

Increasing Robustness of JPSS CrIS Spectral Measurements Through J1 TVAC Sensor Performance and SNPP NEdN Monitoring

Mark Esplin, Deron Scott, Kori Moore, and Ben Esplin

Utah State University Space Dynamics Laboratory

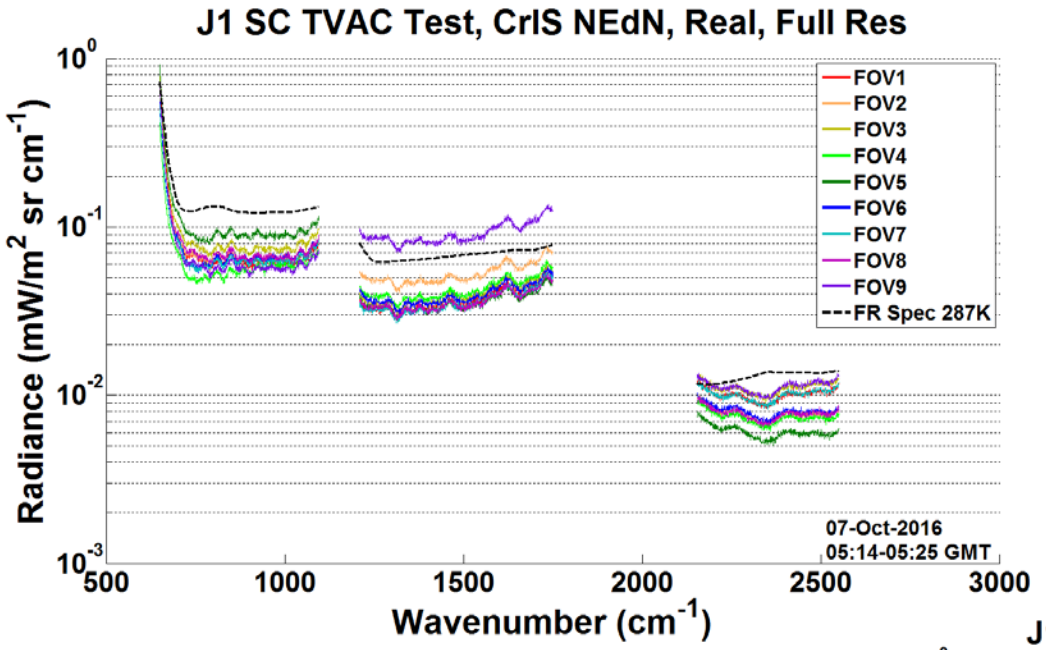
SDL/17-1137-

Outline

- J1 CrIS spacecraft-level TVAC testing
- S-NPP on-orbit performance trending
- Radiation-induced spike correction
- SDR calibration software issues
- Conclusions

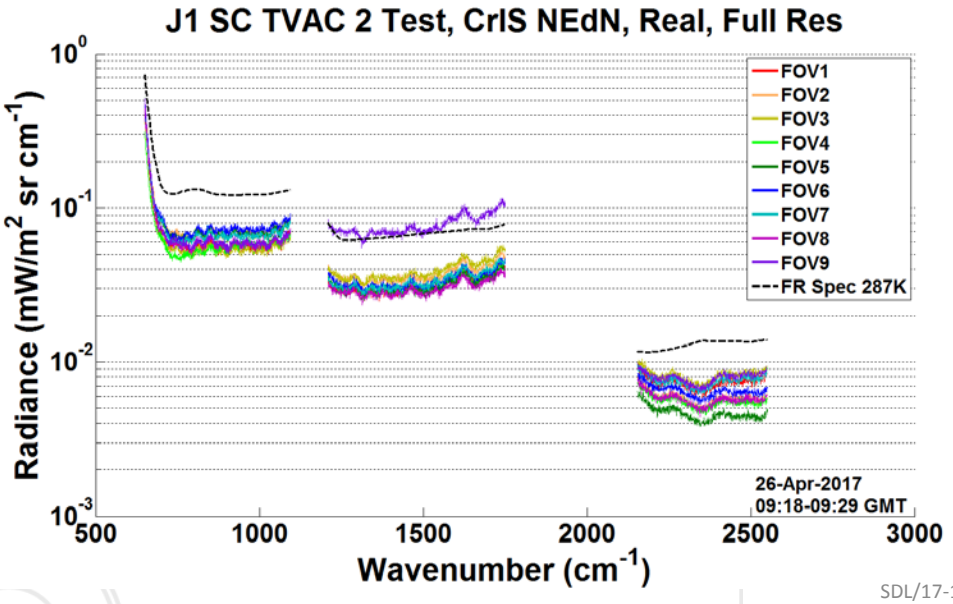
J1 TVAC Testing

J1 Spacecraft TVAC NEdN



- 4-HOT, Stare, TVAC, Aug.–Oct. 2016
- NEdN and Allan deviation results look good at both nominal and full resolution and during all tests except MW FOV9 (previously identified).

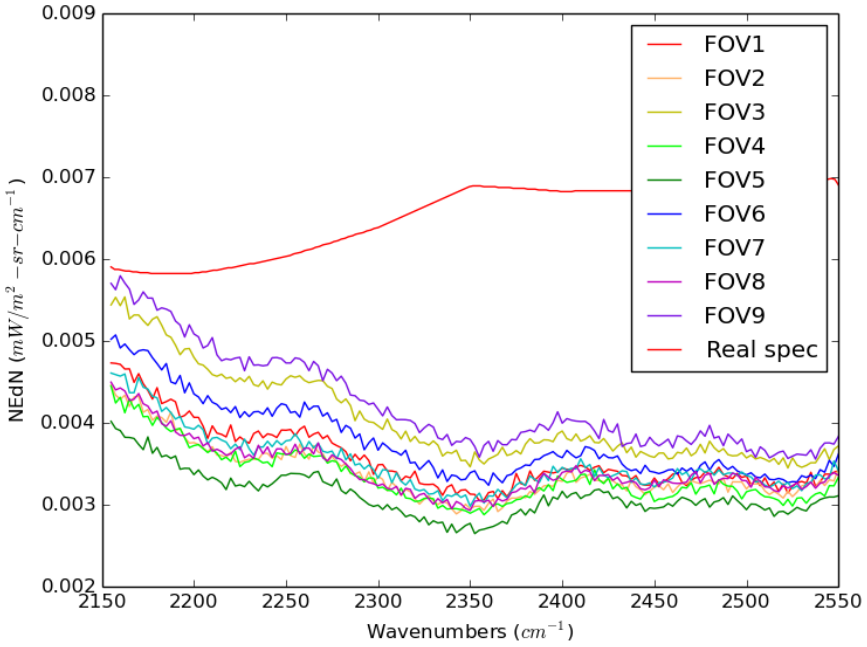
- 2-COLD, Stare, TVAC2, Apr.–May 2017
- NEdN and Allan deviation results again look good at both resolutions except MW FOV9.



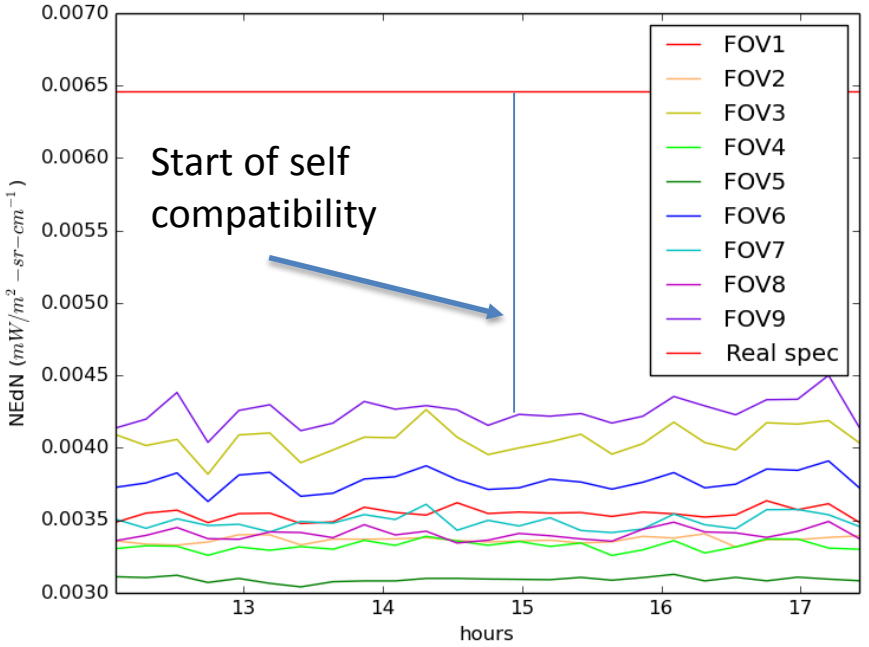
Check if NEdN Increases During Self Compatibility Test

Space Dynamics Laboratory
Utah State University Research Foundation

Full time period



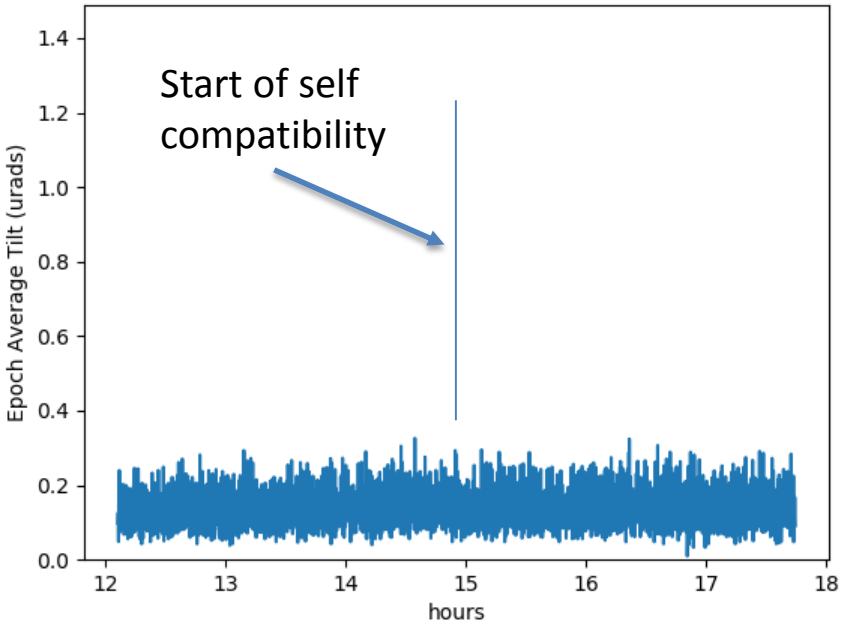
Trend



- NEdN trend calculated for subsets of length 100 spectra
- Self compatibility started at 14:51 (October 7, 2016)
- No increase in NEdN during self compatibility observed
- SW imaginary data

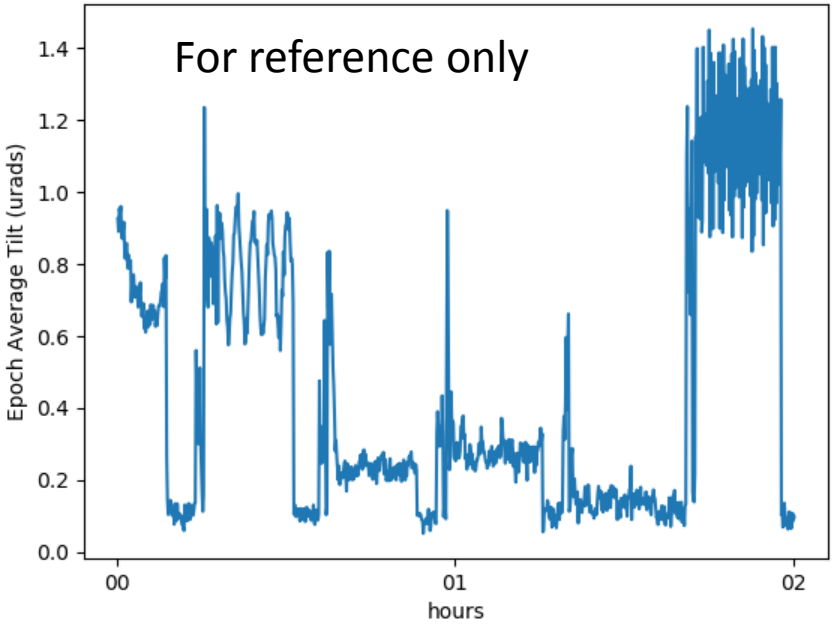
Average DA Tilt Error

Before and during self compatibility



October 7, 2016

Added vibration during sensor TVAC

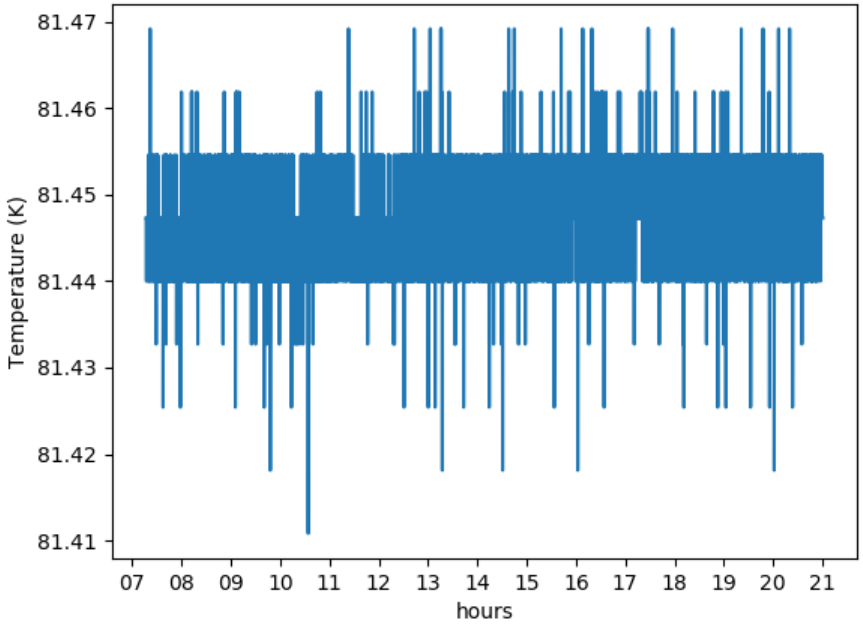


October 7, 2014

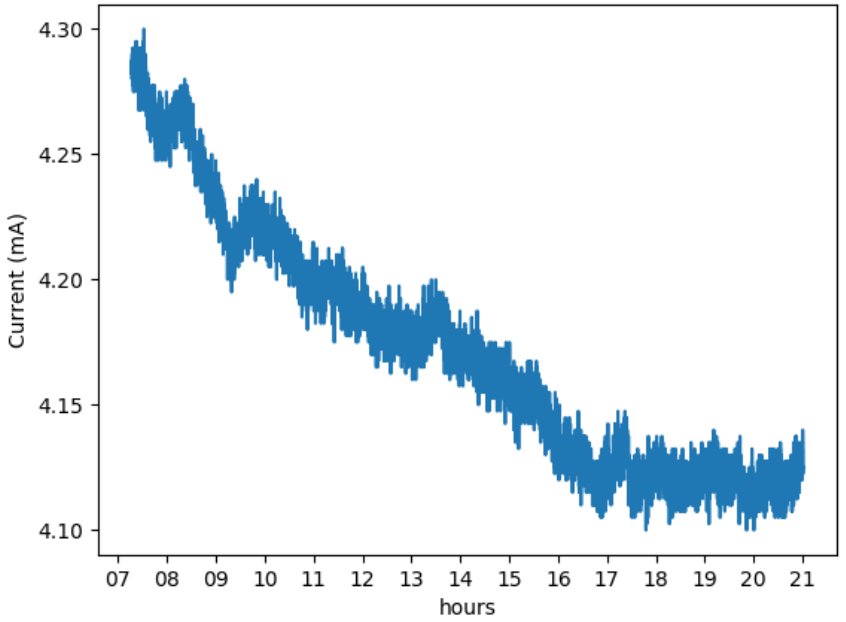
- DA tilt error from housekeeping telemetry data
- During sensor TVAC, CrIS tested with added vibration.

