Space Dynamics Laboratory
Utah State University Research Foundation

J1 CrIS Noise Performance & Impulse-Noise/Bit-Trim Mask Optimization

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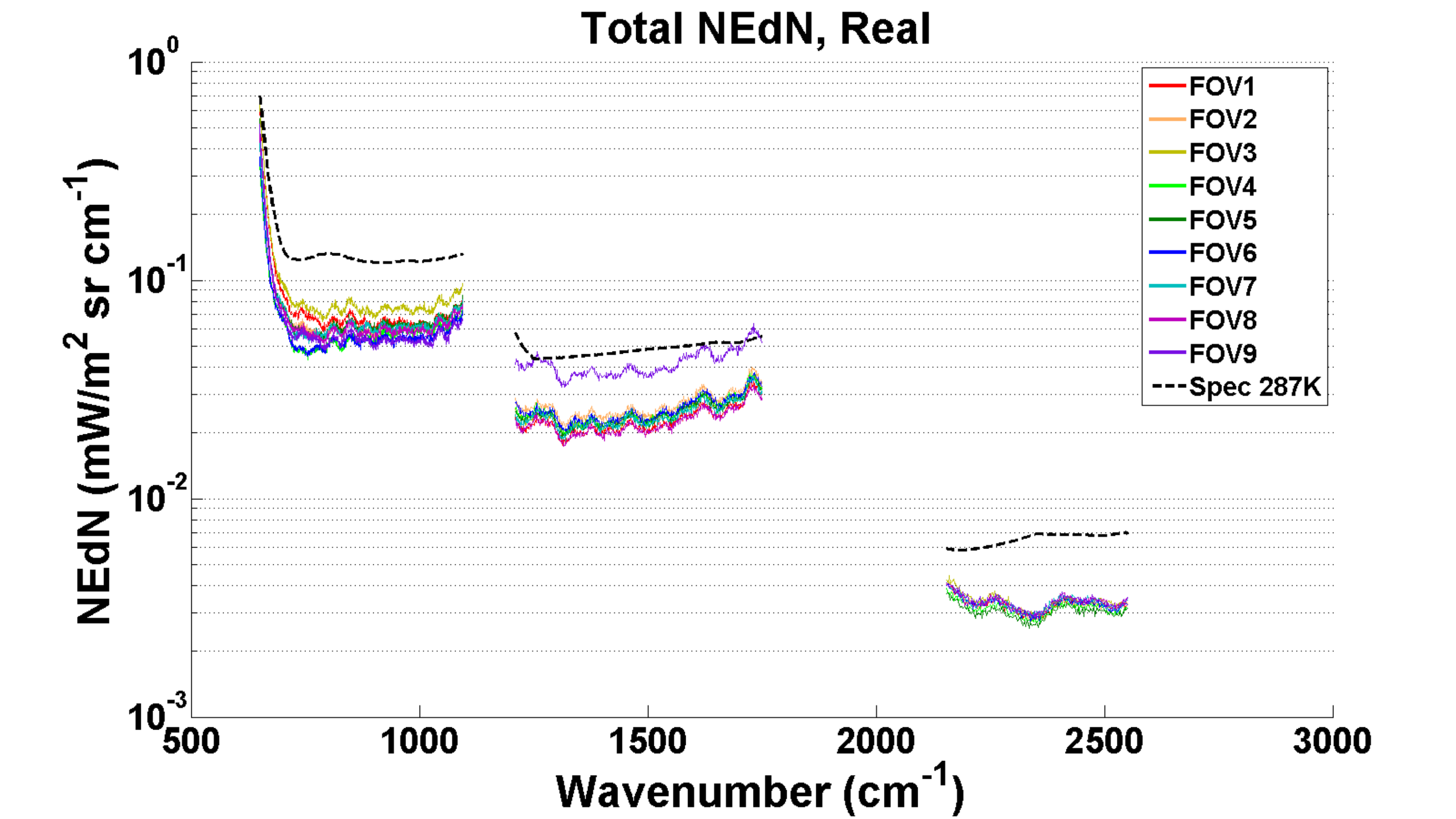
Outline

- Excellent CrIS NEdN performance
- NEdN subtle issues
  - NEdN dependency on photon flux sometimes not as expected
  - Differences in electrical side1 to side 2
- Optimizing bit-trim mask
- Impulse mask considerations
  - Radiation causes spikes in interferograms
  - Detecting/correcting spikes in FIR filtered interferograms

Extensive J1 NEdN Measurements During TVAC

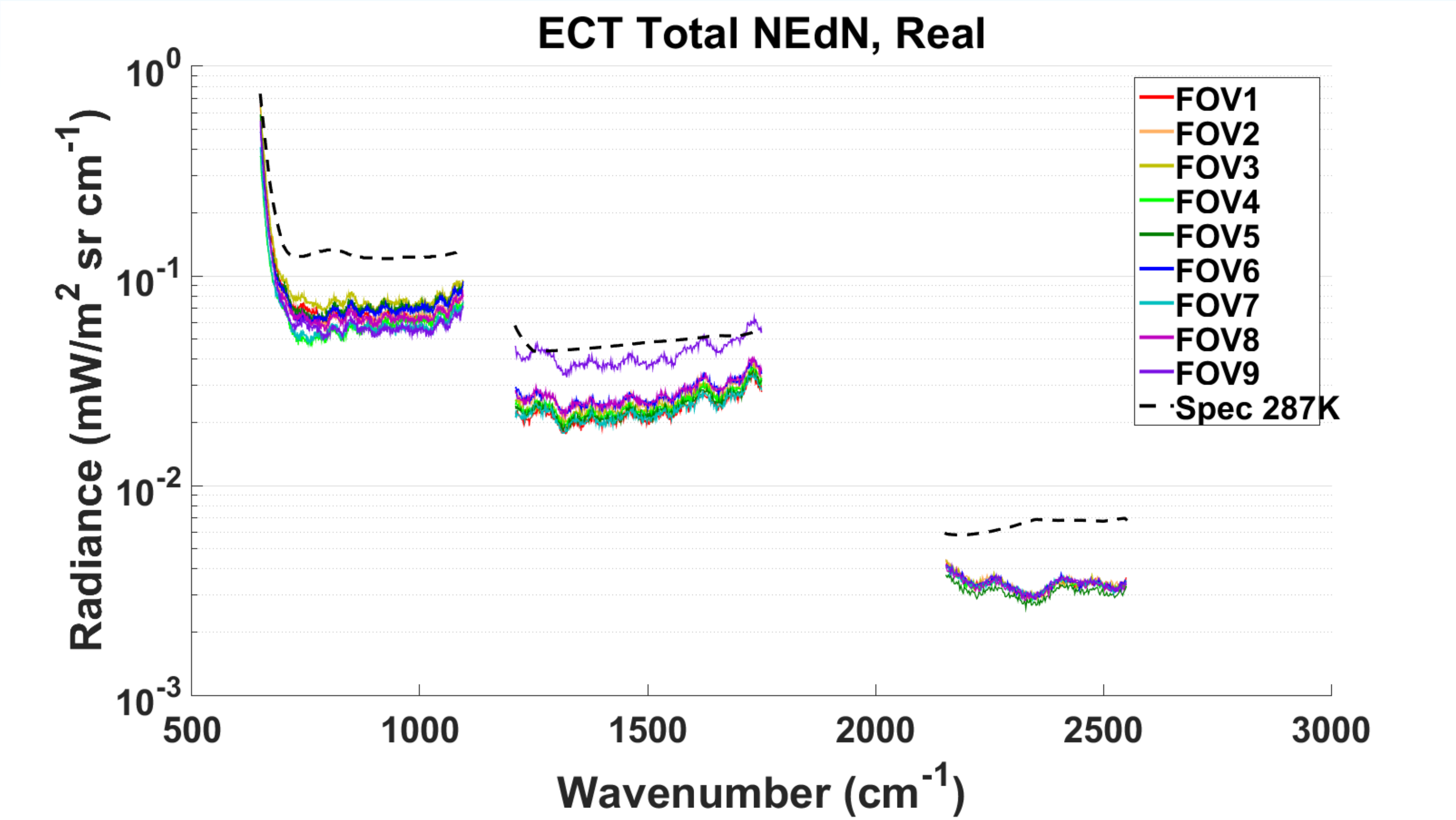
- NEdN from both operational and staring mode
- Three sensor plateaus
  - (PFL) Proto Flight Low (ICT at about 262 K)
  - (MN) Mission Nominal (ICT at about 278 K)
  - (PFH) Proto Flight high (ICT at about 314 K)
- Both electronic sides
- Different power supply voltages
- With induced vibration

Example Staring MN NEdN



- MW FOV9 out of family with other FOVs
- MW FOV9 slightly above spec value
- MN (Mission Nominal) plateau staring mode

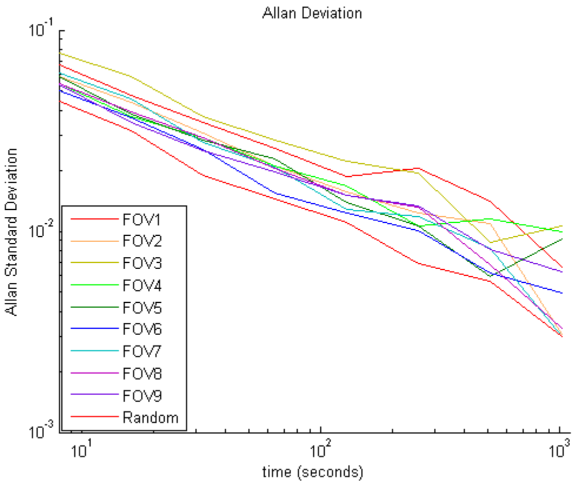
Operational Mode MN NEdN



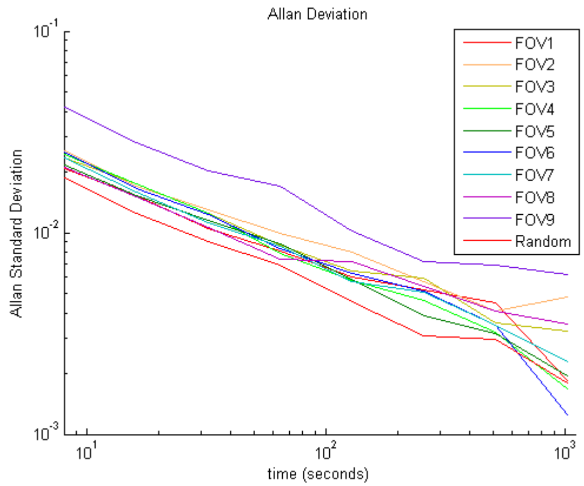
- Staring and operational mode NEdN nearly identical
- MN 287 K ECT, side 1

