Landsat-8 Sensor Performance and Data Quality Update

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LANDSAT-8

Topics

- Instrument Performance and Data Quality Summary
- Data quality improvements in works
  - GCP's
  - Other
- Hot Topic (thermal ghosting, that is)
- Sentinel-2 activities
- Special Issue

Takeaway

- Landsat-8, OLI and TIRS continue to have excellent performance on-orbit
  - Special journal issue in prep to document
- Only significant issue is TIRS ghosting
  - Issue affects band 11 to greatest effect; split window correction techniques to be avoided
  - Band 10 with simple implemented bias adjustment usable for many applications for typical Earth surface temperatures
  - Characterization effort using lunar scans and stray light modeling largely complete and consistent
  - Correction methodologies in development (Schott)
- GCP updates and improved geometric performance in selected parts of the world imminent

Instrument Performance and Data Quality Summary

- Landsat Cal/Val Team
- Geometric Performance Summary
- Radiometric Performance
  - Noise
  - Radiometric Stability
  - Artifacts
  - Pixel-to-Pixel Uniformity
  - Radiometric Accuracy
  - Summary

Landsat Calibration Validation Team

- USGS Earth Resources Observation and Science (EROS)
  - http://landsat.usgs.gov/
- NASA Goddard Space Flight Center (GSFC)
  - http://landsat.gsfc.nas
- NASA Jet Propulsion Laboratory (JPL)
  - http://www.jpl.nasa.gov/
- Rochester Institute of Technology (RIT)
  - http://www.cis.rit.edu/
- South Dakota State University (SDSU) Image Processing (IP) Laboratory
  - http://iplab2out.sdstate.edu/
- University of Arizona (UofA) Optical Sciences Laboratory
  - http://www.optics.arizona.edu/

Geometric Calibration Updates

- Initial on-orbit geometric cal was performed during commissioning
- Several additional on-orbit calibration updates have been issued since the end of commissioning
  - All are minor and none involve internal image geometry

Calibration Parameter	Date of Update	Effective Date	Magnitude	Reason for Update
OLI-to-S/C Alignment	07/01/2013	Launch	17 μrad (pitch)	Analysis of additional data from WRS-2 orbit
Ground Control Thresholds	08/21/2013	Launch	100 m -> 200 m	Allow scenes with GLS control errors > 100m to process to L1T
TIRS-to-OLI Alignment	09/27/2013	09/21/2013 – 09/30/2013	25 μrad (pitch)	Step change following late-September spacecraft anomaly
TIRS-to-OLI Alignment	11/27/2013	10/01/2013 -	10 μrad (pitch)	Account for recovery of TIRS alignment following anomaly
TIRS-to-OLI Alignment	11/27/2013	04/01/2013 - 09/20/2013	12 μrad (pitch)	Improve accuracy for period from arrival in WRS-2 orbit to spacecraft anomaly
OLI-to-S/C Alignment	02/03/2014	10/01/2013 -	13 μrad (roll)	Account for seasonal drift in alignment of both instruments to the spacecraft

L8 Geometric Performance Status

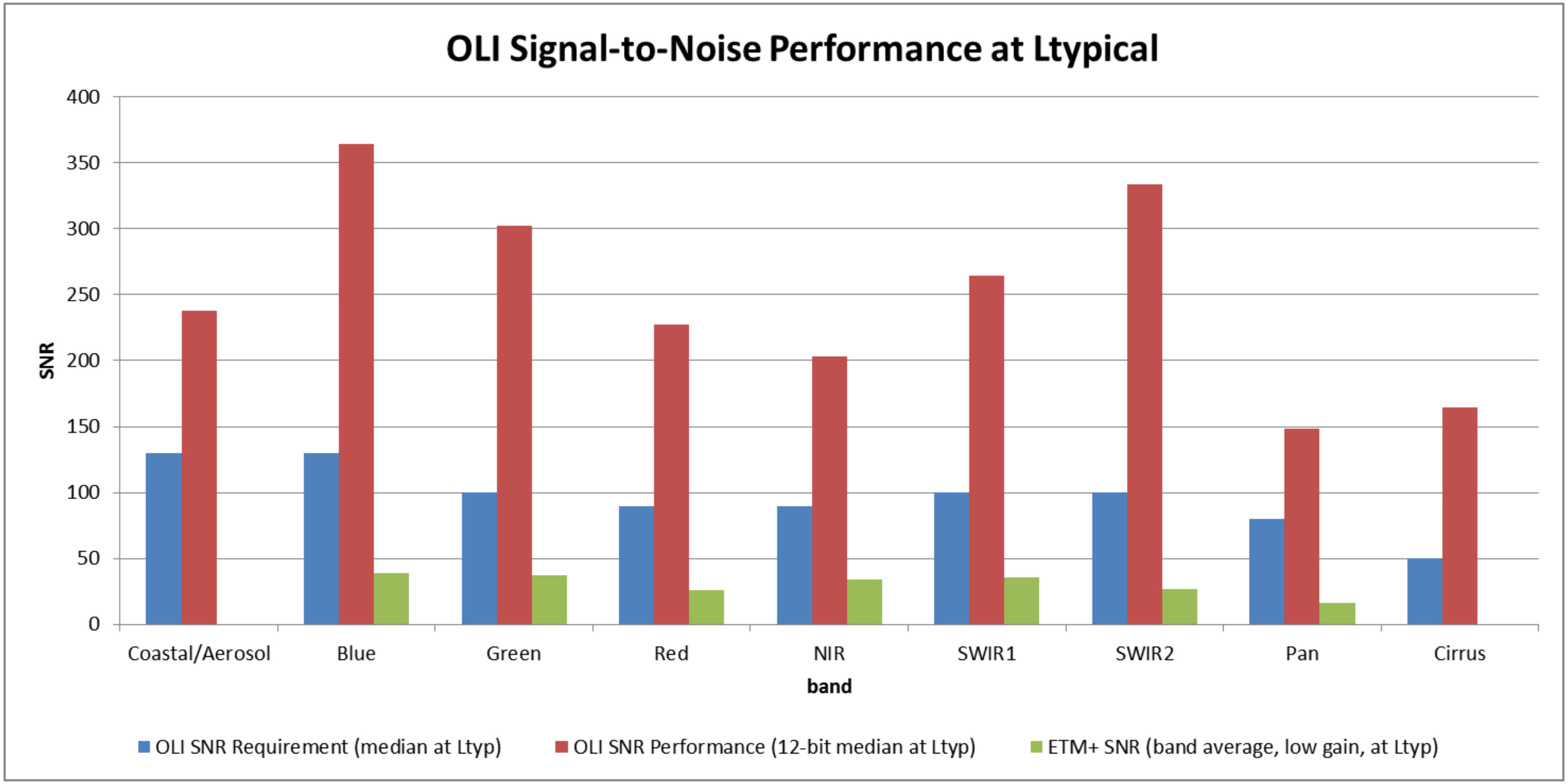
- Landsat 8 on-orbit geometric and spatial performance continues to be excellent, meeting all requirements
- Per pixel angle generation "enhanced" metadata has been turned over to the development team for inclusion in an upcoming IAS/LPGS release

Requirement	Measured Value	Required Value	Units	Margin
OLI Band Registration Accuracy (all bands)	4.15	< 4.5	meters (LE90)	7.8%
OLI Band Registration Accuracy (no cirrus)	3.40	< 4.5	meters (LE90)	25.3%
Absolute Geodetic Accuracy	18.1	< 65	meters (CE90)	72.2%
Relative Geodetic Accuracy	7.6	< 25	meters (CE90)	69.6%
Geometric (L1T) Accuracy	11.7	< 12	meters (CE90)	2.5%
OLI Edge Slope	0.02966	> 0.027	1/meters	9.9%
TIRS Band Registration Accuracy	7.4	< 18	meters (LE90)	58.9%
TIRS-to-OLI Registration Accuracy	21.0	< 30	meters (LE90)	30.0%

Radiometric Calibration Updates

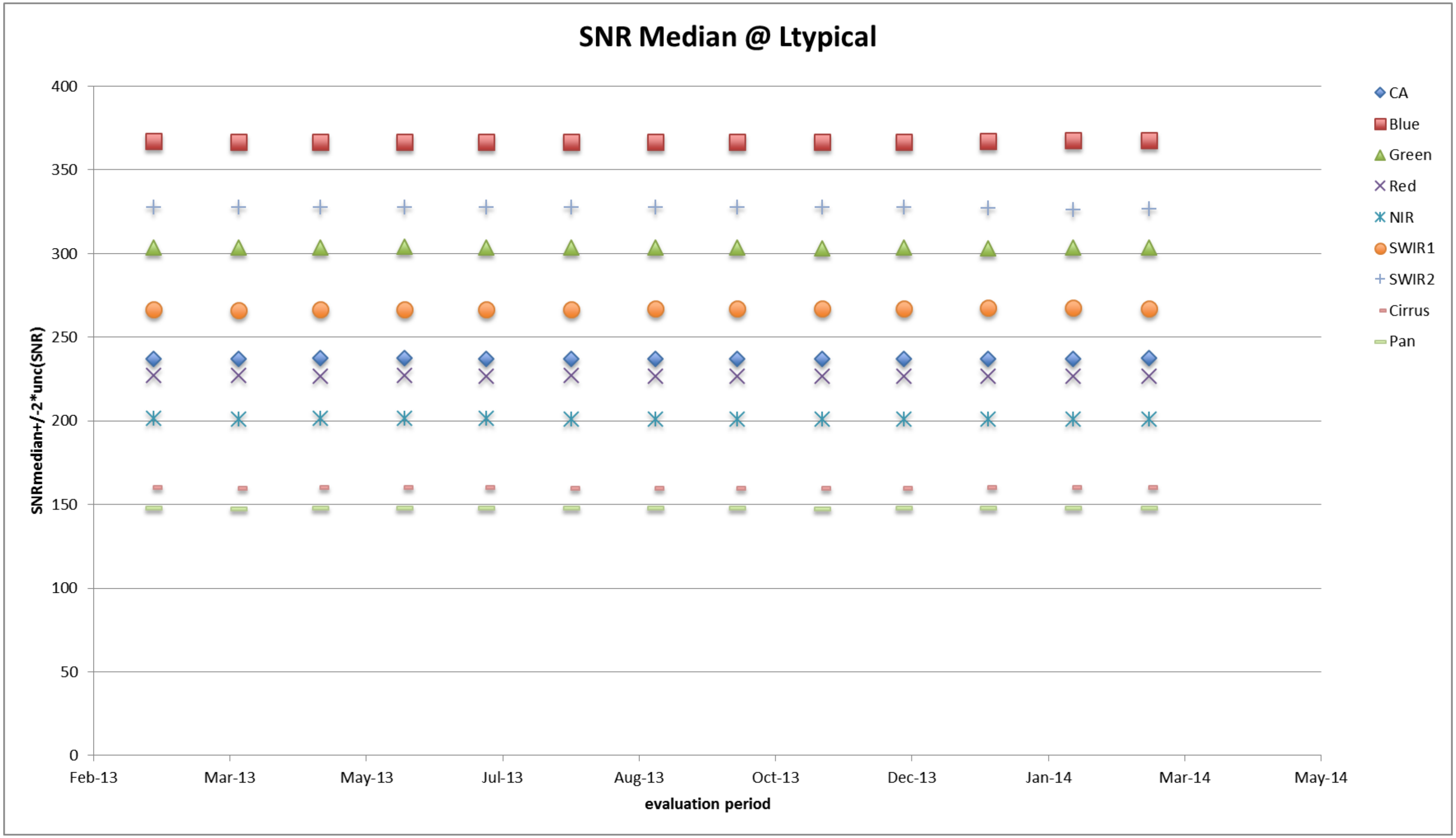
Calibration Parameter	Date of Update	Effective Date	Magnitude	Reason for Update
OLI Relative Gains – all but cirrus band	08/21/2013	08/21/2013		Improve image uniformity
OLI Relative Gains – edge detectors	11/27/2013	11/27/2013		Improve image striping
TIRS RLUT	02/03/2014	Launch	Band 10 -0.29 Band 11 -0.51	Average radiance correction for TIRS stray light
Reflectance to Radiance Conversion Coefficients	02/03/2014	Launch	0 - 0.8%, except 7% cirrus	Correct for insufficient precision in original coefficients
OLI Absolute Radiance Gains	02/03/2014	Launch	-2% - +2%	Reanalysis of pre-launch data
OLI Relative Gains – all bands	02/03/2014	Launch		Improve image uniformity
OLI Linearization RLUT	02/03/2014	Launch		Reanalysis of pre-launch data; revision to linearization treatment
OLI Relative Gains	4/1/2014 7/1/2014	4/1/2014 7/1/2014		Correction for drifts in relative gains; intend to do on quarterly basis in future and back to launch on next reprocessing

Noise: OLI SNR



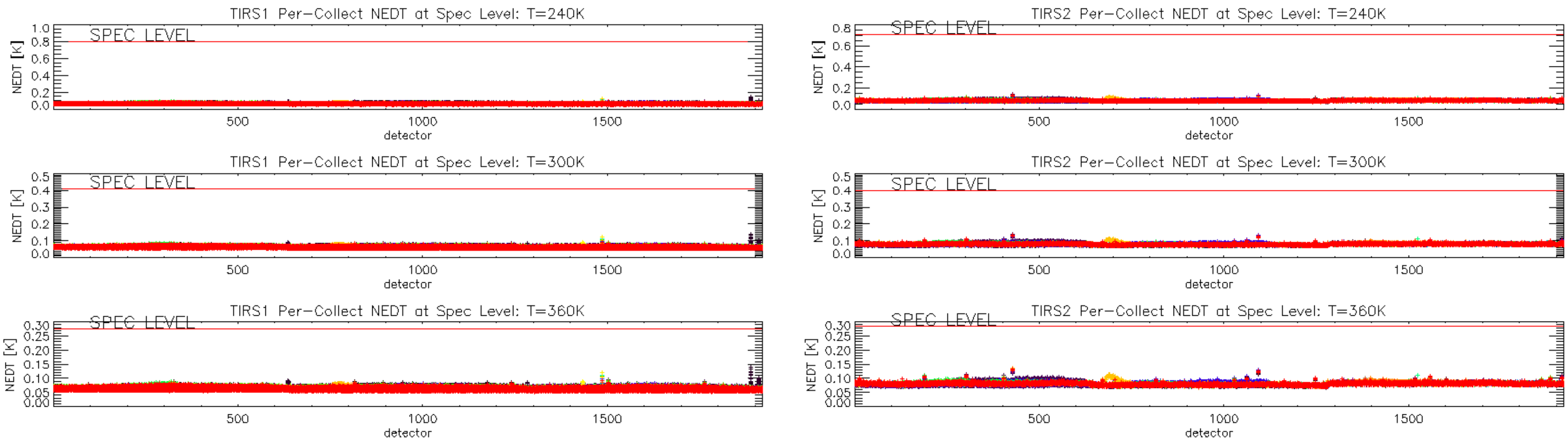
OLI SNR consistent with pre-launch at typically 2-3x better than requirements; 8x better than heritage

SNR Stability



Noise: TIRS NEΔT

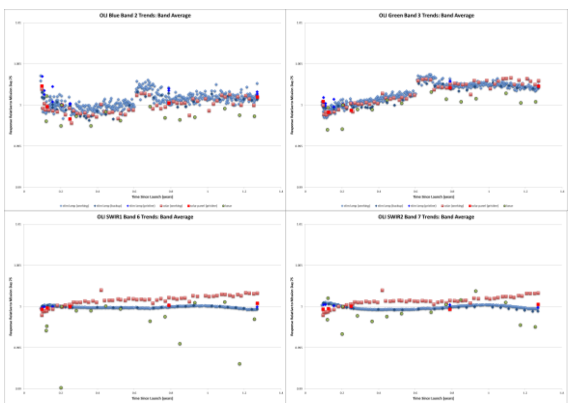
- All TIRS detectors have similar NEΔT
- Band averages:
  - B10: 0.048
  - B11: 0.052

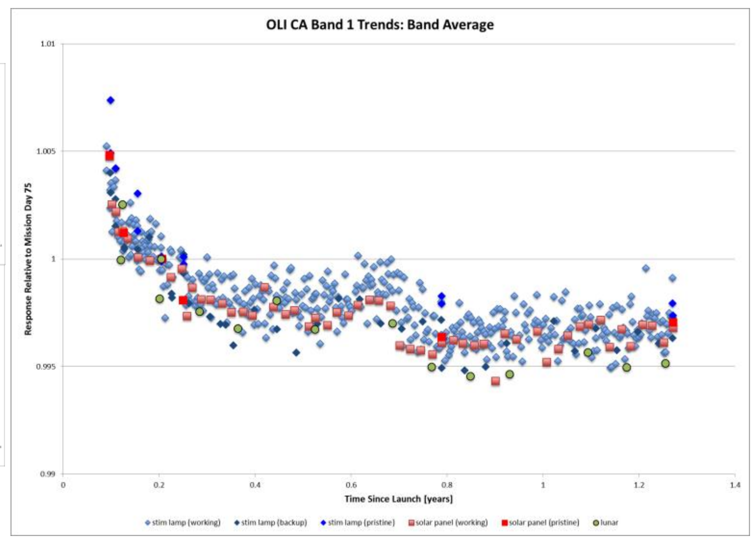


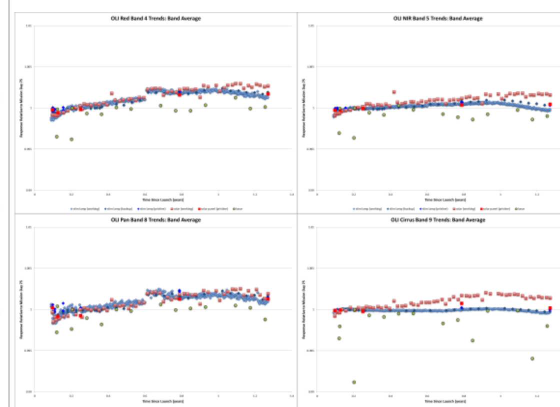
Noise is about 8x better than requirements; about 4x better than heritage

OLI Radiometric Stability

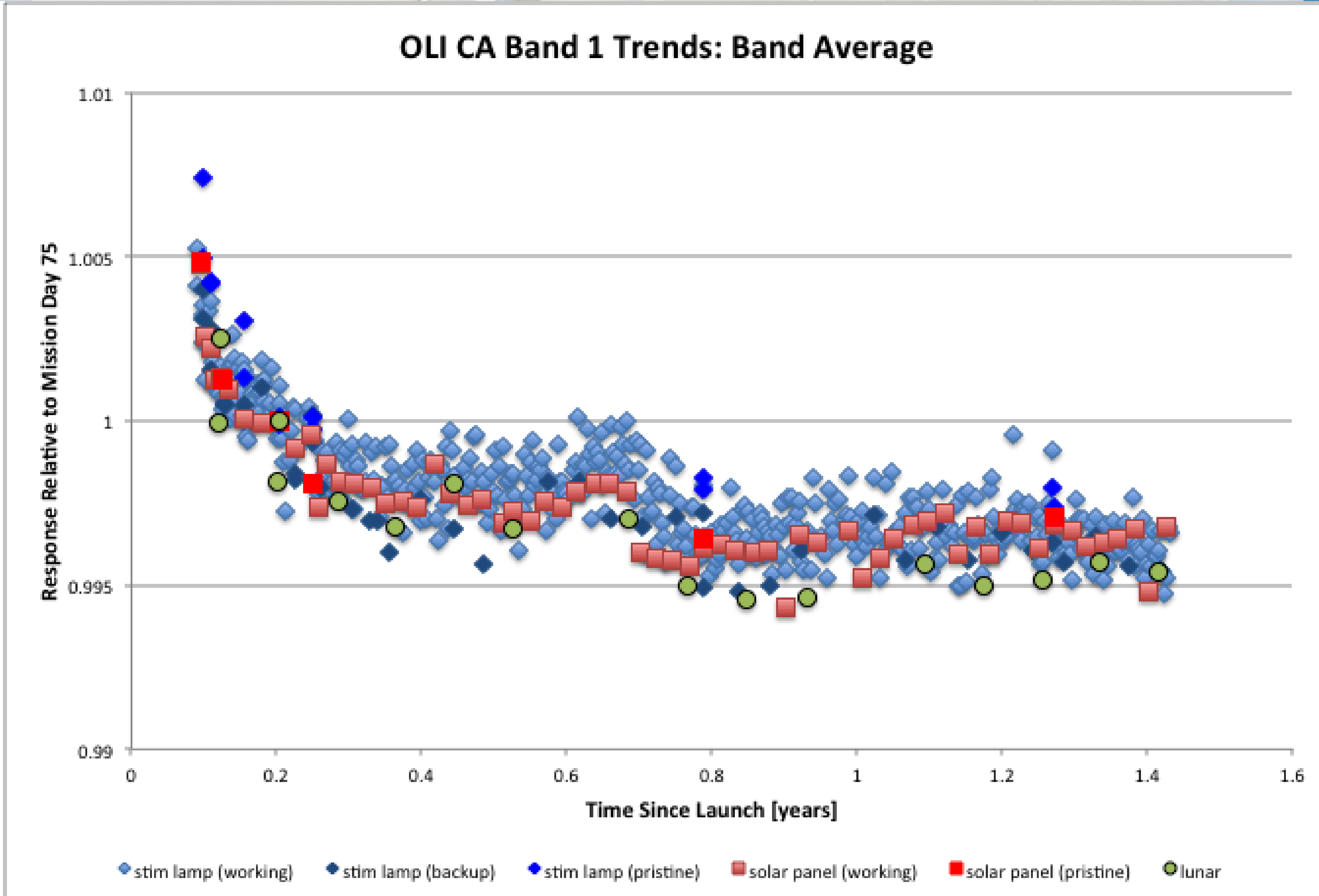
- Around orbit [measured with stim lamps taken at different positions in the orbit]
  - No orbital position sensitivity observed
- Trends less than 0.5% over the first 60 days, i.e., no significant contamination apparent
  - Over mission lifetime, only CA band shows a trend (0.8% degradation) larger than the variation between the calibration sources (~0.2%)





