

TIRS SSM Mode 0 Data Product Impact and Processing Approach

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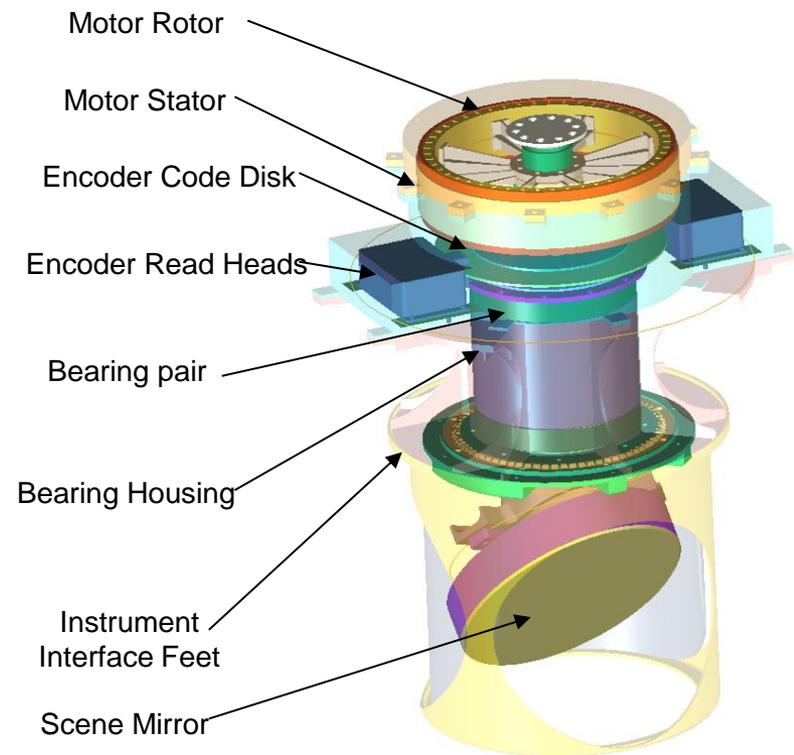


Overview

- **TIRS scene select mirror anomaly background**
 - ◆ SSM operating modes
- **Data processing impacts of mode 0 operation**
 - ◆ Lack of SSM position telemetry
 - ◆ Lack of TIRS calibration data
- **Mode 0 data processing approach**
 - ◆ Use image-based measurements to estimate SSM angle
 - ◆ Generate auxiliary SSM data file from a model fit to the estimated SSM angles
 - ◆ Implement the capability to use estimated SSM angles from the auxiliary SSM data file in the TIRS geometric model
- **Impact on product data quality**
 - ◆ TIRS/OLI coverage overlap and band registration accuracy
 - ◆ Radiometric errors due to loss of calibration data

TIRS SSM Anomaly Background

- The TIRS scene select mirror (SSM) rotates to direct the TIRS field of view toward the Earth, deep space, or the on-board black body
- SSM position is measured by an encoder
 - ◆ Encoder readings are used to both control and provide knowledge of SSM pointing
 - ◆ SSM also has an “open loop” mode that does not use encoder data feedback
- Encoder current draw became anomalous mid-2014
 - ◆ Current increased and began to threaten yellow limit 4Q2014



SSM Anomaly Onset

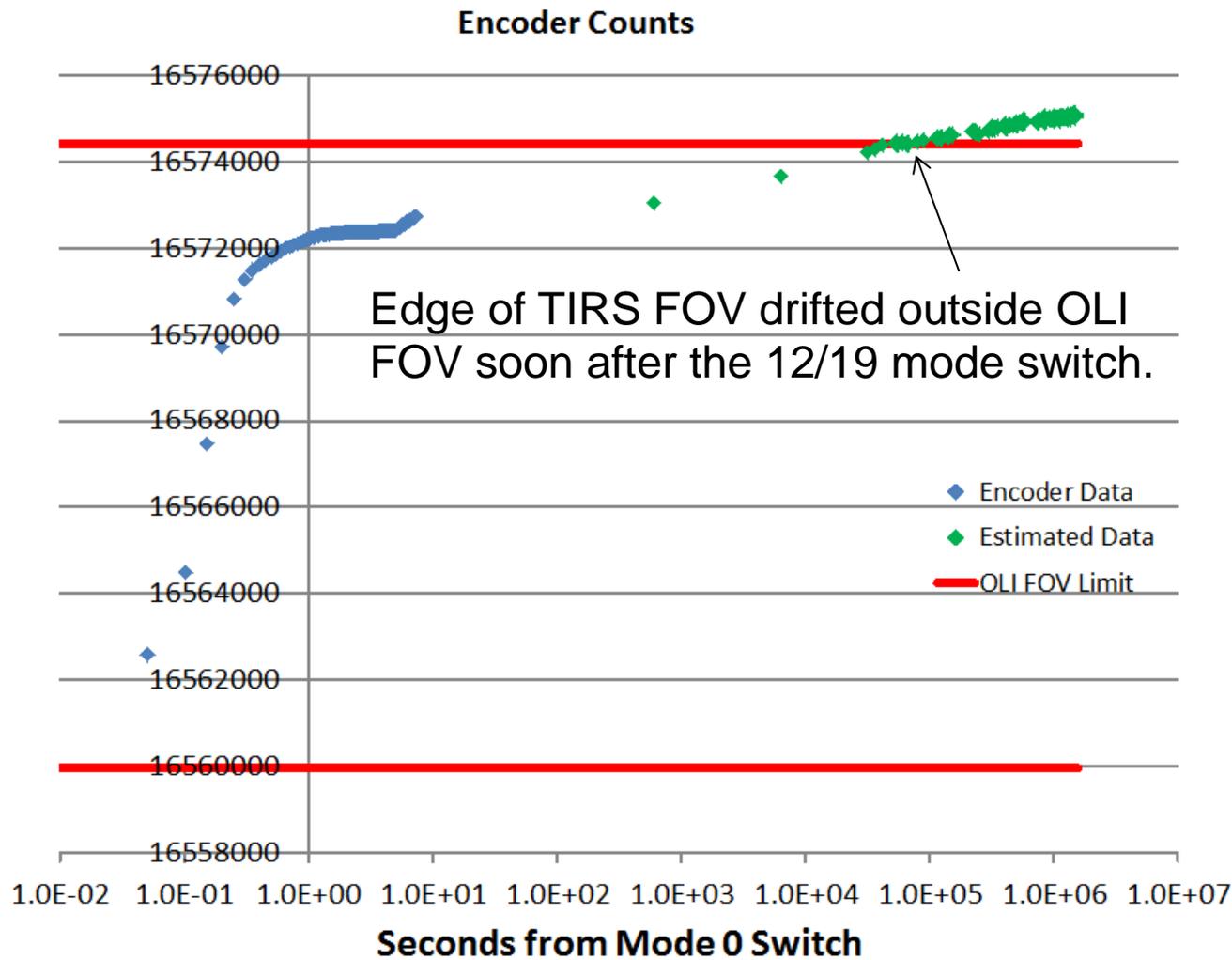
- **Unfavorable encoder current trend prompted a test of the alternate open loop “mode 0” control method**
 - ◆ SSM was operated in mode 0 from 12/09/2014 until 12/12/2014 with the encoder operating but not controlling SSM pointing
 - ◆ This made it possible to monitor SSM behavior in mode 0
- **Encoder current trend worsened shortly after this test leading to another switch from closed loop “mode 4” operation to open loop mode 0 on 12/19/2014**
 - ◆ The encoder was powered off following the switch to avoid exceeding the allowable current draw
- **Since then, several mode switch tests have been conducted to gather information about SSM encoder and motor behavior**

