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NGAS Support to ATMS SDR CalVal

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May 13, 2014

Outline

- NGAS activities in support to ATMS SDR Cal/Val
- Lunar intrusion correction update and assessment of residual errors
- Striping error assessment and mitigation
- J-1 ATMS Channel 16 gain dropout waveform reconstruction
- Summary and future plan

NGAS Activities in Supporting ATMS CalVal

- Validation of ATMS SDR and Remap SDR data product quality performance
  - ATMS calibration accuracy and scan dependent biases
  - Remap SDR quality (B-G approach)
  - Geolocation
- DR investigations
- ATMS SDR algorithm code and LUT updates
  - Lunar intrusion detection and correction
  - G-ADA processing and testing
- Striping noise assessment, root cause analysis, and mitigation
- Support to J-1 sensor performance test and characterization
  - NEdT
  - Striping (gain stability)
  - Nonlinearity
  - Calibration accuracy
  - Anomaly identification and characterization

Lunar Intrusion Correction Code and LUT Update

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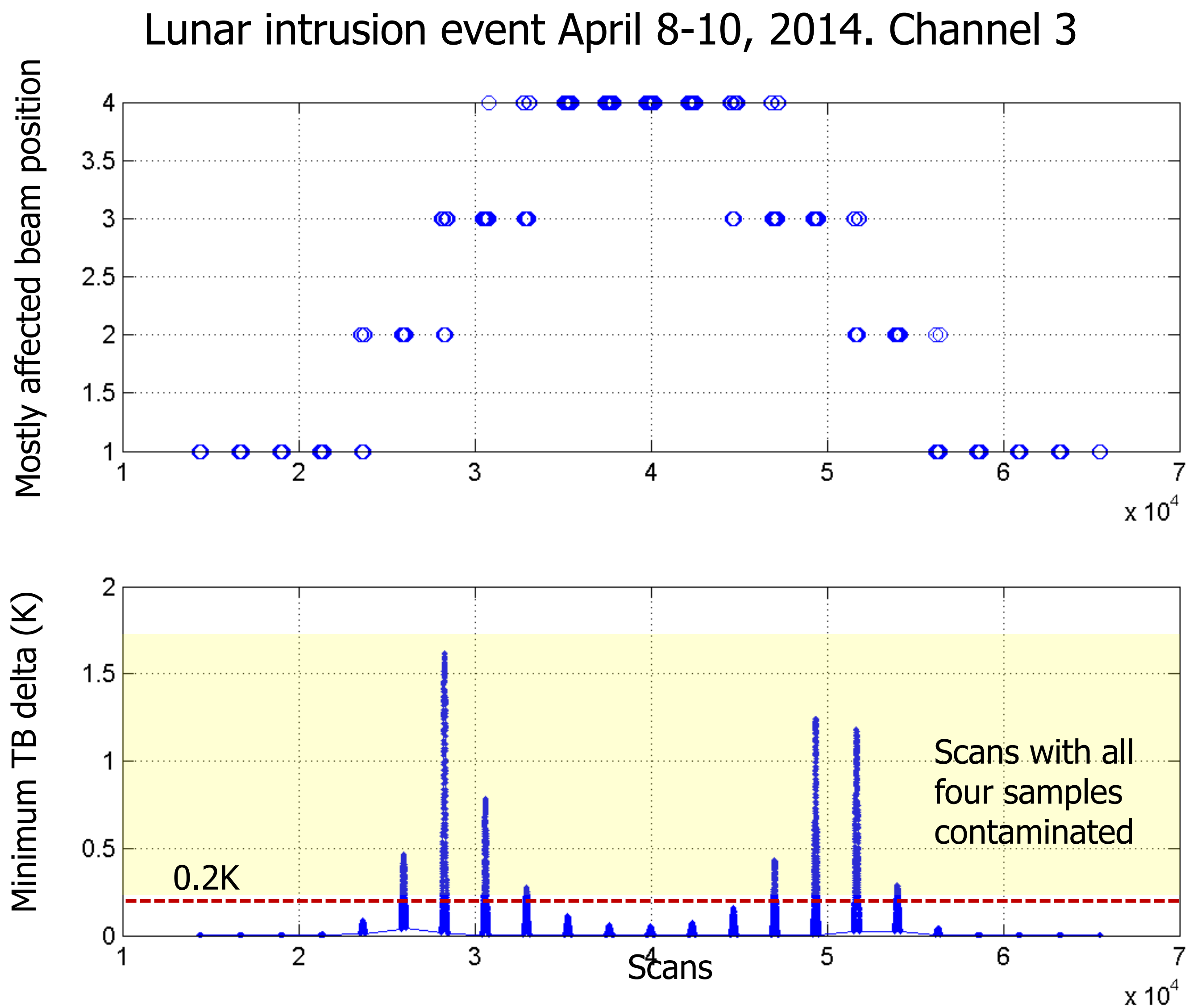
Lunar Intrusion: Cold Counts Contaminated by Moon in Space View



ATMS Lunar Intrusion Issues Before Code Updates

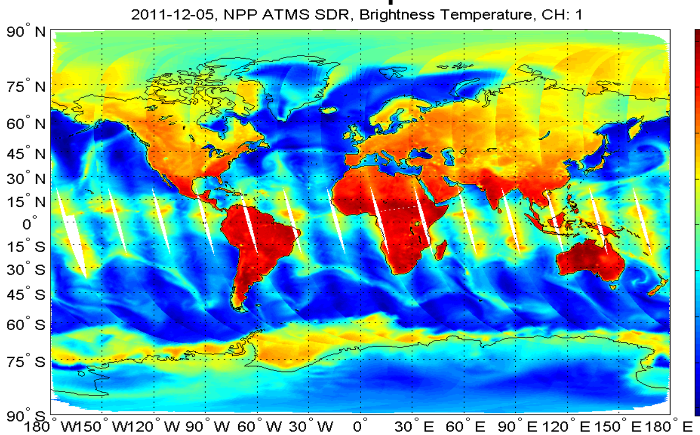
- NGAS found a coding error in ATMS operational algorithm software that caused the algorithm fail to correct for lunar intrusion, resulting up to ~1K errors in the affected ATMS SDR data products
- NGAS found the antenna beam size values in the PCT file are incorrect, causing lunar intrusion quality flags being triggered more extensive than needed to be
- ATMS SDR data gap could be produced if more than one space view samples are affected and the total number of “good” space view samples are less than 3
- Some other minor issues such as errors in NEdT calculation during lunar intrusion

Updated ATMS SDR Algorithm to Improve Lunar Intrusion Detection and Correction

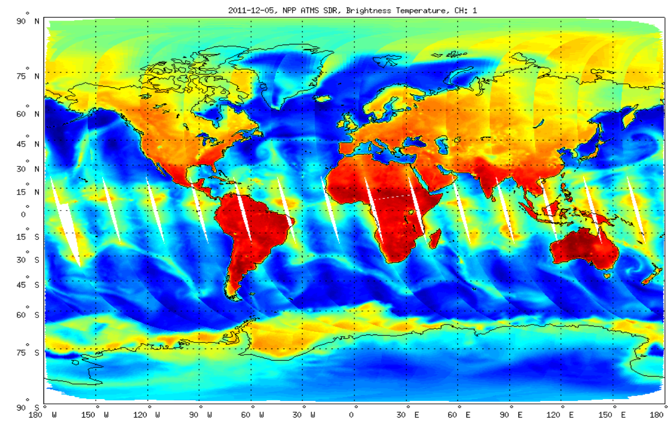
- Fixed the software coding errors so that the lunar intrusion corrected space view counts are used to produce calibrated brightness temperatures
- Modified the algorithm to replace LI-contaminated space view samples with the uncontaminated good counts to avoid data gaps during lunar intrusion
  - If all four space views are affected by LI, good space view counts from the previous most recent scan are used
- Updated PCT file to use correct beam size values
- Code Update was implemented in MX8.3
  - Updated PCT implemented at a later time

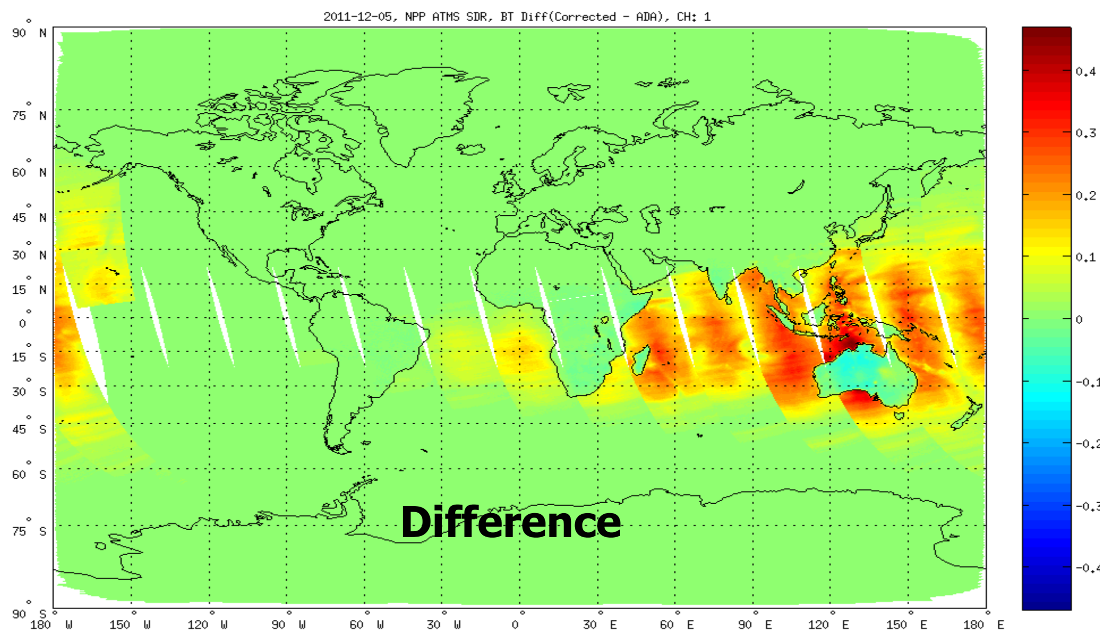
Impact on ATMS SDR Data Product (1)

Before Update



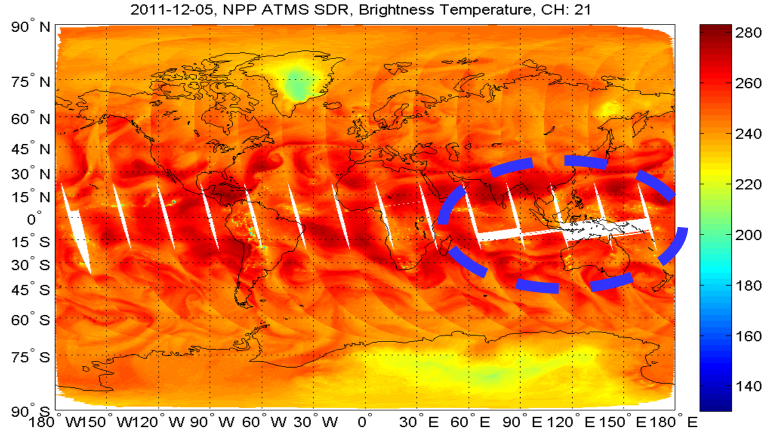
After Update



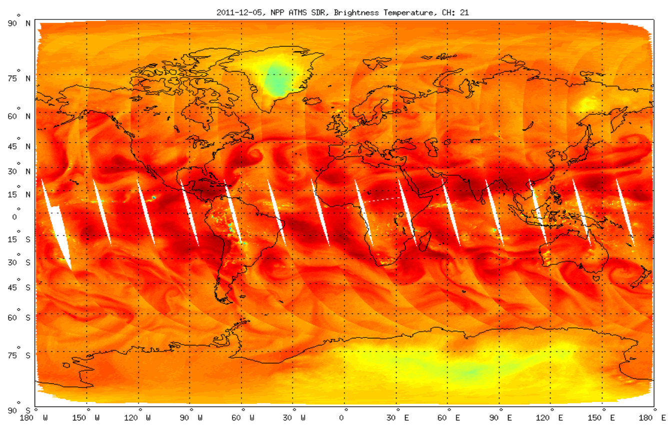


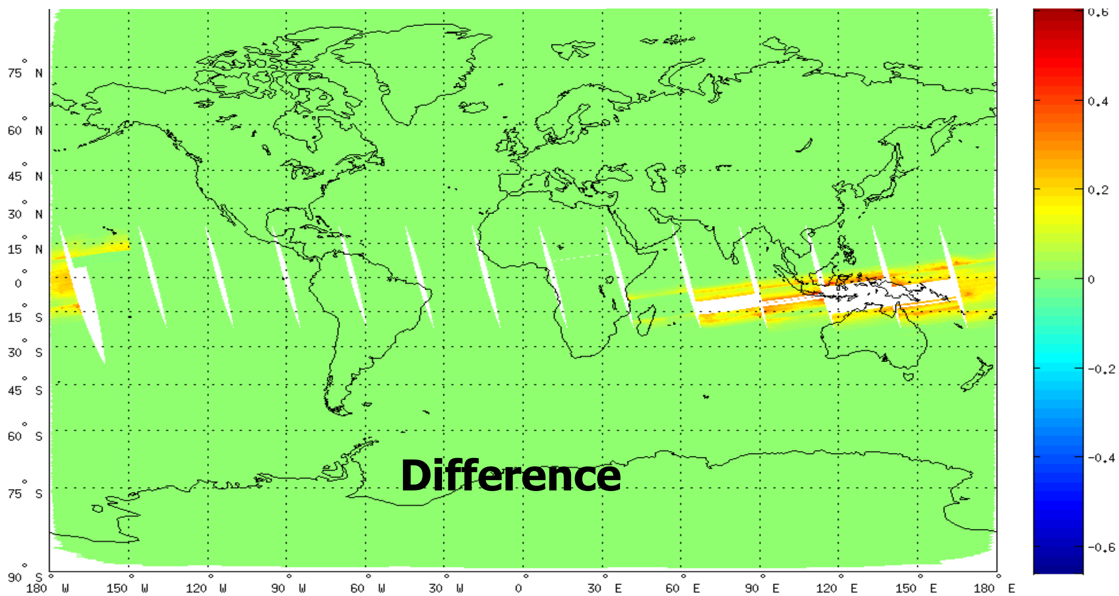
Impact on ATMS SDR Data Product (2)