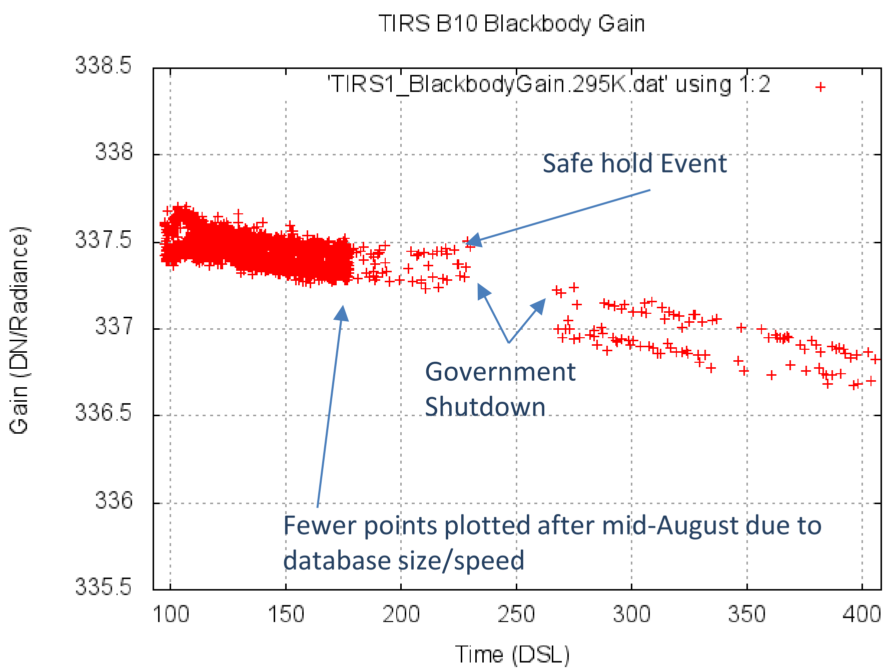


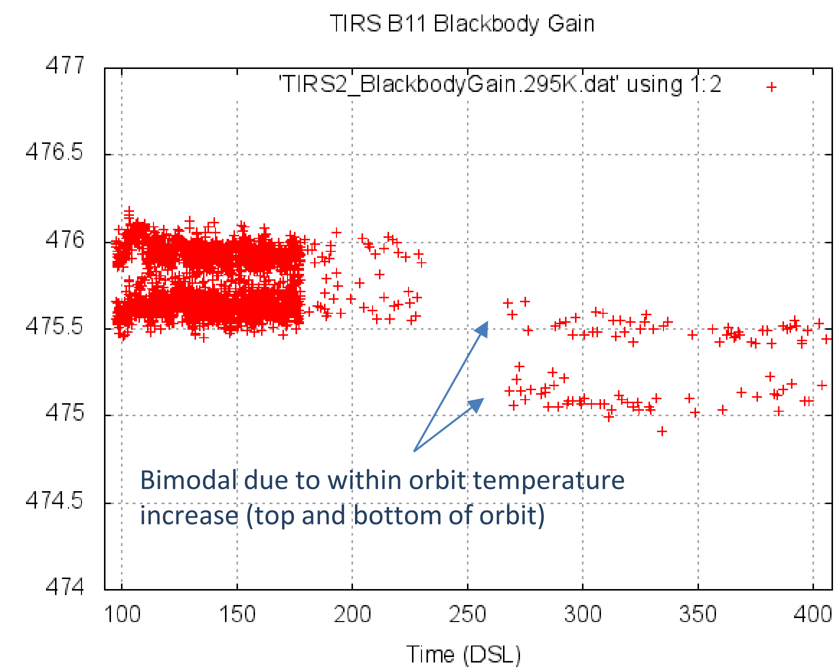
Coastal Aerosol Band Stability



TIRS Radiometric Stability

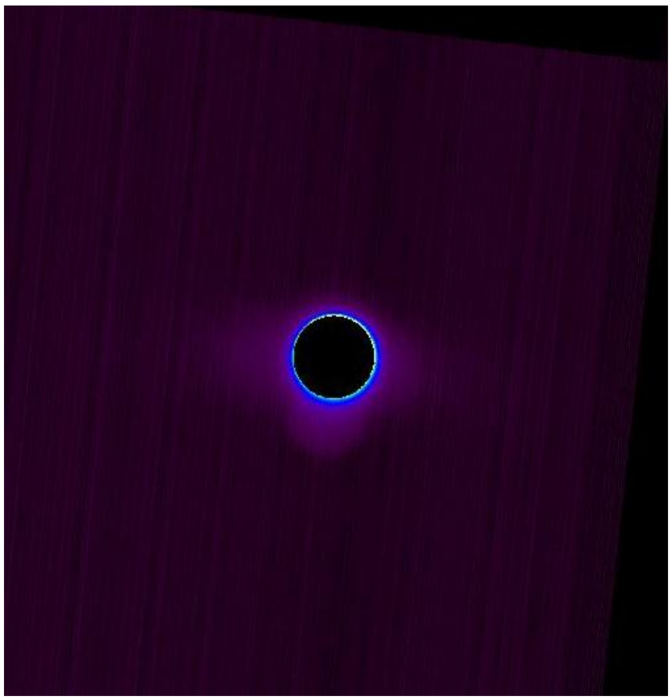
- Within Interval (between calibrations)
  - Typically <0.1% (1 sigma) over 40 minutes; requirement is 0.7% (1 sigma)
  - Similar performance over 1 ½ orbits



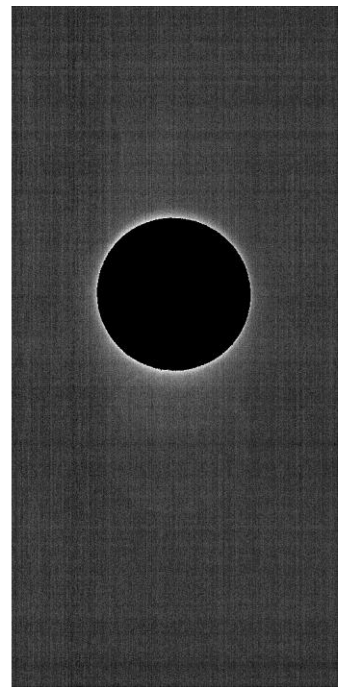


Artifacts

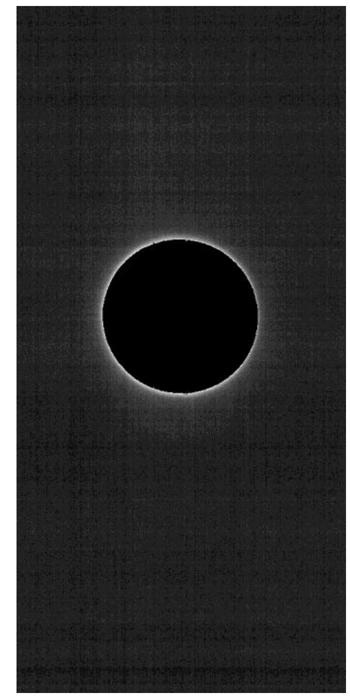
- No coherent (a.k.a. pattern noise) observed in either instrument
- Spatial artifacts (i.e., ghosting, crosstalk) within requirements on both instruments



TIRS band 10 – weak ghost ~0.1% of lunar signal



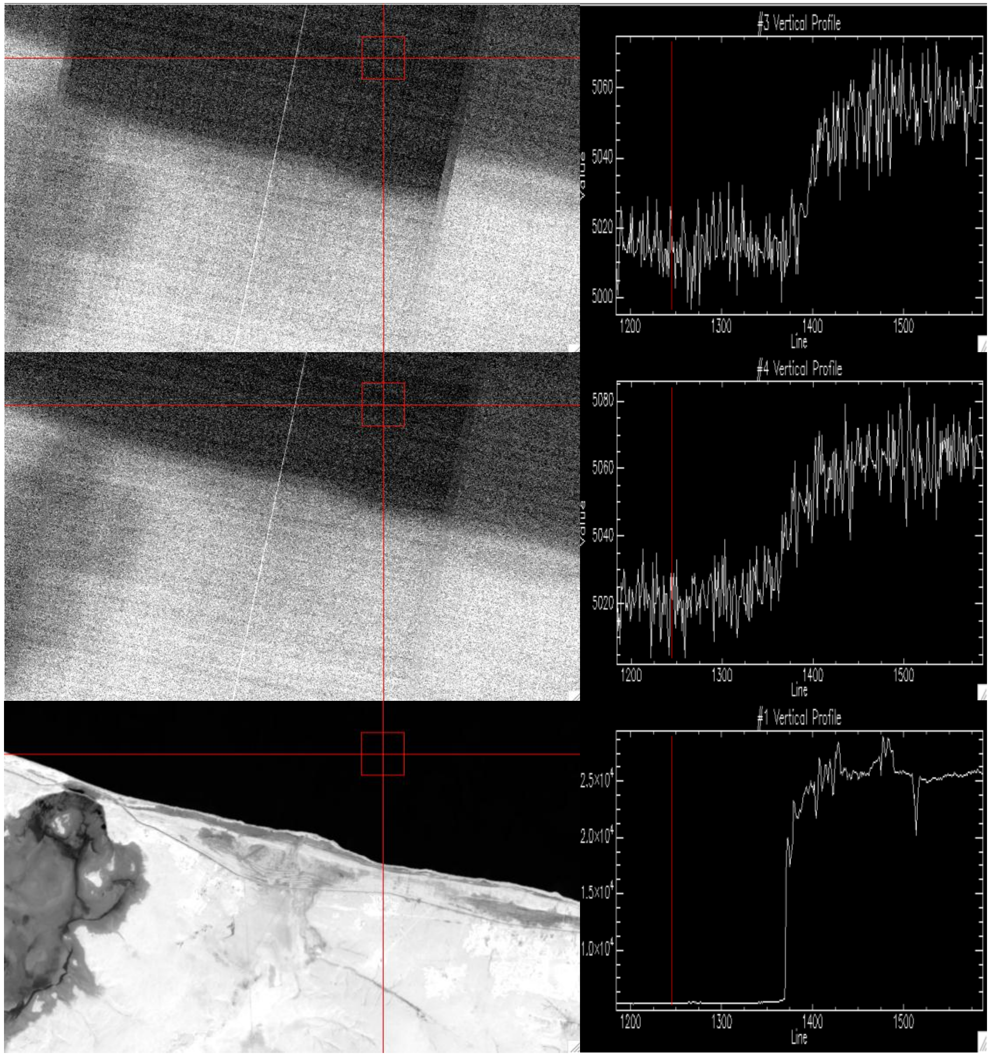
OLI Band 9 (Cirrus)



OLI Band 6 (SWIR 1)

very weak ghost / halo

Artifacts: Cirrus band cross-talk

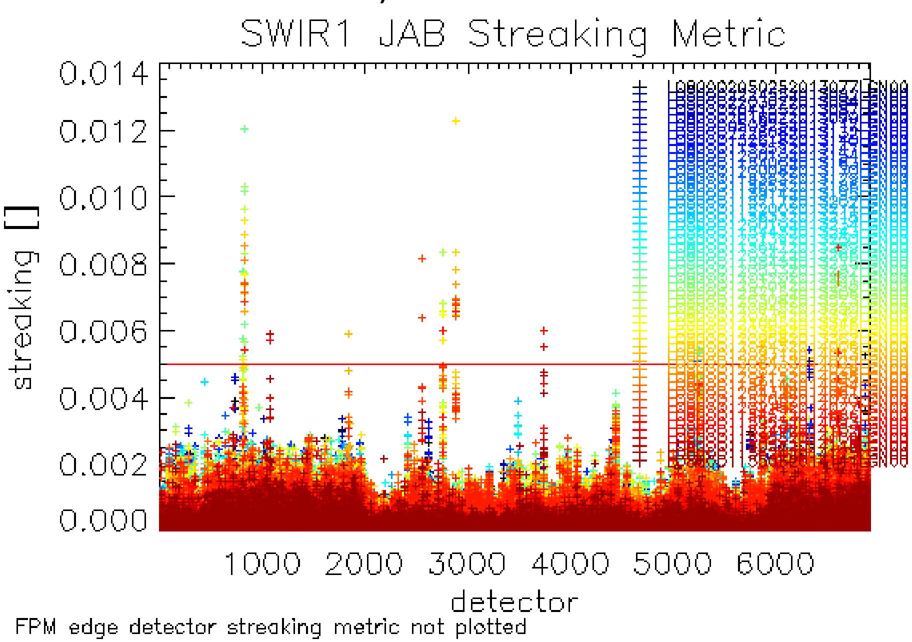


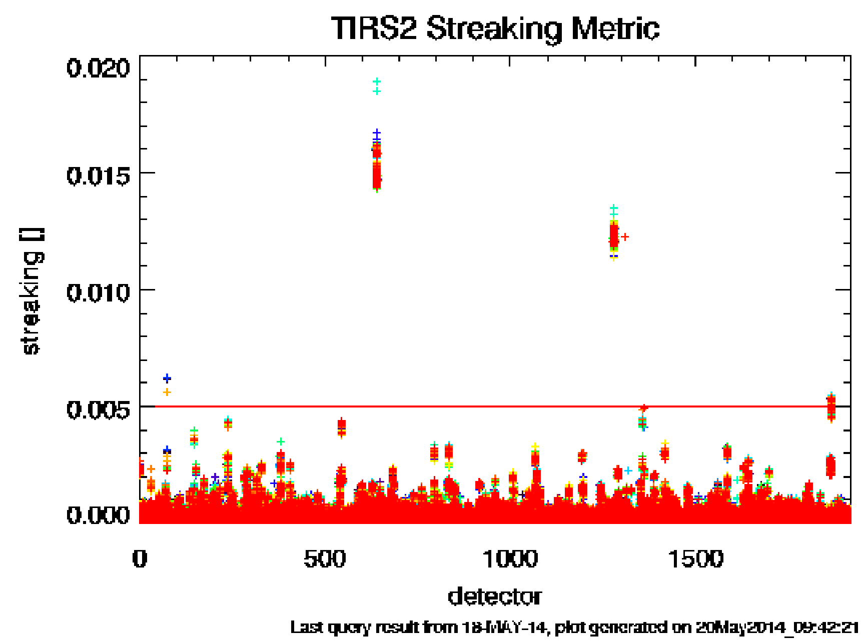
- **Original Cirrus Band Image**
- **Cirrus Band Image**
  - Geometrically processed as SWIR 1 band
  - Land-Water delta ~40 DN in QCAL space
- **SWIR 1 Band Image**
  - Land-Water delta ~20,000 DN in QCAL space

~0.2% of SWIR 1 signal “leaks” into Cirrus band; weakly visible over land targets with moist atmosphere

Pixel-to-Pixel Uniformity – Streaking

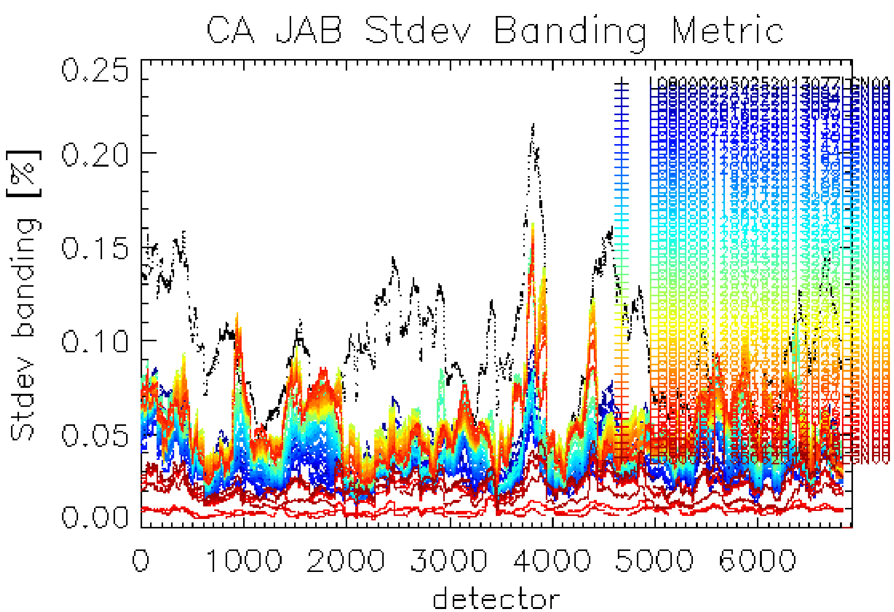
- Streaking is uncorrected individual detector-to-detector variation
  - Requirement is <0.5% [1% for band 8]; limited number of failing detectors allowed in out-of-spec bin (99.75% of detectors in a band must be within spec)
- Most bands meet streaking requirements with current calibration parameters w/o excluding any detectors
  - OLI: occasionally some SWIR detectors (all bands in spec after allowed exclusions)
  - TIRS: few detectors fail, mainly in band 11, though not real streaking (in spec after allowed exclusion)

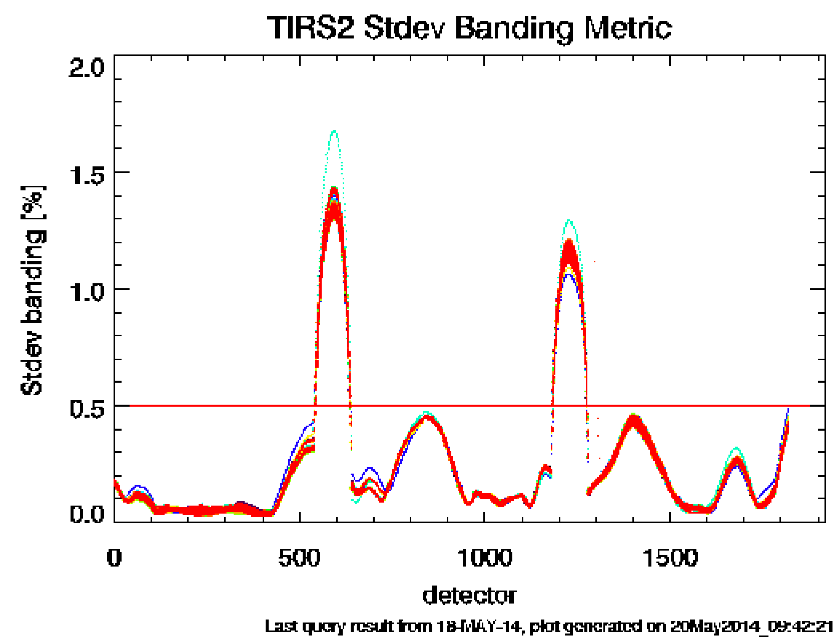




Pixel-to-Pixel Uniformity – Banding

- Banding, under this definition, is the standard deviation across a 100-pixel wide moving window
  - Requirement is 0.25% for OLI and 0.5% for TIRS
  - Usually associated with radiometric discontinuities between adjacent Focal Plane Modules or Sensor Chip Assemblies
- Most bands meet this banding requirement
  - OLI: All bands exceed this requirement
  - TIRS: Does not consistently meet requirement at either SCA boundary



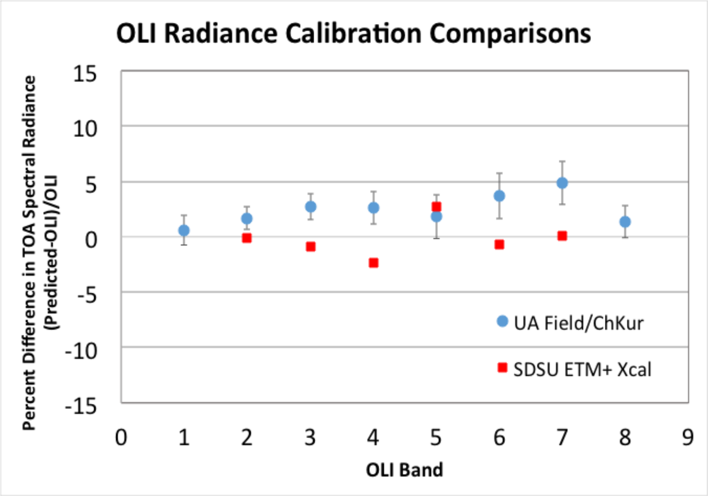


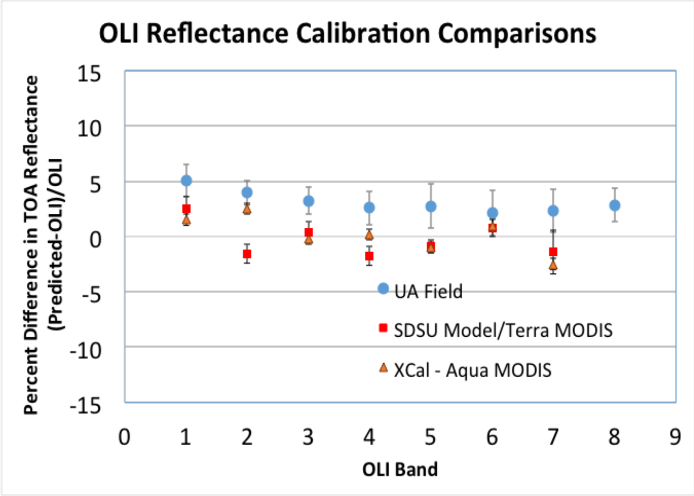
Radiometric Accuracy - Radiance

- Across primary range of radiance levels:
  - OLI absolute radiance uncertainty requirement is < 5% (1 sigma)
  - TIRS absolute radiance uncertainty requirement is < 2% (1 sigma)
- Requirement is met prior to launch via sources traceable to NIST
- On-orbit confirmation involves ground reflectance or temperature measurements and atmospheric propagation or comparison to other sensors, which typically have higher uncertainty, so process typically takes time to tie down. SWIR bands still have significant solar irradiance uncertainty (~4%)
- Ground "vicarious" teams have been in place and will continue to be in place to provide needed measurements
- Between some very dedicated ground teams, well developed techniques and cooperative weather, we have better information at this point than in any previous mission

Radiometric Accuracy - Reflective

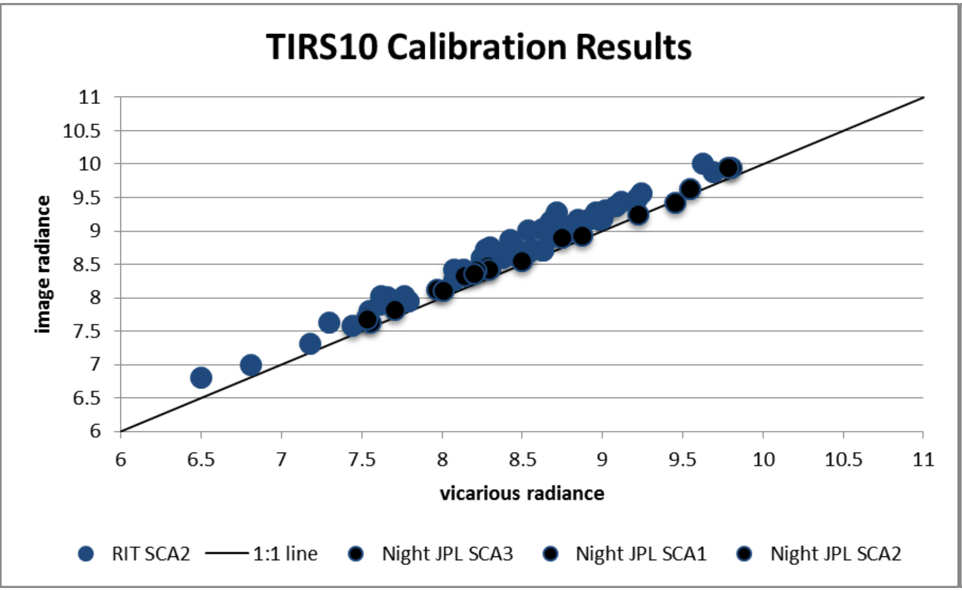
- Our primary reflective band vicarious cal team (University of Arizona) has obtained 10 good calibrations of OLI with excellent reproducibility (circa 1% one sigma)
- Initial analysis shows good agreement to operational OLI radiance calibration (within ~3%, depending which solar spectrum is used)
- Initial analysis of radiance cross calibration with Landsat 7 ETM+ (South Dakota State University) also shows consistent results within 2%
- Reflectance calibration comparison results similar, but show bias (low) relative to Arizona measurements

