Landsat Cal/Val Status

2022/09/01

Esad Micijevic

USGS

emicijevic@usgs.gov

Earth Resources Observation and Science (EROS) Center, Sioux Falls, SD 57198, USA.

U.S. Department of the Interior
U.S. Geological Survey

Landsat Calibration Validation Team

- **USGS Earth Resources Observation and Science (EROS) Ca/Val Center of Excellence (ECCOE)**
  - https://www.usgs.gov/land-resources/eros/calval
- **NASA Goddard Space Flight Center (GSFC)**
  - https://landsat.gsfc.nasa.gov/
- **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**
  - https://www.sdstate.edu/jerome-j-lohr-engineering/engineering-research/image-processing-lab
- **University of Arizona (UofA). College of Optical Sciences. Remote Sensing Group**
  - http://www.optics.arizona.edu/
- **USGS RObotic Lunar Observatory (ROLO)**
  - https://www.moon-cal.org/

Outline

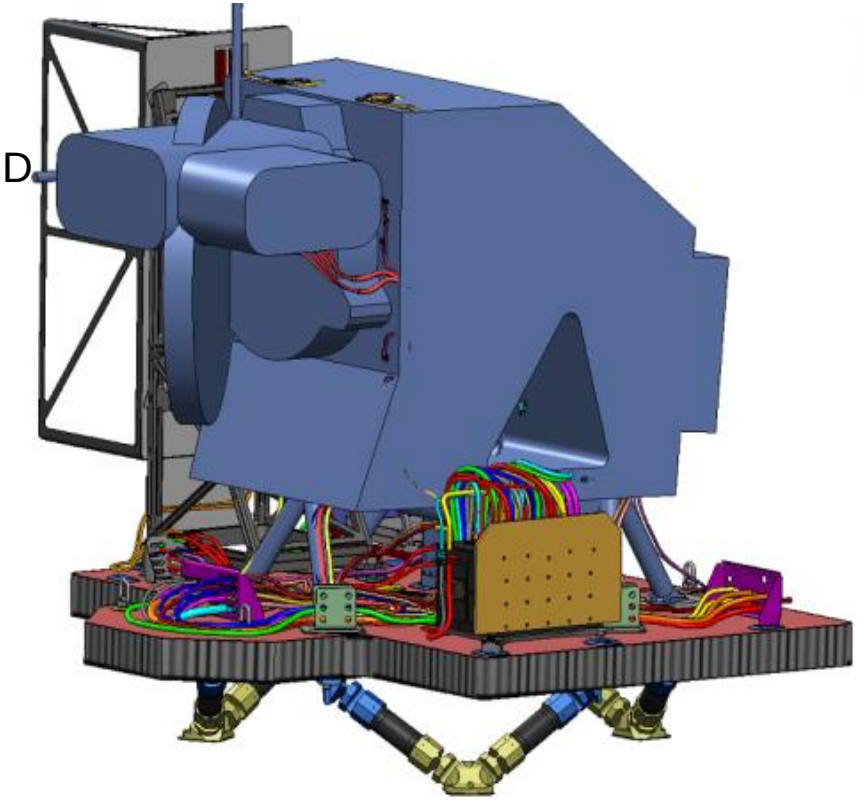
- OLI/TIRS overview
- Landsat 8/9 OLI Radiometric performance
- Landsat 8/9 TIRS Radiometric performance
- Landsat 7 ETM+ Status

Landsat Mission

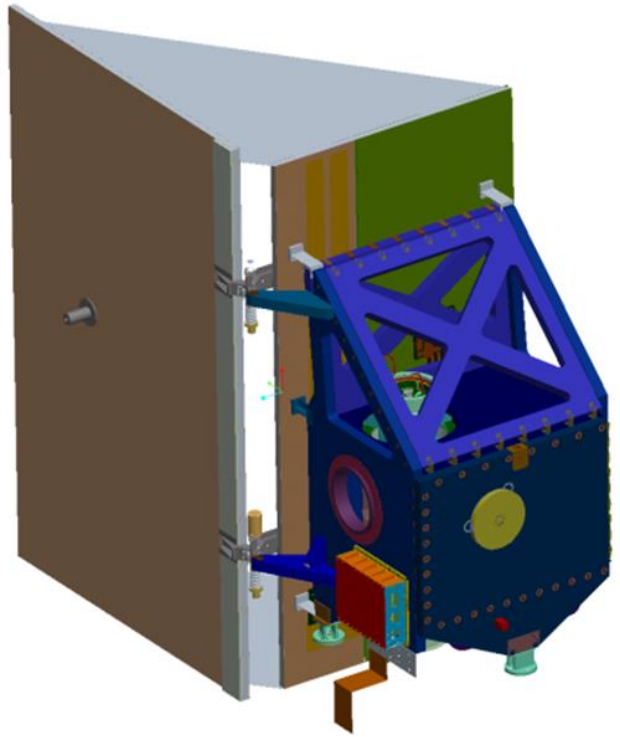
- **Objective is to routinely gather land imagery from space, to enable quantitative global studies of changes on the Earth**
  - Provide continuity in multi-decadal Landsat land surface observations
- **Joint effort of NASA and USGS**
- **Landsat 9 launched on September 27, 2021**
  - 705 km circular, sun-synchronous, near-polar orbit
    - 16-day repeat cycle, in constellation with Landsat 8 - 8-day revisit time
  - Two imaging sensors
    - Operational Land Imager (OLI; Ball Aerospace)
    - Thermal InfraRed Sensor (TIRS; NASA GSFC)
  - In January 2022 successfully completed On-orbit Initialization and Verification
    - Met or exceeded all requirements
  - At the end of 2022 planned image data reprocessing to implement all calibration improvements achieved over the first year in orbit

Landsat 8/9 Sensors

- **2 pushbroom sensors**
  - Operational Land Imager (OLI)
    - 1 panchromatic (500 - 680nm) 15m GSD
    - 5 VNIR bands
      - coastal/aerosol (433nm) 30m GSD
      - blue (482nm) 30m GSD
      - green (562nm) 30m GSD
      - red (655nm) 30m GSD
      - NIR (865nm) 30m GSD
    - 3 SWIR bands
      - SWIR1 (1610nm) 30m GSD
      - SWIR2 (2200nm) 30m GSD
      - Cirrus (1375nm) 30m GSD
  - Thermal Infrared Sensor (TIRS)
    - 2 thermal bands
      - 10.8µm and 12µm
- **185 km swath width**



OLI

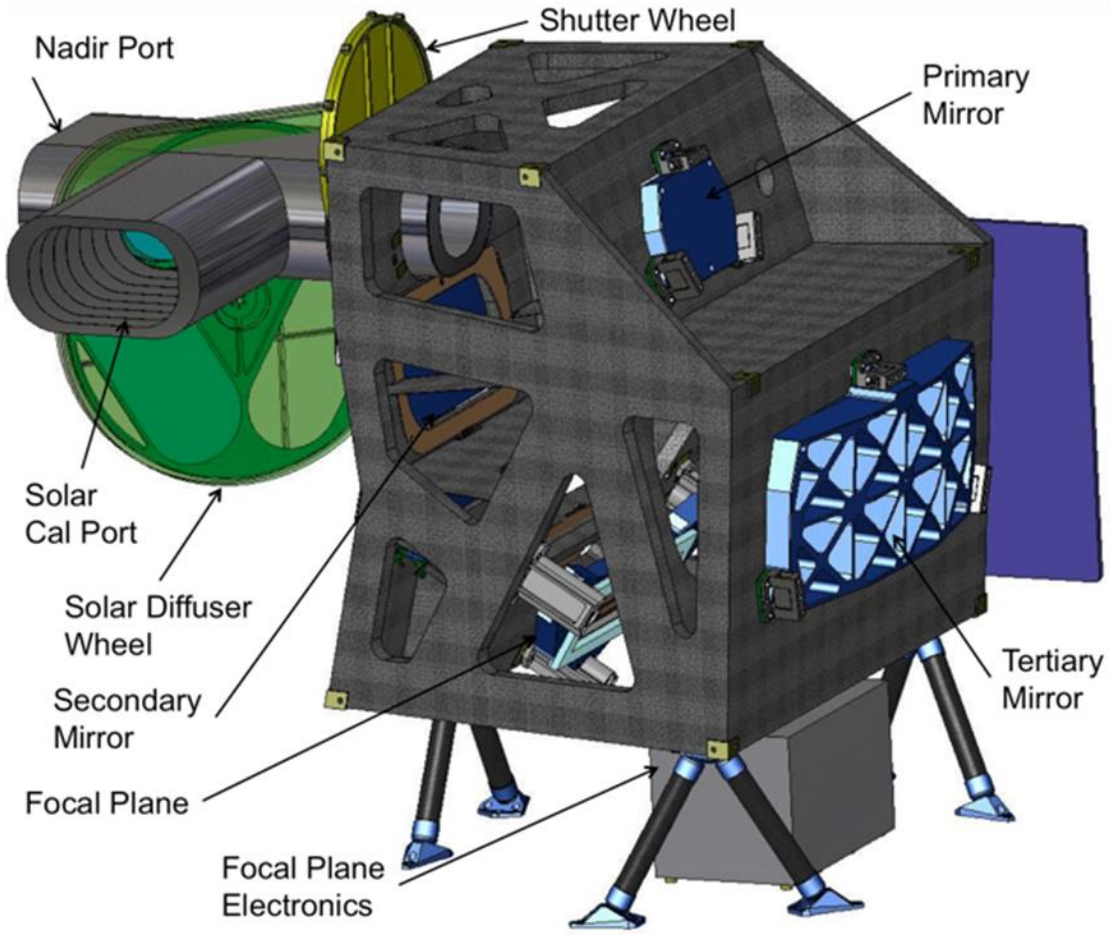


TIRS

Landsat 9 Operational Land Imager (OLI)

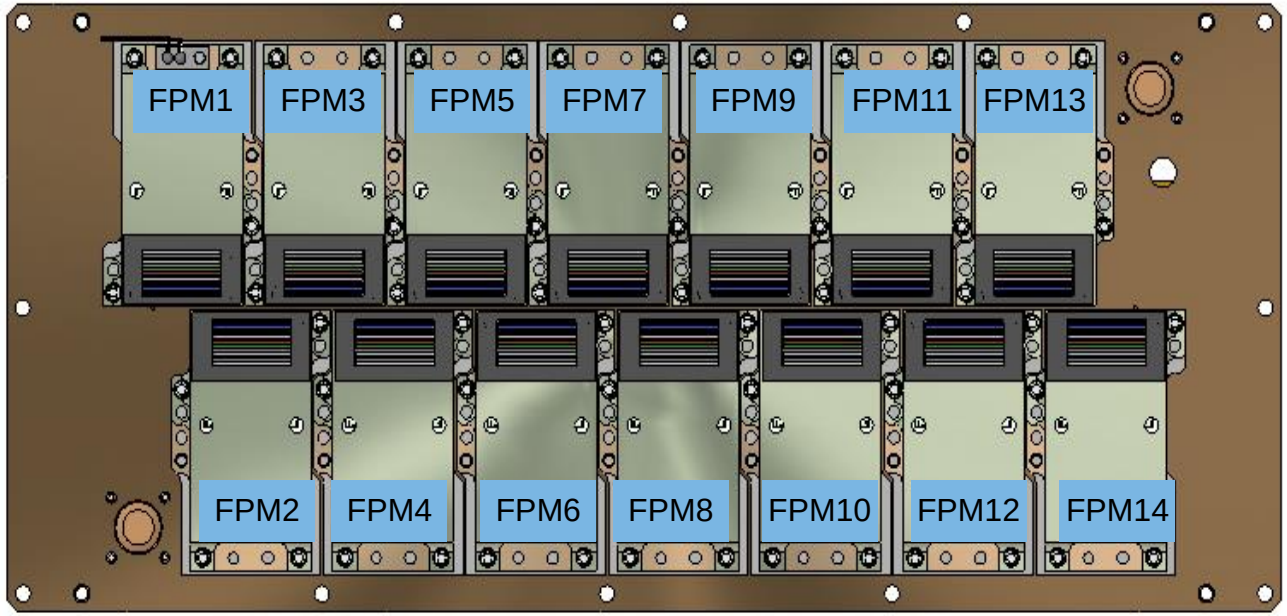
- **Landsat 9 OLI has been built as a copy of Landsat 8 OLI, to the extent possible**
- **Maintaining data continuity with Landsat 8 while minimizing cost and risk**

Band #	Band Name	Lower Band Edge (nm)	Upper Band Edge (nm)	Nominal IFOV (m)
1	Coastal Aerosol (CA)	435	450	30
2	Blue	452	512	30
3	Green	532	589	30
4	Red	636	672	30
5	Near Infrared (NIR)	850	879	30
6	Short Wave Infrared-1 (SWIR-1)	1565	1651	30
7	Short Wave Infrared-2 (SWIR-2)	2105	2294	30
8	Panchromatic (Pan)	503	675	15
9	Cirrus	1363	1384	30



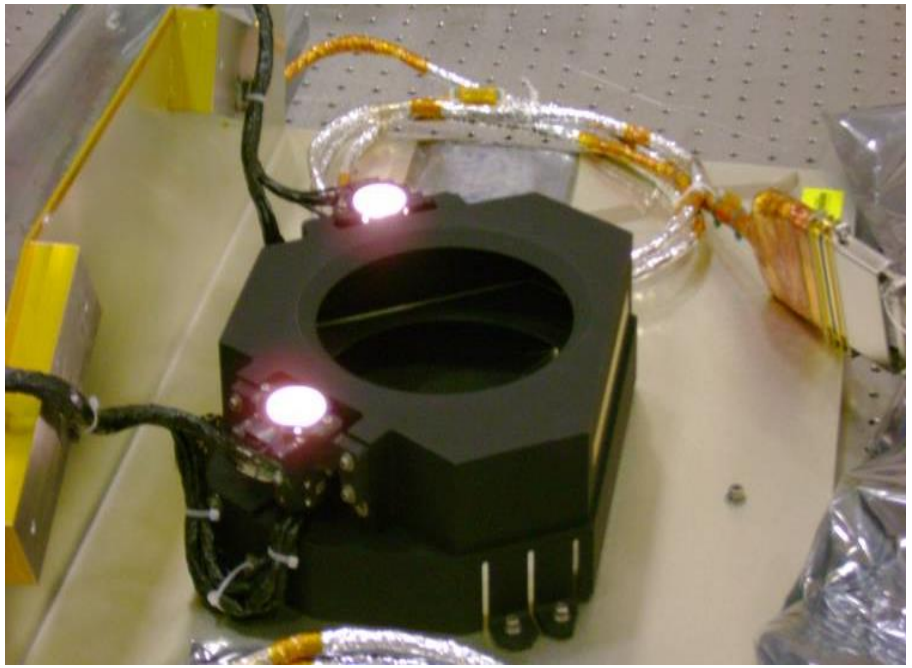
OLI Focal Plane

- **Focal Plane Array**
  - Consists of 14 modules to cover the 15-degree field of view
  - 6916 detectors per multi-spectral band (13832 for Pan band)
- **Focal Plane Module (FPM)**
  - 494-detector array for each multi-spectral band (988 for Pan band)
  - Silicon PIN detectors for VNIR bands, HgCdTe detectors for SWIR bands
  - Butcher-block filter assemblies cover the detector arrays
  - 12 Video Reference Pixels (VRP) per band (24 for Pan band)



OLI Calibration Devices

- **Two solar diffusers**
  - Working – weekly
  - Pristine – twice/year
- **Three lamp pairs**
  - Working – daily
  - Backup – every two weeks
  - Pristine – twice/year
- **Lunar**
  - Once per lunar cycle near full moon
- **Calibration shutter**
  - Twice per orbit
- **Combined band average trends used to characterize response trends**



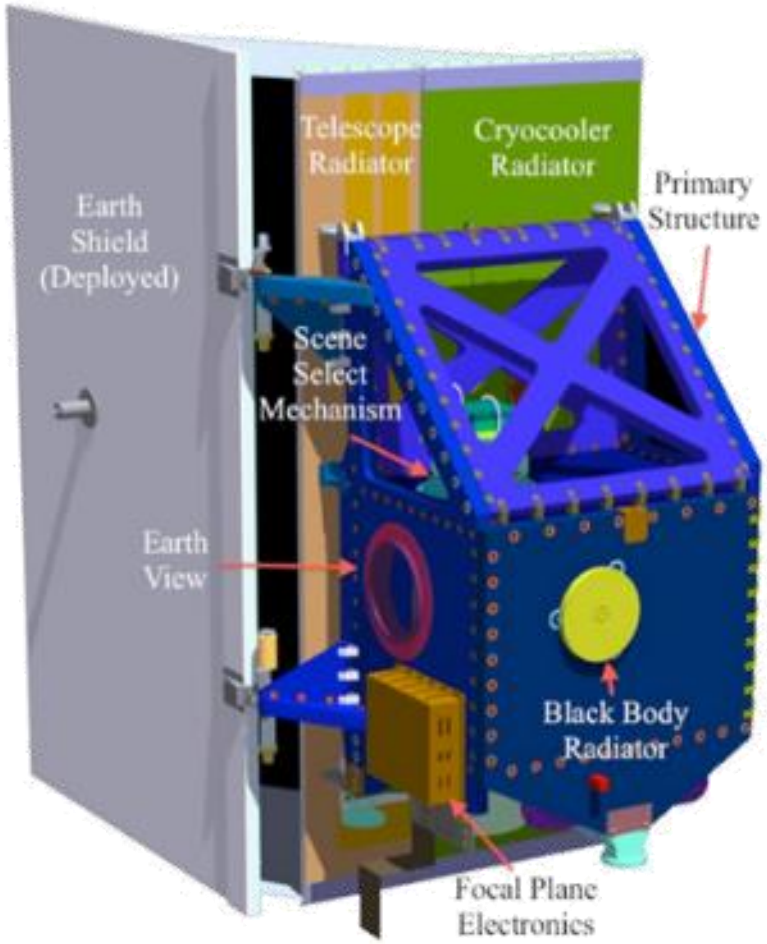
OLI Data Truncation

- **Landsat OLIs have a dynamic range of 14 bits**
- **For Landsat 8 OLI, only 12 bits transmitted by the spacecraft**
  - 12 upper bits for Earth images
    - Increased the quantization noise, which decreases the SNR, particularly at low signal levels
  - 12 lower bits for calibration shutter acquisitions
    - Saturation of bright targets
- **For Landsat 9 OLI, all 14 bits are retained and transmitted to the ground**
  - Expected improvements in performance, especially over dark targets

Landsat 9 Thermal Infrared Sensor (TIRS)

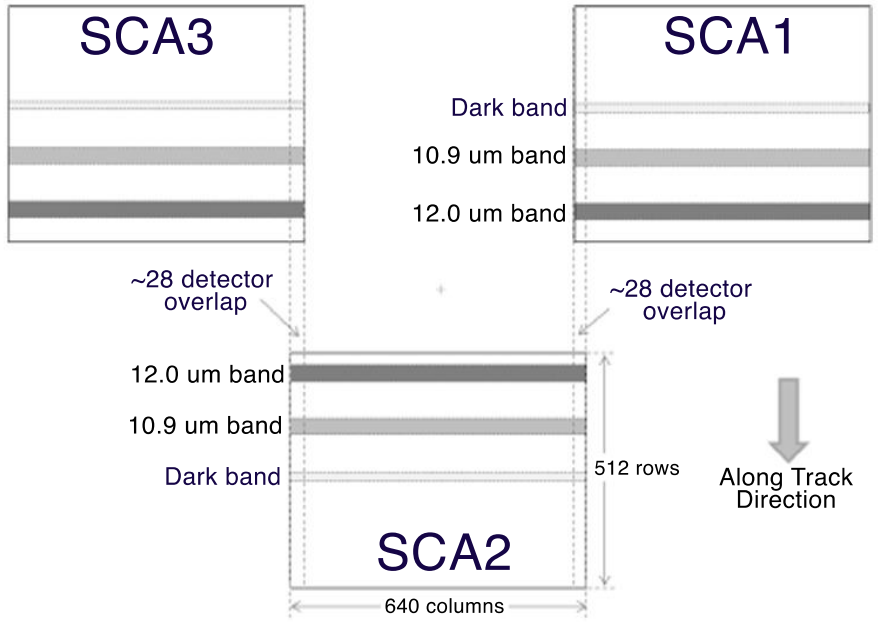
- **Landsat 9 TIRS is a rebuild of Landsat 8 TIRS except it's upgraded from Risk Class C to Class B for Landsat 9**
  - Increased redundancy to satisfy Class B reliability standards
  - Improved stray light performance through improved telescope baffling
  - Improved position encoder for scene select mirror to address problematic encoder on Landsat 8 TIRS

