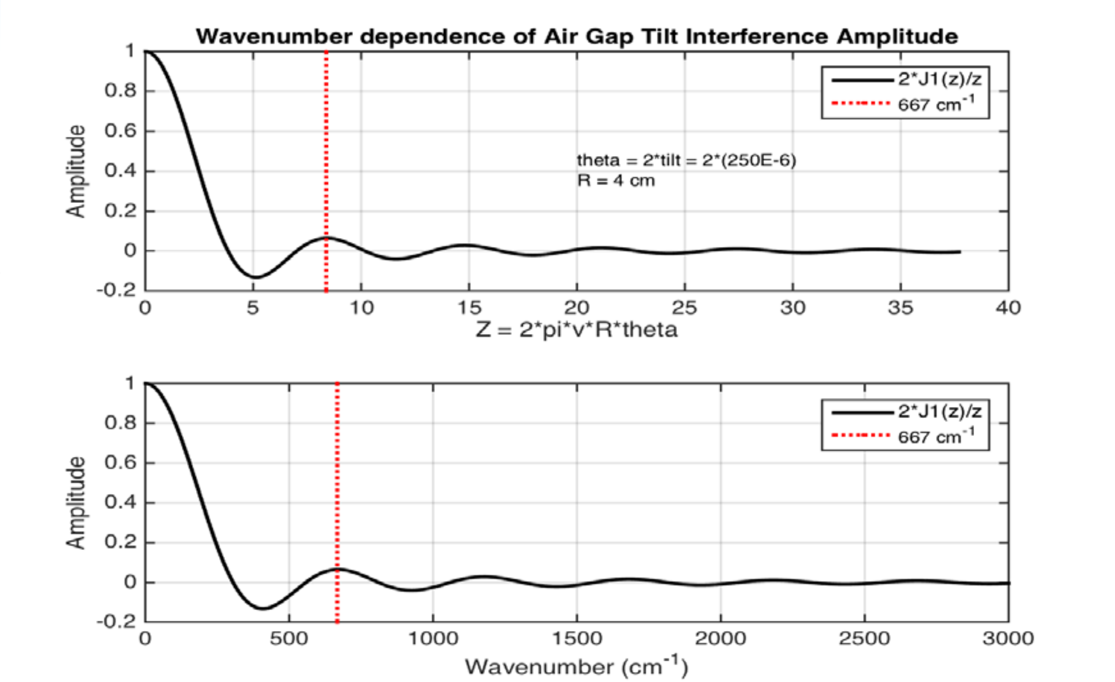
Space Dynamics Laboratory
Utah State University Research Foundation

LW FOV5 Update

Introduction

- For S-NPP CrIS LW FOV5 has higher radiance than other FOVs at 668.125 cm^{-1} for cold scenes
- Numerous presentations on this anomaly
- Latest was from UW exploring unresolved channel spectrum
  - March 16, 2016
  - Beamsplitter gap causes a secondary “ZPD” spike at 0.88 cm OPD
- UW did analysis in the interferogram domain
- Spectral domain analysis should be identical
- Larabee provided monochromatic spectra for hot and cold scenes
- Results ambiguous
- Joe Predina proposed electrical crosstalk as root cause

