

CEOS IVOS 30

EROS CalVal Landsat Update

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Presented By:

Cody Anderson¹, Ron Morfitt², Esad Micijevic¹, Obaidul Haque¹, Jim Storey¹, Mike Choate¹, Mark Lubke¹, Rajagopalan Rengarajan¹, Aparajithan Sampath¹

¹SGT contractor to USGS, ²USGS

cody.anderson.ctr@usgs.gov, Phone # 1 (605) 594-2787

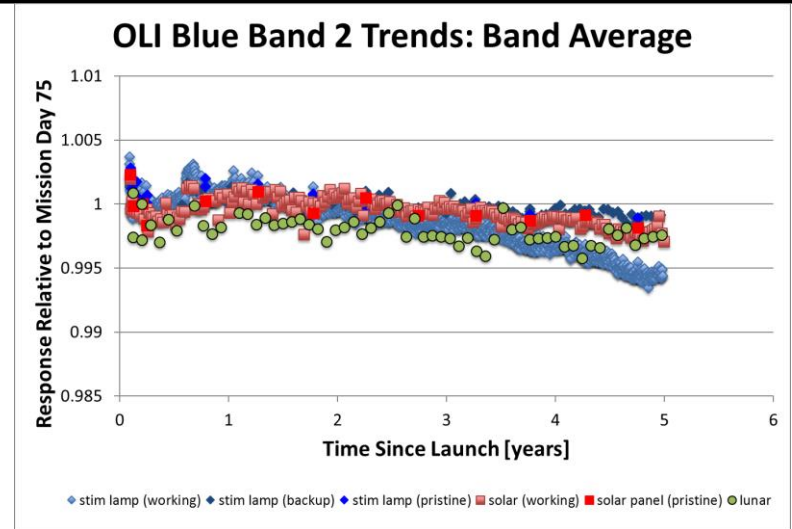
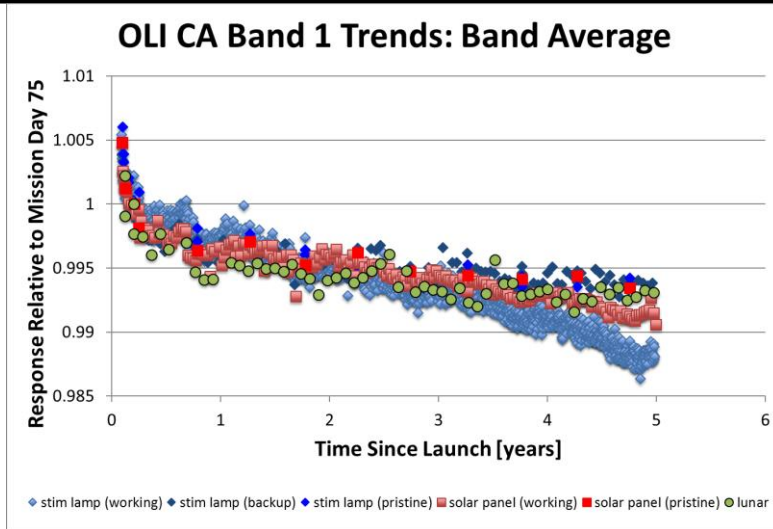
Outline

- **Landsat 8 (OLI and TIRS)**
 - Radiometric Stability
 - Geodetic Accuracy
 - TIRS-OLI Alignment
 - SSM Modeling
 - Phase 4 GCP Status
- **Landsat 7 (ETM+)**
 - Radiometric Stability
 - Geodetic Accuracy
- **Collection 1**
 - Landsat 5 and 4 TM No-PCD
 - Landsat 5-1 MSS

Introduction

- **USGS/EROS is responsible for the production and distribution of Landsat data (L1 – L5 MSS, L4 – L5 TM, L7 ETM+, and L8 OLI/TIRS).**
- **EROS CalVal are also involved in the development of Landsat 9.**
- **EROS CalVal is part of a larger calibration group including NASA/GSFC, NASA/JPL, Rochester Institute of Technology, South Dakota State University, and University of Arizona**

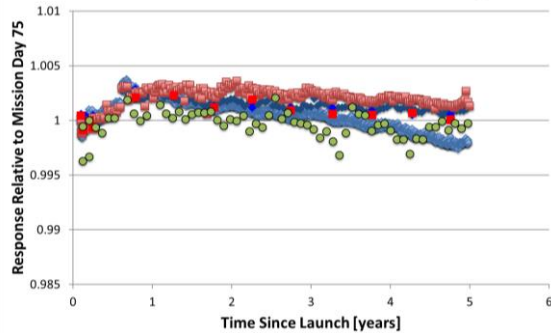
L8 OLI Radiometric Stability



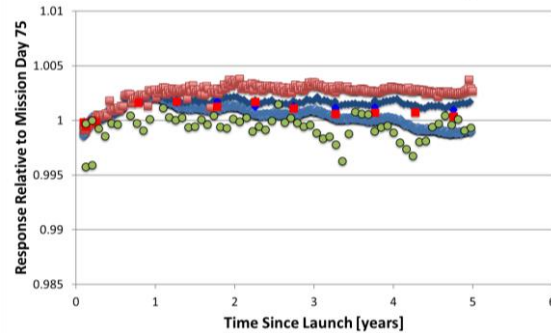
- Overall radiometric response models are a weighted average of the responses from 3 stim lamps, 2 solar diffusers, and lunar collects
- Decay in sensor responsivity over the lifetime indicated by all calibrators
 - CA band ~1.2%; Blue band ~0.2%
- Very good agreement between calibrators
- Workings stim lamps (light blue) showing decay not correlated to other calibrators.
 - Plan to remove this calibrator in future gain updates.

L8 OLI Radiometric Stability (Cont.)