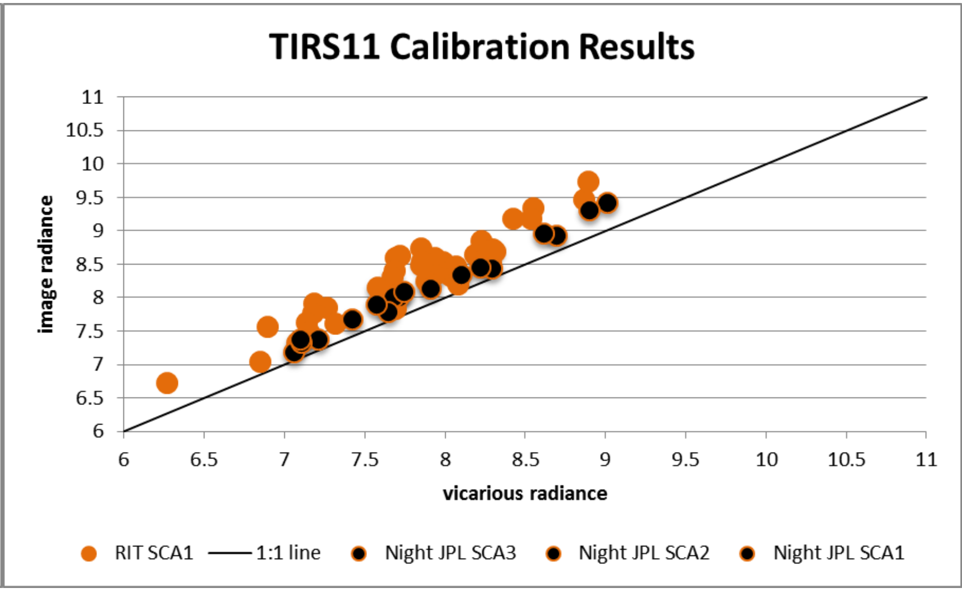




TIRS Radiometric Accuracy

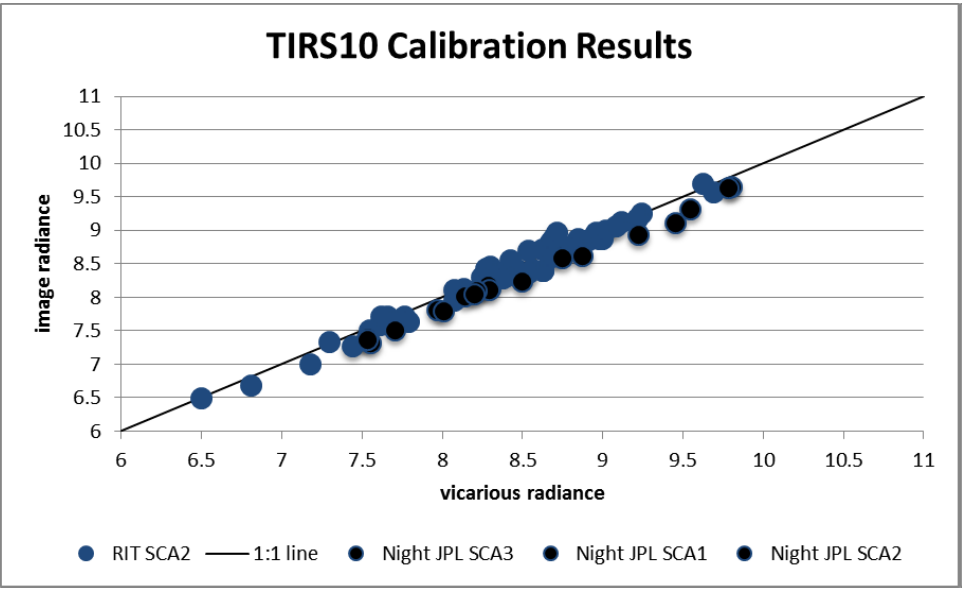
- Thermal calibration teams (RIT and JPL) acquired data from Lake Tahoe, Salton Sea, numerous ocean and Great Lakes buoy data
- Offset determined based on initial calibration, likely due to stray light

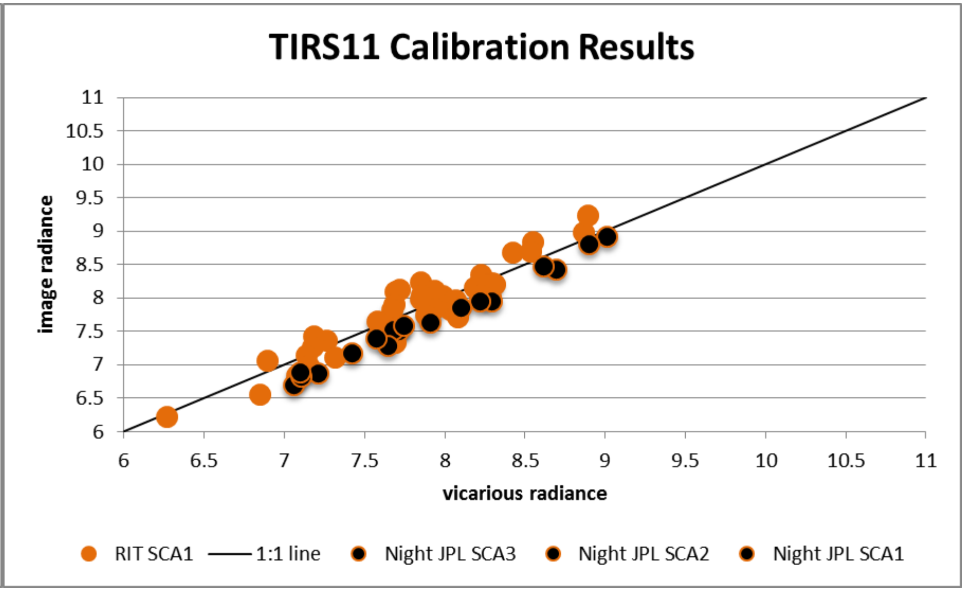




TIRS Radiometric Accuracy

- Current accuracy after offset correction:
  - B10: 1.2% 1σ
  - B11: 2.2% 1σ





OLI Radiometric Performance Summary

Requirement	Measured Value (worst case)	Required Value	Units	Margin (worst case)	Requirement Reference
OLI Ghosting	meets	varies	percent	----	OLI-788
OLI Absolute Radiance Uncertainty	4*	<5	percent	20%*	OLI-792
OLI Absolute Reflectance Uncertainty	reanalysis	<3	percent	TBD	OLI-792
OLI Median SNR Ltypical	meets	varies	-	83%	OLI-875
OLI Median SNR Lhigh	meets	varies	-	87%	OLI-875
OLI Uniformity Full Field of View	0.35	0.5	percent	30%	OLI-951
OLI Uniformity Banding RMS	0.8	1	percent	20%	OLI-955
OLI Uniformity Banding Stdev	0.15	0.25	percent	40%	OLI-962
OLI Uniformity Streaking	0.5***	0.5, 1	percent	---***	OLI-973
OLI Coherent Noise	meets	<equation	---	----	OLI-761
OLI Saturation Radiances	meets	varies	W/m^2 sr µm	8%	OLI-996
OLI 16-day Radiometric Stability	0.23****	1	Percent (2 sigma)	77%+	OLI-1001
OLI 60 second Radiometric Stability	0.1	0.5	Percent (2 sigma)	80%	OLI-1003
OLI Inoperable Detectors	0	<0.1	Percent	100%	OLI-1013
OLI Out-of-Spec Detectors	0.14	<0.25	Percent	44%	OLI-1020

* Band 7 compliance depends on solar spectrum used
*** Few intermittently streaky detectors above requirement level placed in out-of-spec bin as allowed
**** 60 days

TIRS Radiometric Performance Summary

- TIRS product uniformity is current focus of CVT and TIRS team analyses. Significant improvements to the uniformity are expected with updated parameters and/or algorithms

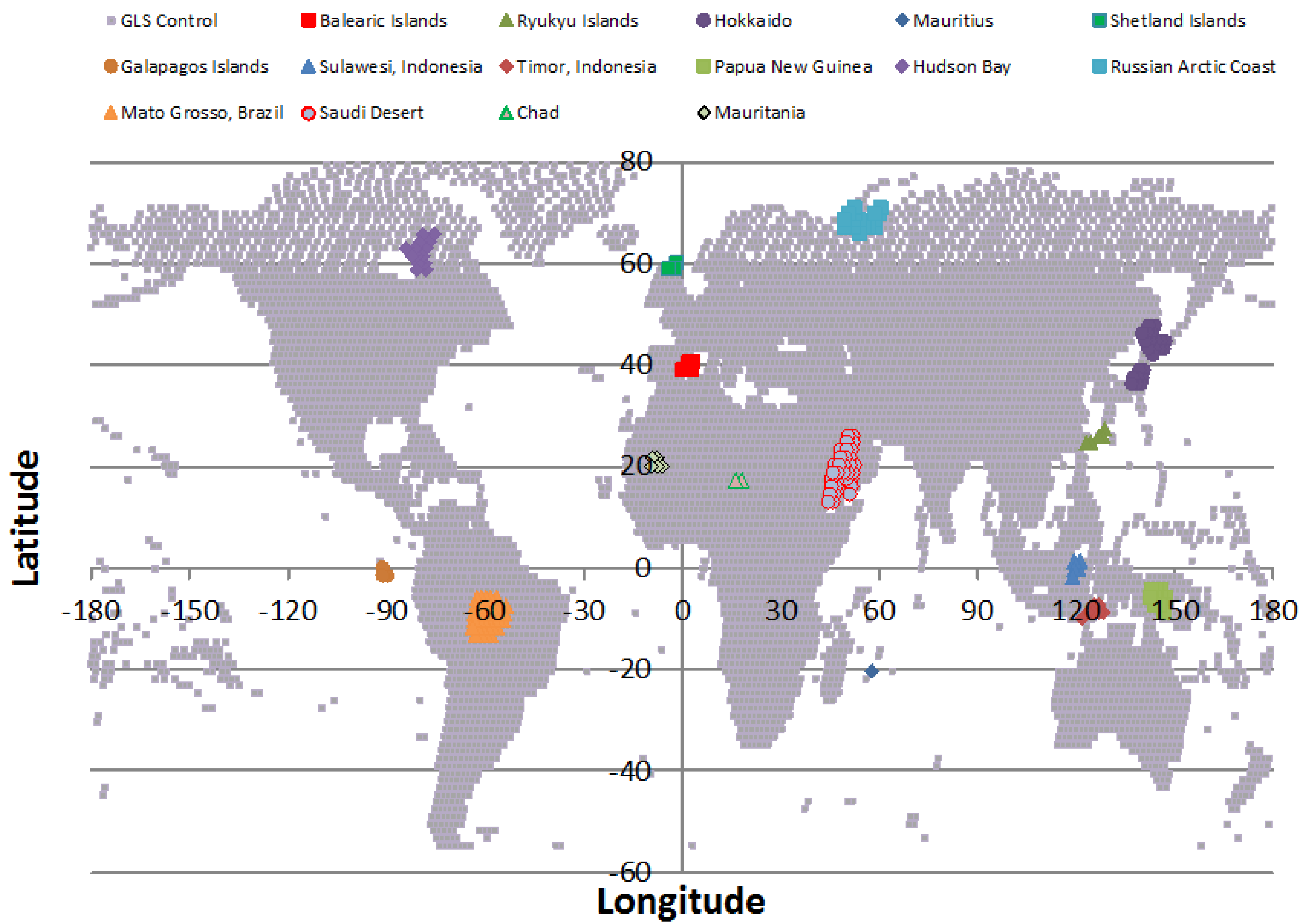
Requirement	**Measured Value (worst case)**	**Required Value**	**Units**	**Margin (worst case)**	**Requirement Reference**
TIRS Ghosting	meets	varies	percent	----	TIRS-403
TIRS Absolute Radiance Uncertainty	6+	2	percent	----*	TIRS-427
TIRS NEDT (@300K)	0.05	0.4	K	80%	TIRS-441
TIRS Uniformity Full Field of View	1	0.5	percent	----*	TIRS-503
TIRS Uniformity Banding RMS	1	0.5	percent	----*	TIRS-507
TIRS Uniformity Banding Stdev	1	0.5	percent	----*	TIRS-514
TIRS Uniformity Streaking	0.4	0.5	percent	20%	TIRS-525
TIRS Coherent Noise	meets	<equation	---	----	TIRS-532
TIRS Saturation Radiances	28.4, 19.2	20.5, 17.8	W/m^2 sr mm	8%	TIRS-545
TIRS 40 minute Radiometric Stability	0.1	0.7	percent (1 sigma)	86%	TIRS-547
TIRS Inoperable Detectors	0	<0.1	percent	----	TIRS-550
TIRS Out-of-Spec Detectors	0.21	<0.25	percent	16%	TIRS-555

* Due to stray light; Cal/Val team working with TIRS team on potential correction algorithm

Landsat GCP Improvement Plan

- The geolocation accuracy of L8 has identified areas where the GLS-derived GCP library is deficient
  - Areas with repeatable large offsets are being re-triangulated
- Triangulation updates are proceeding in three phases:
  - Phase 1 – Fifteen high priority areas with largest offsets
  - Phase 2 – Remaining low latitude areas
  - Phase 3 – High latitude areas
  - Updated GCPs will be released as each phase is completed
- Some regions also exhibit significant temporal and/or seasonal changes that degrade GCP performance
  - Extract additional seasonal or multi-temporal chips as needed
- The existing control library image chips are all Landsat 7 ETM+ (8-bit) circa 2000

Phase 1 Block Locations



Landsat GCP Improvement Status

- Landsat GCP improvement efforts are ongoing
  - Completed first phase with the 15 most problematic areas
    - New GCPs will enter production for all Landsat missions in September with the next IAS/LPGS release
    - The Landsat web site lists the 171 updated WRS path/rows
  - Subsequent phases will address remaining areas
- New circa 2013-2014 OLI image chips will be extracted for the Landsat GCP library
  - Includes examining temporally/seasonally variable areas as candidates for the extraction of multi-date GCP chips
- Once GCP updates are complete we will evaluate DEM data alternatives (e.g., ASTER, WorldDEM) for high latitude areas lacking SRTM data

TIRS Ghosting Investigation

Banding has been observed in Earth imagery that varies from scene to scene

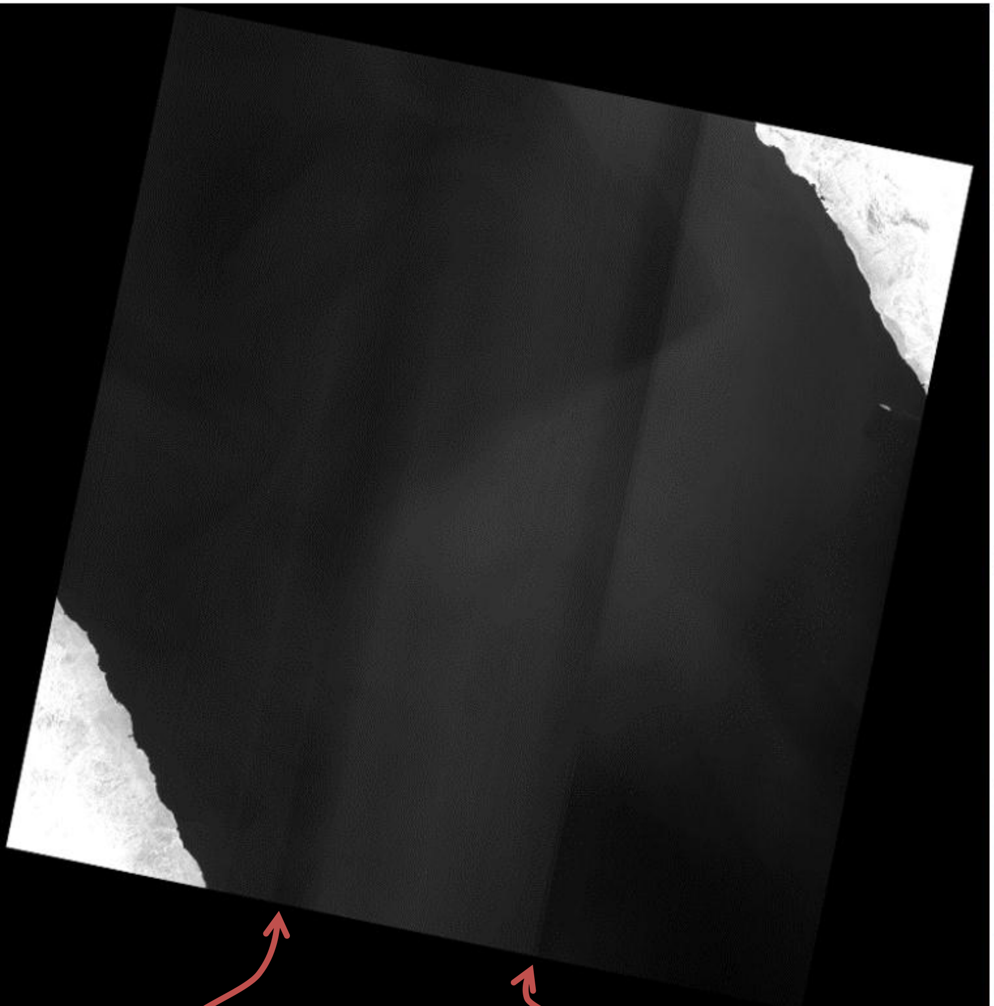
- Suspect stray light from outside the FOV is adding an addition “ghost” signal onto the detectors
- Ghost signal varies per detector depending on the content of the surrounding scene

Absolute calibration error between TIRS and vicarious measurements

- Seems to vary with season
- Implemented bias correction to account for the avg. error in scenes during N. hemisphere growing season

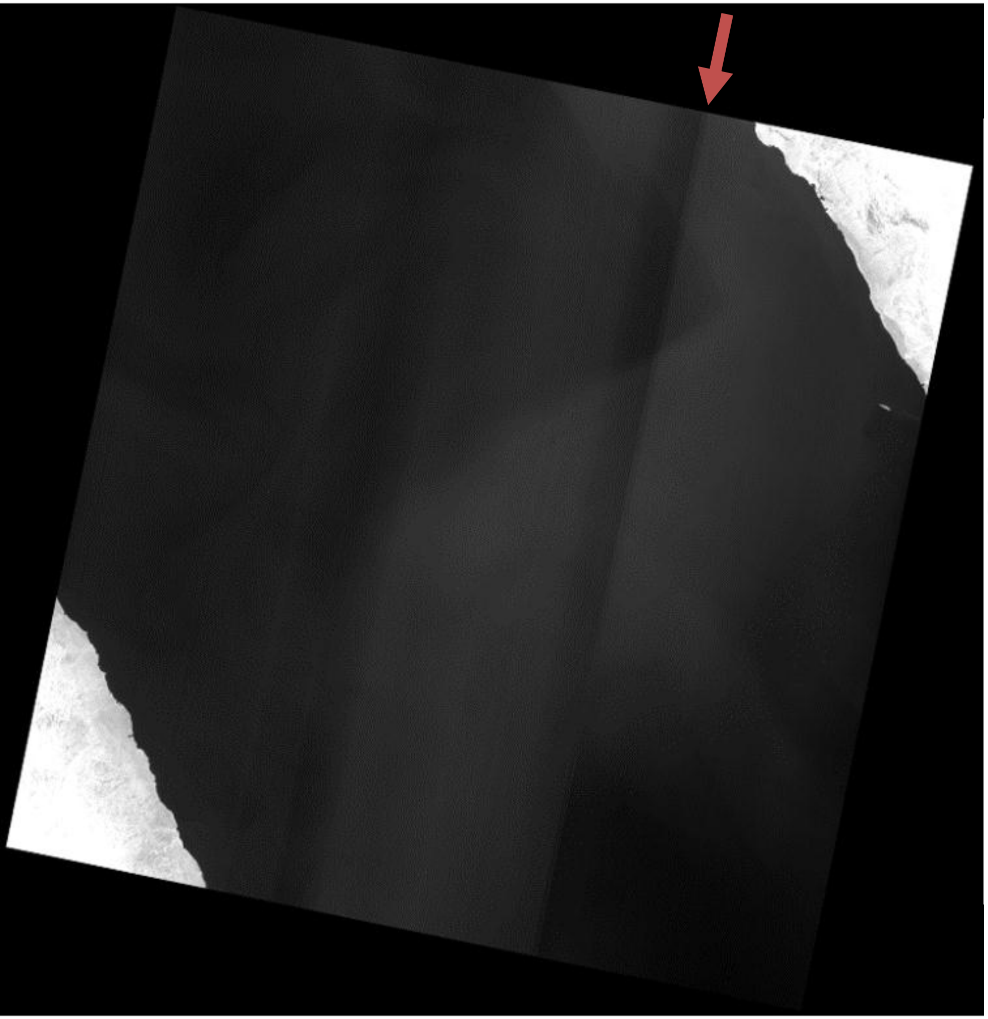
Rea Sea provides a good representative example of the banding artifacts

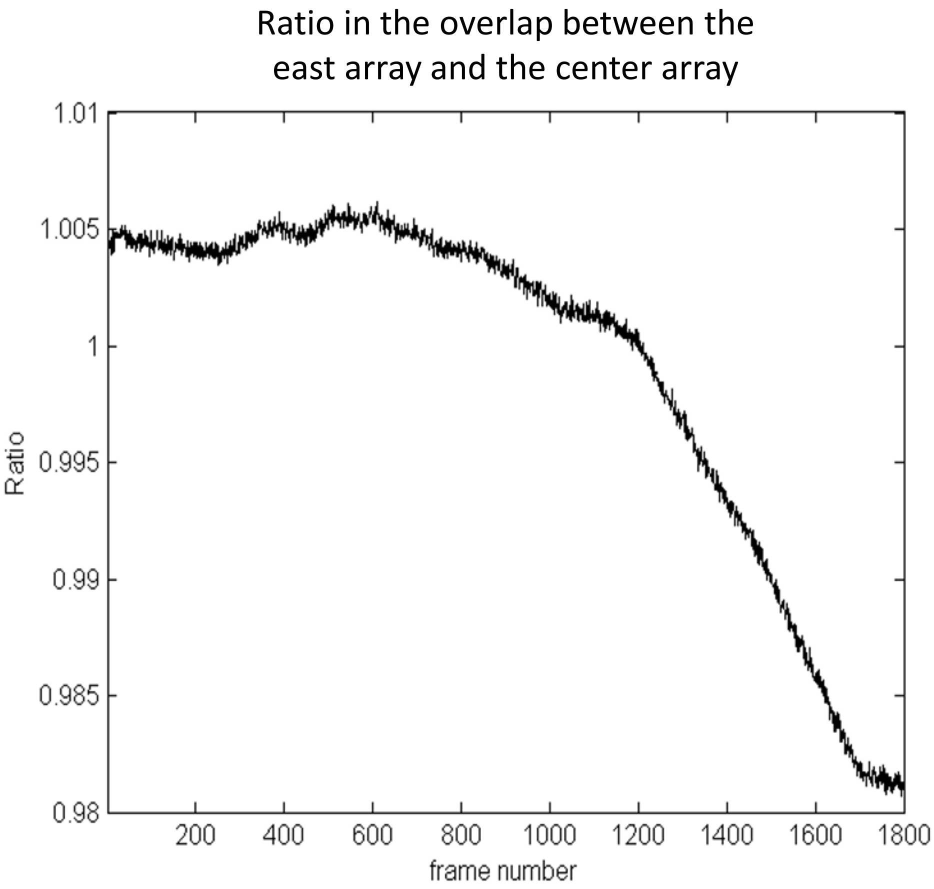
Red Sea (Path/Row: 173/41)