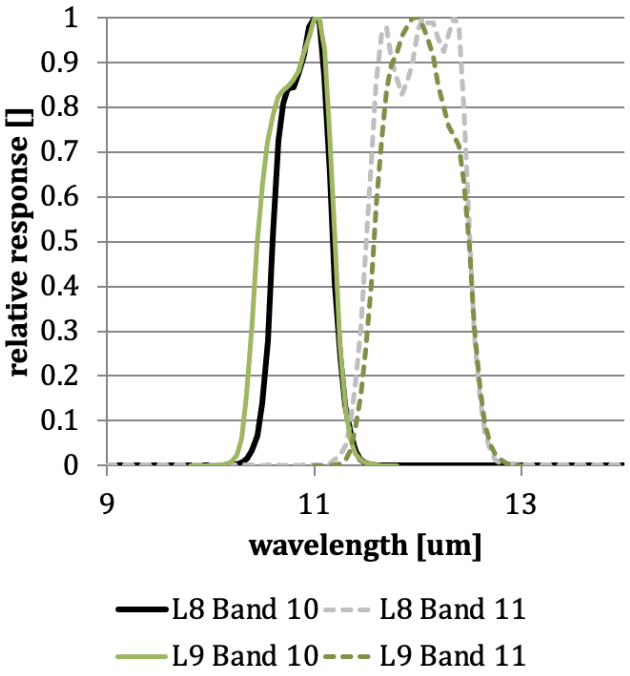
Band #	Band Name	Lower Band Edge (nm)	Upper Band Edge (nm)	Nominal IFOV (m)
10	Thermal-1	10450	11200	100
11	Thermal-2	11600	12500	100



Thermal Infrared Sensor

- **15-degree, 185 km field of view covered by 3 different Sensor Chip Assemblies (SCAs)**
- **SCAs are 512x640 pixel Quantum Well Infrared Photodetectors (QWIP)**
  - Spectral filters cover ~30 unvignetted rows on each chip
  - Science data (earth imagery) comes from one of two rows for each band
- **100 m spatial resolution**
- **Two spectral bands chosen to optimize a split-window atmospheric correction**
  - Not quite identical spectral shape between instruments

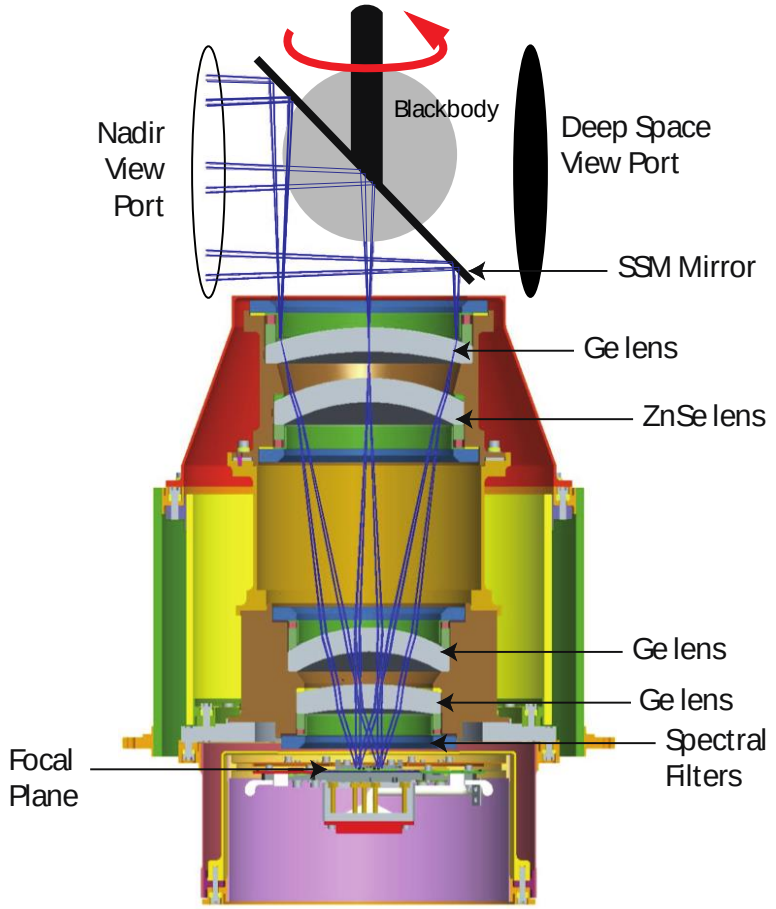




https://landsat.gsfc.nasa.gov/satellites/landsat-9/landsat-9-instruments/tirs-2-design/tirs-2-relative-spectral-response/
https://landsat.gsfc.nasa.gov/satellites/landsat-8/spacecraft-instruments/thermal-infrared-sensor/spectral-response-of-the-thermal-infrared-sensor/

TIRS Design

- **Four-lens telescope**
- **Scene Select Mechanism (SSM) at the end of the telescope switches the view**
- **On-board calibration capabilities with blackbody and deep space view**
  - Variable temperature blackbody allows for rigorous on-board calibrations



Reuter, D.C.; Richardson, C.M.; Pellerano, F.A.; Irons, J.R.; Allen, R.G.; Anderson, M.; Jhabvala, M.D.; Lunsford, A.W.; Montanaro, M.; Smith, R.L.; Tesfaye, Z.; Thome, K.J. The Thermal Infrared Sensor (TIRS) on Landsat 8: Design Overview and Pre-Launch Characterization. *Remote Sens.* **2015**, *7*, 1135-1153. https://doi.org/10.3390/rs70101135
Montanaro, M.; Gerace, A.; Lunsford, A.; Reuter, D. Stray Light Artifacts in Imagery from the Landsat 8 Thermal Infrared Sensor. *Remote Sens.* **2014**, *6*, 10435-10456. https://doi.org/10.3390/rs61110435

TIRS Stray Light Artifact

- **In Landsat-8 TIRS, a stray light feature was discovered in imagery soon after launch**
  - Confirmed by off-axis scans of the moon and by high-fidelity optical modeling
  - Out-of-field radiance was scattering in the optical system
- **Stray light affects every pixel differently**
- **An algorithm was developed to estimate the per-pixel contribution of stray light to the earth imagery**
  - Applied to Landsat-8 TIRS data starting in Collection-1 (2016)
- **Design changes to the baffles in Landsat-9 TIRS reduced the total stray light contribution by >10x**
  - No need to use the correction algorithm on Landsat-9 data

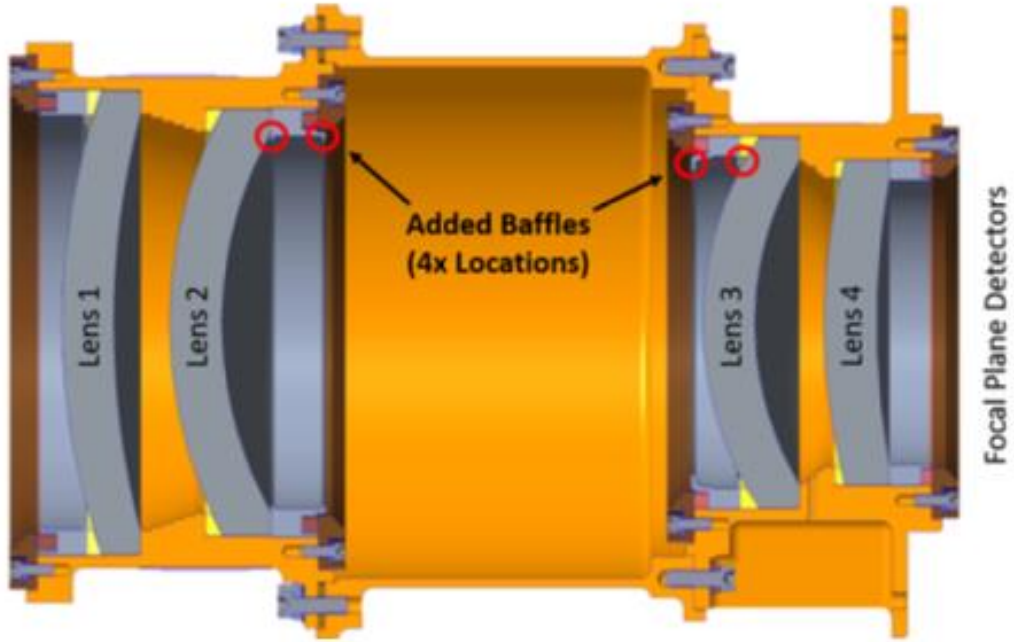
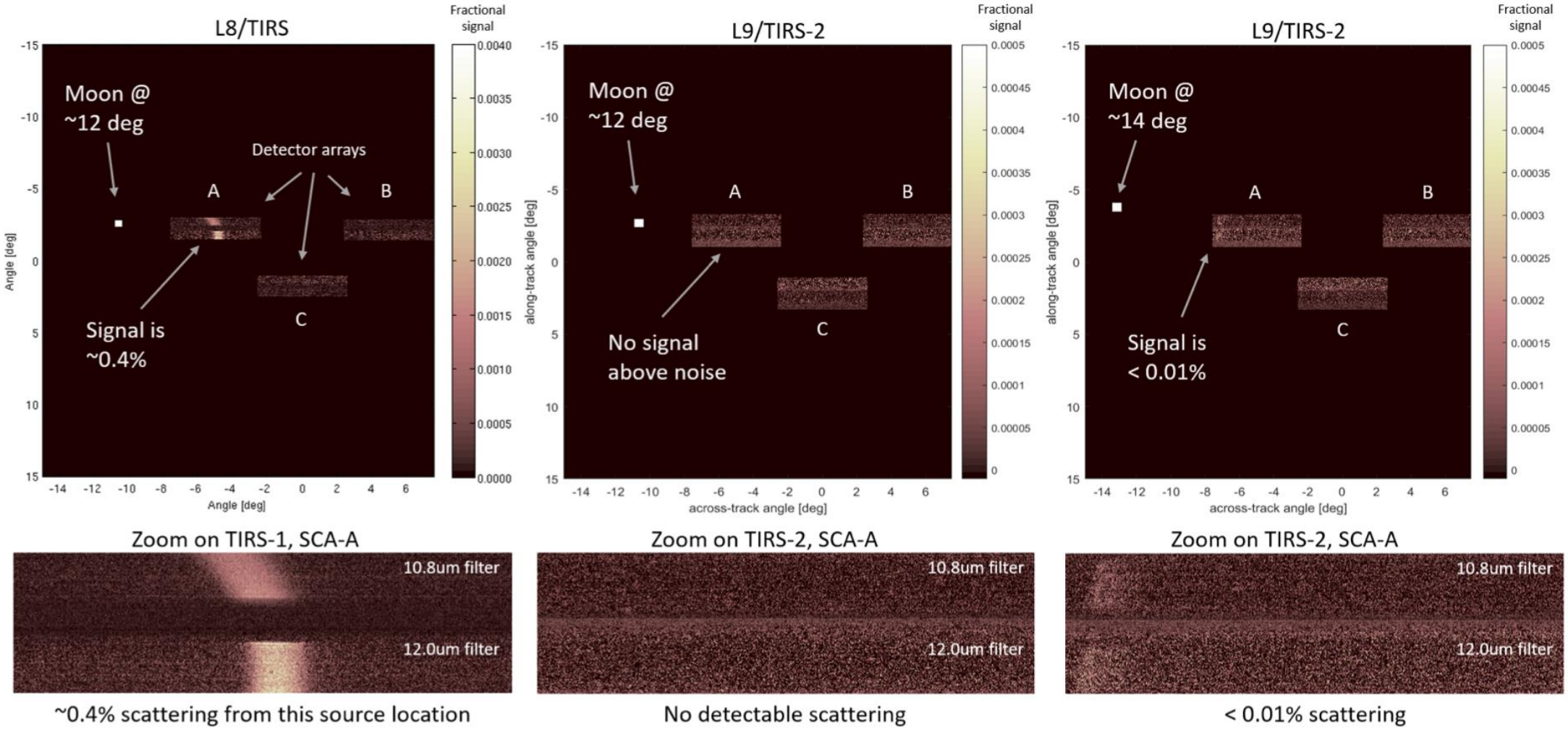


Fig. 1. Cross-section of the TIRS-2 telescope assembly indicating the locations of the added baffles to reduce the effect of scattering over the baseline design.

M. Montanaro *et al*., "Landsat 9 Thermal Infrared Sensor 2 (TIRS-2) Stray Light Mitigation and Assessment," in *IEEE Transactions on Geoscience and Remote Sensing*, vol. 60, pp. 1-8, 2022, Art no. 5002408, doi: 10.1109/TGRS.2022.3177312.

TIRS Stray Light Artifact

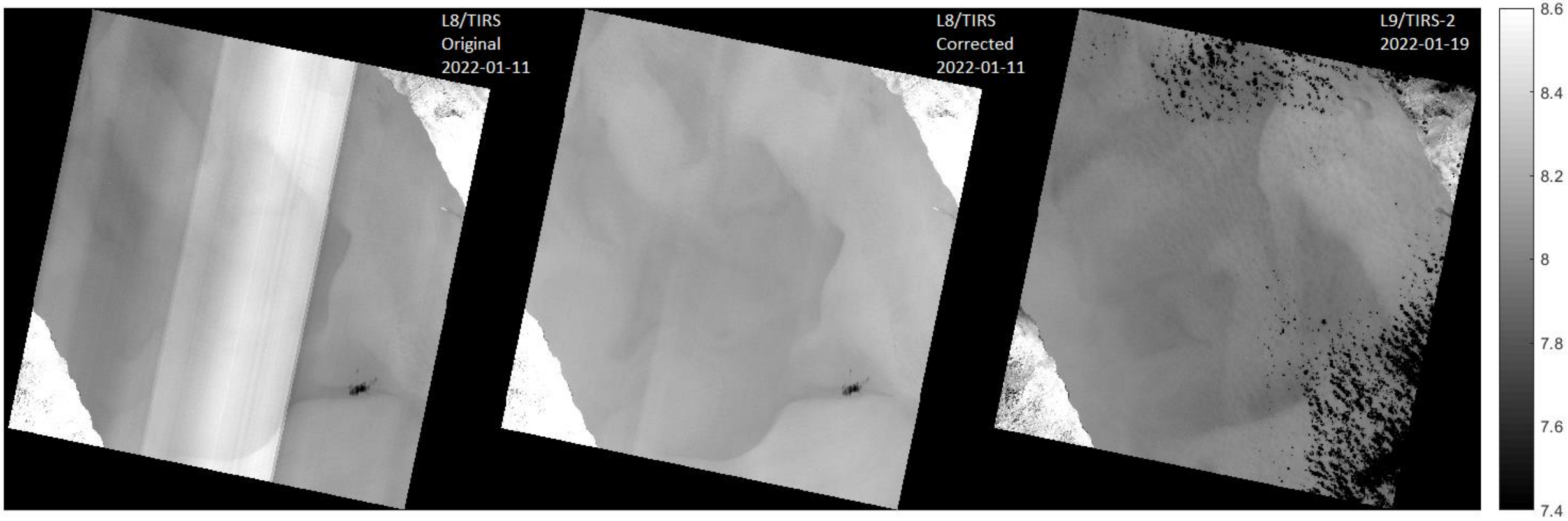


Effect of Stray Light in Imagery

Landsat 8 TIRS Original Product

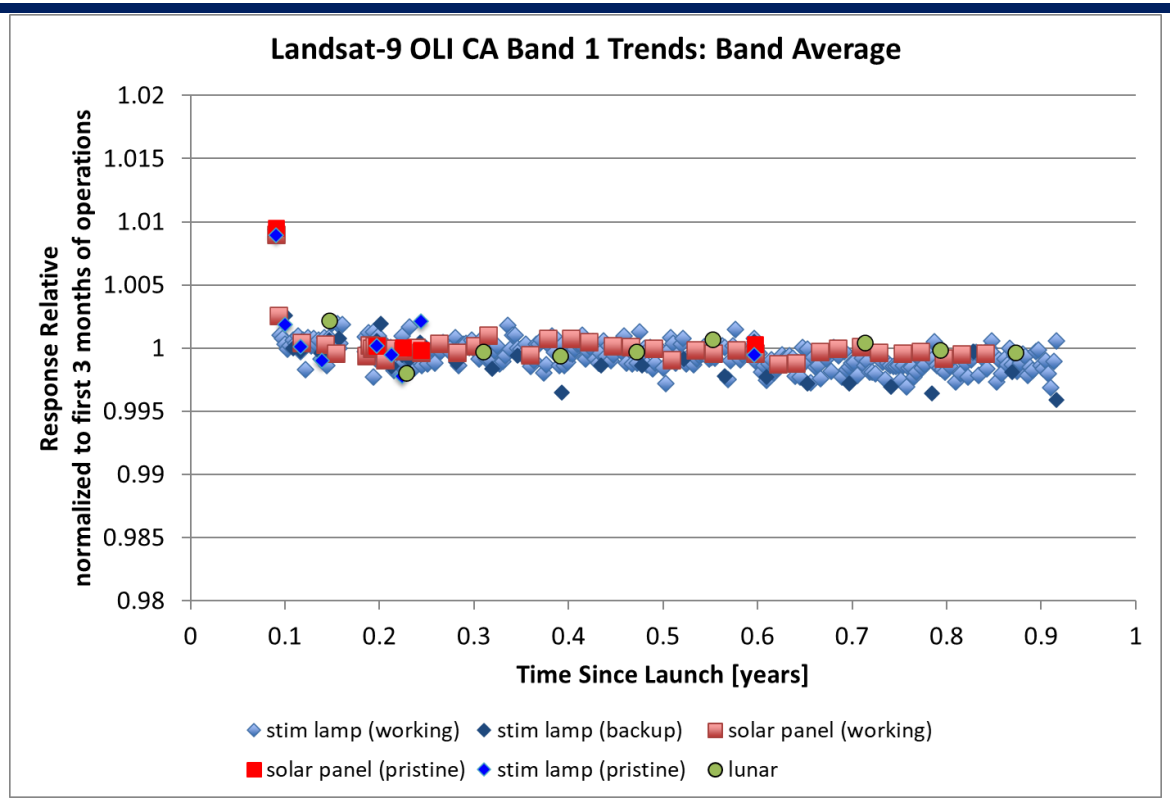
Landsat 8 TIRS Stray Light Corrected Product