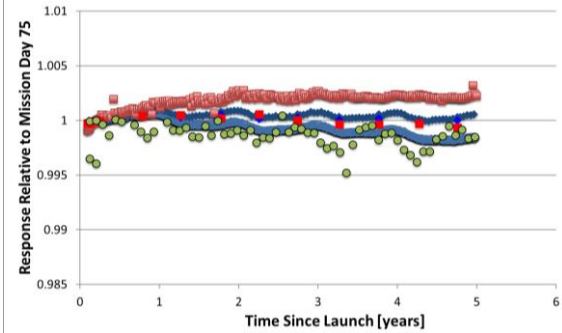
OLI Green Band 3 Trends: Band Average



OLI Red Band 4 Trends: Band Average

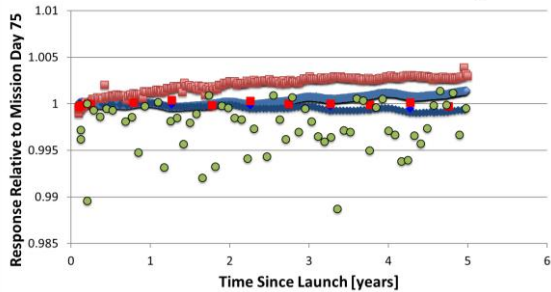


OLI NIR Band 5 Trends: Band Average

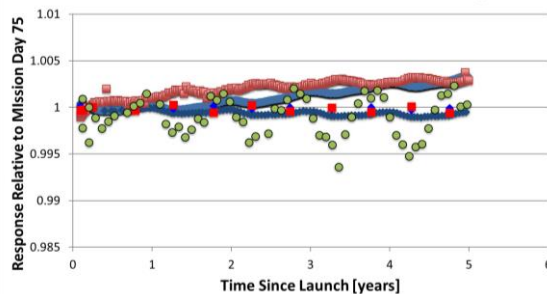


◆ stim lamp (working) ◆ stim lamp (backup) ◆ stim lamp (pristine) ■ solar (working) ■ solar panel (pristine) ● lunar

OLI SWIR1 Band 6 Trends: Band Average

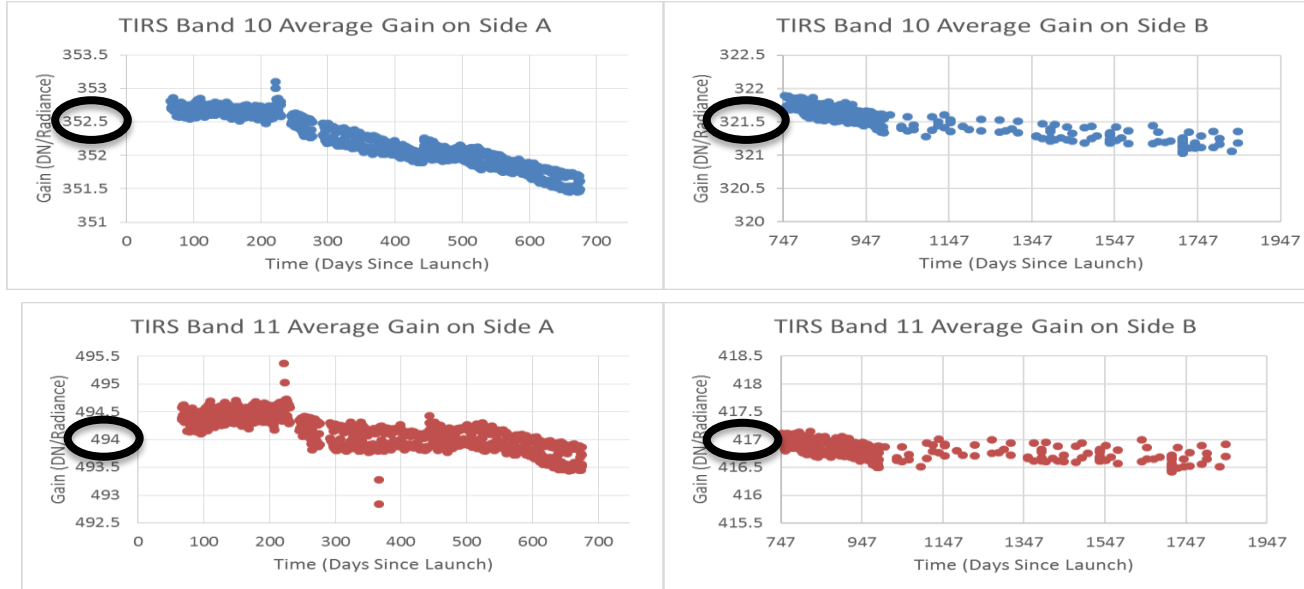


OLI SWIR2 Band 7 Trends: Band Average



- Working stim lamp still in slight disagreement
- Lunar collects show more variability at longer wavelengths
- No modeled decay for these bands