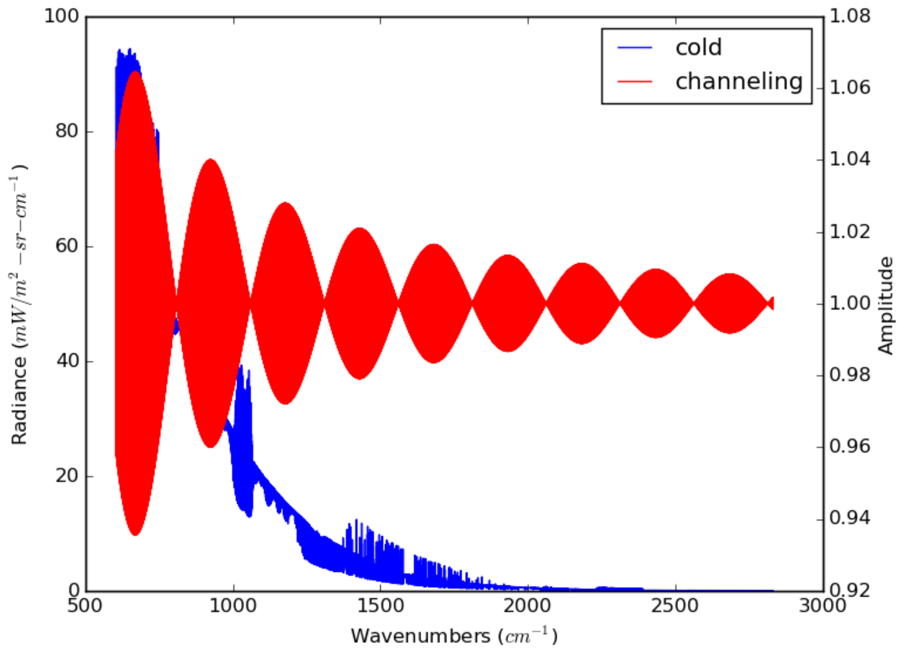
Beamsplitter Gap Wedge Reduces Amplitude

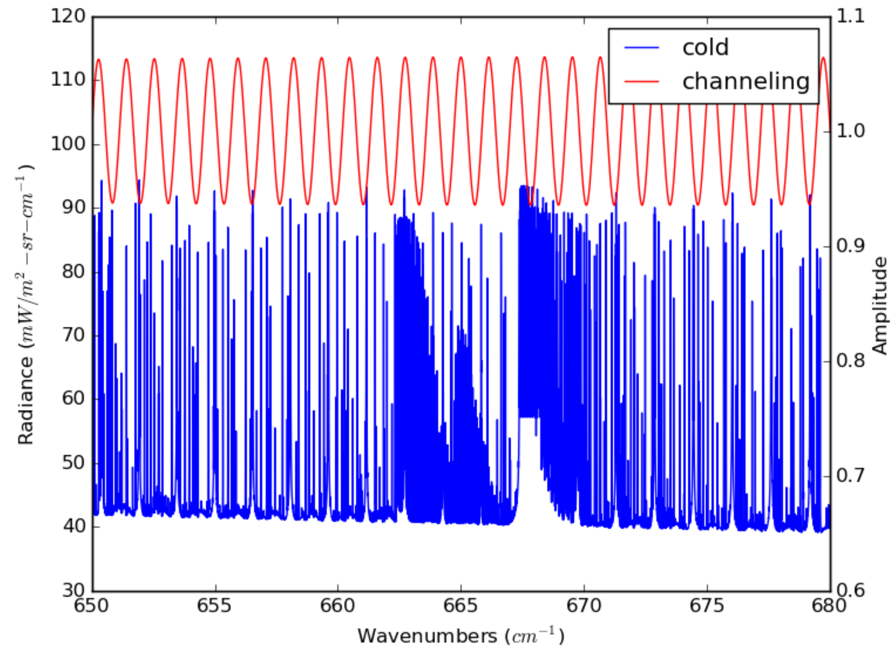


Normalization: 0.5*r ≅ (0.5) * [(n-1)/(n+1)]^2 =0.085 with n = 2.4

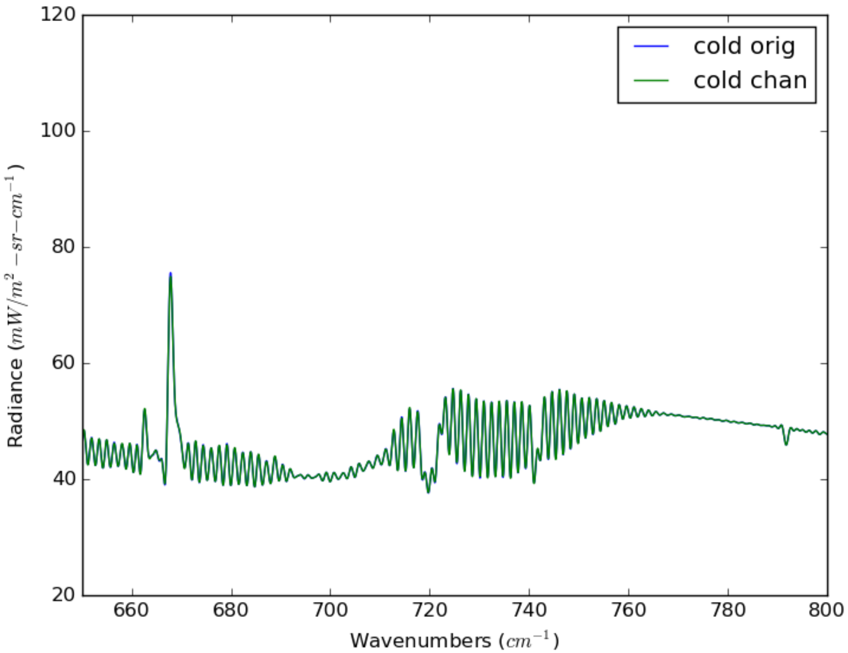
- From March 16, 2015 UW presentation
- Didn't use normalization (conservative analysis)