Before Update



After Update



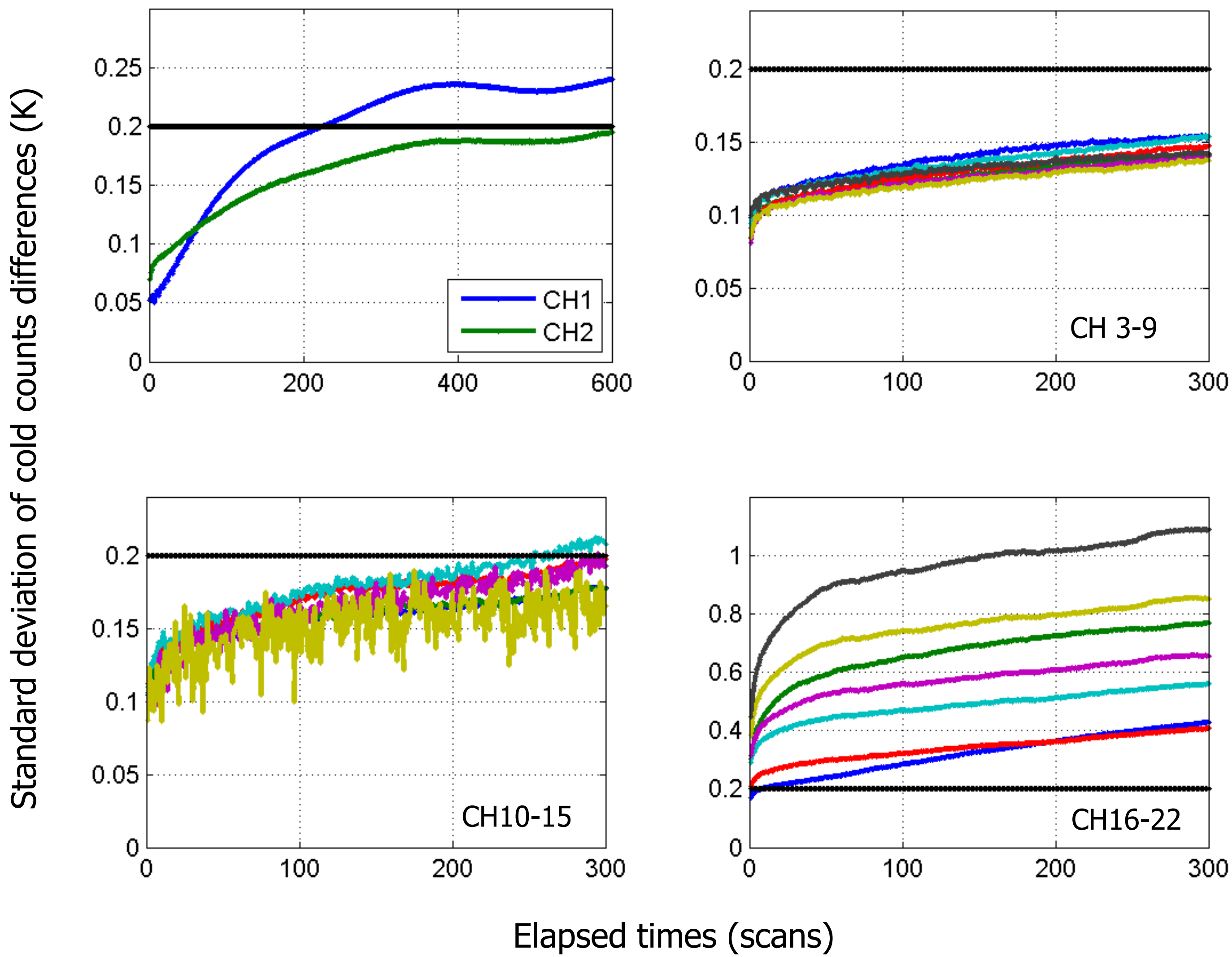


Assessment of Residual LI Correction Errors

- Residual LI correction errors can arise due to:
  - Uncorrected LI intrusion
    - LI affected cold counts not corrected if predicted TB increase < threshold of 0.2K (tunable)
  - Errors in the moon model
    - Simplified model for predicting space view temperature increases due to lunar intrusion
    - Moon position error (e.g., IDPS recently discovered code error)
  - Errors in the corrected cold counts
    - “Natural” changes in cold counts from last known uncontaminated sample to the current scan when all four samples are affected (duo to gain instability, orbital phase variation, etc.)
    - Reduced number of samples per scan (noisier calibration data)

On-orbit Cold Counts Variability

Estimated cold counts variability from autocorrelation analysis

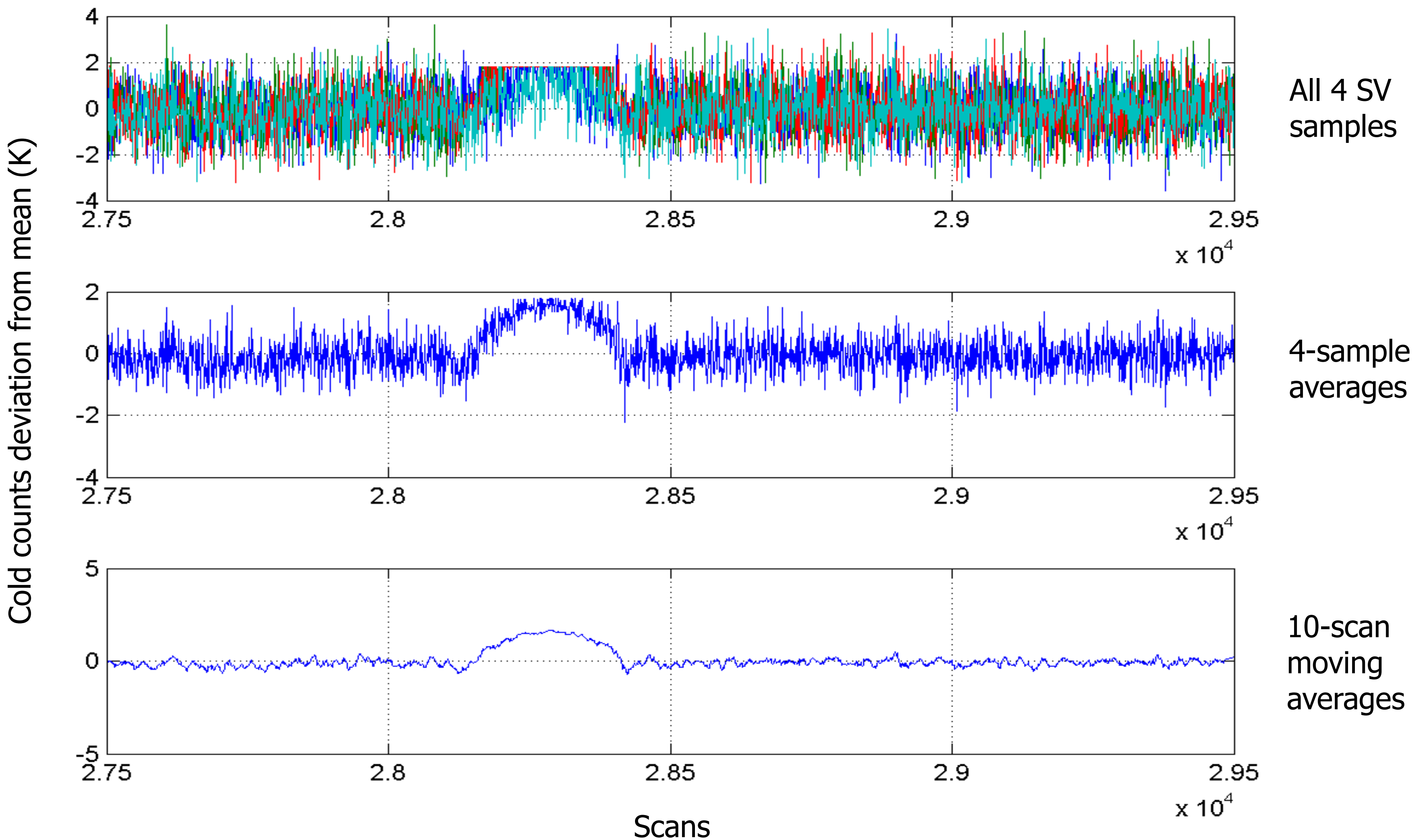


Estimated Residual LI Correction Errors due to Natural Cold Counts Variability

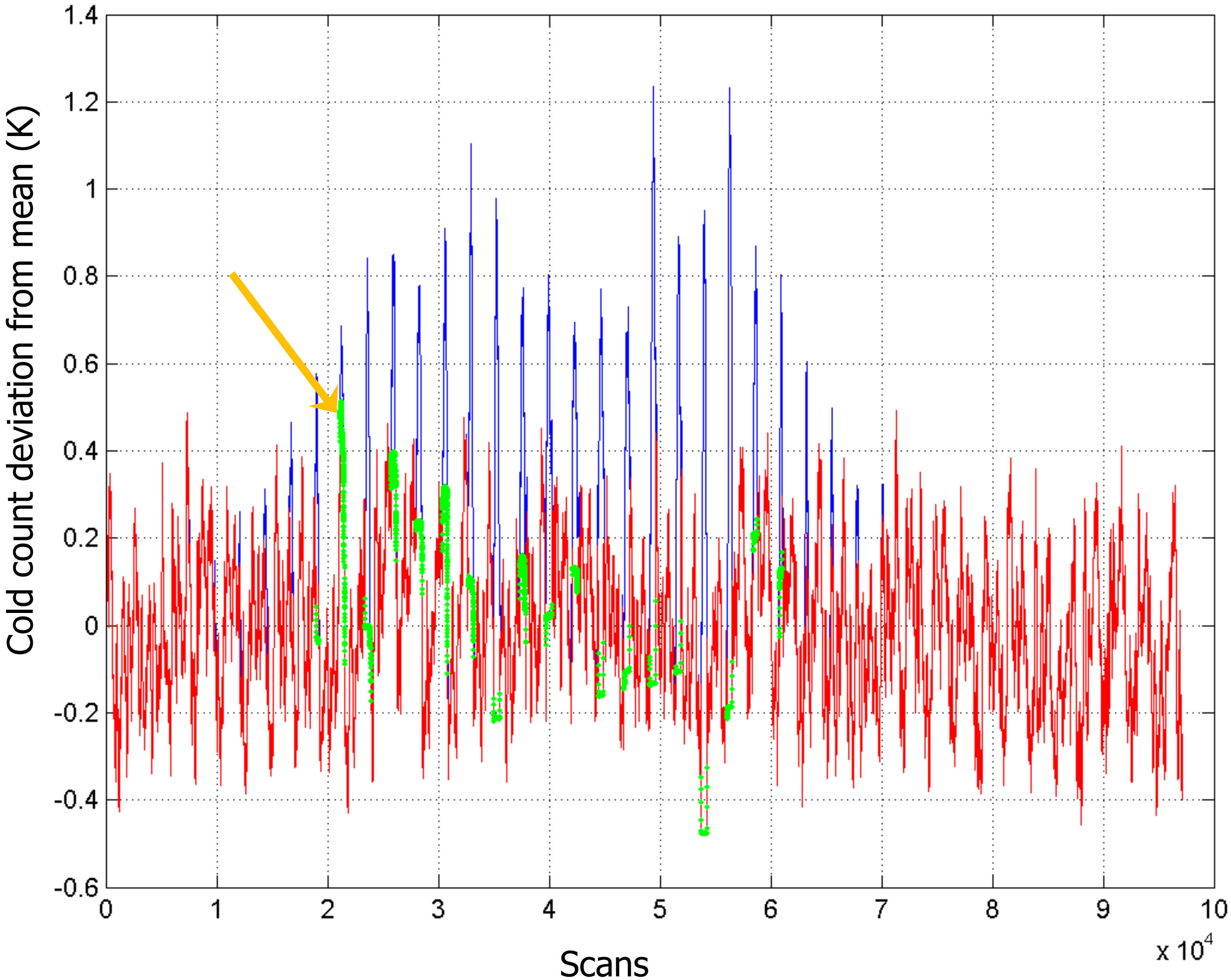
- Residual LI correction Errors will result only when all four space view samples are contaminated
- Nominal number of scans when all four space view samples are contaminated (dependent of FOV size)
  - 500 scans for CH1-2
  - 200 scans for V and W bands CH3-16
  - Not yet encountered for G band channels
- Estimated cold counts error from using history data
  - CH1-2: ~0.2K
  - CH3-15: ~0.15K
  - Ch16: ~0.35K
  - CH17-22: N/A
- When history data is used, the cold calibration data can be noisier due to fewer samples being averaged, causing additional (sometimes dominant) calibration errors (e.g., channel 15)