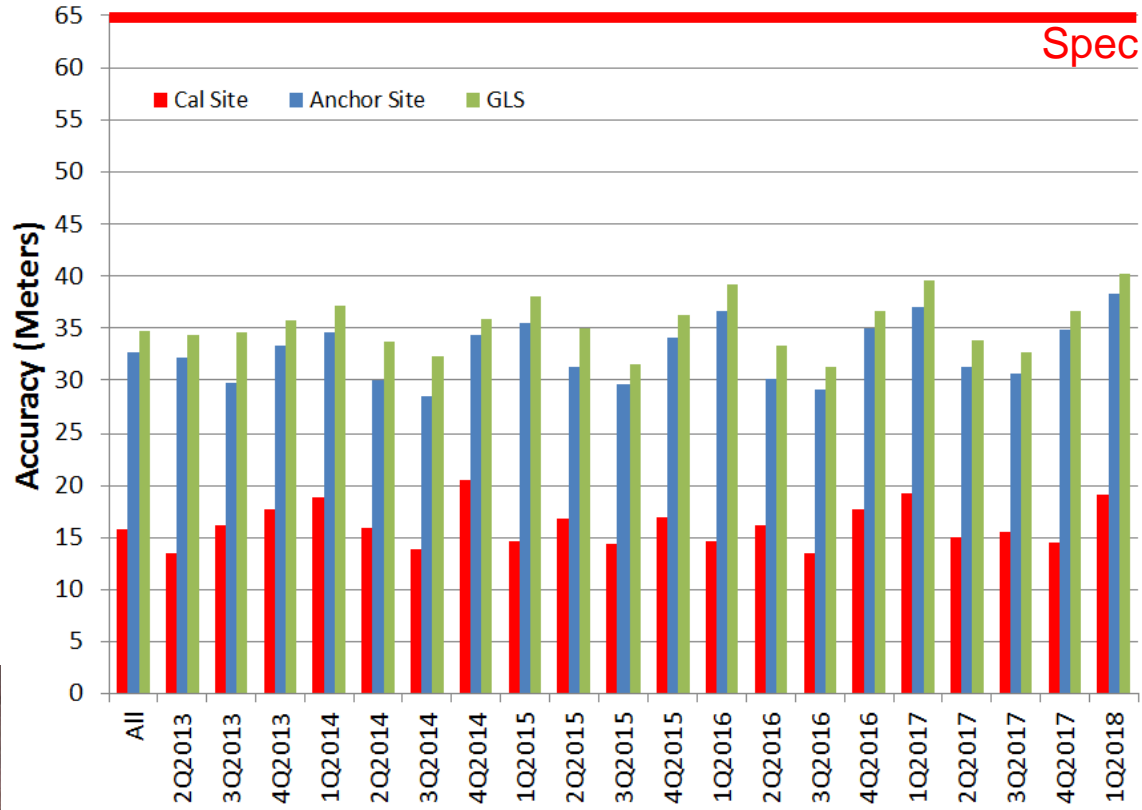
L8 TIRS Gain Radiometric Stability



- Switch from side A to side B electronics due to scene select mirror current draw
- Side B shows better stability than side A
- Different ops con caused the different sampling rate seen in the side B plots.

Geodetic Accuracy by Quarter

GCP accuracy limits the ability to measure absolute geodetic accuracy.



TIRS-to-OLI Pitch Alignment vs. Date

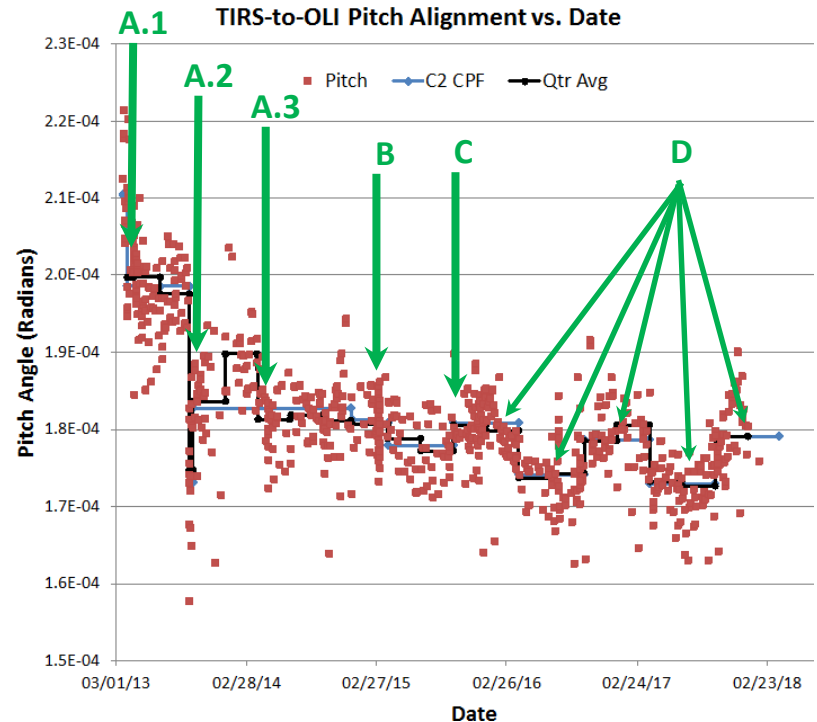
A. Measure TIRS-to-OLI alignment using TIRS 10.8 mm and OLI SWIR1 bands

1. TIRS alignment changed as L8 maneuvered into the final orbit
2. Anomaly in September 2013 caused a step change
3. A safe-hold event in April 2014 had a smaller impact

B. Reformulation of the yaw alignment to improve mode 0 data alignment did not impact roll or pitch alignment

C. Side B pitch alignment has mostly been stable to within +/-10 mrad.

D. A seasonal pitch variation in mode 0 data of ~8 mrad will be corrected in the Collection-2 CPFs.



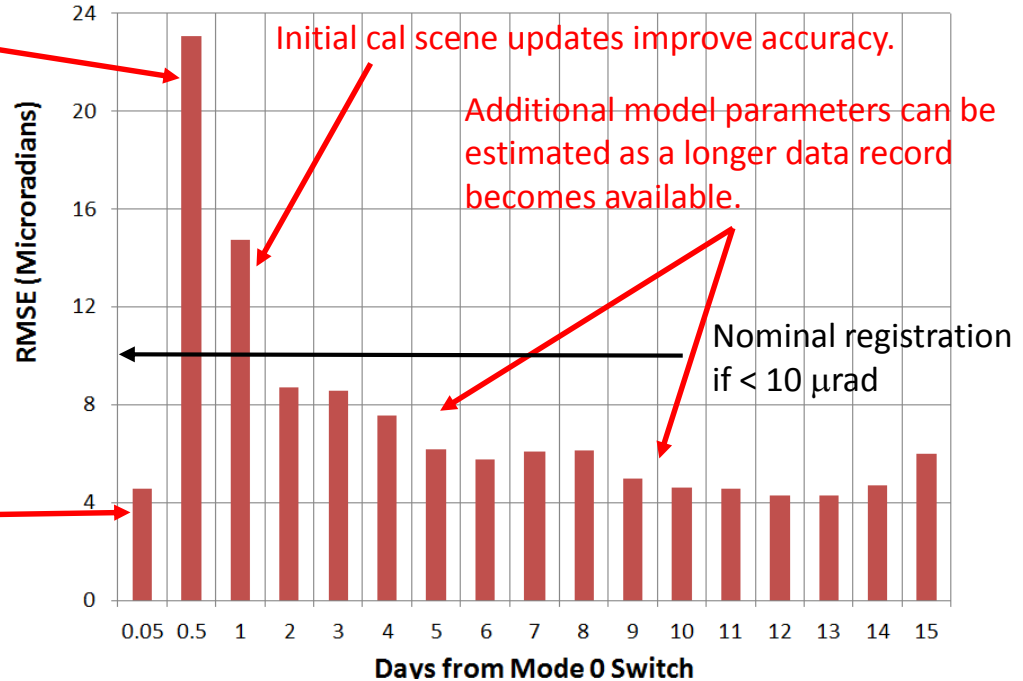
SSM Model Prediction Accuracy

- Computed RMSE statistics as a function of time since mode switch for all events since Dec 2015
- Results reflect performance when telemetry and calibration scene data are available when and where expected.