Impact on Geometric Processing

- **The TIRS SSM moves significantly when switched from mode 4 (closed loop) to mode 0 (open loop)**
 - ◆ Initial rapid motion makes scene data containing the switch event uncorrectable, even with SSM telemetry
- **In mode 0 with the encoder turned off, the lack of valid SSM encoder telemetry causes the current TIRS geometric model to assume nominal nadir viewing**
 - ◆ Due to large initial motion of SSM following the mode switch this leads to severe misregistration of the TIRS bands
- **SSM rate of motion slows, but has not (yet) been observed to completely stop**
 - ◆ Continuing motion makes it impossible to calibrate to a single new mode 0 pointing angle
 - ◆ The TIRS field of view eventually migrates outside the OLI field of view losing complete coincident coverage

SSM Behavior Following 12/19 Switch

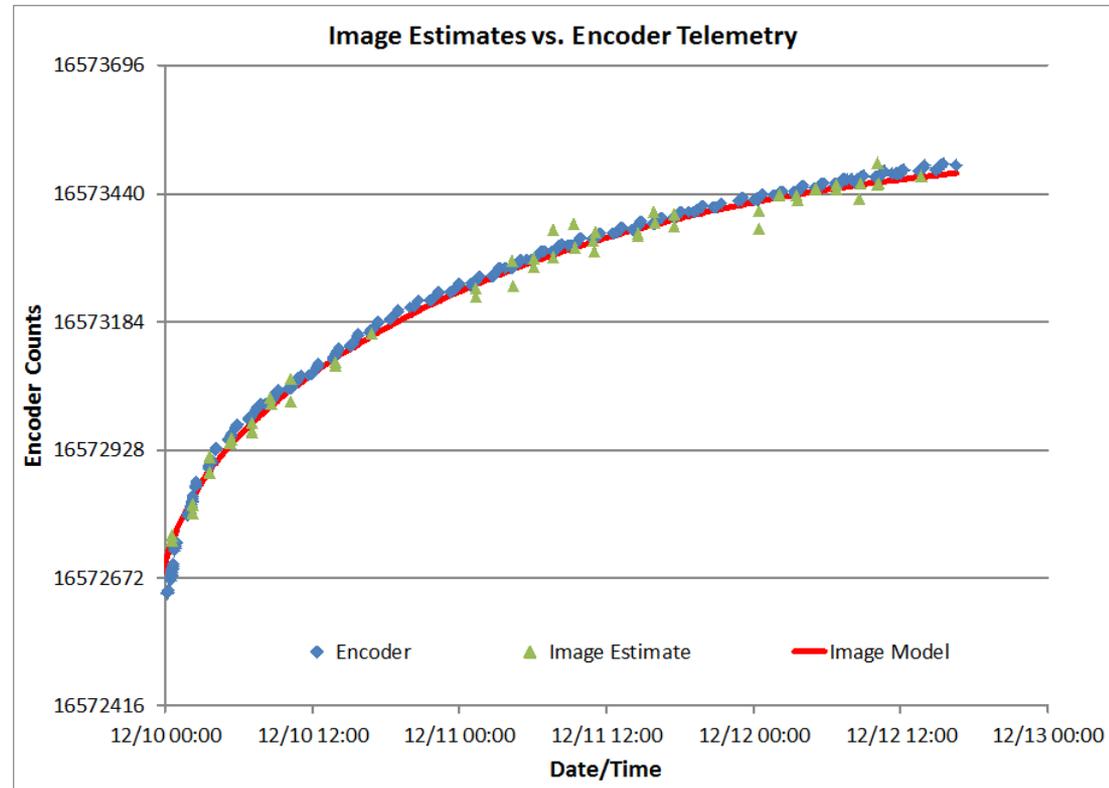
- Log time scale used to show initial rapid change
- Blue diamonds are actual SSM encoder data
- Green diamonds are image-derived estimates
- Red lines show OLI field of view limits on the east (top) and west (bottom) sides of the swath



SSM Position Estimation Method

● Use image measurements to estimate SSM angle

- ◆ TIRS band 10 (10.9 micron) is processed using an estimated SSM angle
- ◆ The resulting image is correlated with OLI band 6 (SWIR1)
- ◆ The measured offsets are used to estimate a correction to the SSM angle and to the TIRS pitch alignment
- ◆ Measurements from multiple scenes are fitted to a decaying exponential function to form a smooth estimate of SSM position over time



Encoder telemetry, image measurements, and fitted model for the 12/09/2014 mode 0 test.

