ON-ORBIT OPTICAL SENSOR BIAS ESTIMATION

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Outline

- **Introduction**
- **Bias Estimation**
- **Shutter Stability**
- **Pre and Post Earth Imaging Shutter Collects**
- **Shutter vs Ocean Night Images**
- **Conclusions**

Introduction

- **Landsat 8**
  - Launched February 11, 2013
  - Polar Sun-synchronous orbit
  - 100% duty cycle
  - 16 day repeat cycle
  - 2 Push-broom sensors
    - Operational Land Imager (OLI)
    - Thermal Infrared Sensor (TIRS)
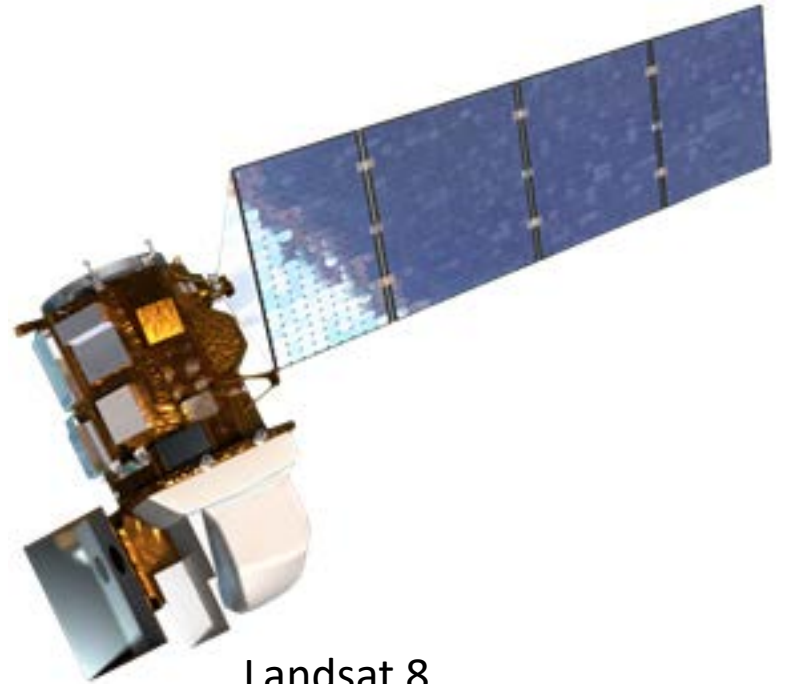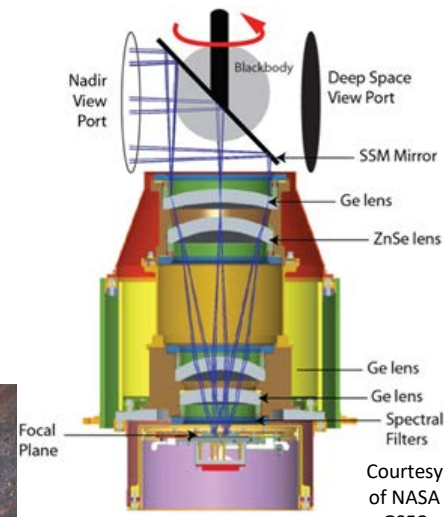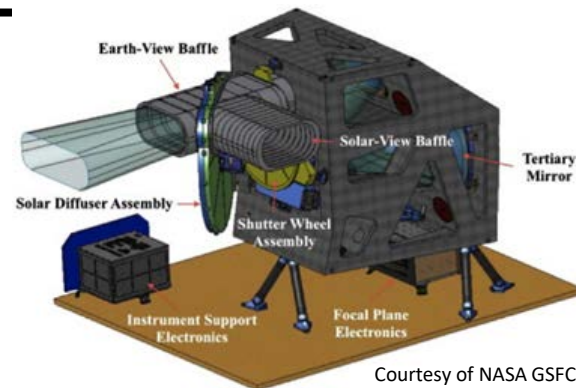

Landsat 8
Courtesy of NASA GSFC

Introduction (Cont.)

- **OLI**
  - 9 spectral bands
    - Costal Aerosol, Blue, Green, Red, NIR, SWIR 1, SWIR 2, PAN, Cirrus
  - 14 Focal Plane Modules
  - 494 Imaging Detectors per FPM
    - 988 for the PAN band
- **TIRS**
  - 2 spectral bands
  - 3 FPMs
  - 640 imaging detectors per band

Courtesy of NASA GSFC

Courtesy of NASA GSFC

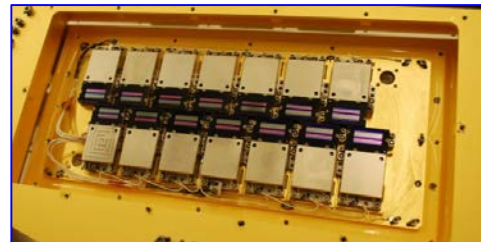# Introduction (Cont.)

- **On Board Calibration**
  - OLI
    - 2 space grade Spectralon® diffuser solar panels
    - Stim lamp assembly with radiance monitoring diode
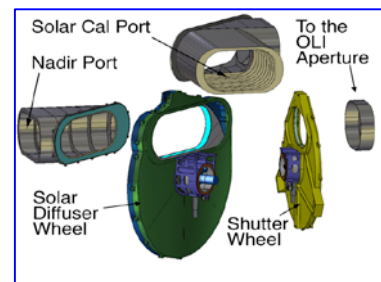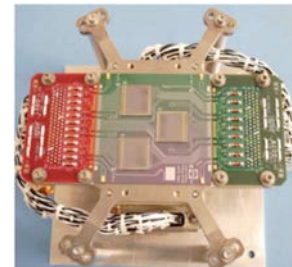   - Shutter
  - TIRS
    - Blackbody

OLI-FPA

Courtesy of Ball Aerospace

OLI-Cal Assembly Diagram

Courtesy of Ball Aerospace


TRIS-FPA

Courtesy of NASA GSFC

Bias Estimation

- The response of a sensor with no input is its bias.

- Subtracting bias is necessary to balance detector-detector responses.

- OLI uses a shutter to block the incoming light.