First few orbits without encoder data are the most problematic.

Encoder is still on.

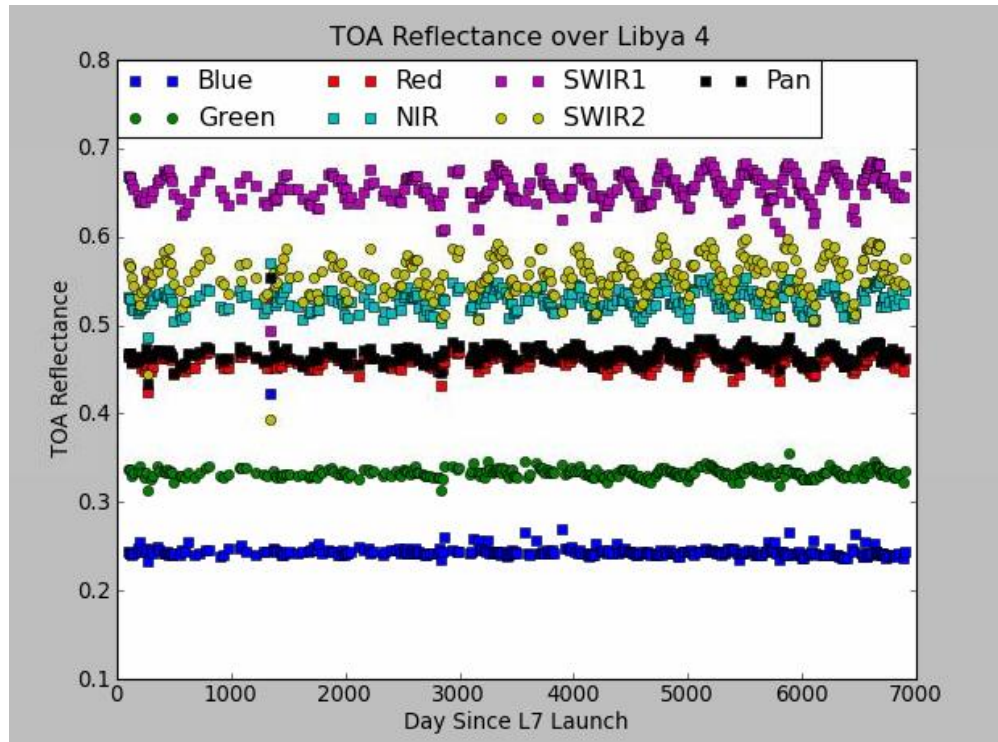
SSM Model RMSE 12/26/2015 to 03/09/2018



L8/S2 Registration Improvement Plan

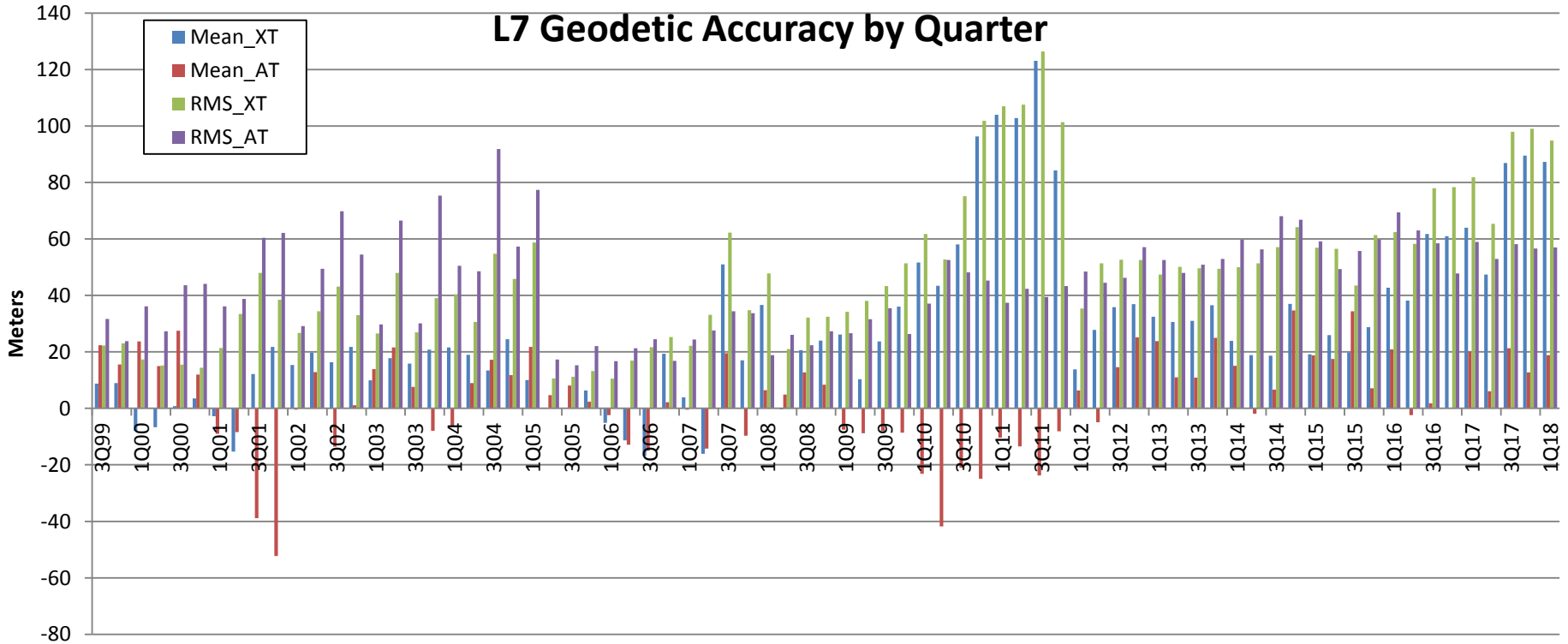
- **Perform global readjustment of the GLS control using L8 data with sparse ties to the Sentinel-2 Global Reference Image (GRI).**
 - Six triangulation blocks are being used to perform this global readjustment.
- **L8-only triangulations are complete for all blocks.**
 - New OLI GCPs were also extracted for all blocks.
 - The adjusted control is available for testing but is not yet being used for product generation.
- **When the S2 GRI L1C data become available, we will re-run the triangulation solution with MSI control added to a subset of scenes.**
 - Some MSI control will be withheld to test the triangulation.
 - Validate using OLI-MSI image registration measurements.