Allan Deviation

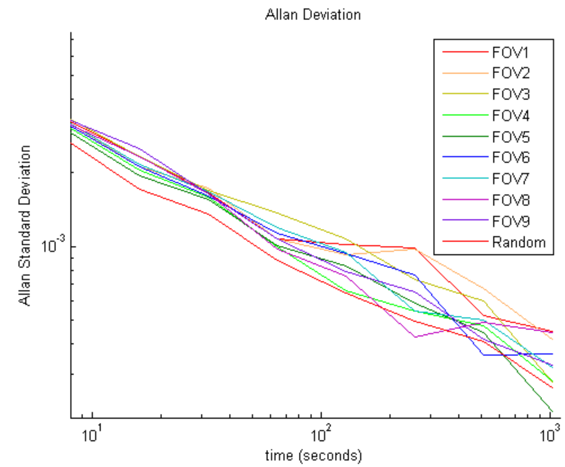
LWIR



MWIR



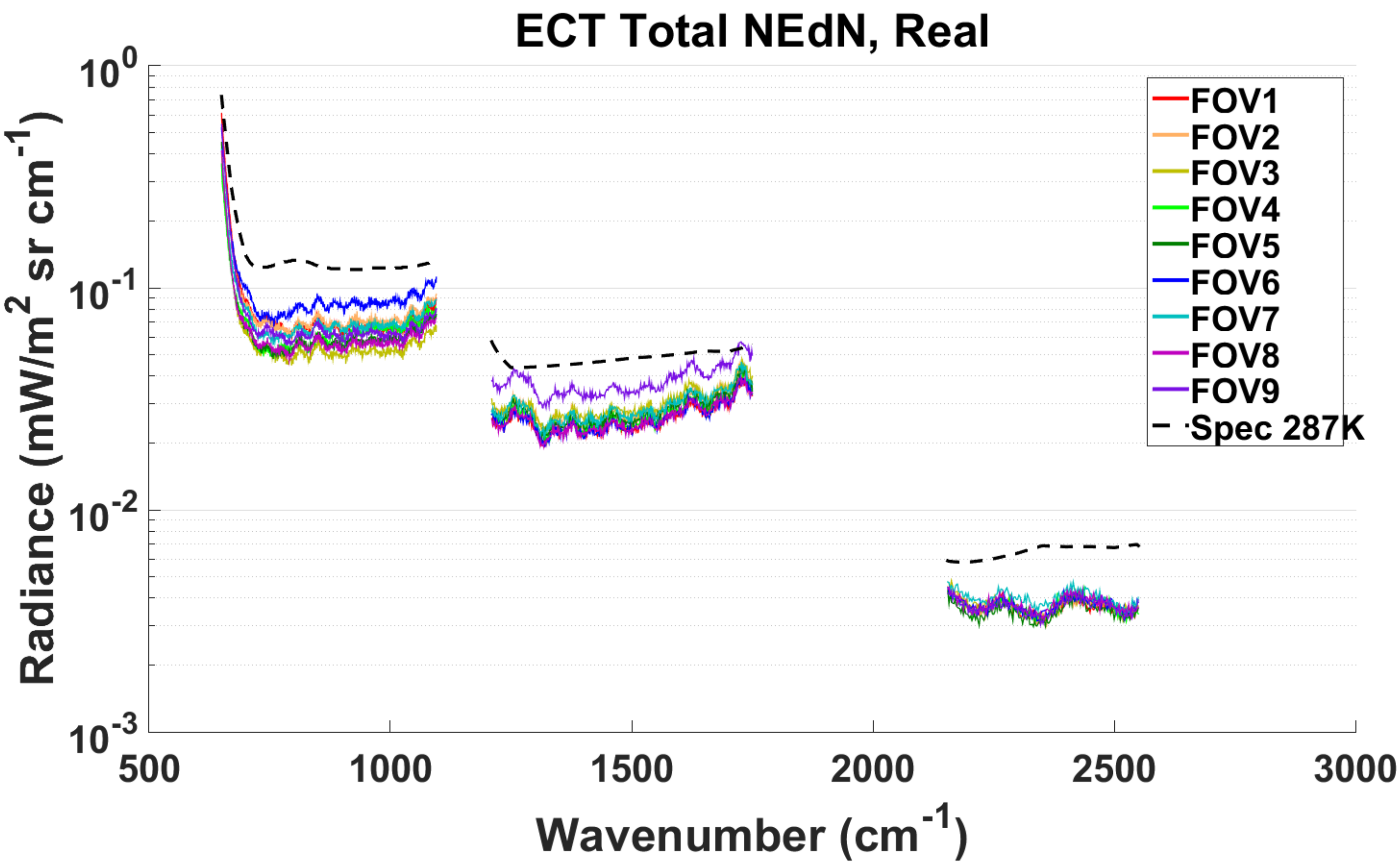
SWIR



- Alternative way to characterize noise behavior
- Standard deviation of sets with increased averaging
- Single spectral channel per band (868, 1234, 2528 cm^{-1})
- MN, 287 K ECT, operational mode, side 1
- Bottom trace is Matlab random noise

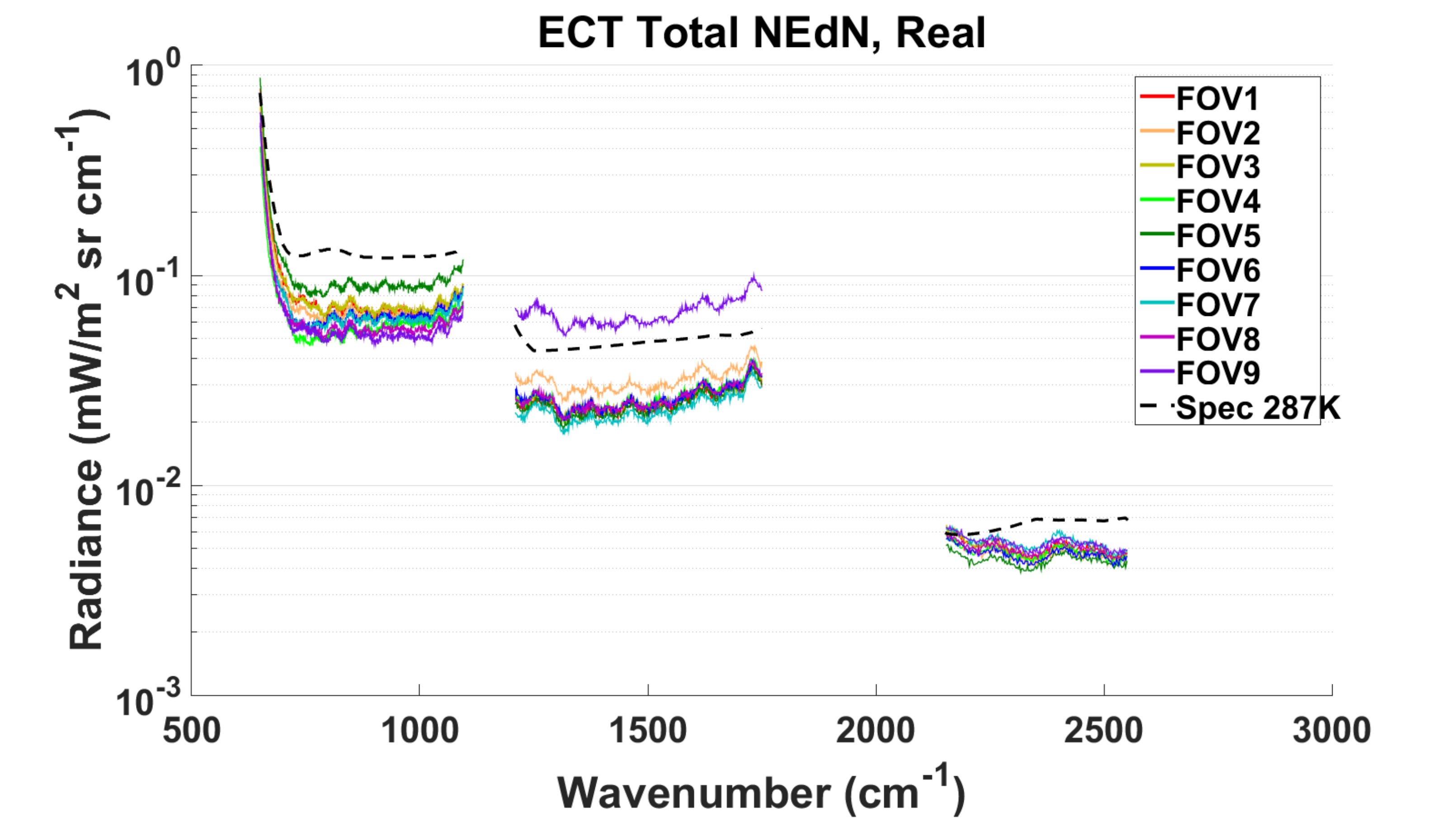
http://www.allanstime.com/AllanVariance/

PFL NEdN



- PFL (Proto Flight High) temperature plateau
- Operational mode, 287 K ECT, side 1

NEdN Slightly Higher for PFH



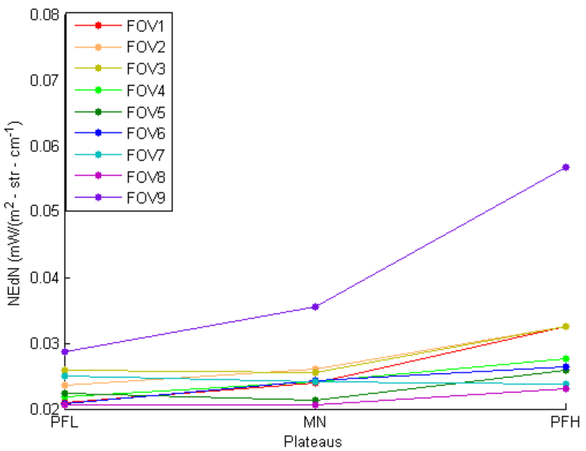
- PFH (Proto Flight High) temperature plateau
- Slightly higher NEdN
- Operational mode, 287 K ECT, side 1

NEdN Verses Photon Flux

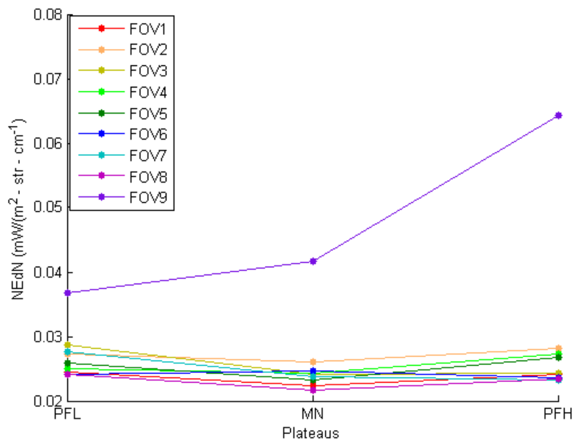
- NEdN expected to increase with photon flux
- Band averaged NEdN of operational mode data
  - LWIR 680-1020 cm^{-1}, MWIR 1220-1600 cm^{-1}, SWIR 2160 – 2400 cm^{-1}
- In general NEdN increases with photon flux as expected
- Exception for large contrast between ECT and CrIS sensor
- Excess noise seen in PFL and PFH
- Behavior may be due to ground testing vibration issue
- Vibration issues also seen during SNPP CrIS TVAC

MWIR Operational NEdN

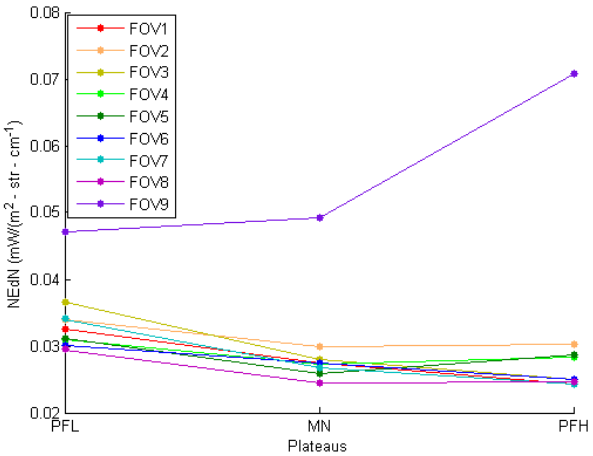
200 K



287 K



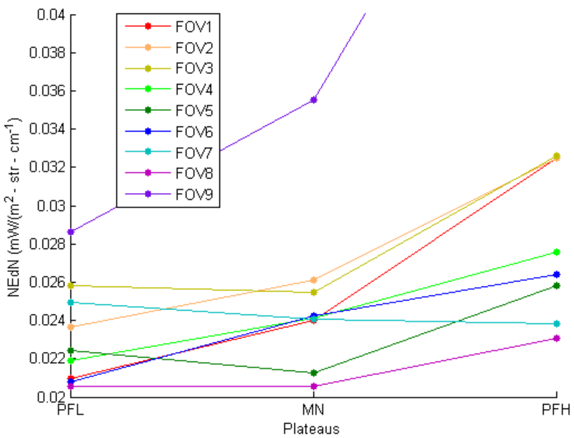
310 K



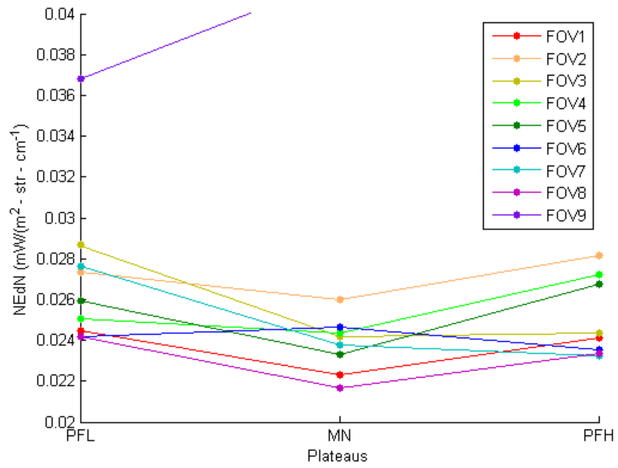
- Average NEdN goes up with photon flux
- MW FOV9 NEdN consistently increases with photon flux
- Component of NEdN difference between sensor and ECT