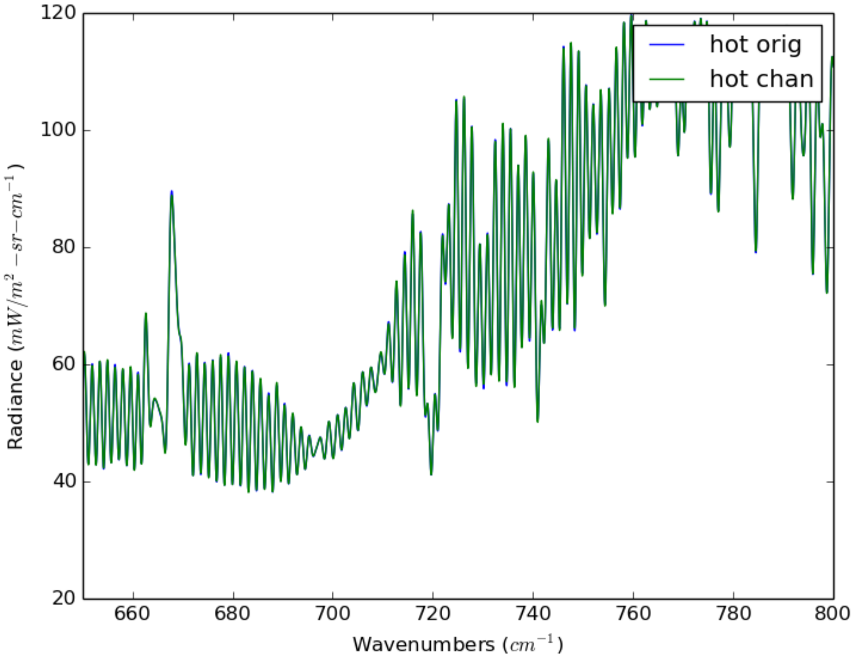
Effect of Beamsplitter Gap Reflection



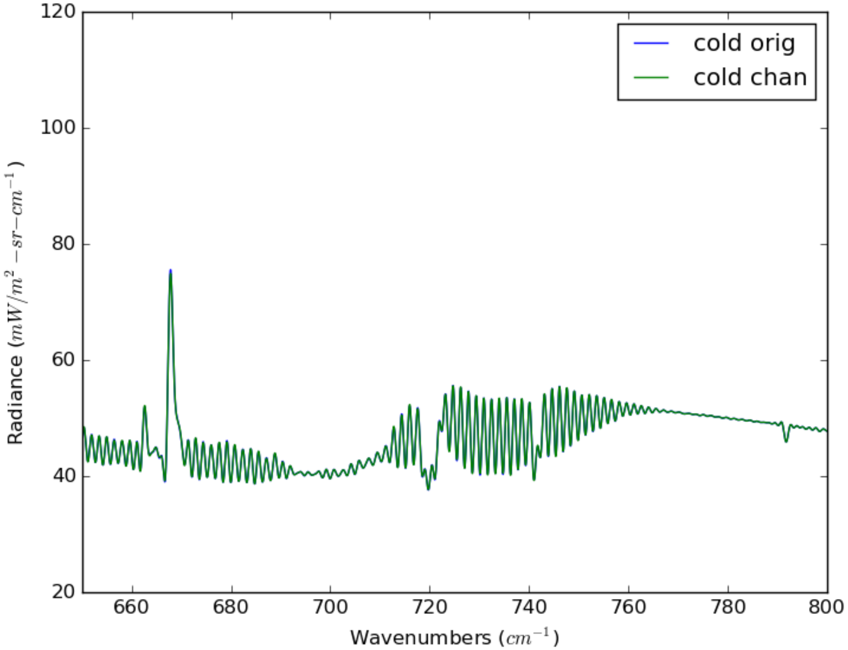


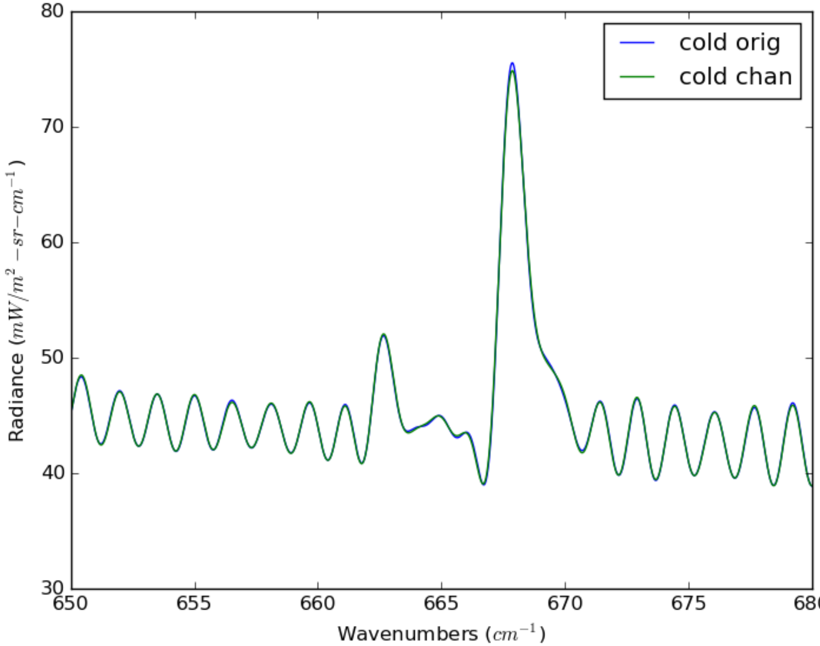
- High resolution spectra is modulated by channeling