Residual LI Correction Errors due to Cold Counts Noises

Channel 15 cold counts variability and effect of averaging



Channel 1 Residual Error Estimates

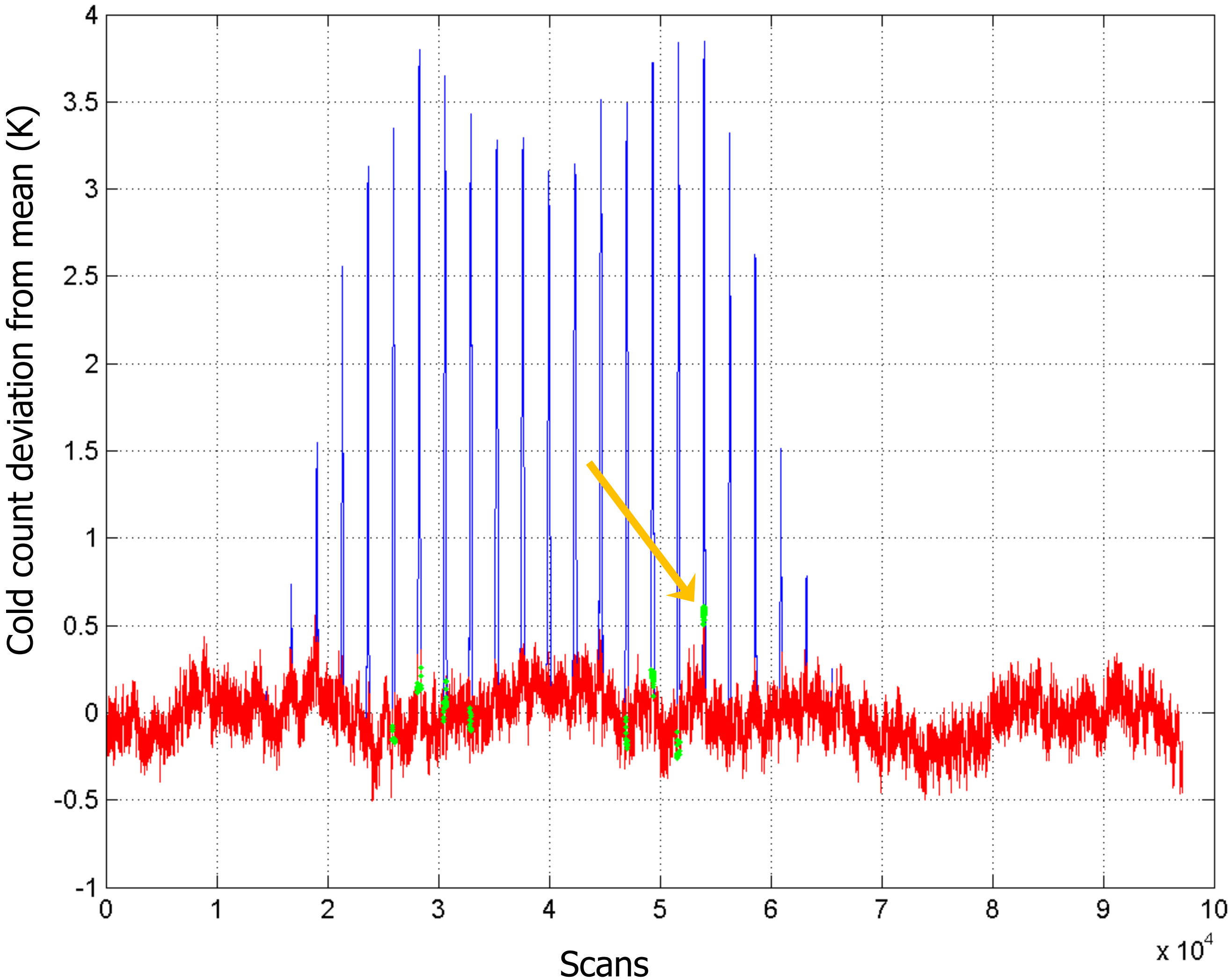


Blue: No LI correction
Red: After LI correction
Green: All four samples contaminated and history data used

Before LI Correction:
Worst cold count error: 1.2K
Median scene temp: 210K
Residual TB errors: 0.3K
Ocean: 180K, 0.45K

After LI Correction:
Worst cold count error: 0.5K
Median scene temp: 210K
Residual TB errors: 0.13K
Ocean: 180K, 0.18K

Channel 10 Residual Error Estimates

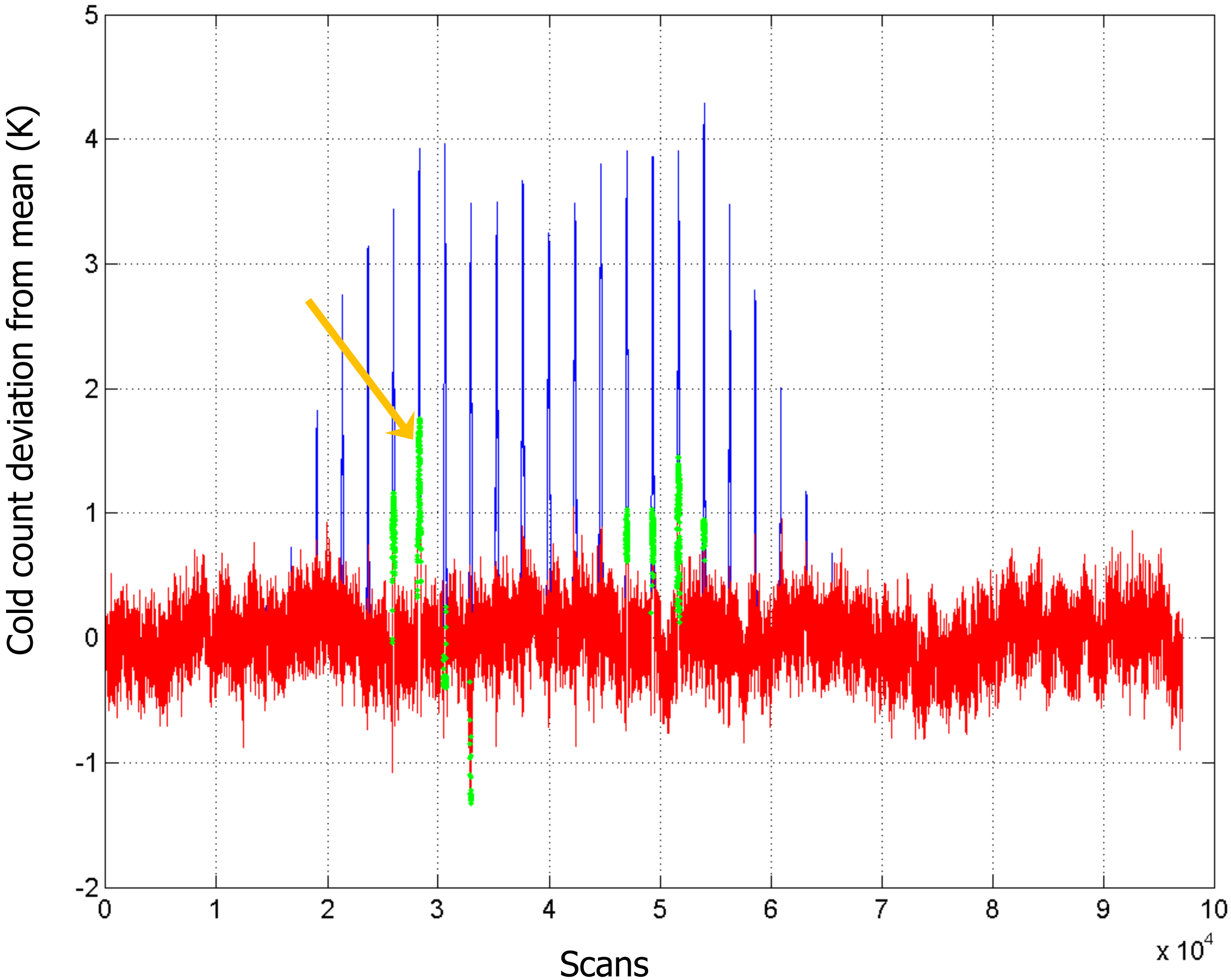


Blue: No LI correction
Red: After LI correction
Green: All four samples contaminated and history data used

Before LI Correction:
Worst cold count error: 3.5K
Median scene temp: 210K
Residual TB errors: 0.9K

After LI Correction:
Worst cold count error: 0.5K
Median scene temp: 210K
Residual TB errors: 0.13K

Channel 15 Residual Error Estimates

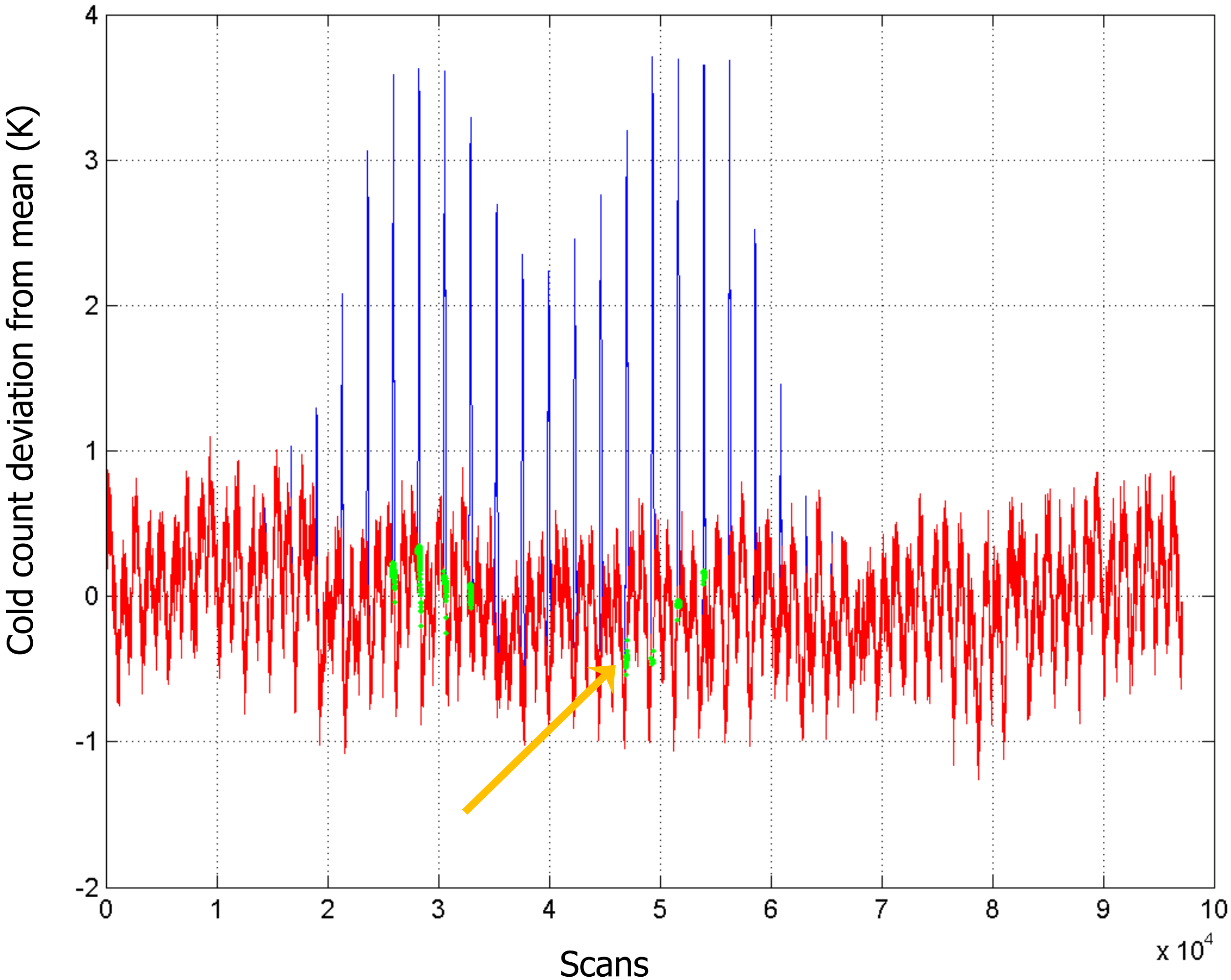


Blue: No LI correction
Red: After LI correction
Green: All four samples contaminated and history data used

Before LI Correction:
Worst cold count error: 4K
Median scene temp: 250K
Residual TB errors: 0.43K

After LI Correction:
Worst cold count error: 1.5K
Median scene temp: 250K
Residual TB errors: 0.17K

