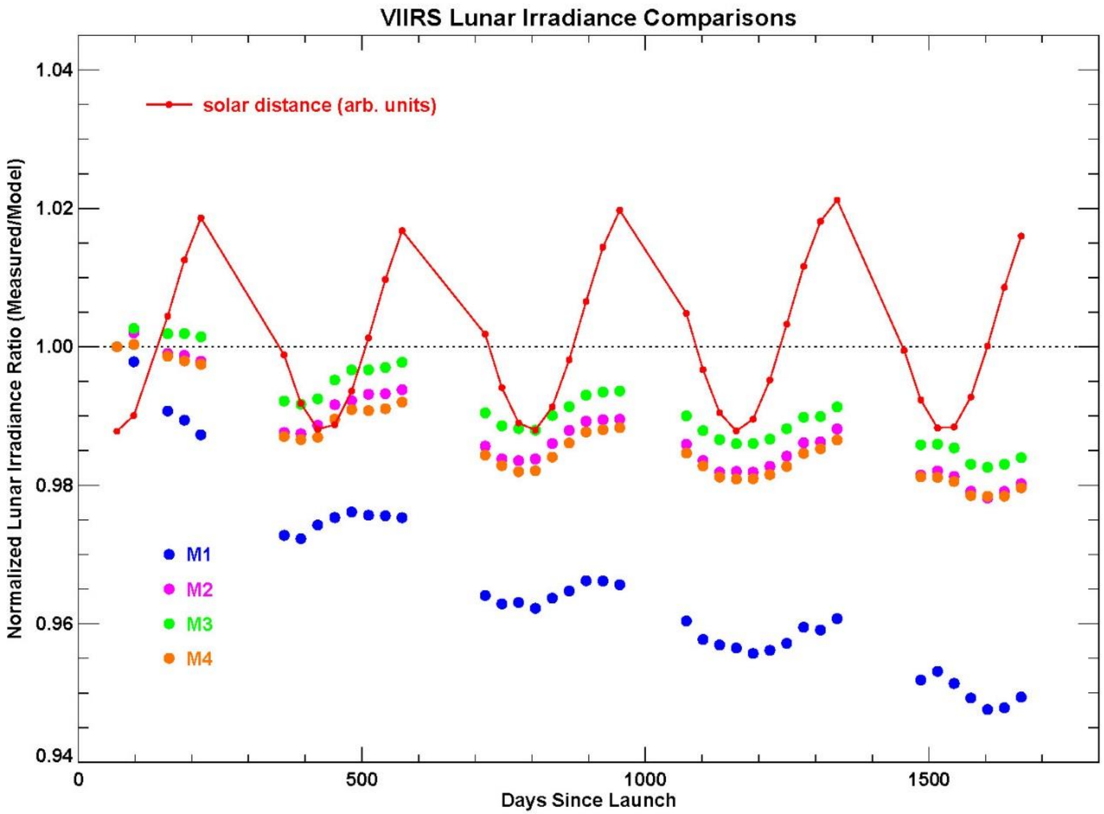
# VIIRS lunar measurement/model comparisons




- normalized to 2012-01-04 (68 days after launch)
- a smooth degradation trend is superposed with regular oscillations
- oscillations appear highly correlated among bands

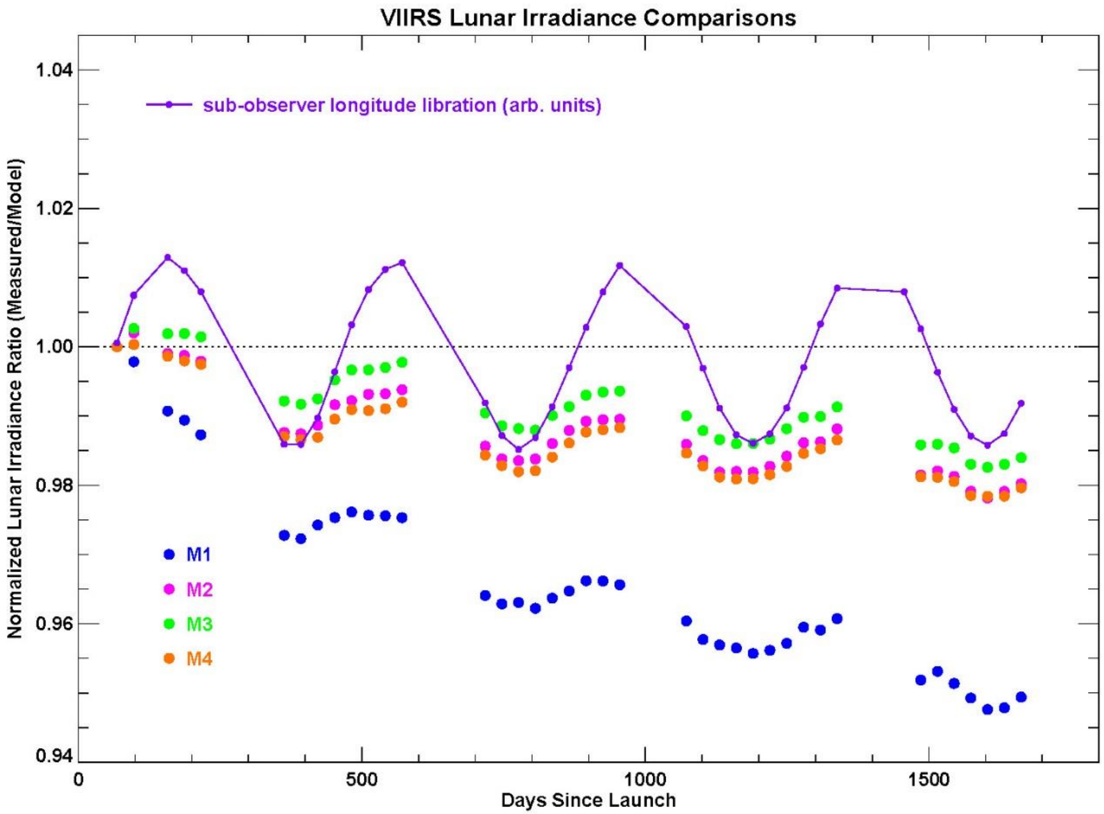
The Moon is inherently stable, and VIIRS sensor response is evaluated by the SD calibration. To assess the oscillatory behavior, look for correlations with characteristic parameters of the lunar observations.

# VIIRS lunar measurement/model comparisons



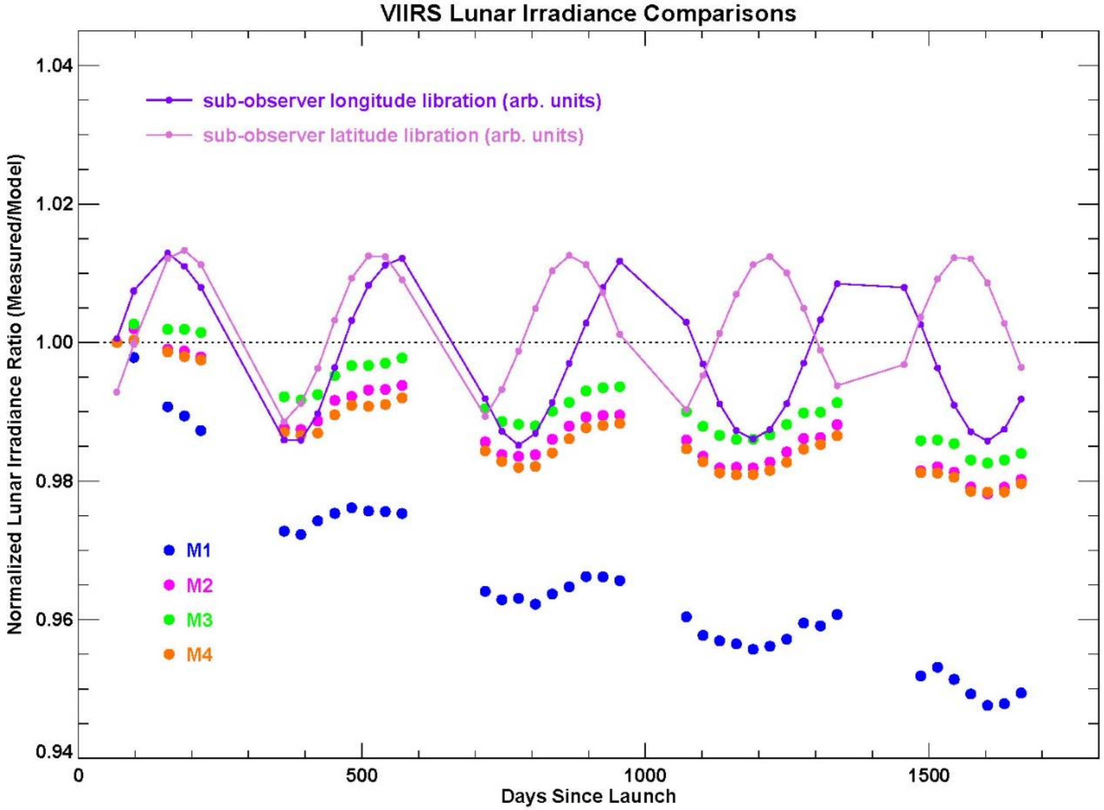

- The Sun–spacecraft distance (scaled above) has a slightly higher frequency, thus the oscillations are unlikely to be an uncorrected sensor temperature effect