L7 ETM+ Radiometric Stability



- **ETM+ radiometric stability is monitored over PICS (here Libya 4)**
- **Longer wavelength bands show some seasonal variation**
- **The data don't show any significant trends, so the current radiometric model is performing well**

L7 Geodetic Accuracy Characterization

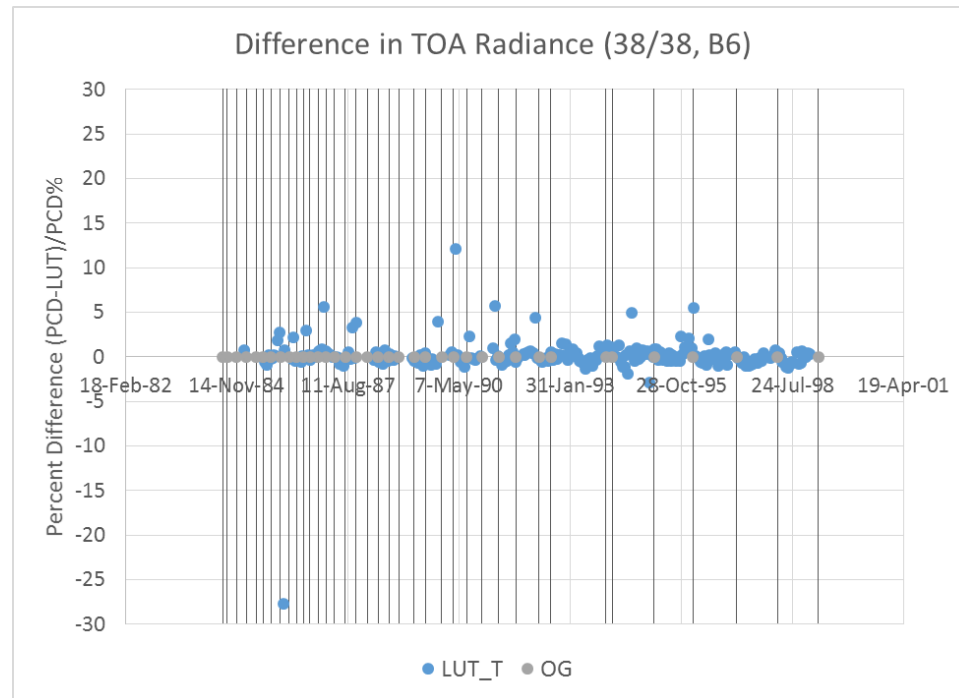


Collection 1

- **TM no-PCD and MSS are now in collection 1.**
- **TM no-PCD (Payload Correction Data)**
 - Lifetime Look-Up-Tables (LUTs) of blackbody and shutter temperatures are used for thermal band processing
 - No-PCD scenes without DE (Definitive Ephemeris) will use TLEs (Two Line Elements) modeled from PCD scenes from the same time period
- **MSS**
 - Establish consistent calibration among different formats of MSS data
 - Update current radiance calibration
 - Transfer L8 OLI reflectance calibration to L1-5 MSS
 - GCP Outlier Rejection Improvement
 - Fill Scan Additions

TM no-PCD (LUTs)

- Plot shows the difference in TOA radiance over an area within path 38 and row 38 between TM no-PCD and standard TM collection1 data. Vertical lines corresponds to outgassing dates
- Difference is normally within 3% percent except for scenes acquired within a few days of outgassing events, where the difference is as high as 28%



MSS (Radiance Update)

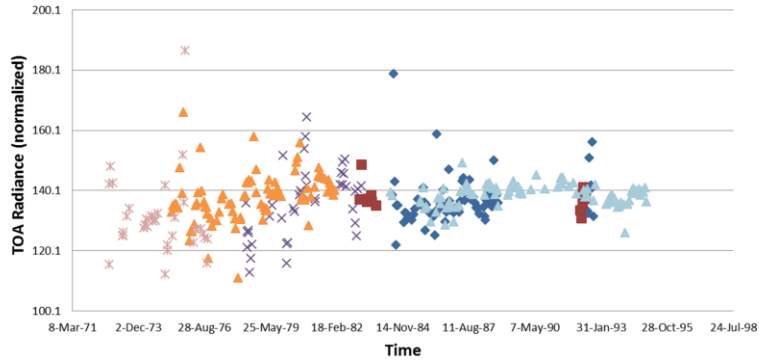
<u>GAIN</u>	MSS-5	MSS-4	MSS-3	MSS-2	MSS-1
Green	0.791 ± 0.006	0.950 ± 0.007	1.003 ± 0.015	1.047 ± 0.021	0.978 ± 0.015
Red	0.912 ± 0.007	0.983 ± 0.007	1.039 ± 0.017	0.891 ± 0.006	0.823 ± 0.008
NIR-1	0.976 ± 0.009	1.018 ± 0.007	1.091 ± 0.016	0.911 ± 0.007	0.941 ± 0.010
NIR-2	0.968 ± 0.009	1.080 ± 0.008	1.013 ± 0.015	0.903 ± 0.006	1.007 ± 0.009
<u>BIAS</u>	MSS-5	MSS-4	MSS-3	MSS-2	MSS-1
Green	#	#	#	-15.62 ± 1.94	-17.30 ± 1.15
Red	#	#	#	#	#
NIR-1	#	#	#	#	#
NIR-2	#	#	#	#	#