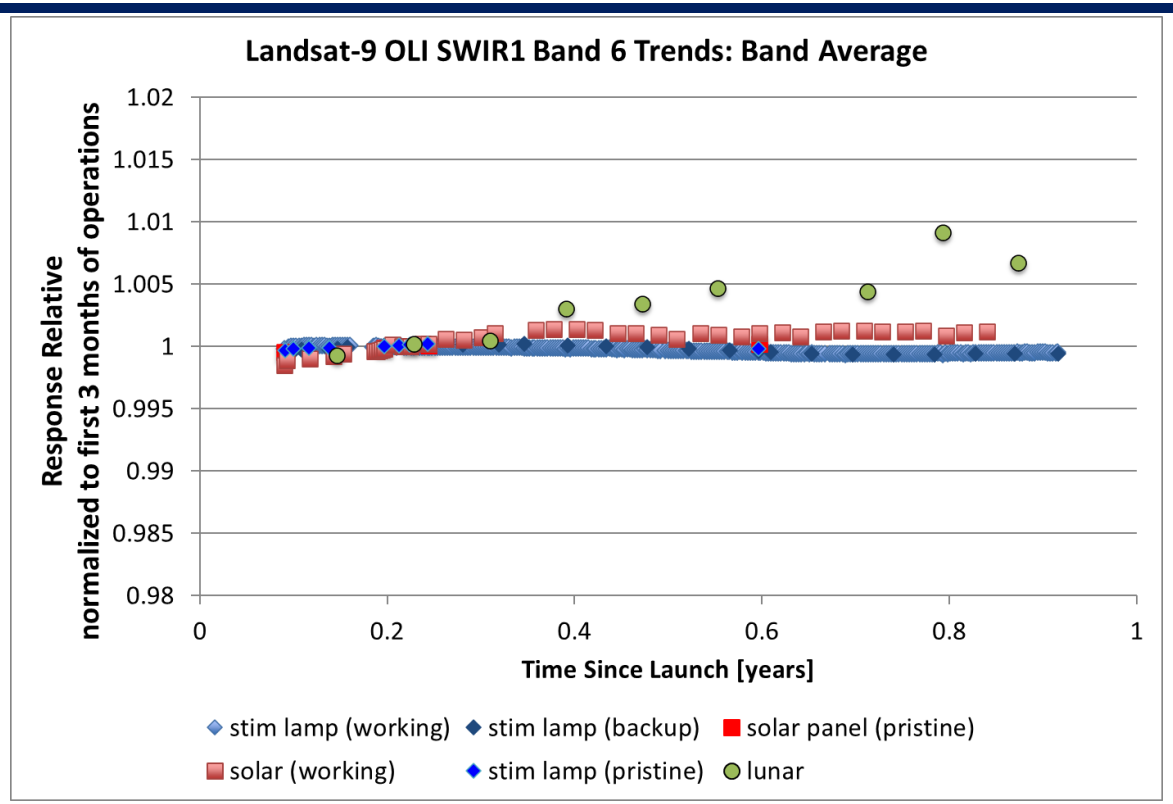
Landsat 9 TIRS Product



OLI Radiometric Performance

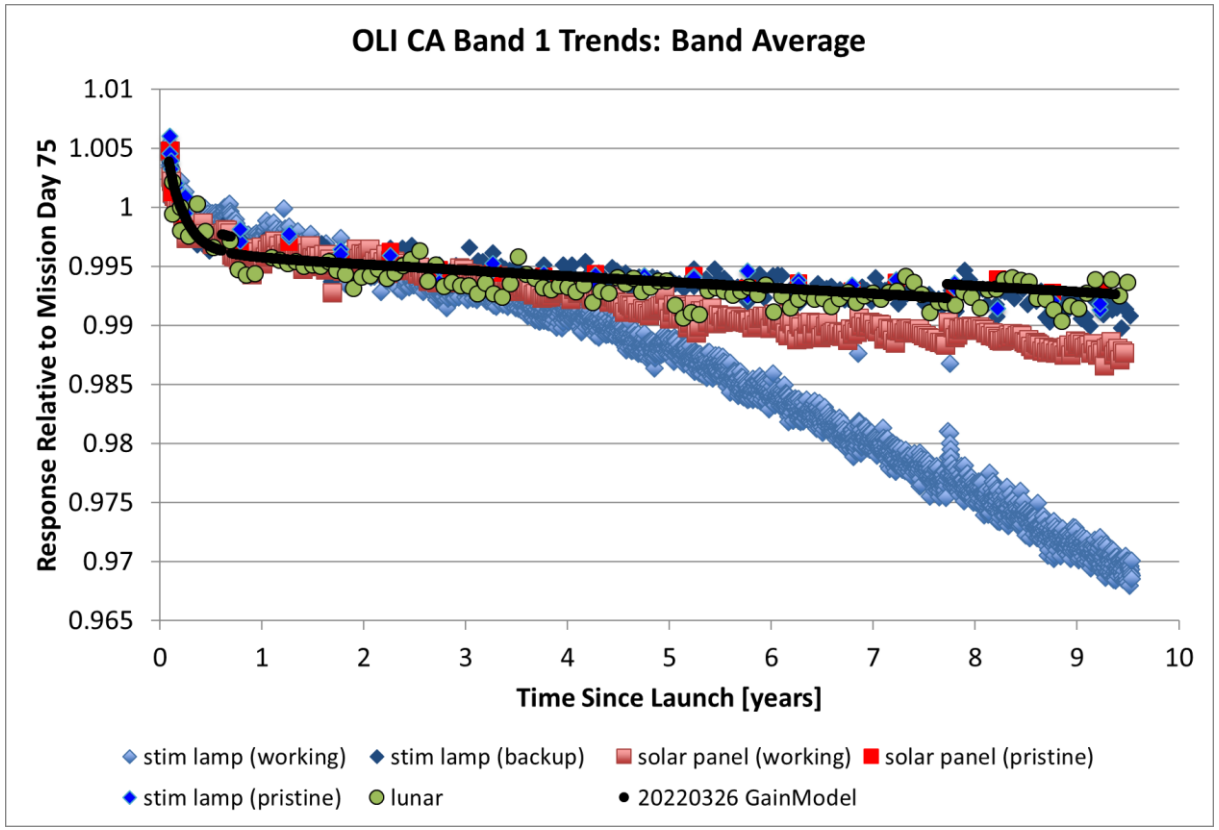
Landsat 9 OLI Radiometric Stability

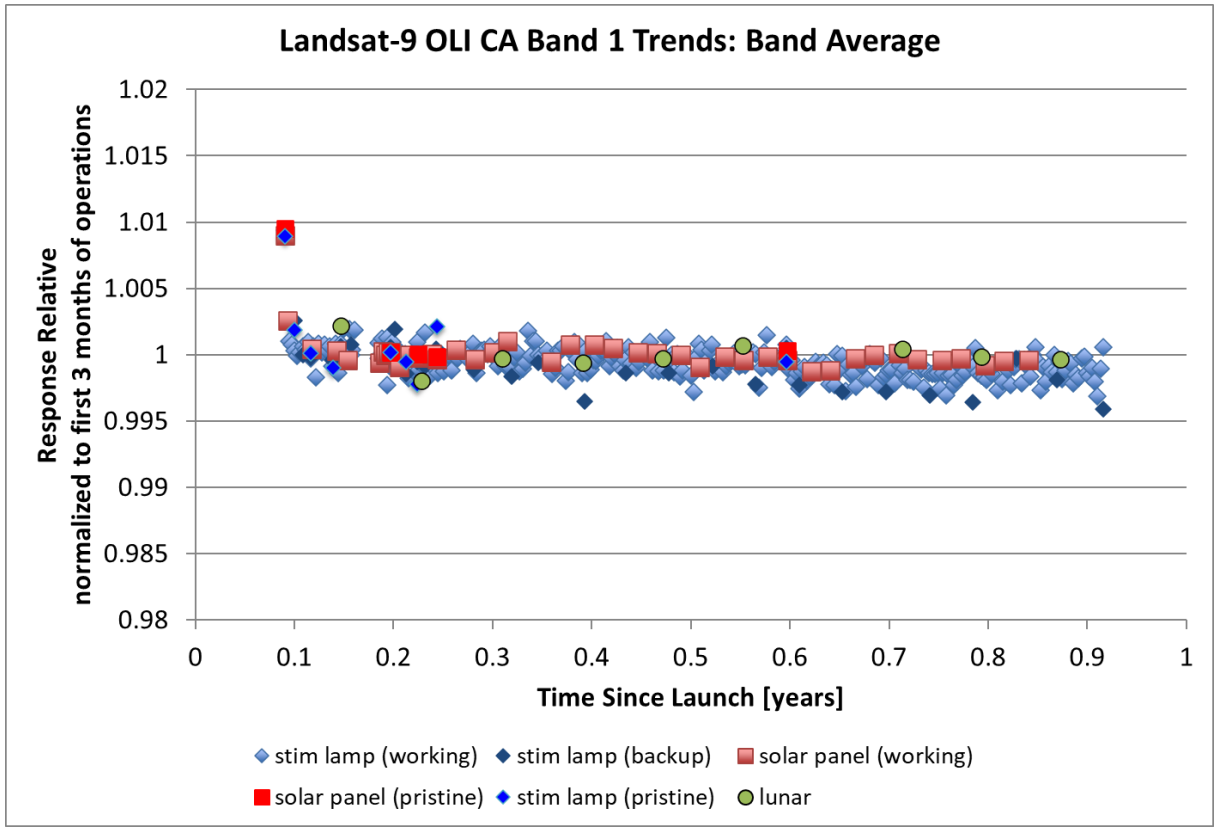




- **On-board band-average radiometric stability is excellent**
- **Based on the working stim lamp, the radiometric calibration of all bands is stable to within ~0.1% since launch**

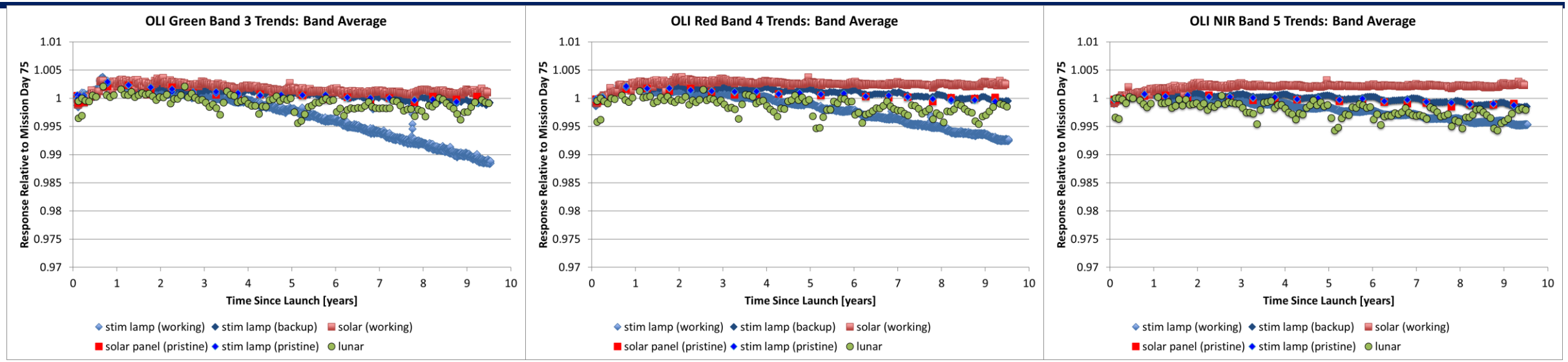
Landsat 8 and 9 OLI – CA Band Stability





- **On-board band-average radiometric stability is excellent**
  - The initial decay seen in the Landsat 8 OLI CA band is not present in the Landsat 9 OLI CA band

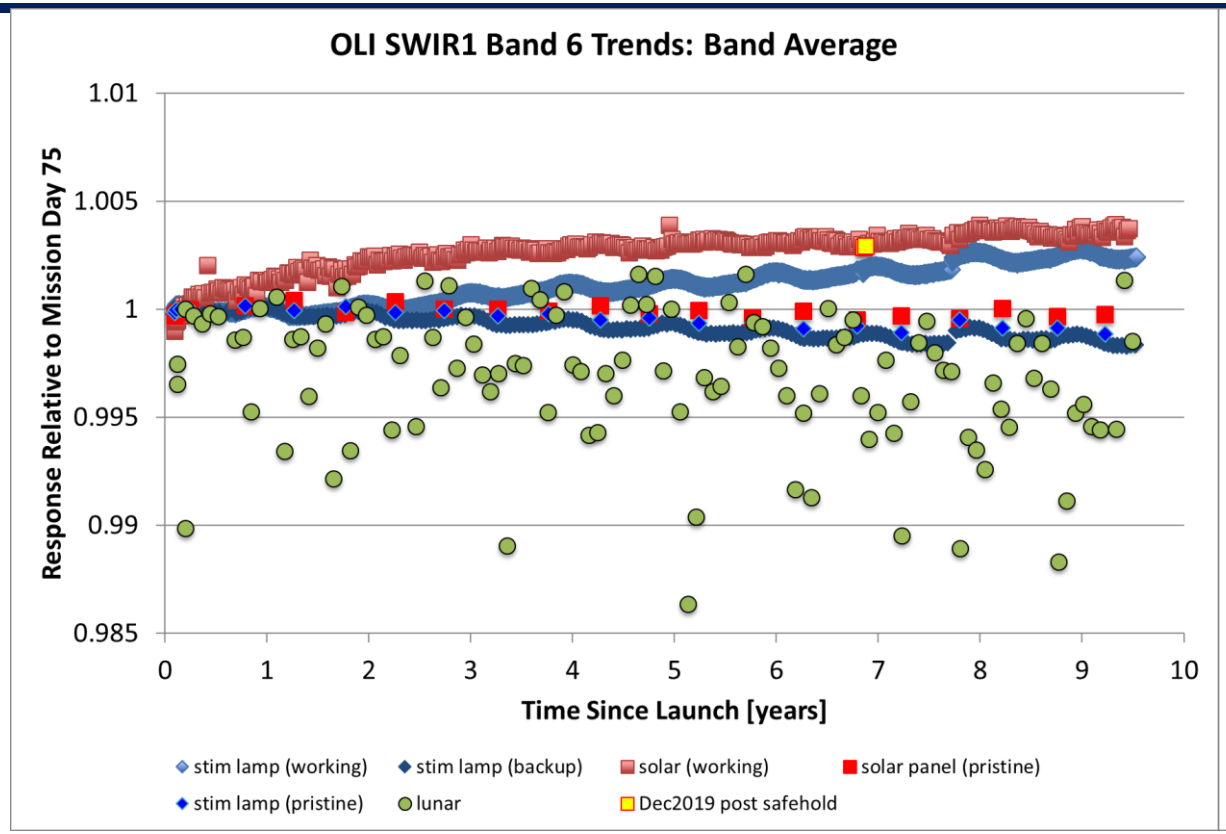
L8 OLI Radiometric Stability – Green, Red and NIR

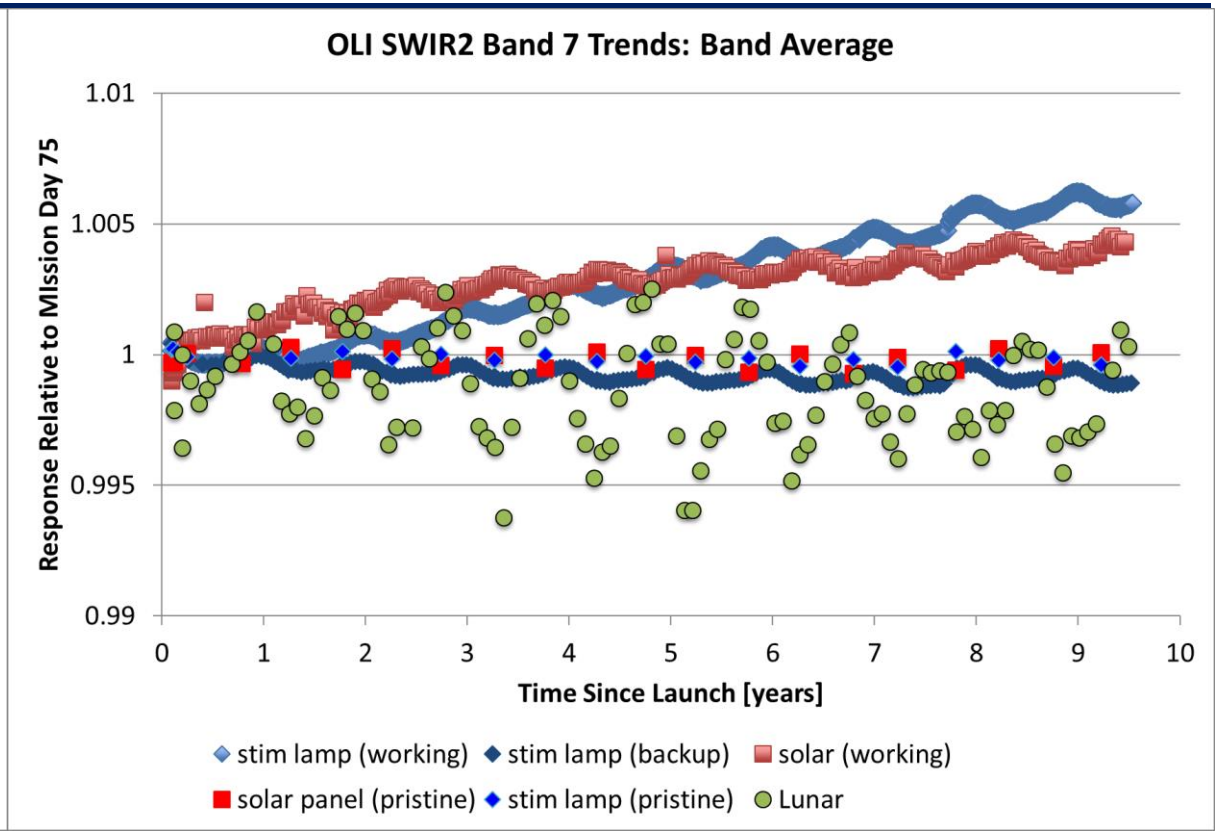


stim lamp (working) stim lamp (backup) stim lamp (pristine) solar (working) solar panel (pristine) lunar

- **Decreasing response to working lamp in VNIR bands (0.5 - 1%)**
  - Possible color temperature shift
- **Oscillations in lamp responses**

L8 OLI Radiometric Stability – SWIR1 and SWIR2





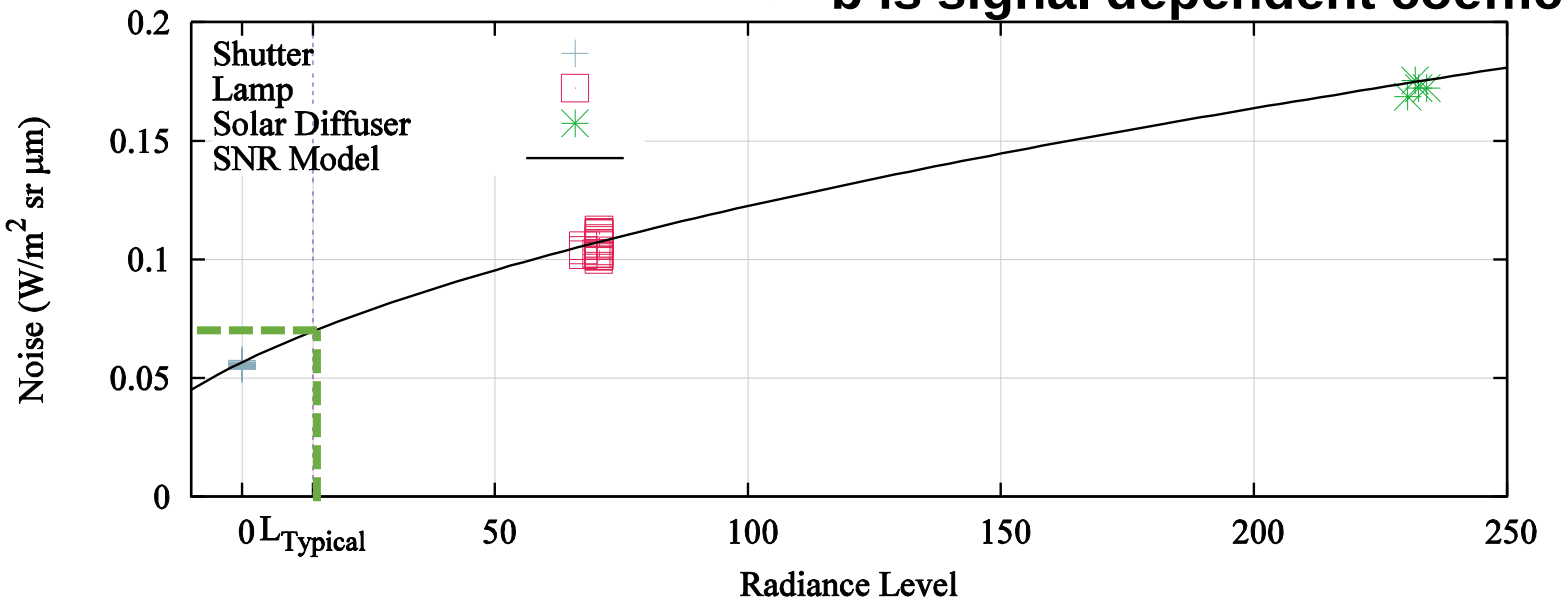
- Increasing response to working diffuser and working lamp (up to ~0.6%)
- Oscillations in response to internal calibrators (~0.1%) caused by different reasons
- Large scatter in SWIR bands lunar response