MWIR Expanded Scale

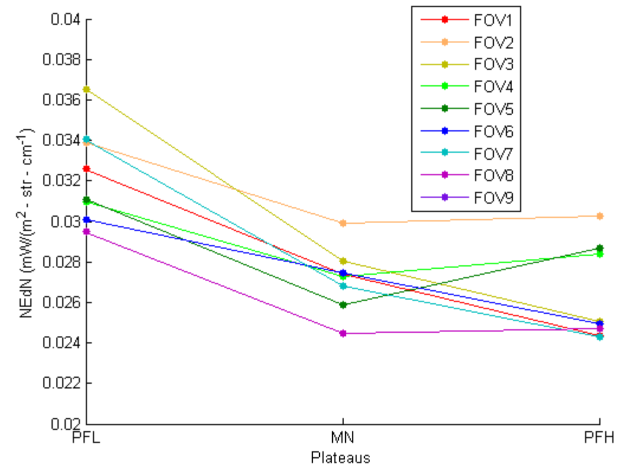
200 K



287 K



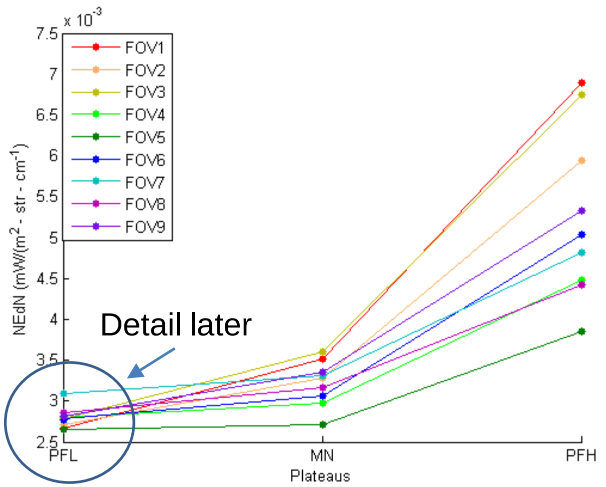
310 K



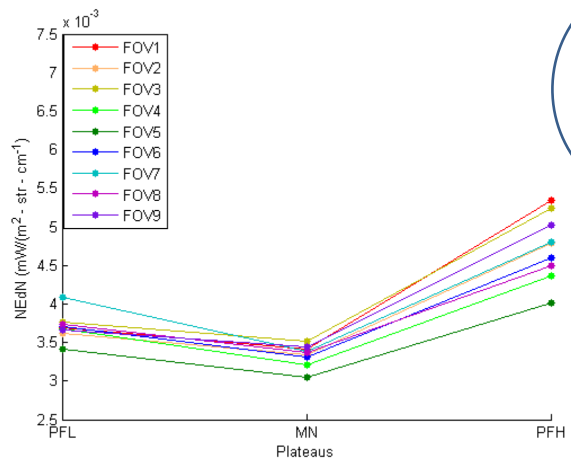
- Average NEdN goes up with photon flux
- Component of NEdN difference between sensor and ECT

SWIR Operational Mode

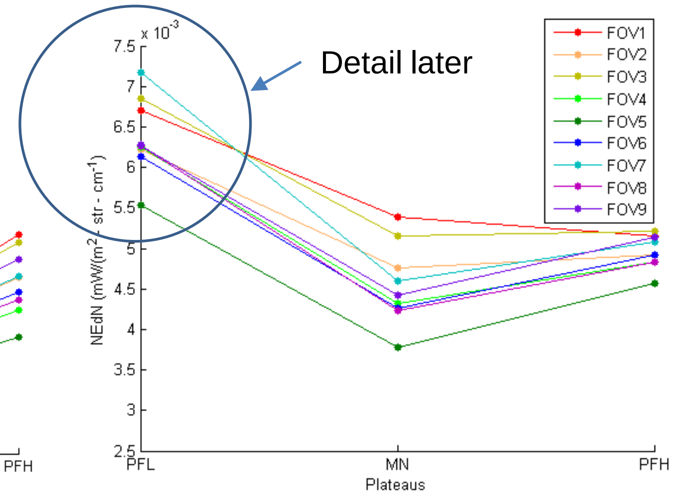
200 K



287 K

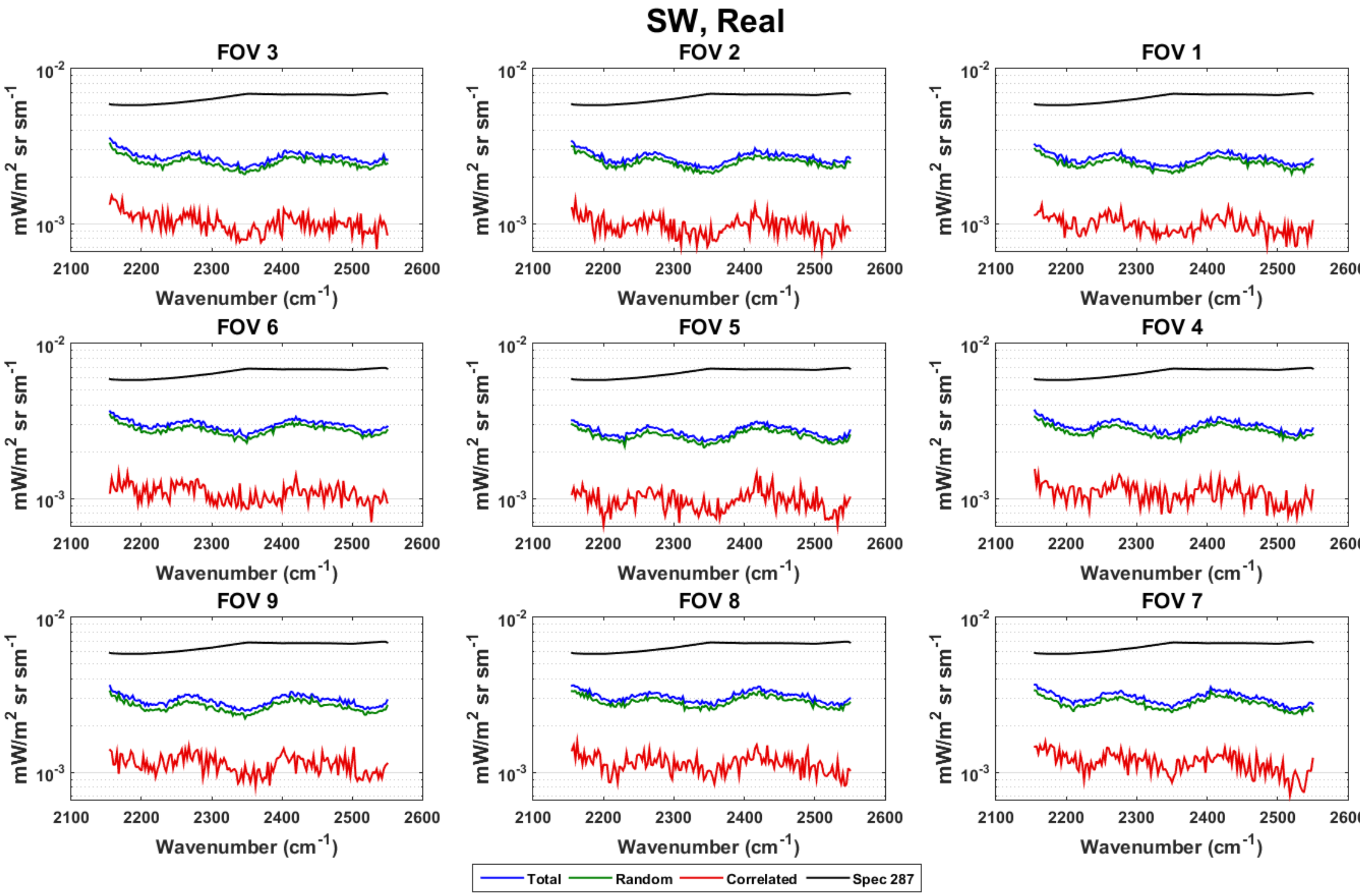


310 K



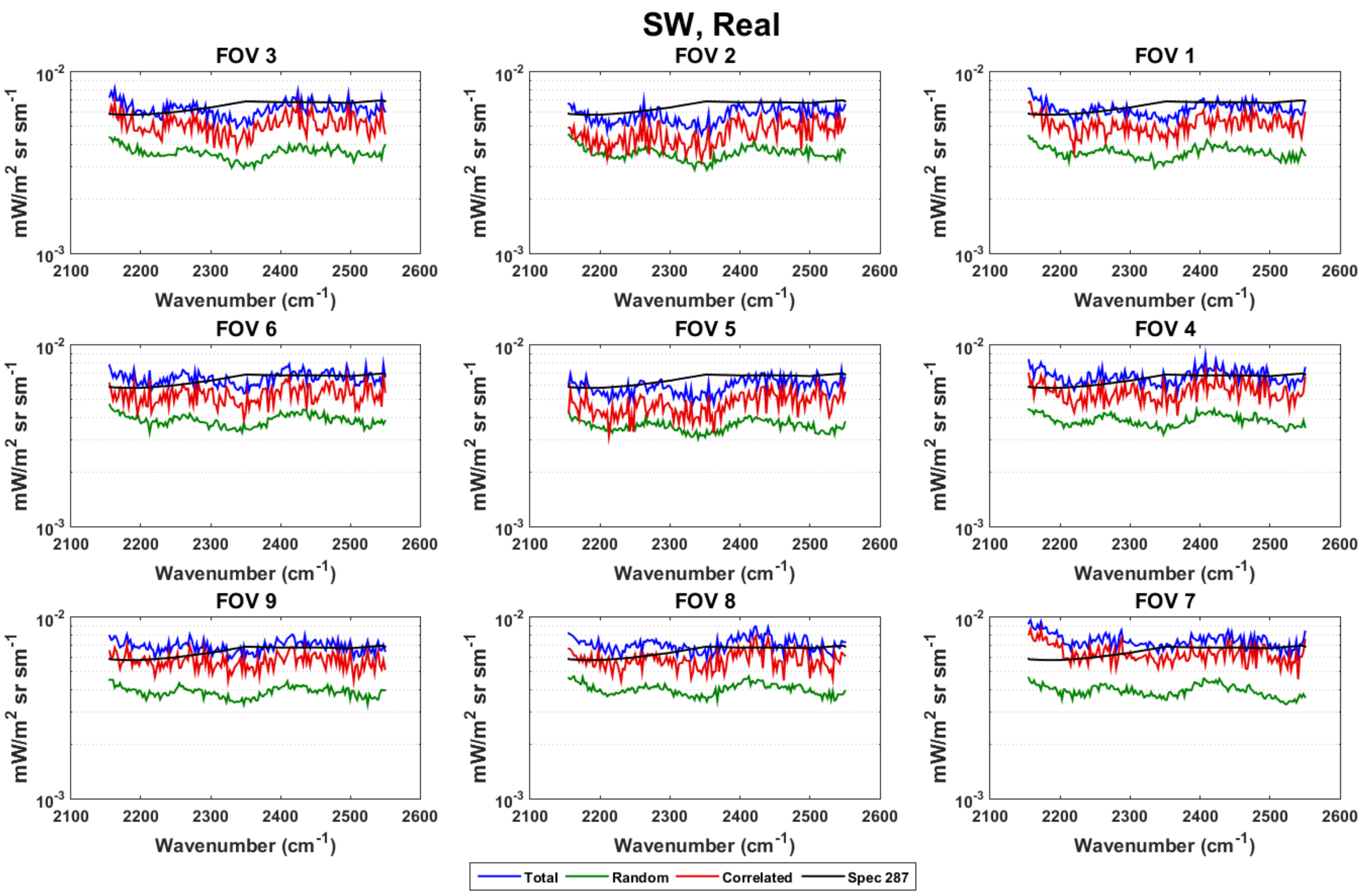
- Average NEdN goes up with temperature
- Component of NEdN difference between sensor and ECT
- Possible indication of vibration effects
- Staring mode data didn't show as large effect

PFL 200 K ECT



- Spectrally correlated noise is insignificant

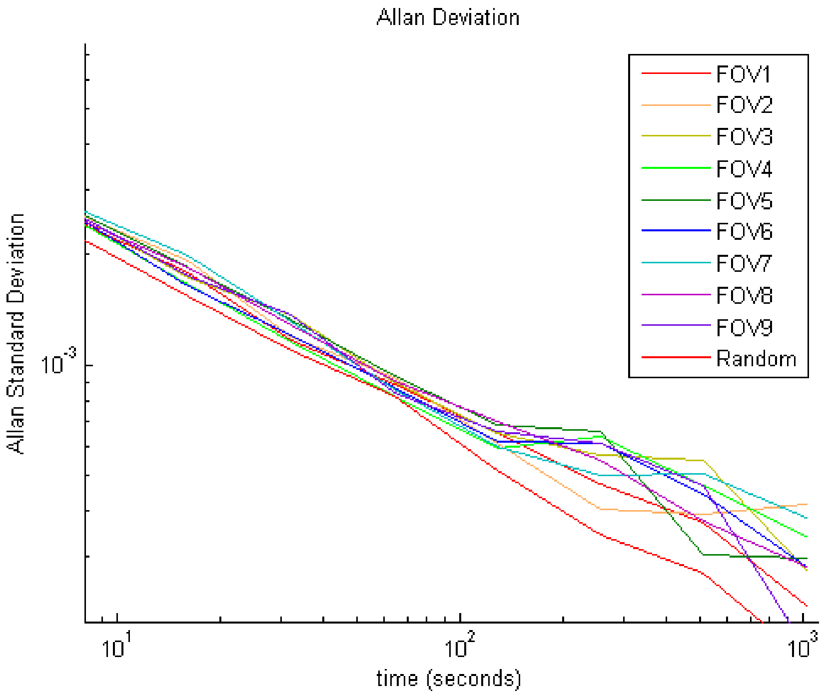
PFL 310 K ECT



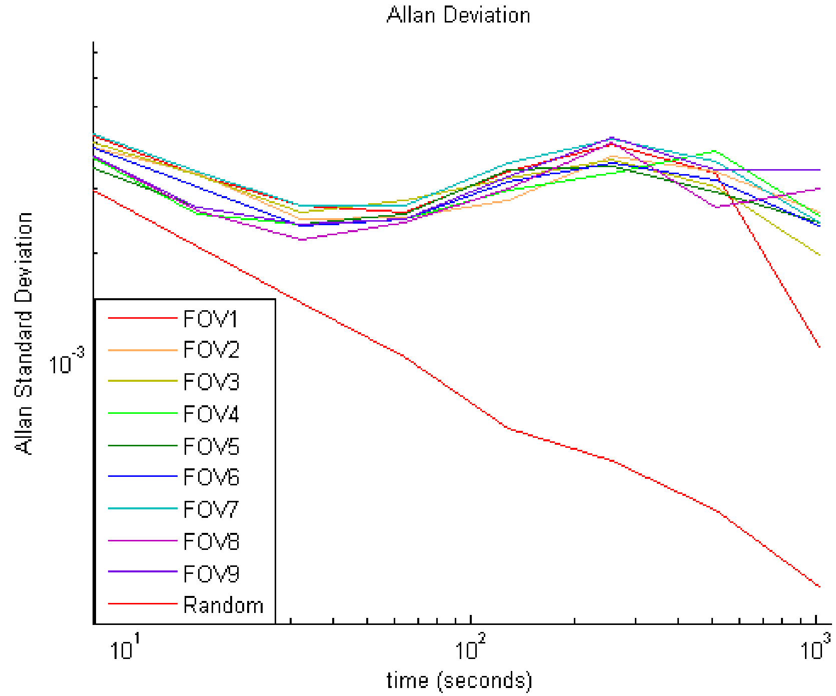
- Spectrally correlated noise dominates random noise