Channel 16 Residual Error Estimates

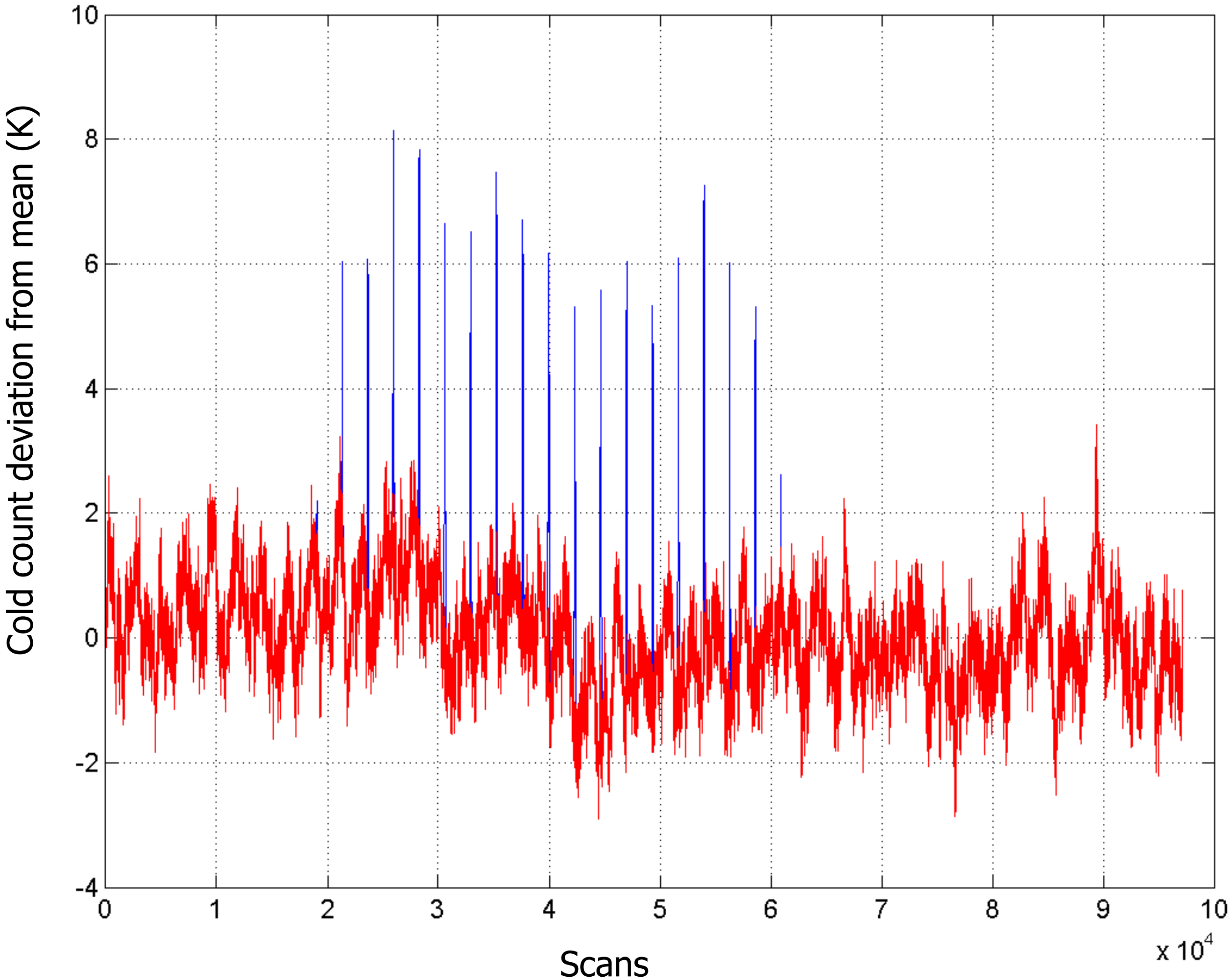


Blue: No LI correction
Red: After LI correction
Green: All four samples contaminated and history data used

Before LI Correction:
Worst cold count error: 3.5K
Median scene temp: 230K
Residual TB errors: 0.63K

After LI Correction:
Worst cold count error: 0.5K
Median scene temp: 230K
Residual TB errors: 0.1K

Channel 17 Residual Error Estimates



Blue: No LI correction
Red: After LI correction
Green: All four samples contaminated and history data used

Before LI Correction:
Worst cold count error: 8K
Median scene temp: 250K
Residual TB errors: 0.85K

After LI Correction:
Worst cold count error: 0.5K
Median scene temp: 250K
Residual TB errors: 0.05K

Assessment of Residual LI Correction Errors

- With MX8.3 code update and the PCT update, brightness temperature errors due to lunar intrusion have been reduced by a factor of 5-10 for most channels, except for channels 1, 2, and 15 which see reductions between 2-3 times
- Worst case residual errors are estimated to be ~0.2K for K/Ka/V band channels, ~0.1 K for the W band, and ~0.05K for the G band channels
  - Based on the analysis of April 8-10, 2014 lunar intrusion event
- Standard deviation of lunar intrusion correction residual errors should be much lower, estimated to be <0.1K for all channels

Striping Noise Assessment and Mitigation

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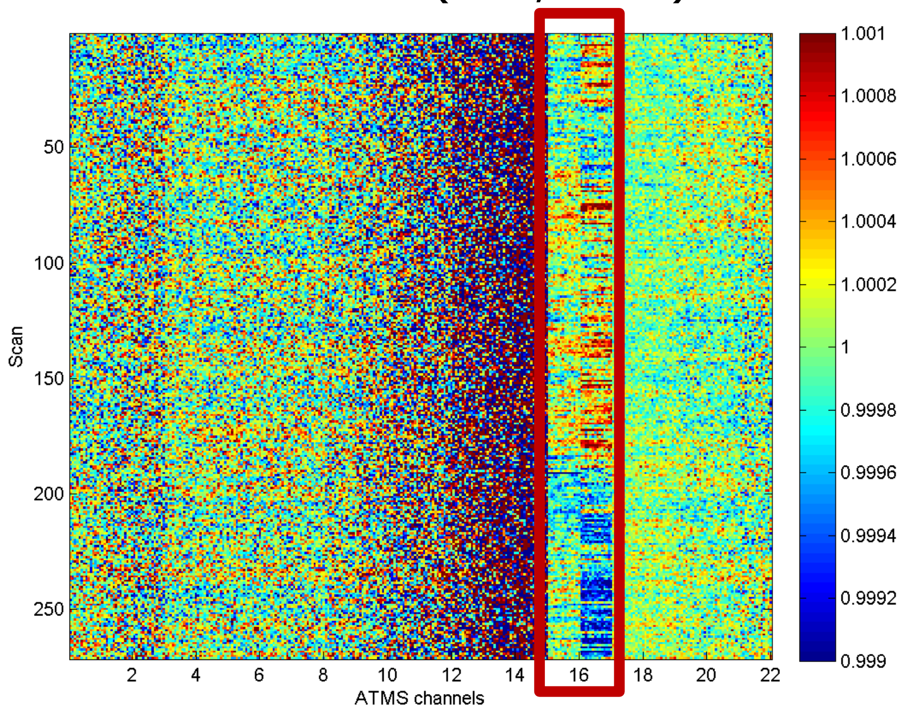
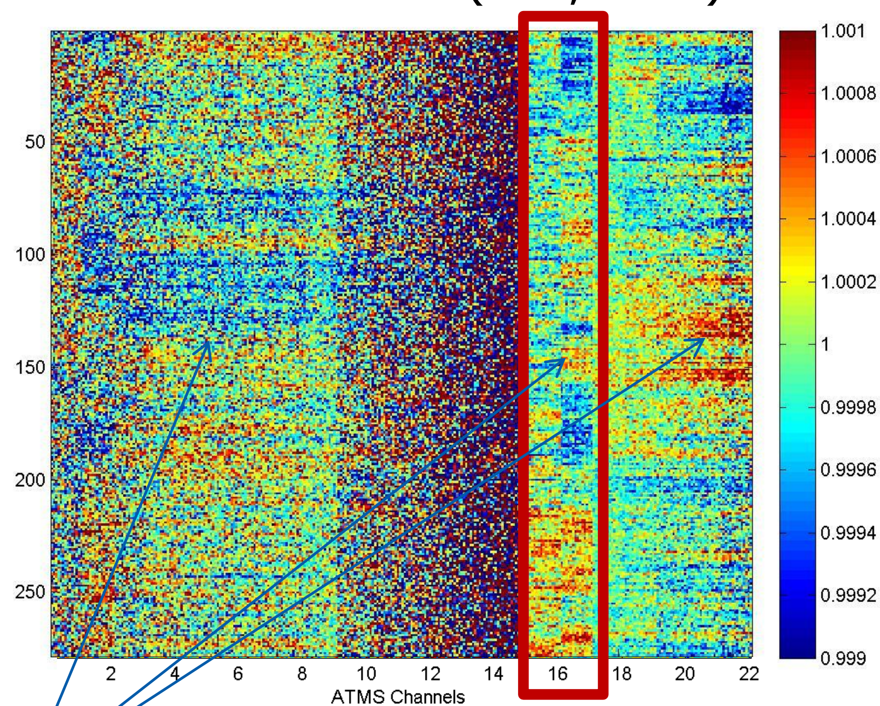
Striping in S-NPP and J-1 Sensor Raw Data

Composite Image of normalized counts

J-1 TVAC Data (RC2, 230K)



S-NPP TVAC Data (RC1, 230K)

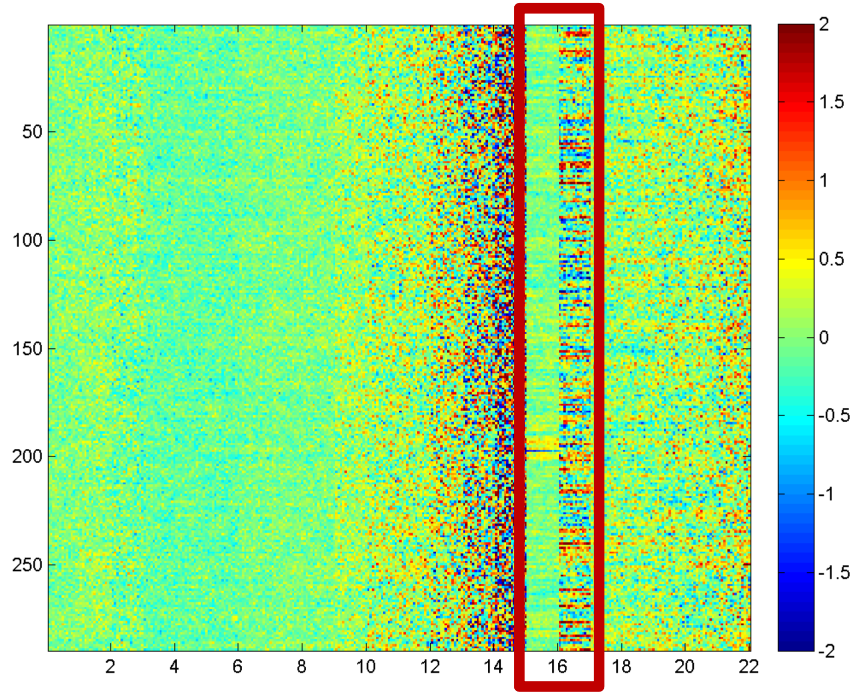


Striping on SNPP image, significantly reduced on J-1 image, except for channels 16 and 17

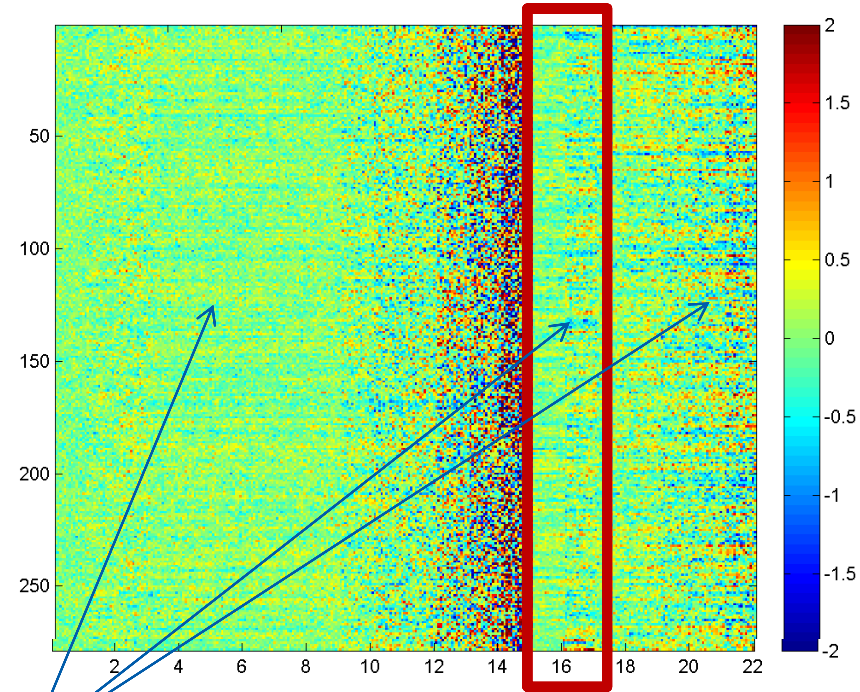
Residual Striping in S-NPP and J-1 Calibrated Brightness Temperatures

Composite Image of calibrated brightness temperatures

J-1 TVAC Data (RC2, 230K)



SNPP TVAC Data (RC1, 230K)



Striping on SNPP image, significantly reduced on J-1 image, except for channel 17

Striping Index to Quantify Striping Noise

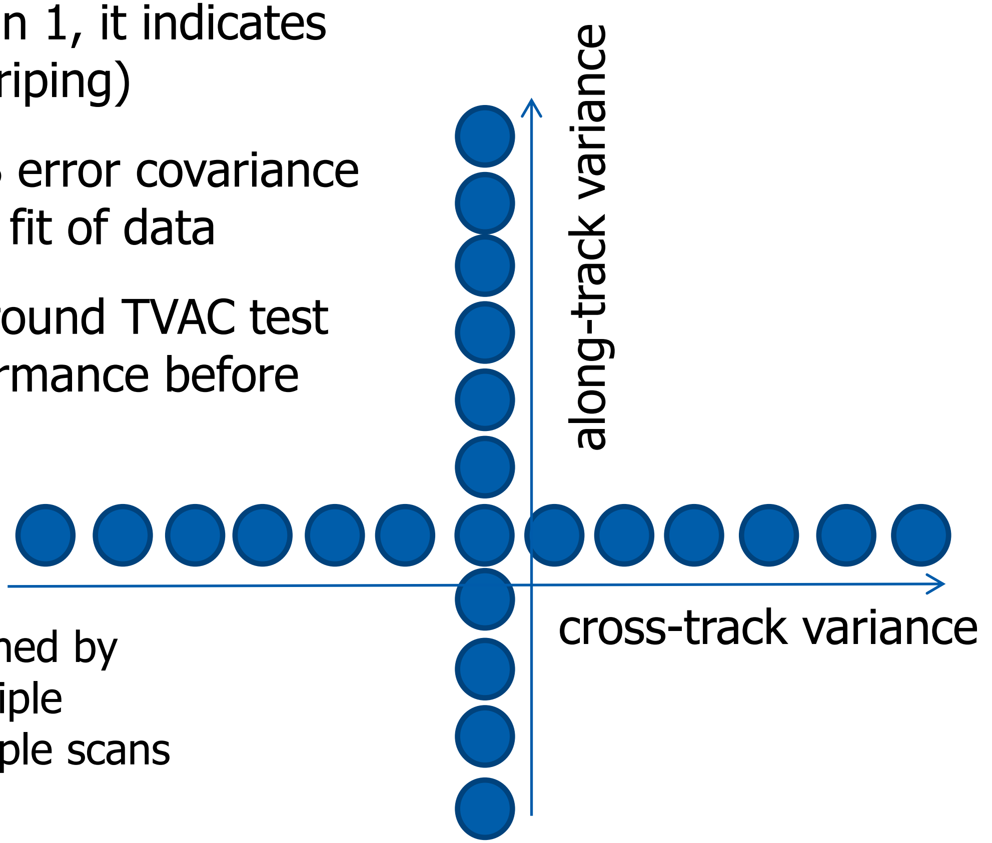
Striping Index (SI) is defined as the ratio of along-track variance to cross-track variance of the observed brightness temperatures

$$SI = V_{AT} / V_{CT}$$

If this index is significantly larger than 1, it indicates additional scan-to-scan variability (striping)