Banding observed especially near the boundary between adjacent focal plane arrays

Banding varies in the along-track direction



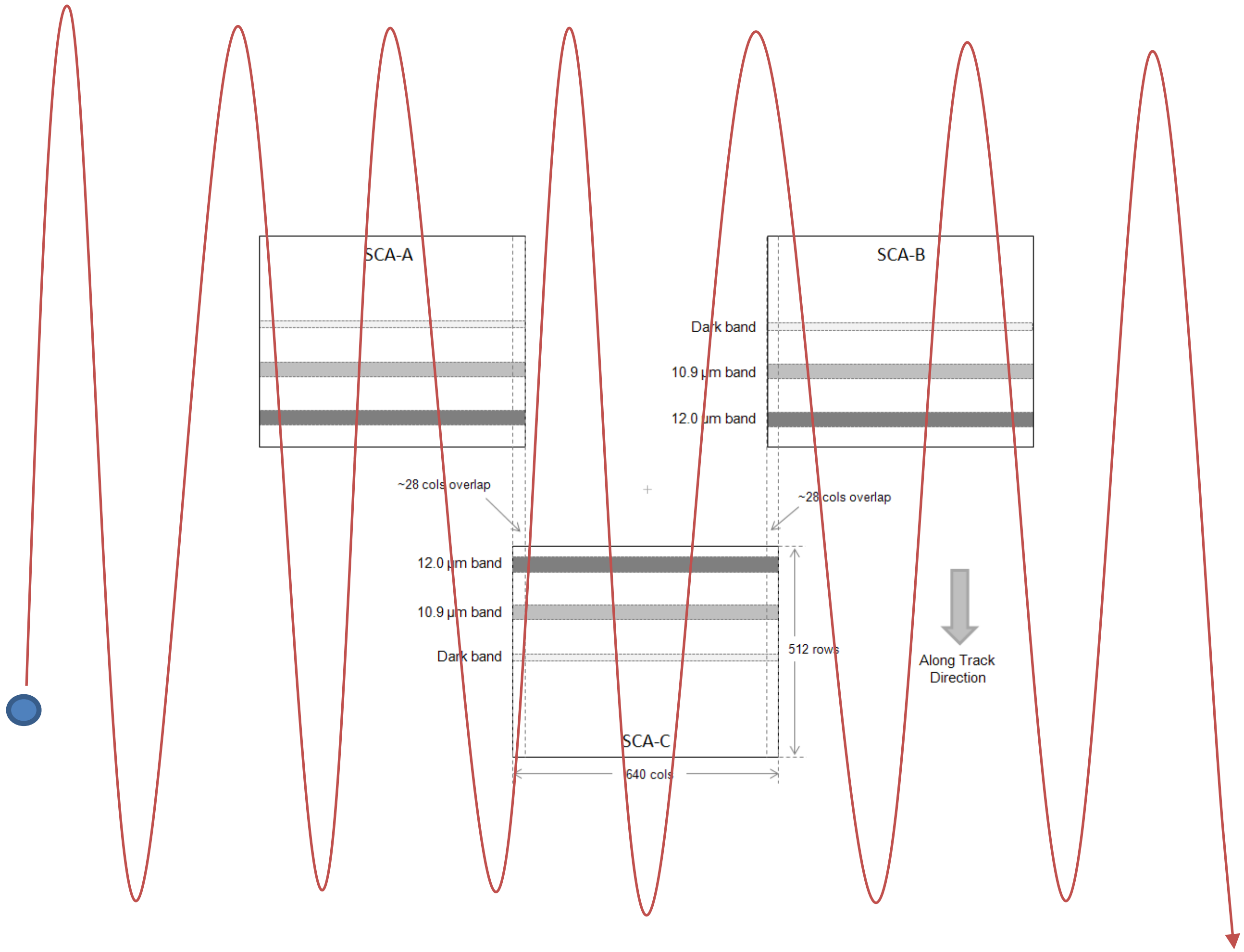


- Overlap ratio varies in the along-track direction (changes with push-broom frame number)
- Not the result of a mis-calibration of the detector since the effect changes with frame number & all indications show instrument is stable

Lunar scans

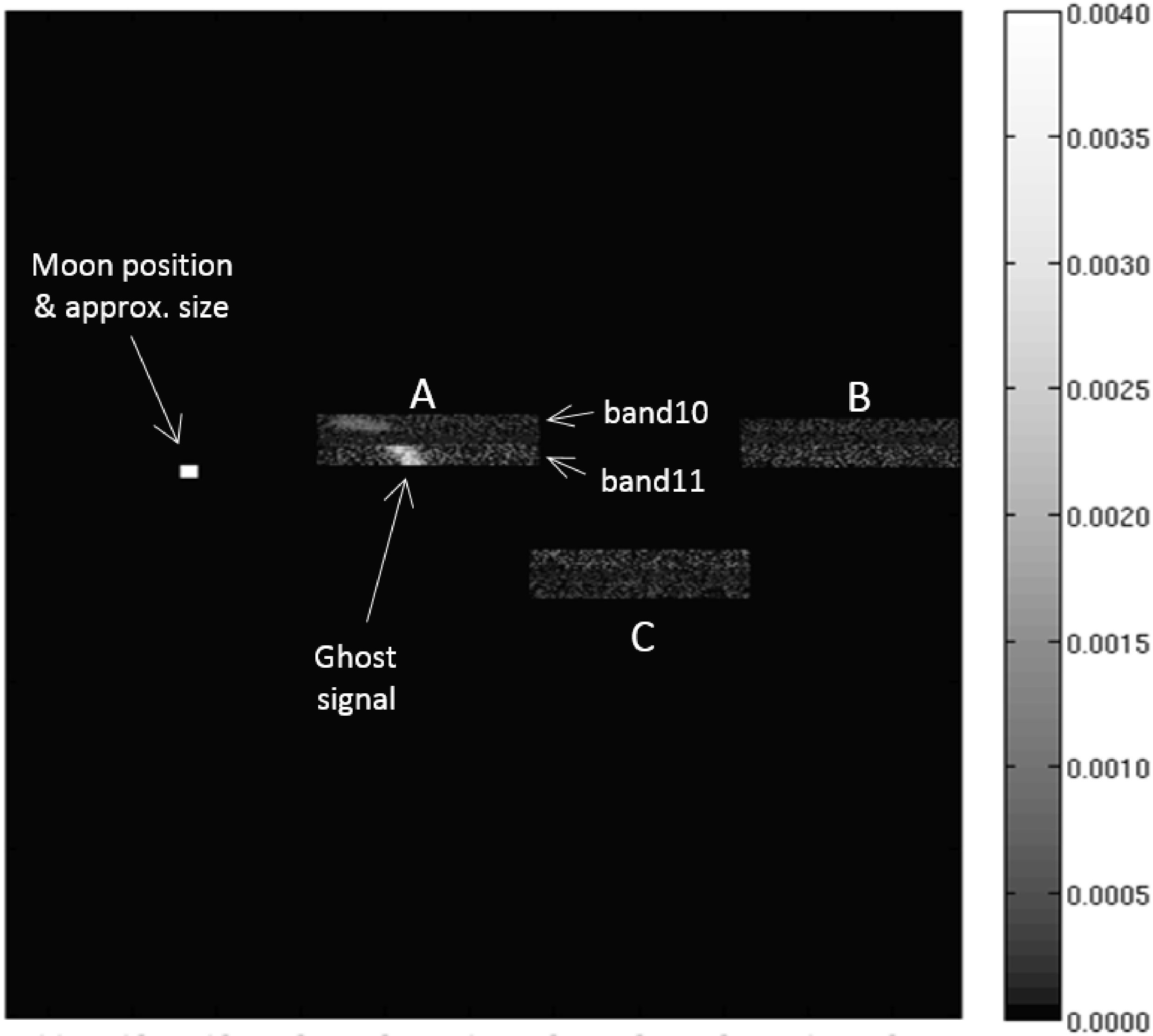
- Investigate stray light theory by slewing the observatory to raster-scan the moon outside the TIRS FOV
- Switch focal plane to the "transmit-all" mode to read out the entire array (acts like a framing camera)
- Record any ghost signals on the arrays when the moon is outside the direct FOV

Raster-scan the moon around the FOV



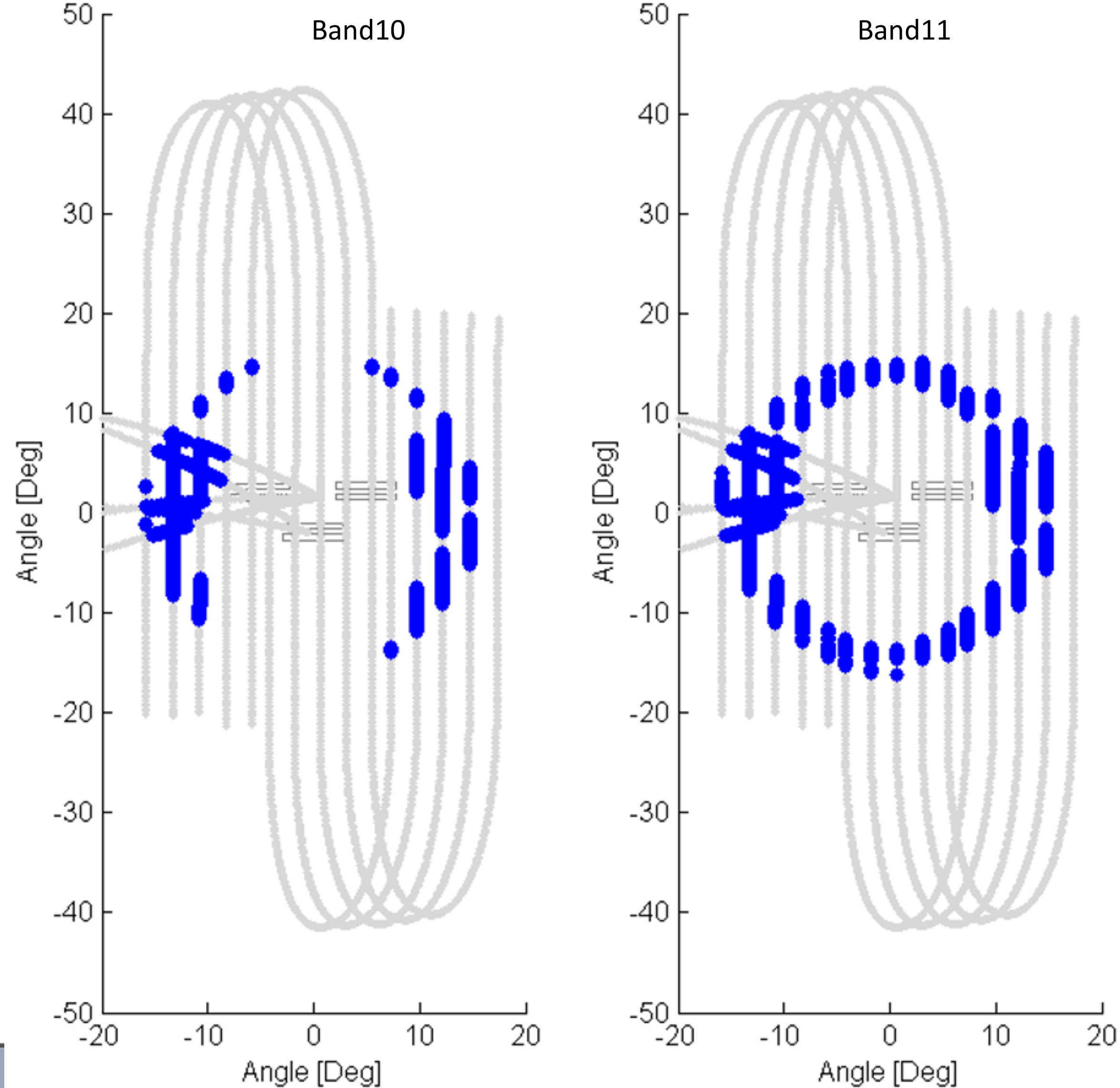
Lunar scans

- Lunar position relative to boresight known from observatory pointing telemetry
- Signal on arrays expressed as a fraction of the direct moon signal (when the moon is directly imaged)



Lunar scans

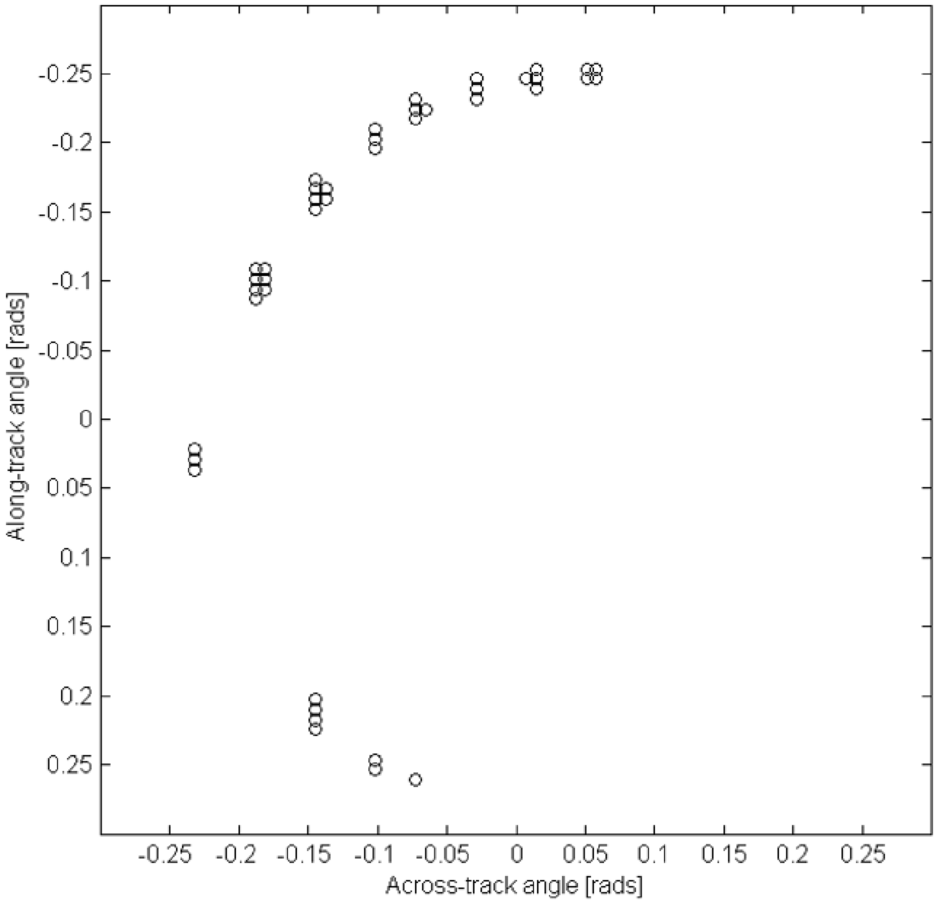
- Gray line indicate locations scanned with the moon
- Blue areas indicate locations that produced a ghost signal anywhere on the detectors



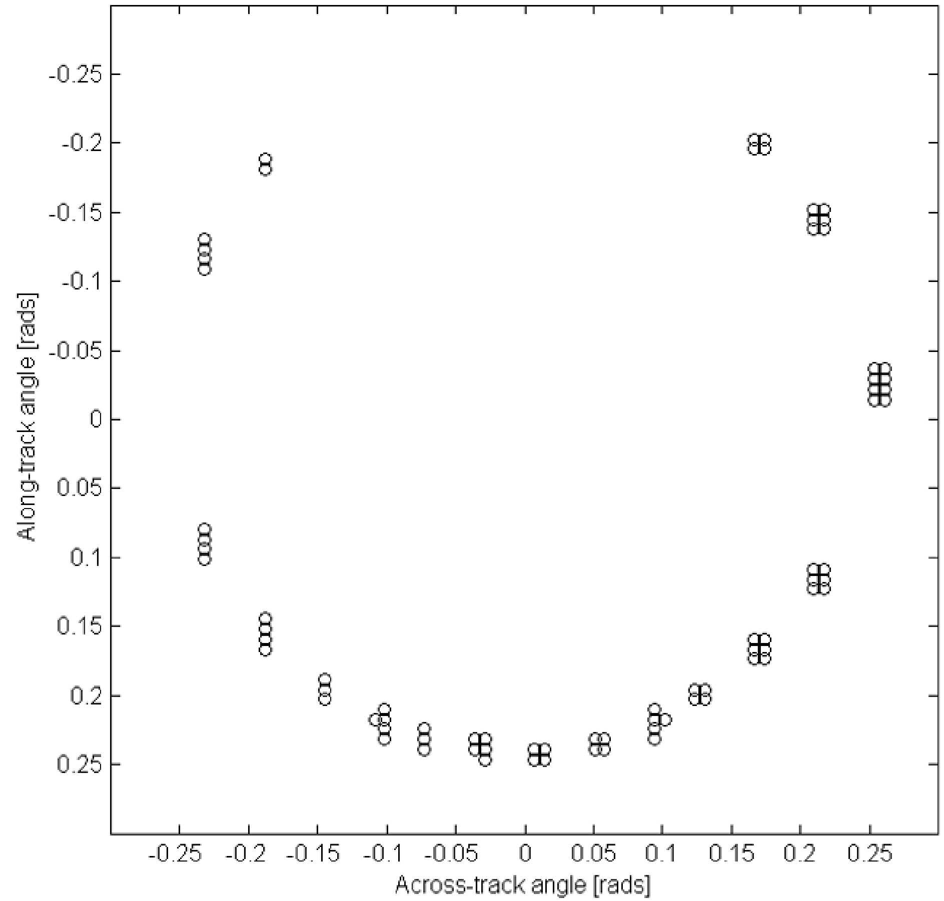
Lunar scans

- Able to produce a sparse map of lunar locations that produced a ghost for each detector
- Essentially have an out-of-field "PSF" for every detector
- Every detector has a different PSF (*i.e.*- the ghost signal is different for every detector)

PSF for one detector on SCA-A

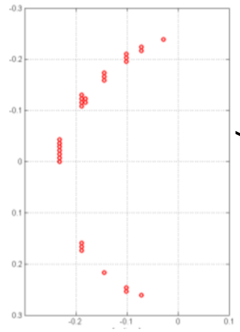


PSF for one detector on SCA-C

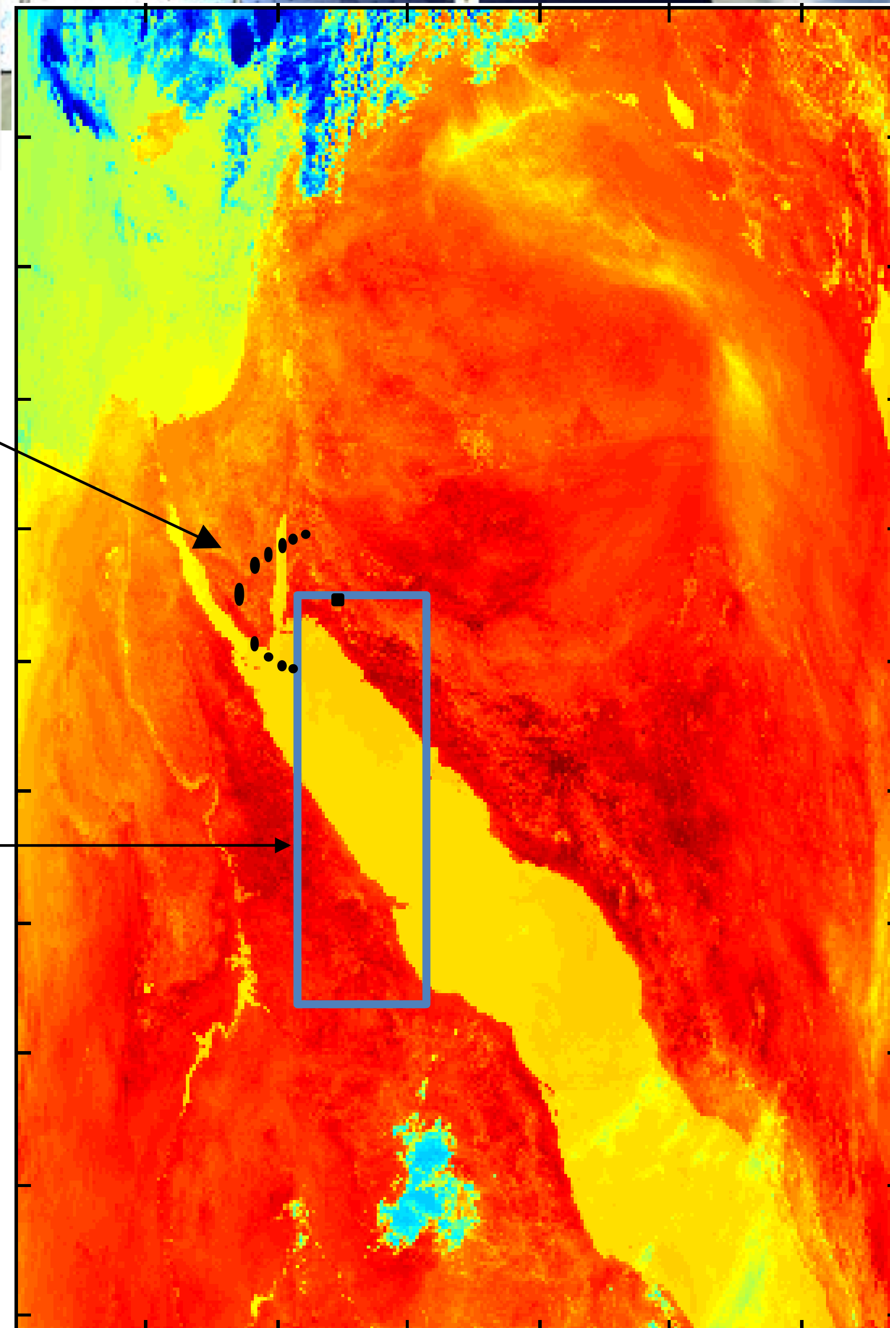


Where the signal comes from relative to TIRS swath

PSF for one detector

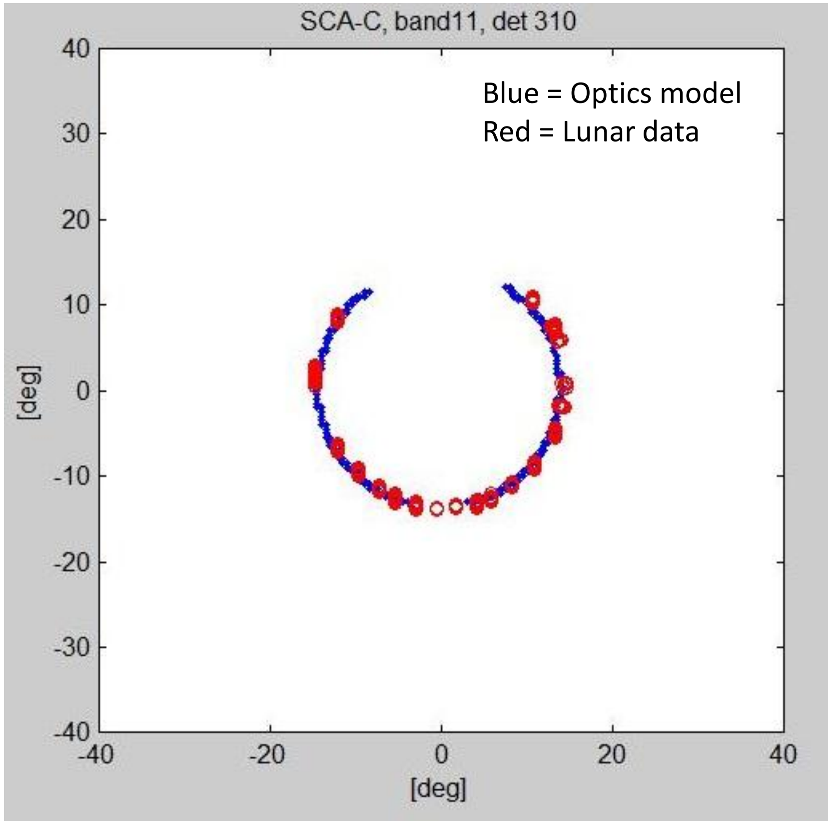


TIRS Imagery



Stray Light modeling

- Lunar data given to Optics branch @ GSFC to refine the stray light model to produce better ghost PSFs
- Optics model PSFs are currently being used to correct TIRS data and validate the method.