- Bias estimates for OLI imagery are the detector averages of two shutter collects: the nearest temporally before and after image acquisition.
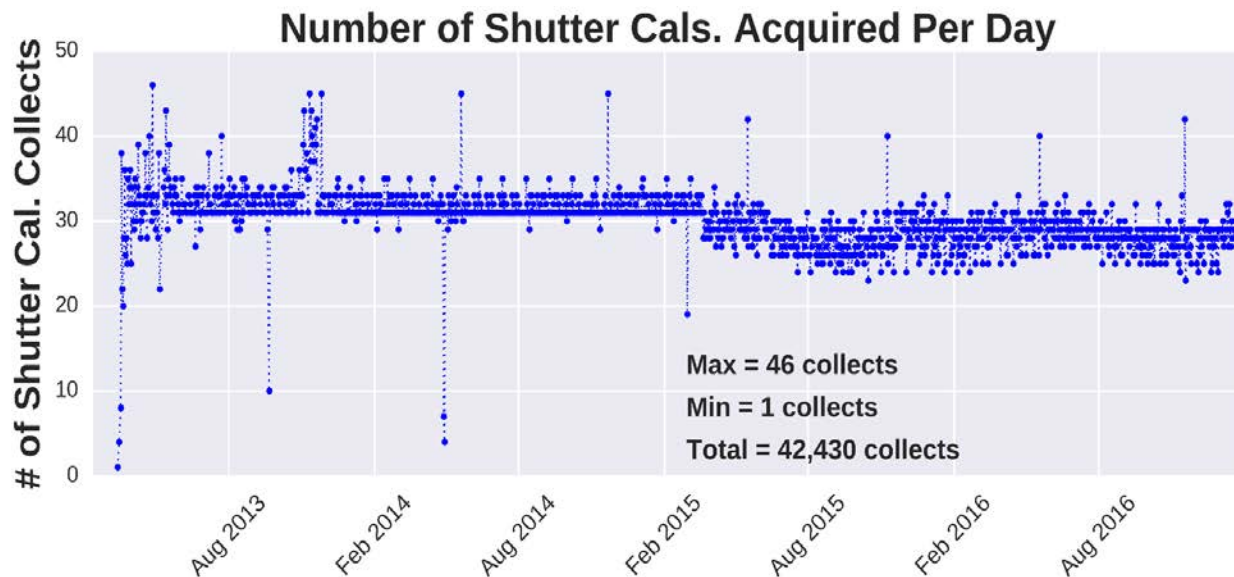
Effect of Bias Error
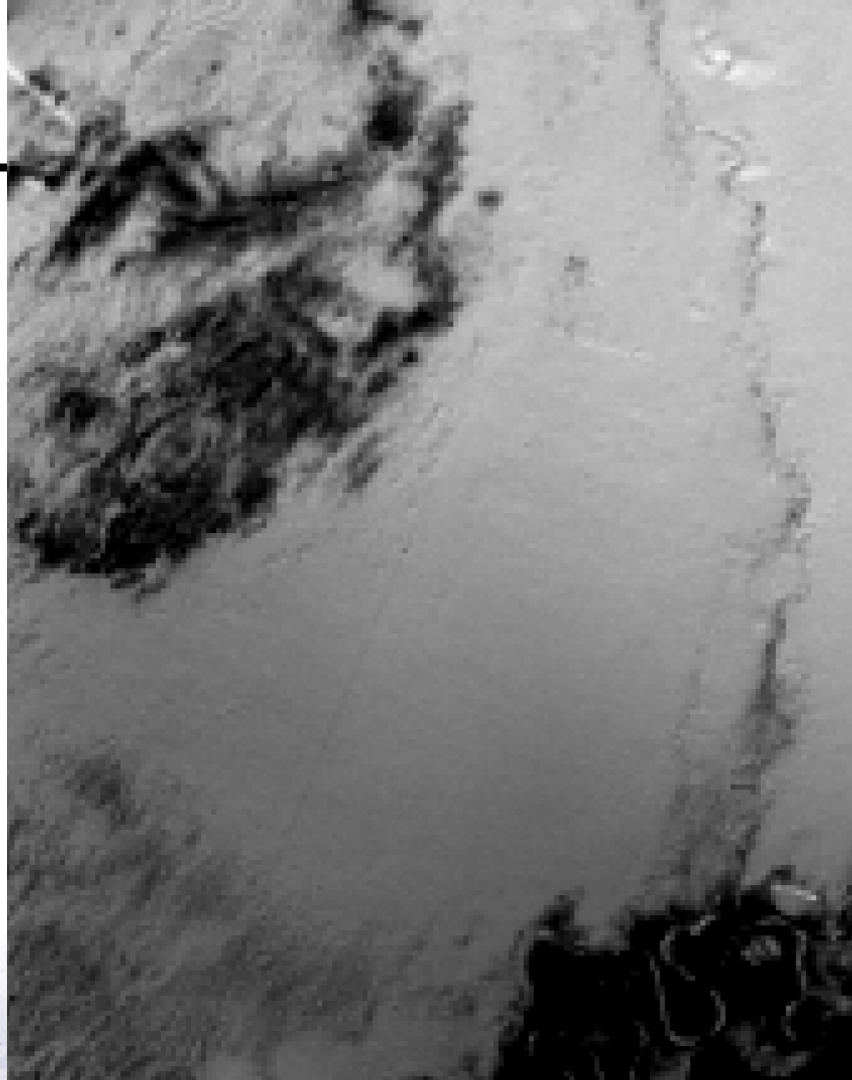
Shutter Stability

Shutter Collects Per Day

- **Typically around 30 collects are acquired per day.**

- **At the top and bottom of each orbit plus before and after each calibration collect.**

Number of Shutter Cals. Acquired Per Day

Max = 46 collects
Min = 1 collects
Total = 42,430 collects

Typical Detector, Long-term Variation

Two Years of Shutter Collect
averages for a Typical Detector
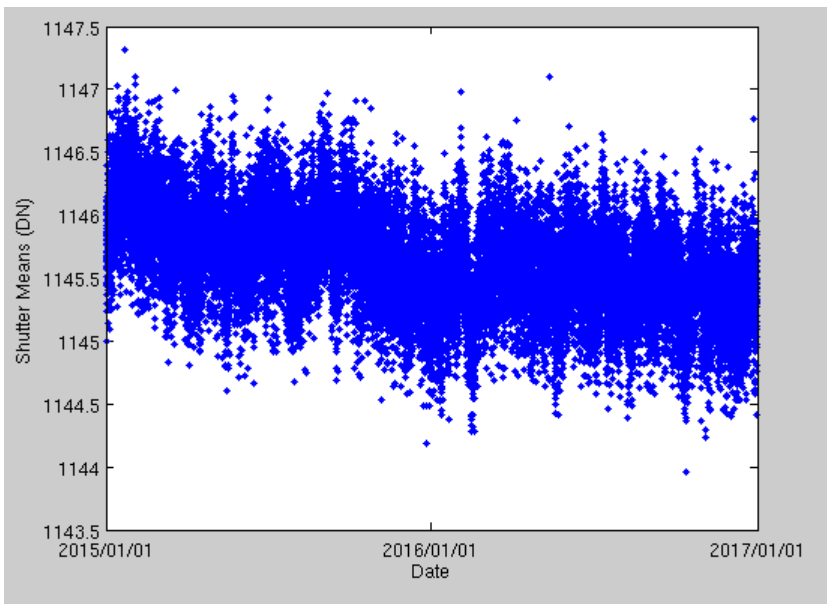
- **A slight trend is visible (≈ 1 DN over 2 years).**

- **Short term variation/spread (max ≈ 2DN).**

Differences Between Shutter Collects vs Time

- **Figure is the difference between every shutter collect and each shutter collect acquired within 24 hours of it.**