$$L_{\lambda,cal,corrected} = (L_{\lambda,cal}) \cdot Gain + Bias$$

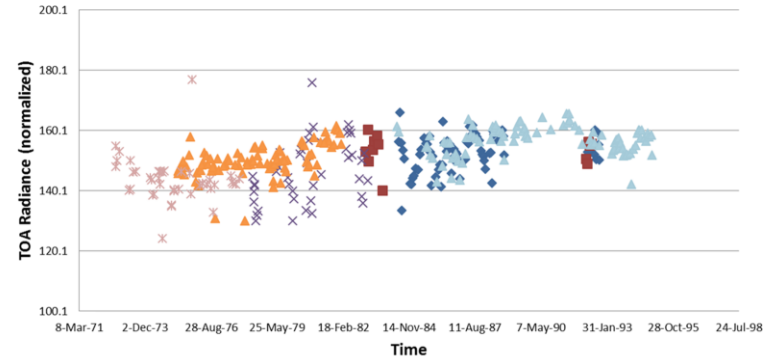
Source: SDSU

Radiance Update (Comparison)

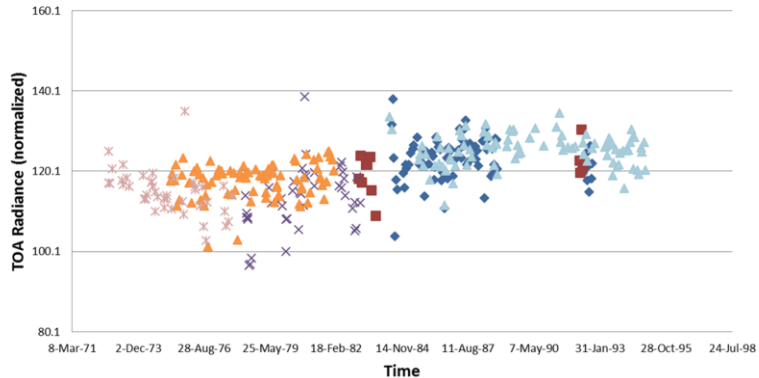
Sonora-Green Band
(Corrected for Spectral Band differences)



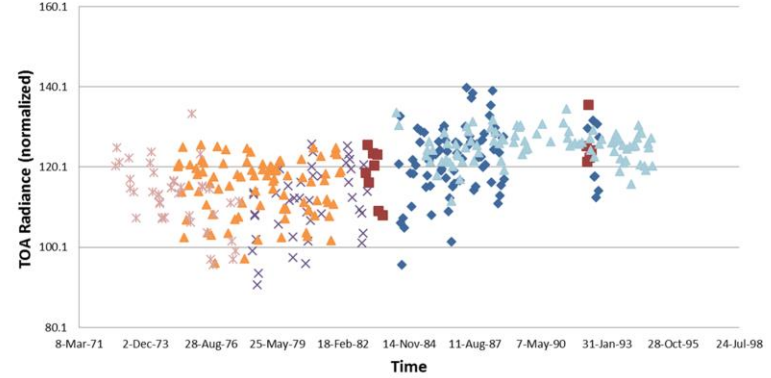
Sonora-Red Band
(Corrected for Spectral Band differences)



Sonora-NIR1 Band
(Corrected for Spectral Band differences)



Sonora-NIR2 Band
(Corrected for Spectral Band differences)



MSS (Reflectance Calibration)

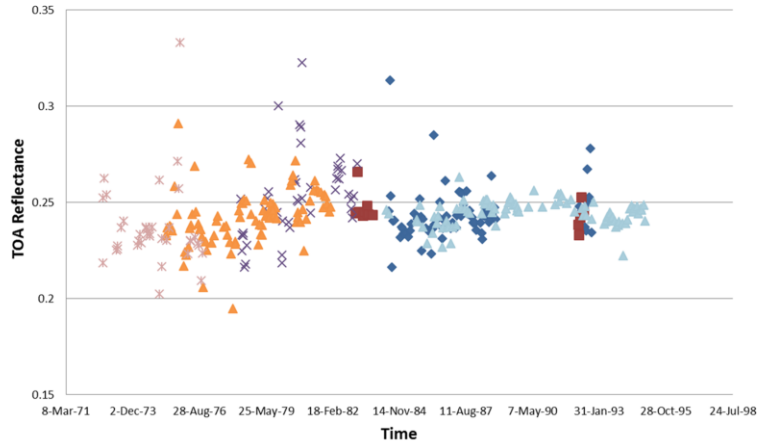
<u>GAIN</u>	MSS-5	MSS-4	MSS-3	MSS-2	MSS-1
Green	562.76 ± 2.98	562.10 ± 3.23	565.10 ± 7.64	571.32 ± 4.52	570.15 ± 6.09
Red	486.48 ± 2.85	485.47 ± 2.95	479.90 ± 6.89	479.63 ± 3.69	489.15 ± 5.47
NIR-1	390.46 ± 2.51	393.27 ± 2.26	402.10 ± 5.23	402.06 ± 3.11	405.67 ± 5.26
NIR-2	263.59 ± 1.90	267.22 ± 1.61	276.59 ± 3.59	275.14 ± 2.17	269.37 ± 2.94

$$\rho_{\lambda} = \frac{DN_{\lambda}}{Gain}$$

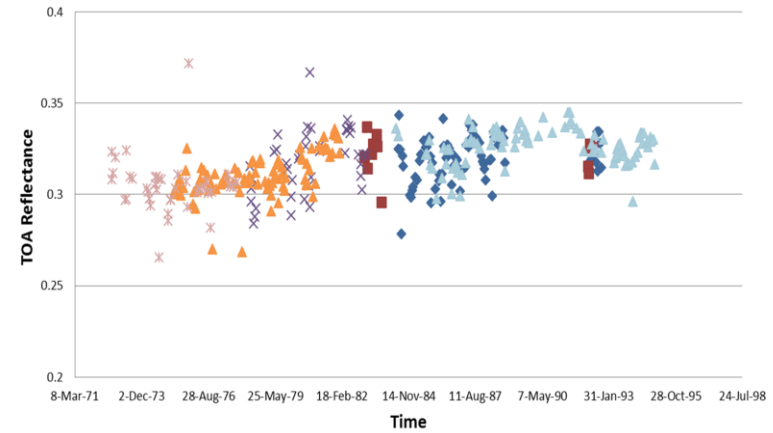
Source: SDSU

Reflectance (Comparison)