Check Stage 4 Cooler Margin

Temperature



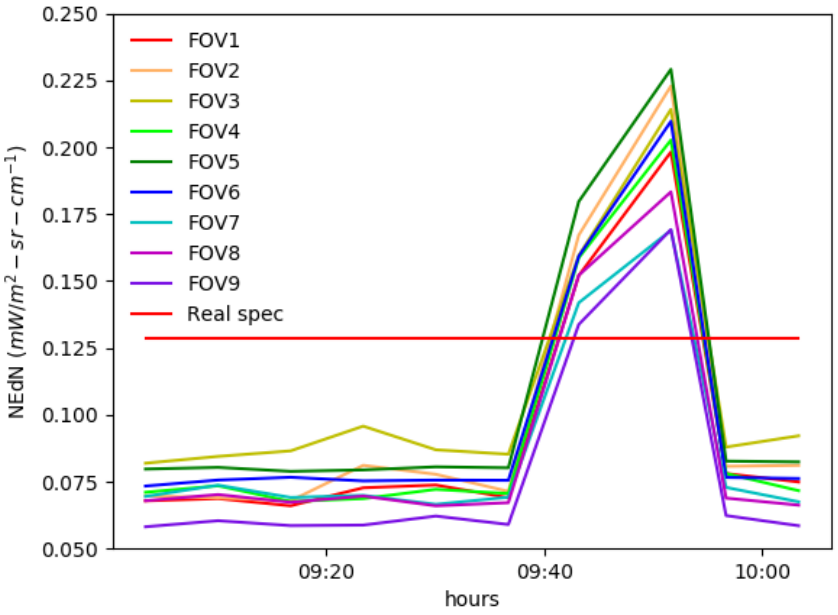
Heater current



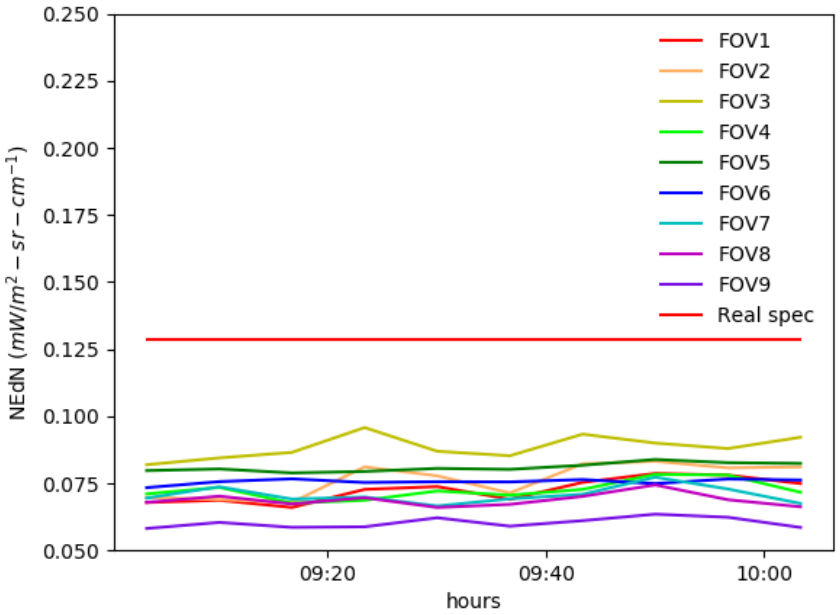
- During TVAC1 stage 4, cooler temperature too high (insufficient cooling margin)
- Issue with ground test equipment not CrIS sensor
- For TVAC2 stage 4, cooler in control at 81.4 K with current margin
- Hot1 (April 19, 2017)

Example of FCE Correction

Original

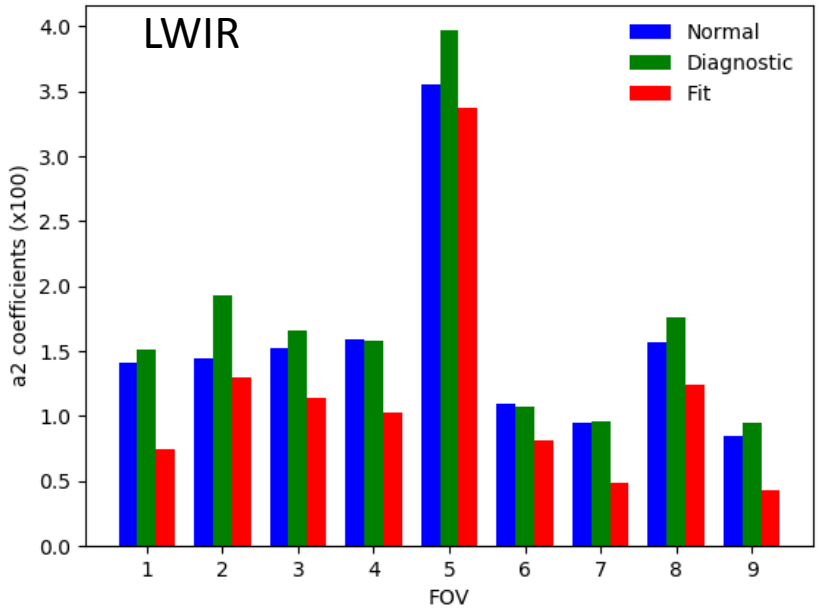


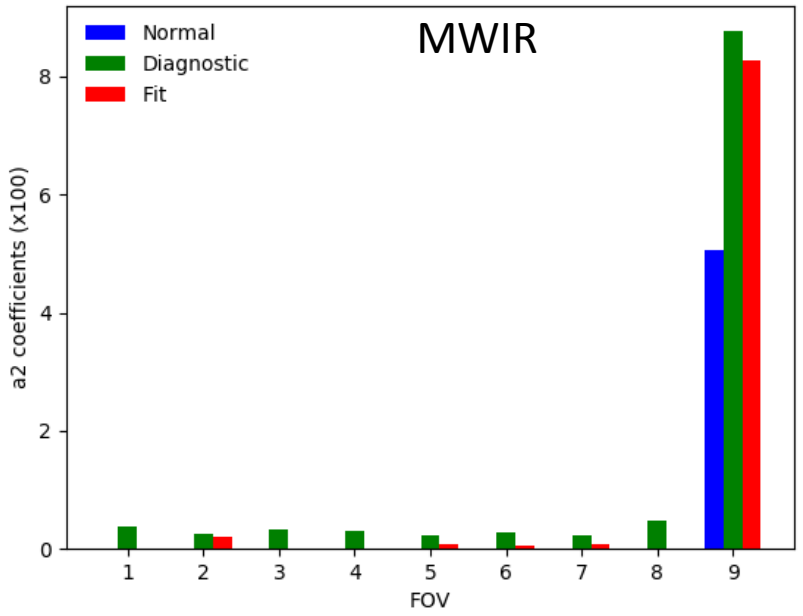
With FCE correction activated in SDR



- Cold1 to hot1 transition, April 18, 2017
- LW imaginary NEdN trend
- ADL 5.3.14

Detector Nonlinearity

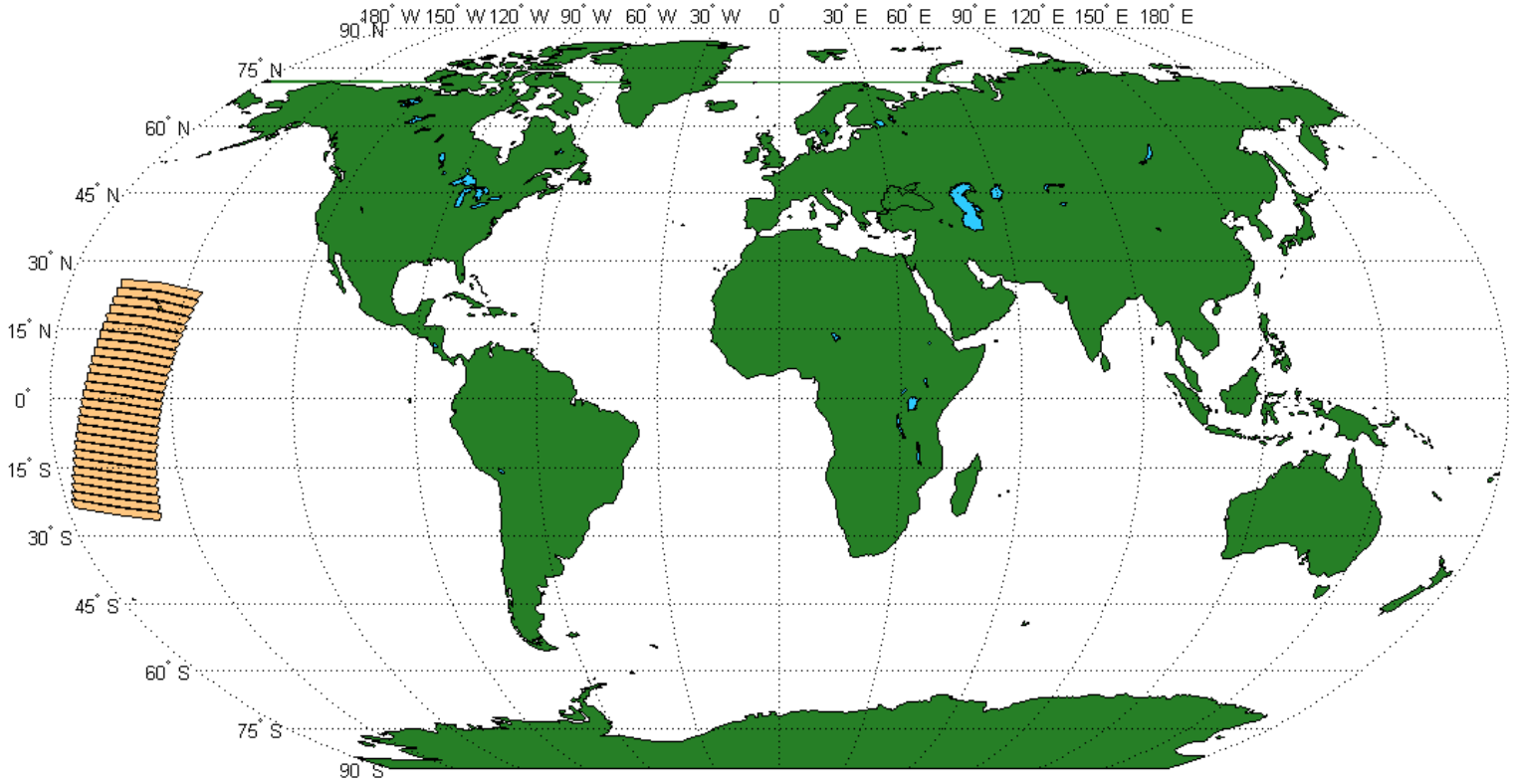




- MW FOV9 nonlinearity appears higher than during sensor TVAC
- Normal is Harris/UW nonlinearity from sensor TVAC using stepped blackbody temperatures
- Diagnostic data using ECT target at Cold4 plateau
- Best fit to TVAC1 cold plateaus (method of changing background)

S-NPP On-Orbit Performance Trending

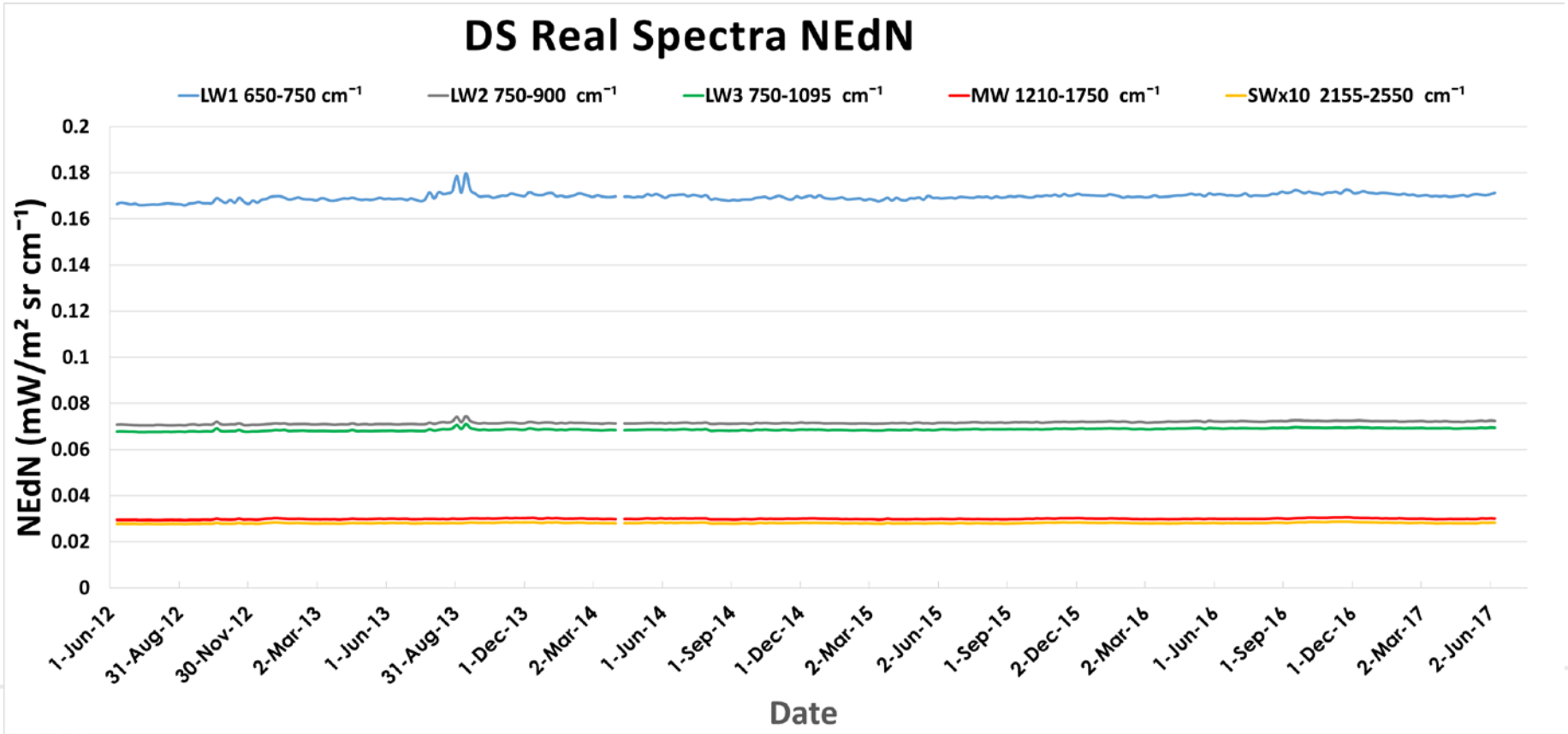
NEdN and Allan Deviation Methodology



- Have processed every 6th day since June 2012
- Location of data used in NEdN and Allan deviation calculations for April 21, 2017 provided as an example
- Night time ~13:00 GMT