Allan Deviation Also Show Non-Ideal Behavior

PFL 200 K ECT



PFL 310 K ECT

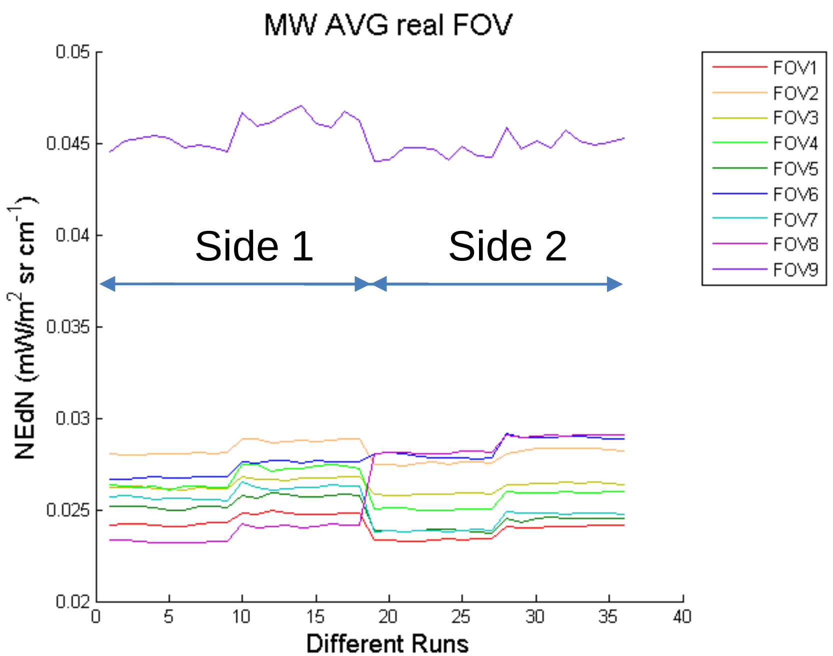


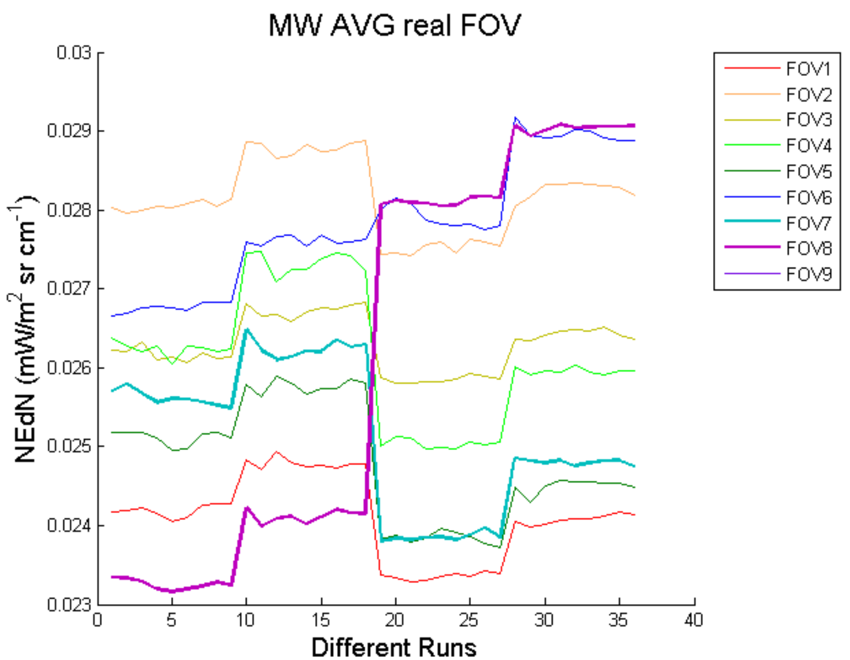
- Same cases as previous two slides
- In 310 K case noise increased and character changed
- Bottom plot Matlab random number generator

Electronic Side 1 Side 2 NEdN Differences

- Differences in NEdN between side 1 and side 2 have been observed
- Actual differences or random measurement error?
- Operational data more representative of on-orbit operation
- LTR (Long Term Repeatability) data set
  - Consists of 36 collections 2 hours each
- Averaged over spectral band to produce one NEdN point for each FOV per 2 hour measurement
  - Removed LWIR NEdN tail (band averaged over 750 – 1050 cm^{-1})
  - Only real data shown, imaginary results are similar
- Concatenated measurements into one time series
- First half side 1, second half side 2

NEdN Trend for MWIR LTR

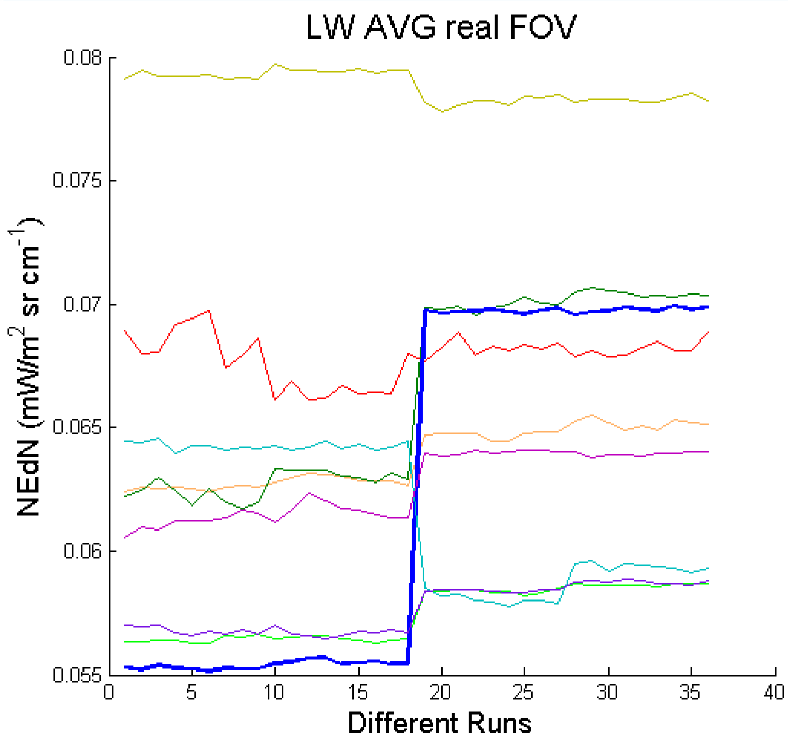


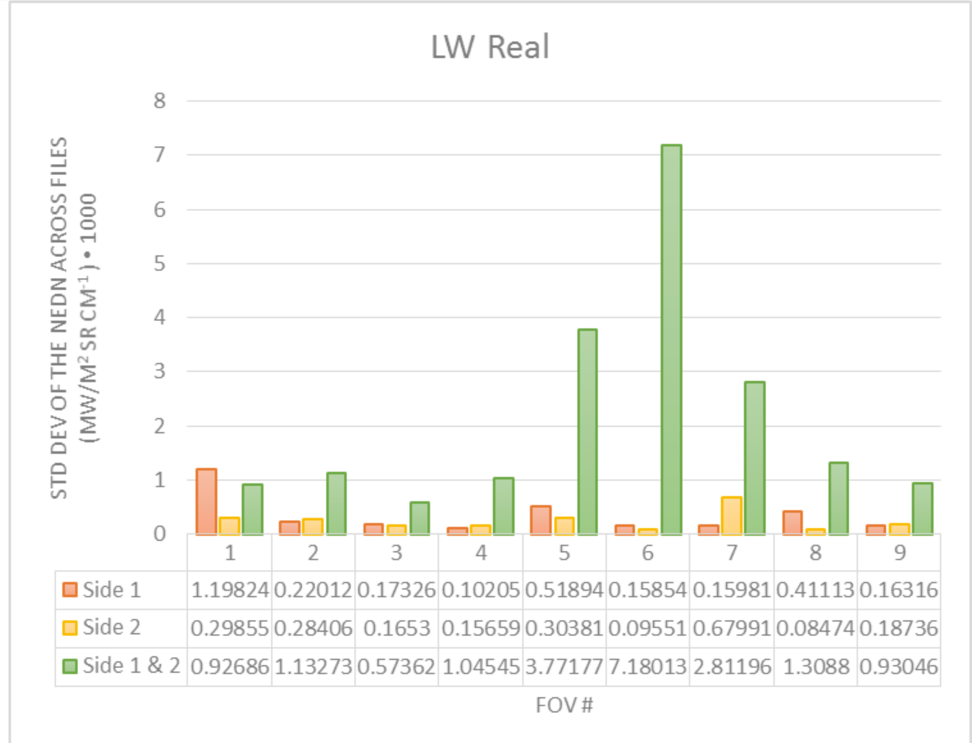


With FOV9 Removed

- FOV9 is out of family
- FOV 8 has positive side 1 to side 2 jump
- FOV7 has negative jump

LWIR LTR

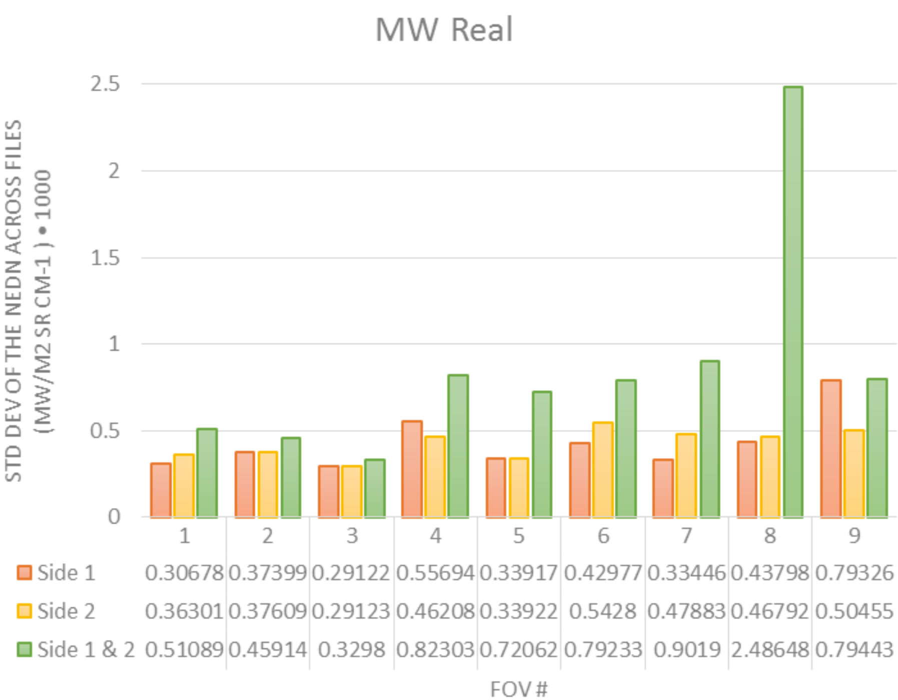




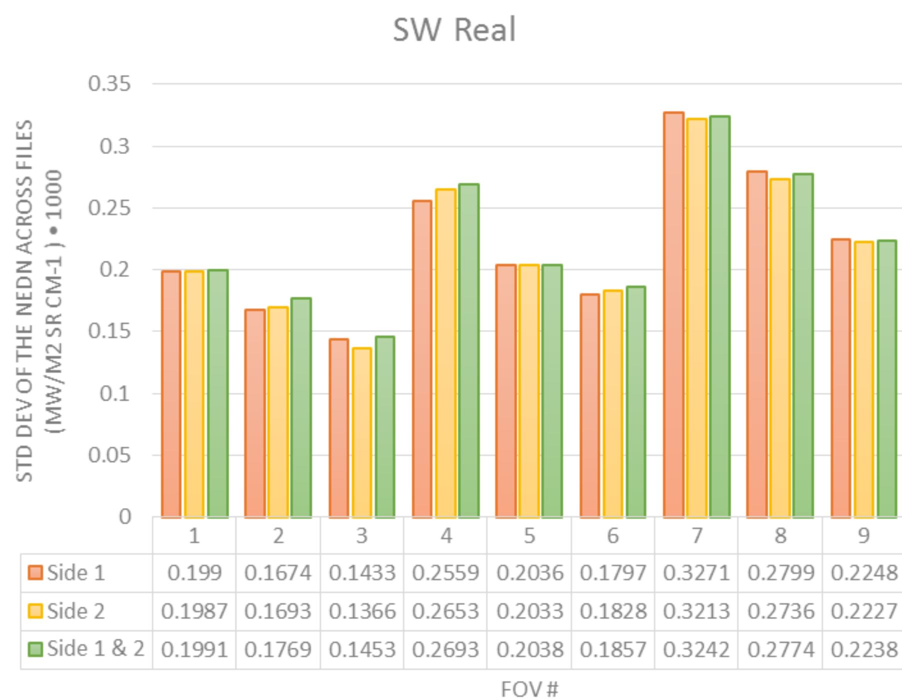
	1	2	3	4	5	6	7	8	9
Side 1	1.19824	0.22012	0.17326	0.10205	0.51894	0.15854	0.15981	0.41113	0.16316
Side 2	0.29855	0.28406	0.1653	0.15659	0.30381	0.09551	0.67991	0.08474	0.18736
Side 1 & 2	0.92686	1.13273	0.57362	1.04545	3.77177	7.18013	2.81196	1.3088	0.93046