- Phase of channeling is unknown





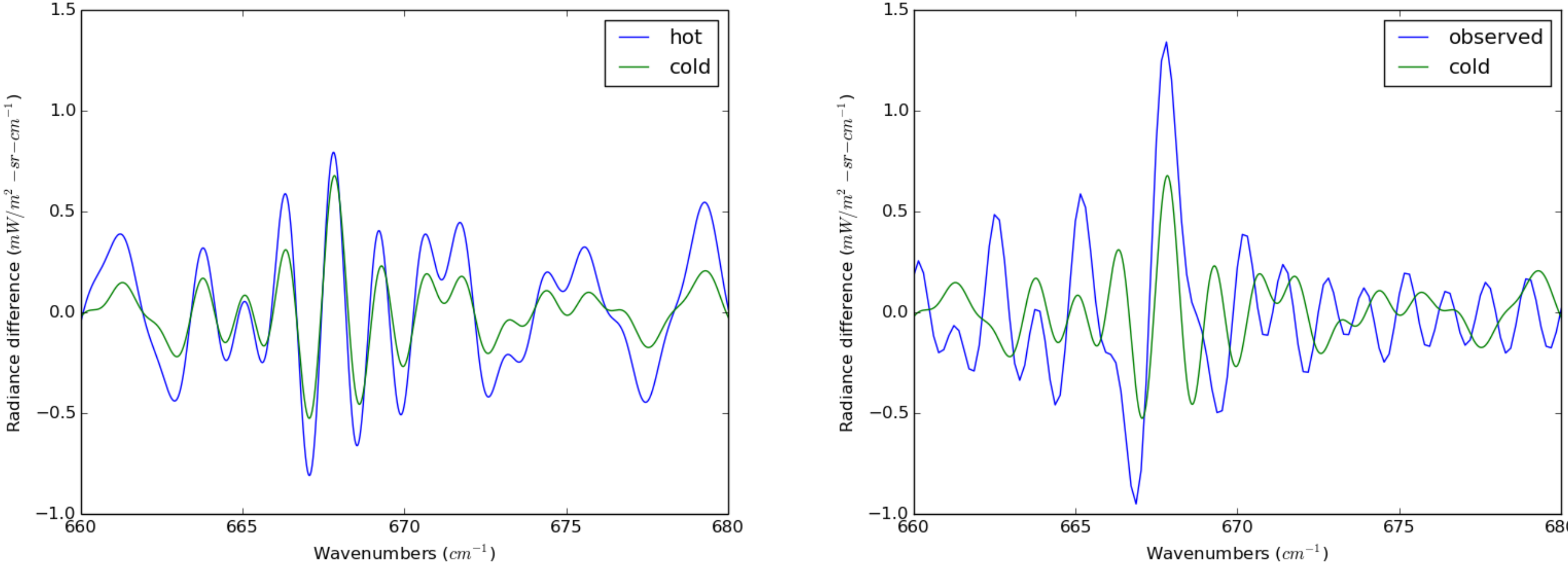
- Monochromatic spectra from Larrabee Strow
- Spectral resolution reduced to CrIS
- Modulation does not have a big affect