TIRS Ghost Correction

using other imaging sensors for truth and out of FOV data

Aaron Gerace

Data in hand:

- 5 TIRS intervals processed with pre-launch cal with on-orbit BBCAL rel. adjustment (possibly a.k.a. v2 cal)

- Per-detector reverse ray trace PSF from Optics model (directions and arbitrary weights)

- Near-coincident GOES TOA radiance thermal band data

- Near-coincident MODIS sea surface temperature product

- Atmospheric parameters for TIRS overflight time

Data processing:

- Propagate MODIS SST data to TOA radiance in TIRS band11 using atmospheric parameters

- Calculate error (Bias) between TIRS image radiance and MODIS TOA radiance

- From Optics model data, sample the GOES TOA radiance and weight according to Optics weights. Sum total out-of-field radiance to get Ghost value for the detector. Repeat for every line (frame) in all scenes.

- Find linear function between Bias and Ghost for all data.

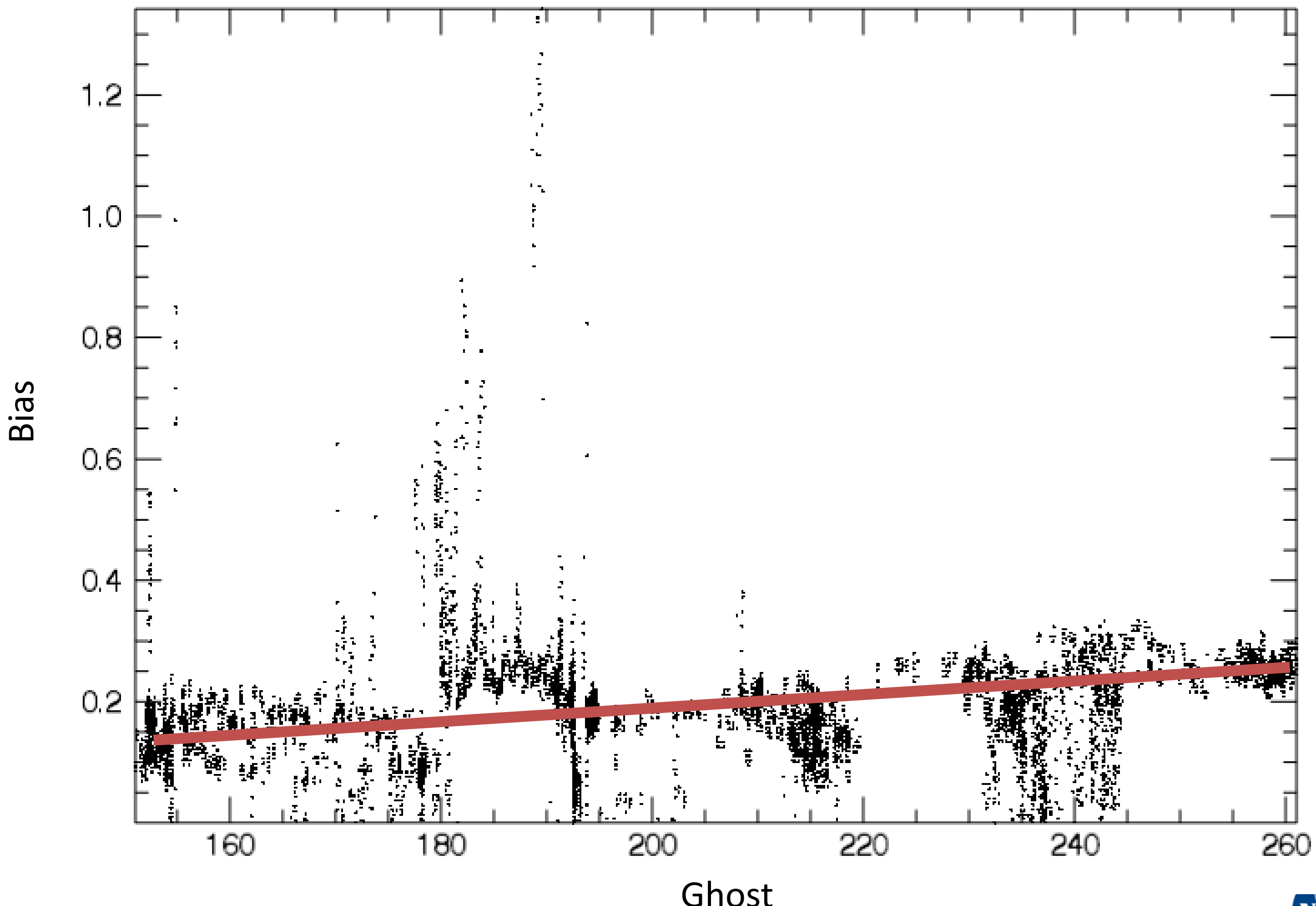
$$Bias = a \cdot Ghost + b$$

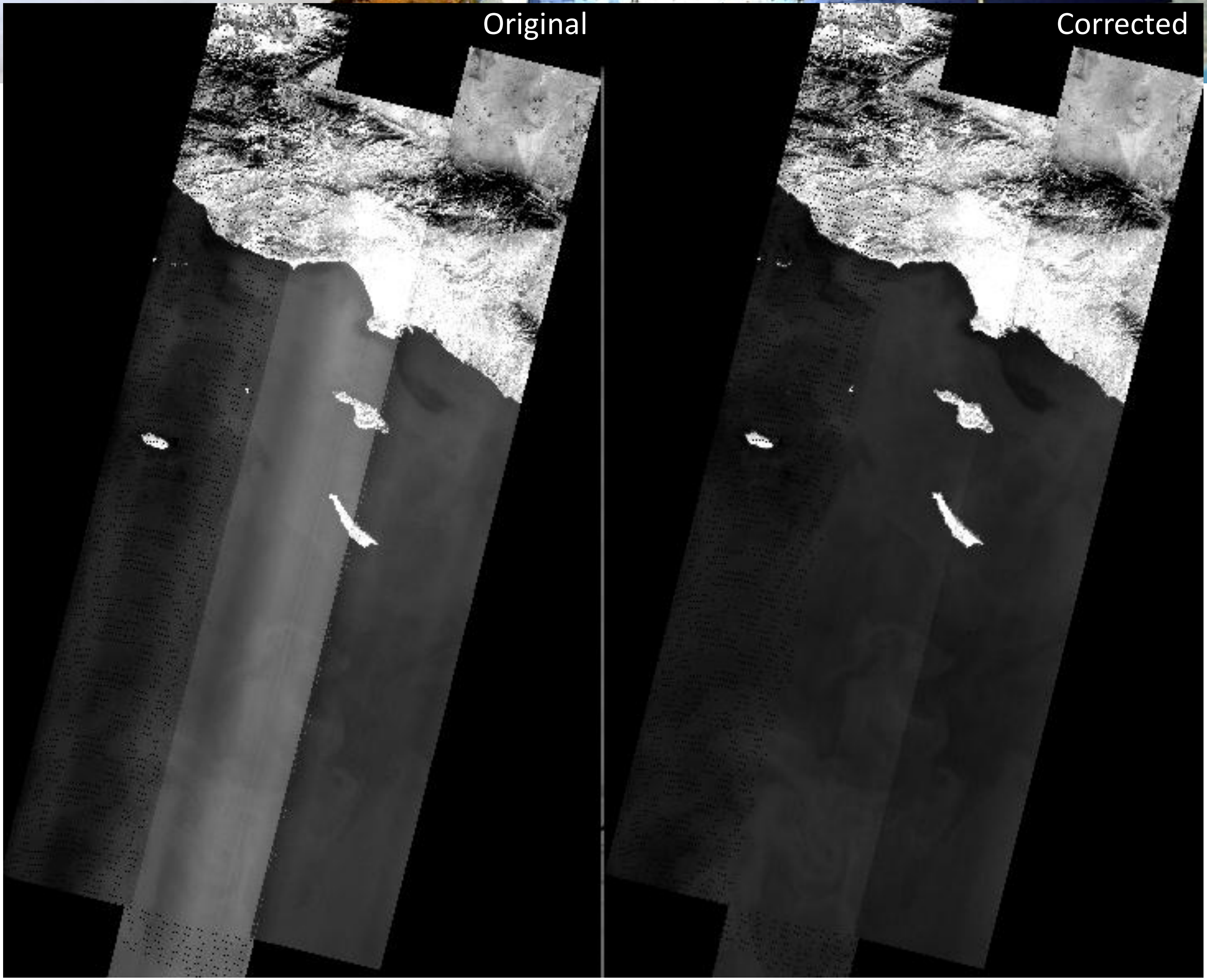
$$= a \cdot \left(\sum L_{GOES_i} \cdot w_i \right) + b$$

- Once a and b are found for every detector, correction equal to the GOES sampled data modified by the linear function

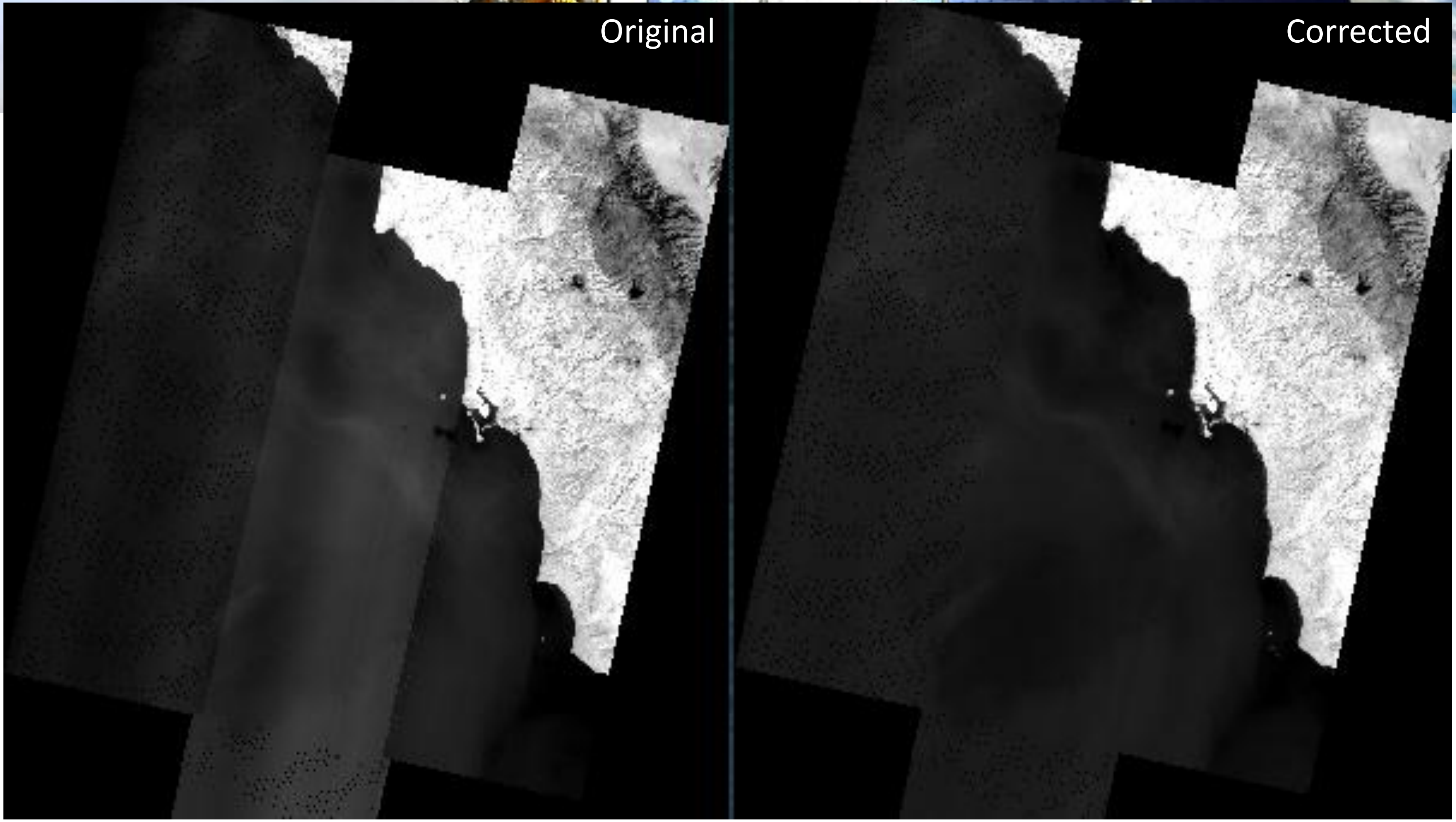
Example detector data of MODIS-derived Bias vs. GOES-derived Ghost

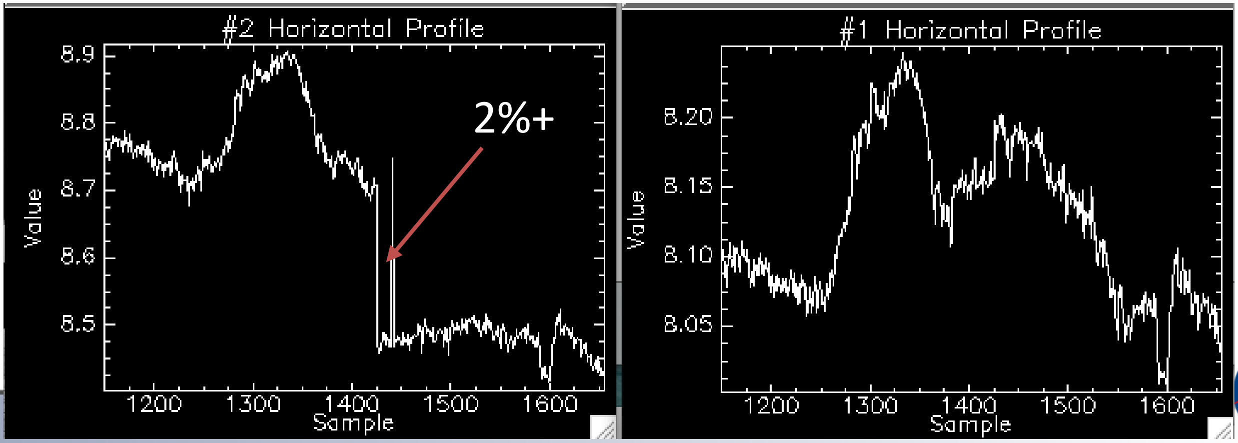
$$Bias = a \cdot Ghost + b$$
$$= a \cdot \left(\sum L_{GOES_i} \cdot w_i \right) + b$$



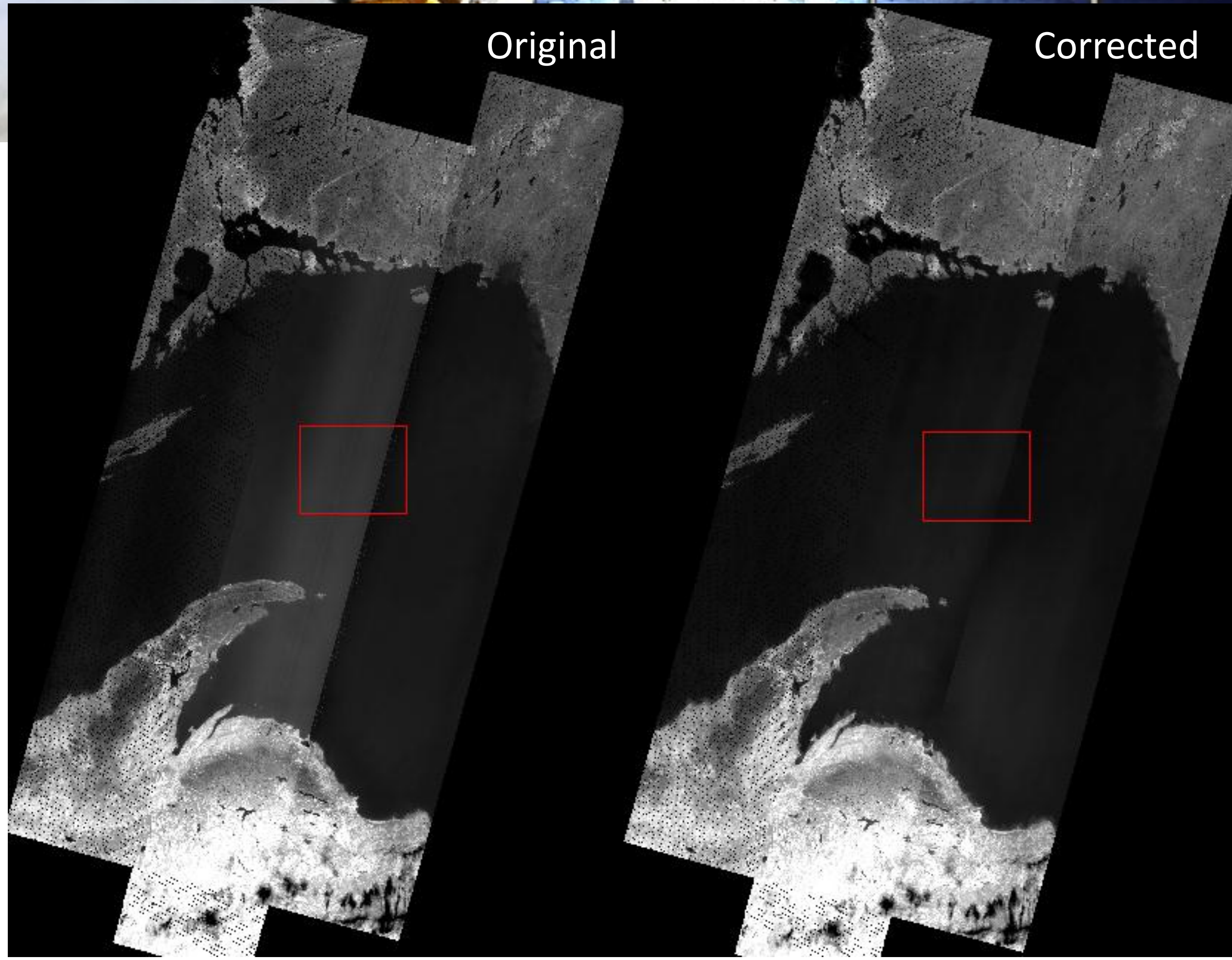


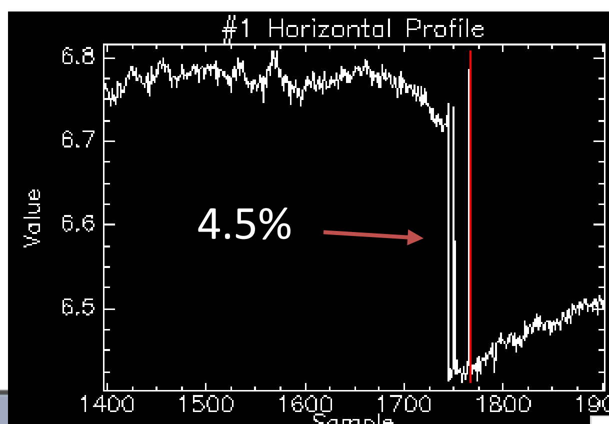
Path41, DOY309

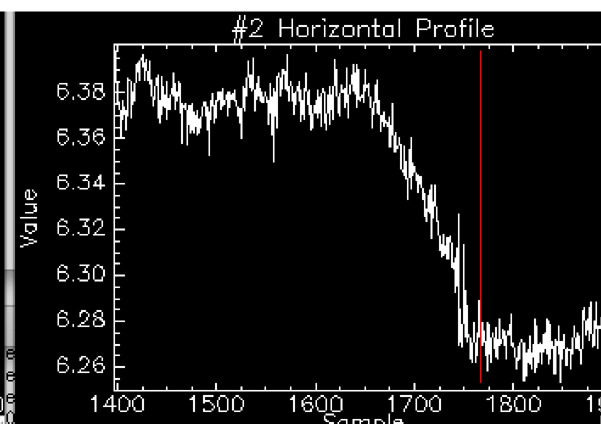




Path39, DOY279







Path24, DOY126

Future improvements:

- Correct the GOES data for the TIRS band shape (i.e.- GOES band does not overlap TIRS band11)
- Account for GOES atmospheric path length
- Accurate atmospheric parameters for time of day for MODIS

The Right Way!!

$$B = A_j \frac{\sum W_{ji} L_i}{\sum W_{ji}} + C_j = A_j \sum w_{ji} L_i + C_j = A_j L_{Gj} + C_j$$

$$B_n = A w_1 L_{n1} + A w_2 L_{n2} + \dots A w_I L_{nI} + C$$

$$\vec{B} = \vec{L}\vec{A}$$

Where $\vec{B}$ is a column vector (unique for each detector) made up of the N bias estimates, $\vec{L}$ is a $[N \times (I+1)]$ matrix comprised of N row vectors each made up of samples of the Ghost radiance (L_i) from I ghost source locations augmented with a one as the last element in each vector, and $\vec{A}$ is a $(I+1)$ column vector made up of the scaled weights (a_i) and the additive term C.