First Mode 0 Test

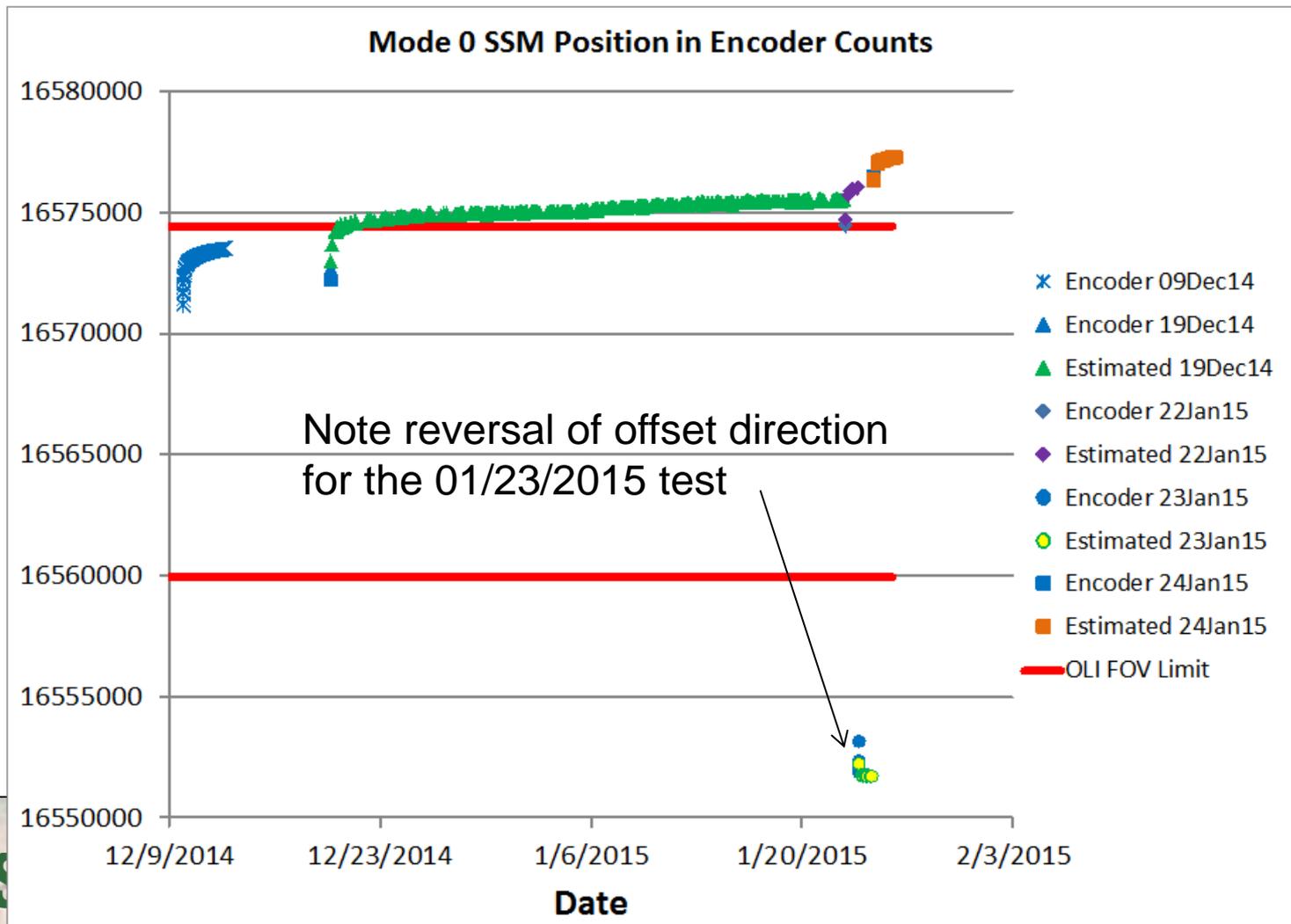
- **An initial on-orbit test of mode 0 was conducted between 12/09/2014 and 12/12/2014**
 - ◆ The SSM encoder remained powered during this test to measure actual SSM motion during mode 0 operation
- **We used this data set as a test case for the image-based SSM position estimation algorithm**
 - ◆ Use image measurements to estimate SSM position
 - ◆ Compare to actual SSM encoder readings
- **Test results**
 - ◆ Used 54 scenes to measure SSM position
 - One rejected as an outlier based upon internal scene statistics
 - ◆ Model fit to 53 scene measurements: 11.6 μ rad LE90
 - ◆ Model vs. encoder data (12/10-12/12): 8.6 μ rad LE90

SSM Anomaly Mode 0 Operation

- **The SSM was switched to mode 0 for the 2nd time on 12/19/2014 to avoid breaching the encoder current limit**
 - ◆ The SSM encoder was unpowered during this period (except for short tests to measure current) since the point of the switch was to shut down the encoder
- **Three more tests of mode 4 to mode 0 switching were conducted in late January (as of 01/28/2015)**
- **The SSM position estimation algorithm has been applied to these data as well**
 - ◆ All exhibited similar rapid initial motion followed by exponential slowing to a steady state drift
 - ◆ The initial offset magnitudes were not particularly repeatable and appear to be sensitive to mirror motion prior to the mode switch