- **2 years of shutter collects.**

- **Maximum difference is within 2.5 DN.**

Difference between Shutter Collects vs Time Between Collects

Single Detector
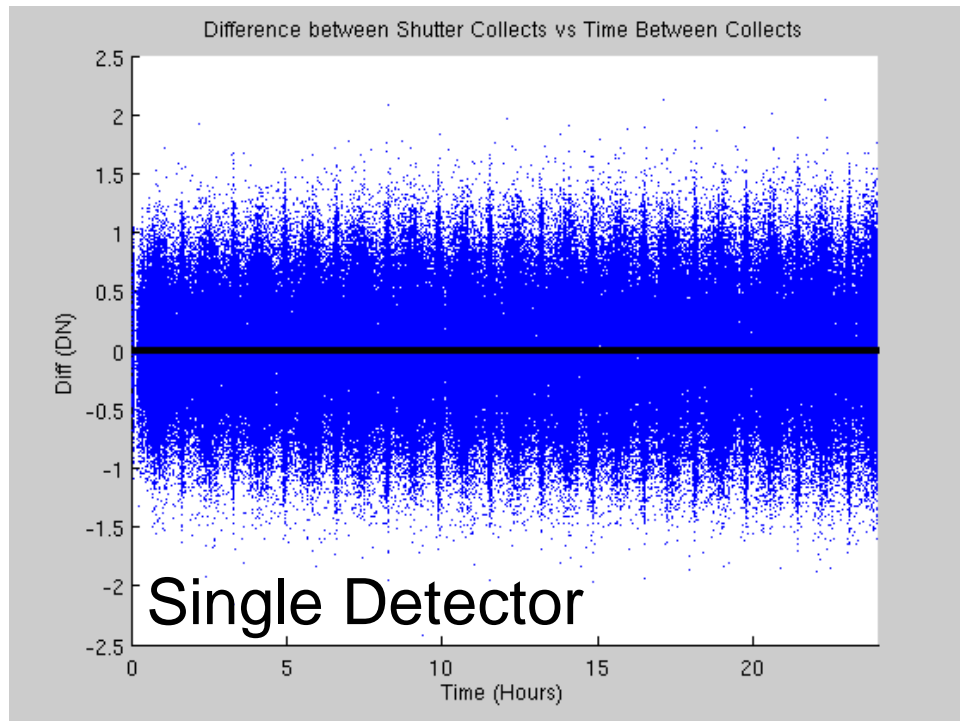
Difference Between Shutters Collected within 1 hour and 24 hours.

- **We looked at the maximum difference between shutter collects acquired within <u>1 hour</u> of each other and ones acquired within <u>24 hours</u>.**

- **Normal operations will collect a shutter every 40-50 minutes.**

- **There was only a shift of 0.5 DNs between waiting for 1 and 24 hours.**

- **Histograms are every detector (nearly 7000) within a band.**
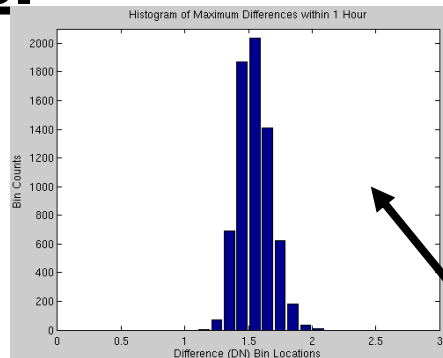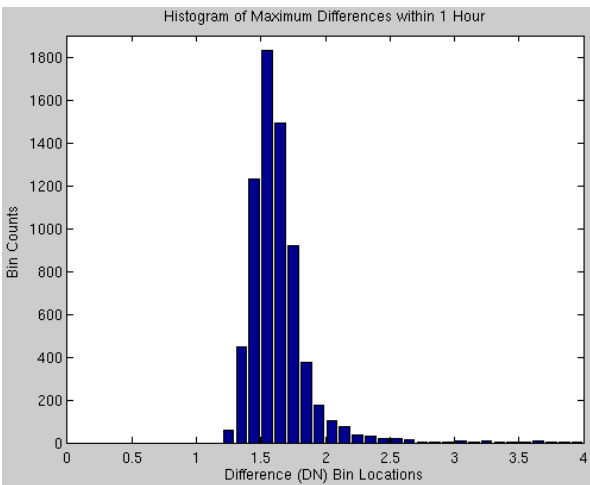

Hist. of Max. Diff. within 1 hour. Mean = 1.55 DN
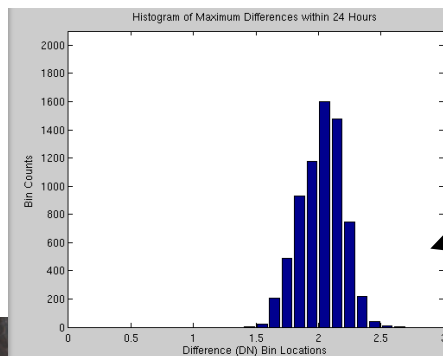
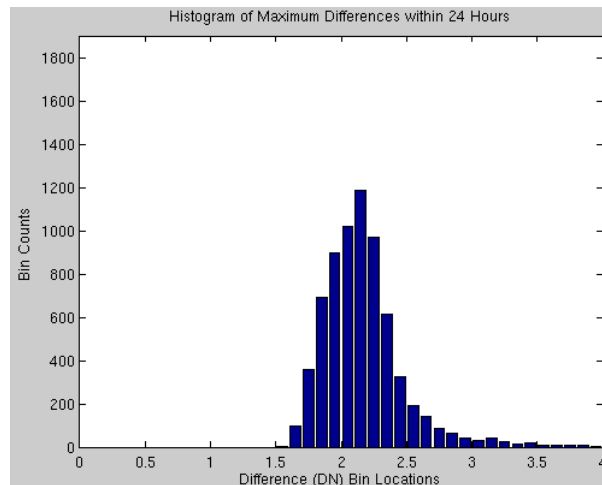Hist. of Max. Diff. within 24 hours. Mean = 2.05 DN
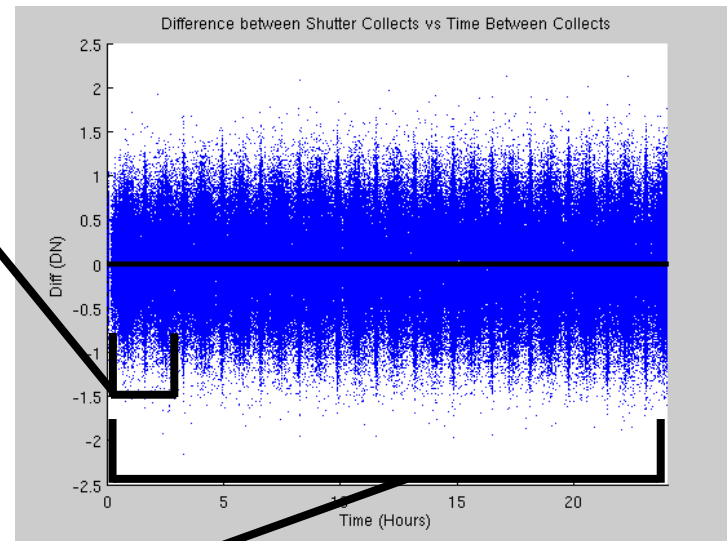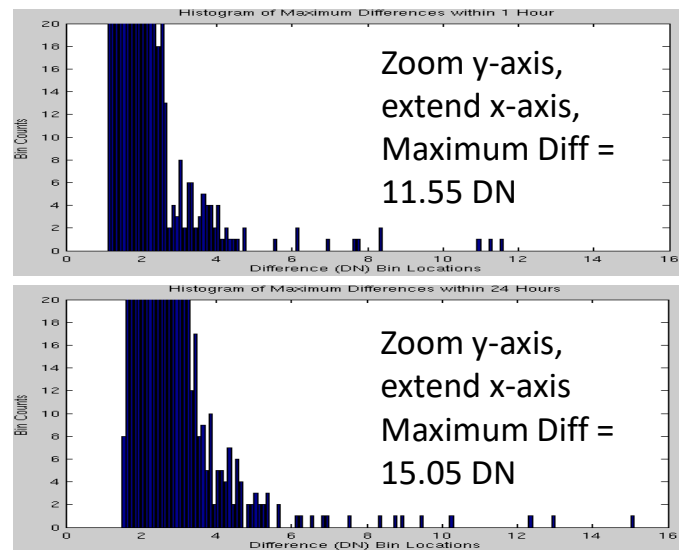