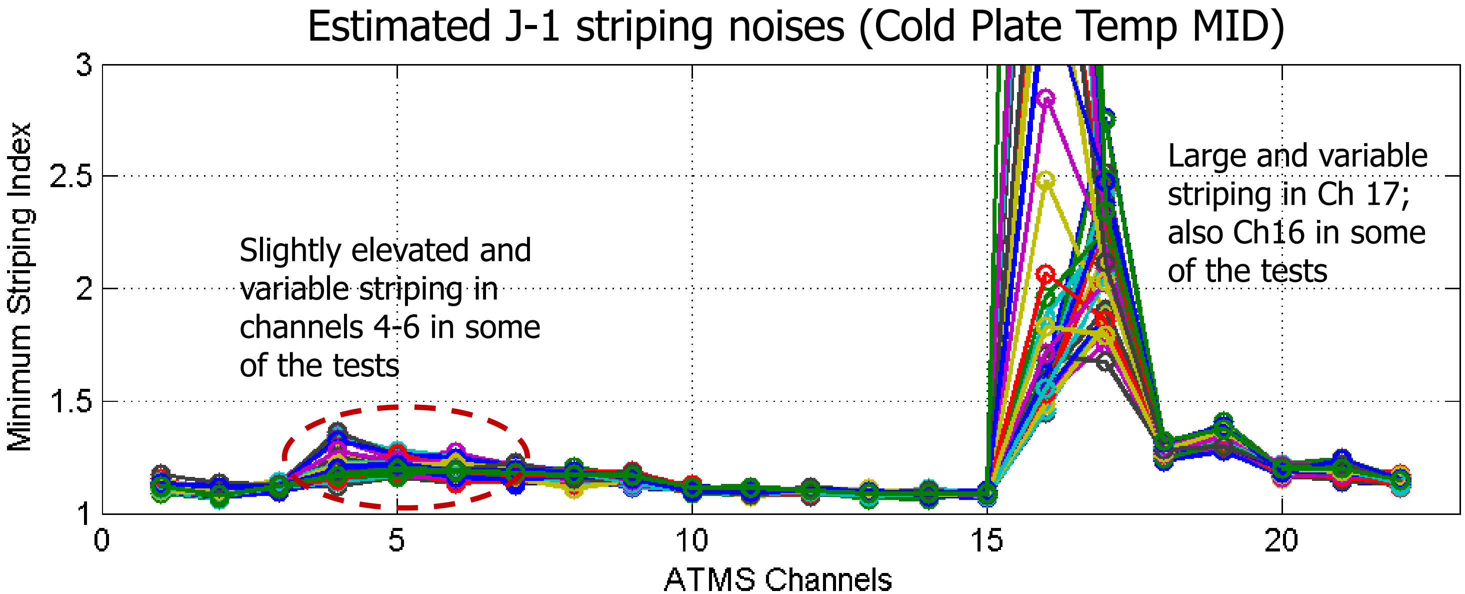
This index can be used to inflate O-B error covariance for NWP assimilation to prevent over fit of data

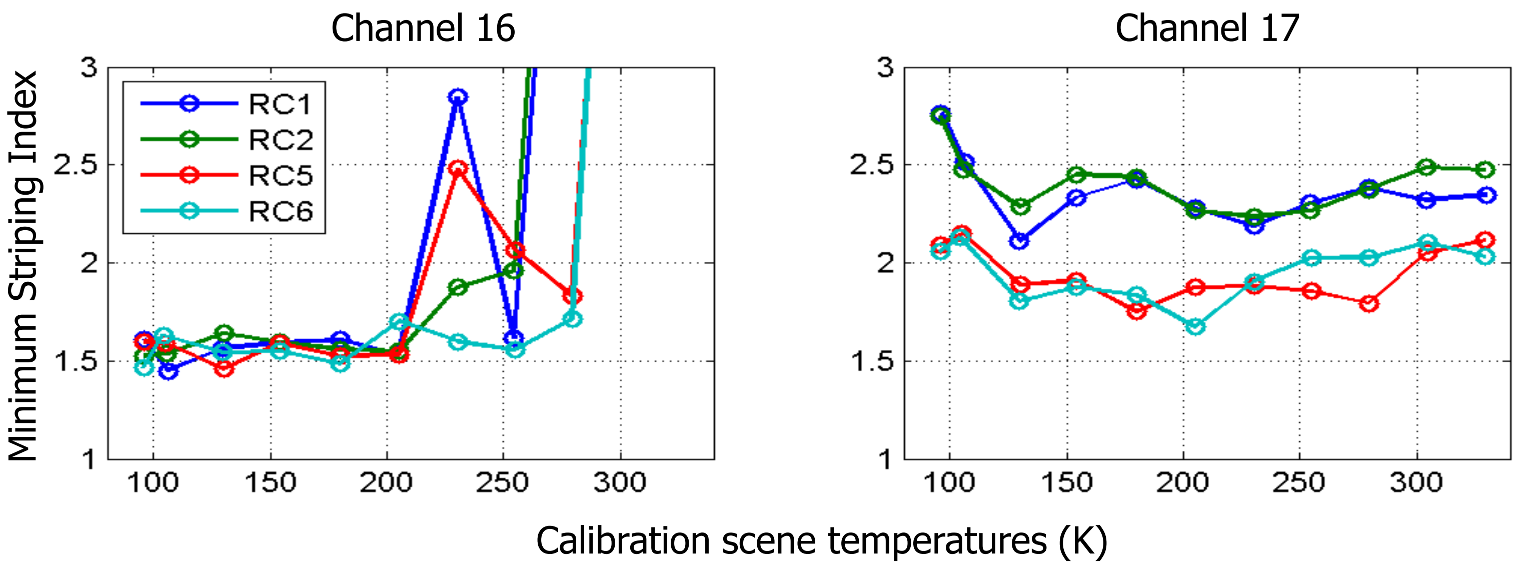
This index can be computed using ground TVAC test data to verify sensor hardware performance before launch



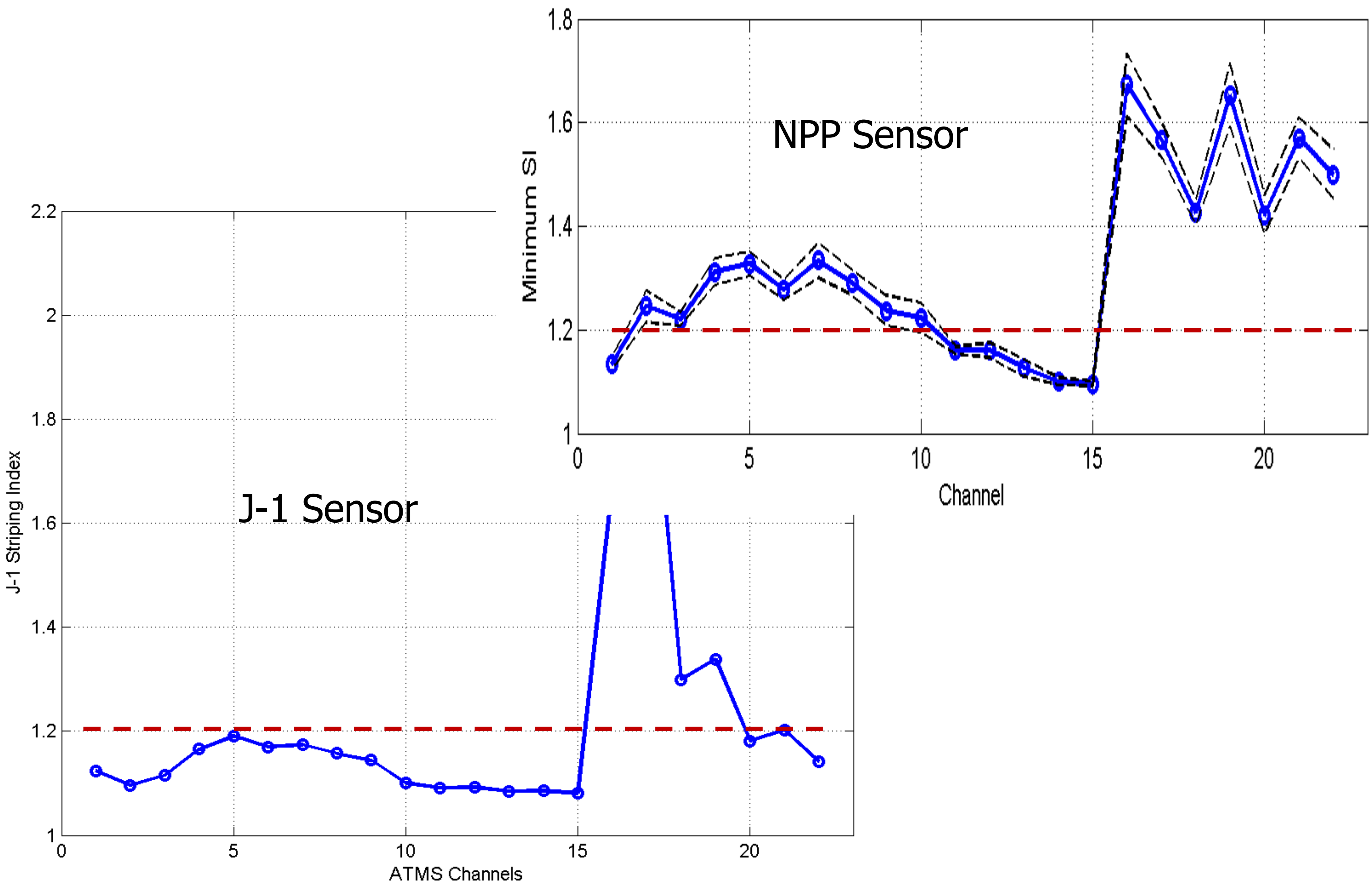
More precise estimate of SI can be obtained by averaging along-track variance over multiple FOVs and cross-track variance over multiple scans