Noise Performance

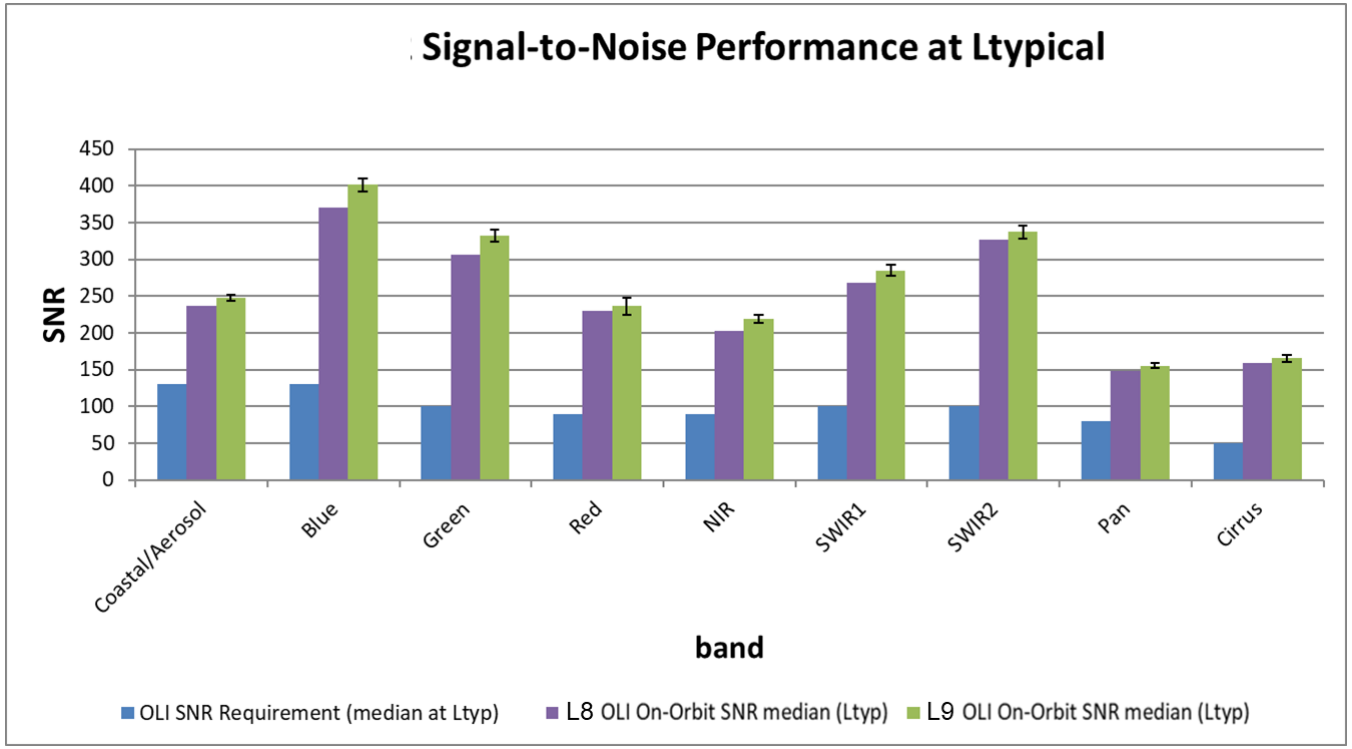
- **At a given radiance level, noise is estimated from the model that is based on dark, lamp and diffuser calibration data:**

$$n_s(L) = \sqrt{a + bL}$$

  - a is signal independent coefficient, $\left(\frac{W}{m^2 sr\ \mu m}\right)^2$
  - b is signal dependent coefficient, $\frac{W}{m^2 sr\ \mu m}$



OLI Signal to Noise Ratio (SNR)

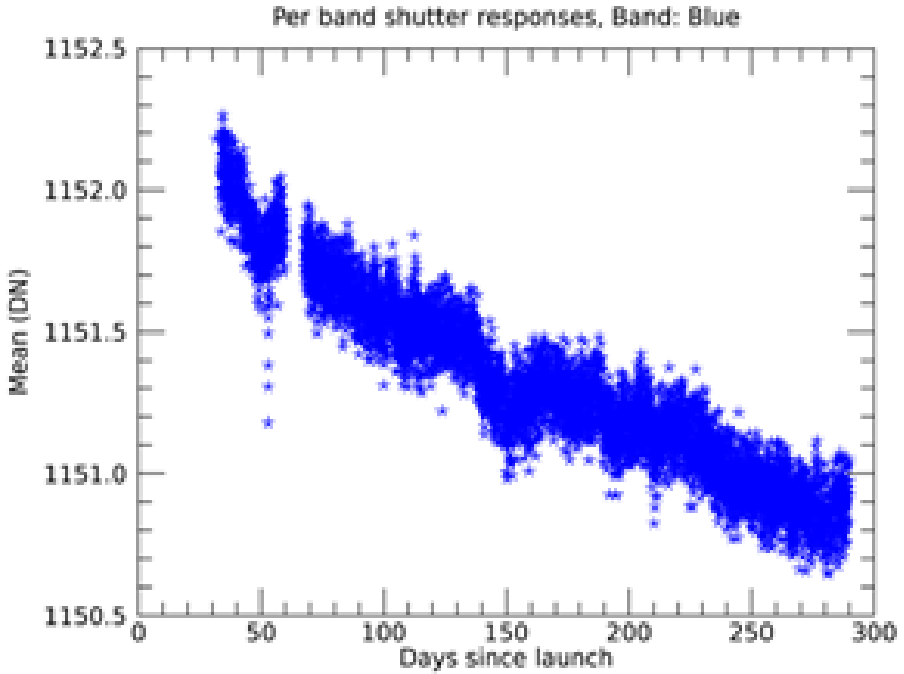


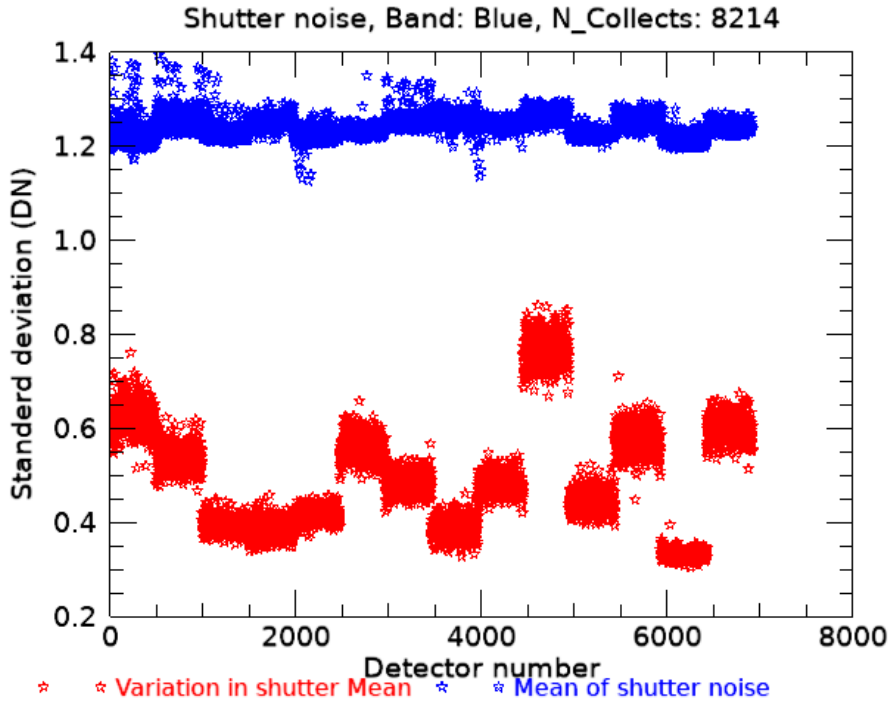
Band	% Diifference
CA	4.5
Blue	8.4
Green	8.2
Red	3.0
NIR	8.0
SWIR1	6.4
SWIR2	3.2
Pan	4.9
Cirrus	3.6

- **Landsat 9 OLI SNR is slightly larger than Landsat 8 OLI**
  - Likely due to the increase in the radiometric precision
- **Since launch, the median SNR for all Landsat-9 OLI bands has been stable to within +/-0.45%.**

L9 OLI Bias Stability

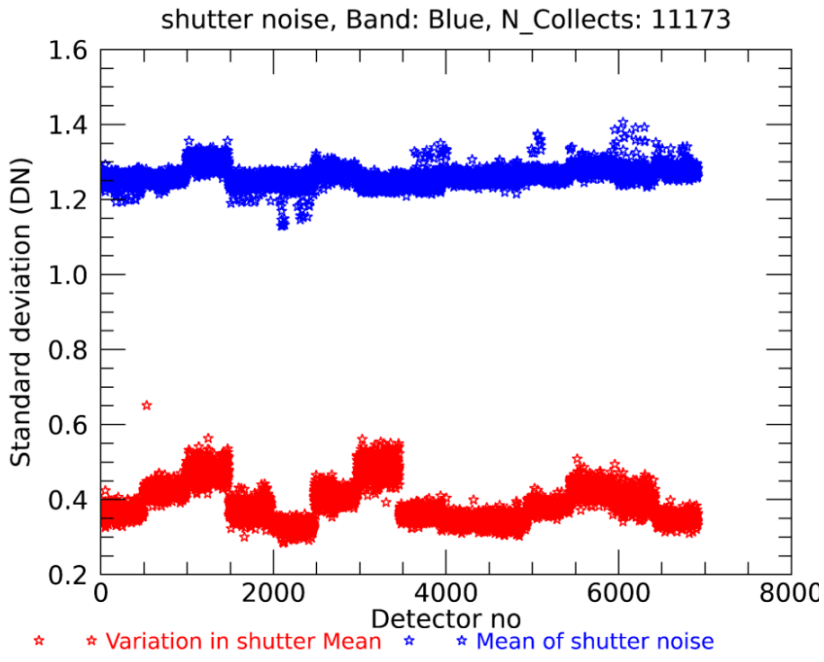
- **Bias is estimated from dark shutter data acquisitions, before and after each imaging interval**
  - Short collects, 500 samples (~2 seconds)
- **Within each shutter interval, the variability is less than 2 DN in all bands**
- **Over the eight months on orbit, the average response to the shutter has varied by less than 1 DN**

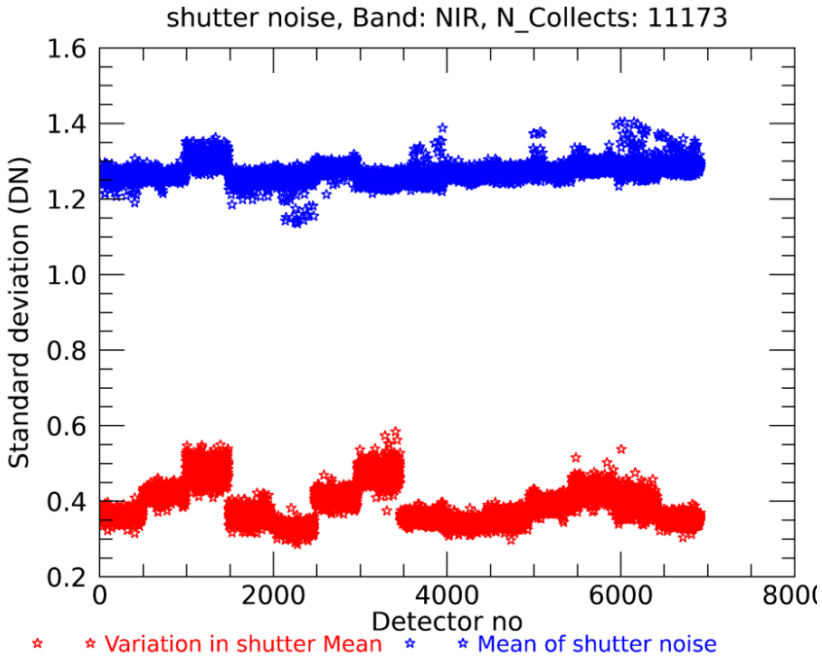


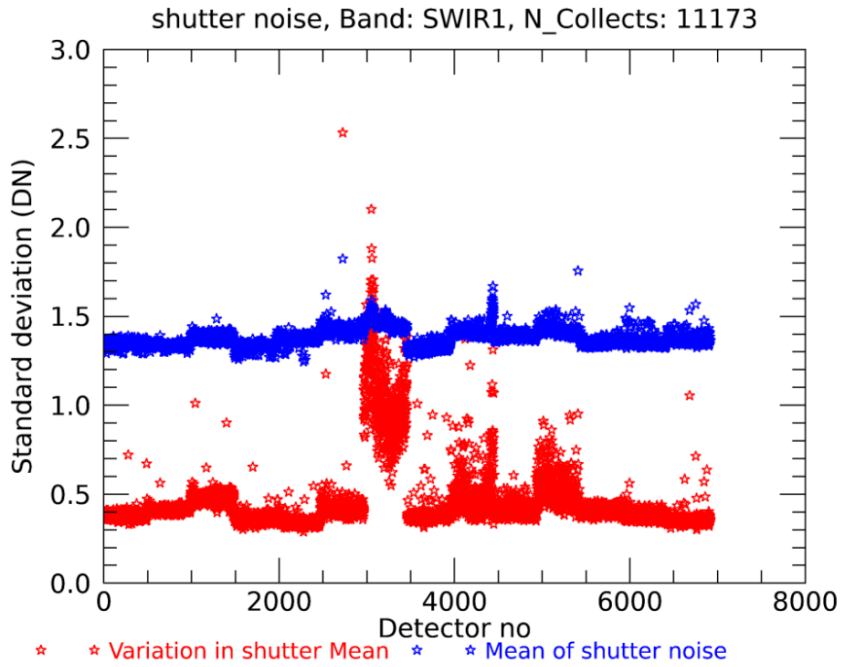


L8 OLI Shutter Response Stability

- Measured by average standard deviation (data used 07012021-07312022)
  - Within interval < 2DN
  - Temporal variation < 1DN except SWIR bands

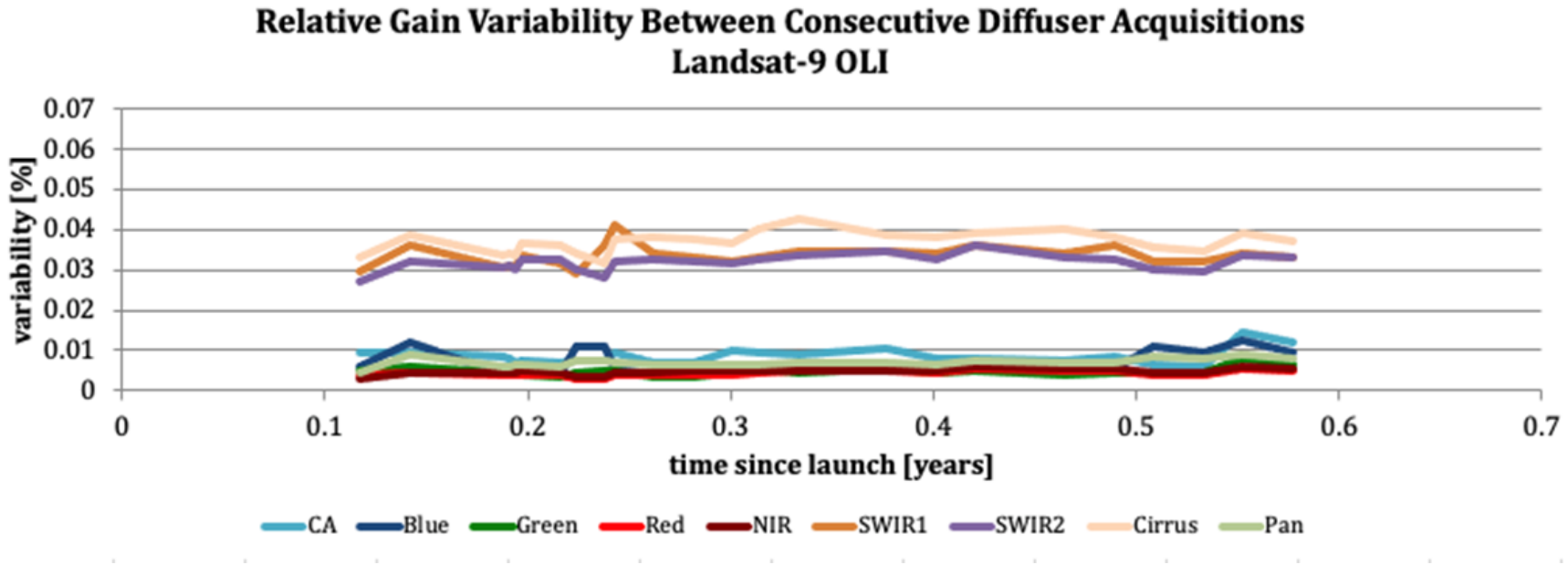






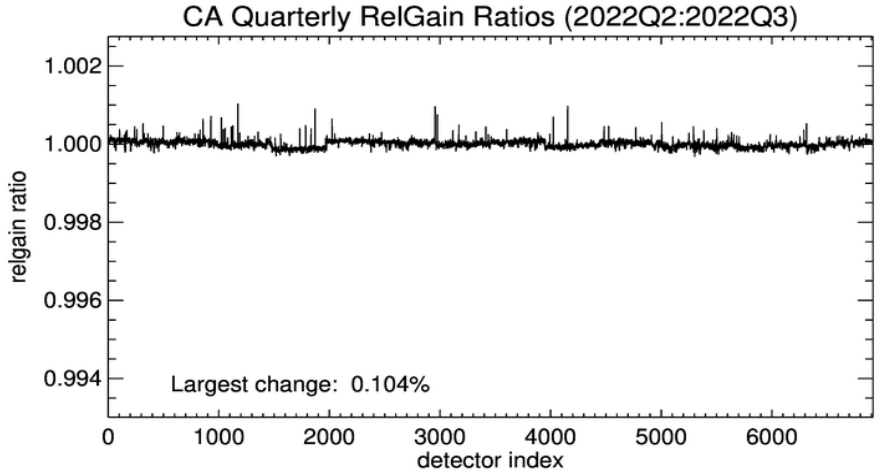
L9 OLI Uniformity

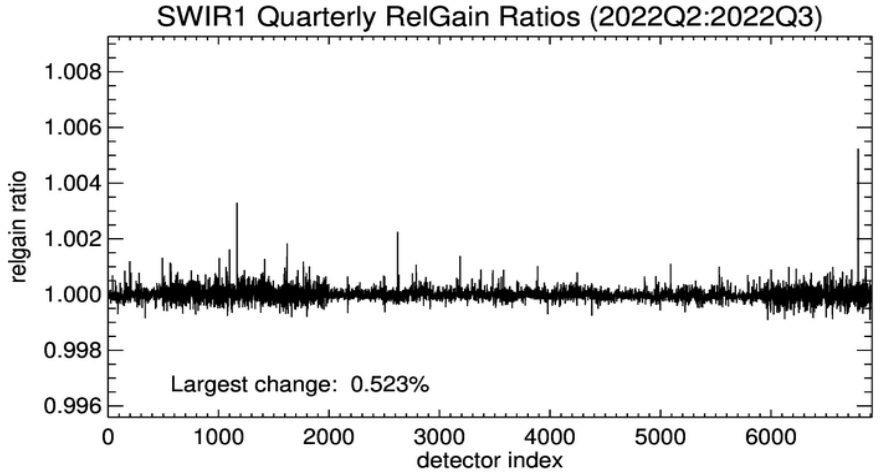
- **With 7000 individual detectors per-band, the relative calibration of each detector is important**
  - If a detector is not normalized to its neighbors properly, there will be stripes in the imagery
- **The plot illustrates the relative level of striping in the imagery since launch, as monitored using the response to the solar diffuser**
  - The flat trends for all bands indicate that the level of striping has been constant since launch