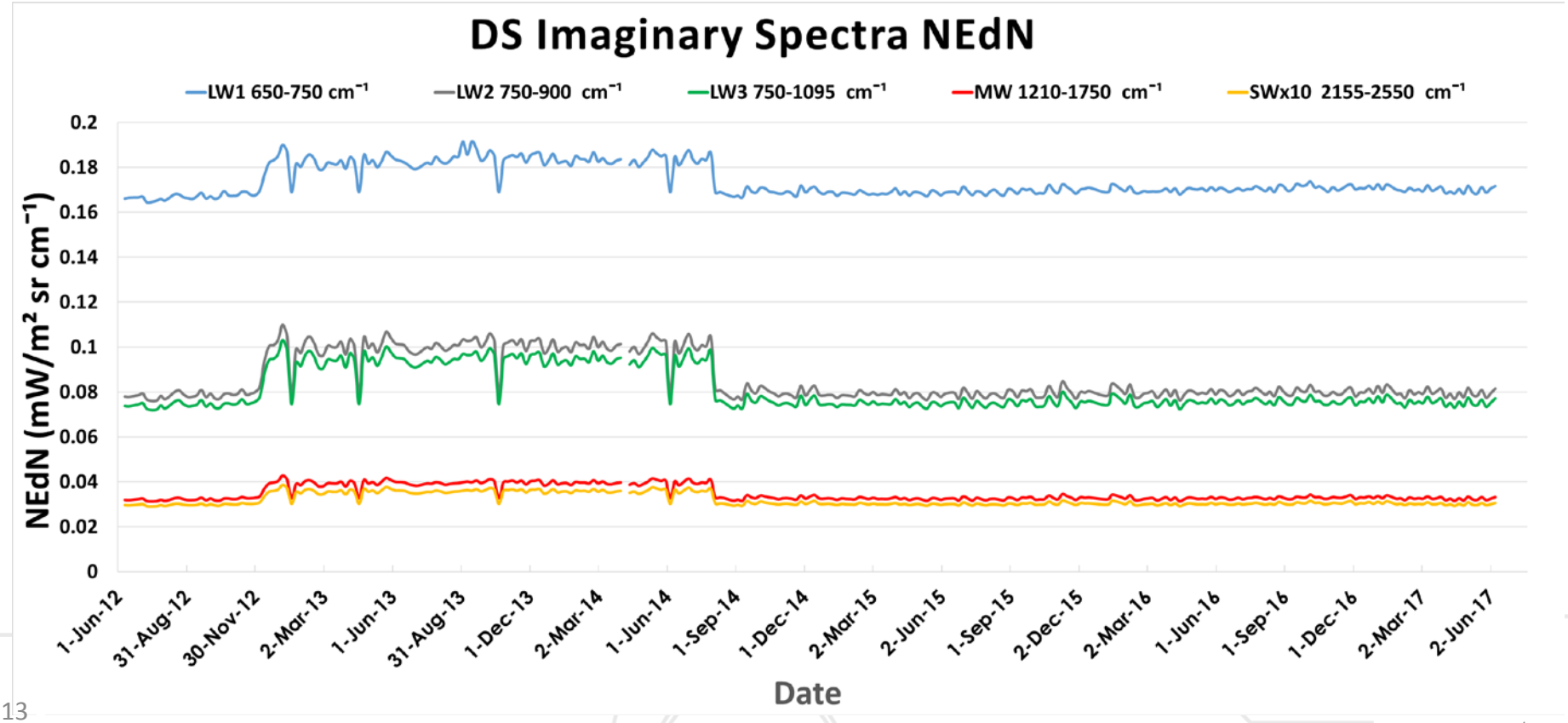
S-NPP DS NEdN Results, Real

- DS (and ICT) Real Spectra NEdN has not changed much over lifetime
  - Slight positive trend of < 0.5%/yr in each band/subband
- A few blips, but otherwise fairly flat

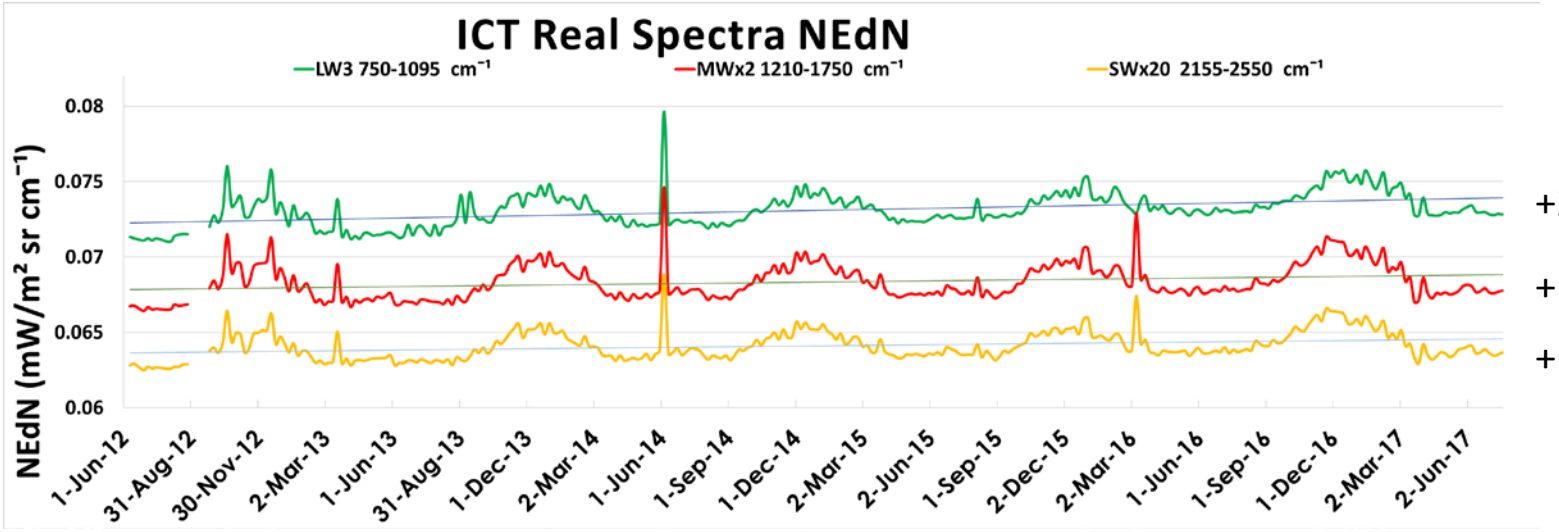


S-NPP DS NEdN Results, Imaginary

- Imaginary DS NEdN has a plateau across all bands/subbands lasting ~1.75 years, then returning to previous level in Aug. 2014
  - Started after CREECBIT error (correlation vs. causation?)
  - Ended after inclination adjustment maneuver (correlation vs. solution?)
- Noisier than Real NEdN, slight positive trend again