- Bar chart gives alternative view of data
- Bars are the standard deviation of data for side 1, side 2, and combined side 1 and side 2
- Shows if differences are statically significant

MWIR and SWIR LTR



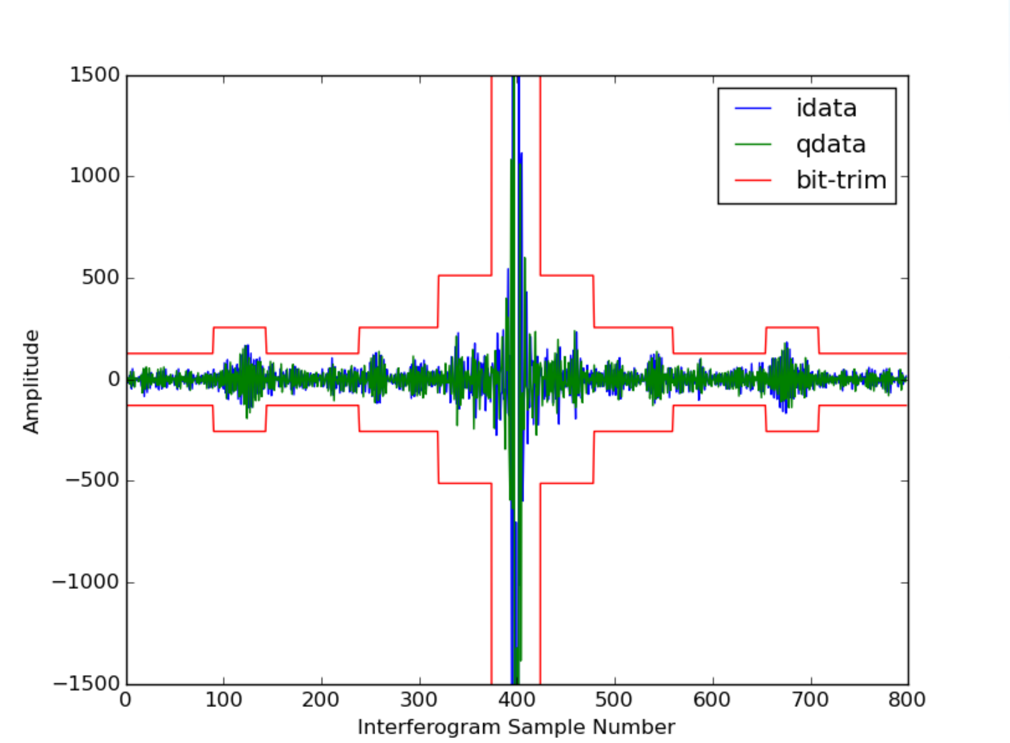
	1	2	3	4	5	6	7	8	9
Side 1	0.30678	0.37399	0.29122	0.55694	0.33917	0.42977	0.33446	0.43798	0.79326
Side 2	0.36301	0.37609	0.29123	0.46208	0.33922	0.5428	0.47883	0.46792	0.50455
Side 1 & 2	0.51089	0.45914	0.3298	0.82303	0.72062	0.79233	0.9019	2.48648	0.79443



	1	2	3	4	5	6	7	8	9
Side 1	0.199	0.1674	0.1433	0.2559	0.2036	0.1797	0.3271	0.2799	0.2248
Side 2	0.1987	0.1693	0.1366	0.2653	0.2033	0.1828	0.3213	0.2736	0.2227
Side 1 & 2	0.1991	0.1769	0.1453	0.2693	0.2038	0.1857	0.3242	0.2774	0.2238

- MW FOV8 shows large side 1 side 2 difference
- SW side 1 to 2 differences are not statistically significant

Bit-Trim Mask Optimization

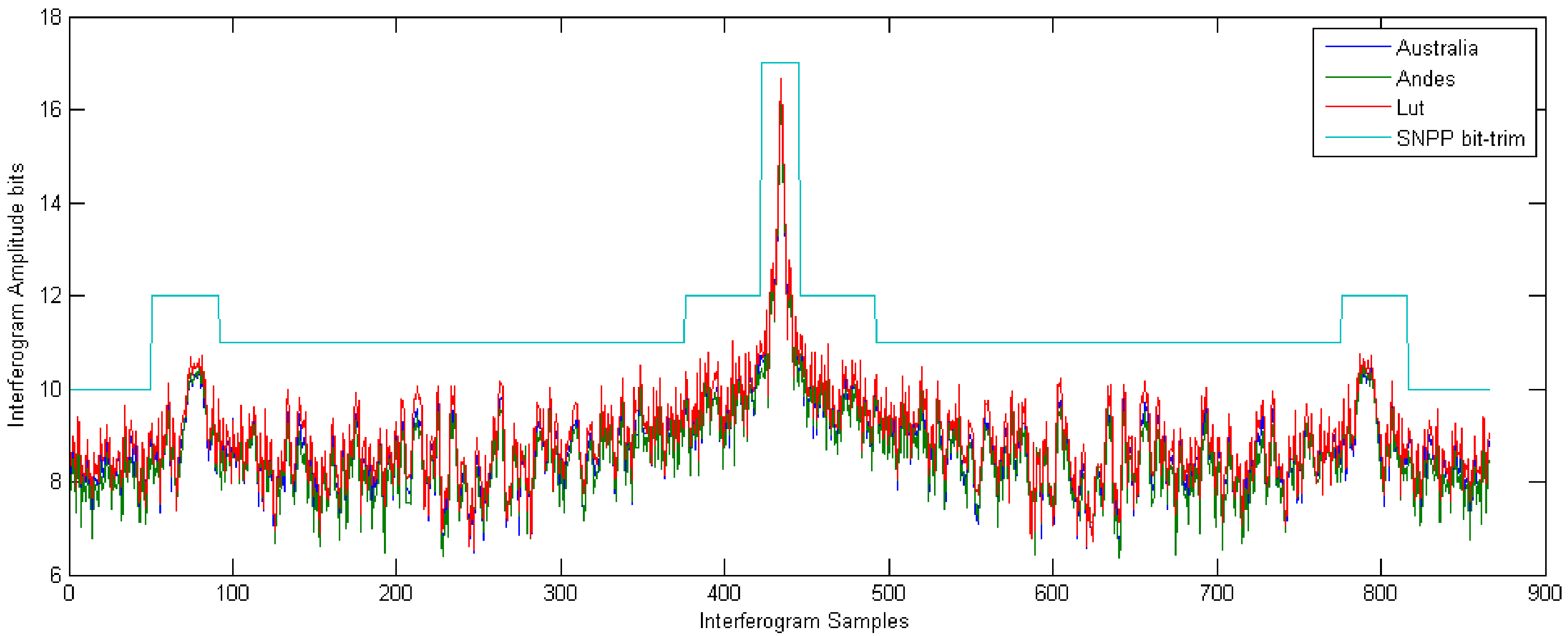


- Number of bits needed to define an interferogram depends on interferogram position
- Larger number of bits needed near center, less in wings
- Lut Desert Iran, 6/21/2015

Bit-Trim Mask Optimization

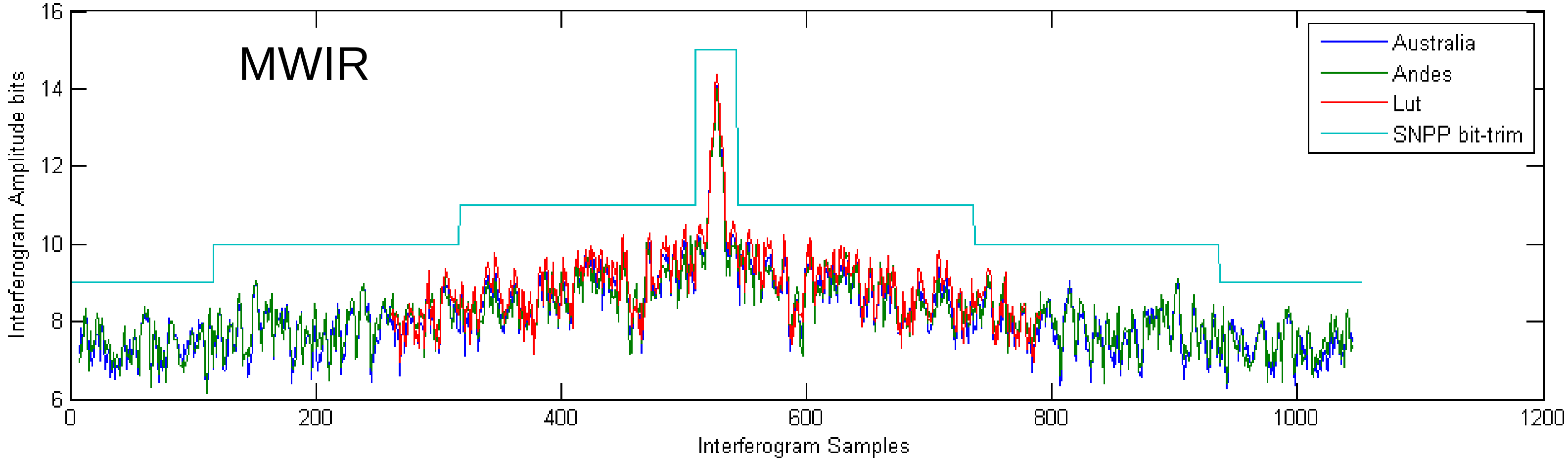
- Bit-trim is a lossless data compression technique
- Needs to be optimized for best performance
  - Bit-trim too conservative waste bandwidth
  - Too aggressive corrupt bright scene data
- J1 can benefit from SNPP data
- Compare largest interferogram amplitude for each interferogram point of a scene with bit-trim mask
- Pick SNPP scenes with high dynamic range
  - Australia February 23, 2012 (orbit 01671)
  - Andes Mountains March 12, 2013 (obit 07113)
  - Lut Desert, Iran July 14, 2012 (orbit 03689)
- Use same bit-trim mask for J1 as presently used for SNPP

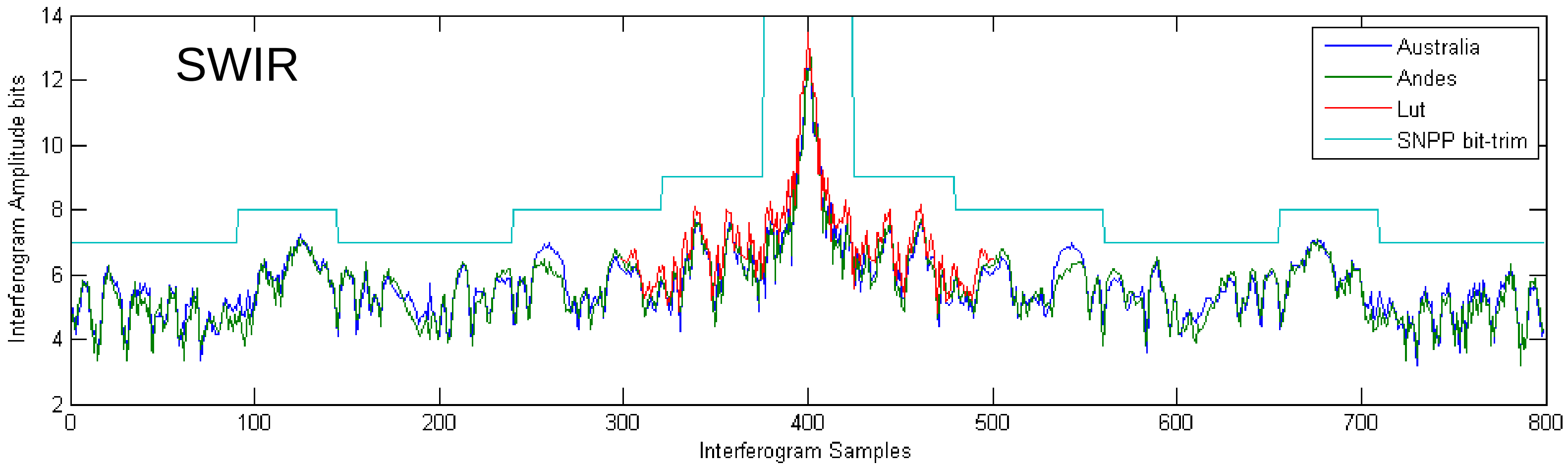
LWIR Bit-Trim Mask



- Absolute value of maximum interferogram at each interferogram position is plotted with positive part of bit-trim mask
- SNPP interferograms are always below bit-trim mask