Estimated J-1 Residual Striping Errors

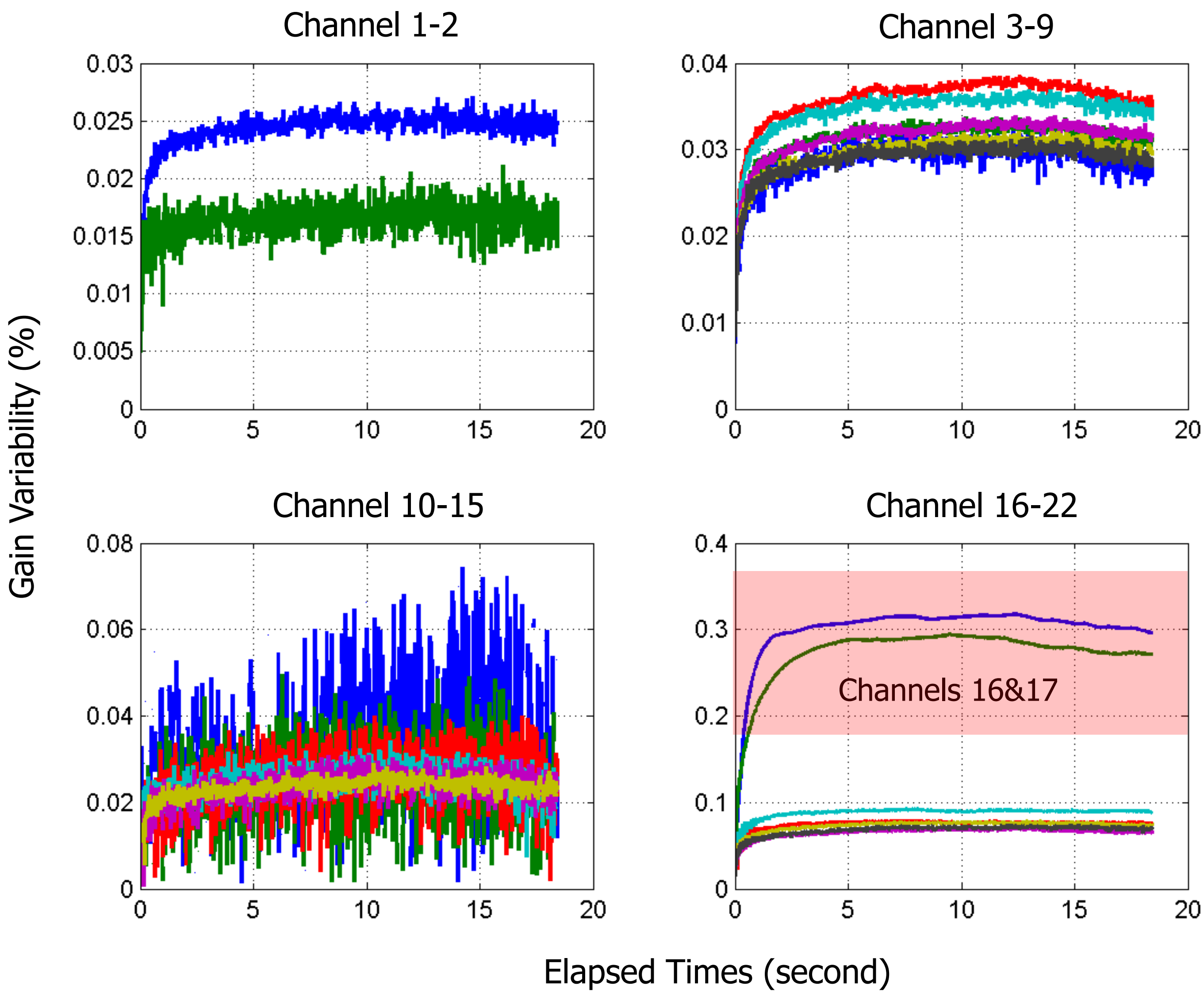




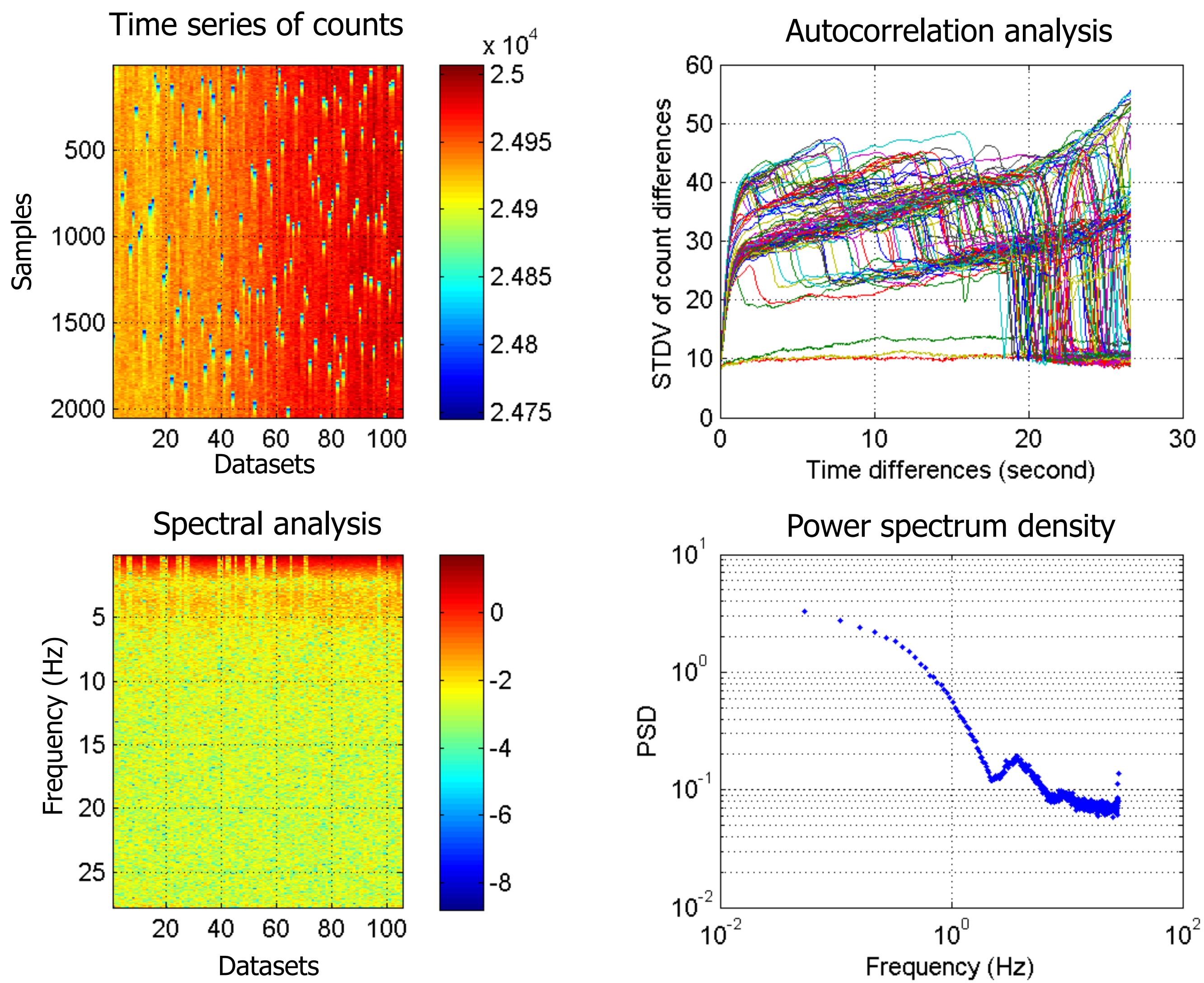
Comparison of J-1 and S-NPP Striping Noises



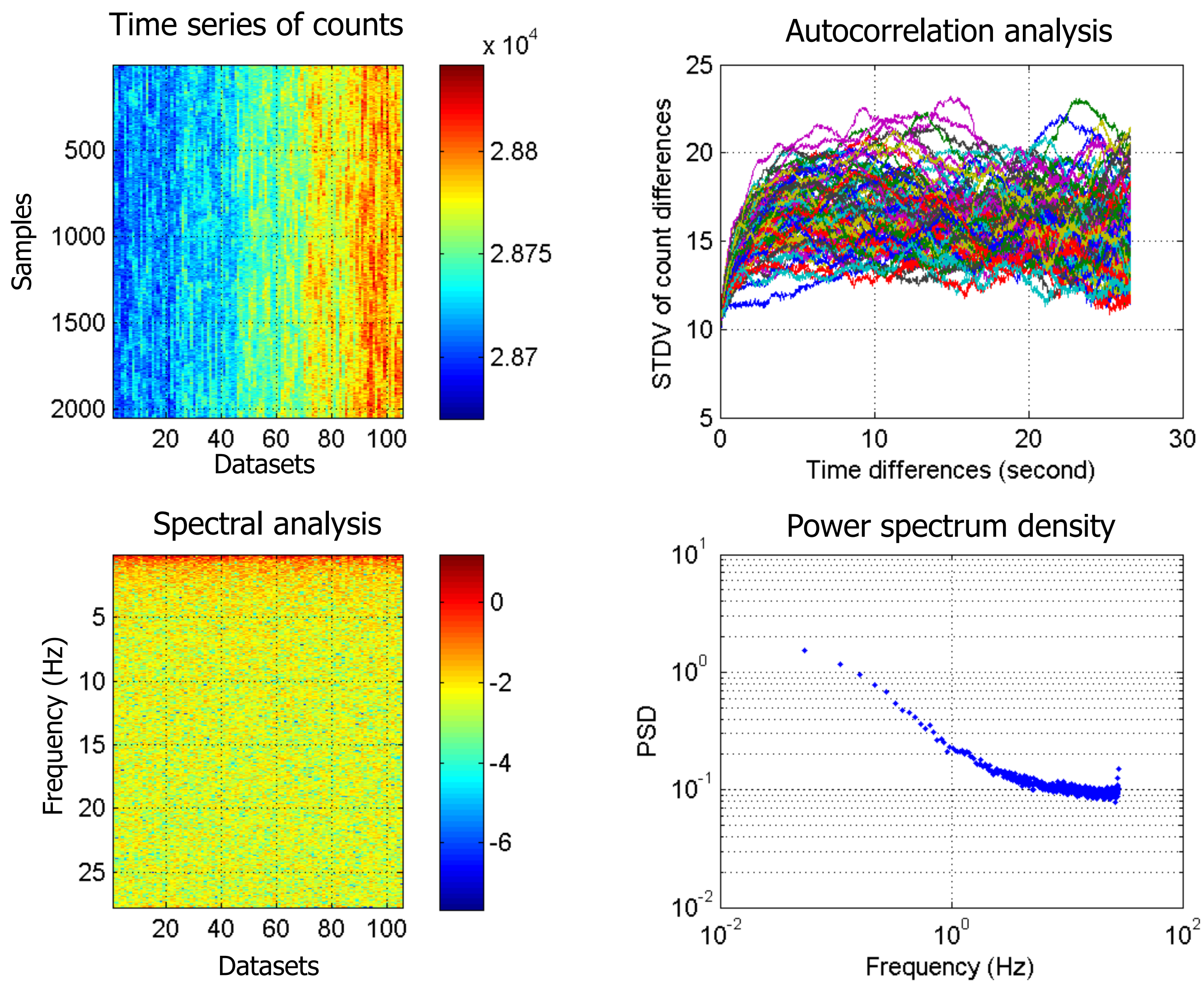
Estimated J-1 Sensor Gain Variability (1-sigma)



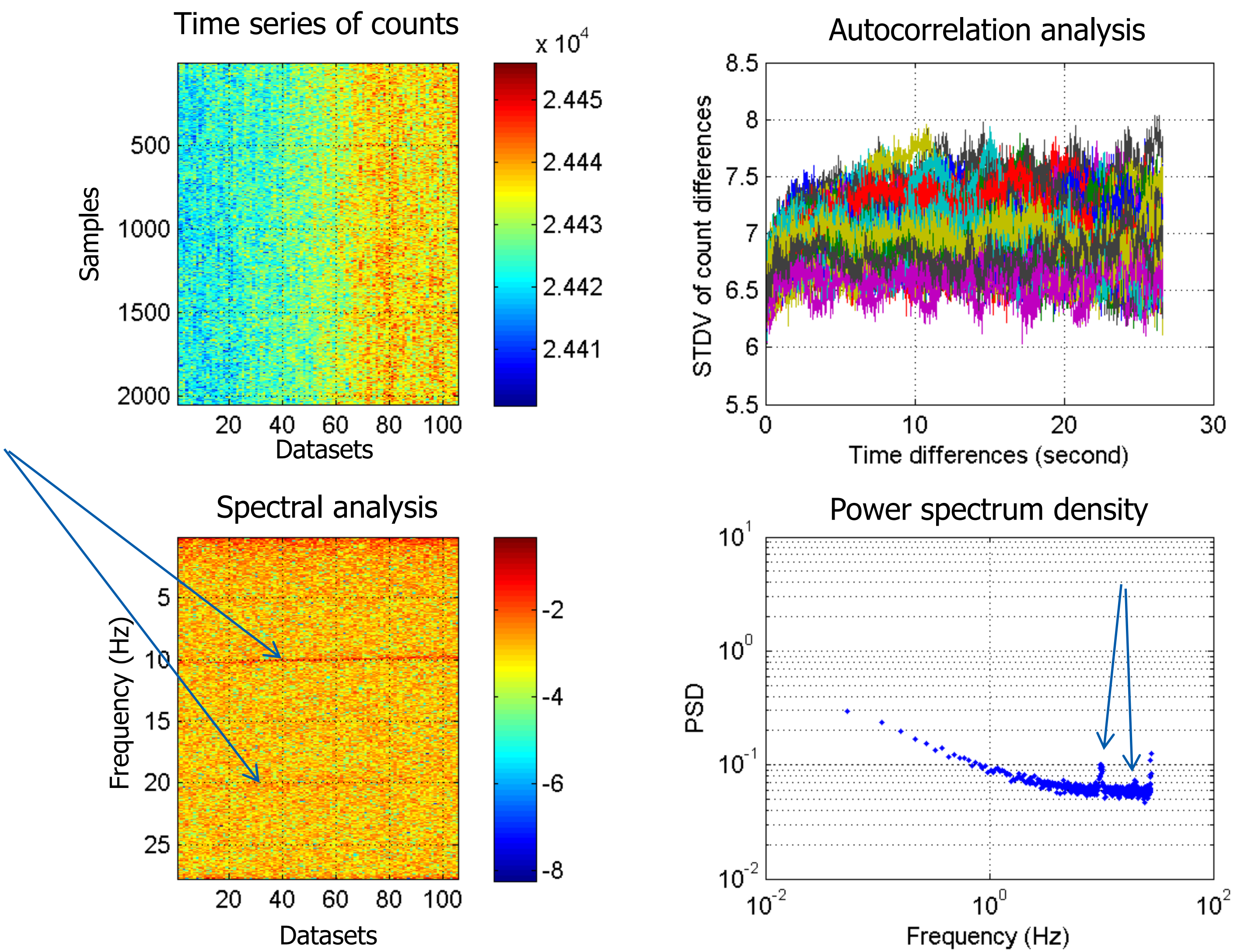
Gain Variability Data Analysis Results: CH 16



Gain Variability Data Analysis Results: CH 17



Gain Variability Data Analysis Results: CH 18



Mitigation of Striping Errors: PCA-EEMD Verification

- Simulated ATMS SDRs by adding random noise and striping noise to evaluate effectiveness of PCA-EEMD method in detecting and quantifying striping noises
  - Random noise added based on the simulated scene temperatures
  - Striping noise added based on scene temperatures and are correlated across scans
  - Magnitudes of random noise and striping noise are derived from previous analyses
- Performed PCA on simulated noisy brightness temperature images (200 scans)
- Extracted the EM's in the first PC scores using the EMD method
  - Special treatment at the edges to minimize ringing
- Assessment:
  - Reconstructed brightness temperature images with the striping-induced EM's removed to visually evaluate the effectiveness
  - Compared the estimated striping errors to the simulated errors to evaluate absolute accuracy