CA Band

SWIR 1 Band Histograms
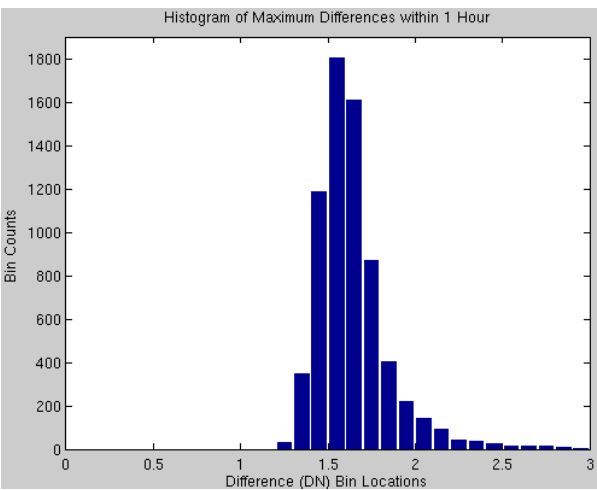

Hist. of Max. Diff. within 1 hour. Mean = 1.55 DN
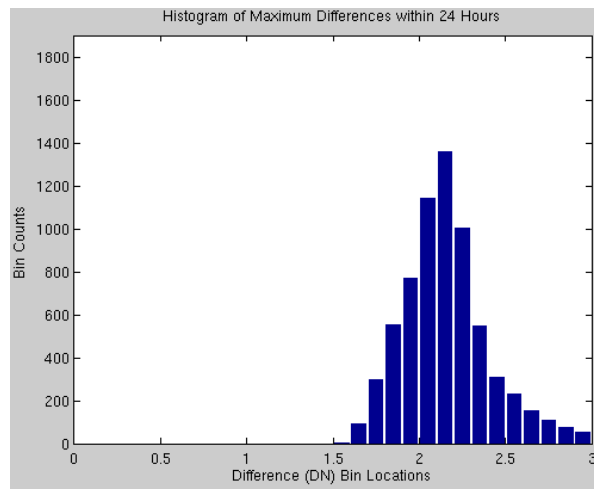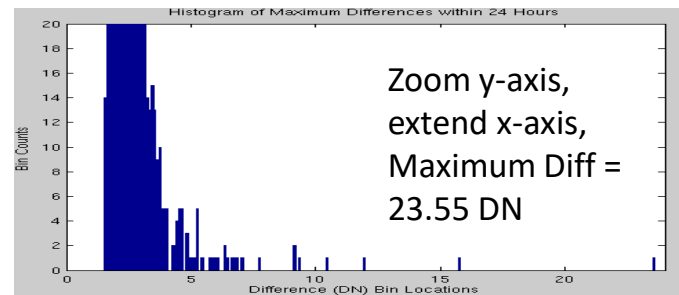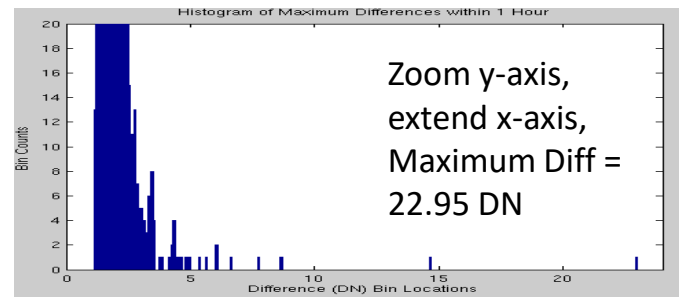
Hist. of Max. Diff. within 24 hours. Mean = 2.15 DN