MWIR and SWIR Bit-Trim Masks

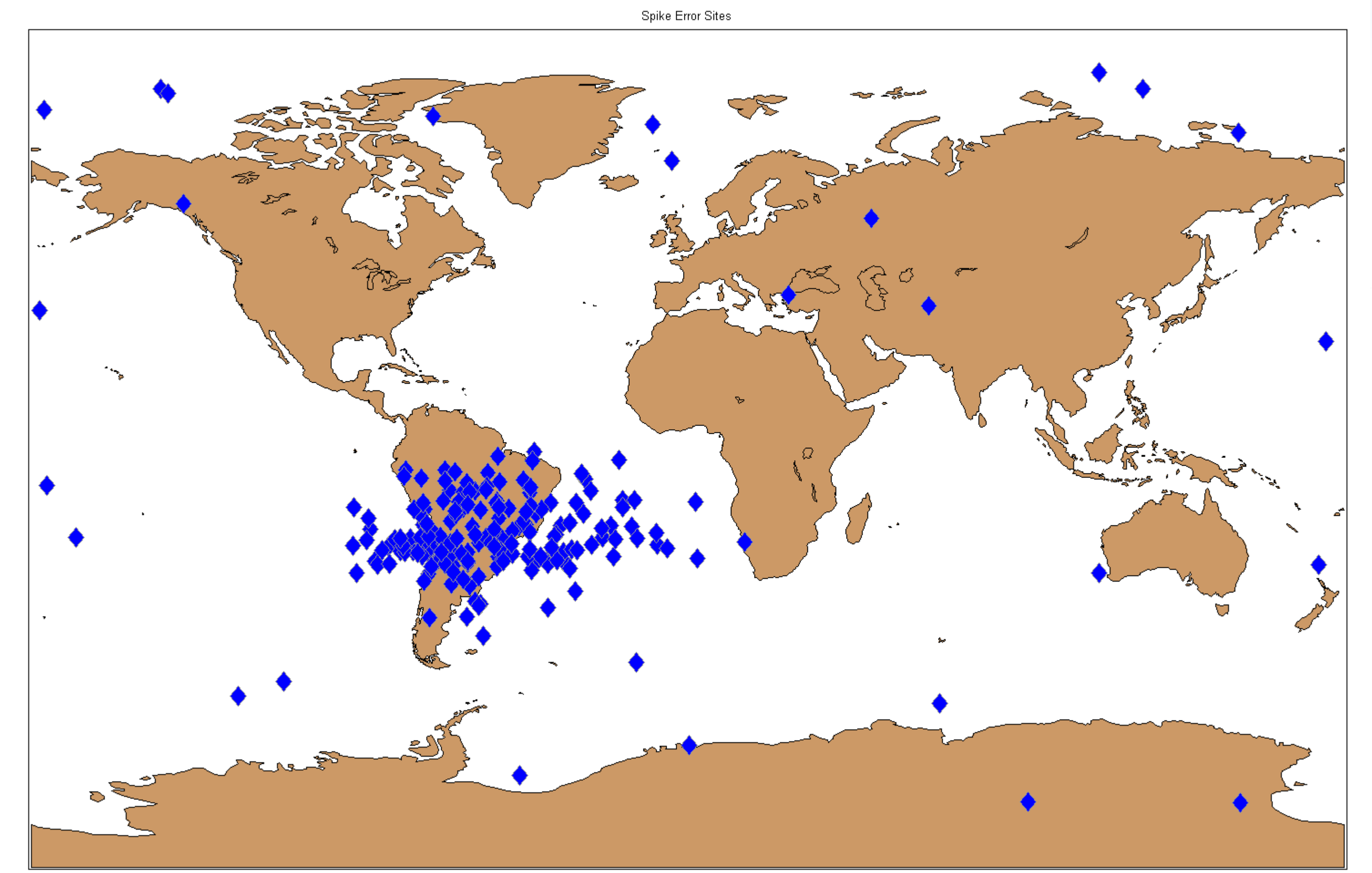




Interferogram Spikes

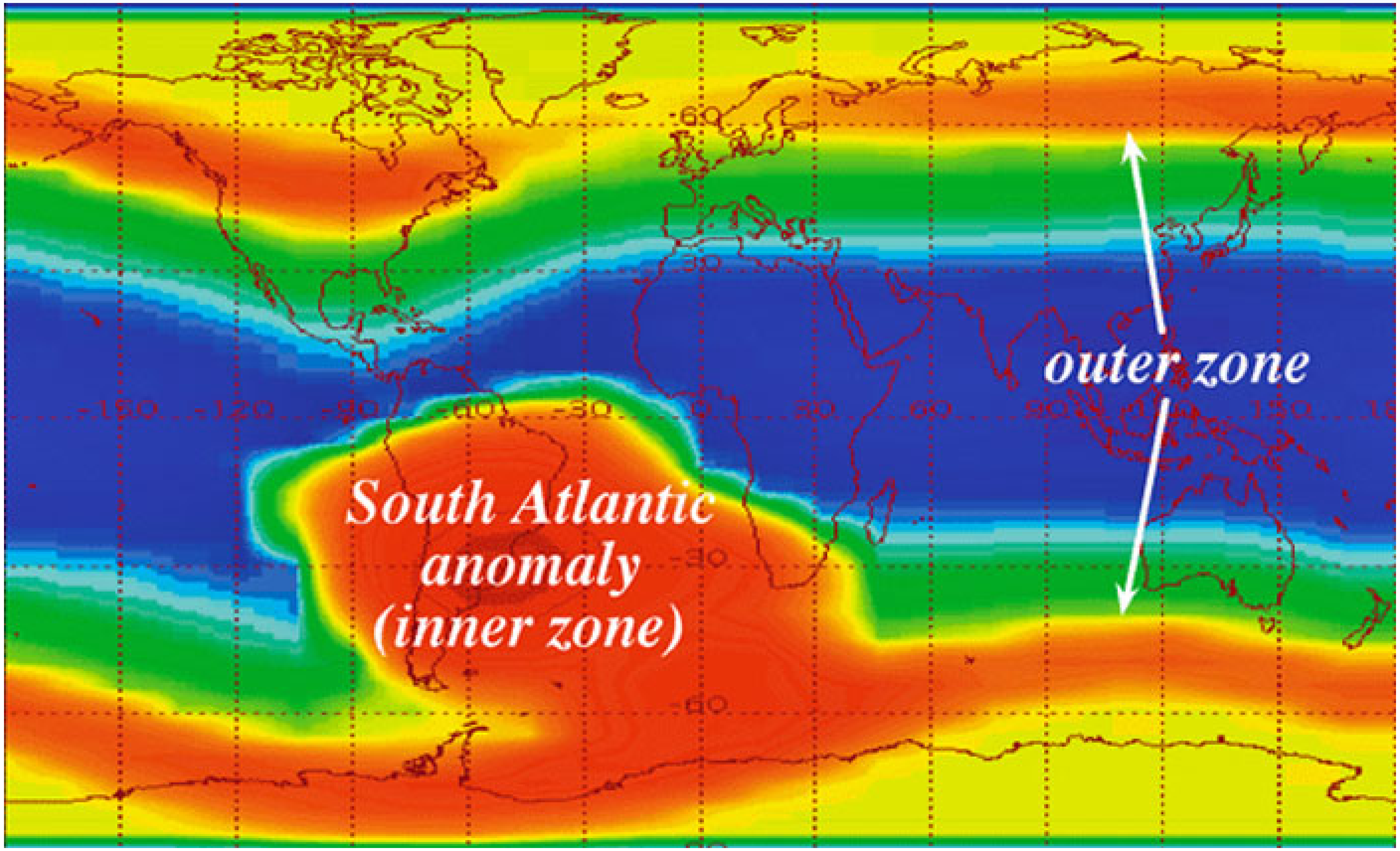
- Radiation can cause spikes in interferograms
- Impulse mask designed to zero out interferogram spikes
- SWIR is most affected (smallest detector current)
- Impulse mask operates on interferograms before FIR filter
- Electrical offsets and low frequency signals cause false triggers
- Impulse mask must be set high to avoid false triggers
- Small spikes are not presently being detected/corrected
- Many more small spikes than large spikes
- A method of detecting spikes is through interferogram asymmetry
- Small spikes can be detected/corrected on the ground

Geographical Distribution of Interferograms with Spikes



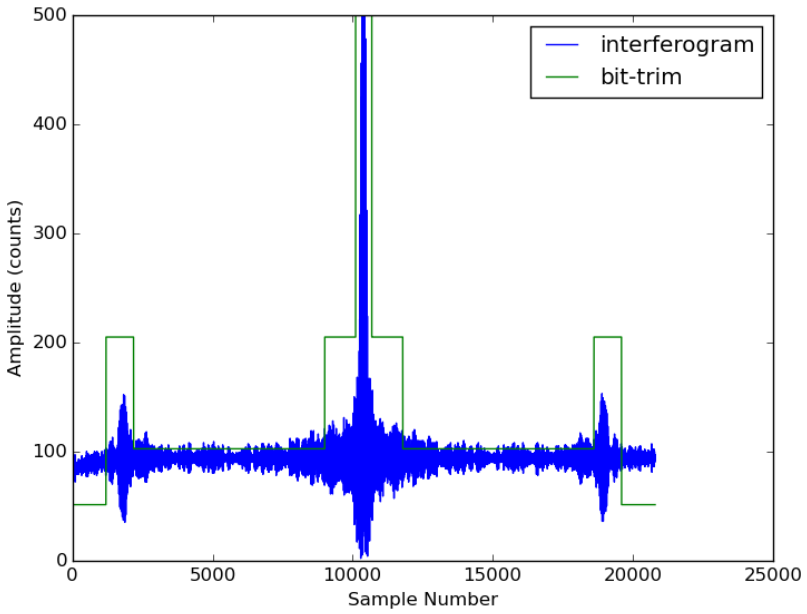
- Medium sized SW spike January to May 2015

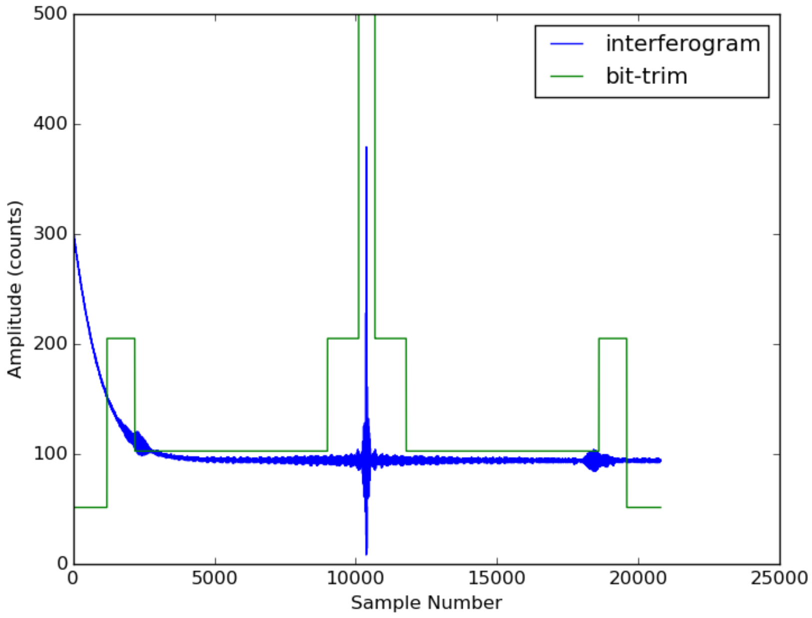
Low Earth Orbit Radiation Distribution



- From NASA/SAMPEX satellite

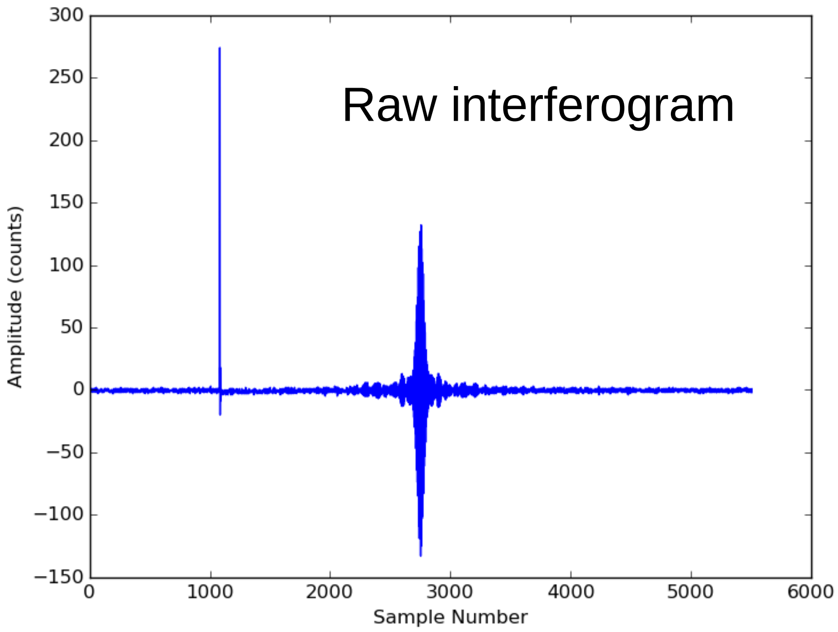
Can’t Use Scaled Bit-Trim Mask for Impulse Mask