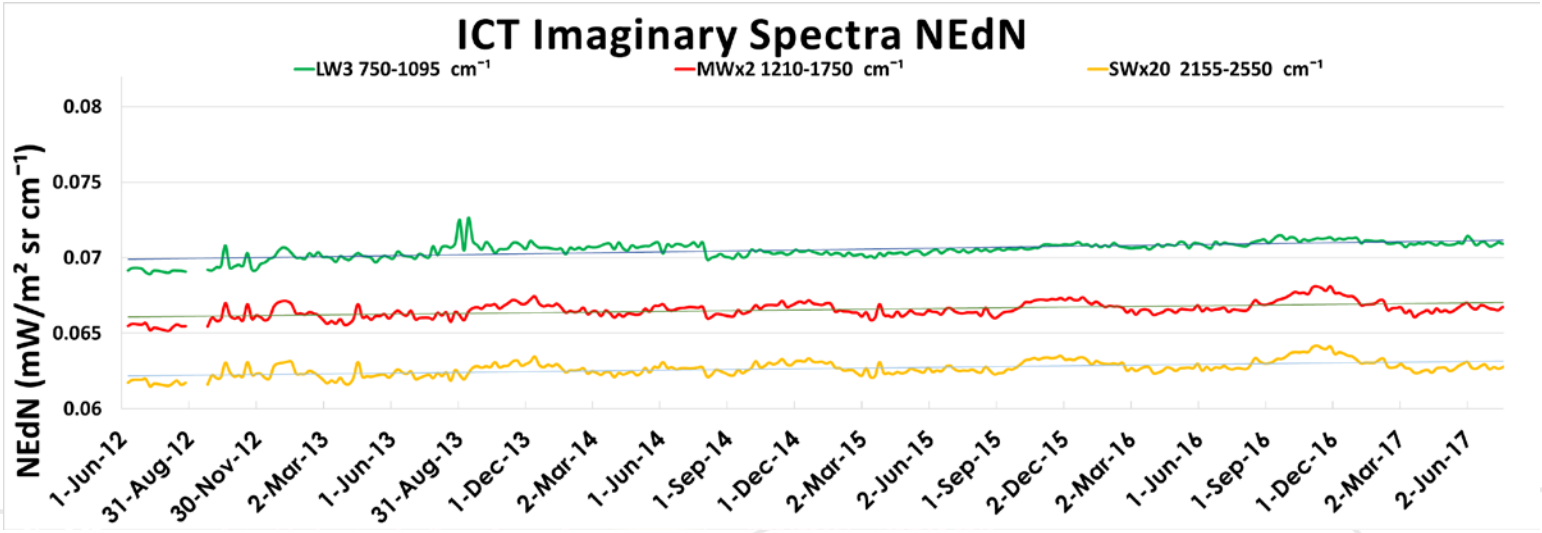
S-NPP ICT NEdN Results



+2.3%, +0.4%/yr

+1.4%, +0.3%/yr

+1.5%, +0.3%/yr



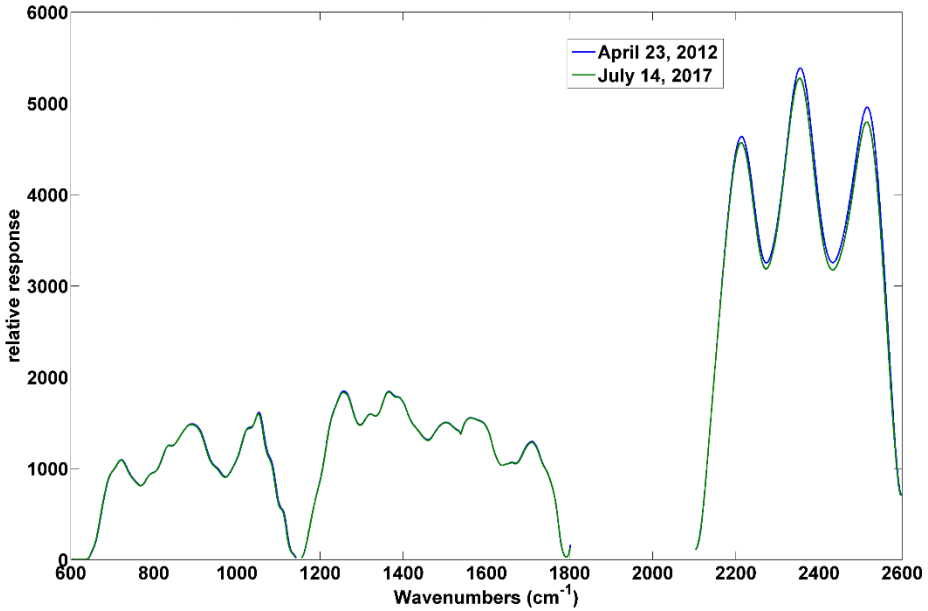
+1.8%, +0.4%/yr

+1.5%, +0.3%/yr

+1.6%, +0.3%/yr

Relative Spectral Response

Raw Response

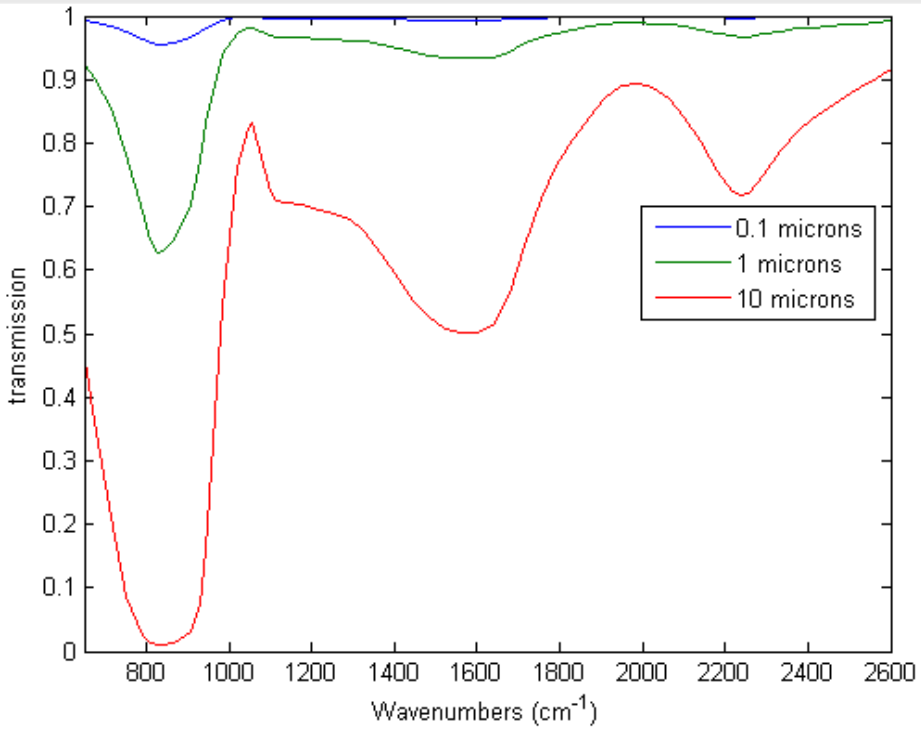


Percent Difference



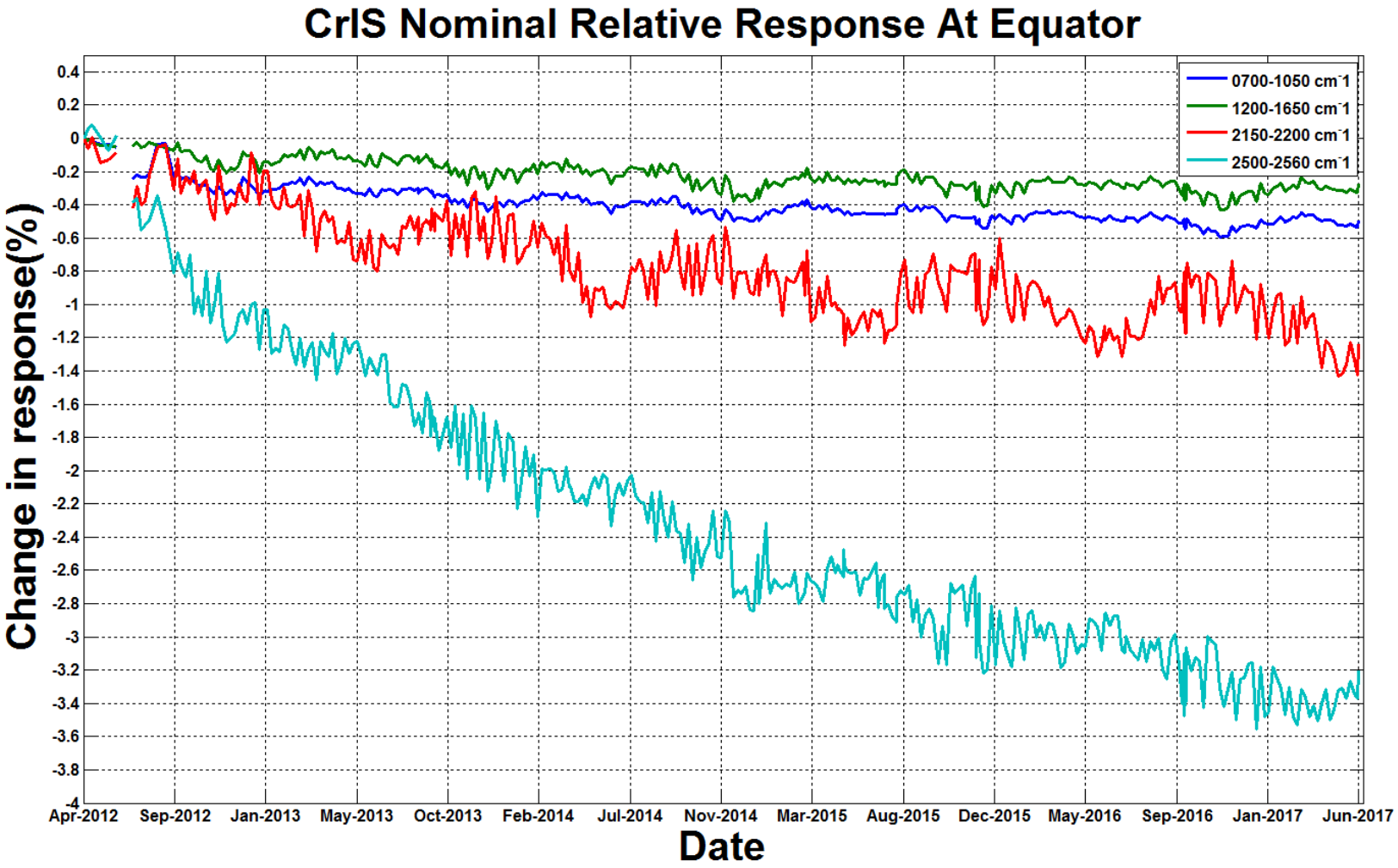
- Non-calibrated raw spectra response very stable over time
- Slight changes in optical alignment cause wave-like structure in the response
- The calibration process removes these structures.
- Always determined at same place in the orbit to increase stability
- No evidence for H_2O ice

Spectral Dependence of Water Ice



- Calculated from imaginary part of the refractive index
  - Data from Owen B. Toon et. el. "Infrared optical constants of H_20 ice, amorphous nitric acid solutions, and nitric acid hydrates," Journal of Geophysical Research, Vol. 99, NO. D12, pp 25,631-25,654, 1994.
- Does not include reflection or scattering losses

S-NPP Detector Lifetime Relative Response



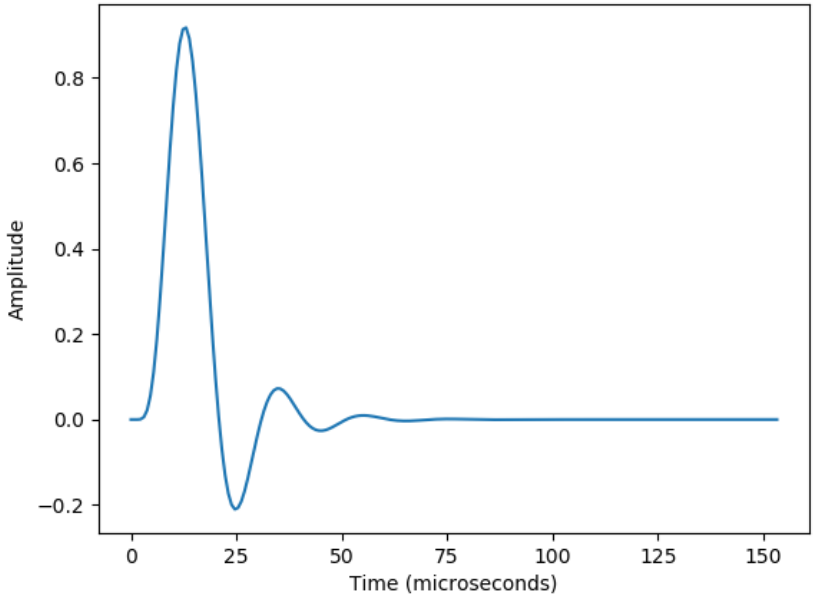
Radiation-Induced Spike Correction

New Spike Correction Method

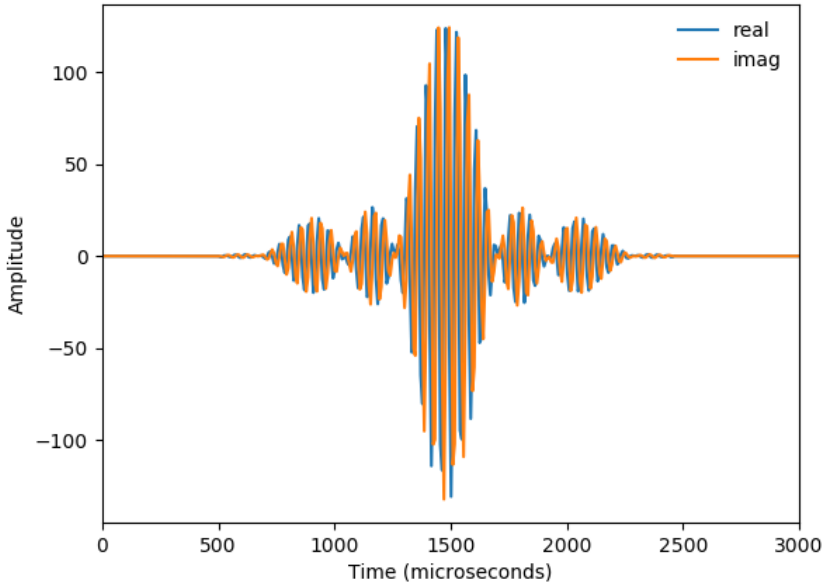
- Correction is achieved by subtracting a modeled spike from the observed interferogram.
- Least-squares fit used to determine position (time) and amplitude of spike.
- Shape of spike is the impulse response of the analog electronics and the digital signal processing.
- Interferogram asymmetry used to detect spikes.
- Binning of interferogram reduces effects of beamsplitter dispersion and sampling offset.
- NOAA STAR improved binning algorithm.
- After correction interferogram is again checked for asymmetry.
- ADL patch has been developed and is planned to be incorporated into operational system.

Spike Shape

Spike in analog electronics



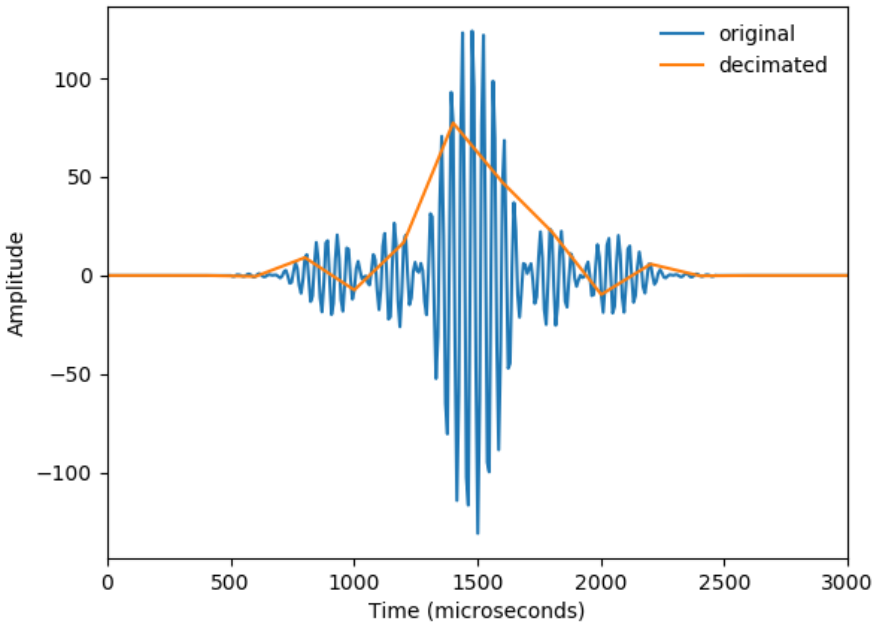
Spike after applying FIR filter



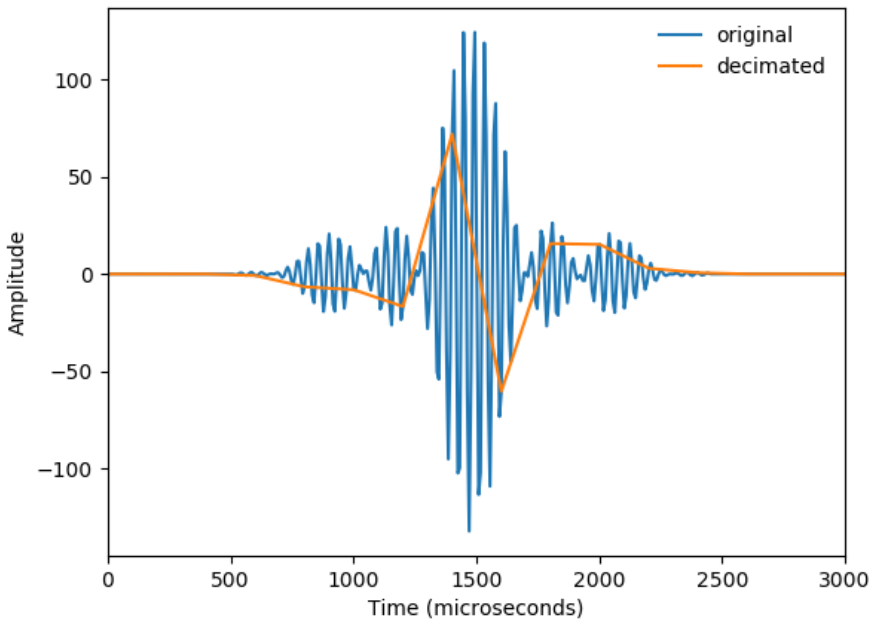
- Shape of spike is impulse response of system
- Analog 5-pole Butterworth filter with 52 kHz cutoff frequency
- FIR filter broadens spike and adds fine structure