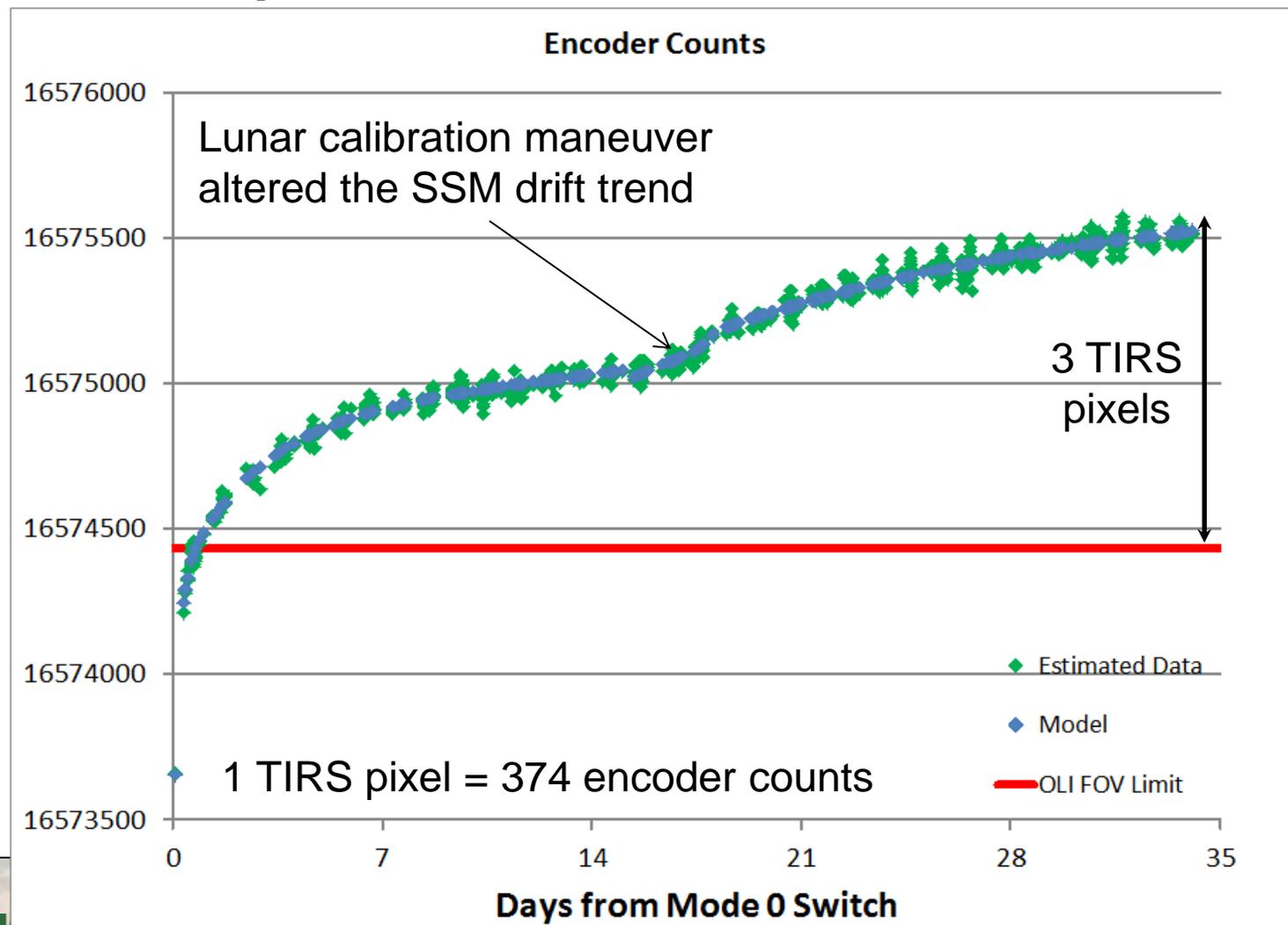
Mode 0 SSM Position History

- Both encoder measurements and image-based position estimates are shown



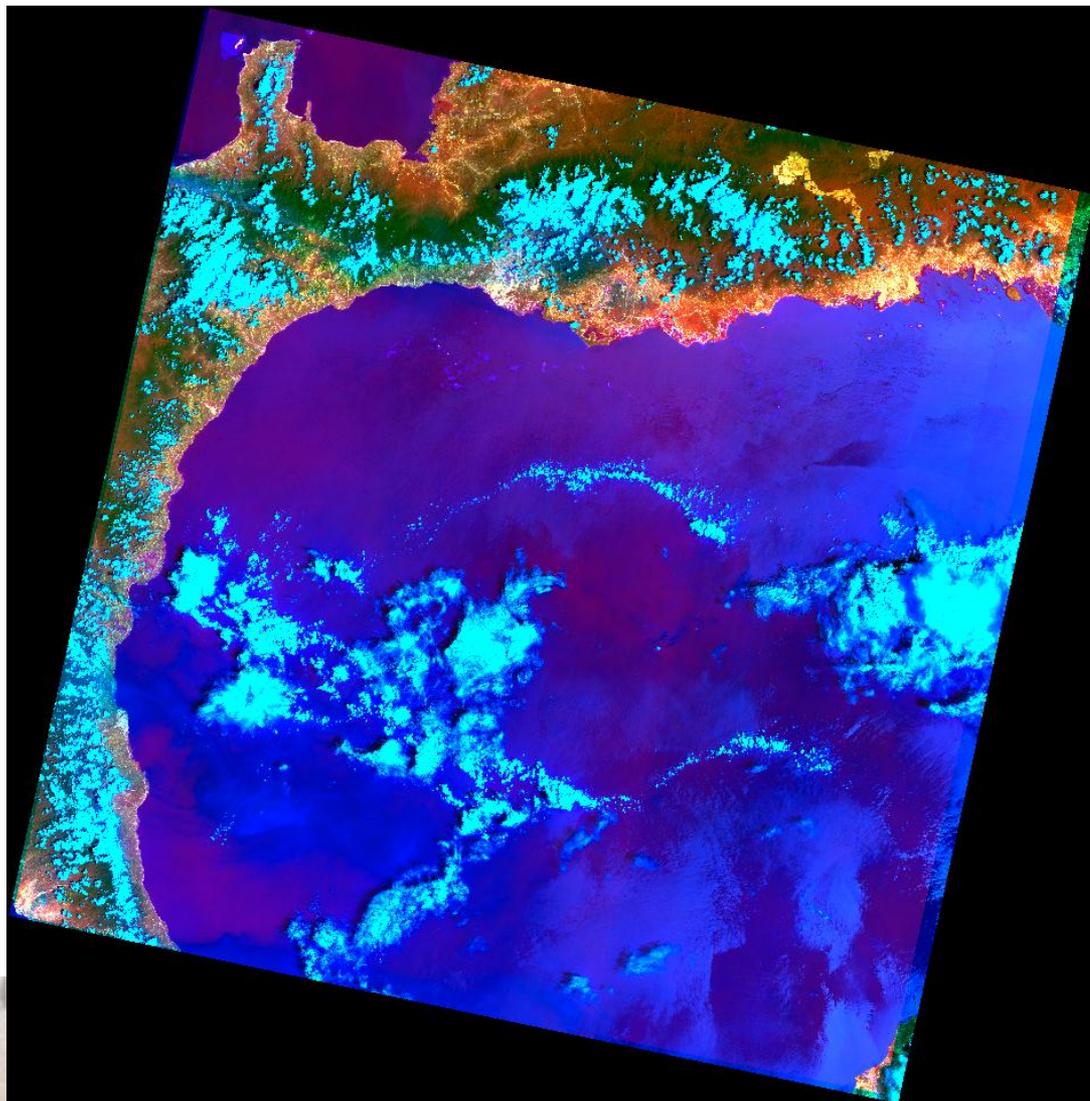
Mode 0 Pointing Behavior