# VIIRS lunar measurement/model comparisons



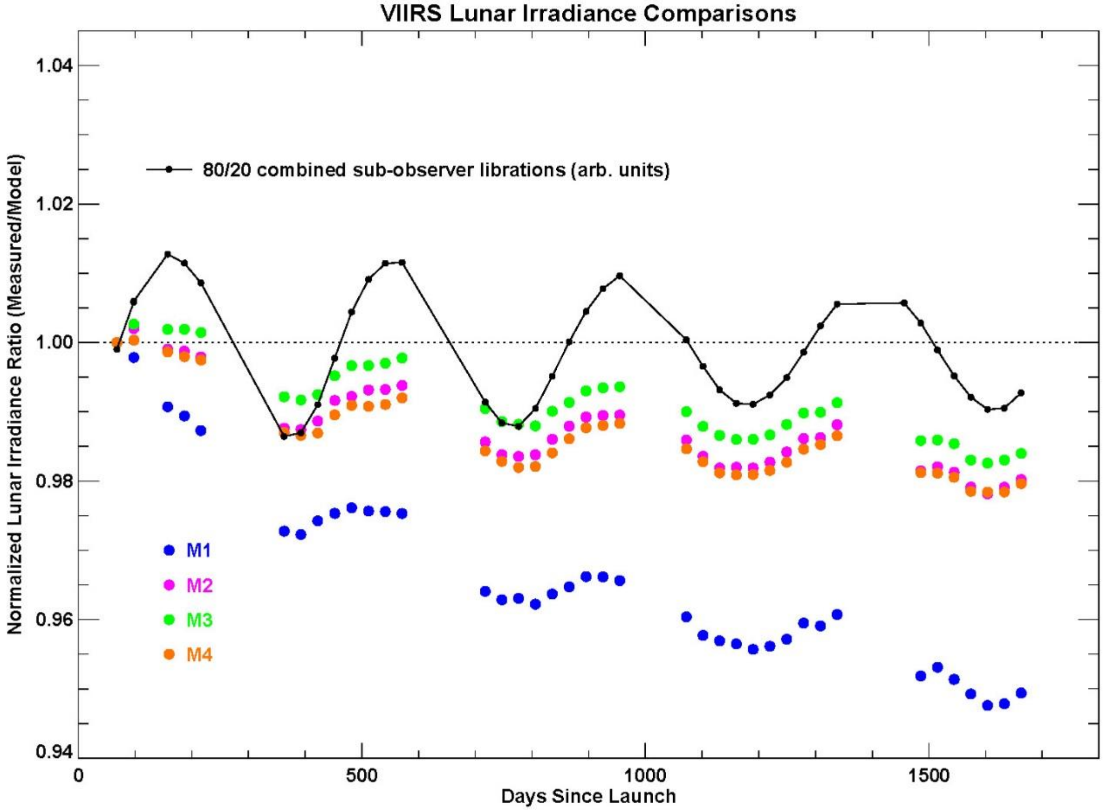

- The lunar libration sub-observer longitude (scaled above) appears to have the correct frequency and phasing, but not a perfect match, so an additional influence may be present

# VIIRS lunar measurement/model comparisons




- The lunar libration sub-observer latitude (scaled above) would seem a likely candidate, but with a much smaller magnitude of its effect

# VIIRS lunar measurement/model comparisons




The combined effect of lunar libration longitude and latitude (scaled above, with 80/20 proportions) appears to be a reasonable match. This suggests the cause is residual dependencies in the lunar model.

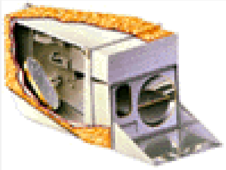
# Conclusions from this VIIRS lunar calibration analysis

The oscillatory patterns in the lunar irradiance comparisons suggest there are residual geometry dependencies in the USGS lunar model.

- subsequent analysis of the MODIS lunar series also found biases correlated with the librations, masked by larger sources of scatter
- a more rigorous correlation study of the VIIRS series is planned, to quantify the libration influences
  - with temporal de-trending applied
  - conduct a frequency analysis; possibly verify with the MODIS series
  - with uncertainty evaluation, to determine confidence in the assessment
- the results can guide refinements to the lunar model
  - in conjunction with reprocessing and re-fitting the ROLO dataset
  - likely manifest as constraints to the fit, or QA on the ROLO data

*This is the focus of near-term USGS work for the NPP Science Team.*

Thank You!



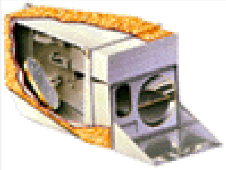
# Aqua MODIS and S-NPP VIIRS Radiometric Calibration Inter-comparison


Aisheng Wu

*MODIS Characterization Support Team*

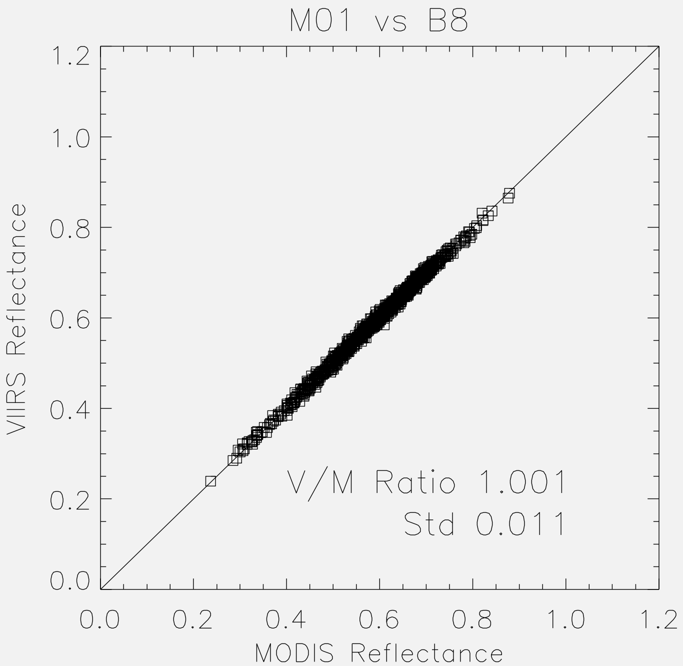

*06/06/2016*

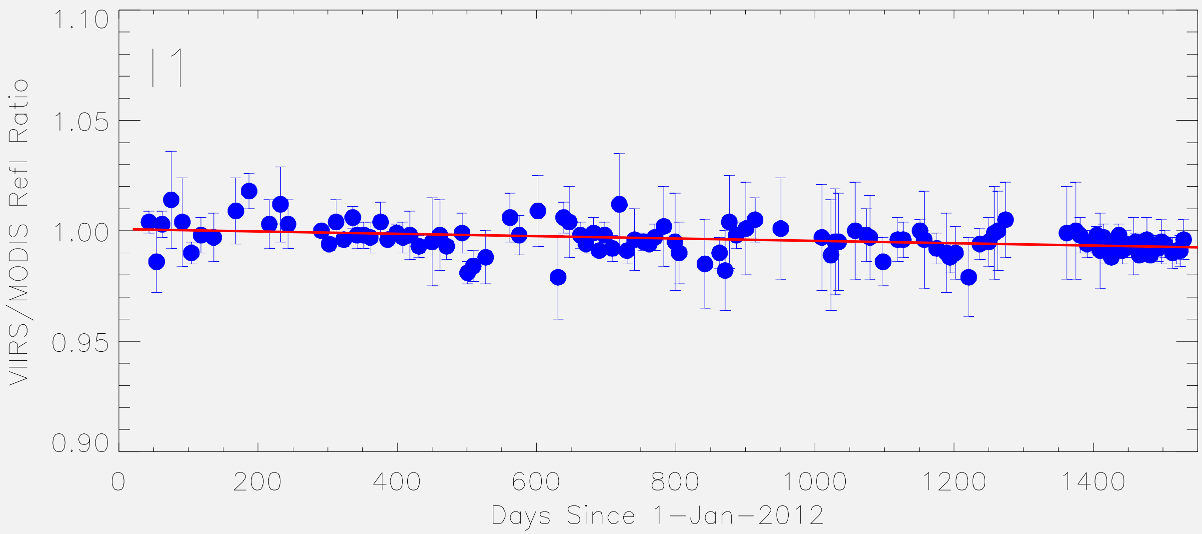
# Outline



- **Introduction**
- **Methodology**
  - SNO (simultaneous nadir overpasses)
  - Pseudo-invariant sites (desert, Dome C)
  - DCC (deep convective clouds)
  - High-level MODIS/VIIRS product
- **Results**
  - Stability
  - Inter-comparison (reflectance and brightness temperature)
- **Summary**

# SNO (Simultaneous Nadir Overpasses)

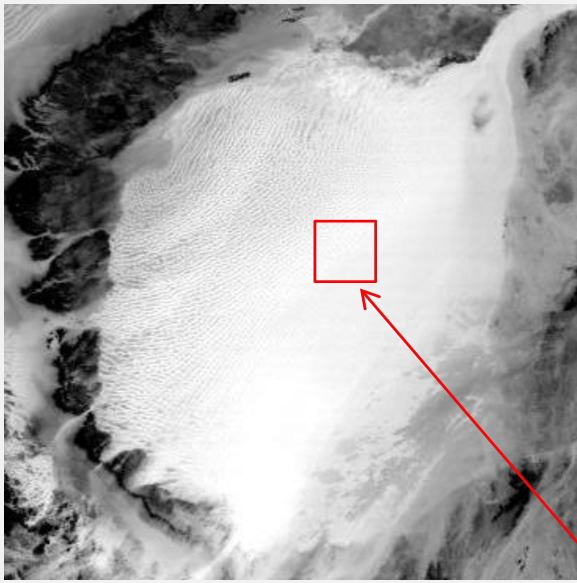



SNO reflectance trend between Aqua MODIS band 1 S-NPP VIIRS I1

- Reflectance ratio approach between two sensors (VIIRS & MODIS)
- Significantly reduce impacts of viewing and illumination angle differences and changing surface (< 30s)
- Always at different locations