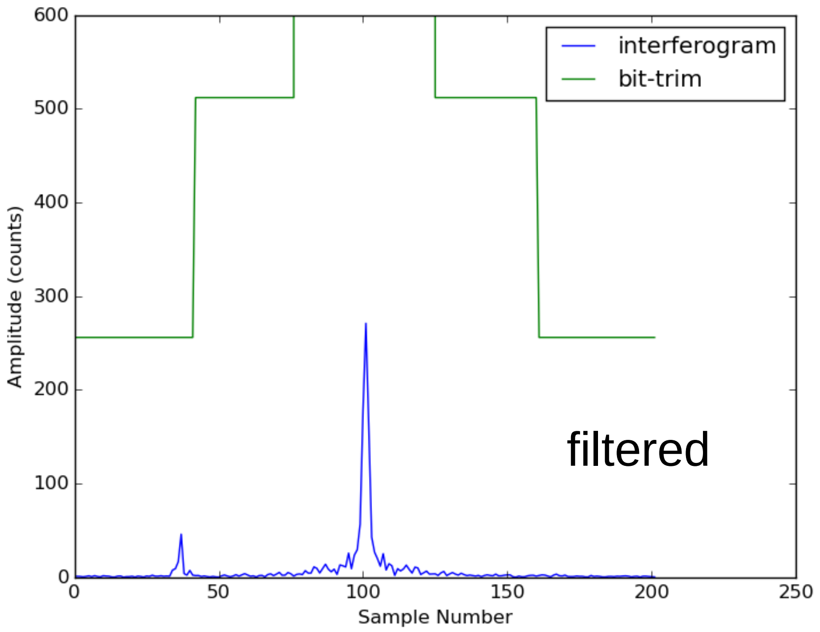




- Diagnostic mode allows view of raw interferograms
- Bit-trim mask scaled to raw interferogram levels
- Electronic offset about 95 counts for LW and MW
- Beginning of scan transient can be around 200 counts

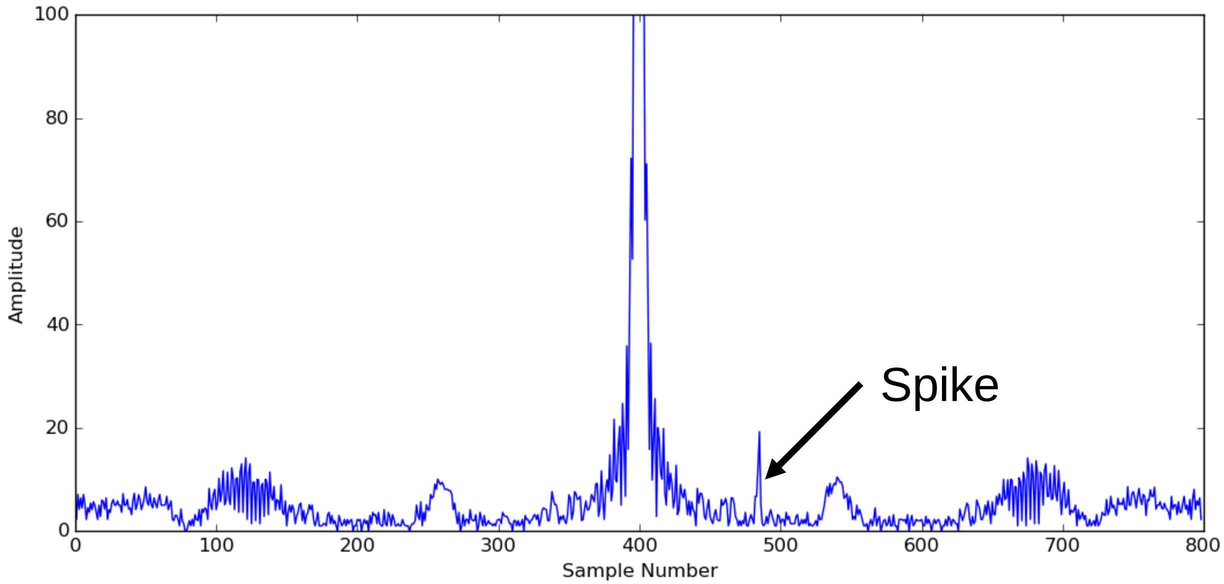
Example of Spike in SW Interferogram





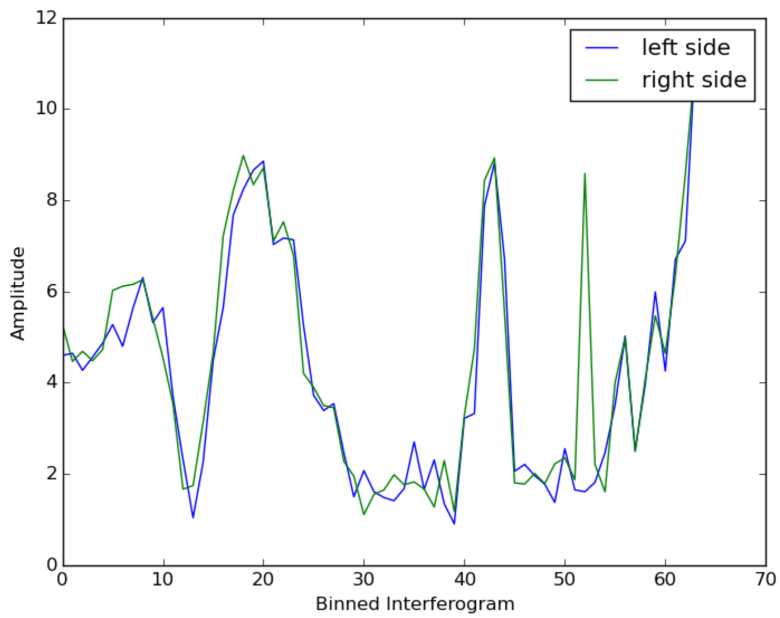
- Filtered interferogram is absolute value
- Many SW interferogram have small amplitudes
  - High dynamic range in the SW scenes
- Xin Jin estimated 123 spikes/day for side (less than 0.07%)

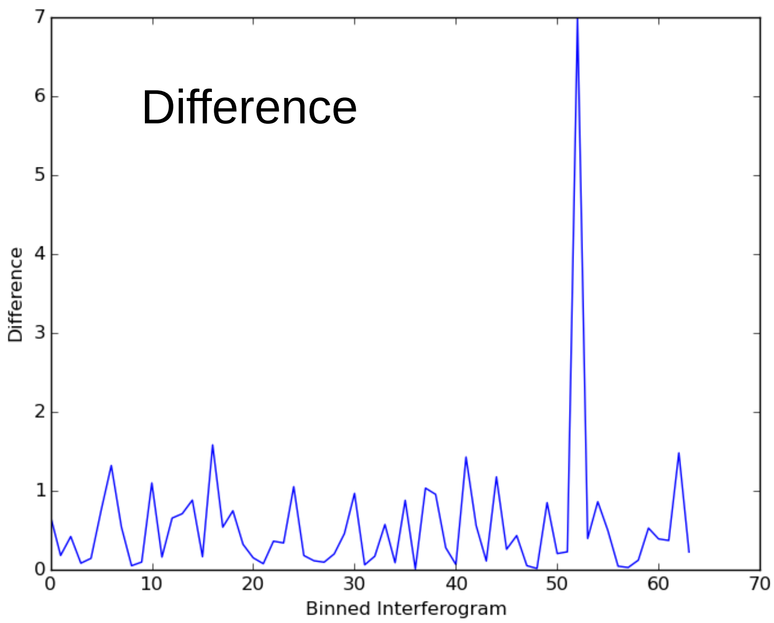
Detecting Interferogram Spikes



- A simple amplitude mask isn't very effective to detect spikes
  - Bright scenes can be larger than spikes
- Interferograms should be symmetric
- Interferogram phase makes direct left side to right side comparisons difficult
- Absolute value of interferogram plotted

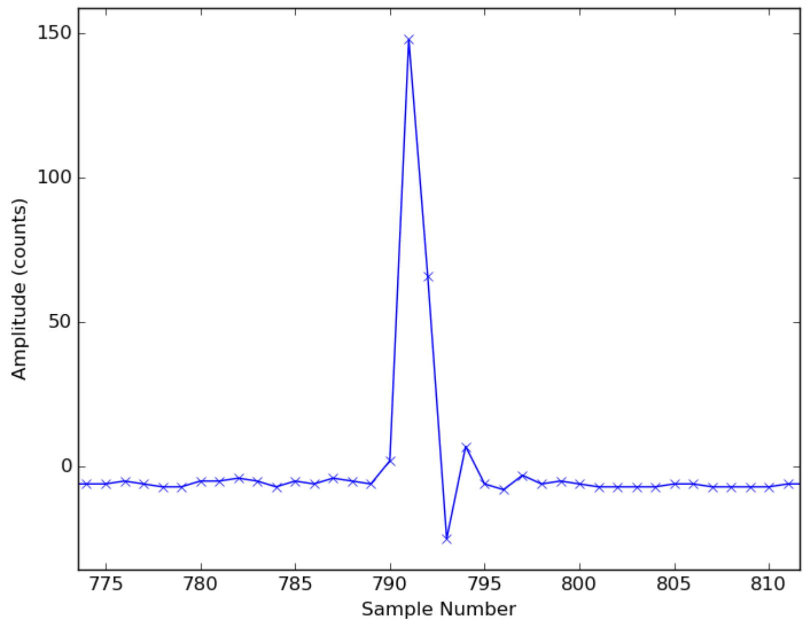
Binned Interferogram

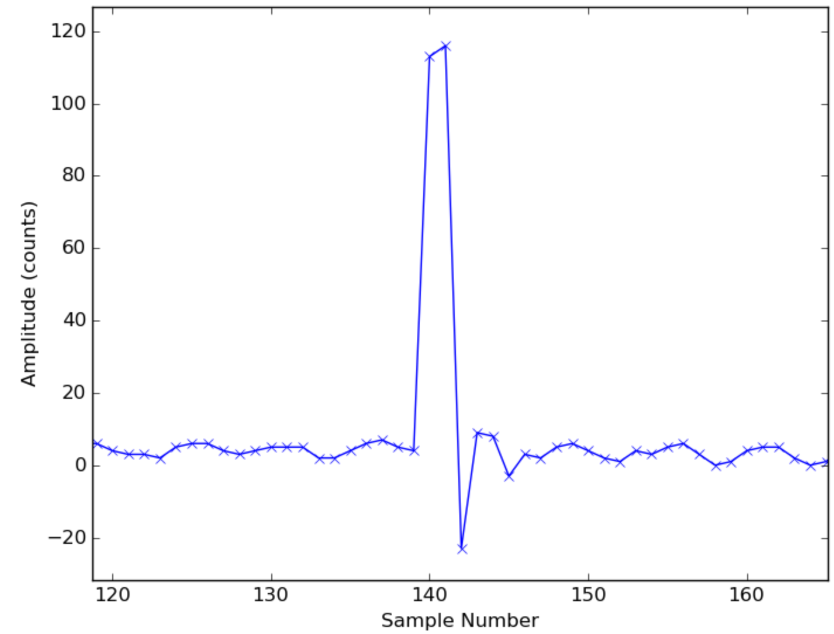




- Interferograms can be binned to make side to side comparisons
- Example is for 6 interferogram points/bin and skip ZPD area
- Right side of interferogram has been flipped
- Difference clearly show spike