After Decimation

Real

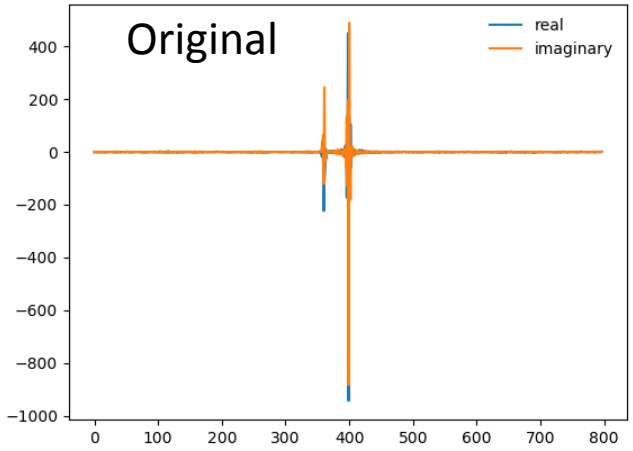


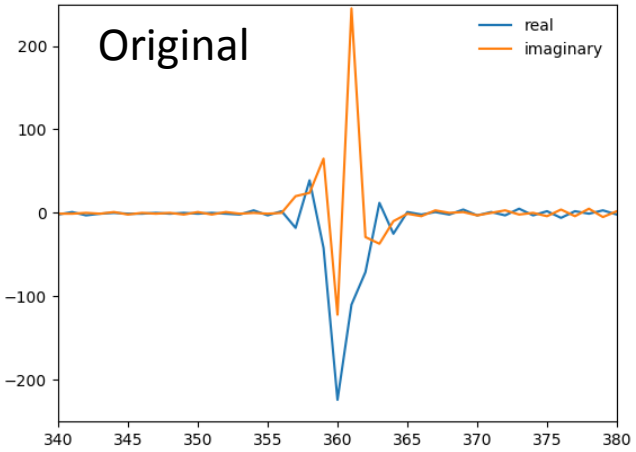
Imaginary

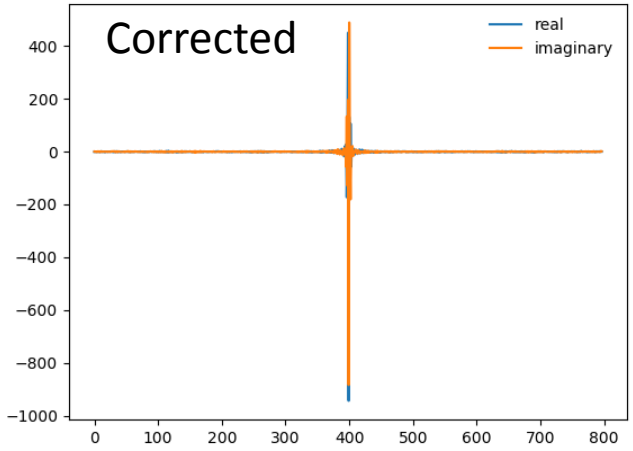


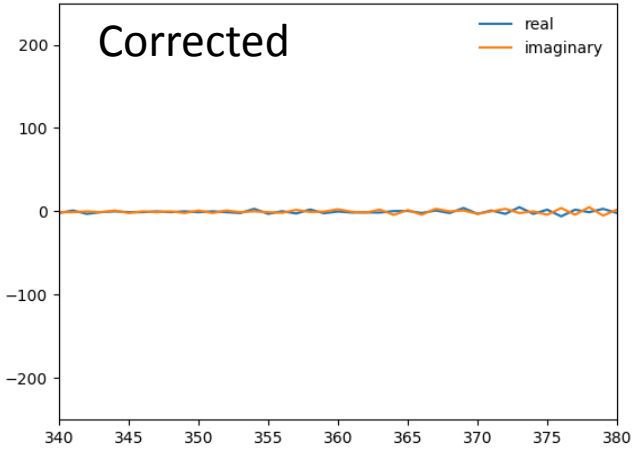
- Decimation reduces number of sampled points by factor of 26 for SWIR band.
- Other sampling would produce a very different looking decimated interferogram.
- Information on spike position and amplitude is preserved through processing chain.

Example Spike Correction: Interferogram





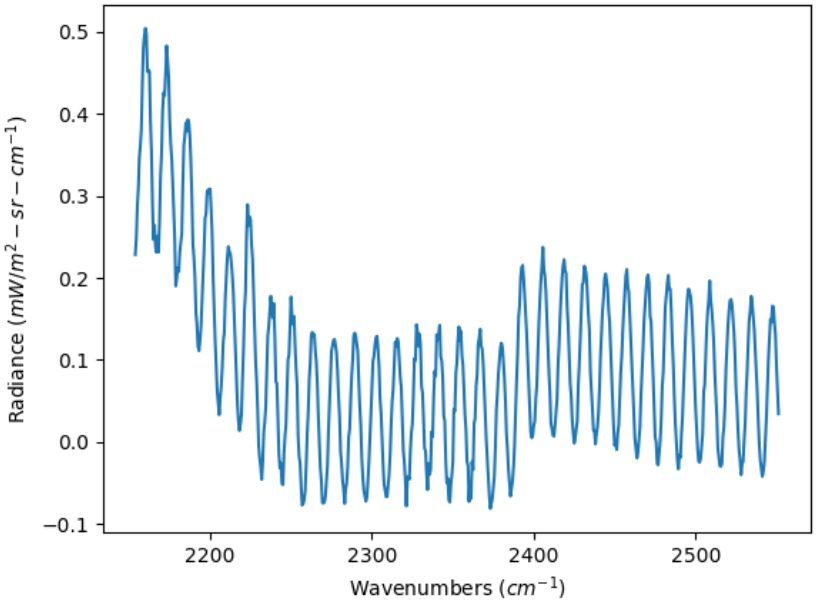




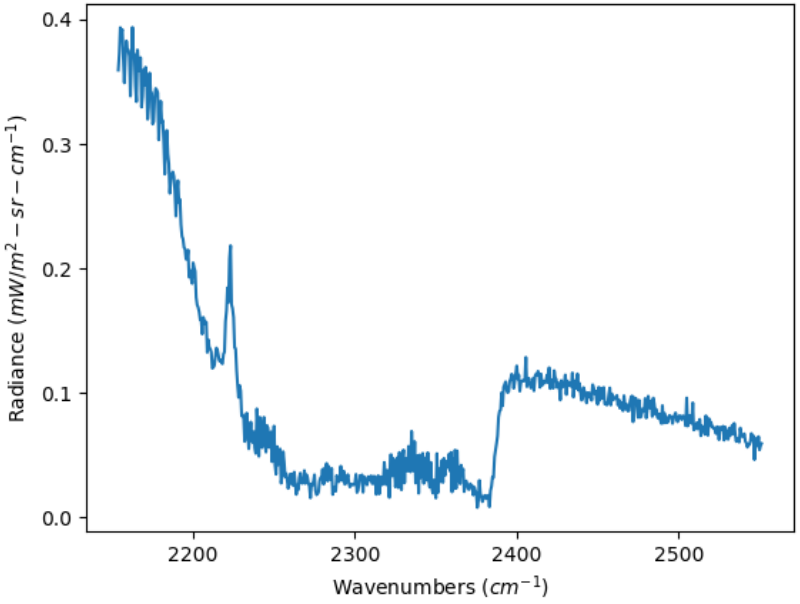
- Removal of spike successful
- January 15, 2017 SWIR FOR4 FOV9

Example Spike Correction: Real Spectrum

Original



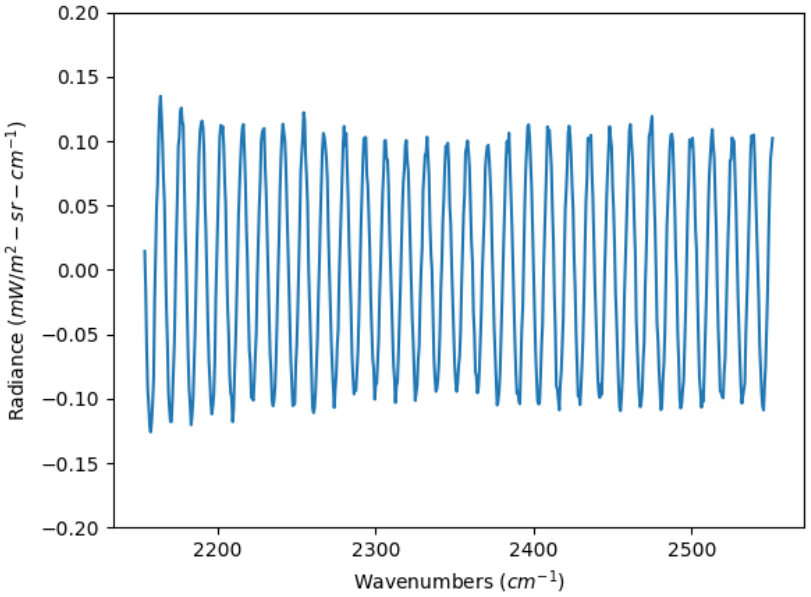
Corrected



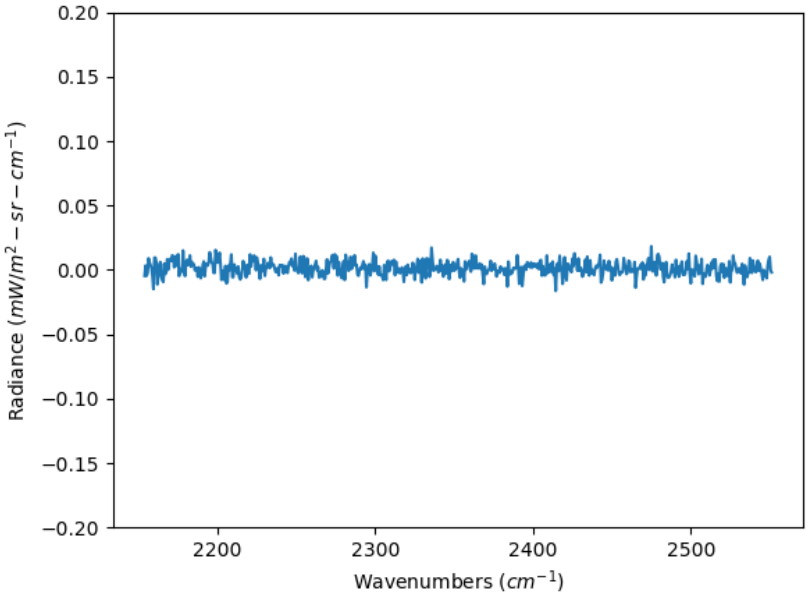
- Real spectrum before and after subtracting modeled spike from interferogram
- Original SDR quality control flags this spectrum as invalid.
- After correction the SDR quality flag for spectrum is good.
- January 15, 2017, SWIR FOR4 FOV9

Example Spike Correction: Imaginary Spectrum

Original

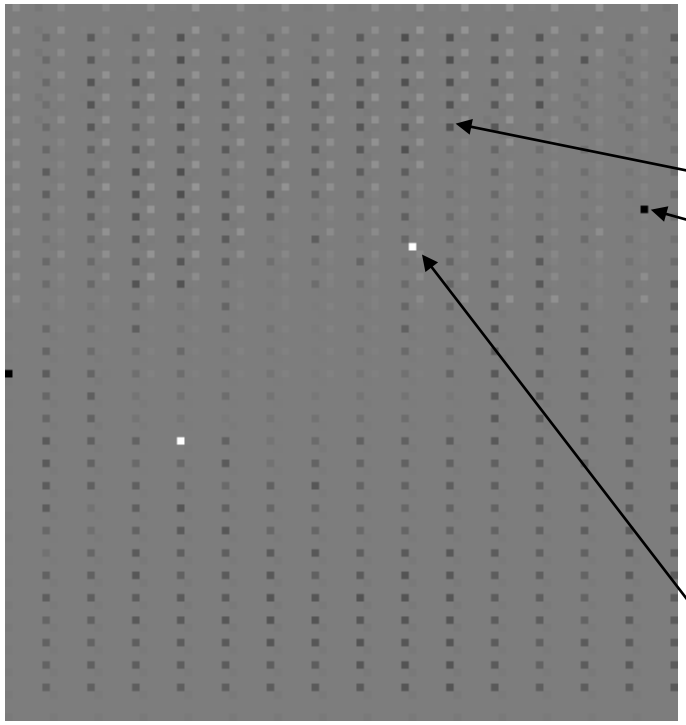


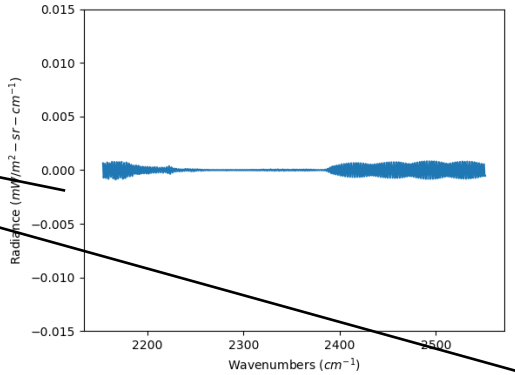
Corrected



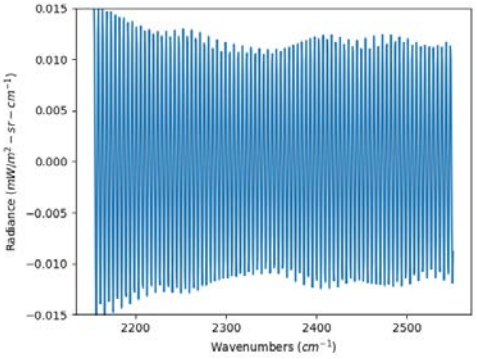
- Imaginary spectra
- Imaginary spectra is a good diagnostic of system performance.
- January 15, 2017, SWIR FOR4 FOV9

Example Over SAA (November 6, 2016, 04:00)

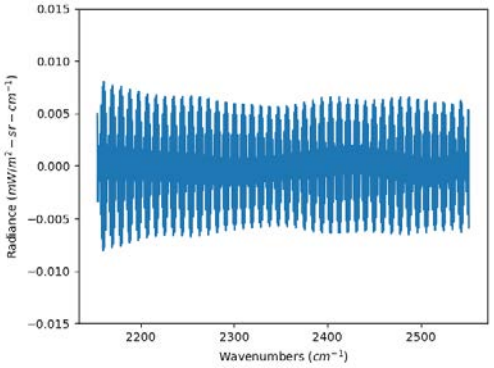




FOR20 FOV6



FOR29 FOV2



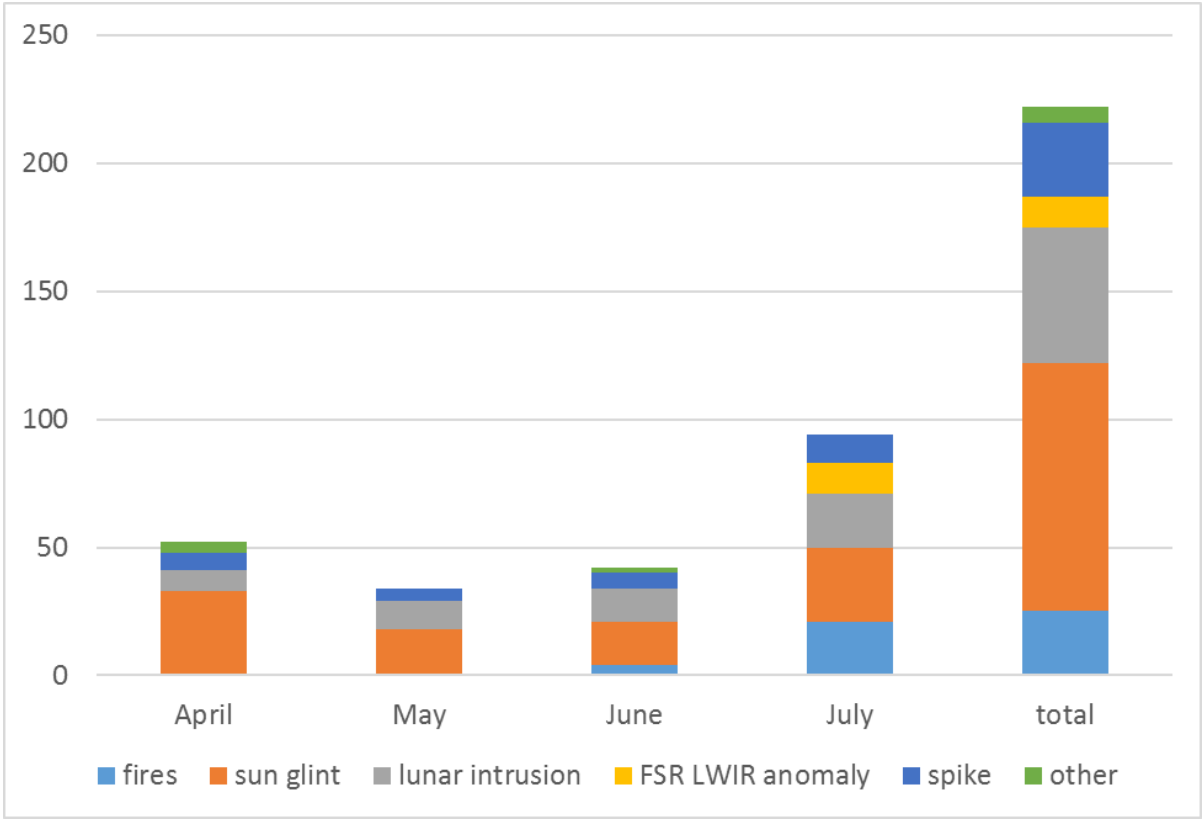
FOR19 FOV7

NEdN spec ≈ 0.0065 $mW/m^2 - sr - cm^{-1}$

- Difference between original and corrected spectra
- Spikes in calibration spectra cause non-localized effects.
- Image at 2412 cm^{-1} brightness scale clipped