Difference = 0.6 DN

Zoom y-axis, extend x-axis, Maximum Diff = 11.55 DN

Zoom y-axis, extend x-axis Maximum Diff = 15.05 DN

SWIR 2 Band Histograms

Hist. of Max. Diff. within 1 hour. Mean = 1.55 DN

Hist. of Max. Diff. within 24 hours. Mean = 2.15 DN

Difference = 0.6 DN

Zoom y-axis, extend x-axis, Maximum Diff = 22.95 DN

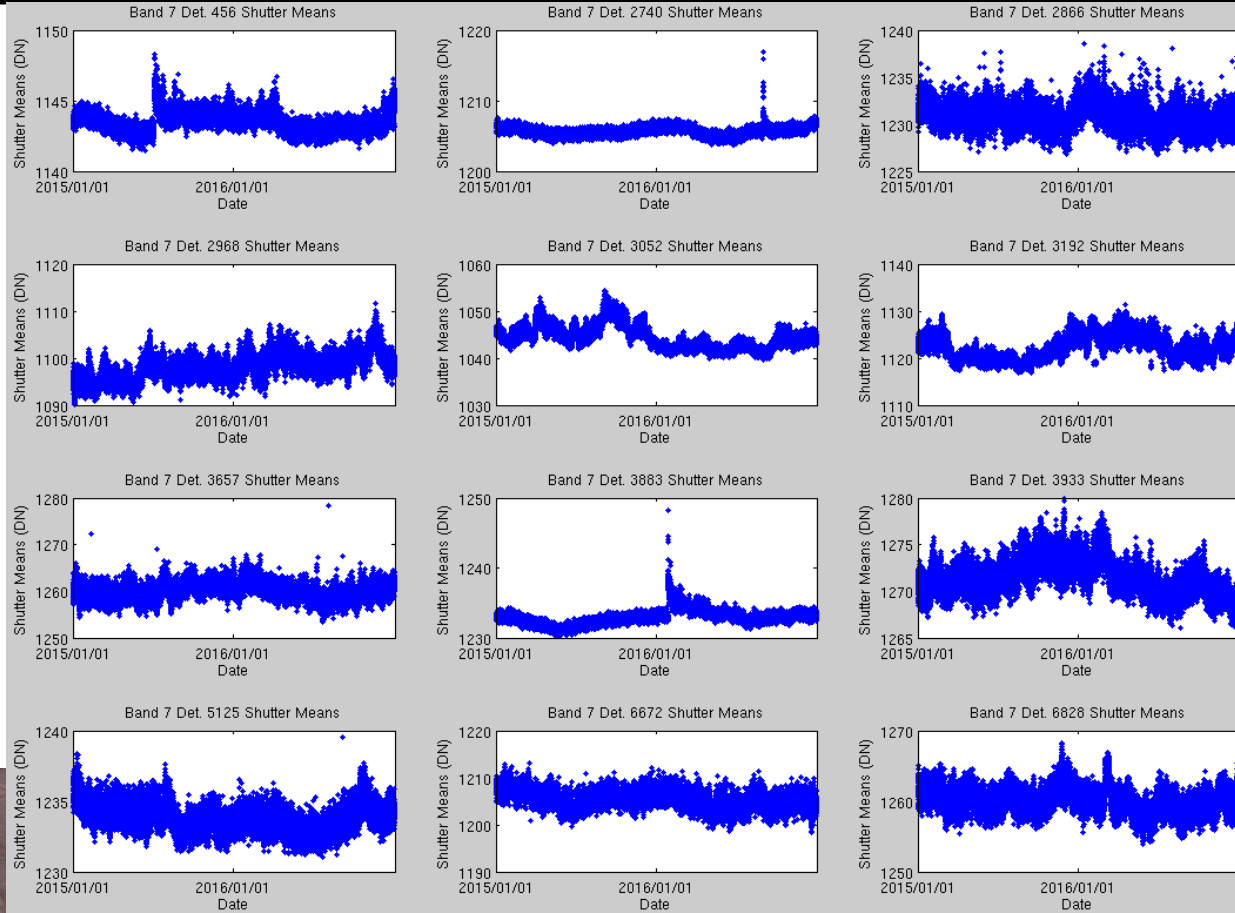Zoom y-axis, extend x-axis, Maximum Diff = 23.55 DN
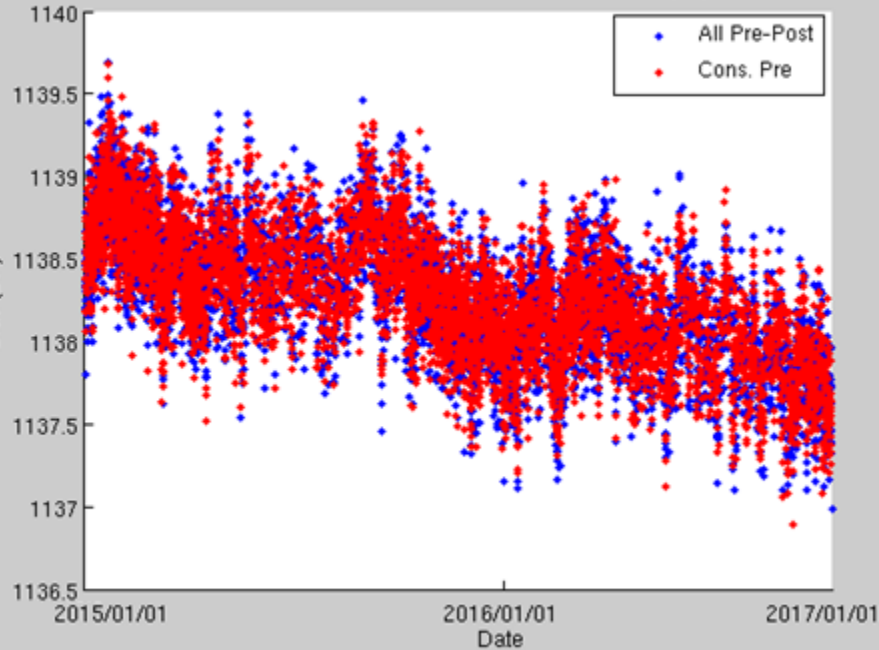
Issue of Noisy Detectors SWIR 1 Band
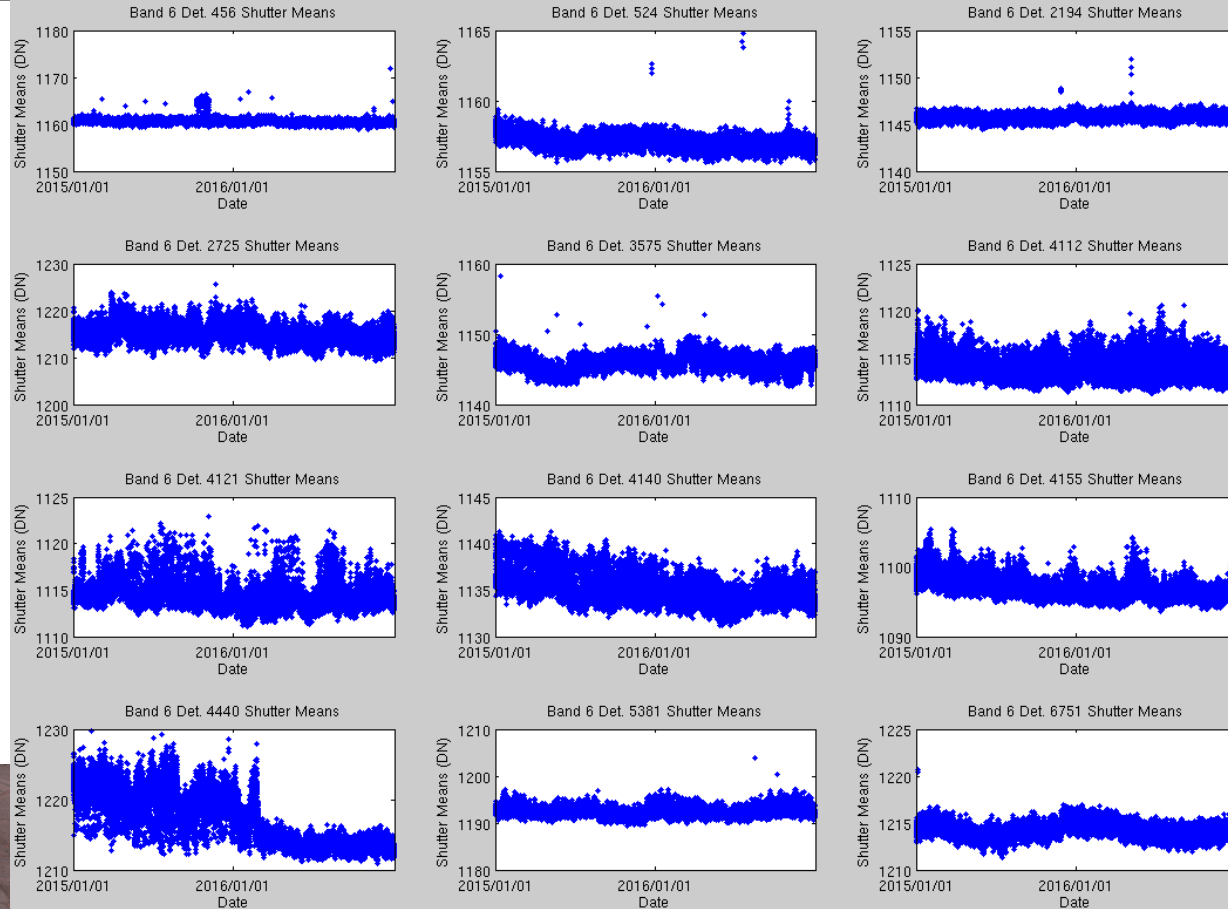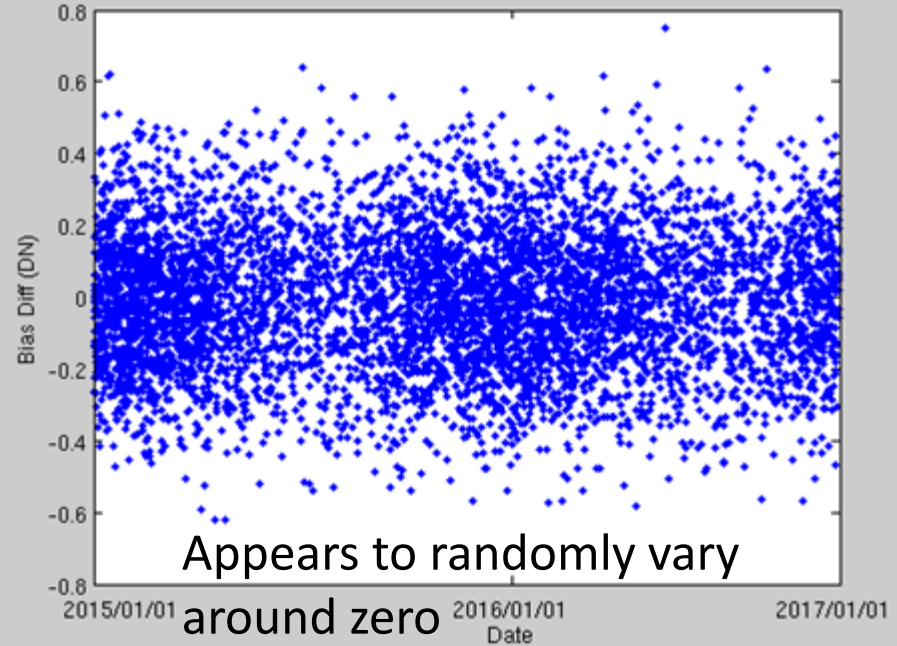
Issue of Noisy Detectors SWIR 2 Band