- Estimated positions are shown with model values

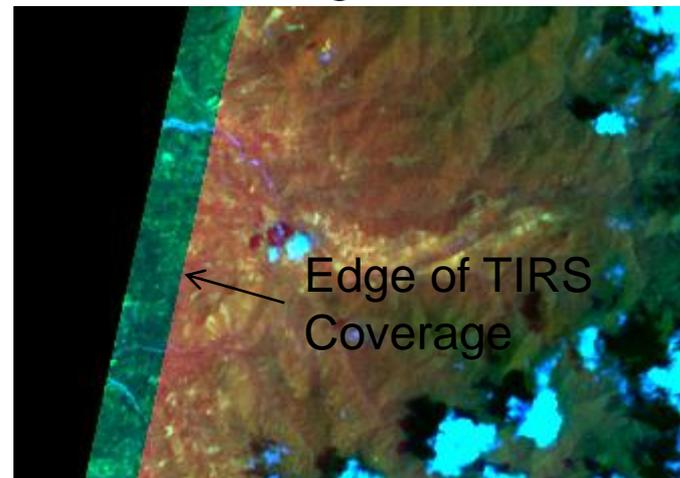


OLI/TIRS Mode 4 Coverage 23OCT2014

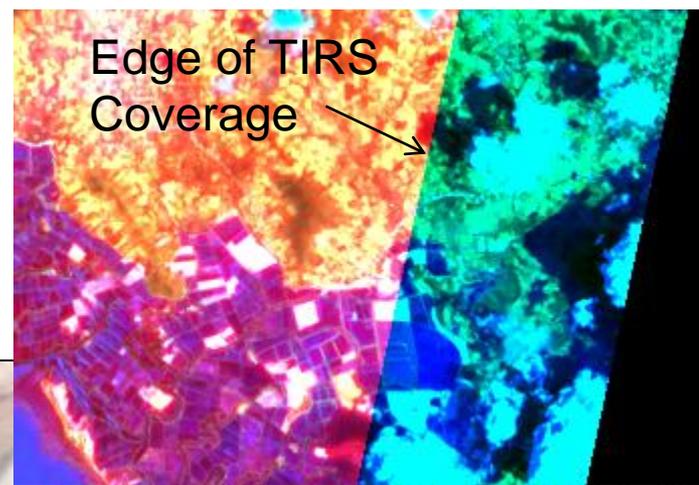
- Red = Band 10 (TIRS) : Green = Band 7 (OLI) : Blue = Band 1 (OLI)