SDR Calibration Software Issues

Granules that Contain Invalid SDRs

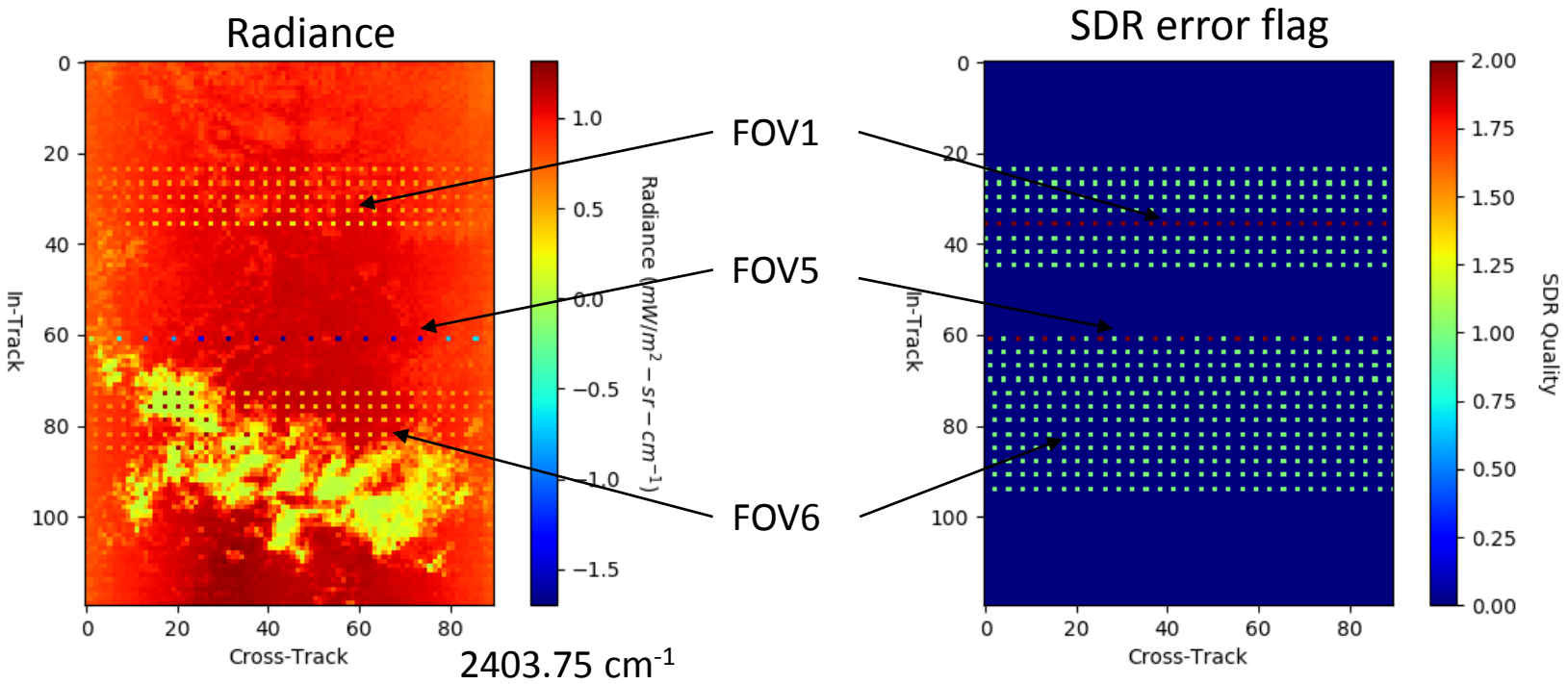


- Total of 222 granules out of approximately 329,400 or 0.067%
- From SDR quality flag
- April to July 2017

SDR Calibration Software Issues

- Occasionally the SDR software is not properly calibrating the RDRs.
- These errors are not frequent but can cause spectral corruption.
- Most significantly corrupted spectra are flagged as invalid.
- However, some errors are also occurring for spectra flagged good.
- The sliding calibration window can become corrupted affecting multiple scans.
- Lunar intrusion
  - If the moon is present in the DS port when the SDR software is initialized, the sliding window can become corrupted.
- FSR LWIR anomaly
  - Which bin in the calibration window corresponds to a given wavenumber depends on the laser wavelength
  - Small changes in the laser wavelength can cause the earth spectra and the calibration spectra to lose registration.

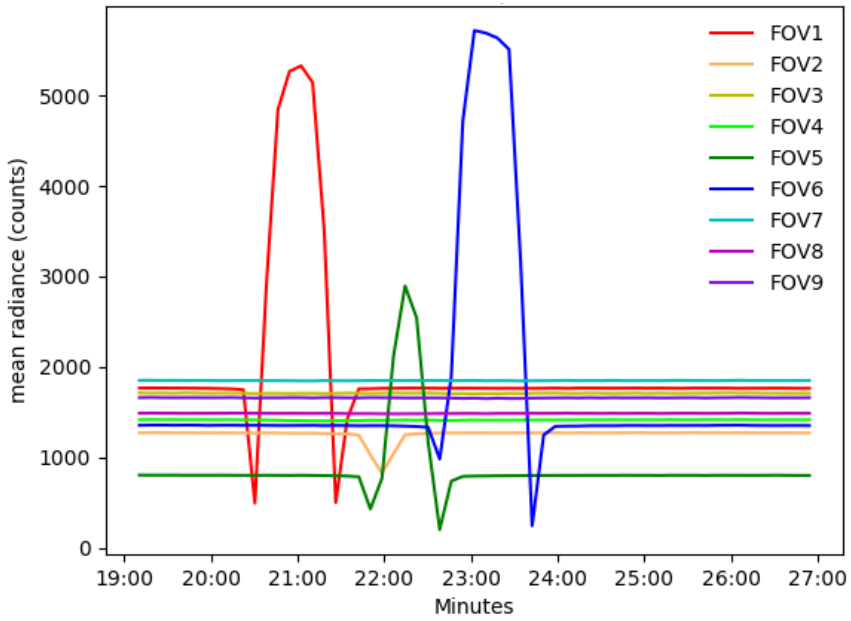
Example of Lunar Intrusion Spectral Corruption



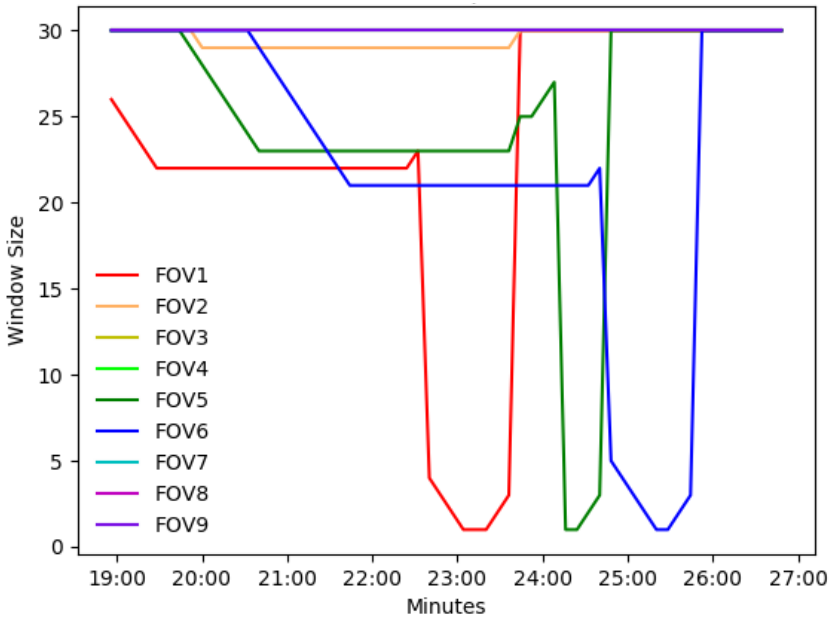
- SDR radiance in SWIR band
- SDR error flag = 2 invalid, flag = 1 degraded spectrum
- Error flag not a good indicator of degree of spectral corruption.
- April 6, 2017, 14:23 to 14:27

DS Window Size is Incorrect

DS Raw Magnitude



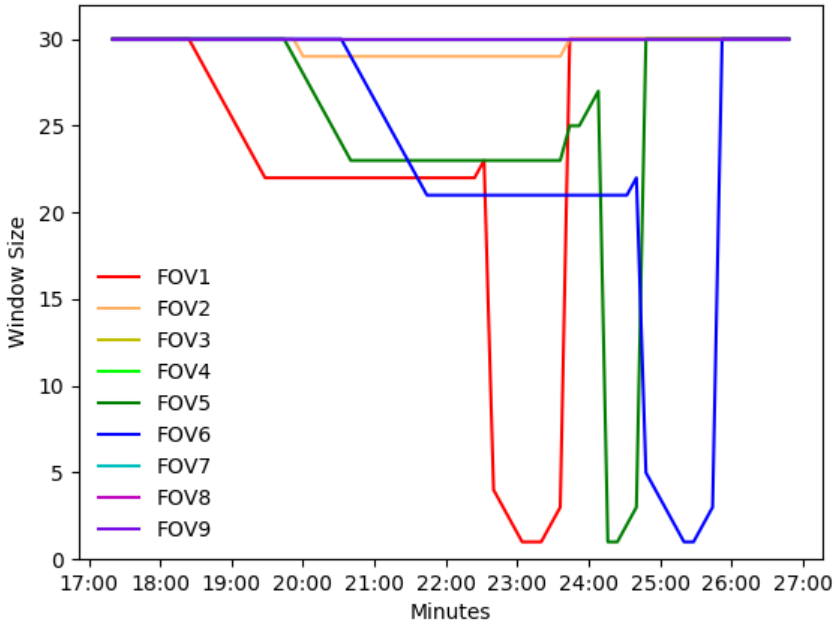
DS Window Size



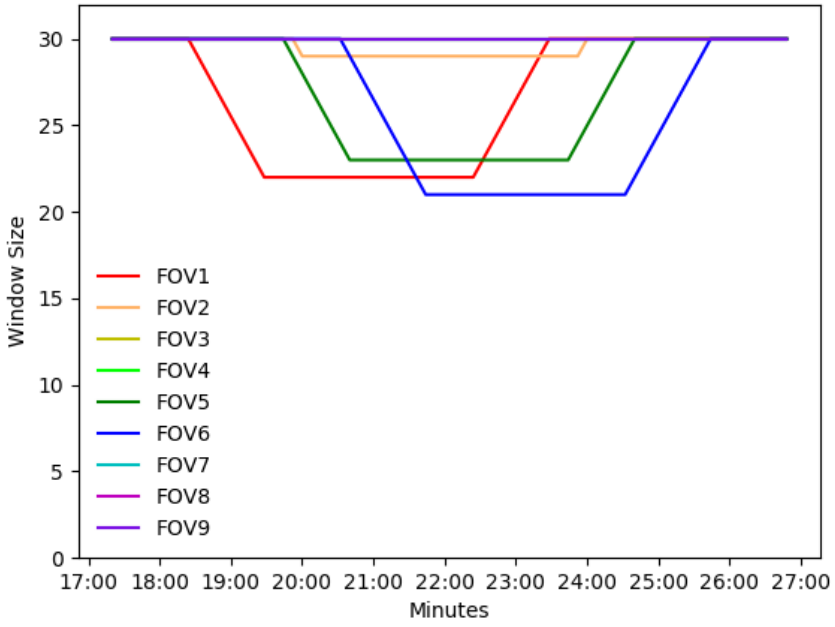
- Corrupted spectra occurs at end of calibration window.
- FOV2 has minor intrusion and works as expected.
- FOVs 1, 5, and 6 are incorrect and show errors in spectra.
- April 6, 2017, 14:19 to 14:27.