Pre and Post Earth Imaging Shutter Collects

Pre and Post Bias Comparison

One Detector Bias from All Pre-Post and Consecutive Pre Imaging Shutter Pairs

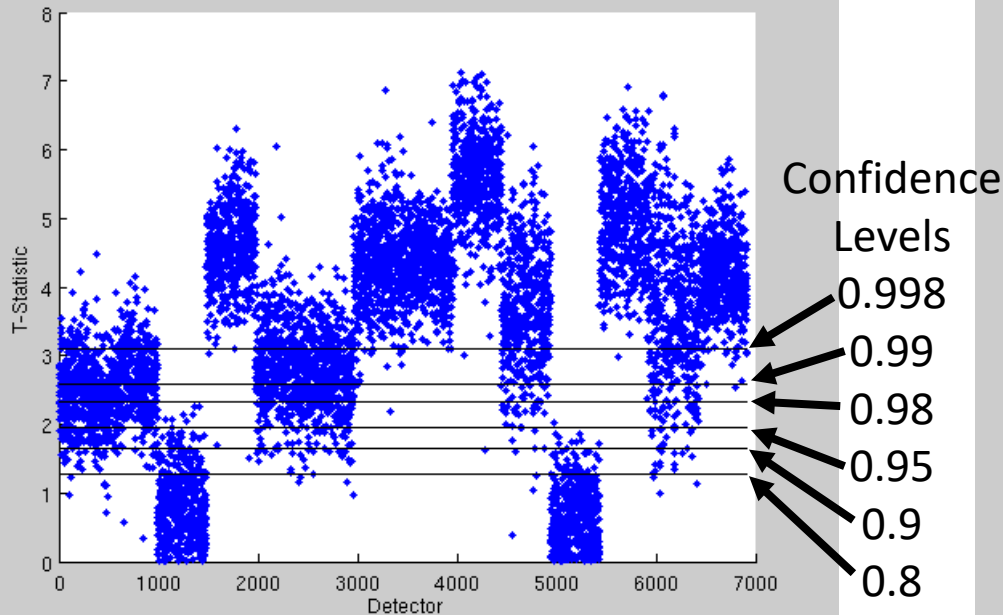One Detector Bias Diff (All Pre-Post - Consec. Pre)

Appears to randomly vary around zero

Bias from Pre and Post Shutters and **Bias from only Pre Shutters** for a Single Detector
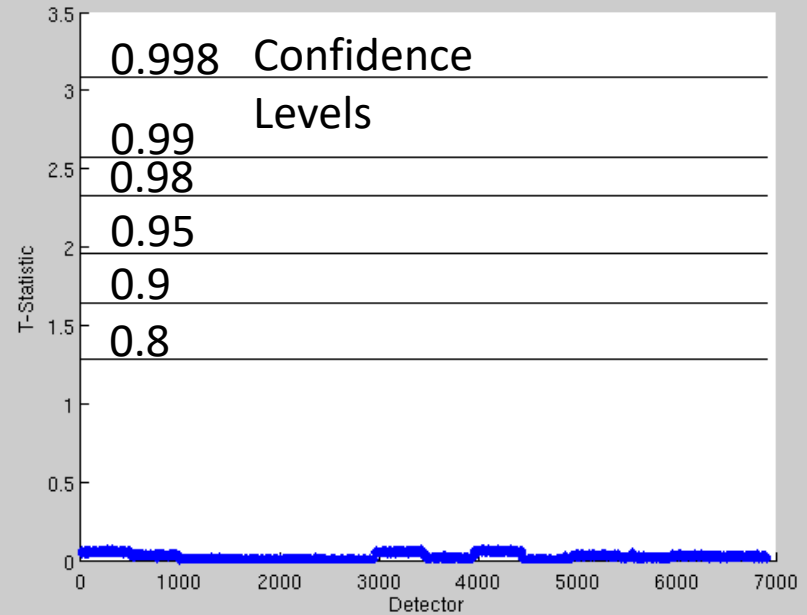
Difference between corresponding blue and red dots

Detector T-Tests for 2 Pre and Pre-Post Bias Estimates (CA Band)

Paired T-Test between Current Bias Estimates (Shutters taken 45mins apart) and Bias Estimates from 2 Pre Shutters taken 98mins.

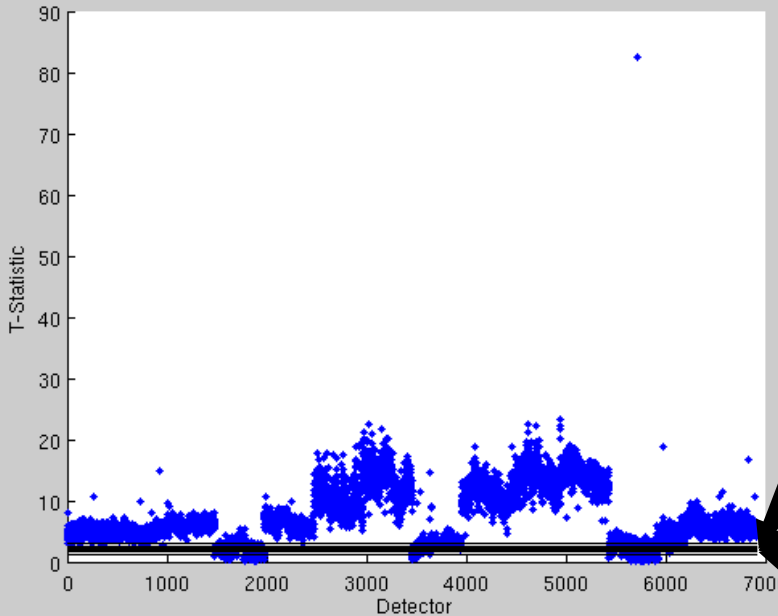Paired T-Test between Current Bias Estimates (Shutters taken 45mins apart) and Bias Estimates from Pre/Post Shutters taken 140mins.