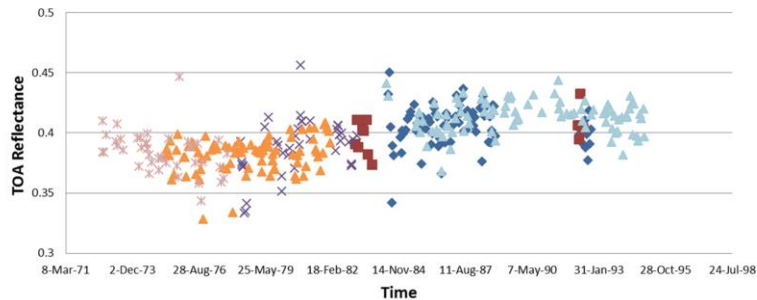
Sonora-Green Band
(Corrected for Spectral Band differences)



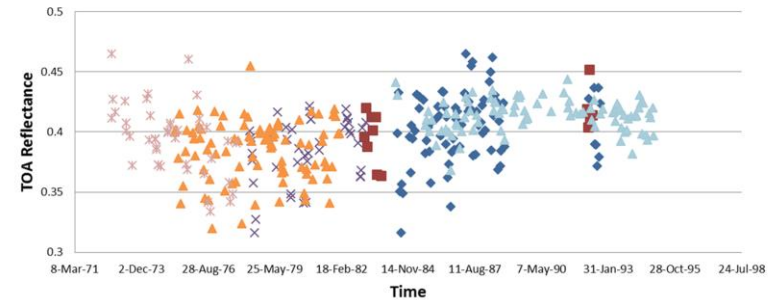
Sonora-Red Band
(Corrected for Spectral Band differences)



Sonora-NIR1 Band
(Corrected for Spectral Band differences)



Sonora-NIR2 Band
(Corrected for Spectral Band differences)



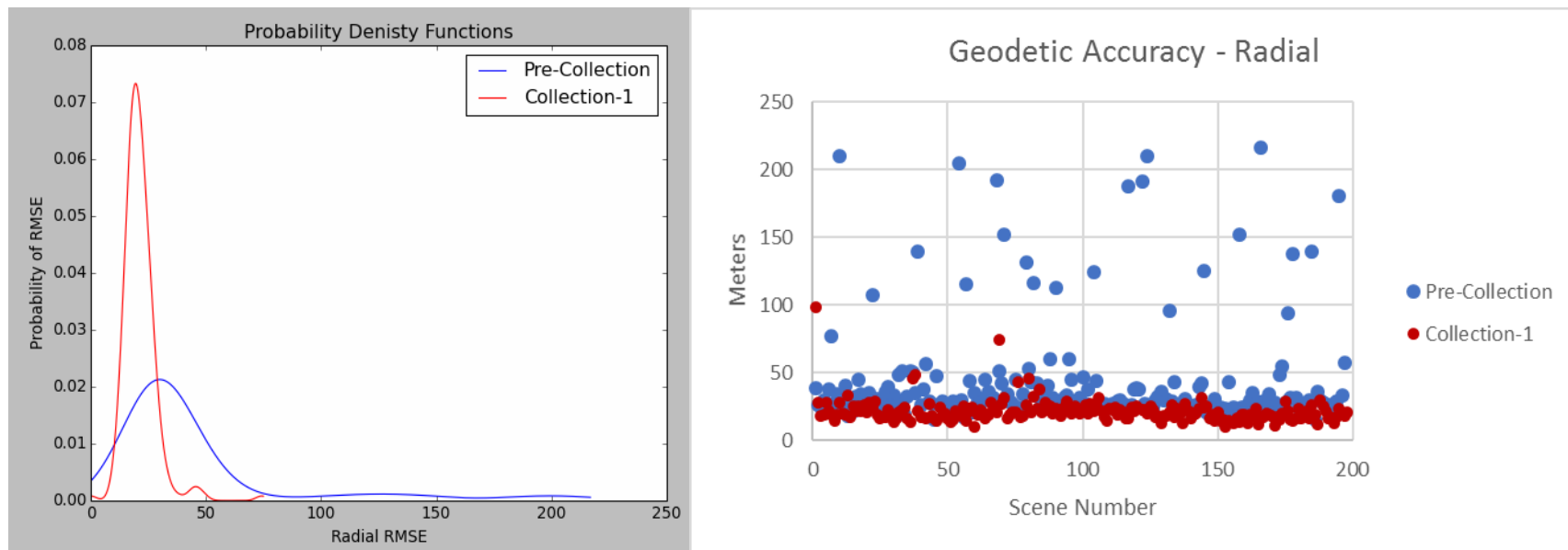
Pre-collection vs Collection 1

- **Average percent change in TOA Radiance and Reflectance between pre-collection and collection 1 products based on lifetime trend of an area over Sonora dessert.**
 - Radiance space: Max ~7% in L1 MSS red and NIR1 band
 - Reflectance space: Max ~11% in L3 MSS red band
 - A positive difference indicates that collection 1 product will be darker compared to pre-collection product.