Serial Processing Fixes DS Window Size

Parallel

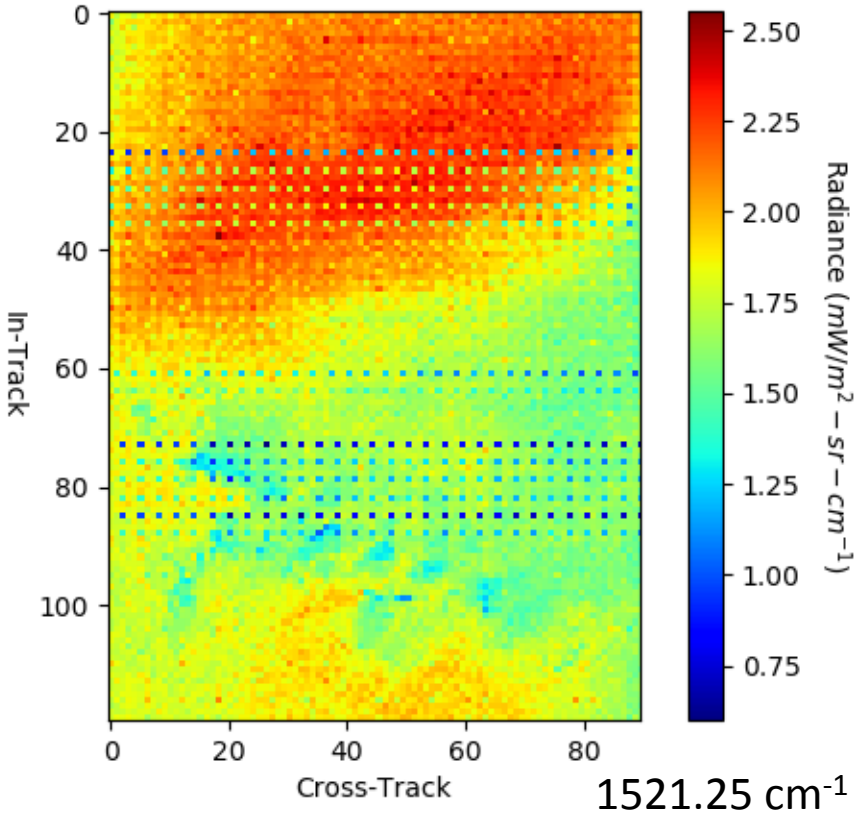


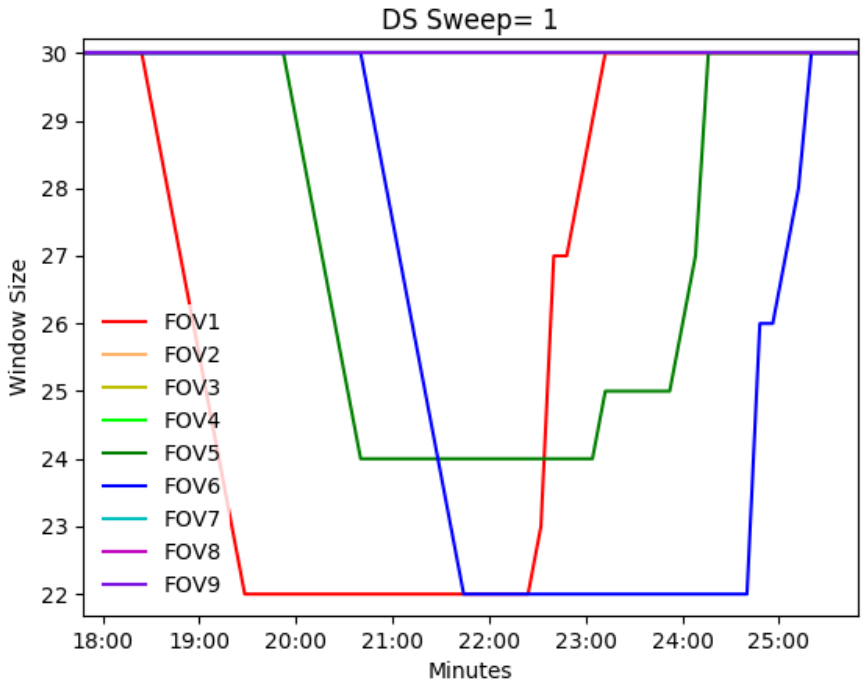
Serial



- DS window size versus time
- Processing with ADL in series corrects DS window errors
- Corrupted spectra also not observed
- April 6, 2017, SWIR band

MWIR Band DS Window also Corrupted

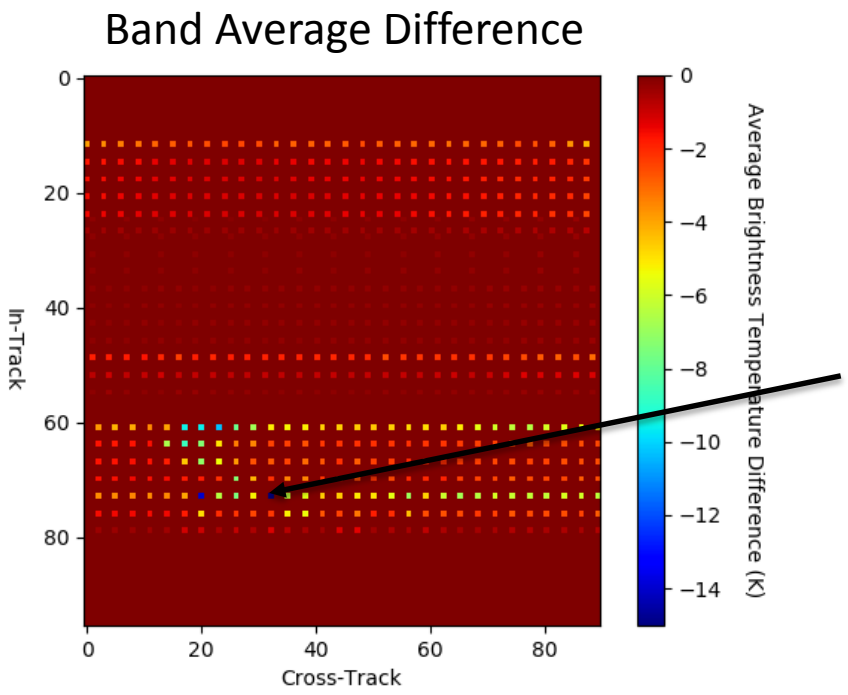


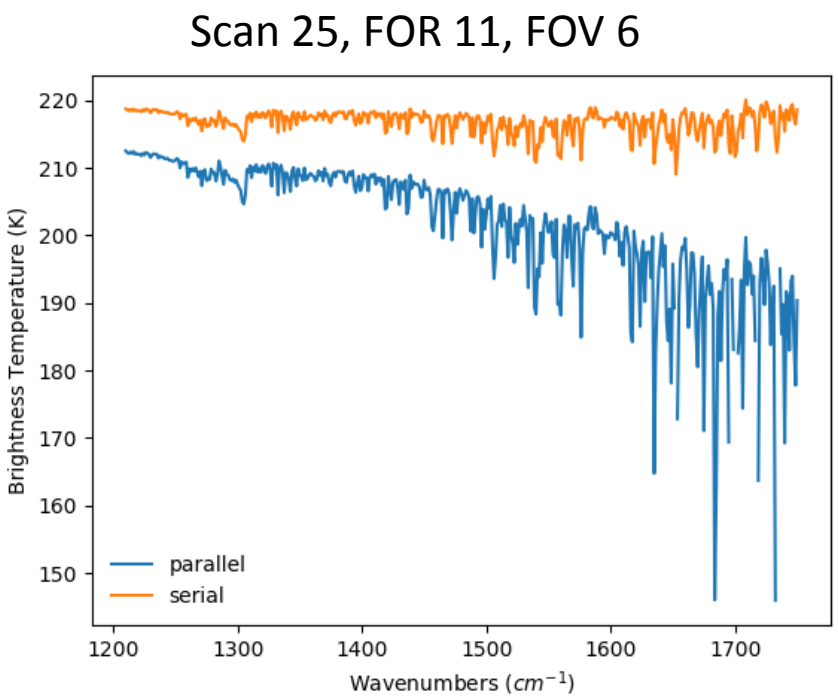


- Corruption is less in MW.
- Window size still incorrect

- All spectra flagged good
- IDPS MW, April 6, 2017, 14:21-14:27

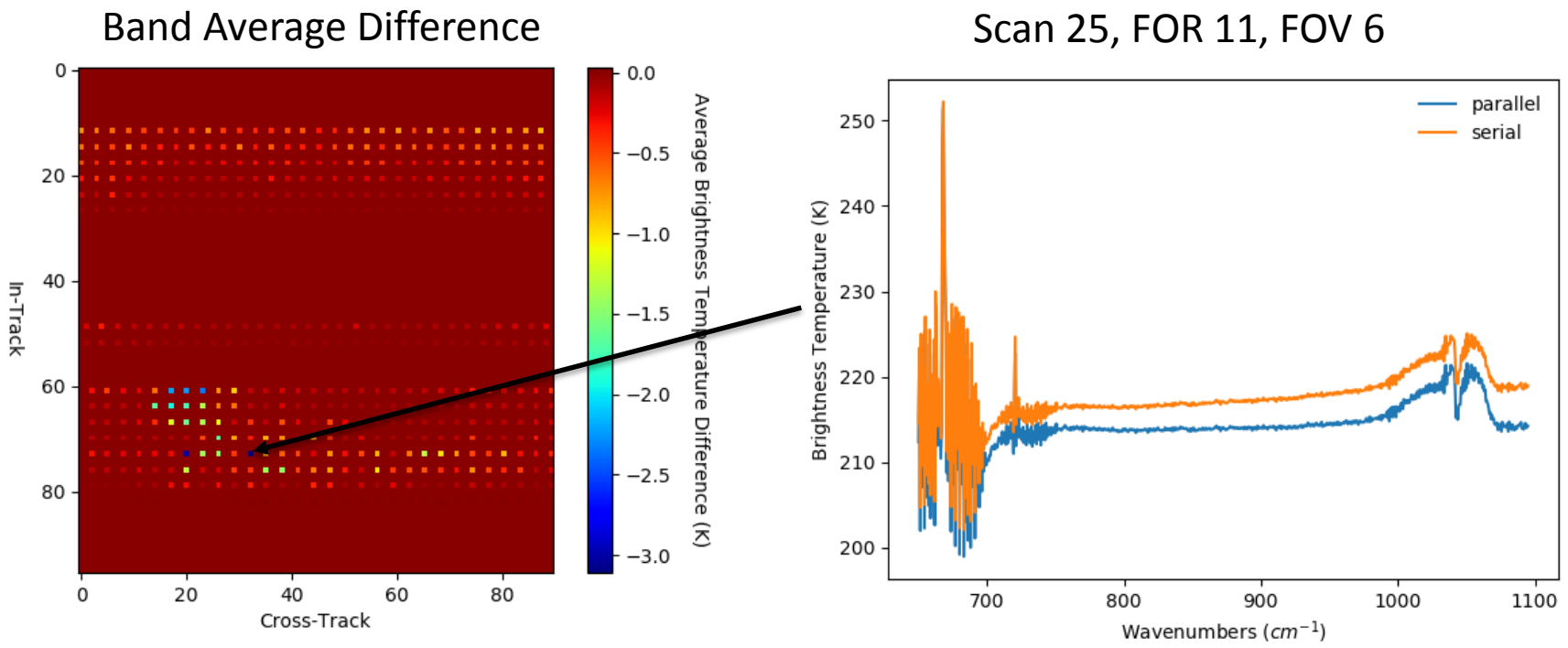
MWIR Errors Due to Lunar Intrusion Bug





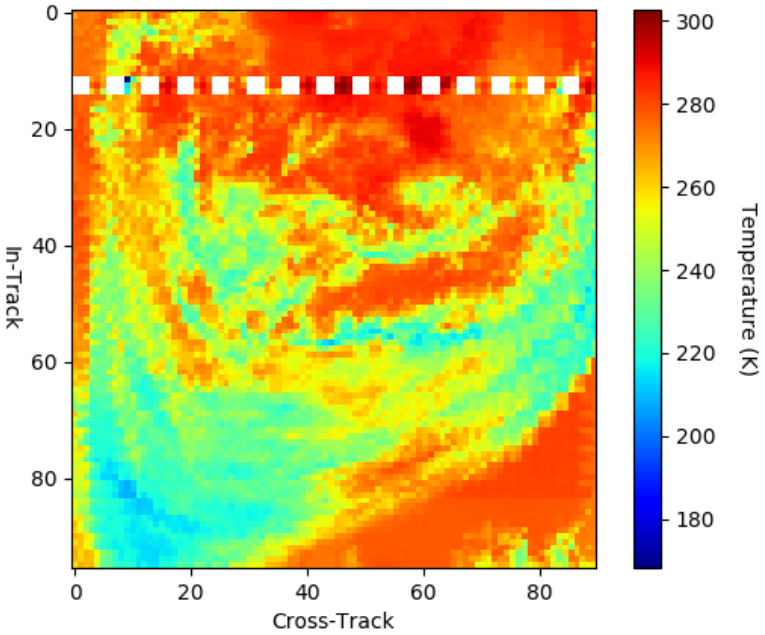
- ADL can be used to replicate IDPS lunar intrusion bug.
  - Tasking granules in parallel causes errors (see slides 22 – 24)
- MWIR difference between ADL serial and parallel processing.
- April 6, 2017, 14:22:08 to 14:26:22

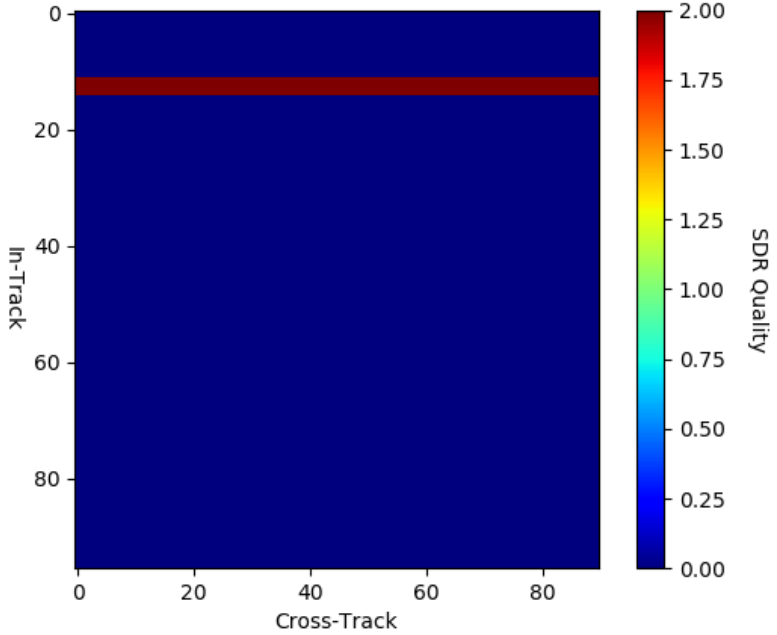
LWIR Error Due to Lunar Intrusion Bug



- Difference between ADL serial and parallel processing
- LWIR brightness errors are smaller but still significant
- April 6, 2017, 14:22:08 to 14:26:22