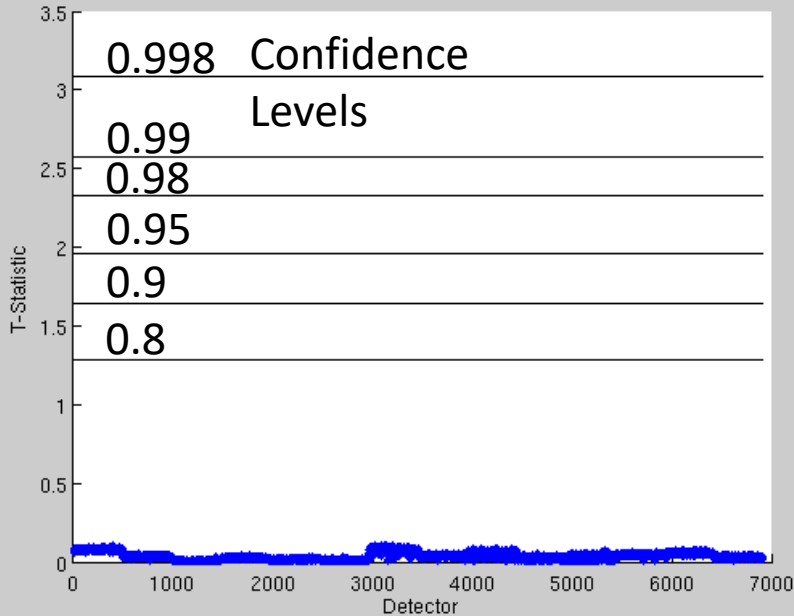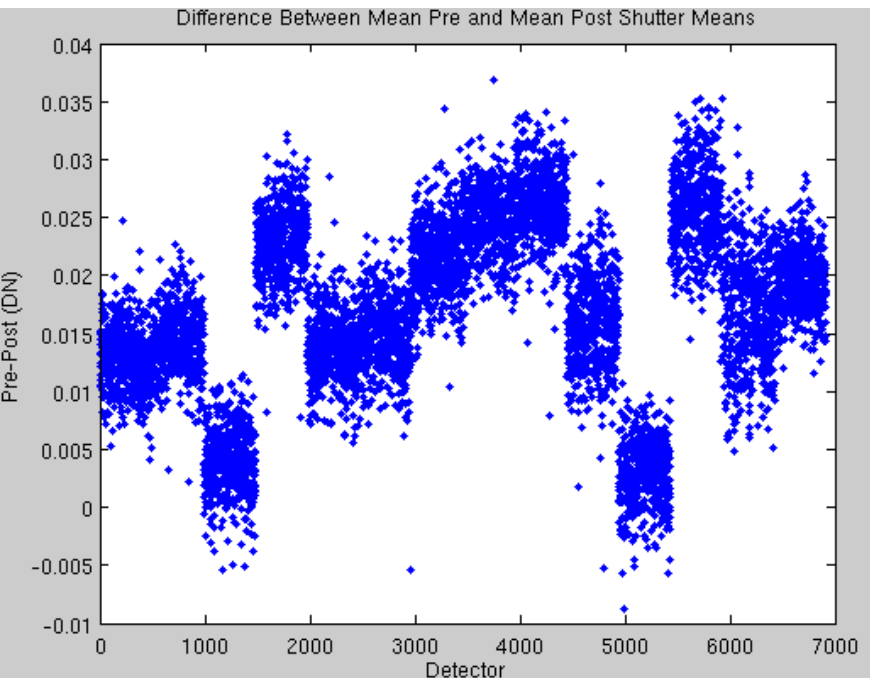# Detector T-Tests for 2 Pre and Pre-Post Bias Estimates (SWIR 2 Band)

Paired T-Test between Current Bias Estimates (Shutters taken 45mins apart) and Bias Estimates from 2 Pre Shutters taken 98mins.
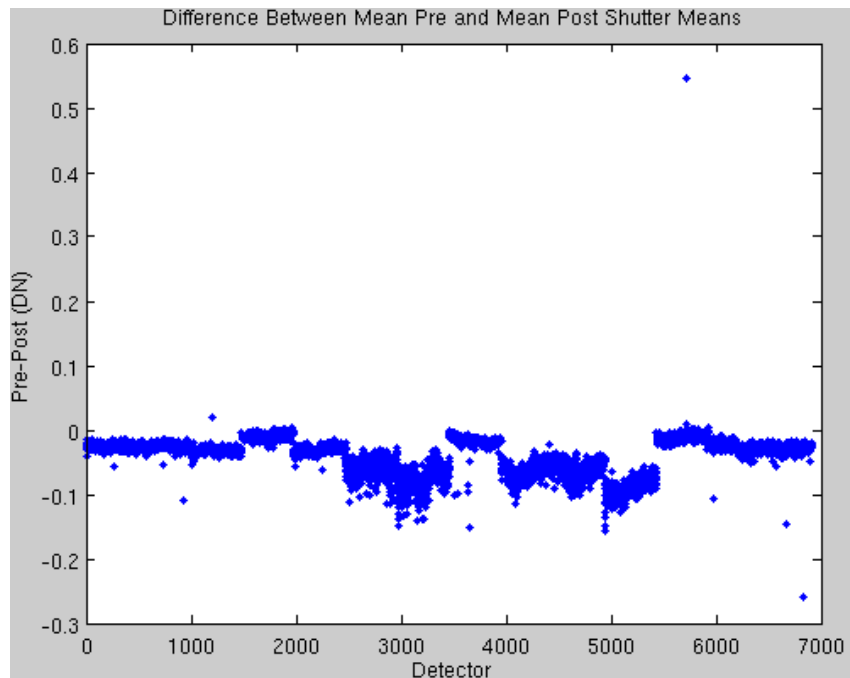
Paired T-Test between Current Bias Estimates (Shutters taken 45mins apart) and Bias Estimates from Pre/Post Shutters taken 140mins.
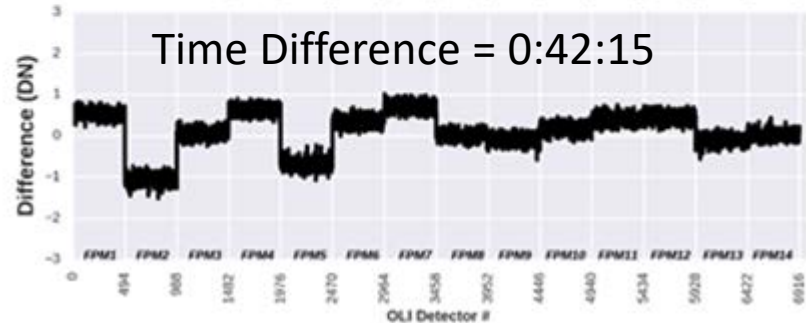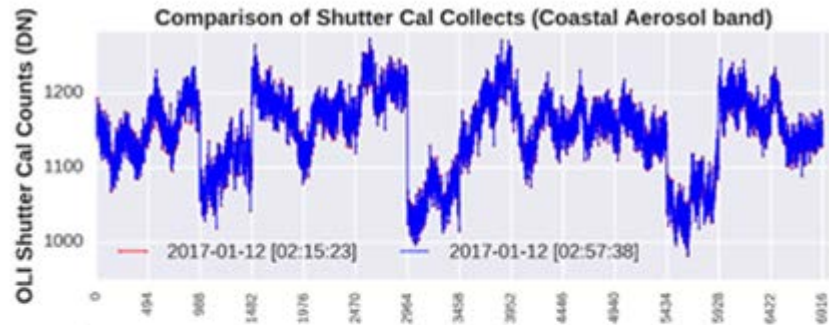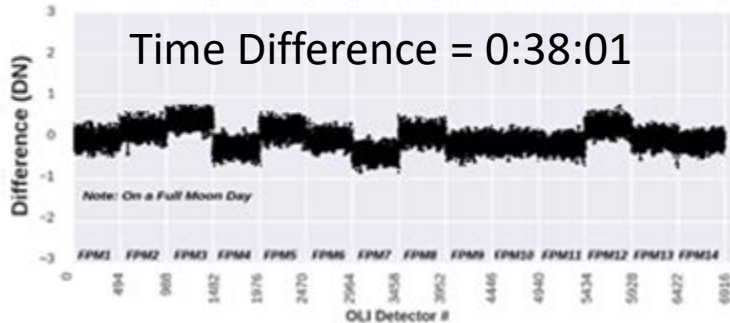
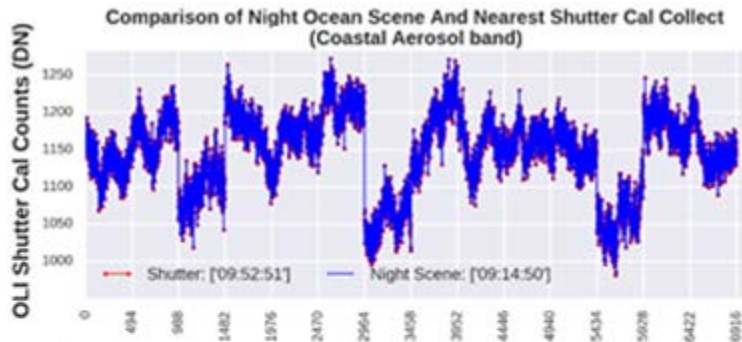# Mean Pre Collect – Mean Post Collect