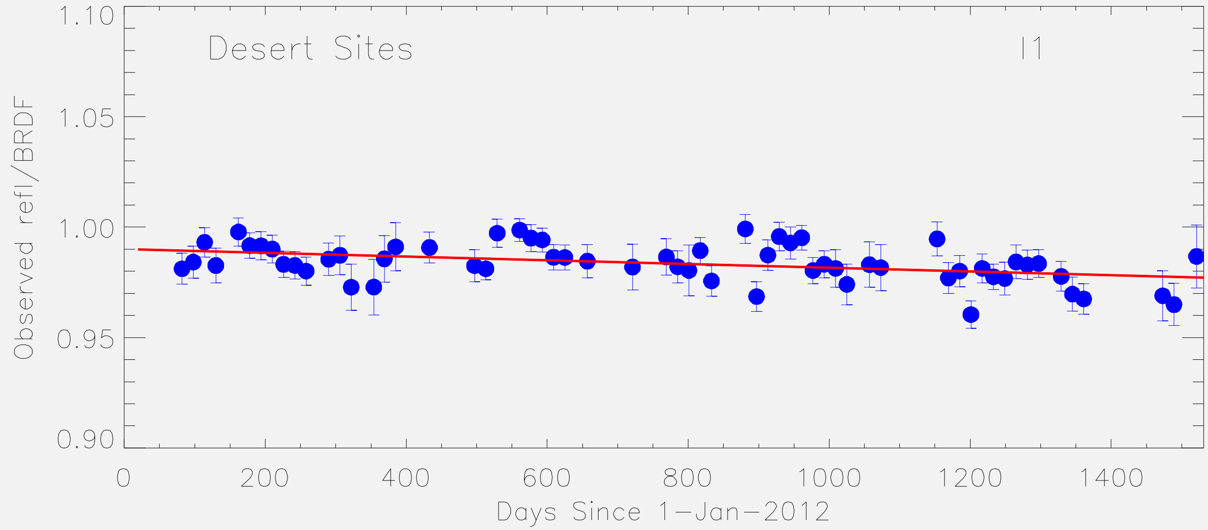
# Libya 4 desert site



Libya 4 Desert (2007/275)

(28.55°N, 23.39°E)

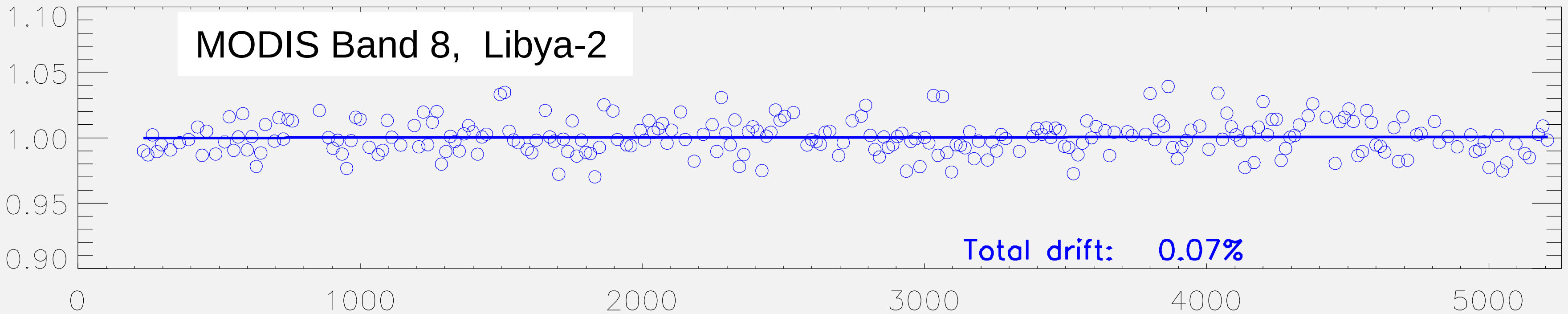
20 x 20 km

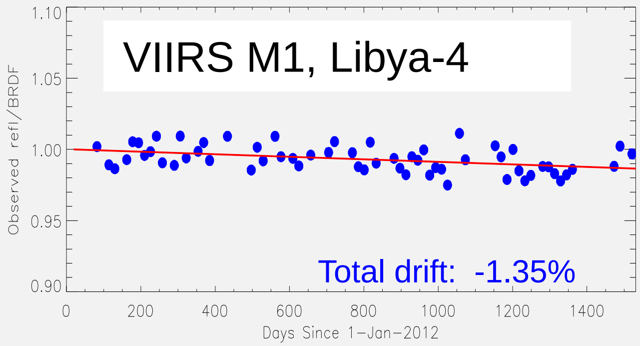



A site-dependent bi-directional reflectance function (BRDF) is normally applied

- Excellent radiometric stability
- Repeatable orbits (every 16 days) maintain constant viewing angles to each site
- Need surface measurements and atmospheric correction to conduct absolute calibration

# MODIS and VIIRS reflectance stability

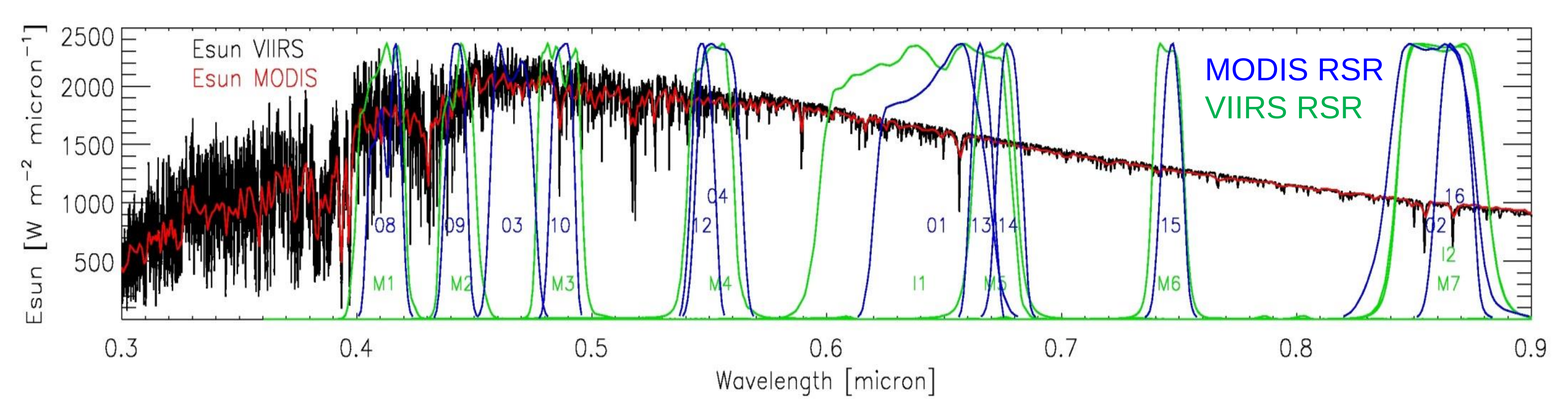


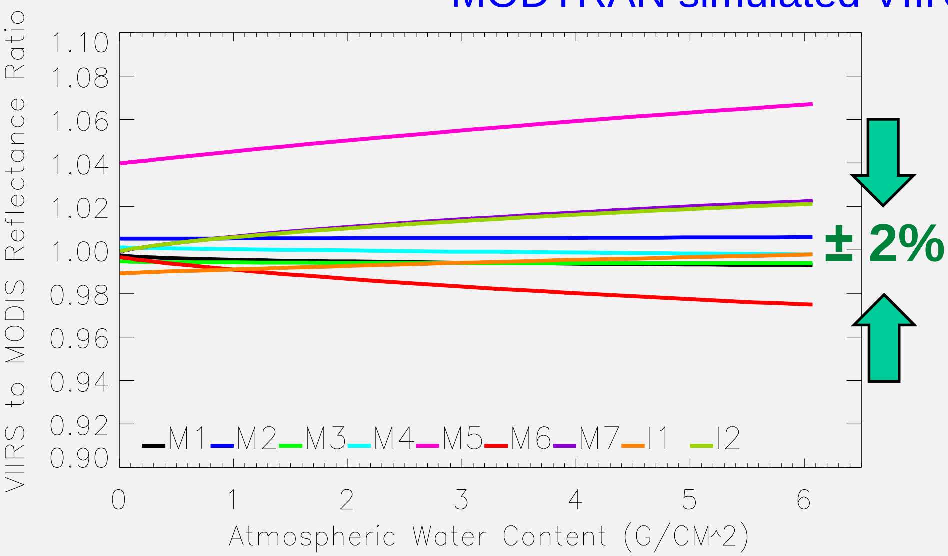

- Aqua MODIS RBS show a drift of 1.5% for the two imagery bands (bands 1 and 2) and well within 1% for all other RSB over the Aqua mission (more than 14 years)
- S-NPP VIIRS RSB show a drift of within 1.5% for a few shortest wavelength bands* (M1 to M3) and well within 1% for all other RSB over its mission (more than 4 years)
- VIIRS is referenced to the well calibrated MODIS RSB to check its post-launch stability

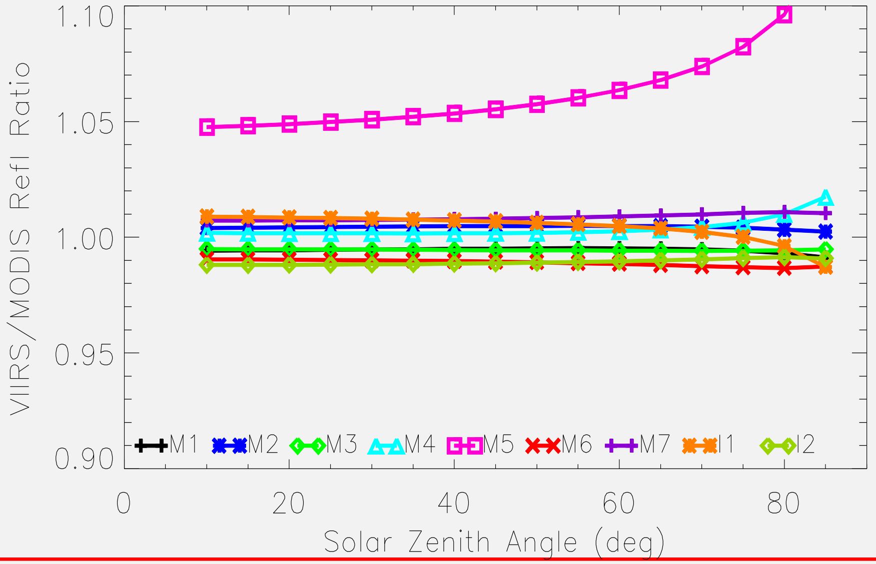
** For IDPS SDR, exclude data before May 2012*