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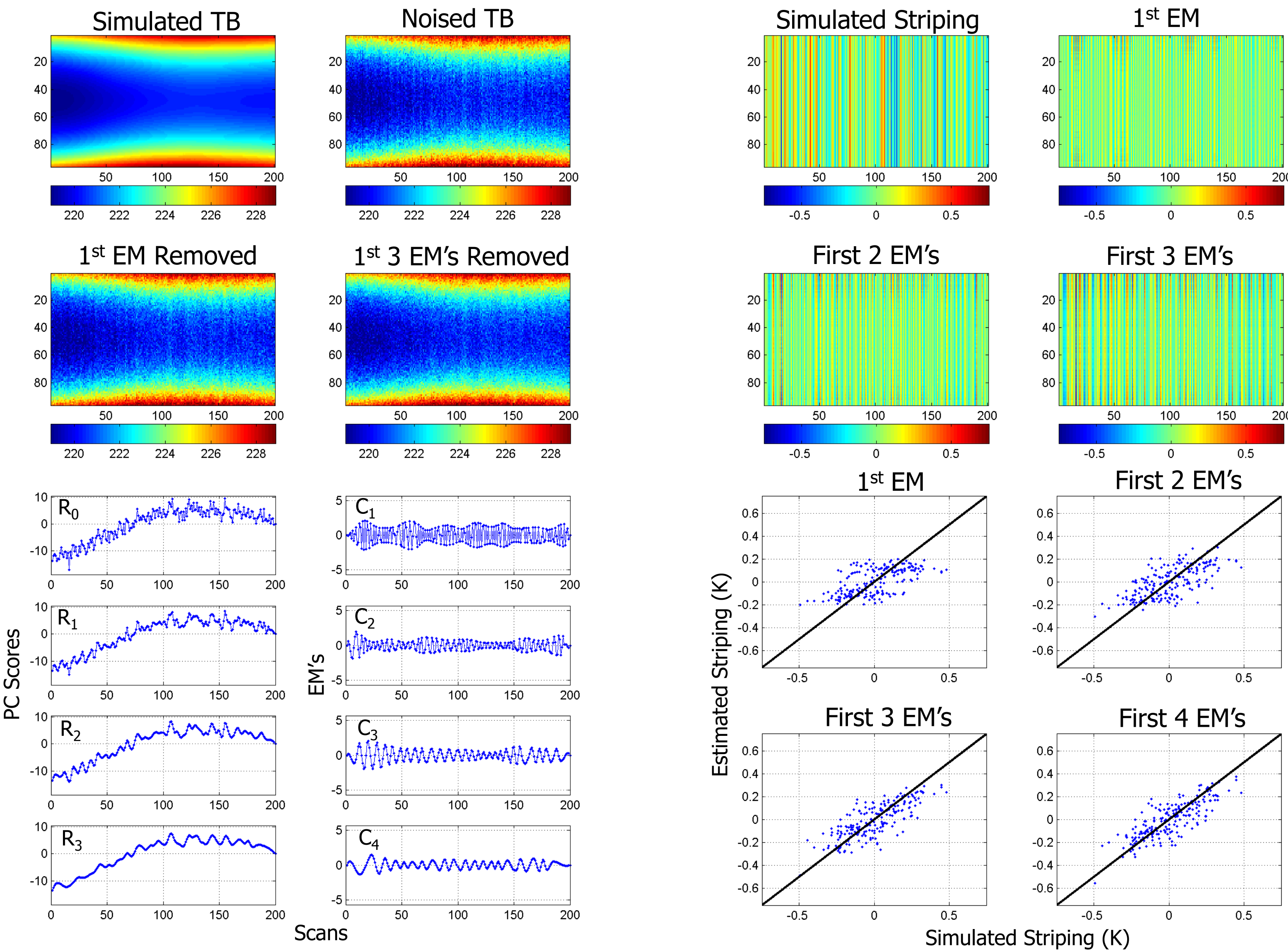
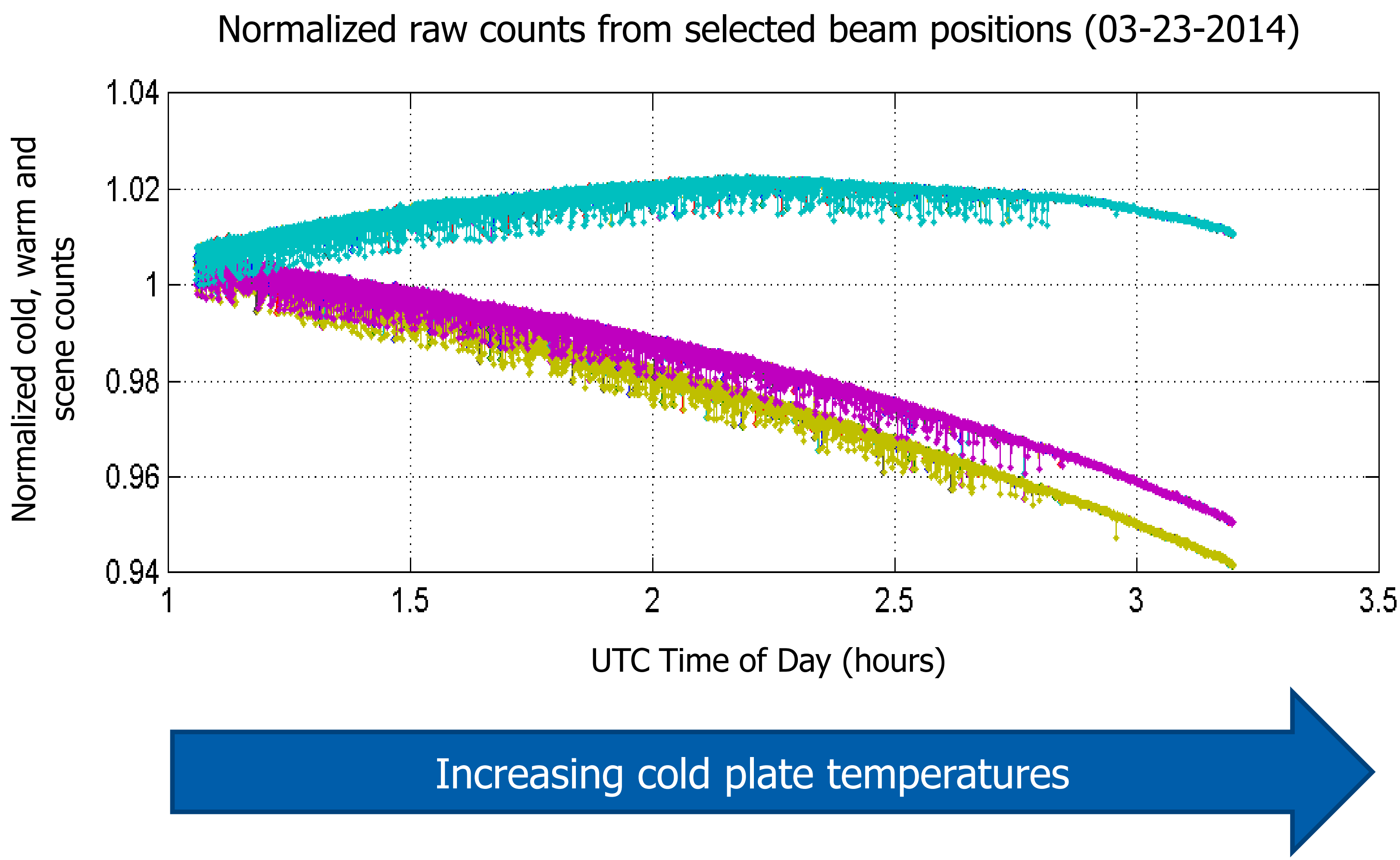
ECMWF Simulated SDR Channel 12

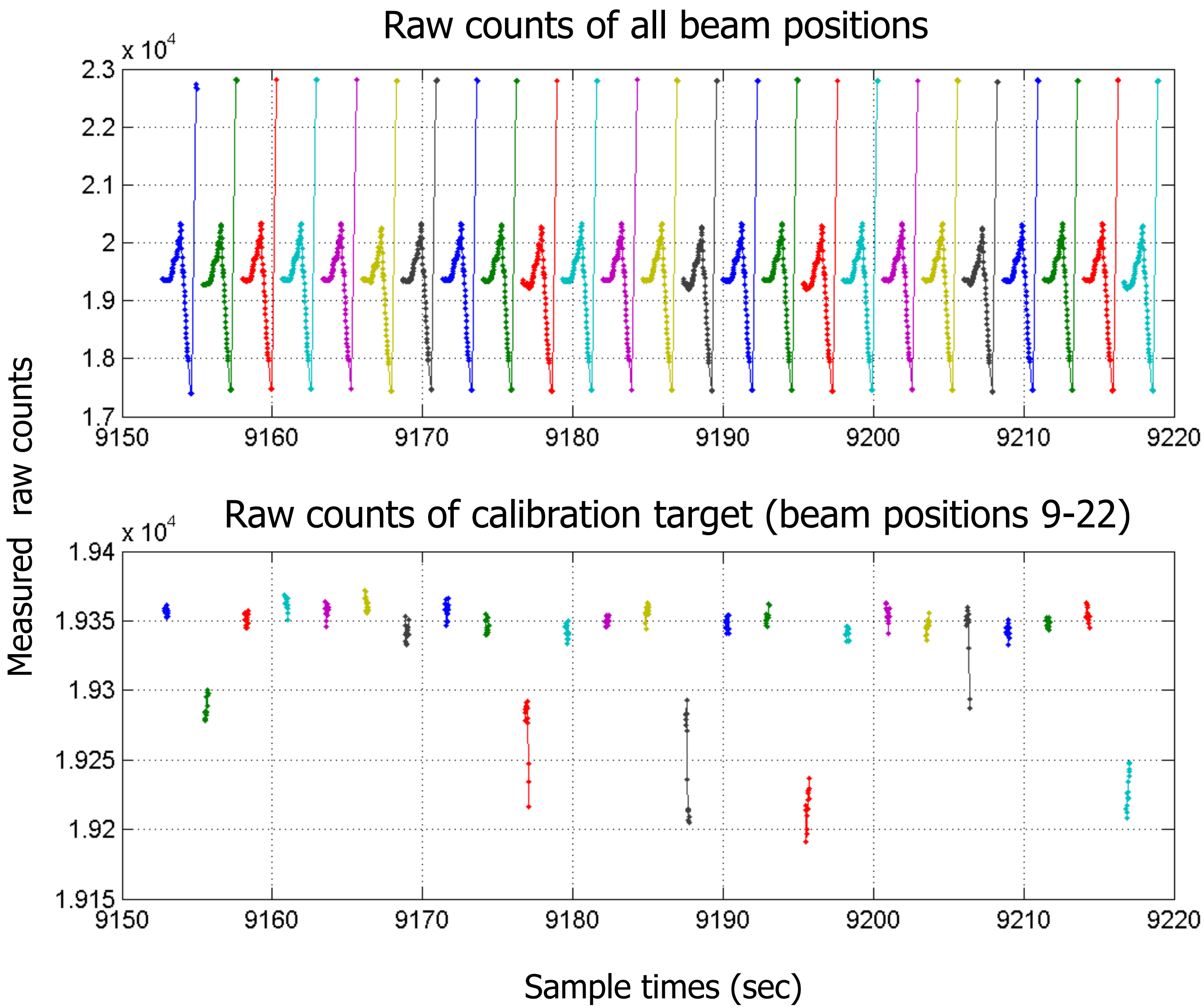


J-1 Channel 16 Gain Dropout Waveform Construction

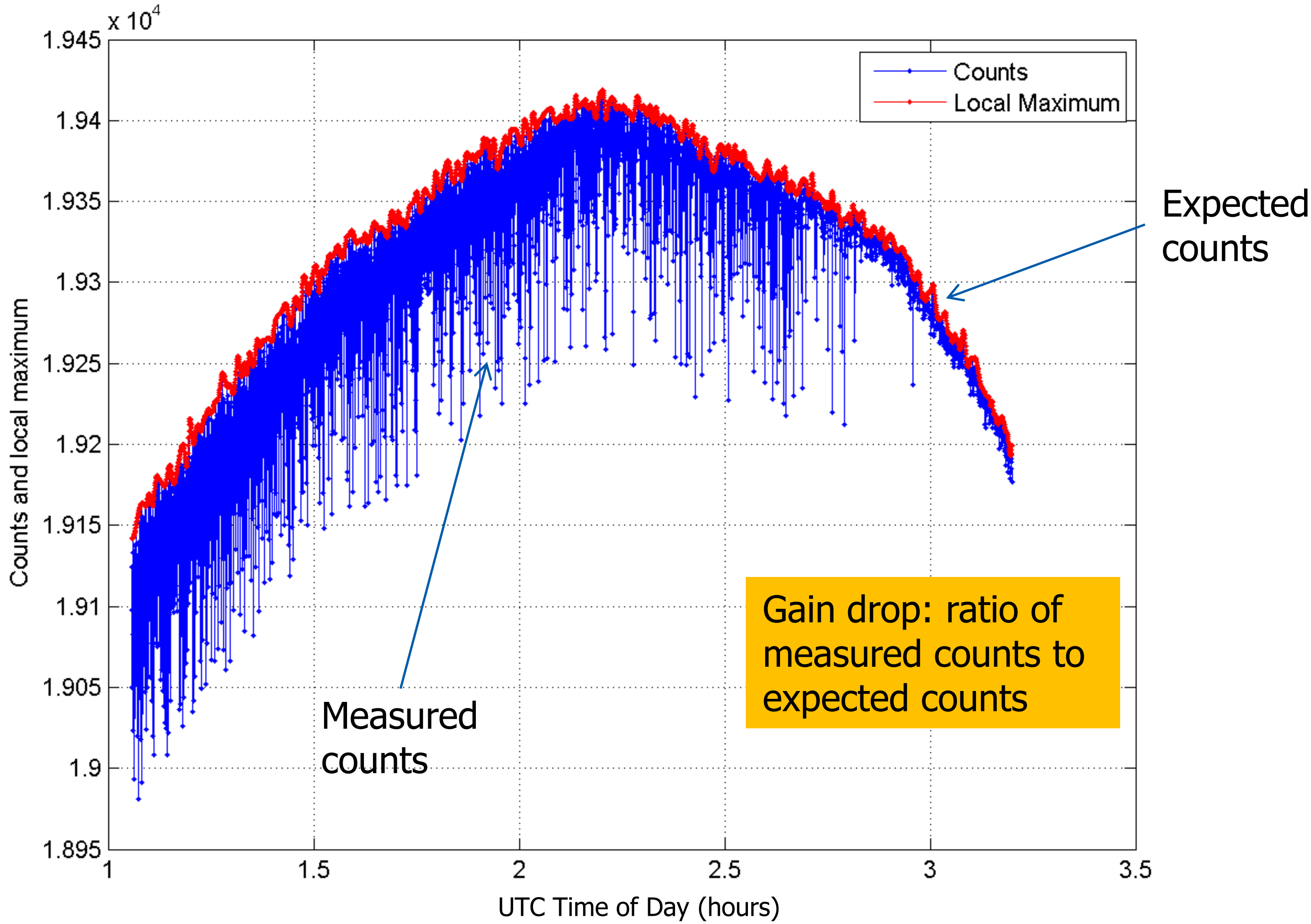
Observed J-1 Sensor Channel 16 Gain Dropouts During Transition from CP LOW to CP MID