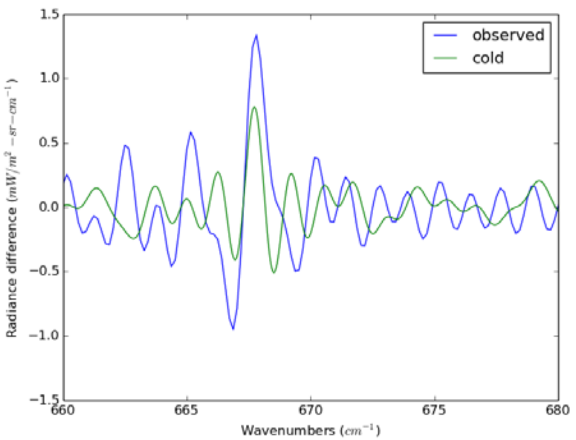
- Spectral resolution reduced to CrIS
- Modulation does not have a big affect

Observed Anomaly Doesn't Match Model

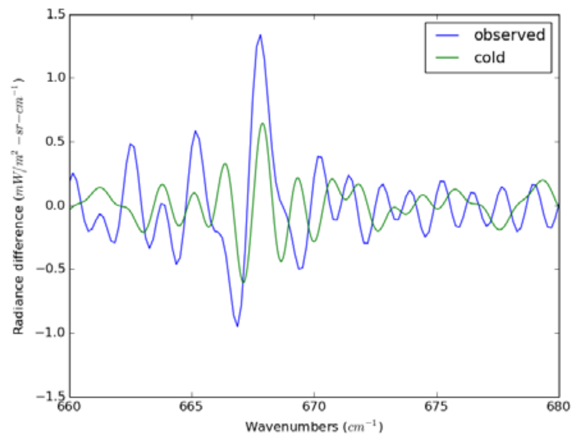


- Observed anomaly larger than modeled
- Larger affect seen for hot spectra than cold
- Shape not a very good match
- Could there be a non-LTE spectral line not in model