# Solar Irradiance models and RSR impacts

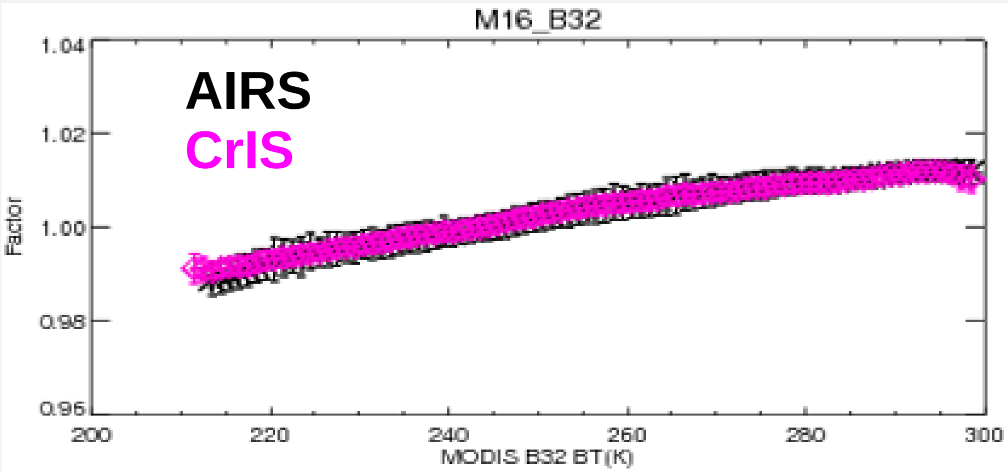



MODTRAN simulated VIIRS/MODIS reflectance ratio



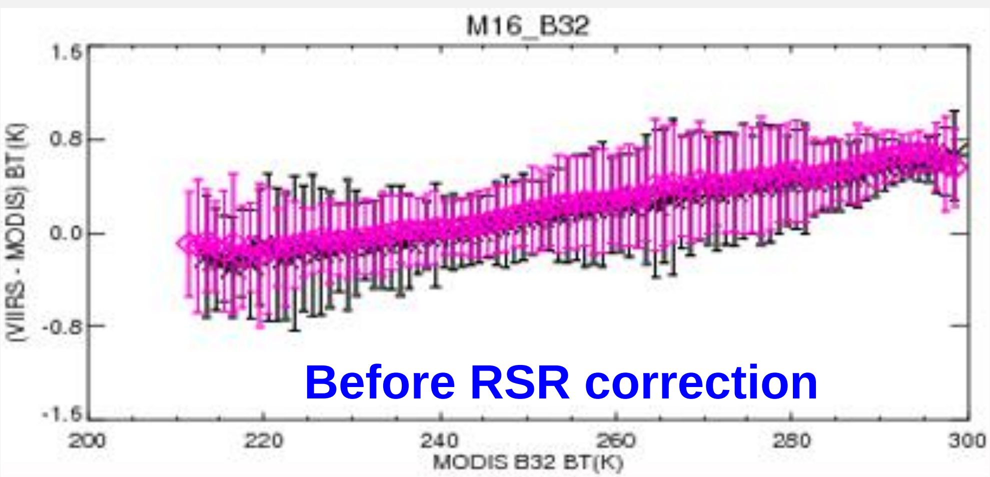



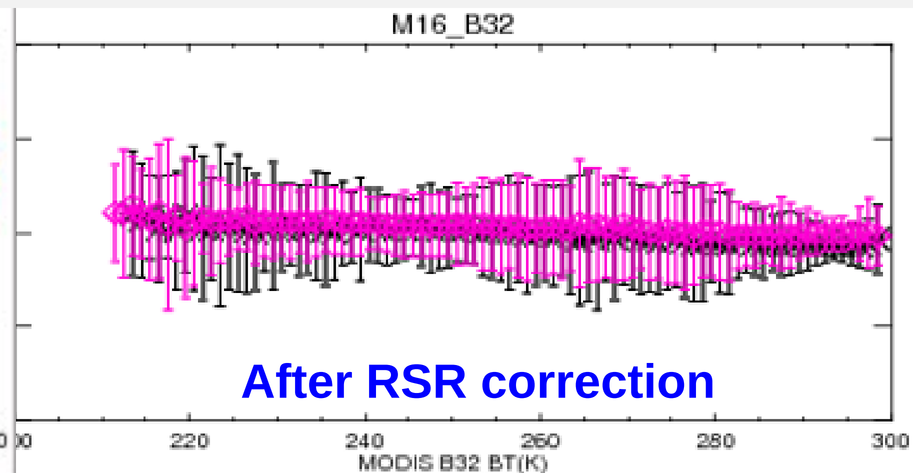
# RSR impacts on thermal emissive bands




$$SBAF = \frac{rad_{simulated}(VIIRS)}{rad_{simulated}(MODIS)}$$

Spectral band adjustment factor (SBAF) is determined using hyper-spectral measurements from Aqua AIRS and S-NPP CrIS after co-location.



# Averaged NPP VIIRS and Aqua MODIS Reflectance Differences (%) *

| V/M Band | SNO [1] | SNO [2] | Dome C [1] | Dome C [3,4] | Desert [1] | Desert [3,4] | DCC [5] | Ocean [6] | Ocean [2] |
|---|---|---|---|---|---|---|---|---|---|
| M1/B8 | -0.4±1.2 | 0.8±0.8 | -1.3±1.0 | -0.2±0.7 | 0.3±0.9 | 1.6±0.3 | -0.5±1.0 | -2.0±1.5 | 1.2±0.5 |
| M2/B9 | -1.0±1.2 | -1.7±0.6 | | -0.5±0.7 | -0.3±0.9 | 0.4±0.3 | -0.5±0.8 | -4.0±2.0 | -1.8±0.5 |
| M3/B10 | -0.9±0.8 | -1.3±0.4 | 0.2±0.9 | -0.2±0.8 | | 1.3±0.4 | -1.0±0.8 | -3.5±2.0 | -0.1±0.6 |
| M4/B4 | 1.5±0.8 | -1.5±0.3 | 1.8±1.5 | 1.6±1.0 | -0.8±1.0 | -0.2±0.4 | 2.0±1.0 | -1.5±1.5 | -0.2±0.9 |
| M5/B1 | | 10.0±0.6 | | 4.8±0.9 | | 9.5±0.5 | 9.0±0.7 | 1.5±0.5 | |
| M7/B2 | 2.6±0.7 | 4.0±0.5 | 2.2±1.7 | 2.8±1.4 | 3.9±0.6 | 4.0±0.5 | 2.5±0.5 | 4.0±2.0 | |
| M8/B5 | | 3.5±0.4 | | 5.8±4.0 | | 2.8±0.6 | | | |
| M10/B6 | | | | | | 0.5±0.4 | | | |
| M11/B7 | | | | | | -6.0±1.0 | | | |
| I1/B1 | -0.3±0.7 | | -0.4±1.5 | | -0.7±0.8 | | | | |
| I2/B2 | 2.6±0.7 | | 2.3±1.8 | | 3.4±0.6 | | | | |

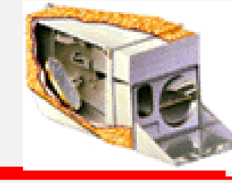
Highlighted areas: 1) large RSR difference, 2) less confident due to atmospheric impact, xtalk etc.

1) Difference is computed as magnitude of
(VIIRS – MODIS) *100%/MODIS
2) Non RSR correction is applied
3) Numbers shown in the bracket are referred to references
4) Results are based on MODIS Collection-6 L1B and VIIRS IDPS/Land PEATE SDR

# Averaged NPP VIIRS and Aqua MODIS BT Differences (K)*

| VIIRS/MODIS Band | SNO [1] | SNO [2] | Dome C [3] | SNO [1] | SNO [4] | SST [5] |
|---|---|---|---|---|---|---|
| Without RSR correction | | | | With RSR correction | | |
| M12/B20 | | | 4.9±4.5 | | | 0.20±0.03 |
| M13/B22 | 1.0±1.0 | | 4.9±3.0 | 0.15±1.00 | | |
| M13/B23 | 0.8±0.5 | 0.6±0.3 | | 0.07±0.50 | 0.00±0.30 | |
| M14/B29 | -0.1±0.5 | 0.7±0.2 | 1.5±2.7 | | | |
| M15/B31 | 0.1±0.5 | 0.1±0.2 | 1.5±2.9 | -0.02±0.50 | -0.10±0.60 | 0.02±0.04 |
| M16/B32 | 0.3±0.5 | 0.2±0.2 | 1.4±2.8 | 0.05±0.50 | 0.01±0.60 | 0.06±0.03 |

* 1) Difference is computed as magnitude of BT(VIIRS) – BT(MODIS)
Numbers shown in the bracket are referred to references
2) Current results are based on average over all samples each approach



# Summary

- Aqua MODIS and S-NPP VIIRS show excellent stability of within 1% for most RSB over the mission. There is a drift of ~1.5% for MODIS two imagery bands and a few VIIRS shortest wavelength bands.
- Averaged VIIRS and MODIS reflectance differences are within 1.5% for the spectrally matched VIS/NIR bands except for the results at 0.85 µm, where the differences are larger than 2%.
- Differences of brightness temperature between VIIRS and MODIS are within 0.10K after correction of the spectral response difference, based on measured scene temperatures at 3.70, 4.05, 8.55, 10.76, and 12.01µm.