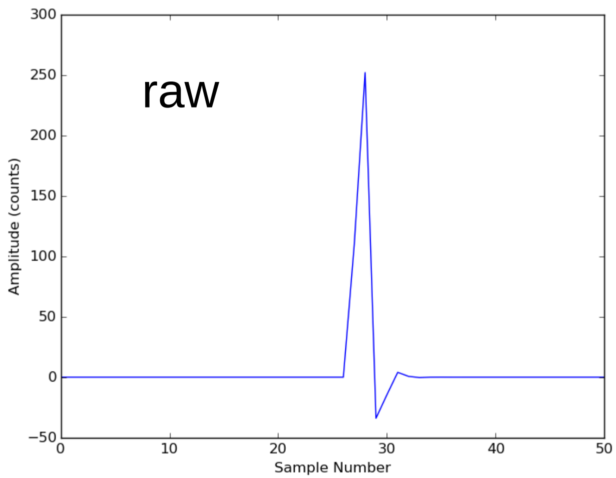
Spikes Are Not Single Sample Events

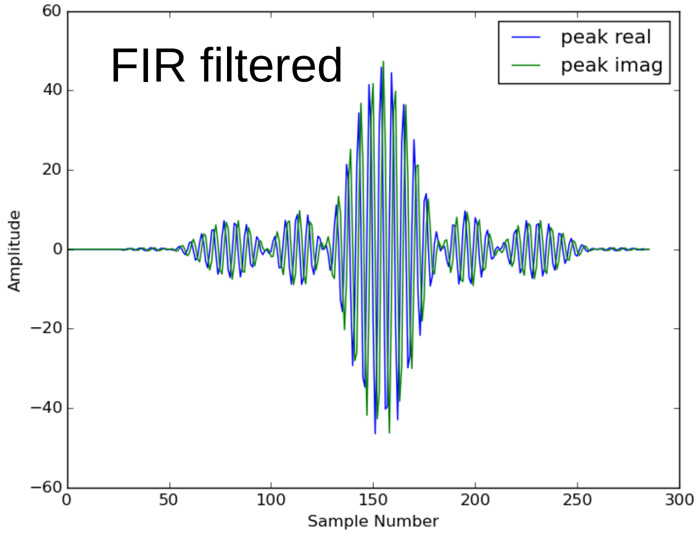


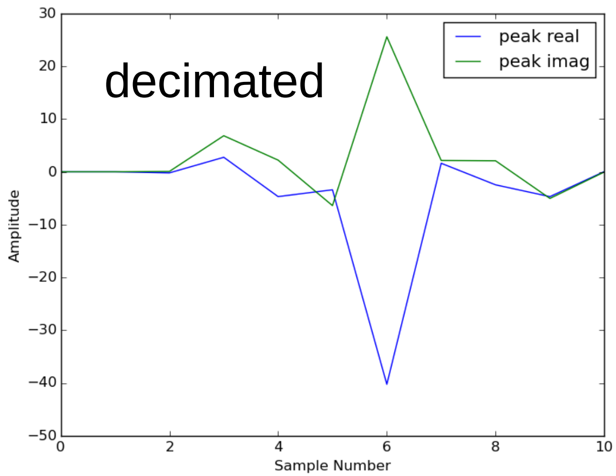


- Raw diagnostic mode data
- Data points indicated by “x” connected by straight lines
- Shape similar to that of a damped oscillator
- Least-squares fit to spike
- Subtract modeled spike from interferogram

Affect of Filtering and Decimating on a Spike

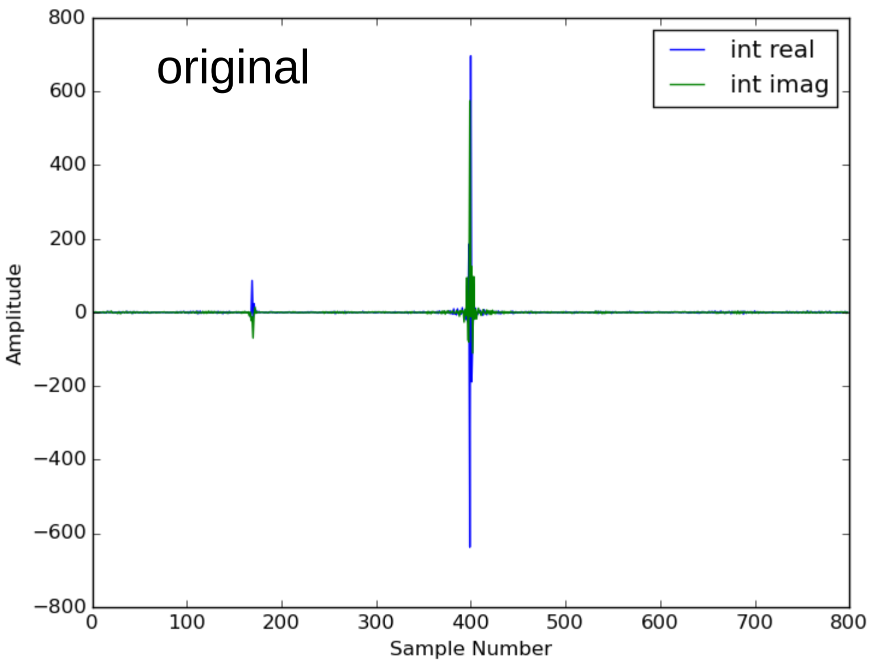


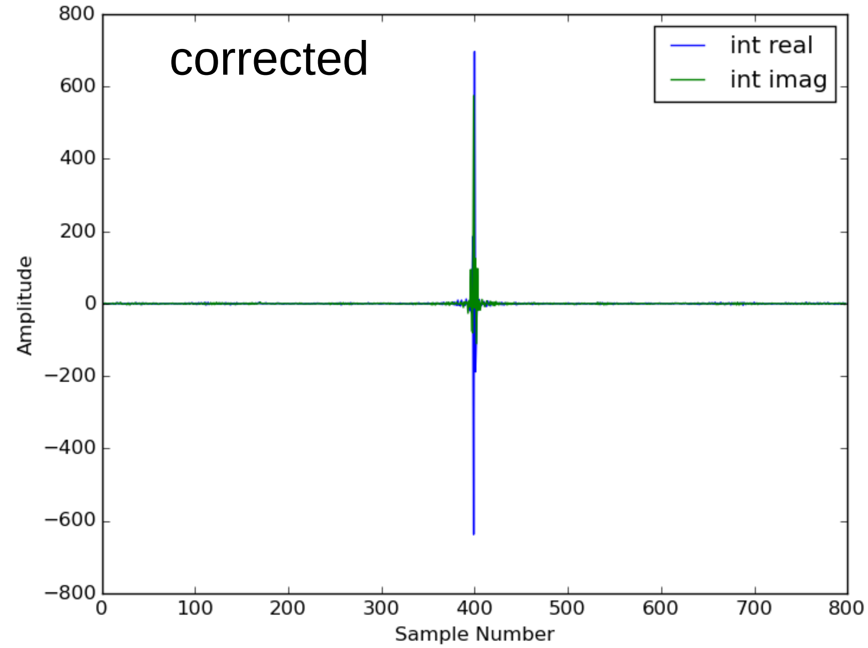




- Modeled spike
- SW band
- Fit uses real and imaginary componet

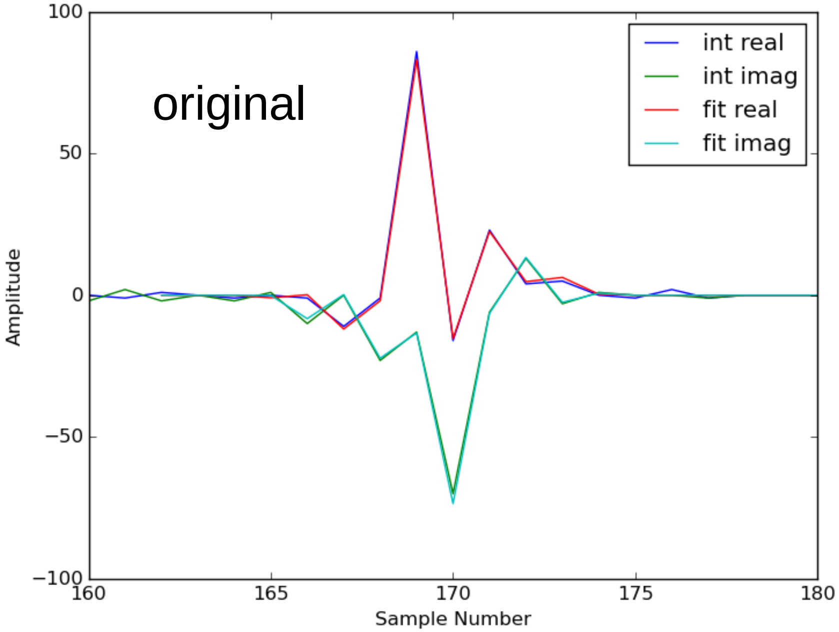
Example of Spike Removed from Interferogram

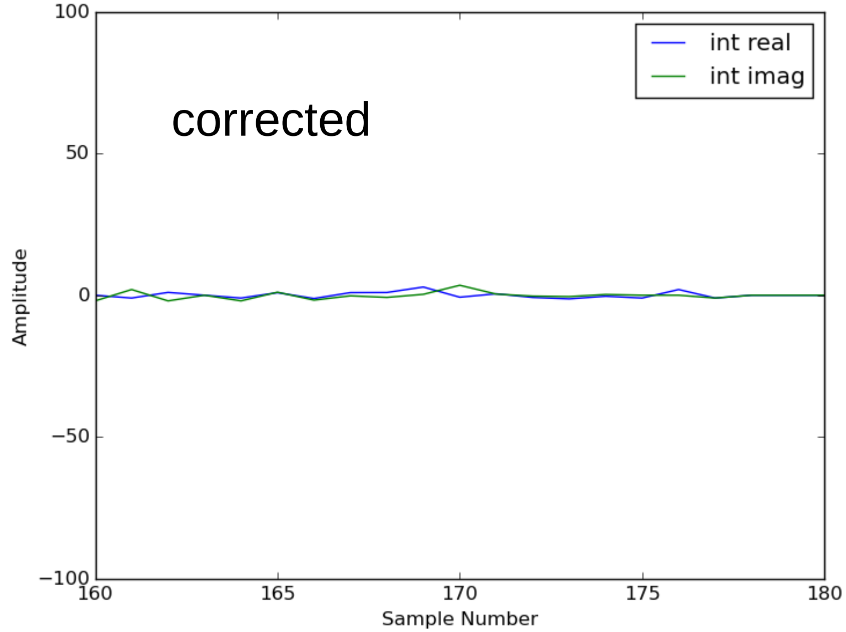




- Correction though subtracting modeled spike from original interferogram
- No residual error visible
- FOR 27, FOV6, 2/18/2015 18:11:11.367

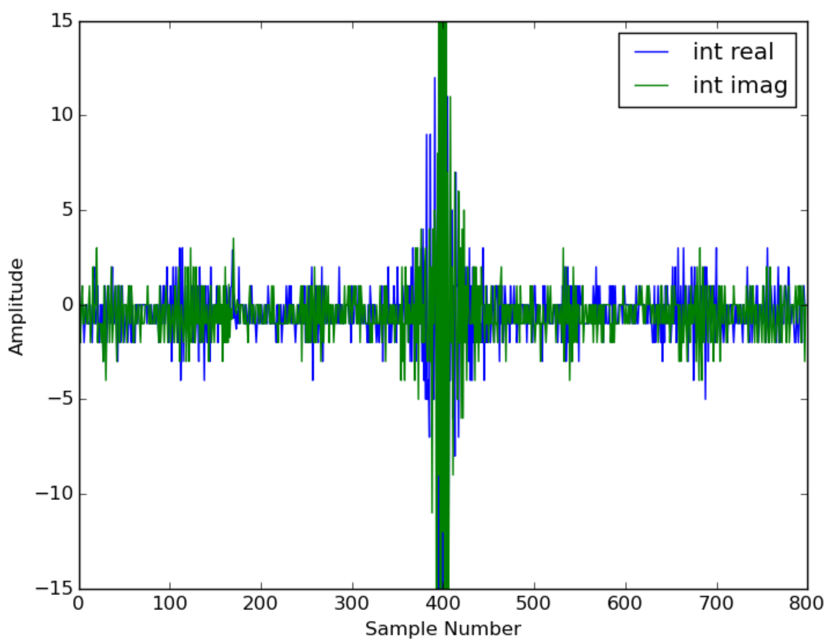
Expanded Vertical Scale





- Fit to spike is very good
- Residual error not visible in expanded view of interferogram

Expanded View of Corrected Interferogram



- Spike residual error not visible
- Quantization noise clearly visible

Conclusions

- CrIS J1 has excellent NEdN performance
- Evidence for vibration effects in ground testing
  - Not an issue for MN
  - Noticeable for PFL and PFH
- Some FOVs show consistent differences in side 1 to side 2 NEdN
- Bit-trim mask optimization for CrIS SNPP can be applied to J1
- Impulse mask needs to be set high to avoid false triggers
- Number of interferogram effected by spikes is low with respect to operability requirement of 99%
- Radiation spikes can be detected and removed through ground processing