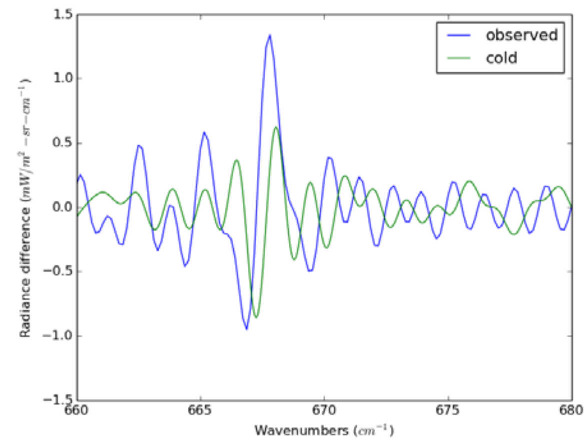
Spectral Shift of Anomaly



Phase 0



Phase -30



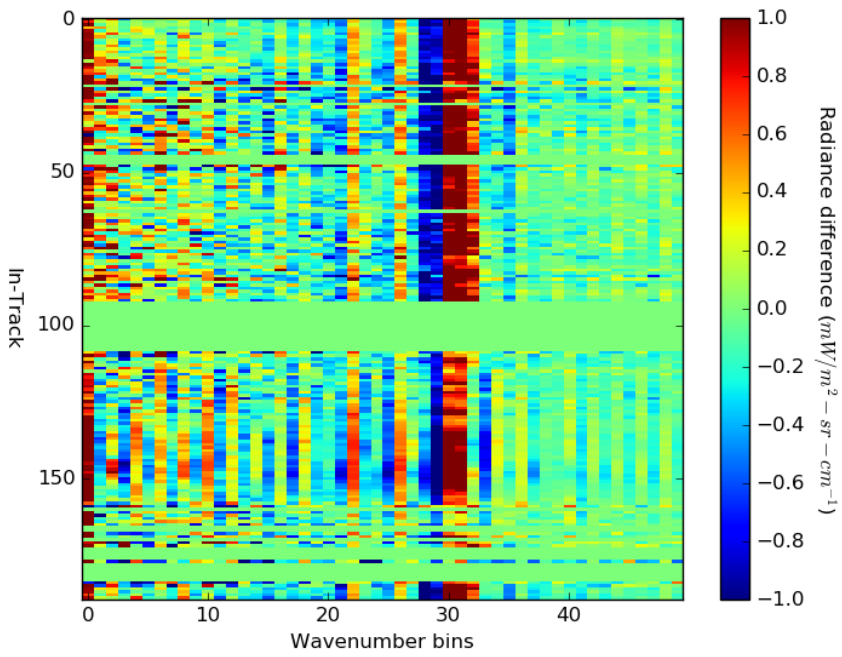
Phase -60

- Position of peak sensitive to the modulating phase
- Beamsplitter gap OPD is 0.88 cm^{-1} or 8800 µm
- Aluminum has thermal expansions of $24 \times 10^{-6}/^{o}C$ at 20 C
- Change in length for 1 C change 0.21 µm compared to wavelength of 15 µm (5 degrees of phase)
- On orbit OMA temperature change not large enough to expect to see change

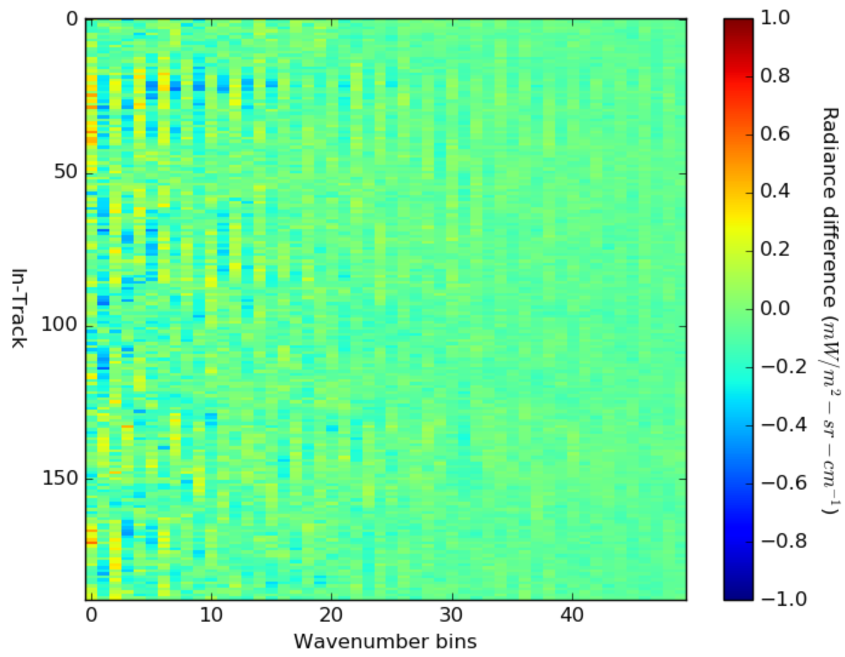
Electrical Cross-Talk

- Joe Predina proposed the effect could be due to electronic cross-talk
- General electronic pickup would likely not have same phase as optical signal and would show in imaginary spectra