# References for RSB inter-comparison


1. Wu, A., X. Xiong, C. Cao, and K. Chiang, “Assessment of SNPP VIIRS VIS/NIR radiometric calibration stability using Aqua MODIS and invariant surface targets”, IEEE Transactions on Geoscience and Remote Sensing, Vol. 54, No. 5, pp. 2918-2924, 2016.

2. Uprety, S.,C. Cao, X. Xiong, S. Blonski, A. Wu, and X. Shao, “Radiometric Intercomparison between Suomi-NPP VIIRS and Aqua MODIS Reflective Solar Bands Using Simultaneous Nadir Overpass in the Low Latitudes”, J. Atmos. Oceanic Technol., 30, 2720–2736. 2013.

3. Uprety, S., C. Cao, S, Blonski, W. Wang, Assessment of VIIRS radiometric performance using vicarious calibration sites, Proc. SPIE 9218, Earth Observing Systems XIX, 92180I, 2014, doi:10.1117/12.2061855.

4. Uprety, S., , C. Cao, Suomi NPP VIIRS reflective solar band on-orbit radiometric stability and accuracy assessment using desert and Antarctica Dome C sites, Remote Sensing of Environment, Vol. 166, pp. 106–115, 2015, doi:10.1016/j.rse.2015.05.021.

5. Wang, W. and C. Cao, “Assessing the VIIRS RSB calibration stability using deep convective clouds”, Proc. SPIE, 9264, Earth Observing Missions and Sensors: Development, Implementation, and Characterization III, doi:10.1117/12.2068434, 2014.

6. Pahlevan, N., Z. Lee, R. Arnone, and A. Lawson, Investigating the Consistency between VIIRS and MODIS over the Oceans: The Sensor/Environmental Data Records (SDR/EDR), 2013.

7. Eplee Jr, R., G. Mesiter, F. Patt. R. Barnes, S. Bailey, B. Franz, C. McClain, On-orbit calibration of SeaWiFS, Appl. Opt., 51, pp. 8702-8730, 2012.

8. Bhatt, R., D. Doelling, A. Wu, X. Xiong, B. Scarino, C. O. Haney and A. Gopalan, “Initial Stability Assessment of S-NPP VIIRS Reflective Solar Band Calibration Using Invariant Desert and Deep Convective Cloud Targets”, Remote Sens., 6, pp. 2809-2826, 2014.

9. A. Wu ; X. Xiong ; C. Cao ; C. Sun, Monitoring NPP VIIRS on-orbit radiometric performance from TOA reflectance time series, Proc. SPIE 8866, Earth Observing Systems XVIII, 88660Q, 2013; doi:10.1117/12.2023388.

10. Cao, C., S. Uprety ; S. Blonski, Establishing radiometric consistency among VIIRS, MODIS, and AVHRR using SNO and SNOx methods, IEEE International Geoscience and Remote Sensing Symposium, pp. 6928-6931, 2012, doi:10.1109/IGARSS.2012.6352569.

11. Cao, C., F. J. De Luccia , X. Xiong, R. Wolfe, F. Weng, Early On-Orbit Performance of the Visible Infrared Imaging Radiometer Suite Onboard the Suomi National Polar-Orbiting Partnership (S-NPP) Satellite, IEEE Transactions on Geoscience and Remote Sensing, Vol. 52, No. 2, pp. 1142-1156, 2013, doi:10.1109/TGRS.2013.2247768.

12. Blonski, S., C. Cao, S. Uprety, X. Shao, Using antarctic Dome C site and simultaneous nadir overpass observations for monitoring radiometric performance of NPP VIIRS instrument, IEEE International Geoscience and Remote Sensing Symposium, pp. 1061-1064, 2012, doi:10.1109/IGARSS.2012.6351367.

13. Wang, W., C. Cao, DCC Radiometric Sensitivity to Spatial Resolution, Cluster Size, and LWIR Calibration Bias Based on VIIRS Observations, Journal of Atmospheric and Oceanic Technology, 2015, DOI: [http://dx.doi.org/10.1175/JTECH-D-14-00024.1](http://dx.doi.org/10.1175/JTECH-D-14-00024.1).

14. Pahlevan, N., Z. Lee, A. Lawson, R. Arnone, Scene-based cross-comparison of SNPP-VIIRS and Aqua-MODIS over oceanic waters, Proc. SPIE 8866, Earth Observing Systems XVIII, 88660J, 2013, doi:10.1117/12.2023423.

15. Xiong, X., A. Angal, J. Fulbright, N. Lei, Q. Mu, Z. Wang, A. Wu, Calibration improvements for MODIS and VIIRS SWIR spectral bands, Proc. SPIE 9607, Earth Observing Systems XX,2015; doi:10.1117/12.2185818.

16. Uprety, S., C. Cao, Radiometric performance assessment of Suomi NPP VIIRS SWIR Band (2.25 μm), Proc. SPIE 9607, Earth Observing Systems XX, 96072C , 2015; doi:10.1117/12.2188285.

17. Uprety, S. C. Cao, S. Blonski, X. Shao, Evaluating radiometric consistency between Suomi NPP VIIRS and NOAA-19 AVHRR using extended simultaneous nadir overpass in the low latitudes, Proc. SPIE 8866, Earth Observing Systems XVIII, 88660L , 2013, doi:10.1117/12.2023335.

18. Blonski, S., C. Cao, X. Shao, S. Uprety, VIIRS reflective solar bands calibration changes and potential impacts on ocean color applications, Proc. SPIE 9111, Ocean Sensing and Monitoring VI, 911106, 2014, doi:10.1117/12.2053315.

## References for TEB inter-comparison


1. Li, Y., A. Wu and X. Xiong, Inter-Comparison of S-NPP VIIRS and Aqua MODIS Thermal Emissive Bands Using Hyperspectral Infrared Sounder Measurements as a Transfer Reference, Remote Sens., 8(1), 72, doi:10.3390/rs8010072, 2016.
2. Liu, Q., C. Cao, F. Weng, Assessment of Suomi National Polar-Orbiting Partnership VIIRS Emissive Band Calibration and Inter-Sensor Comparisons, IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, pp. 1737-1748, 2013, doi:10.1109/JSTARS.2013.2263197.
3. Madhavan, S., J. Brinkmann, B. N. Wenny, A. Wu, and X. Xiong, Evaluation of VIIRS and MODIS Thermal Emissive Band Calibration Stability Using Ground Target, Remote Sens., 2016, 8(2), 158; doi:10.3390/rs8020158.
4. Efremova, B.; Wu, A.; Xiong, X. Relative spectral response corrected calibration inter-comparison of S-NPP VIIRS and Aqua MODIS thermal emissive bands. Proc. SPIE 2014, 9218, doi: 10.1117/12.2061917.
5. Liang, X., A. Ignatov, AVHRR, MODIS, and VIIRS radiometric stability and consistency in SST bands, Journal of Geophysical Research: Oceans, pp. 3161-3171, 2013, DOI: 10.1002/jgrc.20205.
6. Moeller, C.; Tobin, D.; Quinn, G. S-NPP VIIRS thermal band spectral radiance performance through 18 months of operation on-orbit. Proc. SPIE 2013, 8866, doi: 10.1117/12.2023389.
7. Liang, X., A. Ignatov, M. Kramar and F. Yu, Preliminary Inter-Comparison between AHI, VIIRS and MODIS Clear-Sky Ocean Radiances for Accurate SST Retrievals, Remote Sens. 8(1), 203, doi:10.3390/rs8030203, 2016.

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# THE CAL/VAL OF MODIS AND VIIRS USING RADCATS

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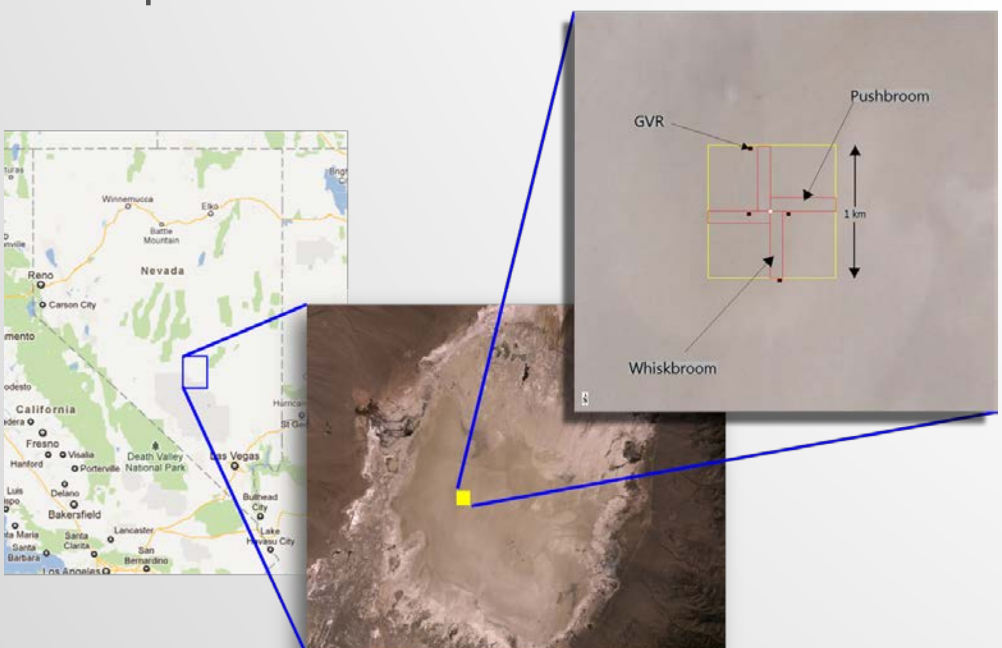
# SUMMARY