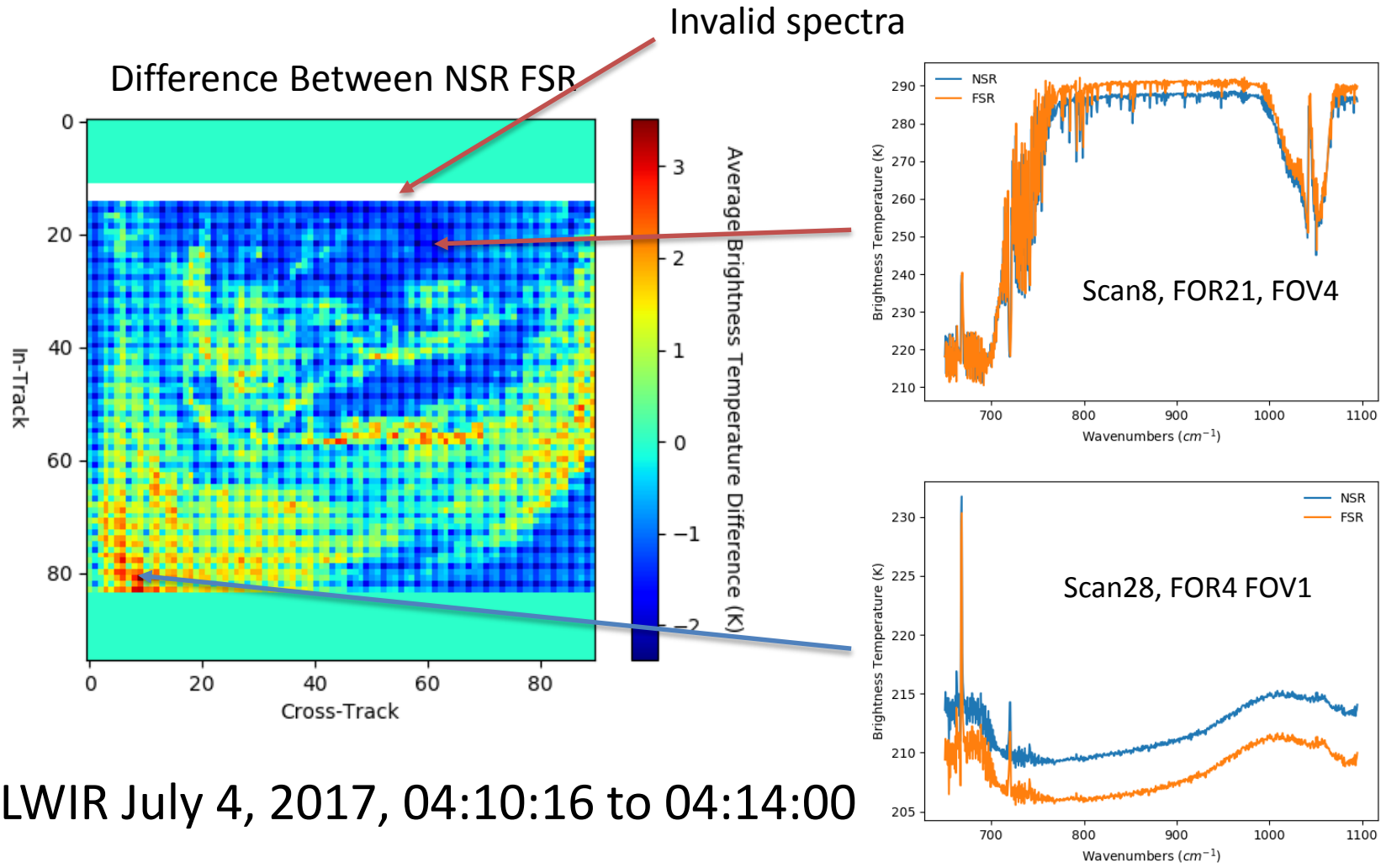
FSR LWIR Anomaly





- Anomaly causes a full row to be flagged invalid.
- SDR quality flag with a value of 2 is invalid.
- LWIR July 4, 2017, 04:10:16 to 04:14:00

Significant Error for Spectra Flagged as Good



- LWIR July 4, 2017, 04:10:16 to 04:14:00

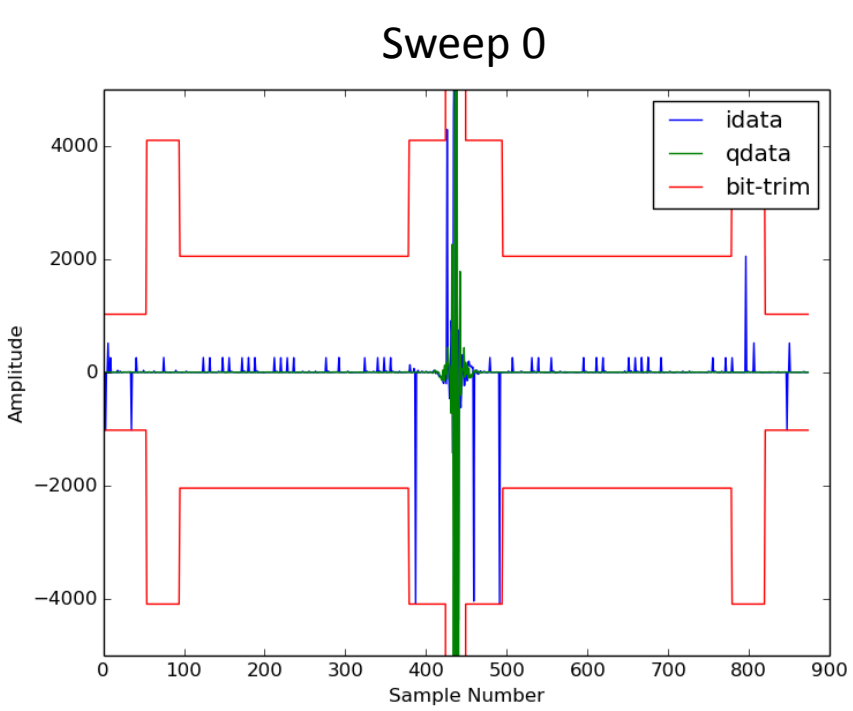
Conclusion

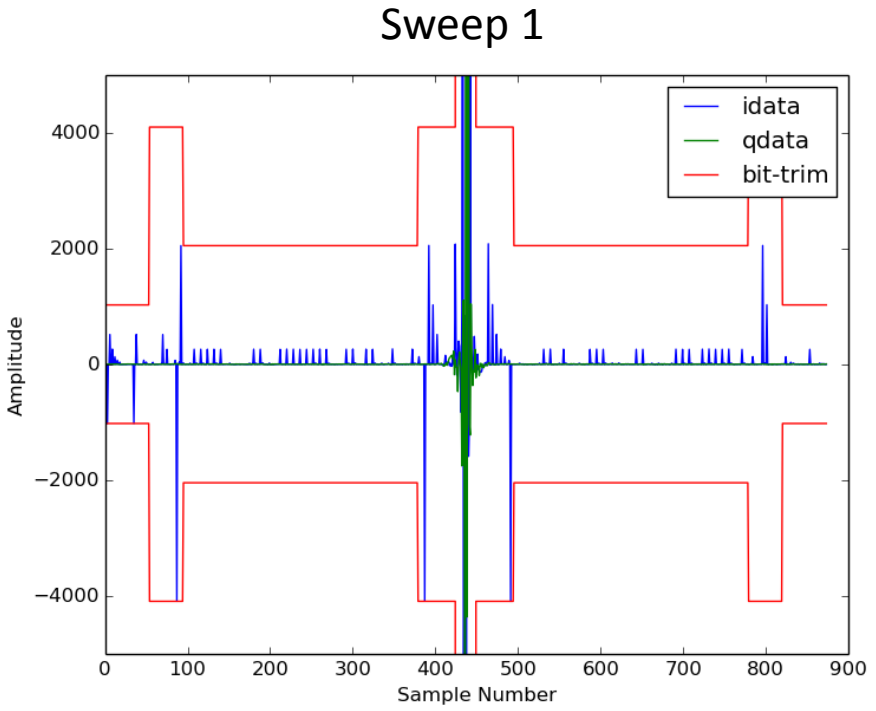
- J1 CrIS sensor has completed ground testing and is ready for launch.
- S-NPP on-orbit performance trending shows the sensor is operating very well with only minimal degradation over five years.
- A new spike correction algorithm has been implemented and tested.
- This new algorithm will be implemented into the ground SDR software.
- Rarely occurring bugs in the SDR software need to be resolved.
- Root causes of these bugs have been identified and software modification is in process.

Backup

S-NPP LWIR Signal Processor Anomaly

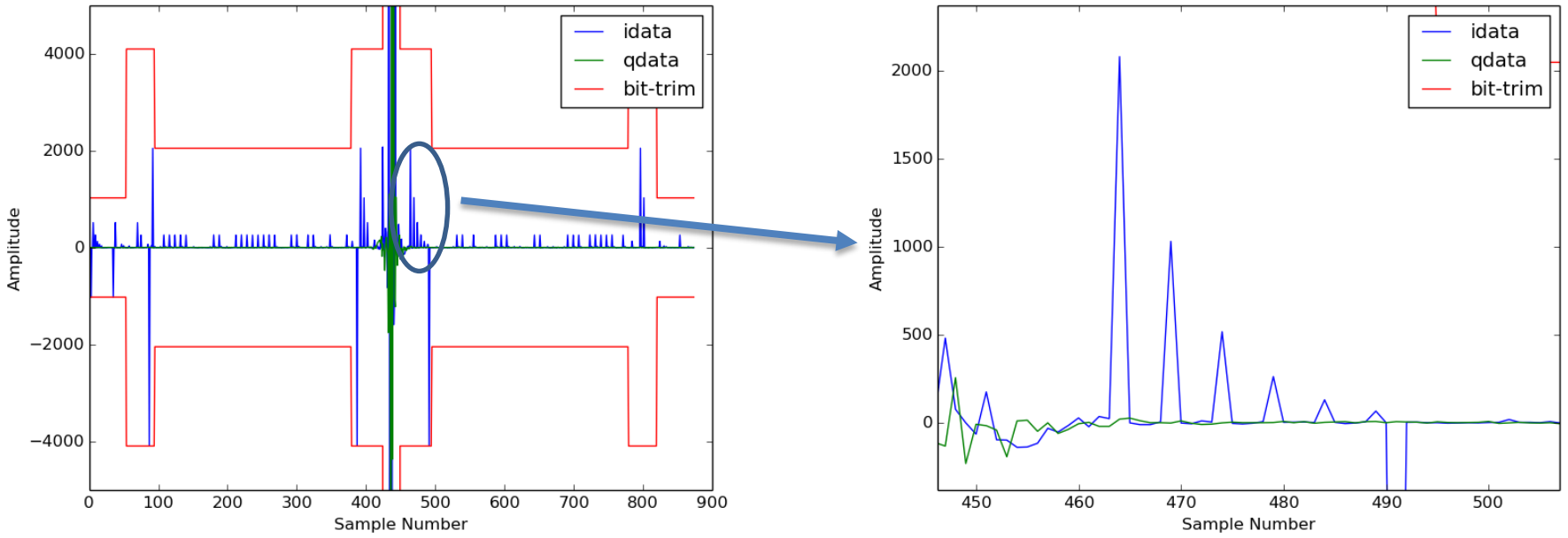
September 28, 2016 Event





- Deep Space FOV9
- Some spikes are repeated in sequential interferograms.
- Does not trigger bit-trim error because of spike placement

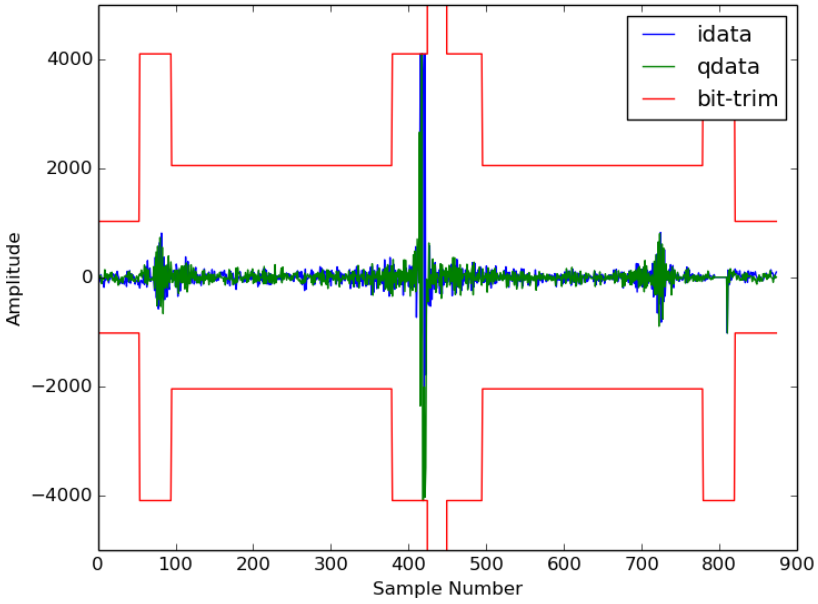
Spikes Appear Quantized



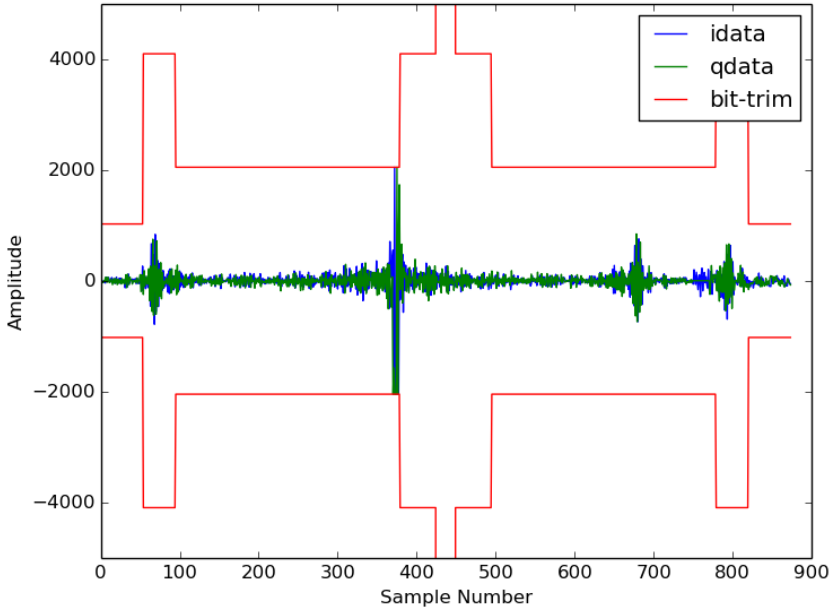
- Peak heights near powers of 2: 64, 128, 256, 512, 1024, 2048
- Data probably correct except for one bit in error.
- Source of errors is after the FIR filter since it affects idata but not qdata.

October 7, 2016 Event

FOR23



FOR24



- Significant apparent shift in ZPD position (both I and Q data)
- FOR23 and FOR24 opposite interferometer sweep directions
- A real interferometer shift would reverse ZPD offset directions.
- Data collection and interferometer not synchronized
- After the LW signal processor was reset, these errors disappeared.