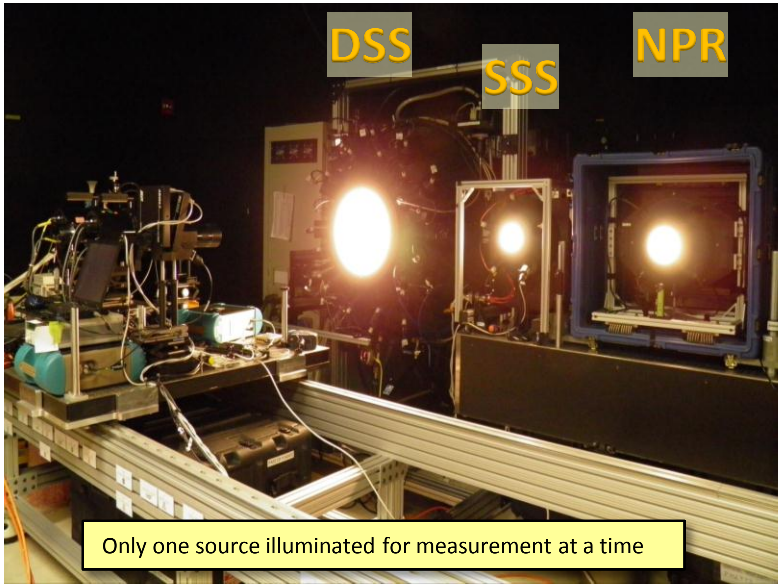
Sentinel-2 MSI and Landsat-8 OLI Inter-Calibration

- Sentinel-2 and Landsat are similar missions
- Many users will benefit from using the Sentinel-2 Multispectral Instruments (MSI) and the Landsat-8 OLI data together
  - Higher frequency coverage
- NASA and ESA joint effort to inter-calibrate data
  - Pre-launch calibration source comparison
  - Diffuser sample round robin
  - On-orbit inter calibration (with CNES)

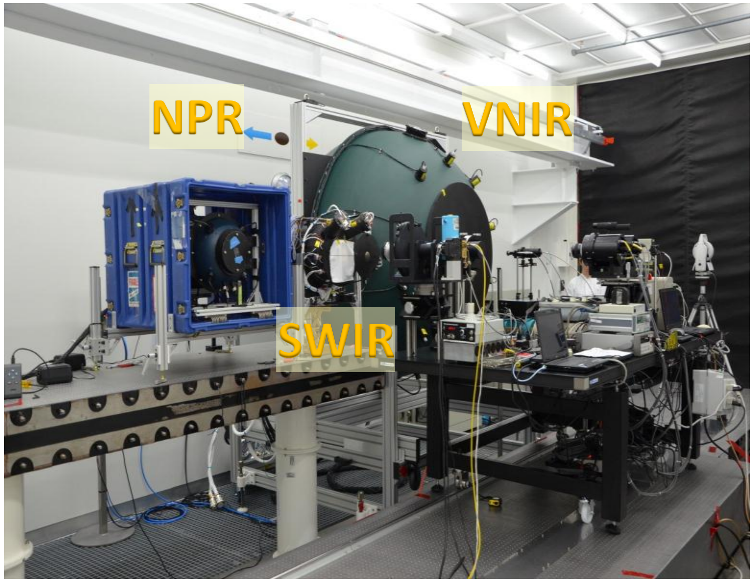
Pre-Launch Calibration Source Comparison

- Radiometers from NASA, NIST and the University of Arizona characterized the OLI and MSI calibration sources

- OLI - January 2011 -- @ BATC with BATC radiometers



- MSI – November 2012 -- @ Astrium with Astrium radiometers



- Initial differences as large as 15% reduced to less than 5%

Diffuser Sample Round Robin

- Both OLI and MSI use solar diffusers for a reflectance-based radiometric calibration
- OLI diffusers measured by University of Arizona (UA)
- MSI diffusers measured by Centre Spatial de Liege (CSL)
- NASA and ESA are circulating MSI diffuser witness and reference samples between CSL, GSFC and UA
  - Measured at GSFC and UA; now back at CSL
  - Will compare results when completed; document differences

Special Issue Papers (planned)

1 Landsat-8 Operational Land Imager Design, Characterization, and Performance. Edward J. Knight, Geir Kvaran,

2 The Spectral Response of the Landsat-8 Operational Land Imager. Julia A. Barsi*, Kenton Lee, Brian L. Markham, Geir Kvaran, Jeffrey A. Pedelty

3 Landsat-8 Operational Land Imager Radiometric Calibration and Stability. Brian Markham, Julia Barsi, Geir Kvaran, Lawrence Ong, Edward Kaita

4 OLI Radiometric Performance On-Orbit. Ron Morfitt, Pat Scaramuzza, Esad Micijevic, Julia Barsi, Raviv Levy, Brian Markham

6 Radiometric Non-Uniformity Characterization and Correction of Landsat 8's OLI using Earth Imagery-Based Techniques. F. Pesta, S. Bhatta, D. Helder, J. Brinkman

7 RADIOMETRIC CROSS CALIBRATION OF LANDSAT OPERATIONAL LAND IMAGER (OLI & LANDSAT 7 ENHANCED THEMATIC MAPPER PLUS (ETM+) . Nischal Mishra , Md. Obaidul Haque, Larry Leigh, David Aaron, Dennis Helder

8 The ground-based absolute radiometric calibration of Landsat 8 OLI, Jeffrey Czapla-Myers, Joel McCorkel, Nikolaus Anderson, Kurtis Thome, Stuart Biggar, Dennis Helder, David Aaron, Larry Leigh, and Nischal Mishra

10 Landsat 8 Operational Land Imager On-Orbit Geometric Calibration and Performance. James Storey, Michael Choate and Kenton Lee

11 Thermal Infra-Red Sensor Design and pre-launch Performance. Reuter et al

13 TIRS Absolute Radiometric Calibration and Traceability. Montanaro, Lunsford, Reuter

14 TIRS On-Orbit Radiometric Performance. Montanaro, Vanderwerff, Levy

15 TIRS Vicarious Radiometric Calibration. Barsi, Schott, Hook, …

16 TIRS Ghosting Effects. Montanaro, Gerace, Rohrbach

17 Landsat 8 Thermal Infra-Red Sensor Geometric Characterization and Calibration. James Storey, Michael Choate, and Donald Moe (SGT/USGS EROS)

18 Pre- and Post-Launch Spatial Quality of the Landsat 8 Thermal Infrared Remote Sensor (TIRS) . Brian Wenny, Dennis Helder, Jungseok Hong

19 Use of NOAA Moored Buoys to Calibrate Landsat Thermal Bands and Evaluate a Land Surface Temperature Product. Monica Cook, John Mandel, Nina, Schott

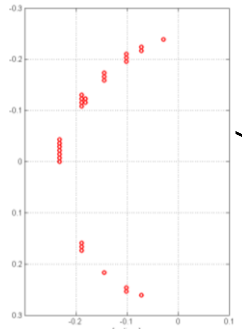
22 **An Analysis of the Side Slither On-Orbit Calibration Technique Using the DIRSIG Model. Gerace...**

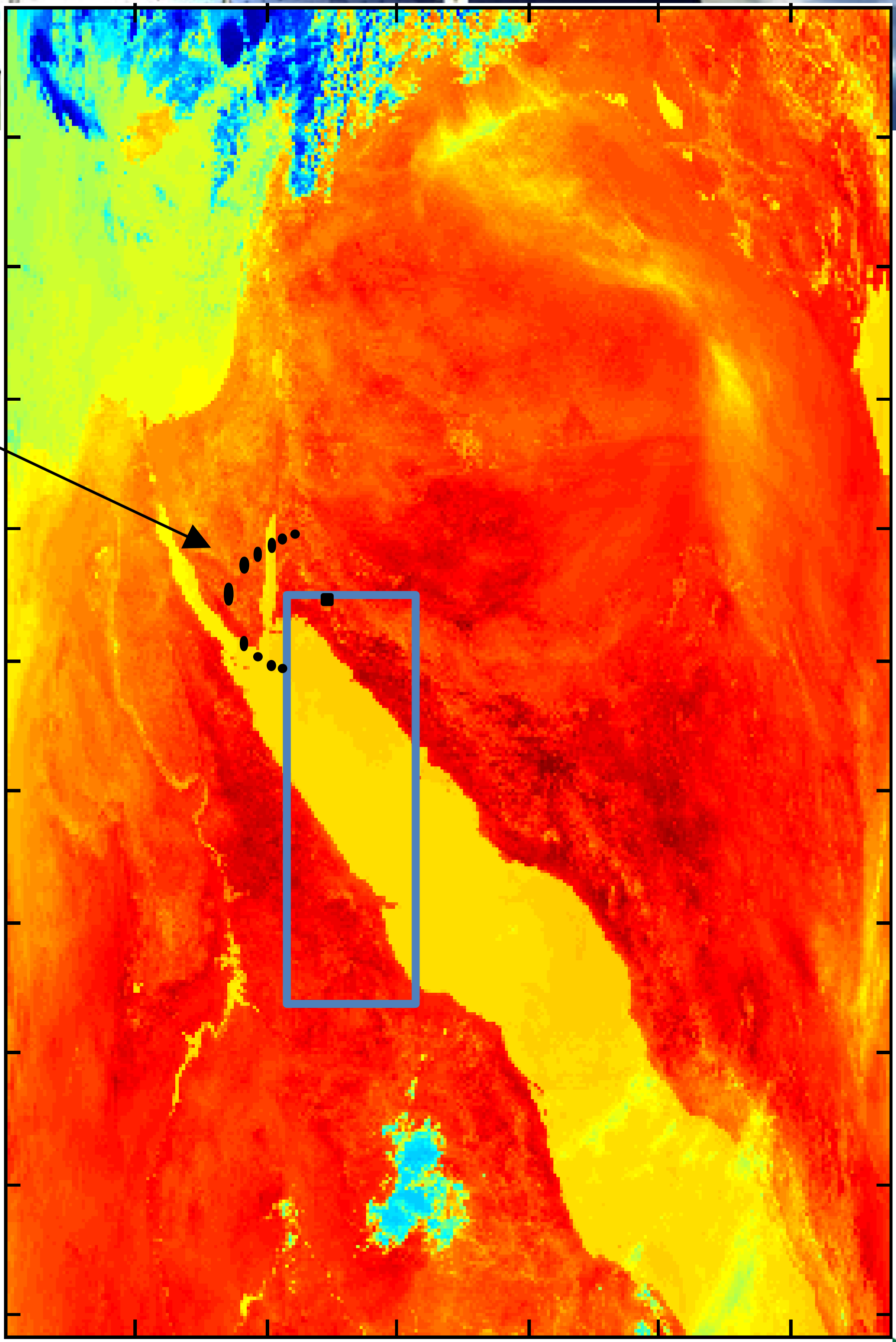
Towards a stray light correction…

- If coincident wide-field image data is available, then the content of surrounding scene is known

- For each detector's ghosting function (PSF), sample wide-field image (MODIS) with appropriate weights to determine extra (ghost) signal on that detector

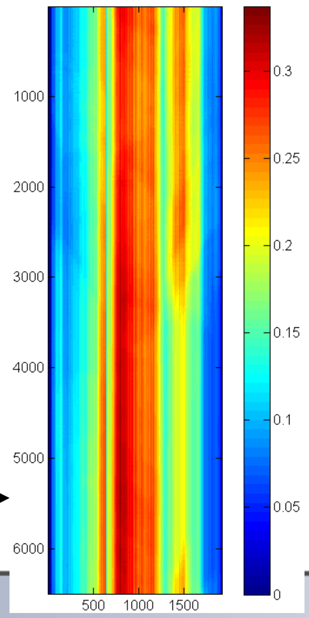
PSF for one detector





- Repeat for each line (frame) in the TIRS image

- Now have the ghost signal for every detector and for every frame. Subtract this from TIRS image to remove the stray light artifacts.

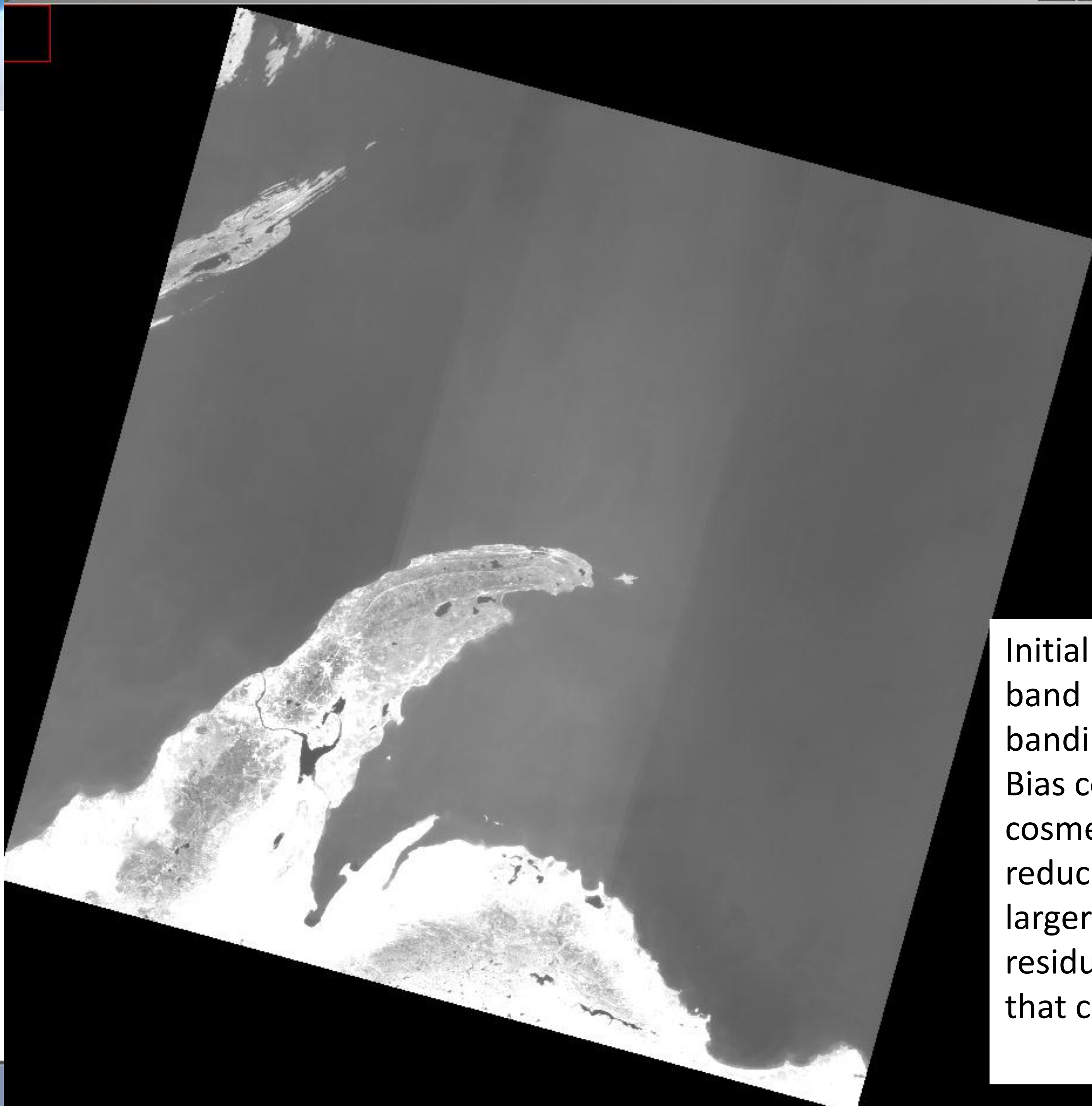


Ghost signal that must be removed from TIRS image

TIRS GHOST Contributions

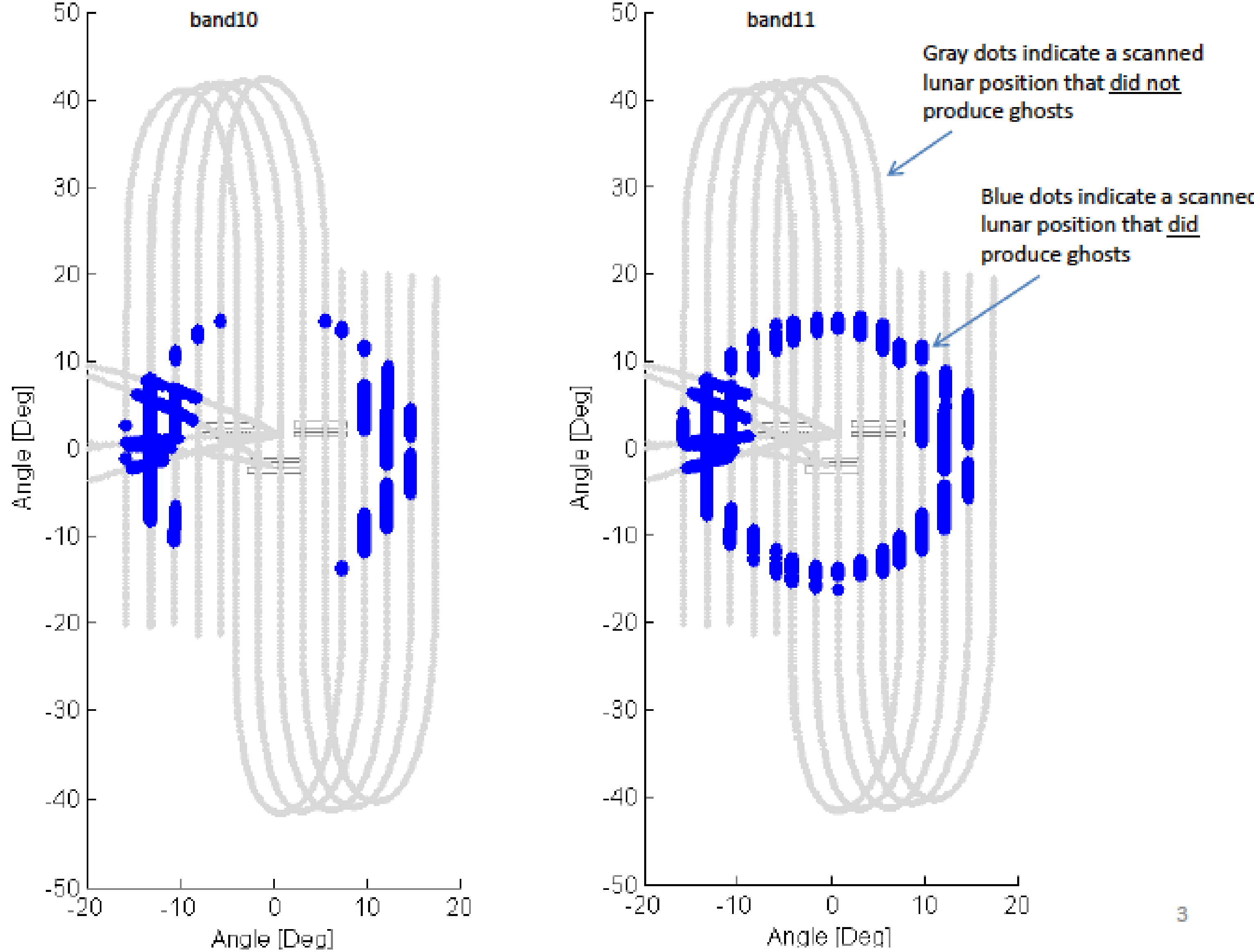
July,2014

Rochester Institute of Technology
John Schott
Aaron Gerace
Nina Raqueno
Emmett Ientilucci
Rolando Raqueno
Monica Cook



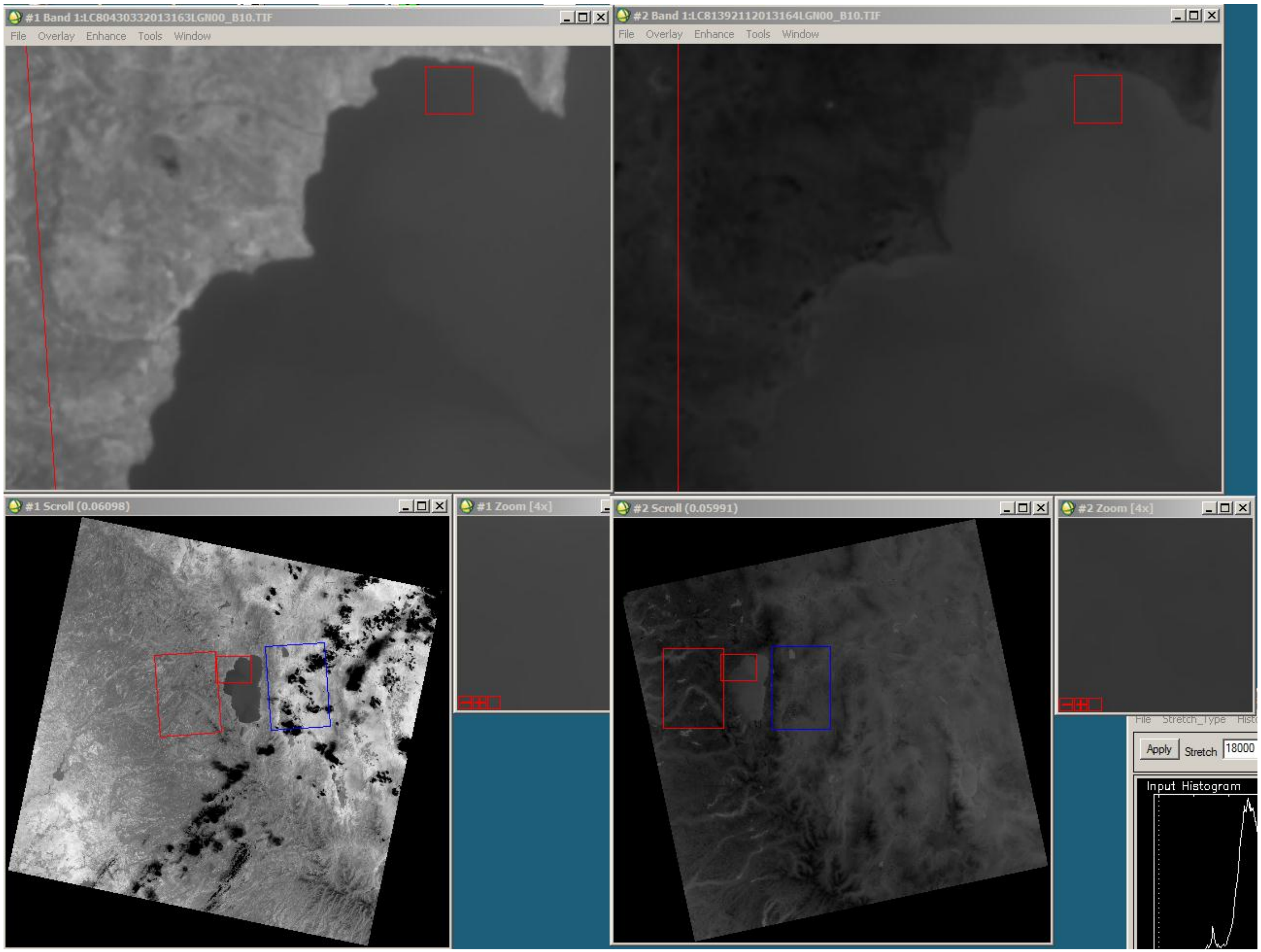
Initial error of about 2K in band 10, 4K in band 11 plus banding and striping.
Bias correction and ad hoc cosmetic flat fielding reduced errors but left larger than expected residual errors and banding that comes and goes.