- Radiometric Calibration Test Site (RadCaTS) at Railroad Valley
- Current results
- RadCaTS web portal for SNPP VIIRS results
- CEOS WGCV Radiometric Calibration Network (RadCalNet)
- Future work

# THE RADIOMETRIC CALIBRATION TEST SITE (RADCATS)

- Concept similar to Lake Tahoe validation site
- Daily data collect
- Originally designed for large-footprint sensors (e.g. MODIS)
- Currently being used for sensors with 1–1000 m footprints




- Current status:
  - 4 ground-viewing radiometers
  - 1 Cimel sun photometer
  - 1 meteorological station
  - 1 satellite uplink base station

# CURRENT RADCATS WORK

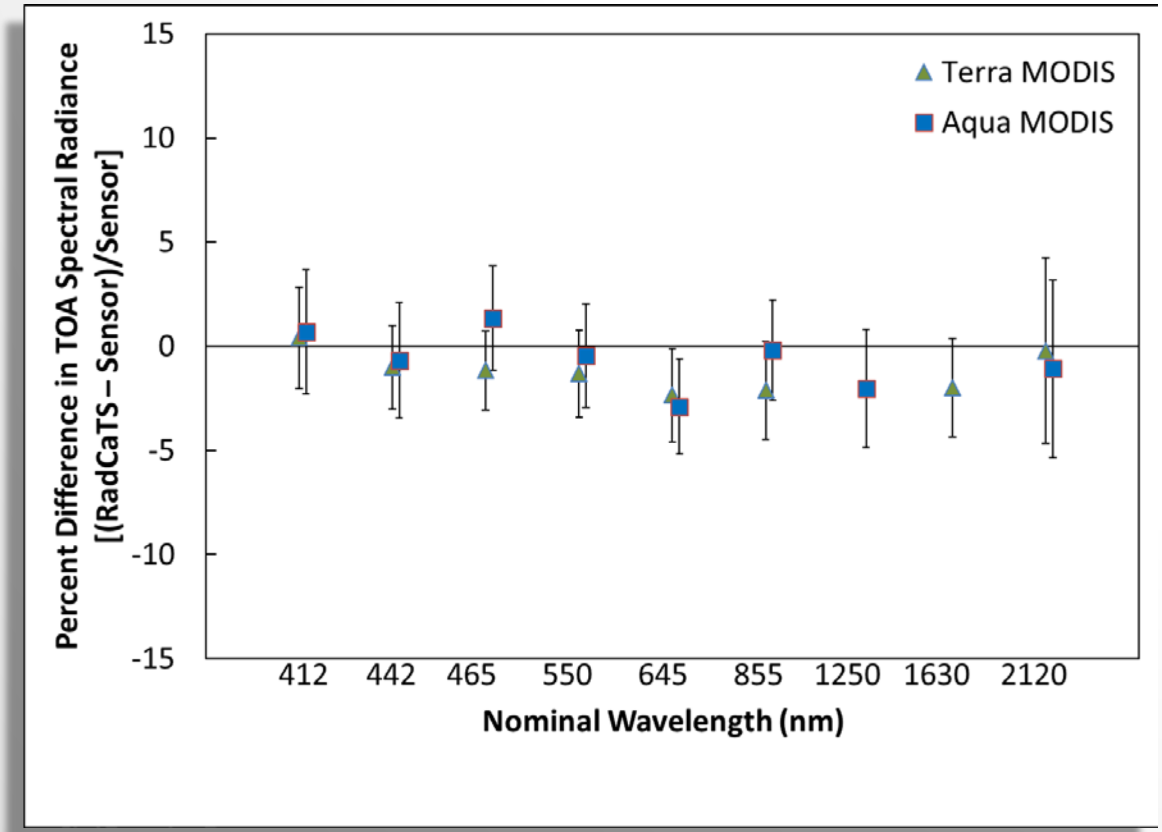
- Landsat 7 & 8, MODIS, MISR, ASTER, SNPP VIIRS, Sentinel-2A
- RapidEye and WorldView
- MODIS AND VIIRS Sensor characteristics:

| | Center Wavelength (nm) |
|---|---|
| Band | MODIS |
| 1 | 645.7 |
| 2 | 856.3 |
| 3 | 466.1 |
| 4 | 553.9 |
| 5 | 1242.1 |
| 6 | 1628.6 |
| 7 | 2113.7 |
| Pixel (m) | 250, 500 |

| | Center Wavelength (nm) | |
|---|---|---|
| Band | SNPP VIIRS (I) | SNPP VIIRS (M) |
| 1 | 638.3 | 420.8 |
| 2 | 861.5 | 445.7 |
| 3 | 1601.1 | 489.5 |
| 4 | - | 552.0 |
| 5 | - | 671.1 |
| 6 | - | 745.0 |
| 7 | - | 861.7 |
| 8 | - | 1240.5 |
| 9 | - | 1375.2 |
| 10 | - | 1601.9 |
| 11 | - | 2257.2 |
| Pixel (m) | 375 | 750 |

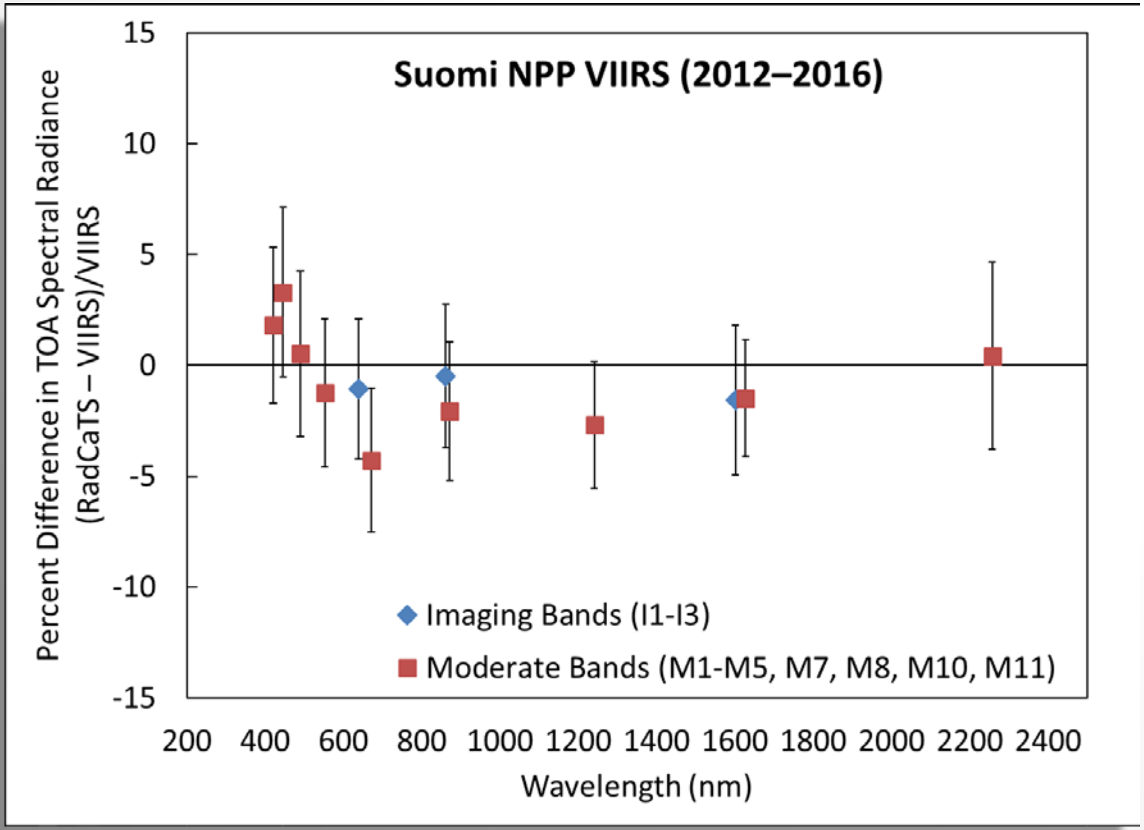
# TERRA AND AQUA MODIS

- RadCaTS TOA spectral radiance for bands 1–9
- Uncertainty bars are the 1σ standard deviation of the measurements