% Change in TOA Radiance					
Band	L5 MSS	L4 MSS	L3 MSS	L2 MSS	L1 MSS
Green	1.73	-0.01	-1.55	0.87	-0.21
Red	0.14	-0.59	-6.06	4.37	6.96
NIR1	-1.25	1.47	-4.33	0.84	-7.01
NIR2	0.52	-0.90	1.08	6.81	1.59

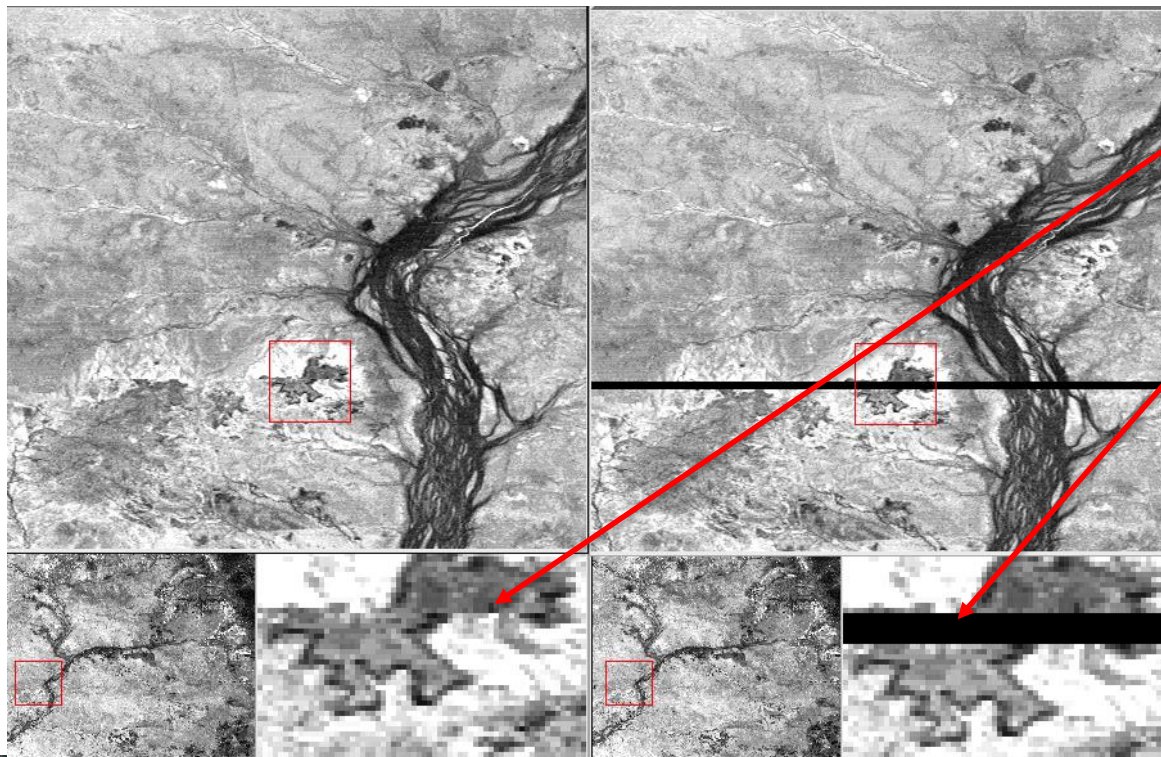
% Change in TOA Reflectance					
Band	L5 MSS	L4 MSS	L3 MSS	L2 MSS	L1 MSS
Green	-2.93	-4.49	-4.60	-2.62	-0.26
Red	-3.81	-4.67	-10.69	-2.29	3.74
NIR1	-1.25	1.13	-2.60	2.50	-3.84
NIR2	-3.18	-1.98	2.32	7.71	1.52

MSS Improved GCP Outlier Rejection



- Rejecting Outlying GCPs has significantly improved Radial RMSE

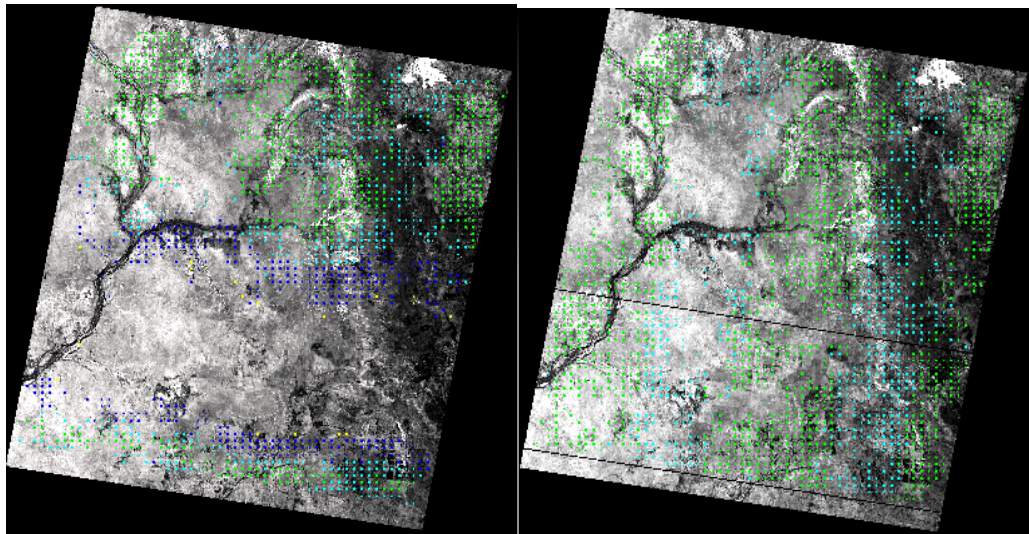
MSS Fill Scan Addition



LM50950761997115ASA01 (Missing scan)

LM50950761997115ASA01 (Fill scan)

MSS Fill Scan Addition (Cont.)



LM50950761997115ASA01 (Missing scan)
Gverify results on left, show a much more rainbow set of results which is not good. Radial RMSEs are in the 2.0 pixel range.

LM50950761997115ASA01 (fill scan)
Gverify results on right, show a much more consistent result with radial RMSEs in the 1.0 pixel range.

Future Work

- **Collection 2**
 - Phase 4 GCP improvements
 - Gain Updates
 - Cloud Computing
 - Level 2 (Surface Reflectance and Surface Temperature)
- **Landsat 9**
 - Ground System PDR (3/20-22)
 - Mission CDR (4/17-19)
 - Dec. 2020 Launch