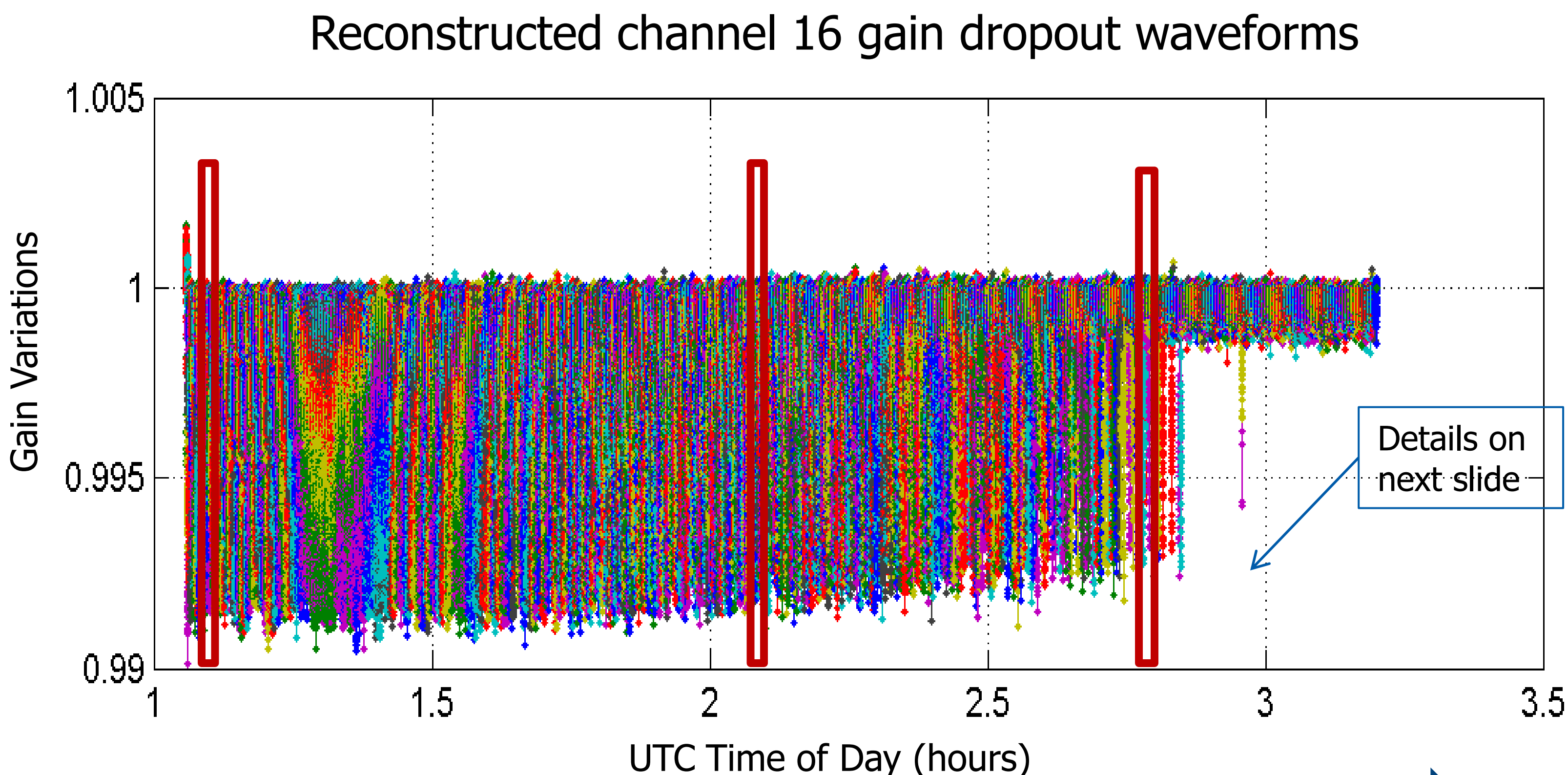
J-1 Channel 16 Gain Dropouts in Scan Data



Reconstruction of Gain Dropouts from Thermal Cycle Test Datasets



Reconstructed Gain Dropout Waveforms During Transition



Increasing cold plate temperatures

Reconstructed Gain Dropout Waveforms at Different Instrument Temperatures

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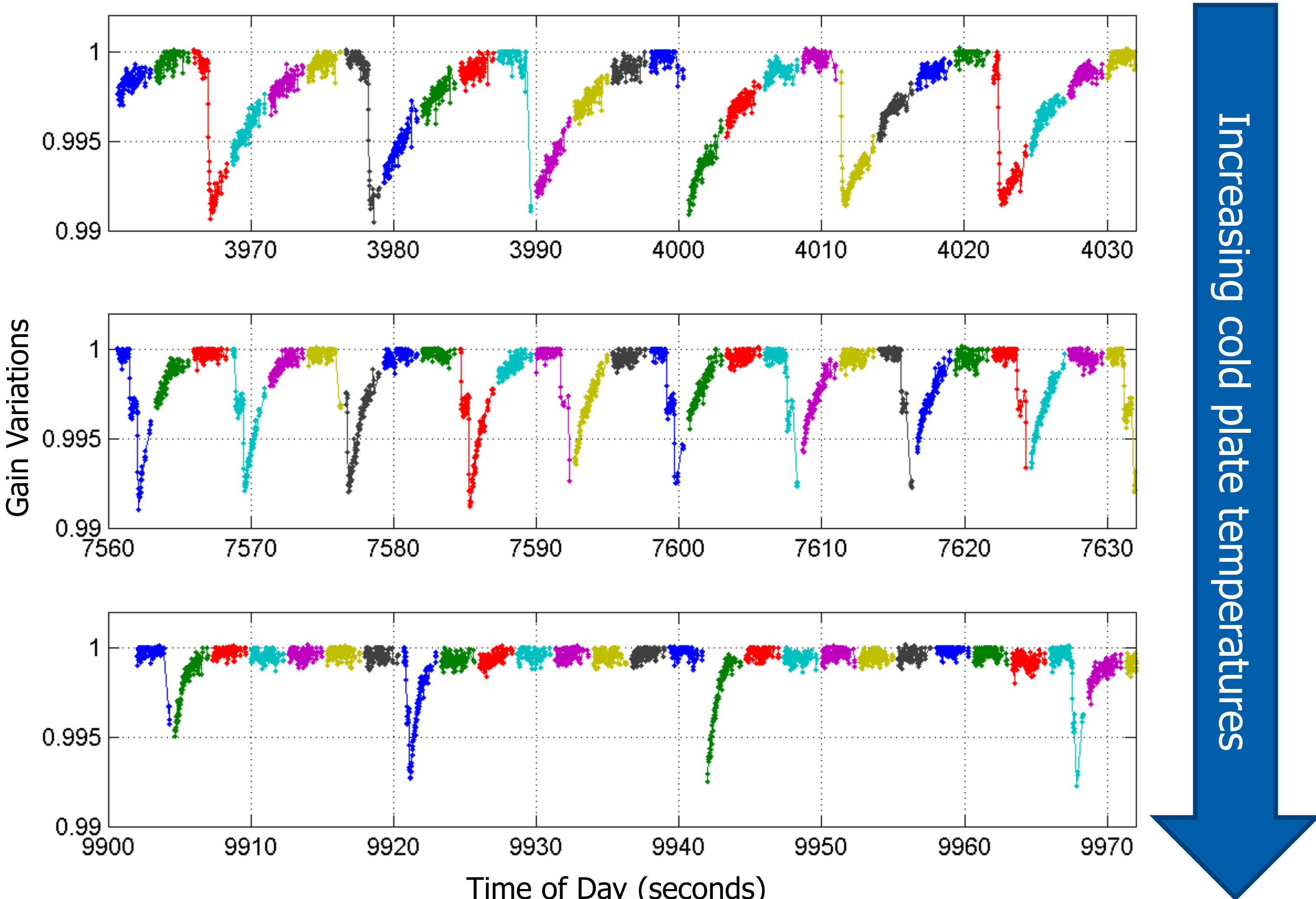
Reconstructed gain dropout waveforms as cold plate temperature increases during transition from Cold #7 to Hot #8 at selected time windows. 2014-04-24 01:03-03:12 (UTC)

Continuous dropouts that takes ~3-4 scans to recover at Cold CP temp

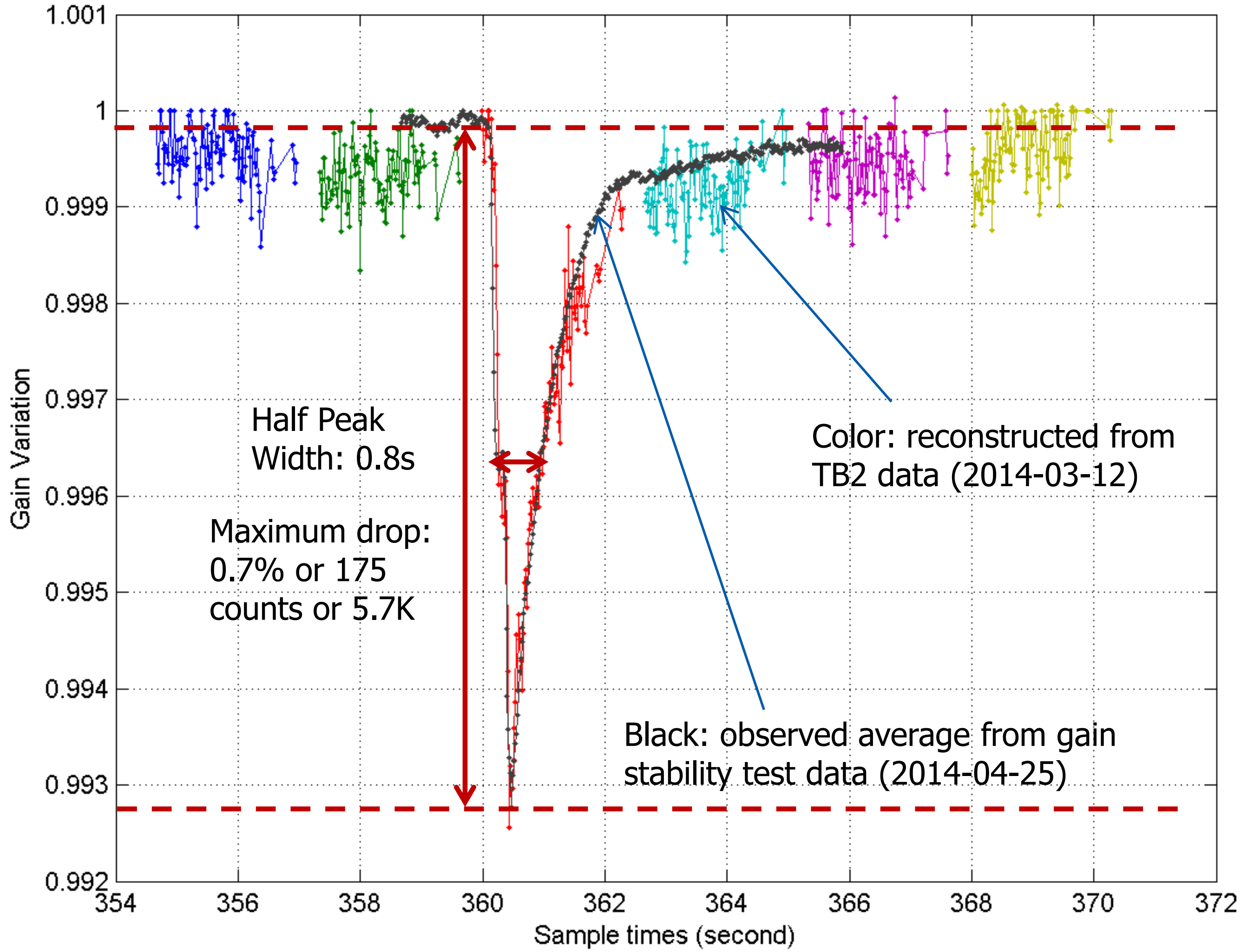
Frequent dropouts that recovers in ~2 scans at transitional CP temp

Occasional dropouts that recovers in ~1 scan at near MID CP temp



(Degui Gu and Alex Foo, NGAS)

Verification of Reconstructed Waveforms against the Observed Waveforms



(Degui Gu and Alex Foo, NGAS)

Summary and Future Work

- NGAS ATMS team will continue to support S-NPP ATMS SDR CalVal activities as the focus transitioning to LTM
- We plan to continue to support J-1 ATMS sensor testing and characterization
  - Support to sensor sell off
  - Support to J-1 algorithm development and improvement
  - Support to J-1 algorithm LUT/PCT coefficients derivation and verification
    - Calibration coefficients and nonlinearity correction
    - Beam efficiency correction coefficients
    - Striping noise mitigation by filtering
    - Geolocation LUT (sensor pointing and mounting data verification)