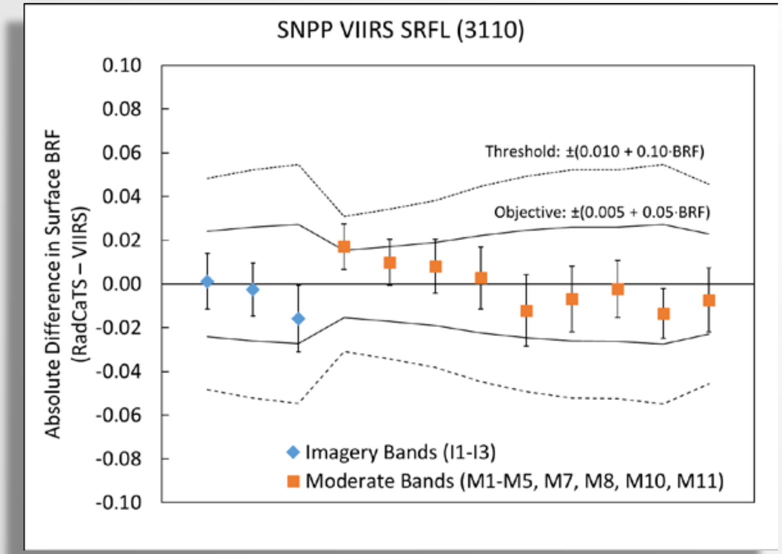
# SUOMI NPP VIIRS

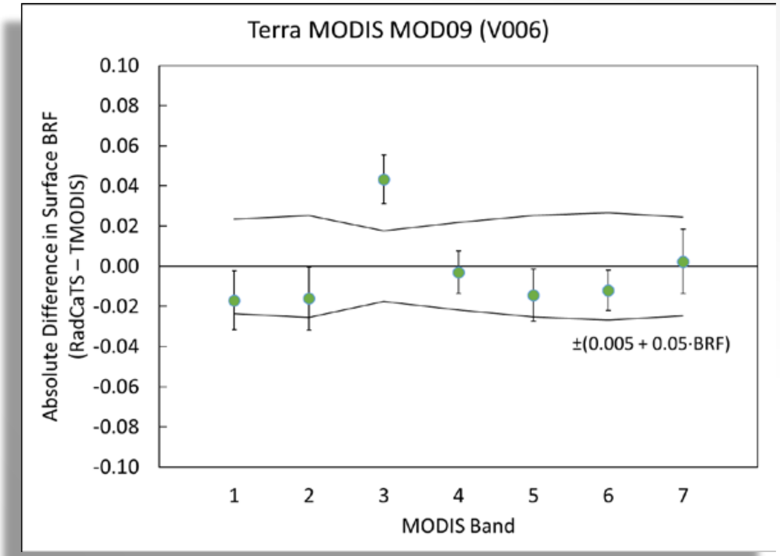
- Imaging (I) band: 375 m
- Moderate (M) band: 750 m

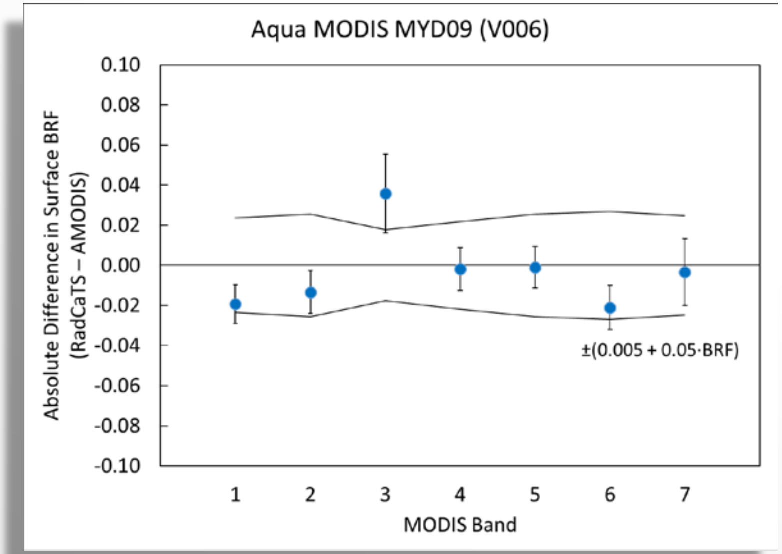


# SURFACE REFLECTANCE PRODUCT VALIDATION

- Surface reflectance products:
  - MODIS: MOD09 (MYD09), Collection 6
  - VIIRS: NPS_SRFLIIP_L2 NPS_SRFLMIP_L2, 3110

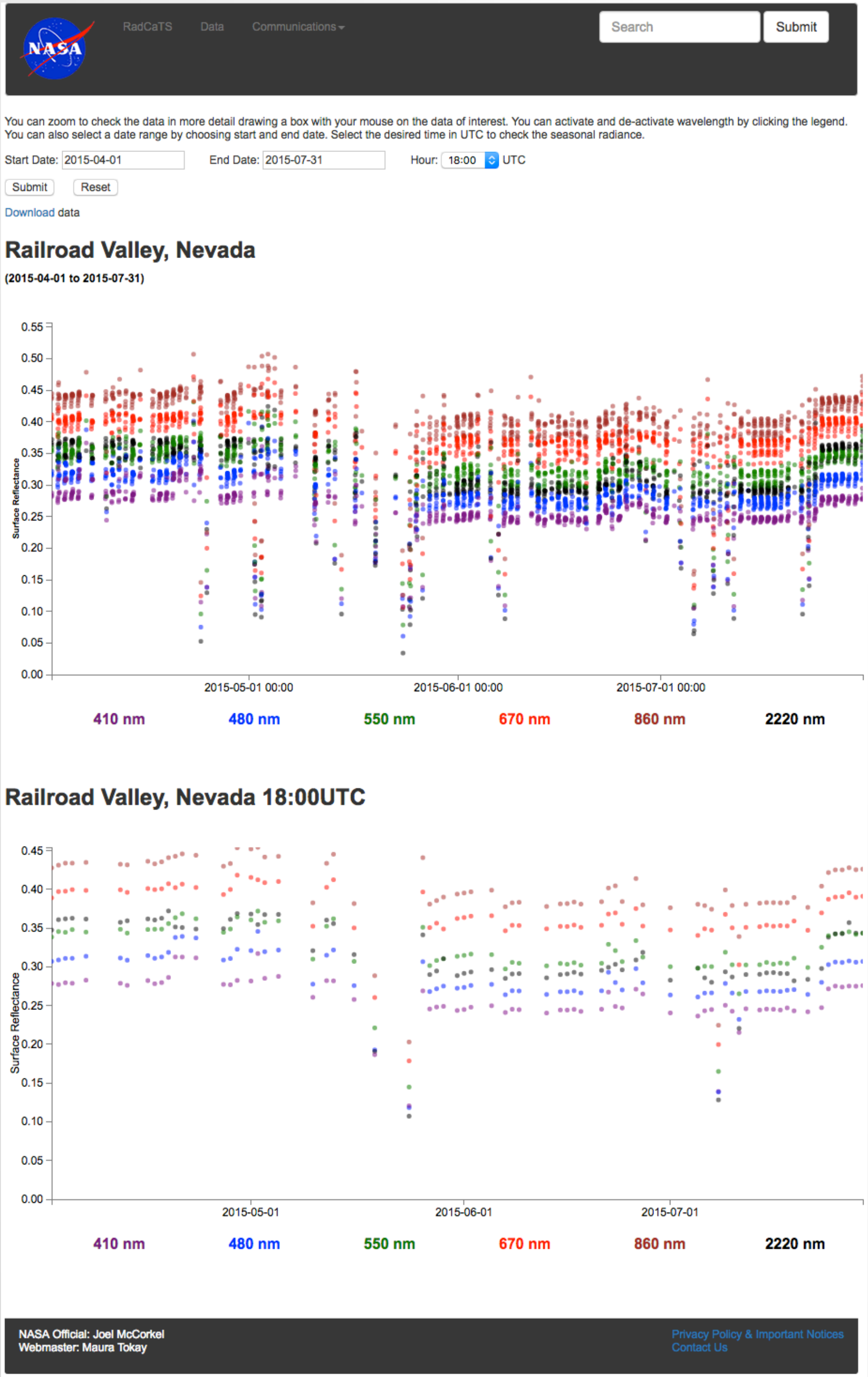


# WEB PORTAL FOR SNPP VIIRS RESULTS

- Data are currently being downloaded from RadCaTS via satellite uplink for processing at U Arizona
- Data processing:
  - RadCaTS raw data processed to surface reflectance at U Arizona
  - Surface reflectance data sent to NASA GSFC for processing to TOA reflectance
  - Distribution on NASA web site
- radcats.gsfc.nasa.gov
  - Currently under construction
  - Surface reflectance data shown as example, but will be TOA reflectance