West Edge of Scene



East Edge of Scene

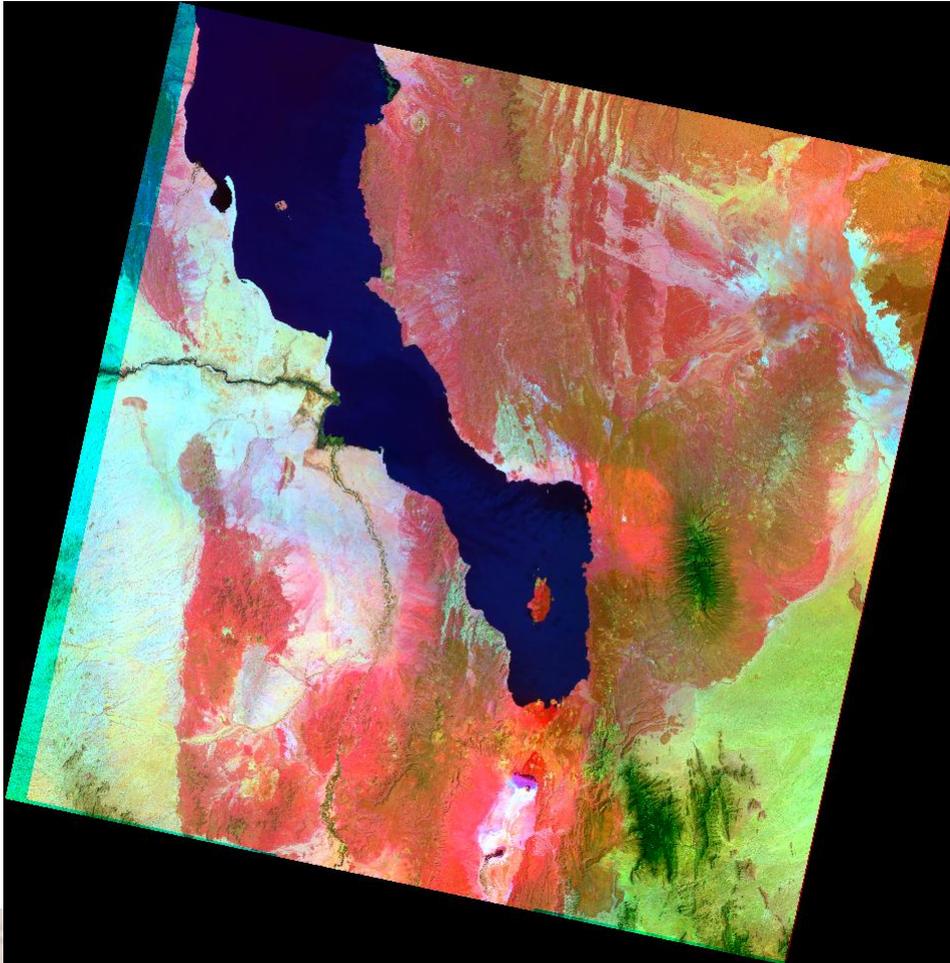


OLI-TIRS Mode 0 Coverage 28JAN2015

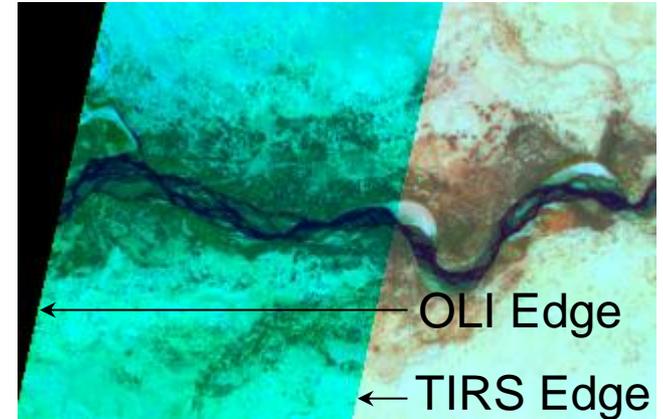
- TIRS coverage now extends slightly beyond OLI

WRS 169/058

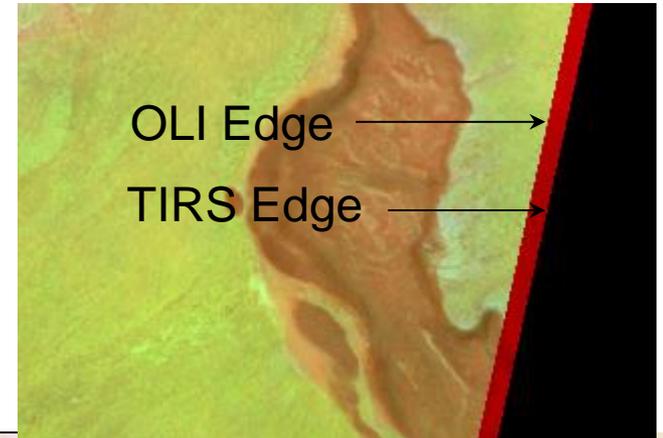
R: 10 (TIRS) G: 6 (OLI) B: 2 (OLI)



West
Edge



East
Edge

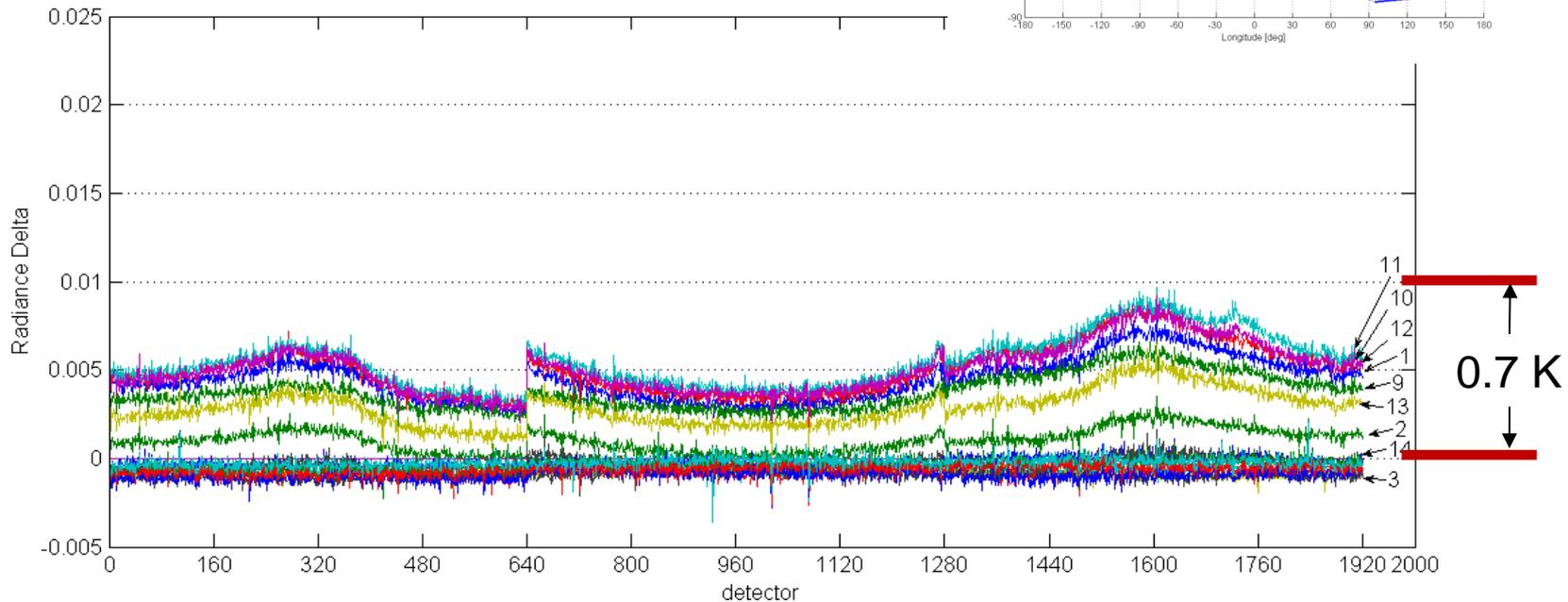
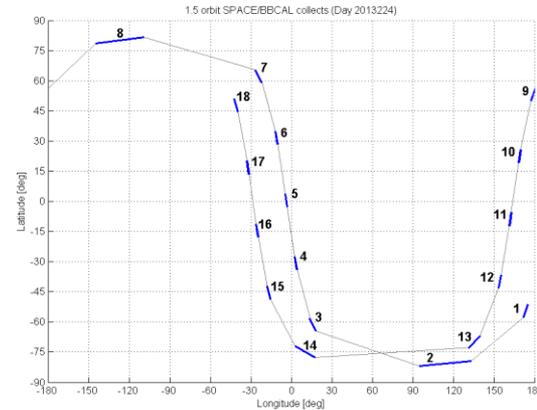