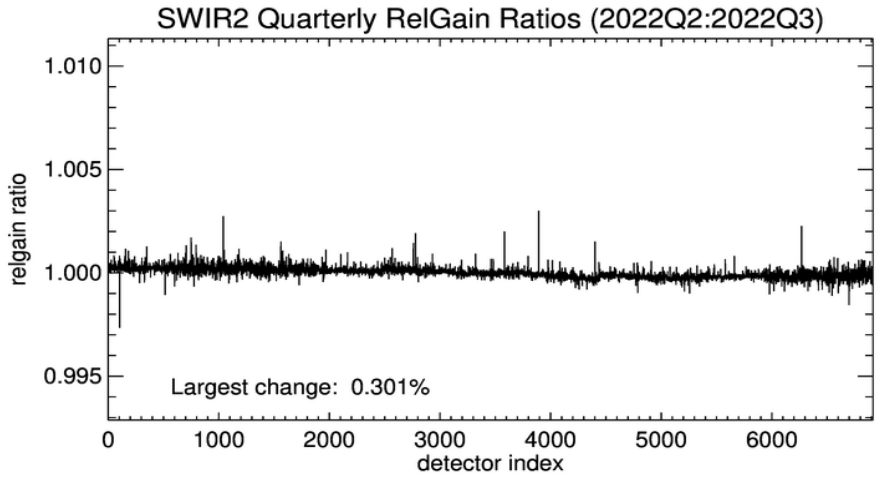


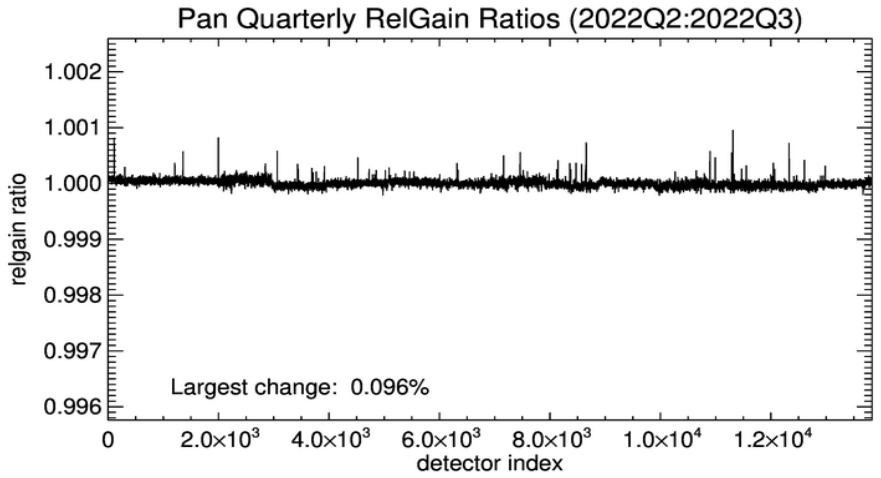
L8 OLI Relative Gain Updates

- **Relative gains are updated quarterly**
  - Using solar diffuser acquisitions
- **Examples of actual changes from 2022 Q2 to 2022 Q3**
  - Using data from within the quarter
  - Correction for this change is applied in the following quarter (2022 Q4)



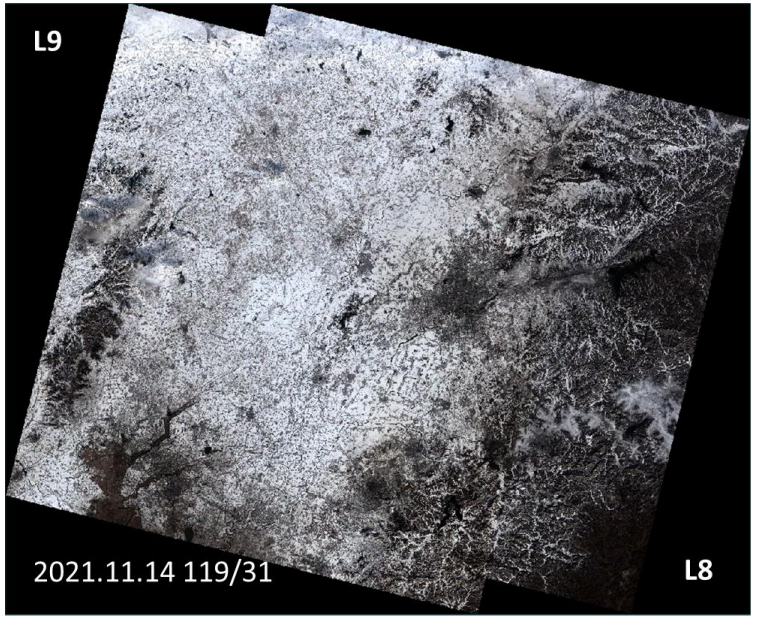




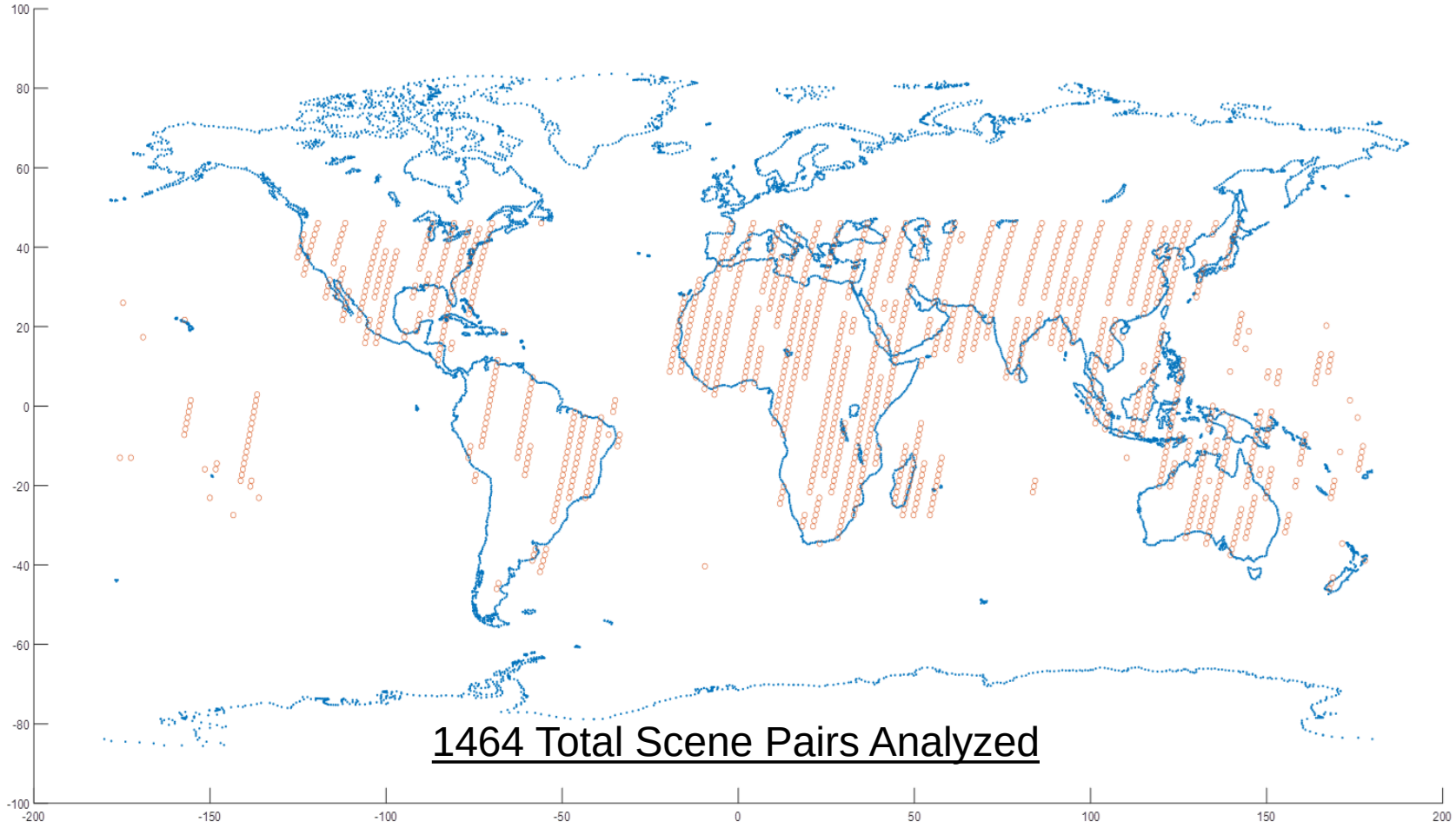


Landsat 8 and 9 Cross-calibration

- **On the ascent to its 705 km orbit, Landsat 9 was positioned in orbit underneath Landsat 8**
  - For about five days in November 2021, the OLI instruments saw the same locations on the ground, acquired within 30 minutes through almost the same atmosphere and at common view and sun angles
- **A team at South Dakota State University analyzed hundreds of Landsat 8/Landsat 9 scene pairs**
  - Defined 13 land cover types and computed the ratio of Landsat 9 response to Landsat 8 response for each type separately
  - The 13 types were grouped back into larger, statistically significant groups
    - Soil & Sand
    - Vegetation
    - Snow & Ice
  - The weighted average of the three large classes was used to determine the cross-calibration gain



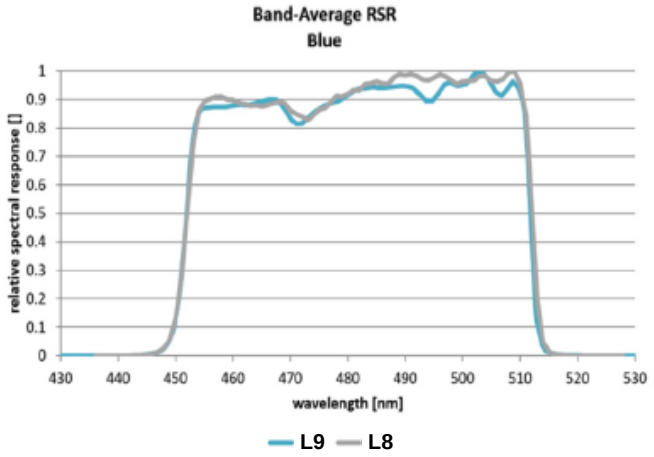
Landsat 8 and 9 Cross-calibration

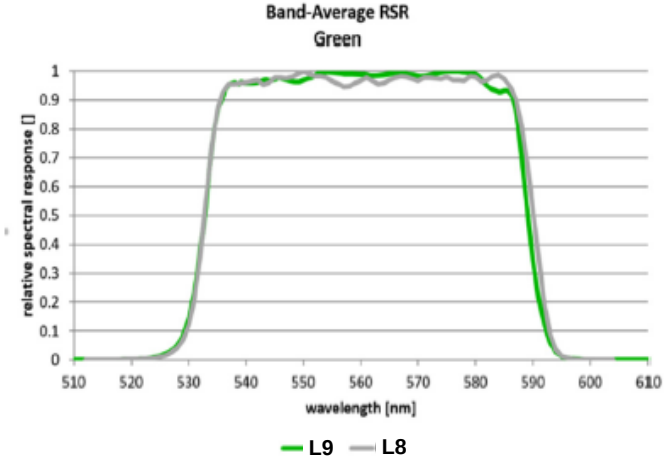


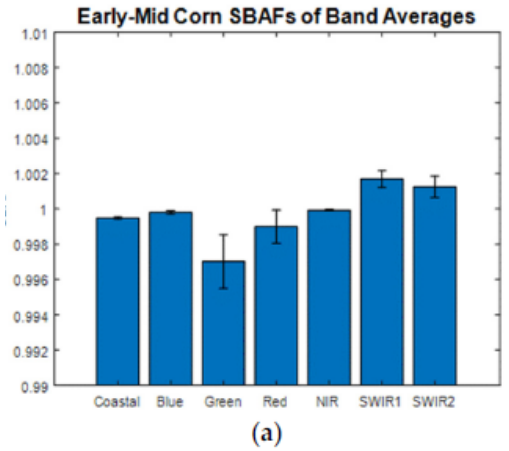
1464 Total Scene Pairs Analyzed

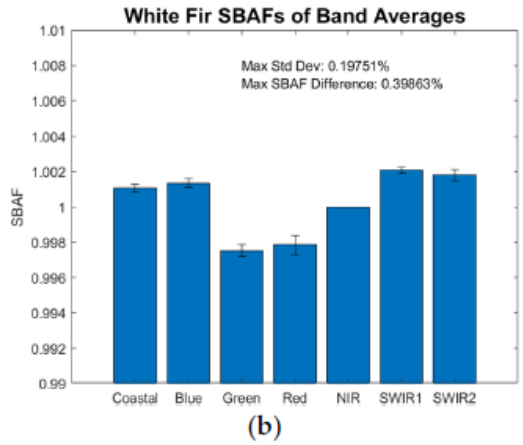
- **Data limits and prioritization were set on**
  - Sun Elevation
  - Sensor View Angle Difference
  - Signal Level
- **Homogeneous ROIs in scene pairs were used**

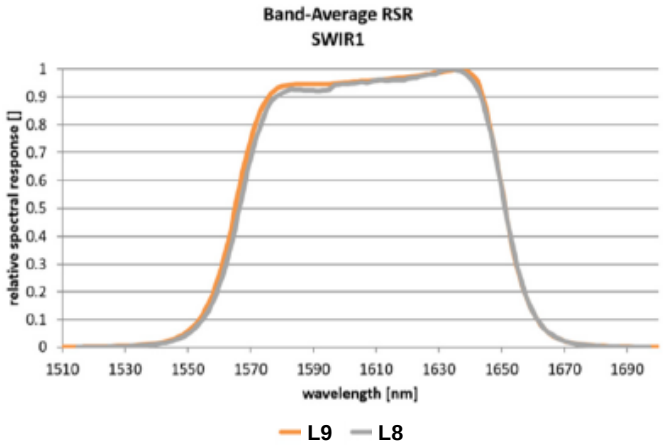
Landsat 8 and Landsat 9 RSRs and Response Differences

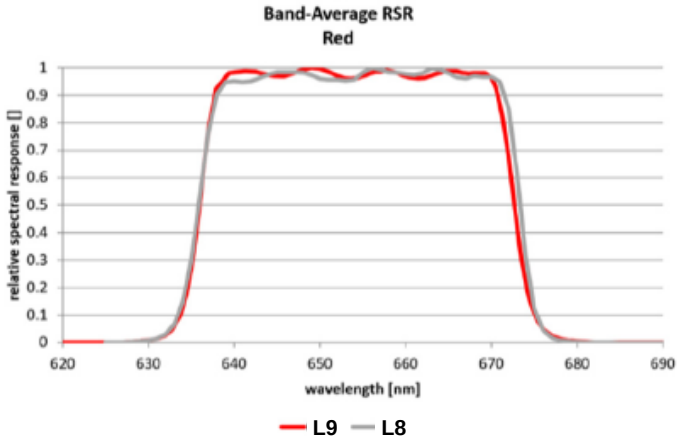


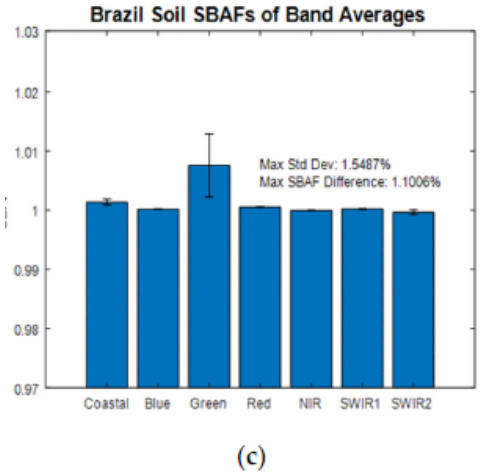


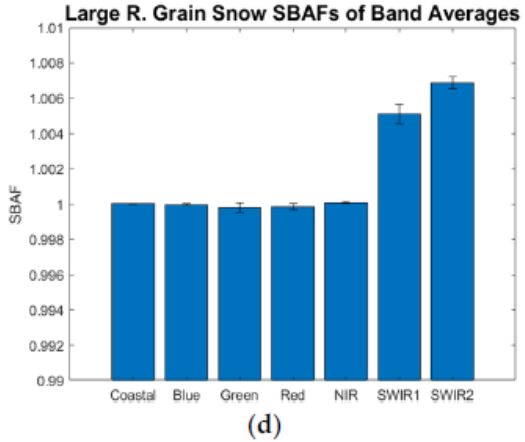






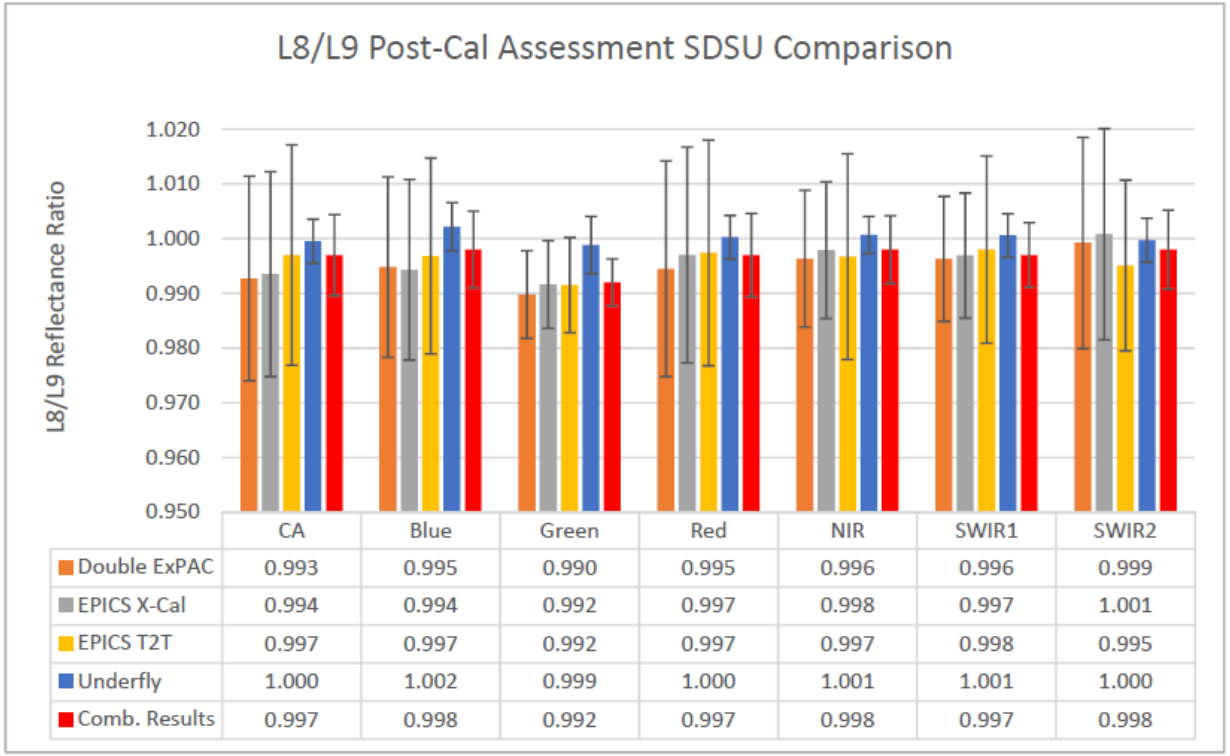






Landsat 8 and 9 Cross-calibration

Band #	Spectral Band	Landsat 8 / Landsat 9 adjustment factor [%]
1	CA	1.31
2	Blue	1.40
3	Green	1.31
4	Red	0.79
5	NIR	0.78
6	SWIR1	-0.44
7	SWIR2	1.33
8	Panchromatic	0.24
9	Cirrus	N/A