Map where the moon was when a ghost occurred somewhere on the science rows
(from 5 extended lunar collects and 5 Earth-to-Moon slews [TXA mode])



From Dr Montanaro

Investigation of surrounding pixels impact on Tahoe Day/Night pairs



Two large ROIs were defined WEST and EAST of Lake Tahoe.

ROI size: ~1,400,000 pixels
~20 x 25 miles

Day 163

Night 164

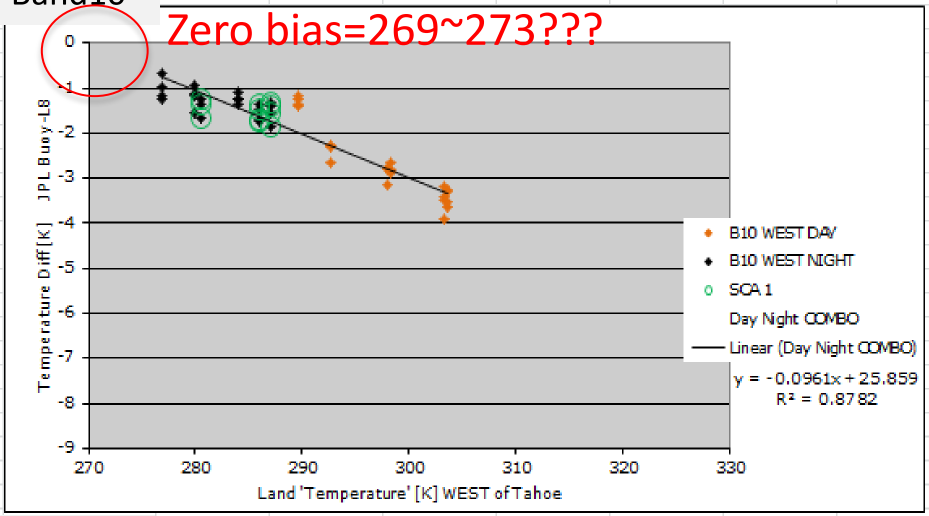
TOA Temperature Bias

Comparison TOA Apparent Water Temperature Difference (JPL Buoys-L8) to Surrounding East/West Land ROI Selections ***(Land 'Temperature')***

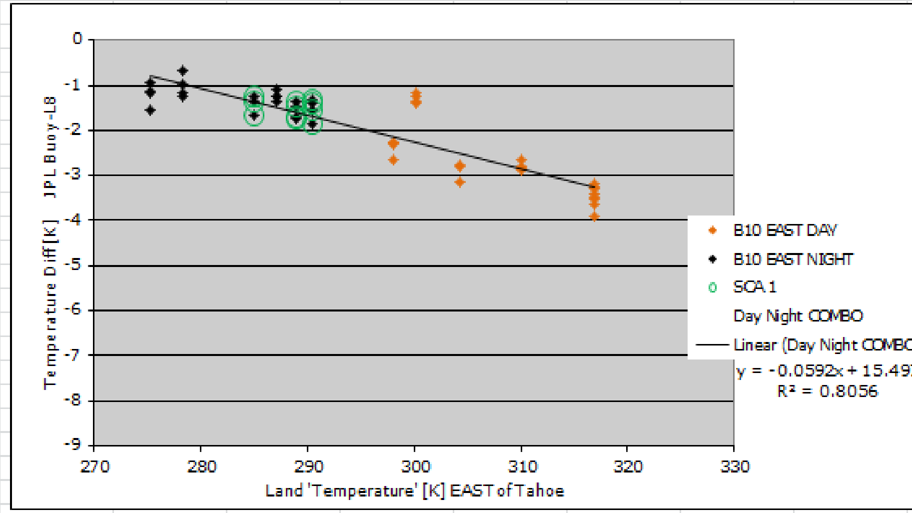
Band10

WEST

Zero bias=269~273???



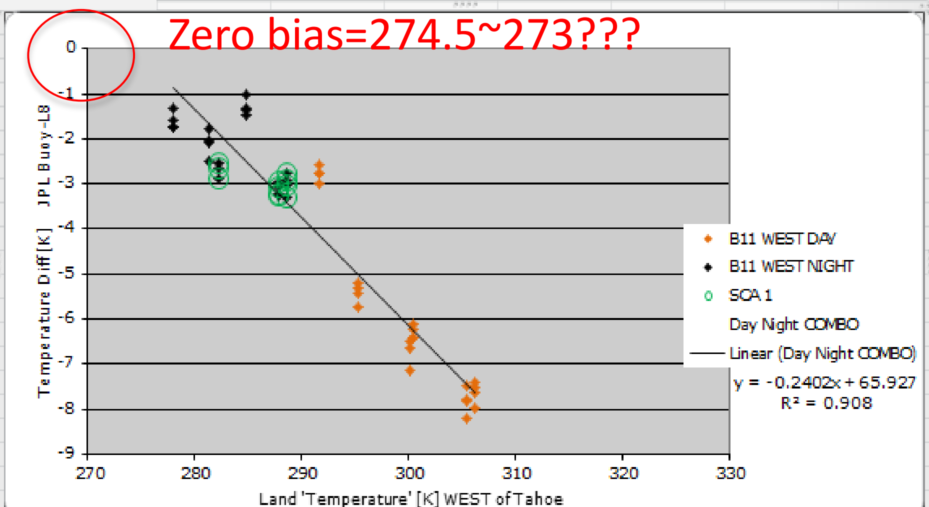
EAST

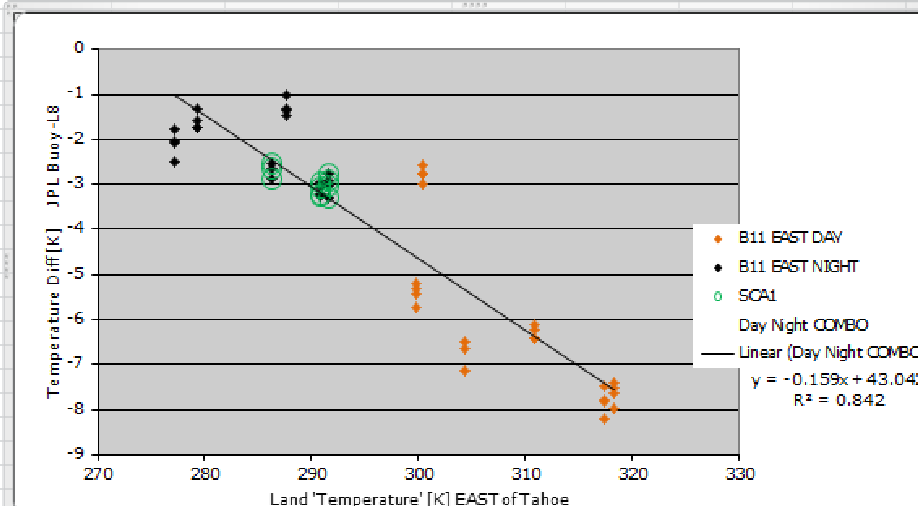


Note 10.4k change in surround/ 1k bias error in band 10

Band11

Zero bias=274.5~273???

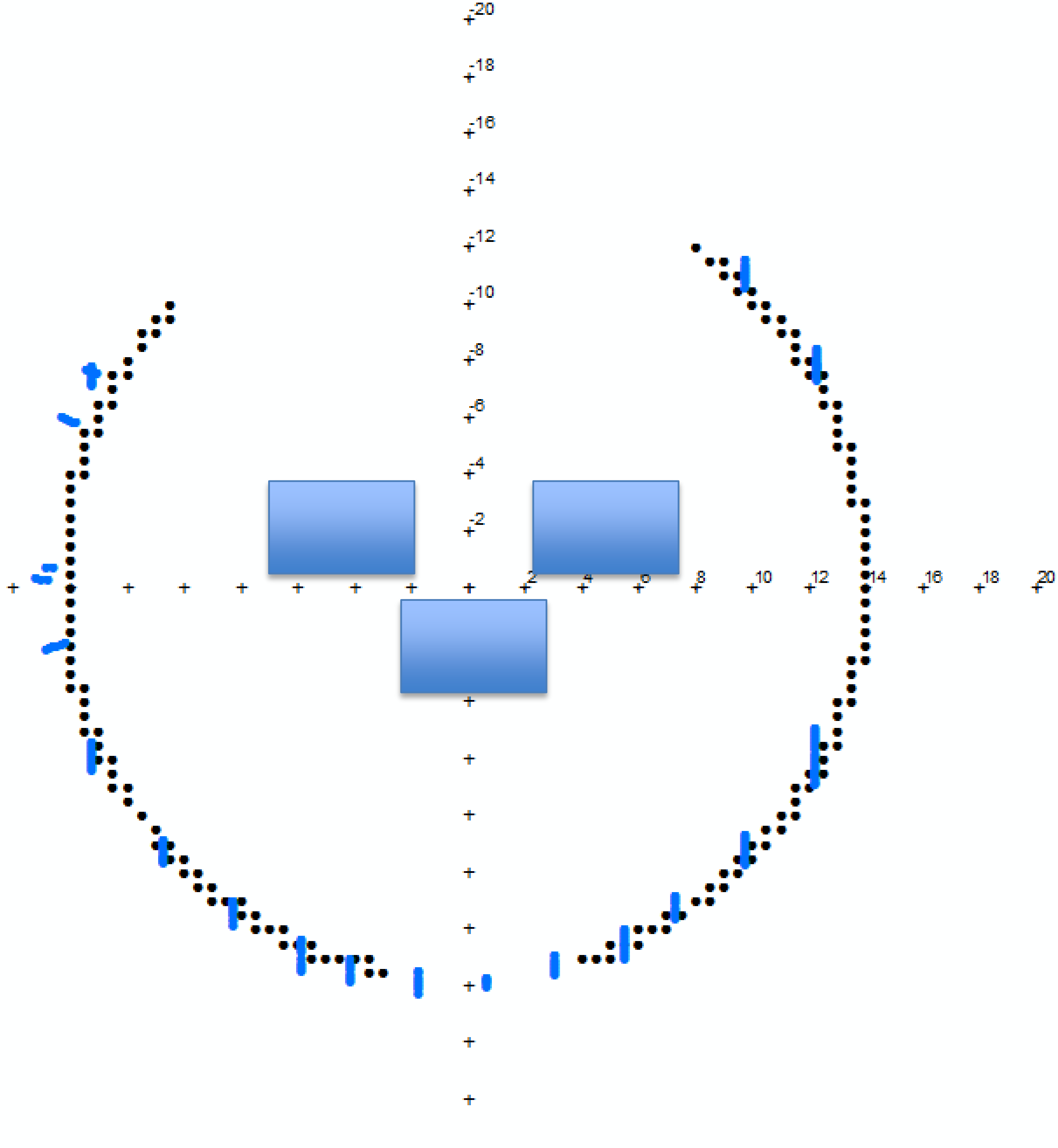


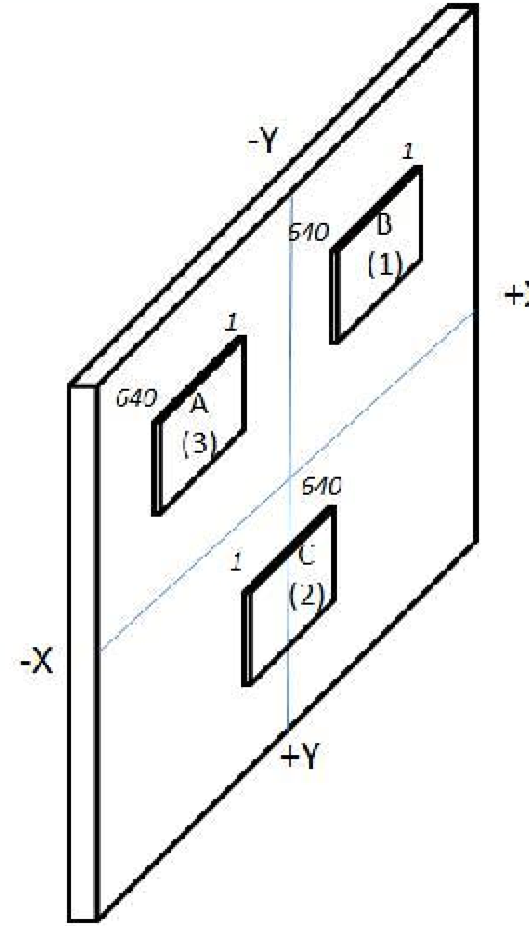


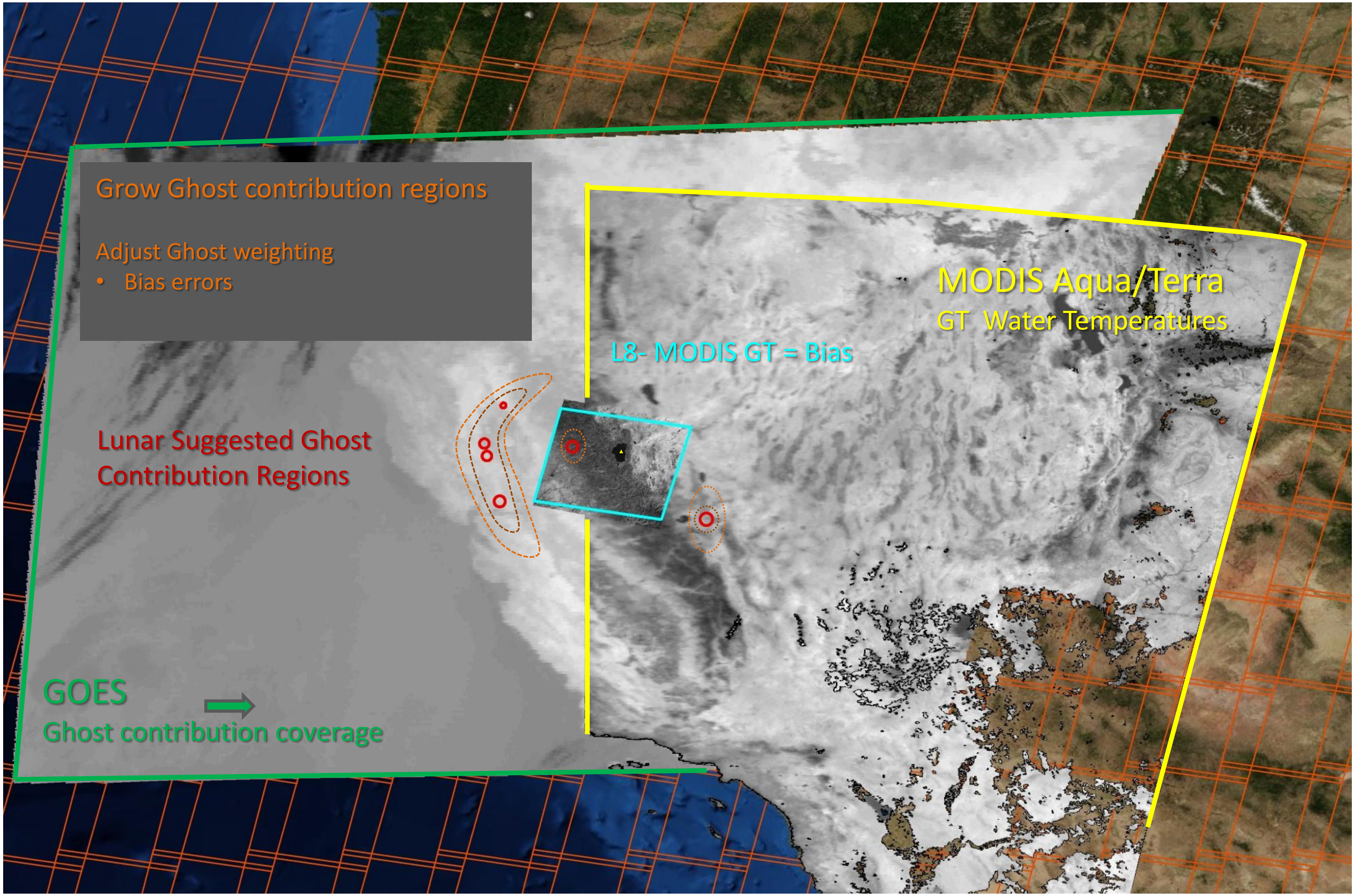
Note 4.16k change in surround/ 1k bias error in band 11

note all buoys fall within SCA 2, unless circled in green-SCA1

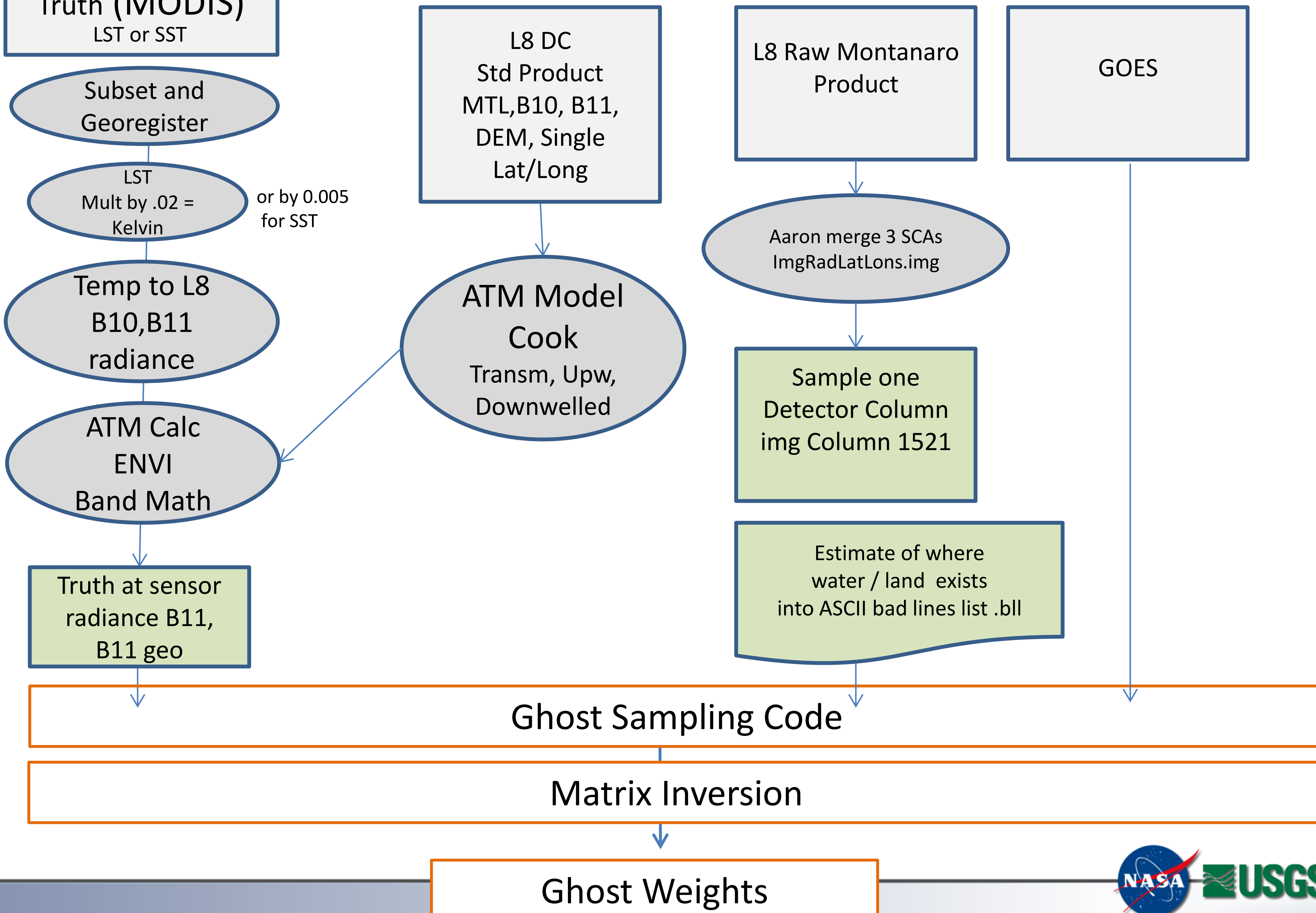
Initial Ghost Sampling Using Optics Model predictions