Impact on Radiometric Processing

- **Executing the normal TIRS deep space and blackbody collects requires SSM encoder position data**
 - ◆ Without these data, normal TIRS calibration operations are suspended while in mode 0
 - ◆ Loss of calibration collects limits the ability to monitor TIRS radiometric stability
 - ◆ TIRS stability makes this tolerable over the short term
- **To make mode 0 operations feasible over the long term a new operations concept would be required for TIRS calibration data, for example:**
 - ◆ Periodic switch to mode 4 for a calibration sequence
 - The large rapid SSM motion following a switch to mode 0 would degrade geometric accuracy for the first day or so
 - ◆ Open loop SSM rotation to sweep past BB and space port
 - Not clear how this would be controlled or how SSM position knowledge would be regained after the event
 - ◆ Estimate background response based on instrument temperatures
 - Radiometric errors potentially decreased without the need to move SSM

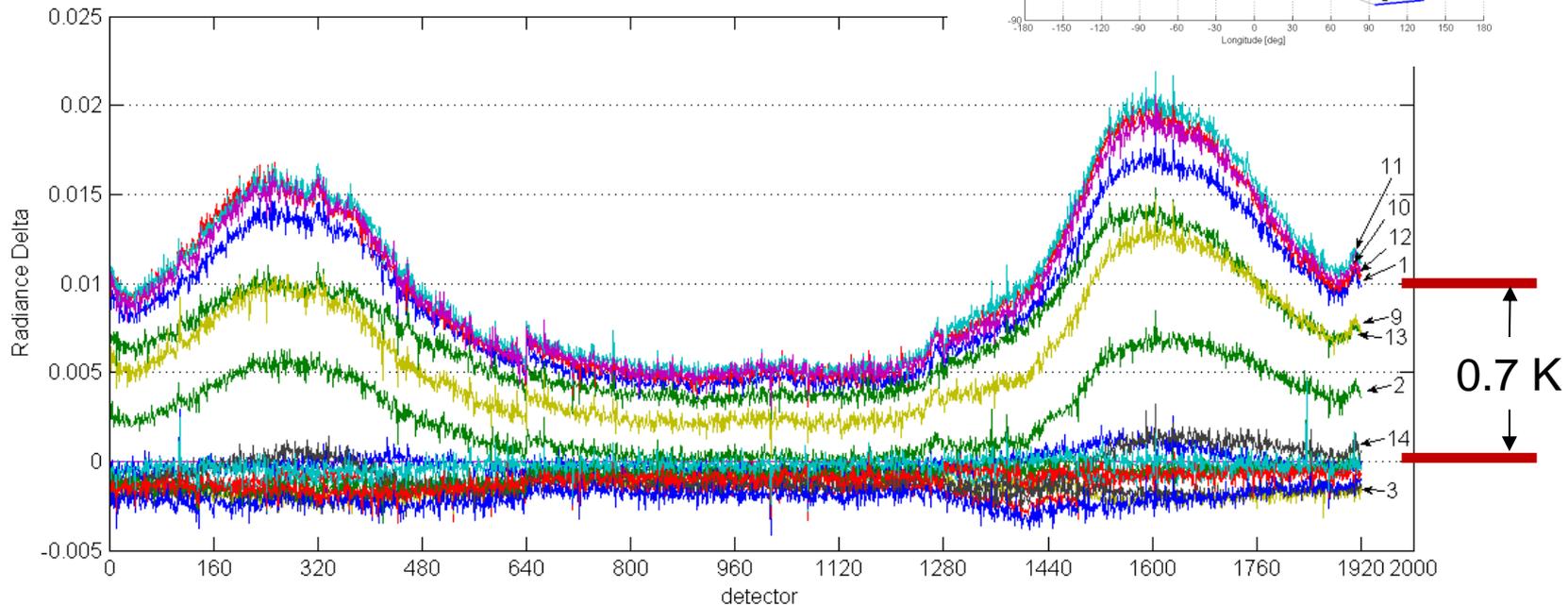
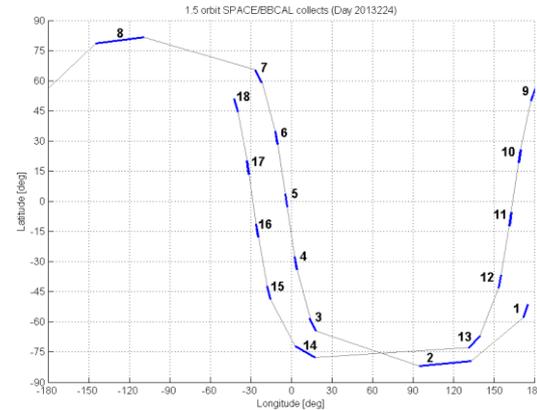
Within Orbit Background Response Changes—Band 10