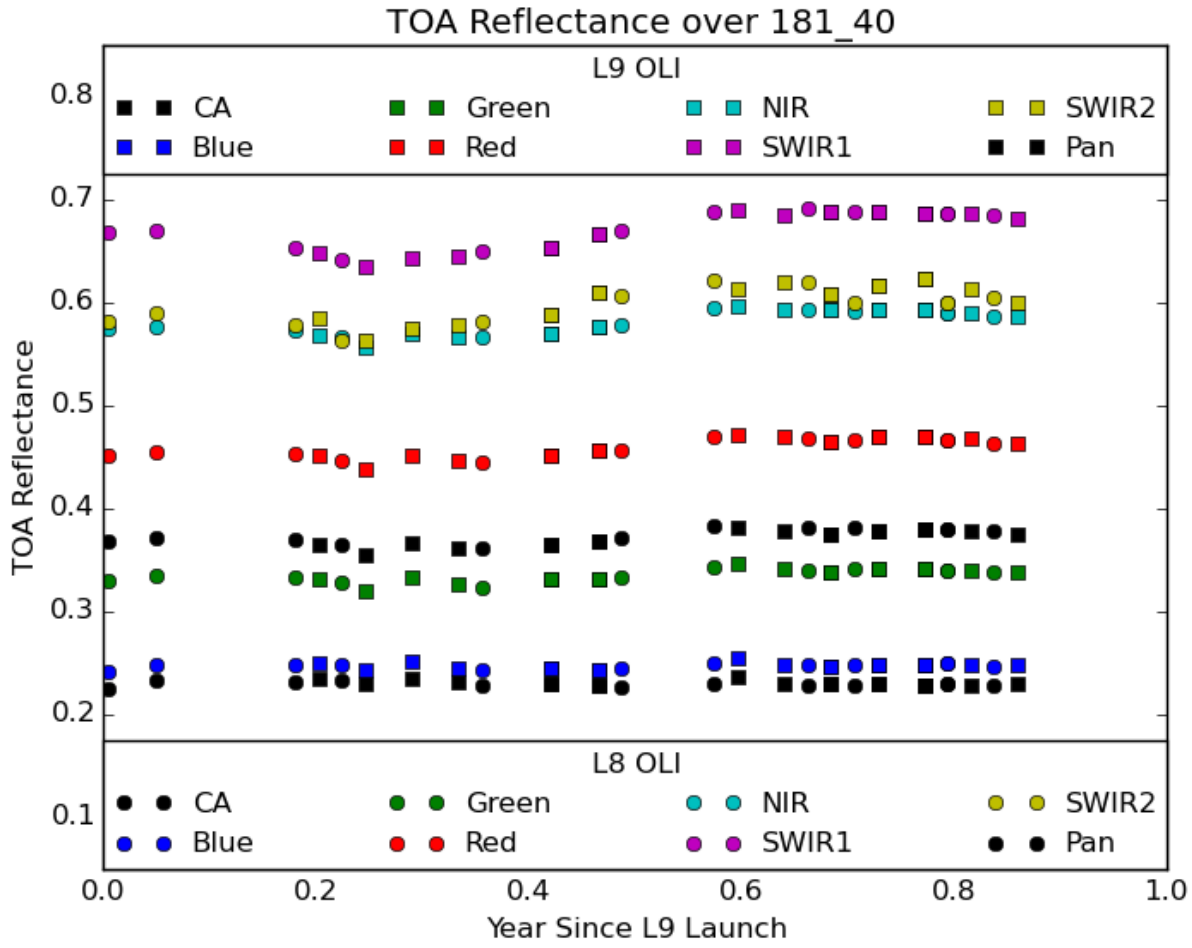


	CA	Blue	Green	Red	NIR	SWIR1	SWIR2
Double ExPAC	0.993	0.995	0.990	0.995	0.996	0.996	0.999
EPICS X-Cal	0.994	0.994	0.992	0.997	0.998	0.997	1.001
EPICS T2T	0.997	0.997	0.992	0.997	0.997	0.998	0.995
Underfly	1.000	1.002	0.999	1.000	1.001	1.001	1.000
Comb. Results	0.997	0.998	0.992	0.997	0.998	0.997	0.998

- **The difference between Landsat 8 OLI and Landsat 9 OLI was found statistically significant, but within the uncertainties of the prelaunch calibration for both instruments**
- **The Landsat 9 OLI radiometric calibration gains were adjusted to align the radiometric response of the two OLI instruments**

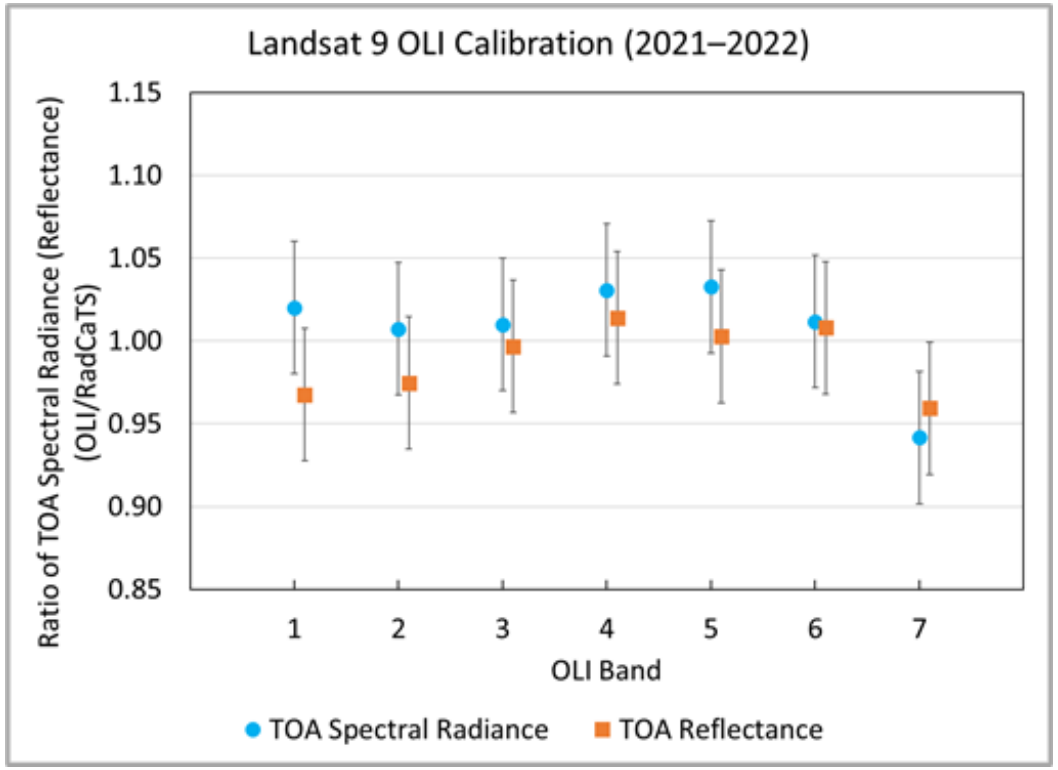
OLI-2 & OLI PICS Trends over Libya 4

- Plot shows TOA reflectance over Libya 4
- No correction applied for BRDF
- TOA reflectances measured by both sensors agree well
- Similar trend by both sensors suggest consistent calibration



L9 OLI Absolute Calibration

- **The requirement for the Landsat 9 OLI is 5% in spectral radiance and 3% in spectral reflectance**
  - Two independent NIST-traceable calibration standards
- **Teams from South Dakota State University, University of Arizona and USGS/EROS all made surface measurements under Landsat 9 OLI**
- **The measurements did not indicate any absolute calibration error in either radiance or reflectance, within the uncertainties of the teams' processes**



The RadCaTS results are shown as the average of four successful collects during the period Nov 2021 to Jul 2022

OLI Summary

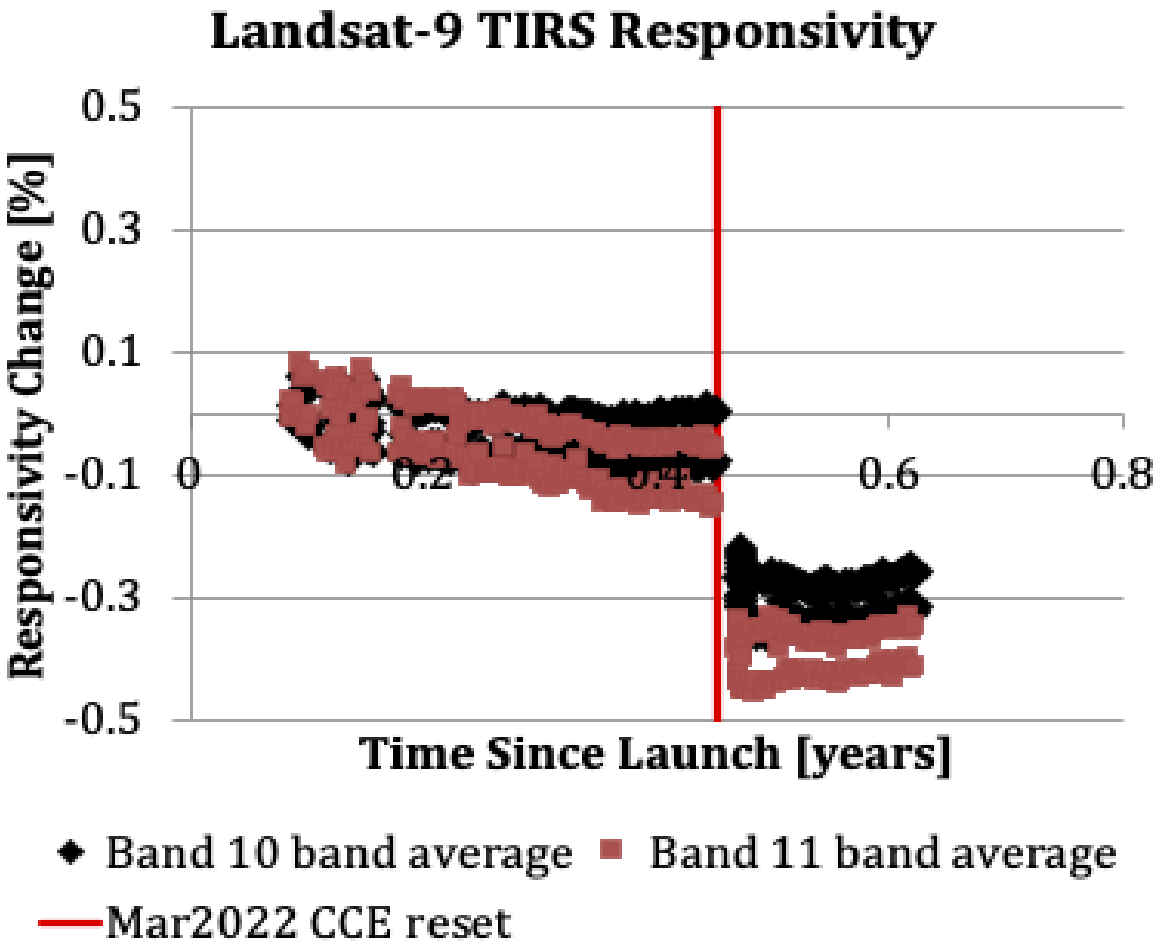
- **Landsat 8 OLI is continuously exceeding expectations in terms of data quality**
- **The Landsat 9 OLI radiometric performance is outstanding. In general, the performance metrics are just slightly better than those of Landsat 8 OLI:**
  - The Landsat 9 OLI is showing no signs of the degradation in responsivity in the CA and Blue bands that appeared soon after launch in Landsat 8 OLI
    - The other bands have been equally stable
  - The SNR is between 3 and 8% better than L8 OLI in all bands, likely due to the improved radiometric precision
  - The relative per-detector radiometry is more stable resulting in more consistent full field of view uniformity over time
- **While the absolute calibration results indicated that the Landsat 9 OLI was calibrated to within requirements and uncertainties, its radiometric gains were adjusted based on the underfly results before releasing calibrated image data to the public to align the radiometry of the two OLI instruments**

TIRS Radiometric Performance

Landsat 9 TIRS Radiometric Stability

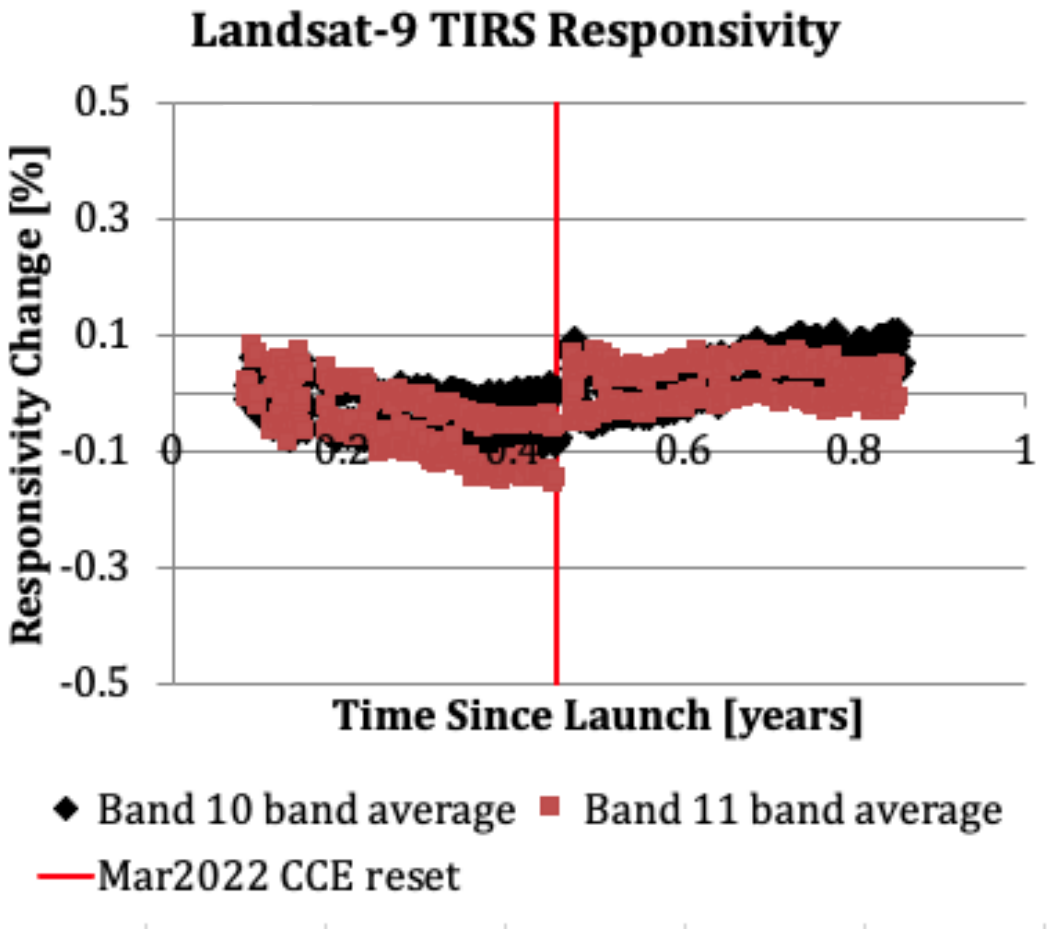
Responsivity stability estimates here are based on the 295K blackbody acquisitions

- Prior to Mar 2022, the internal calibration system indicated that TIRS was stable to better than 0.05% in B10, 0.2% in B11.
- A reset of the TIRS Cryocooler Electronics (CCE) in March 2022 resulted in the powering down of the instrument and loss of thermal control
- After control was recovered, internal calibration data indicated the responsivity changed by ~0.2%



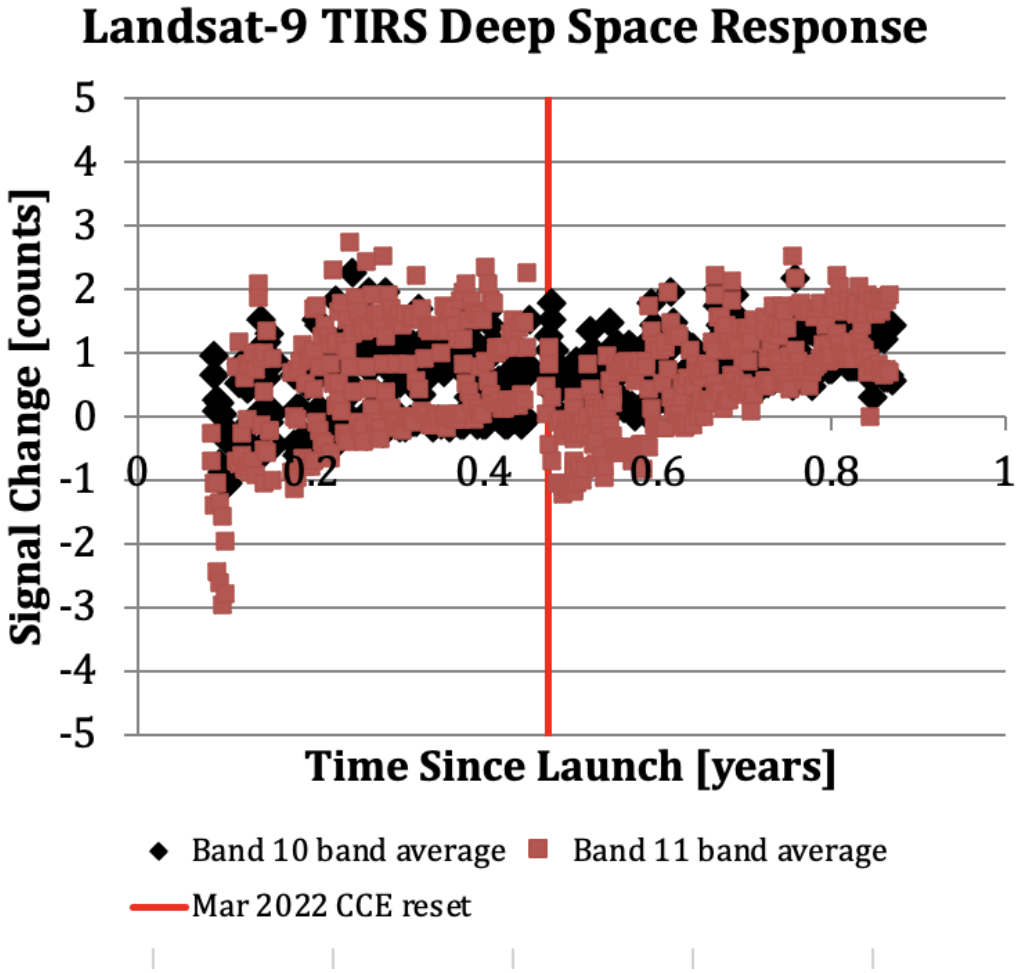
Landsat 9 TIRS Radiometric Stability

- **On-board calibration sequence was performed to establish the new radiometric gains**
  - Blackbody temperature sweep
- **Radiometric gains were updated to account for the change**
  - Instrument is stable to better than 0.05% in both bands
- **This change in TIRS responsivity is transparent to users of Level-1 and Level-2 data products**