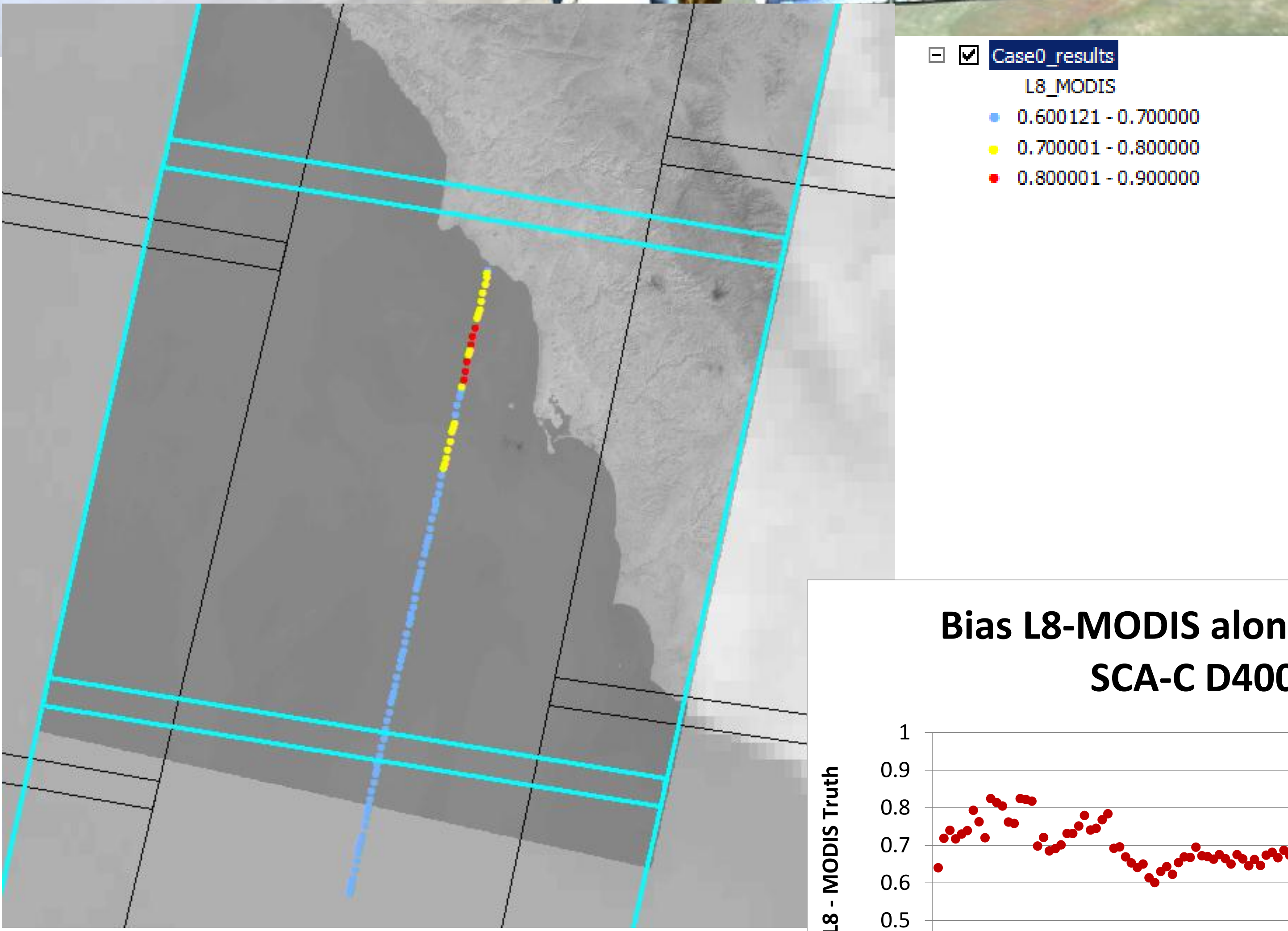


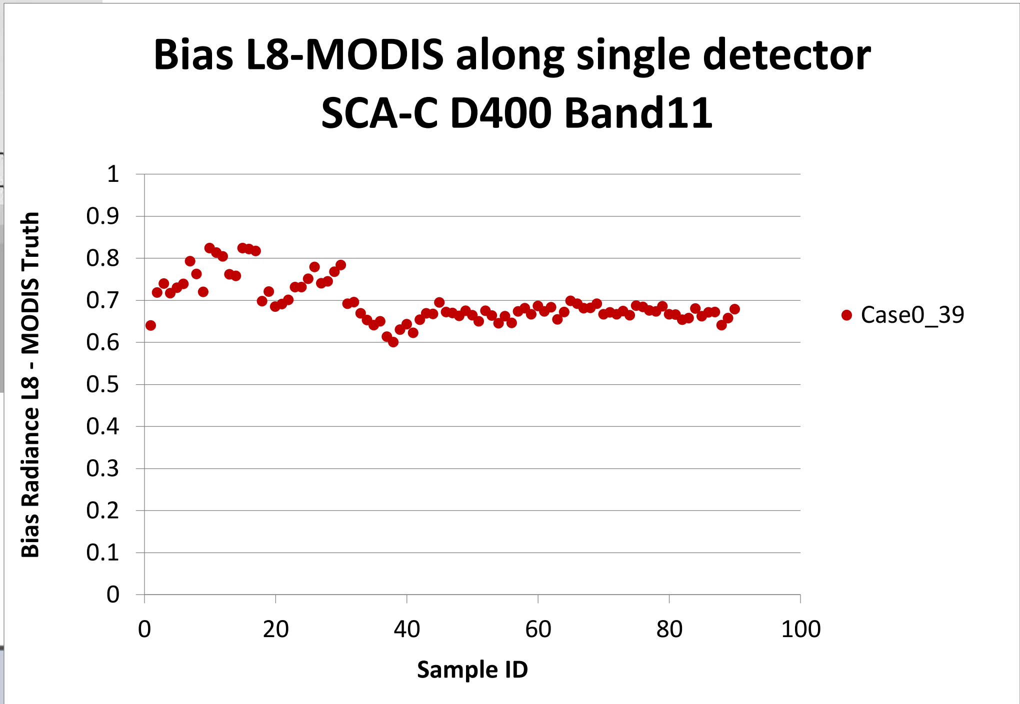

Grow Ghost contribution regions
Adjust Ghost weighting
• Bias errors
MODIS Aqua/Terra
GT Water Temperatures
L8- MODIS GT = Bias
Lunar Suggested Ghost
Contribution Regions
GOES
Ghost contribution coverage

Per Detector Bias Calc MODIS – L8



Case 0, US west coast Per Detector Bias L8-MODIS



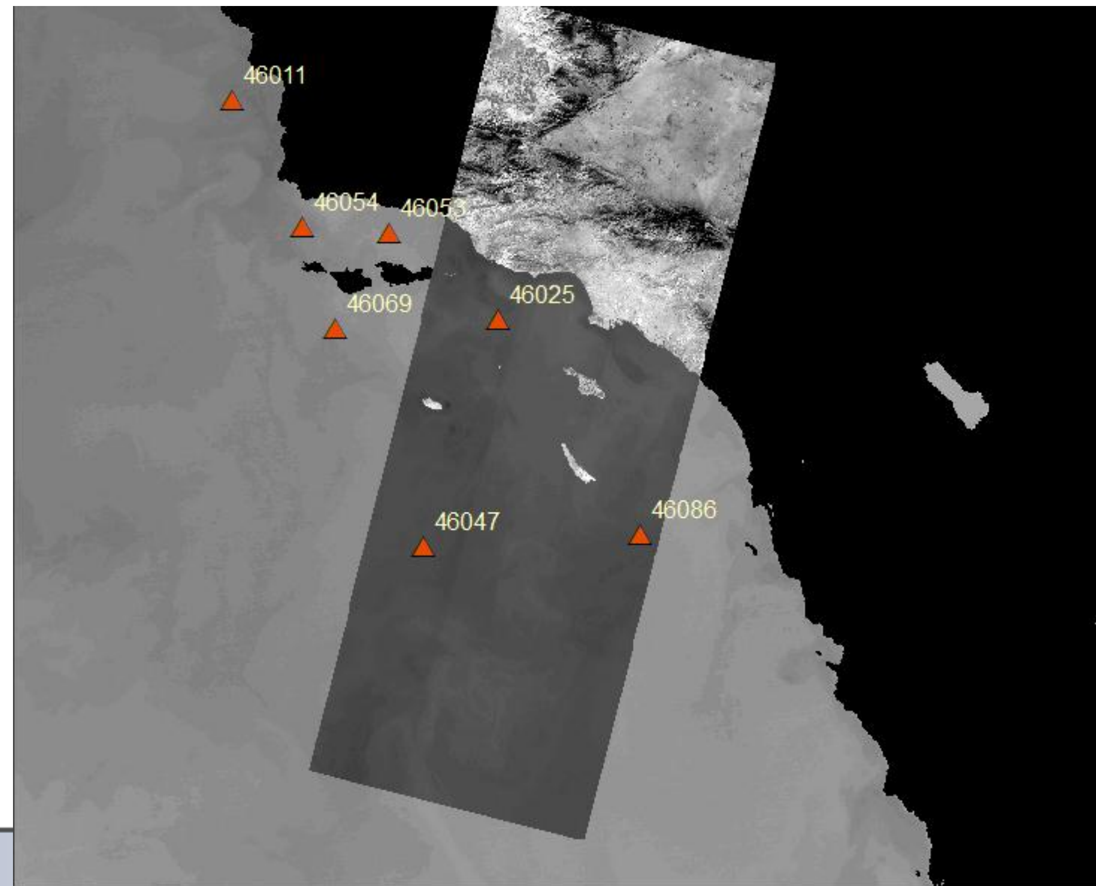


West Coast Buoys: Day

- Path41 Rows 36-37-38 (38 is an extended collect just for buoys. Not always collected)

- MODIS coverage
- L8 cloud ‘free’
- path 38 exists
- buoy data exists
- L8 18:30
- MODIS 21:10
- Land pixels 1-1299

Case 1: doy309 2013 buoy: ran291K
DATE_ACQUIRED = 2013-11-05
SCENE_CENTER_TIME = 18:30:28.8204324Z
CORNER_UL_LAT_PRODUCT = 34.21888
CORNER_UL_LON_PRODUCT = -120.00133



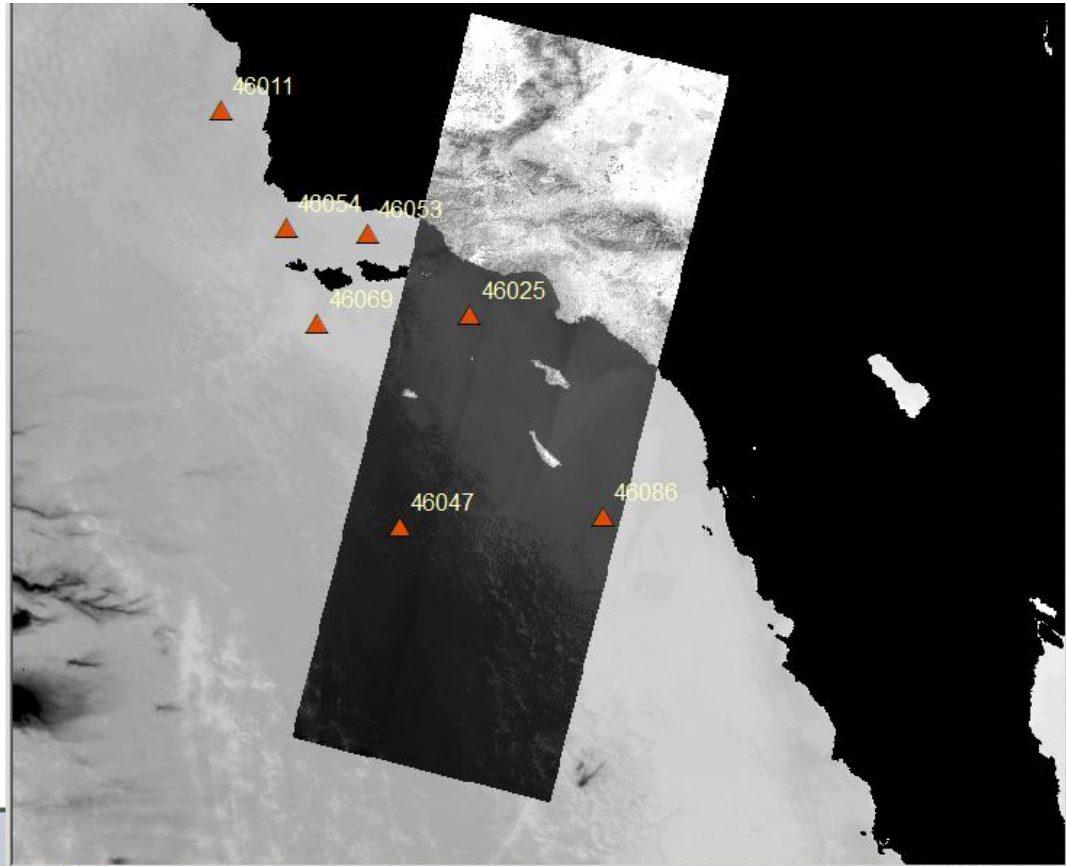
West Coast Buoys: Day with clouds

- Path41 Rows 36-37-38 (38 is an extended collect just for buoys. Not always collected)

- MODIS coverage
- L8 cloud 'free'
- path 38 exists
- buoy data exists

- scanlines 1200-2100 water
- note some clouds may exist in column881
- max scanline 4970

Case 2: doy104 2014 buoy: exists
DATE_ACQUIRED = 2014-04-14
SCENE_CENTER_TIME = 18:28:42.9106669Z
CORNER_UL_LAT_PRODUCT = 34.21872
CORNER_UL_LON_PRODUCT = -120.00783

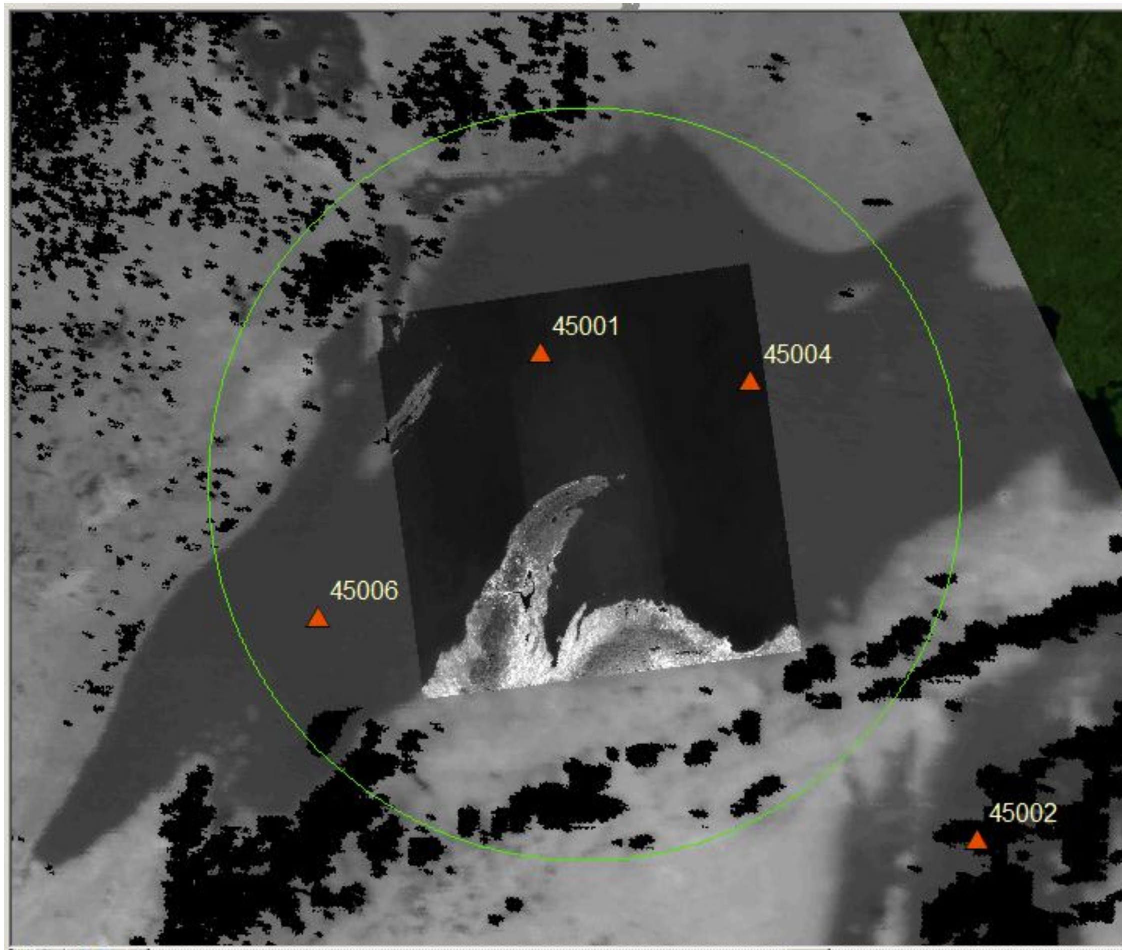


Lake Superior: Day

- Path24 Row 27: Buoys 45001

Identified 2 dates:

- MODIS coverage
- L8 cloud 'free'
- buoy data exists



Lake Superior buoy 45001
Option 1: doy126 2013 **TIRS only date**
Path24 Row27
DATE_ACQUIRED = 2013-05-06
SCENE_CENTER_TIME = 16:41:31.4446151Z
CORNER_UL_LAT_PRODUCT = 48.47905
CORNER_UL_LON_PRODUCT = -89.43032

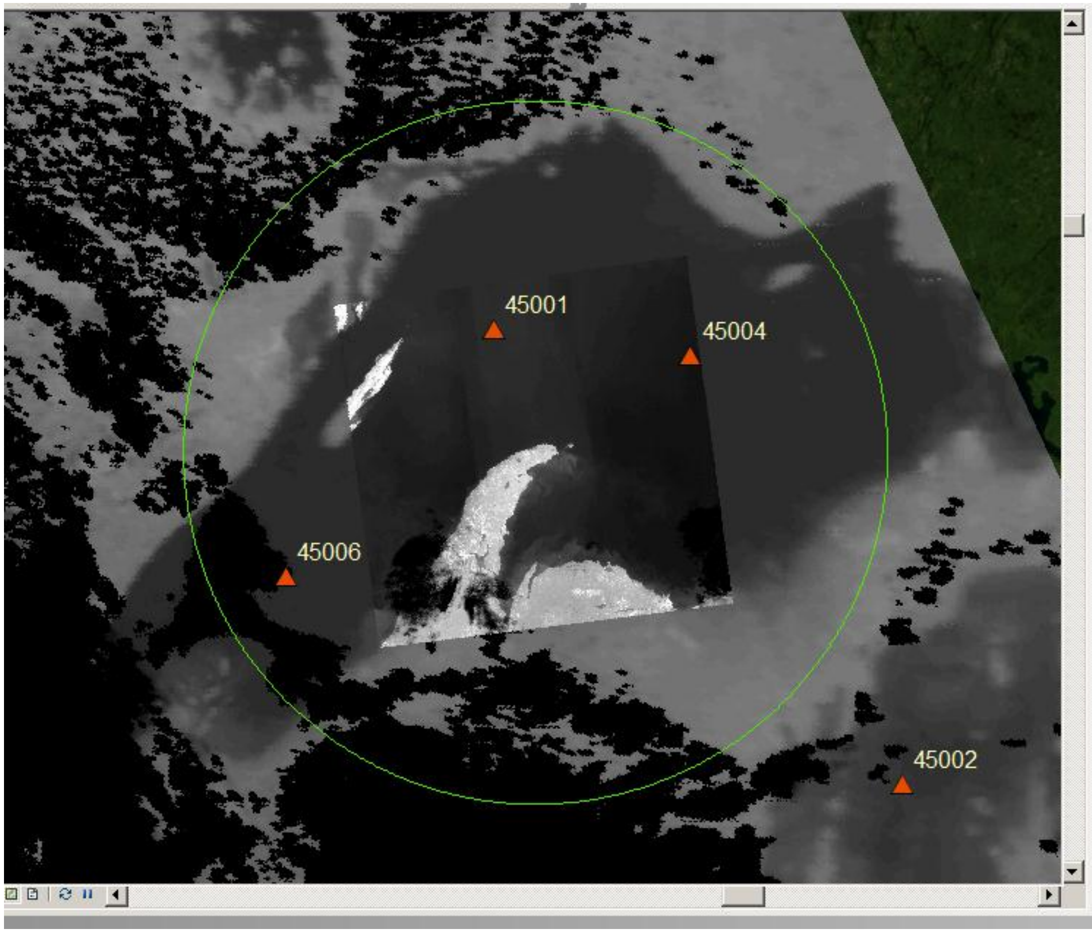
Lake Superior: With Clouds

- Path24 Row 27: Buoys 45001

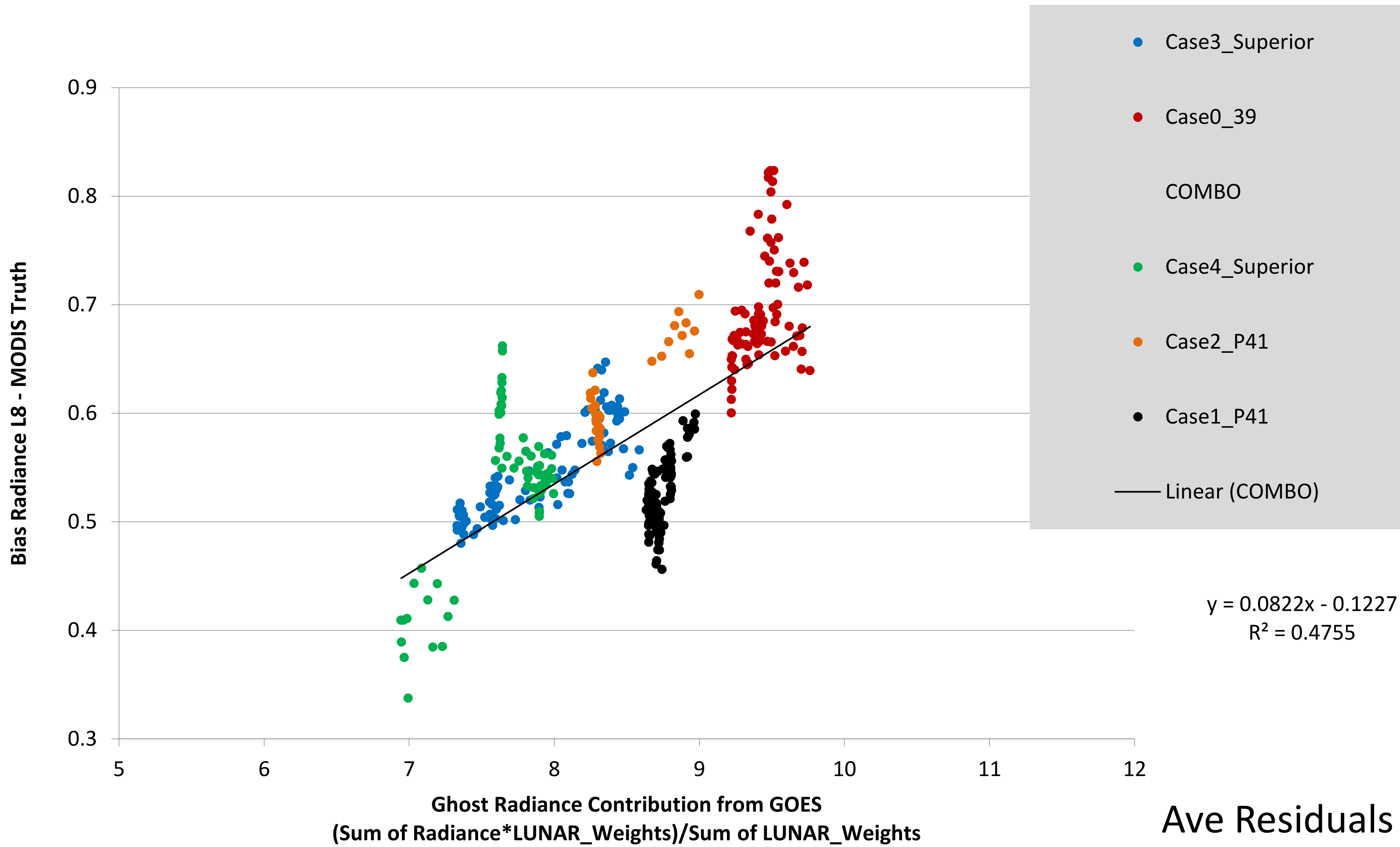
Identified 2 dates:

- MODIS coverage
- L8 cloud 'free'
- buoy data exists

Option 2: doy158 2013
TARGET_WRS_PATH = 24
TARGET_WRS_ROW = 27
DATE_ACQUIRED = 2013-06-07
SCENE_CENTER_TIME = 16:41:42.9656200Z
CORNER_UL_LAT_PRODUCT = 48.44618
CORNER_UL_LON_PRODUCT = -89.45310



Bias L8-MODIS along single detector SCA-C D400 Band11



Ave Residuals 0.106325