- Background response varies cyclically with orbit position (temperature)
- Small effect across detectors (~0.4 K)

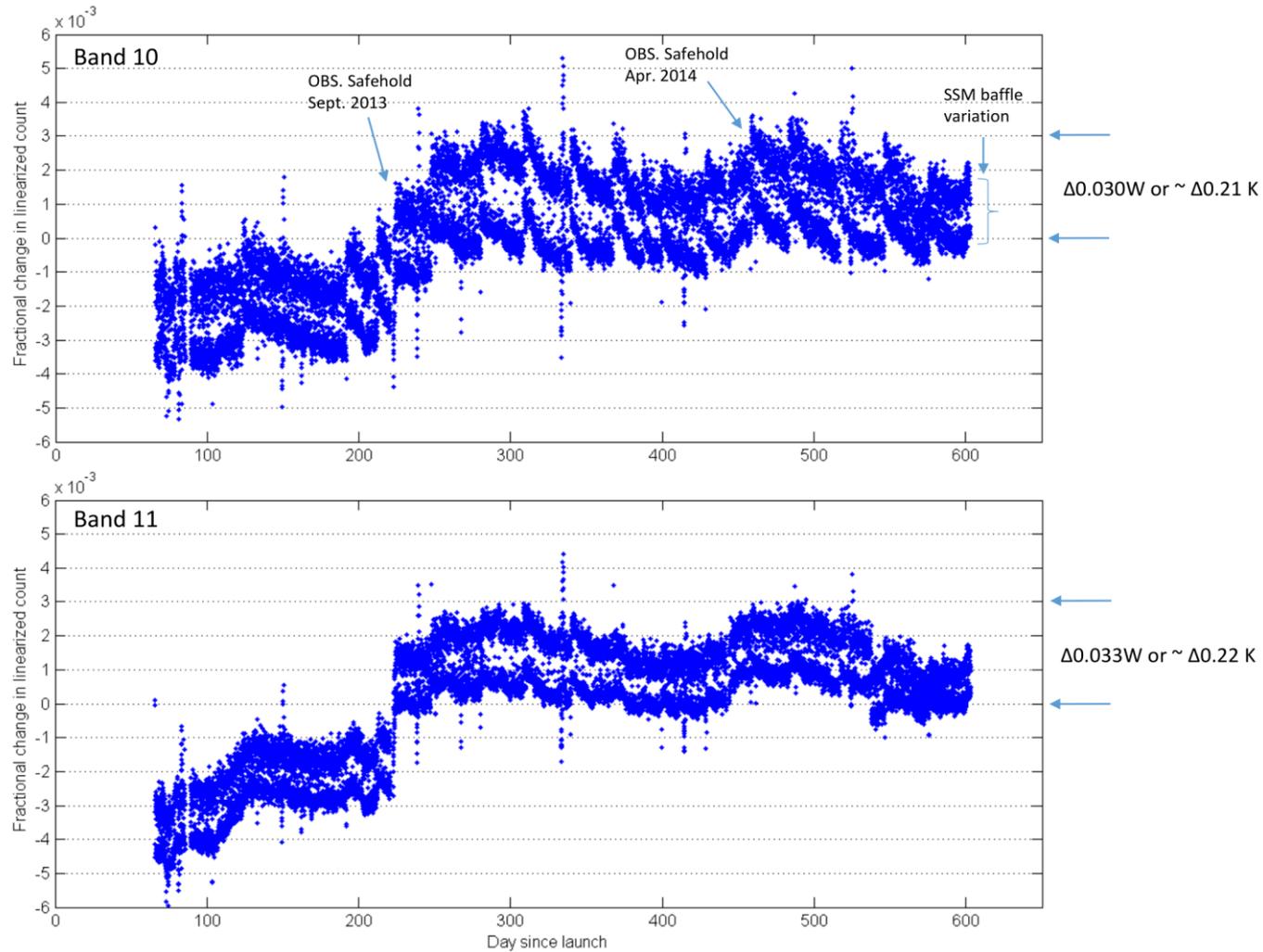


Within Orbit Background Response Changes—Band 11

- Background response varies cyclically with orbit position (temperature)
- Varies about twice as much as band 10 varies across detectors (~1 K)



Lifetime Background Response Changes



Mode 0 Data Processing Approach

- **Scenes were initially processed using a prototype version of the TIRS line-of-sight model that takes a SSM angle as an optional input**
 - ◆ Approximate angles allow the SSM angle measurement algorithm to work
 - ◆ Fitting a model to measurements from multiple scenes improves accuracy
- **Revise TIRS line-of-sight model to implement an external SSM data capability**
 - ◆ Interpolate SSM angles from an external file in place of encoder telemetry from ancillary data file
- **A new SSM position model has to be generated for each mode 0 switch event**
 - ◆ Fit exponential model to scenes after each switch
- **No action taken for radiometric effects**

Summary

- **Estimating SSM position based on imagery appears feasible**
 - ◆ SSM continues to move slowly and smoothly after initial rapid adjustment to mode 0
- **Fitting model to estimated SSM position provides external source for TIRS data processing**
 - ◆ Model accuracy on the order of 10 microradians expected for times more than 8 hours after a mode 0 switch
 - Degrades TIRS-OLI cross-track registration accuracy from 19m to ~23m (LE90)
- **TIRS model creation software changes needed to process the mode 0 data currently being acquired**
 - ◆ This update is scheduled for the next IAS/LPGS software release (April 2015)
- **Radiometric accuracy slightly affected**
 - ◆ Insignificant compared to stray light effects
 - ◆ Working on estimating background response to minimize errors
 - ◆ Potentially implement radiometric adjustments into IAS/LPGS at the same time as TIRS stray light correction (Summer/Fall)