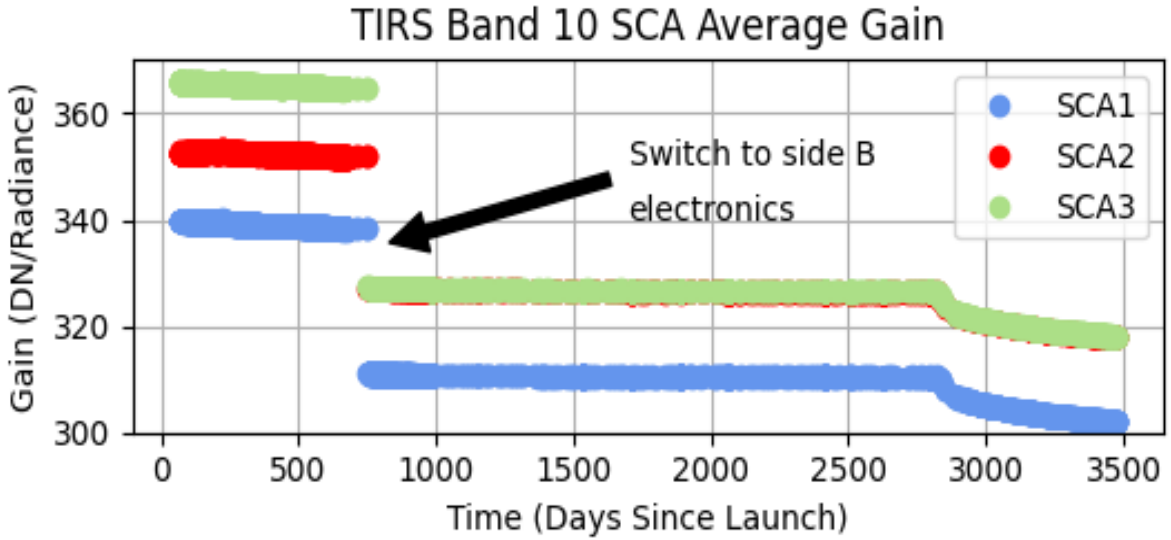
Landsat 9 TIRS Radiometric Stability

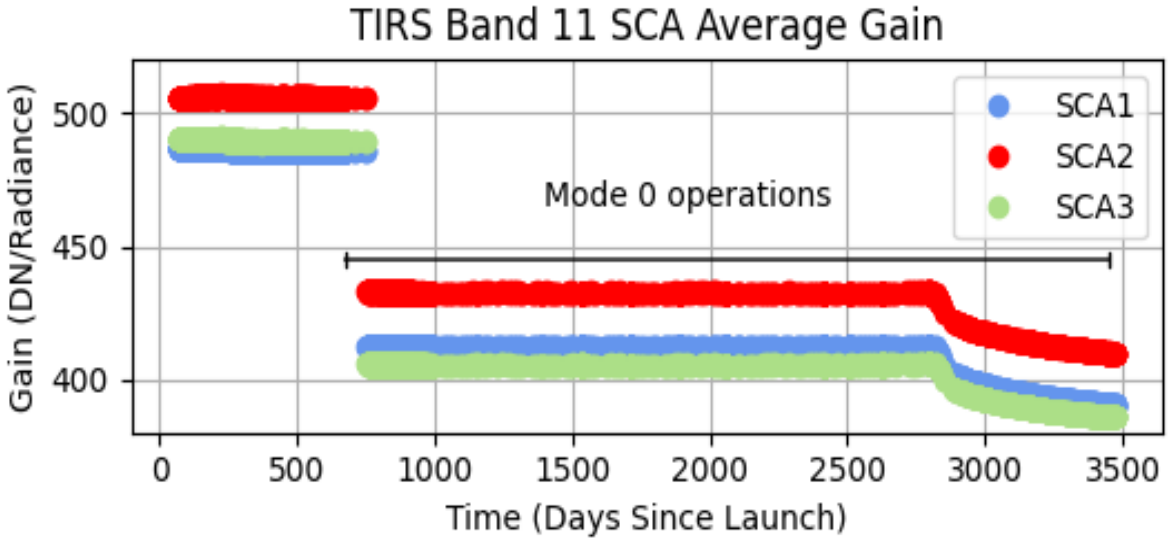
- **Response to deep space serves as indication of instrument bias**
  - Data from both bands indicate a small level of drift, within +/- 2 DN (<0.2%)
  - The March 2022 TIRS CCE appears to have reset the drift
  - Landsat-8 TIRS drift was more stable over time at this point in the mission, but less stable within orbit (+/- 4 DN)



Landsat 8 TIRS Radiometric Stability

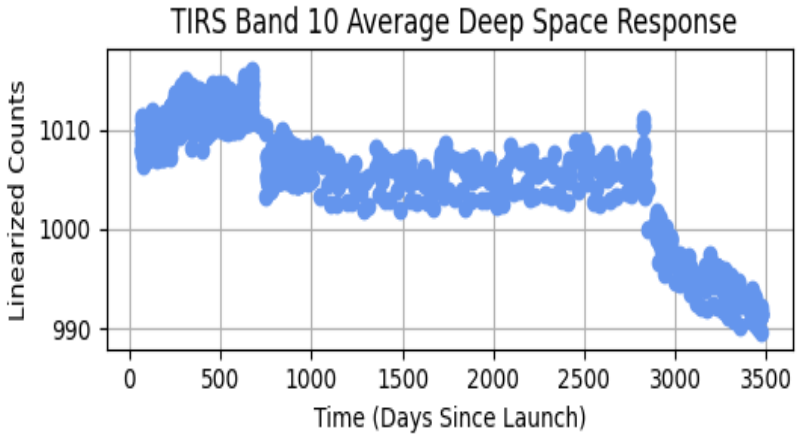
- **Within Interval (between calibrations)**
  - Typically < 0.1% (1 sigma) over 40 minutes; requirement is 0.7% (1 sigma)
  - Similar performance over 1 ½ orbits
- **Since Achieving Final Telescope Temperature until November 1, 2020**
  - Typically range of ± 0.02% over ~ 30 days; slight variation within interval
- **Stability has been well preserved after switch to side B electronics**

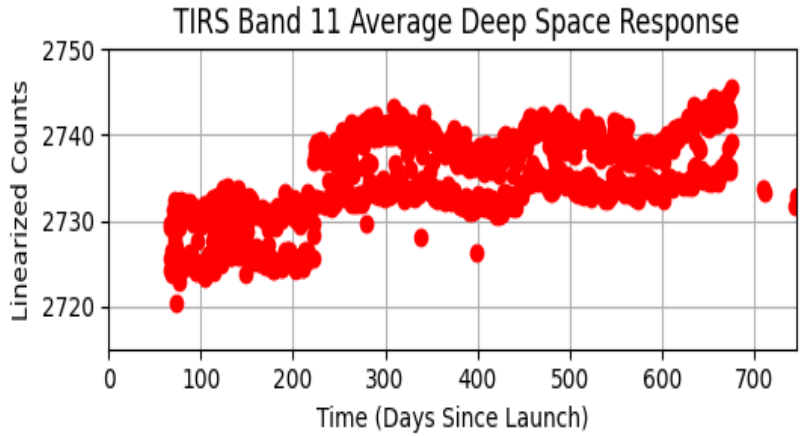


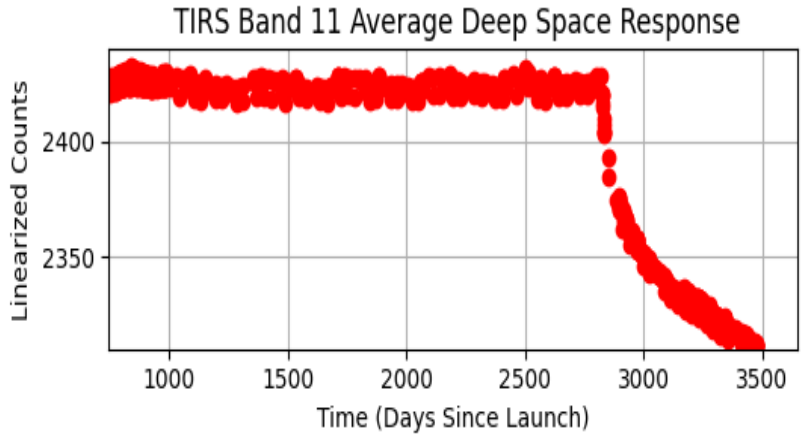


Landsat 8 TIRS Long Term Bias Stability

- **Very stable deep space response until the November 2020 safeholds**
  - Within ~6 counts in Band 10
  - Within ~12 counts in Band 11
- **Deep Space collects acquired approximately every 14 days until December 2020 provided a good bias estimate**
  - Minimal impact on radiometric accuracy with a risk to miss sudden short-term variations
- **Since Dec 2020 Deep Space collected on a weekly basis to better capture degradation in bias since the November 2020 safehold**



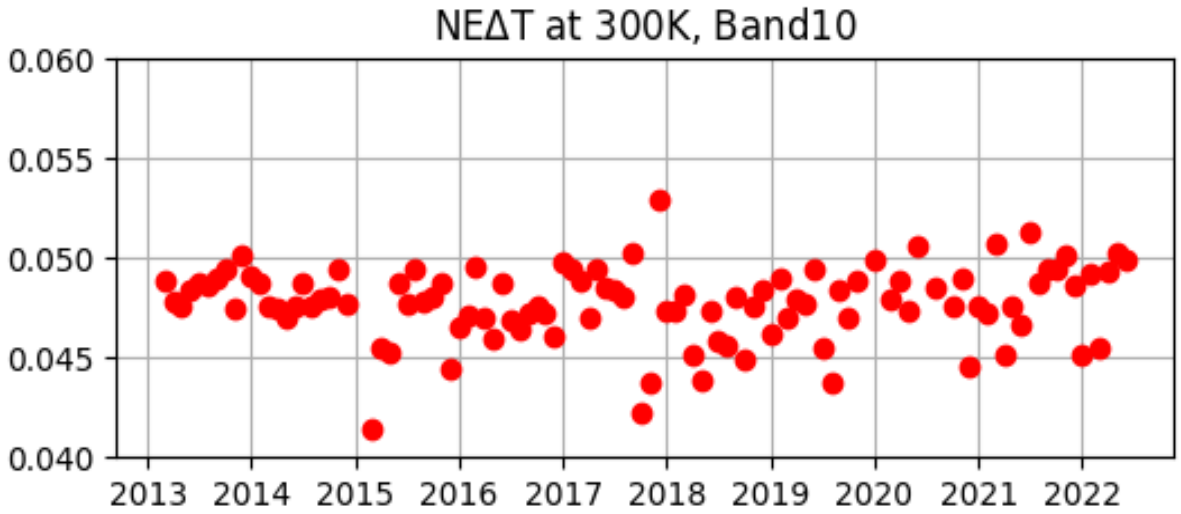


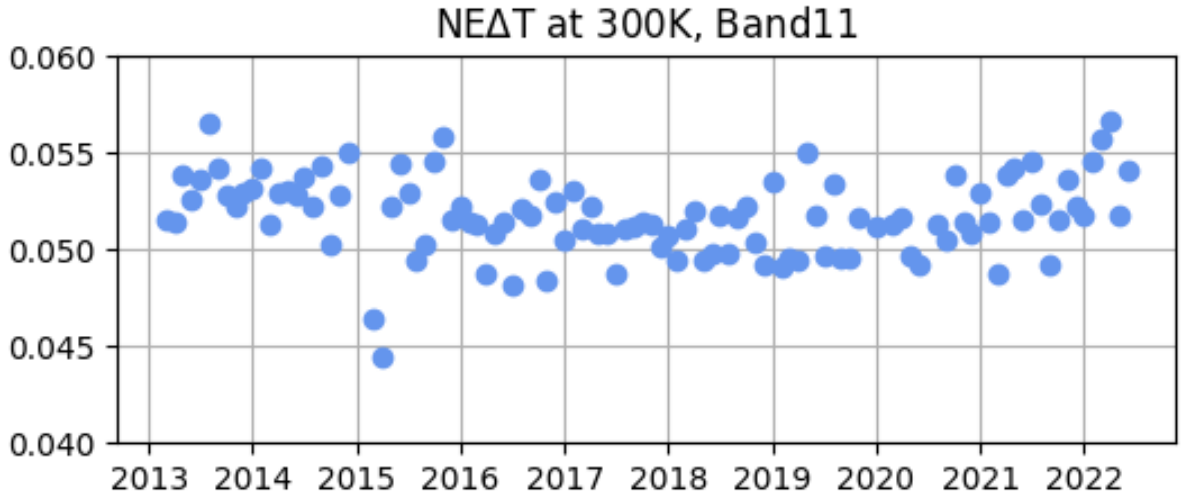


Noise: Landsat 8 TIRS NEΔT

- **All TIRS detectors have similar NEDT**
  - Band averages at 300K (Requirement: NEΔT < 0.4K):

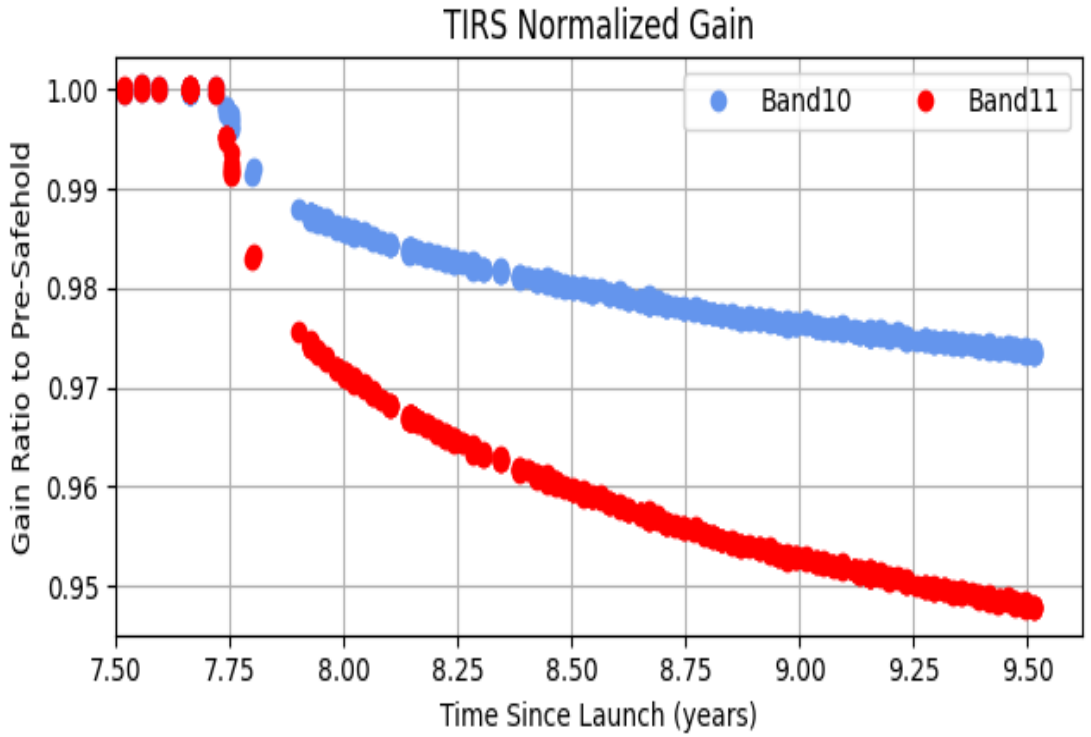
NEΔT [K]	Side A Electronics	Side B Electronics
Band 10	0.048	0.053
Band 11	0.048	0.051

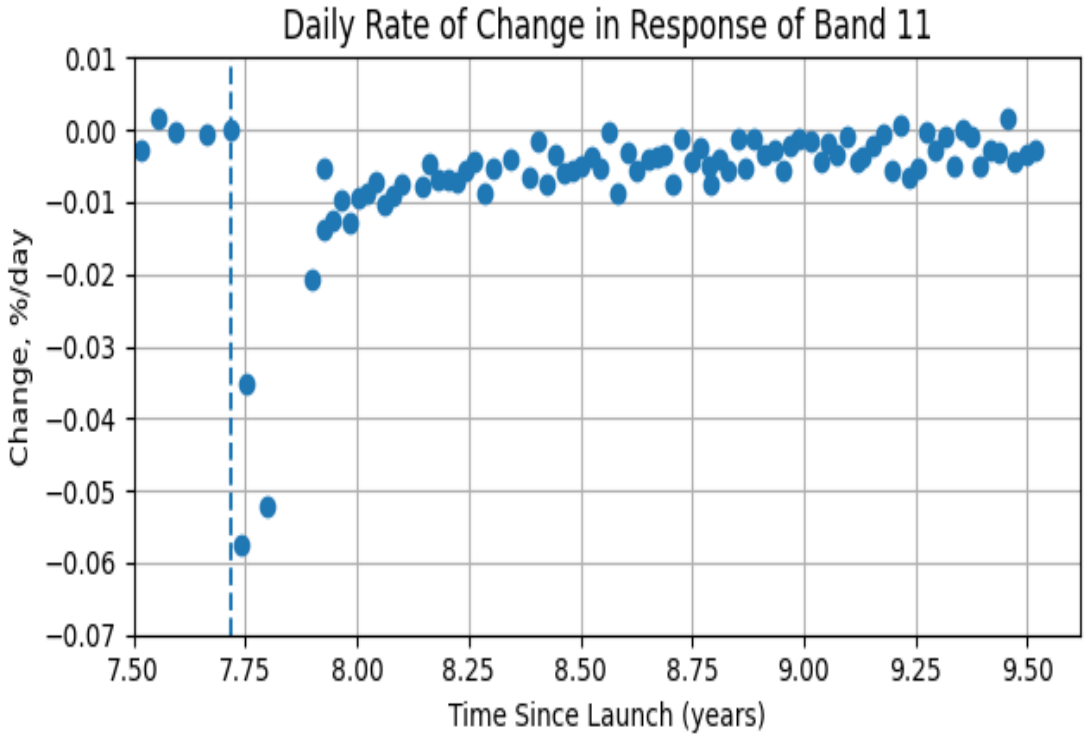




Noise performance is about 8x better than requirements; about 4x better than heritage

Landsat 8 TIRS Response Degradation





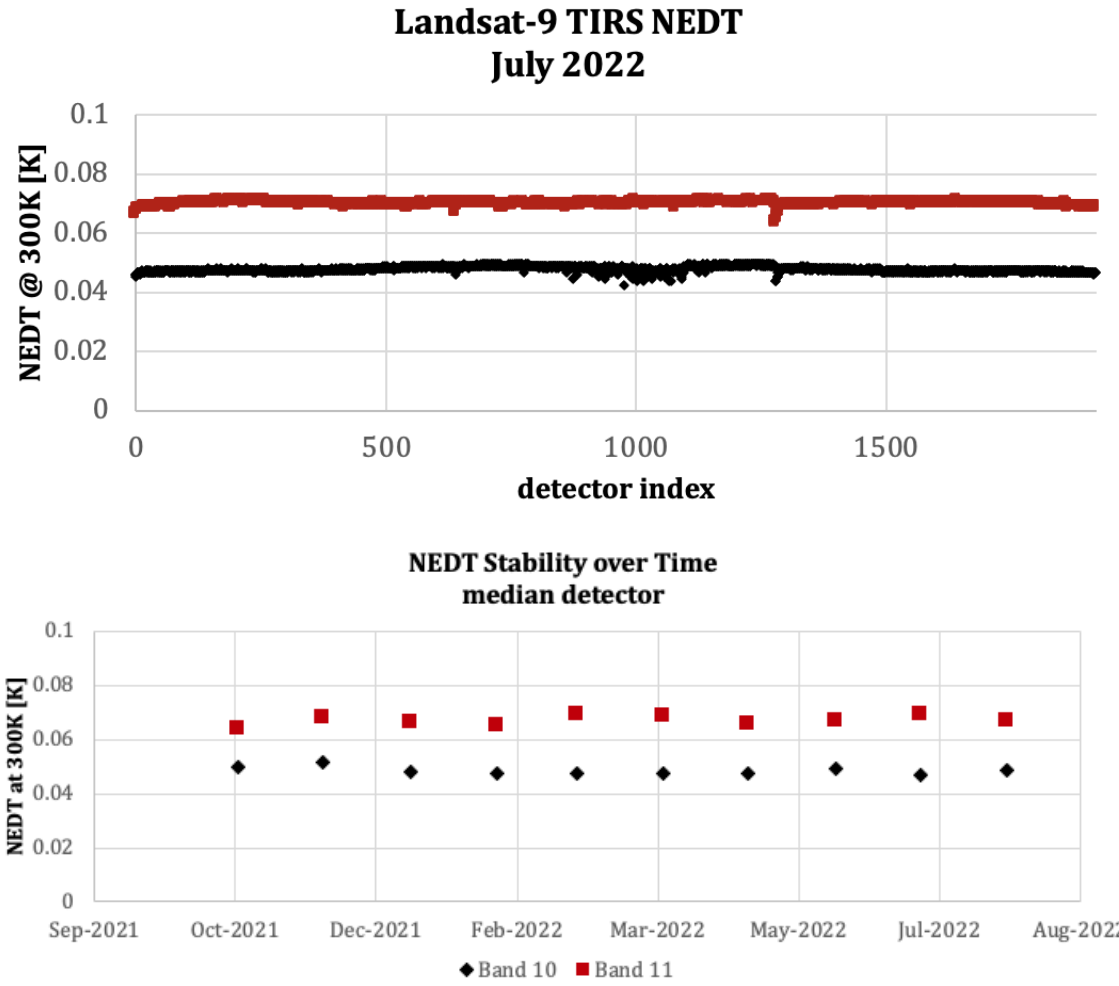
- **Band 11 has degraded about twice as much as Band 10**
- **Change in response of each single detector varies depending on its location on the focal plane**
- **The rate of change in TIRS gains has slowed, but it is still changing (<2%/year)**

Landsat 8 TIRS Degradation Summary

- **The safehold events in November 2020 affected response of TIRS bands**
  - The change in responses have been characterized
  - TIRS responses are still changing – currently about 0.45% per quarter
    - They are actively characterized and corrected to maintain product stability within 0.5%
  - Weekly calibration acquisitions allow for regular monitoring of the degradation
  - Radiometric gains were being updated monthly to account for the degradation
    - **Starting 2Q 2022 radiometric gains are updated quarterly**
  - Noise performance is not affected
  - All TIRS data acquired after the safehold on Nov 1, 2020 have been processed using calibration gains that account for the degradation