CA Band

SWIR 2 Band

Shutter vs Ocean Night Images

Shutter Collect vs Ocean Night Scene (CA Band)

Detector Mean Differences between a <u>Full Moon Cloudy Night</u> Collect and its nearest Shutter Collect.

Detector Mean Differences between Two Shutter Collects.

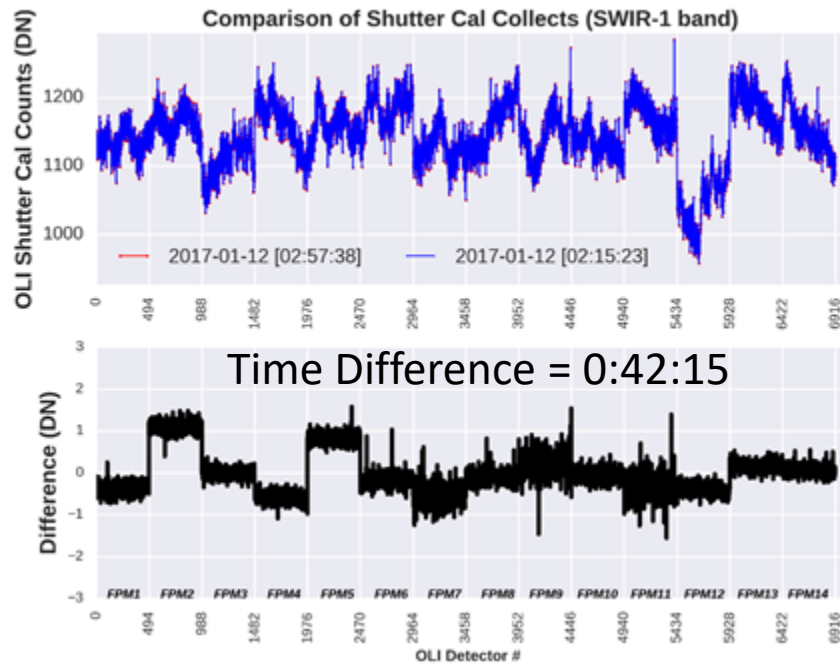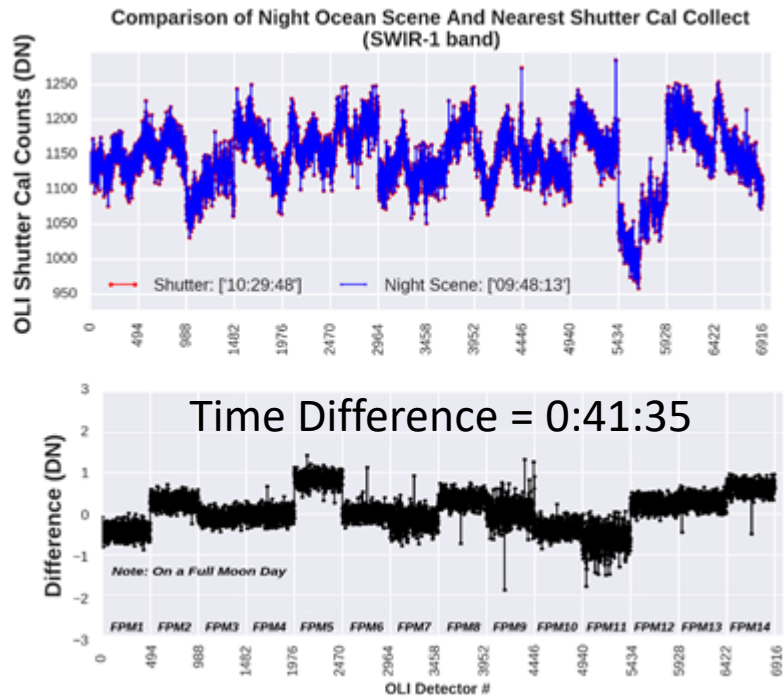# Shutter Collect vs Ocean Night Scene (SWIR 1 Band)

Detector Mean Differences between a Full Moon Cloudy Night Collect and its nearest Shutter Collect.

Detector Mean Differences between Two Shutter Collects.

Conclusions

- **Short term variation of shutter collect detector means is less than 2 DN for most detectors.**

- **The difference between shutter collects spaced 1 hour apart or 24 hours apart is less than 0.6 DN for most detectors.**
  - Detectors which show higher differences are noisy or otherwise anomalous.

- **There is a statistically significant difference between Pre and Post Earth imaging shutter collects.**
  - However this difference is less than 0.2 DNs.

- **The difference between shutter collects and night ocean scenes is similar to the difference between two shutter collects.**