NASA
RadCaTS
Data
Communications
Search
Submit
You can zoom to check the data in more detail drawing a box with your mouse on the data of interest. You can activate and de-activate wavelength by clicking the legend.
You can also select a date range by choosing start and end date. Select the desired time in UTC to check the seasonal radiance.
Start Date: 2015-04-01
End Date: 2015-07-31
Hour: 18:00 UTC
Submit
Reset
Download data
Railroad Valley, Nevada
(2015-04-01 to 2015-07-31)
Surface Reflectance
2015-05-01 00:00
2015-06-01 00:00
2015-07-01 00:00
410 nm
480 nm
550 nm
670 nm
860 nm
2220 nm
Railroad Valley, Nevada 18:00UTC
Surface Reflectance
2015-05-01
2015-06-01
2015-07-01
410 nm
480 nm
550 nm
670 nm
860 nm
2220 nm
NASA Official: Joel McCorkel
Webmaster: Maura Tokay
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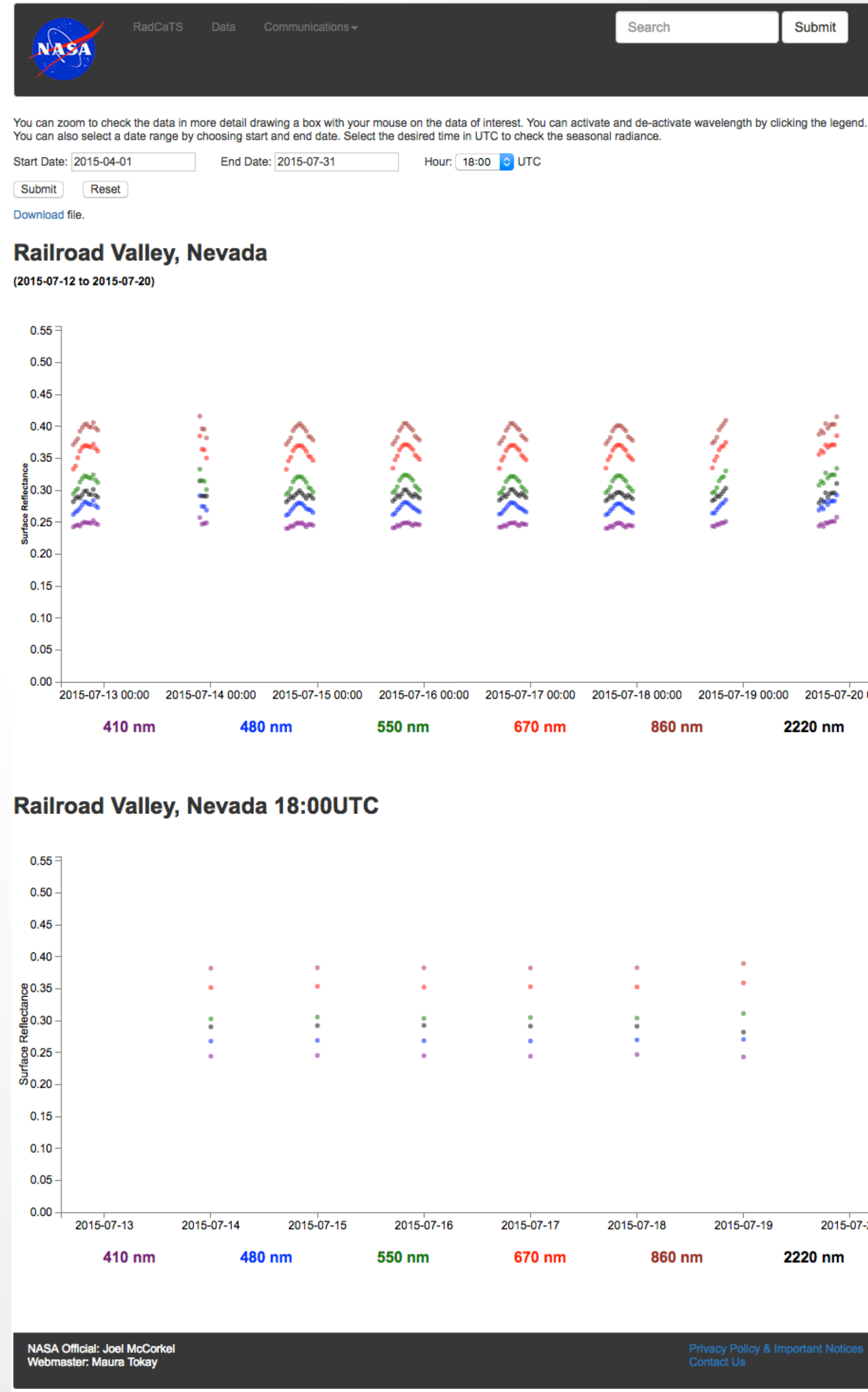
NASA
RadCaTS
Data
Communications
Search
Submit
You can zoom to check the data in more detail drawing a box with your mouse on the data of interest. You can activate and de-activate wavelength by clicking the legend.
You can also select a date range by choosing start and end date. Select the desired time in UTC to check the seasonal radiance.
Start Date: 2015-04-01
End Date: 2015-07-31
Hour: 18:00 UTC
Submit
Reset
Download file.
Railroad Valley, Nevada
(2015-07-12 to 2015-07-20)
Surface Reflectance
2015-07-13 00:00
2015-07-14 00:00
2015-07-15 00:00
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2015-07-17 00:00
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410 nm
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Railroad Valley, Nevada 18:00UTC
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410 nm
480 nm
550 nm
670 nm
860 nm
2220 nm
NASA Official: Joel McCorkel
Webmaster: Maura Tokay
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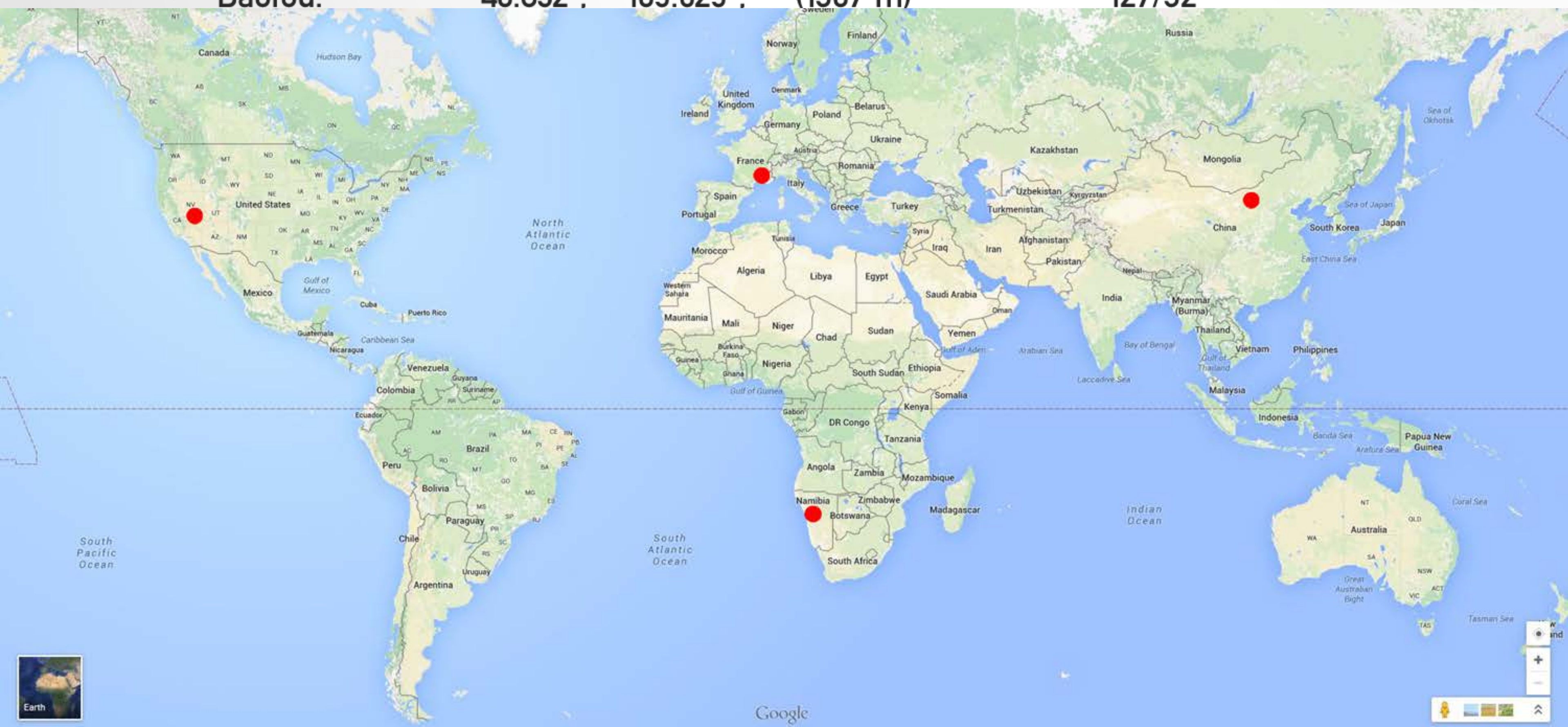
# RADIOMETRIC CALIBRATION NETWORK (RADCALNET)

- RadCalNet is a small working group that is part of CEOS WGCV
- International collaboration: members from France, Italy, Netherlands, UK, USA, and China
- Composed of four sites in the US, France, China, and Namibia
- Objectives
  1. Define the architecture of RadCalNet
  2. Demonstrate the operational concept using current sensors
  3. Provide recommendations to CEOS WGCV for the evolution of RadCalNet
- Deliverable product
  - TOA reflectance at 30-min intervals
  - 400 – 2500 nm
  - 9:00 – 15:00 local time
  - Nadir view
- Current work uses Landsat 8 OLI results for site intercomparison
- Jun 2016: data open to beta users
- Jan 2017: data open to all registered users

# RADCALNET SITES

| Lat, lon, (elevation) | | | | WRS-2 (path/row) |
|---|---|---|---|---|
| Railroad Valley: | 38.497°, | –115.690°, | (1435 m) | 40/33 |
| La Crau: | 43.559°, | 4.864°, | (18 m) | 196/30 |
| Gobabeb: | –23.501°, | 15.095°, | (470 m) | 179/76 |
| Baotou: | 40.852°, | 109.629°, | (1307 m) | 127/32 |



# FUTURE WORK

- Maintenance/calibration of RadCaTS ground instrumentation
- Automated processing of RadCaTS data on a daily basis
- Go live with web portal
- Continued participation in COES WGCV RadCalNet

# ACKNOWLEDGEMENTS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  - NNX14AJ19G
  - NNX14AP68A
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  - Bureau of Land Management (BLM) Tonopah, Nevada, office for their assistance and permission in using Railroad Valley
  - Brent Holben (PI) and AERONET for processing and distribution of the Railroad Valley Cimel data

# THANKS!

- www.optics.arizona.edu/rsg

# EXTRA SLIDES

# RADCATS UNCERTAINTY ANALYSIS

- Uncertainty sources:
  - Radiometric calibration of GVRs
  - Output voltage from each GVR
  - Exoatmospheric solar irradiance
  - Atmospheric transmission
  - Solar position
  - Diffuse sky irradiance
  - Surface reflectance retrieval
- Current estimation:

Surface reflectance

| Source of Uncertainty | Surface BRF Uncertainty | | | |
|---|---|---|---|---|
| | GVR Band | | | |
| | **450 nm** | **650 nm** | **850 nm** | **1550 nm** |
| Individual GVR measurement | 2.7% | 2.4% | 2.5% | 2.2% |
| Scaling hyperspectral reference data | 2.6% | 1.7% | 2.8% | 3.3% |
| Total BRF uncertainty | **3.7%** | **2.9%** | **3.8%** | **4.0%** |

TOA Spectral Radiance

| RadCaTS TOA Spectral Radiance Uncertainty | | | |
|---|---|---|---|
| GVR Band | | | |
| 450 nm | 650 nm | 850 nm | 1550 nm |
| 4.1% | 3.1% | 4.1% | 4.1% |