Landsat 9 Noise Performance: NEDT

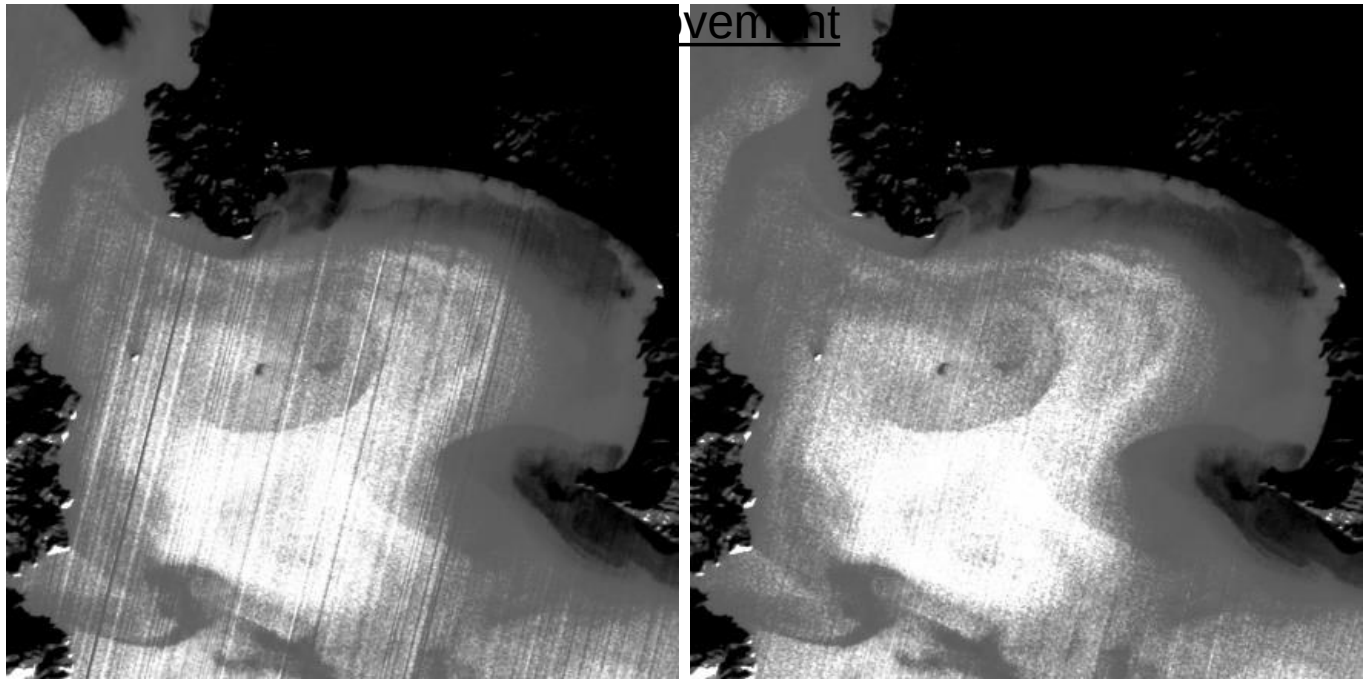
- **Noise Equivalent Delta-Temperature is monitored using the on-board blackbody**
  - NEDT at 300K is less than 0.05K in Band 10 and 0.07K in Band 11 for all detectors
  - NEDT is consistent within 1 mK (1-sigma) across all detectors in both bands
  - The NEDT of the median detector is stable to within 2 mK (1-sigma) since the start of standard operations (Jan 2022)



TIRS Uniformity

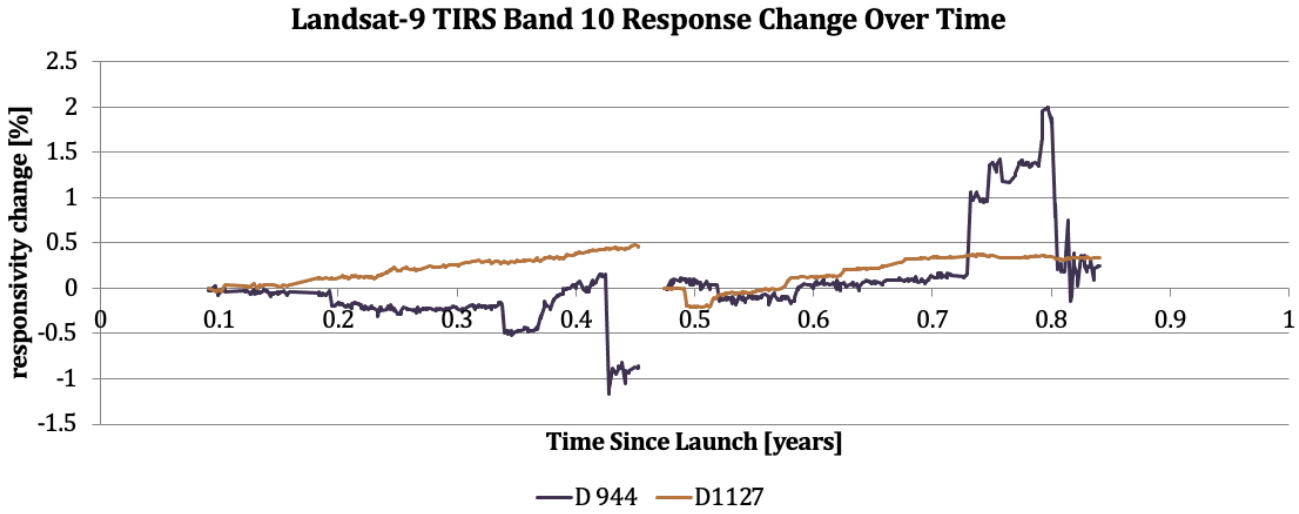
- **With almost 2000 detectors in each band, per-detector normalization is a challenge**
- **Landsat-8 TIRS relative gains were found to change slowly over time and the drift was not being corrected for**
- **Starting in 2020, with the introduction of Collection-2, the relative gains are updated on a quarterly basis for Landsat-8 TIRS**
- **Same process is used for Landsat-9 TIRS**

Landsat-8 TIRS - Relative Gain



Landsat 9 TIRS Uniformity

- **Individual detectors whose responses change by 0.5% in one "jump" are tracked**
- **Individual detectors whose responses have drifted by >0.25% over time are tracked**



- **The Landsat-9 focal plane appears have slightly fewer stable detectors than Landsat-8.**
  - At this point in the Landsat-8 mission, there were fewer total jumpers and drift has not been a problem to date.

Totals through 0.85 years since launch

	L9 TIRS Band 10	L9 TIRS Band 11	L8 TIRS Band 10	L8 TIRS Band 11
Jumpers	7	3	0	5
Drifters	5	7	-	-

Landsat 9 TIRS Uniformity

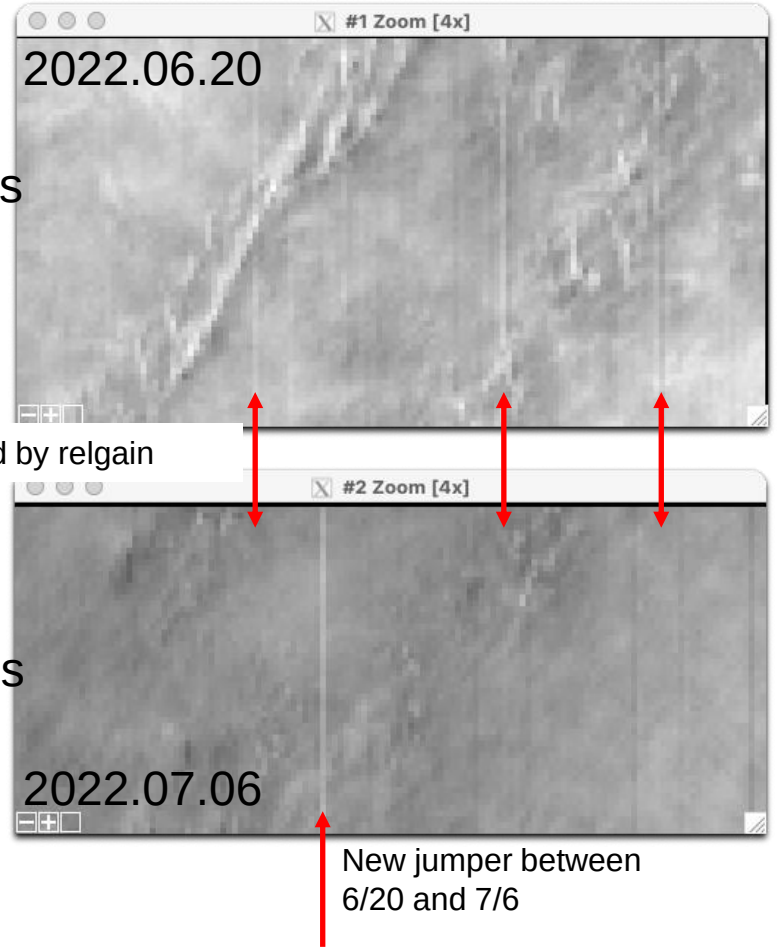
- **Relative gains are updated quarterly, to account for regular changes**

Subset of images from a very uniform desert illustrate the visible changing nature of the detector responsivities.

There are stripes visible in June 2022 that get corrected for by the July 1, 2022 calibration update.

But another detector's responsivity changed (D944 from previous plot) by the July 2022 image.

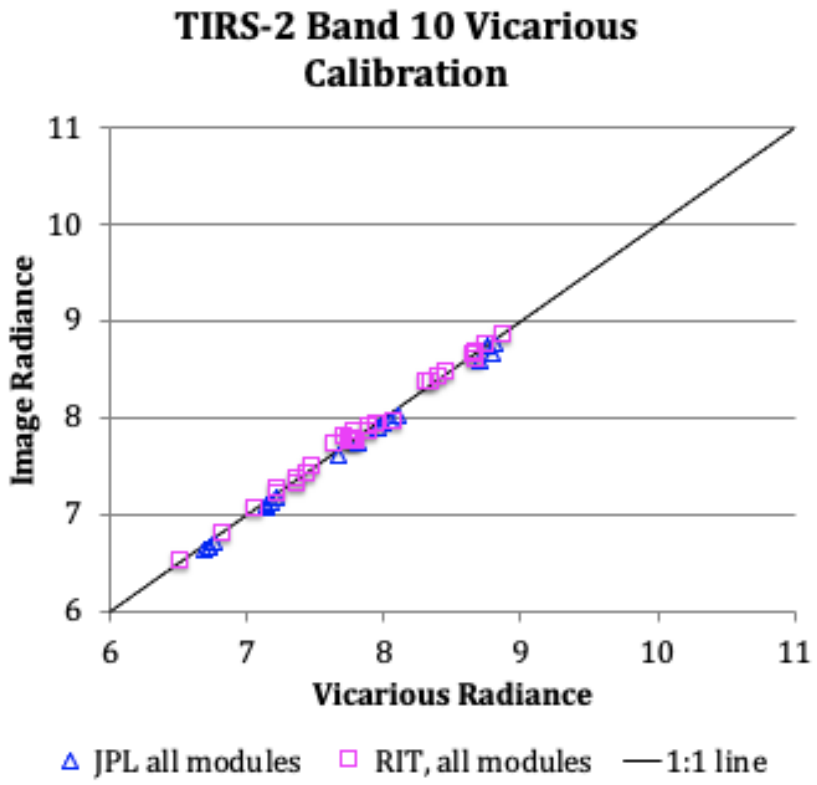
Before relative gain updates

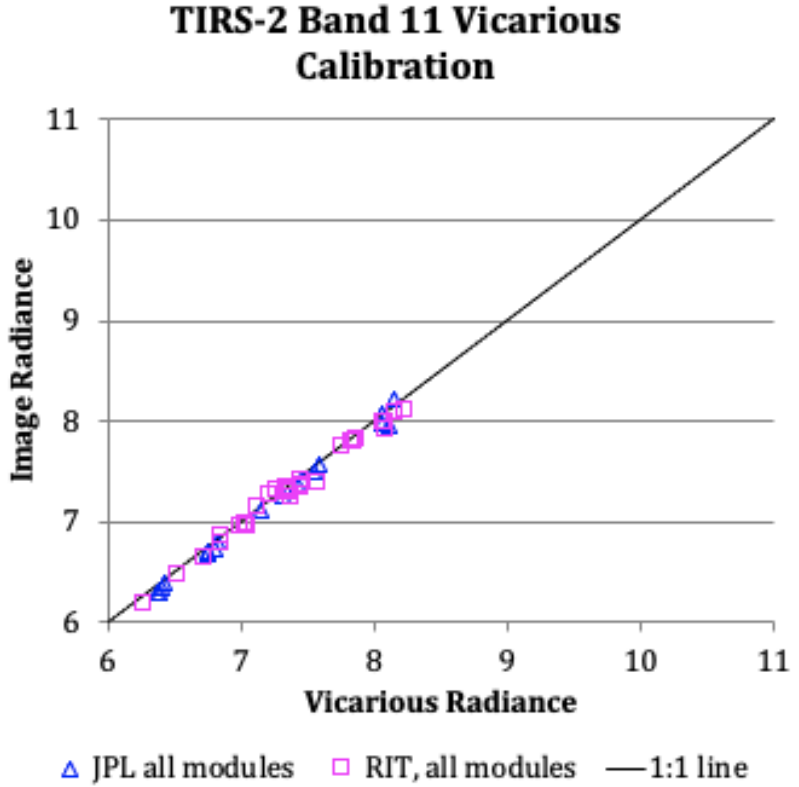


After relative gain updates

Landsat 9 Vicarious Calibration Results

- **Landsat-9 TIRS absolute calibration is based on the prelaunch calibration, with an adjustment made for the shift after the CCE reset (March 2022)**

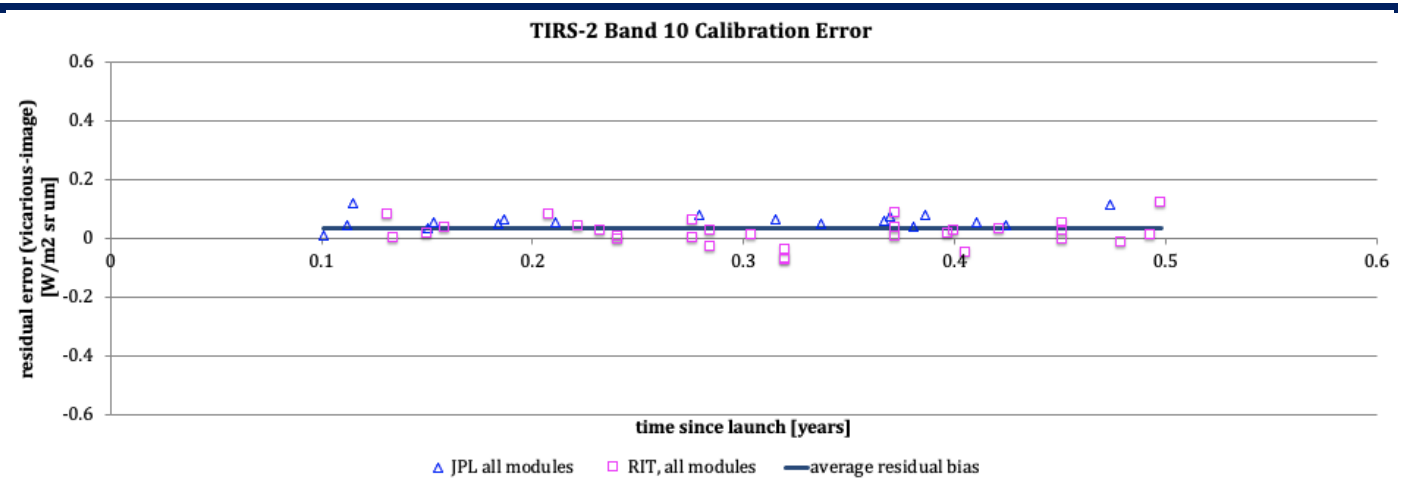


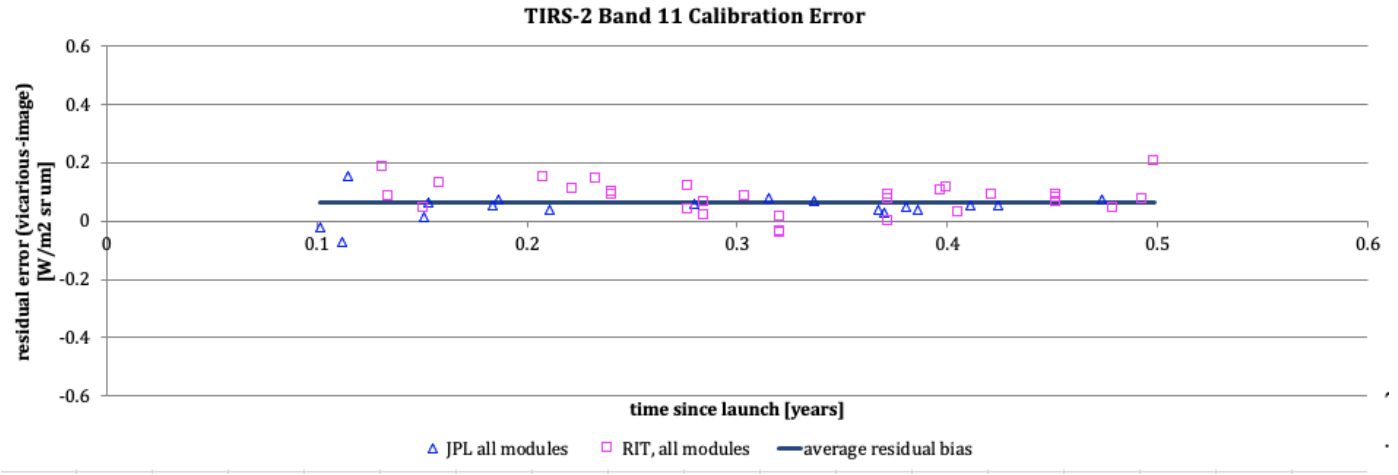


Current Landsat 9 Vicarious Results: Residual Error Over Time

- The averages indicate slight offsets in both bands, 0.2K in Band 10 and 0.6K in Band 11 at 300K

- But there are no seasonal effects apparent and there is no sign of a signal-dependent calibration error. Both these issues were present in the Landsat-8 TIRS vicarious calibration results.





Summary: Vicarious Calibration Results

- Residual errors are based on a small dataset but statistically significant
- No action to correct for this yet. Possible to correct it with the ~1 year on orbit reprocessing

- Note that the uncertainties at this point for Landsat 9 are much better than Landsat 8, which has been corrected multiple times

Landsat-9

Daytime	N	Residual Error [K @ 300K]	RMSE [K]
B10	35	0.16	0.3
B11	35	0.61	0.5

Landsat-8 (2015-2022)

Daytime Side-B	N	Residual Error [K @ 300K]	RMSE [K]
B10	356	0.02	0.5
B11	356	0.25	0.9

TIRS Summary

- **Landsat-9 TIRS radiometric instrument performance is excellent**
  - Landsat-9 TIRS has negligible amount of stray light (On-orbit tests match prelaunch stray light expectations)
  - Stable within a power-on cycle; on-board calibrator indicates stability to better than 0.1%
  - Low noise
  - Early suggestion of small calibration error, but vicarious calibration results suggest data can be calibrated to within 0.5K in both bands
- **Landsat 8 TIRS response degradation since the safehold in November 2020 are actively characterized and corrected to maintain product stability within 0.5%**

Landsat 7 Status

- **Still imaging – In April 2021, its orbit has been lowered to 697 km**
  - Low fuel level – no orbital correction maneuvers
    - Planned to be re-fueled
  - Earlier Equatorial crossing time – lower sun angles
  - Extended science imaging resumed on May 5, should continue to September 30, 2022
    - Fewer ground stations (no polar imaging)
    - Underflying Landsat 8 and Landsat 9 periodically
  - Not on WRS-2 system anymore
  - Calibration
    - Radiometry not affected so far
    - Minor geometric updates – to account for changes in Sun-sensor geometry
  - Level 1 / Level 2 products released to public