Anomaly Only Visible in Real Spectrum



real



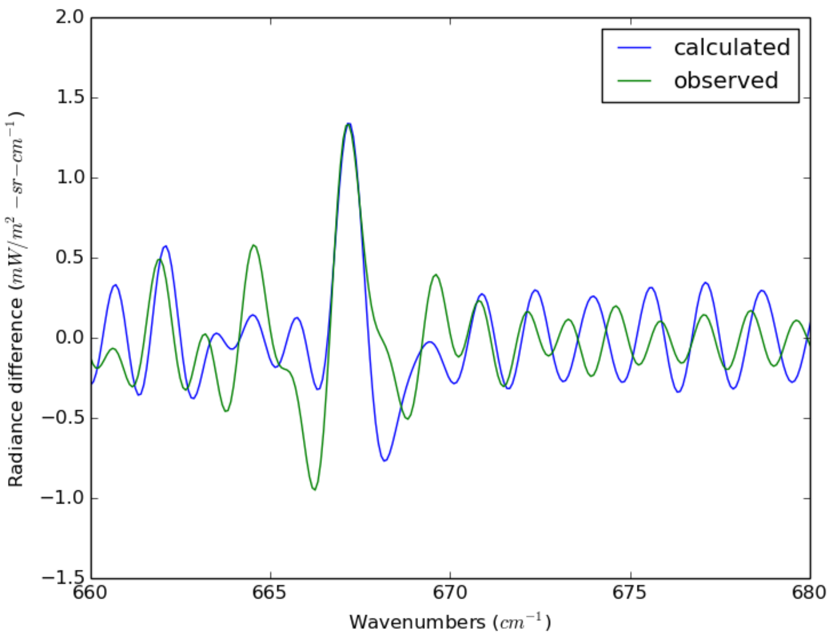
imaginary

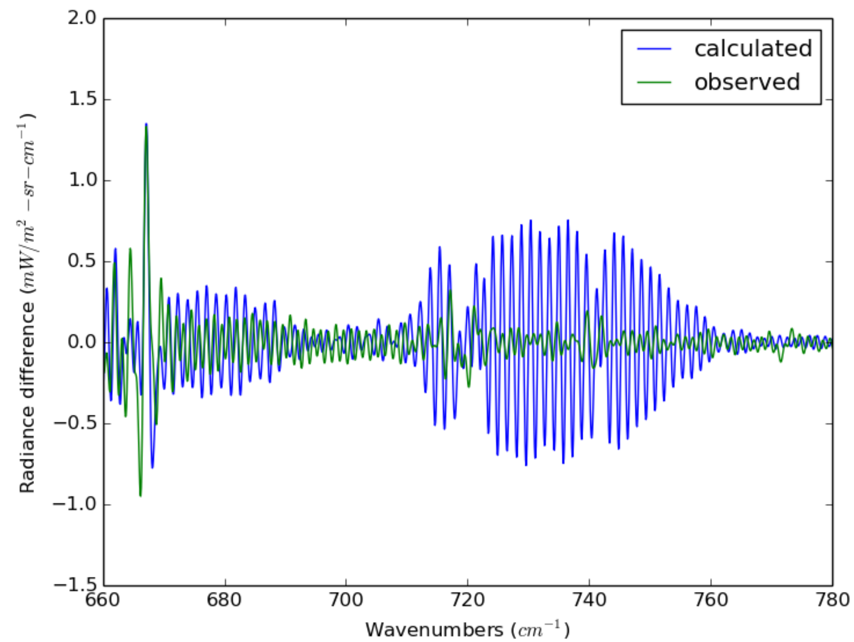
- Difference between FOV5 and FOV6
- Anomaly shows up in real but not imaginary spectra
- August 1, 2015 orbit 19478

Electrical Cross-Talk

- If optical or detector electrical cross-talk were getting into FOV5 the line shape would be incorrect
- Synthesized spectra including SA matrix effects
  - From Larrabee Strow’s high resolution spectrum
- Added small amount of FOV1 and FOV2 into FOV5
- Applied inverse SA matrix for FOV5
- Plot difference between correct FOV5 spectra

Adding Cross-Talk Not Consistent with Anomaly

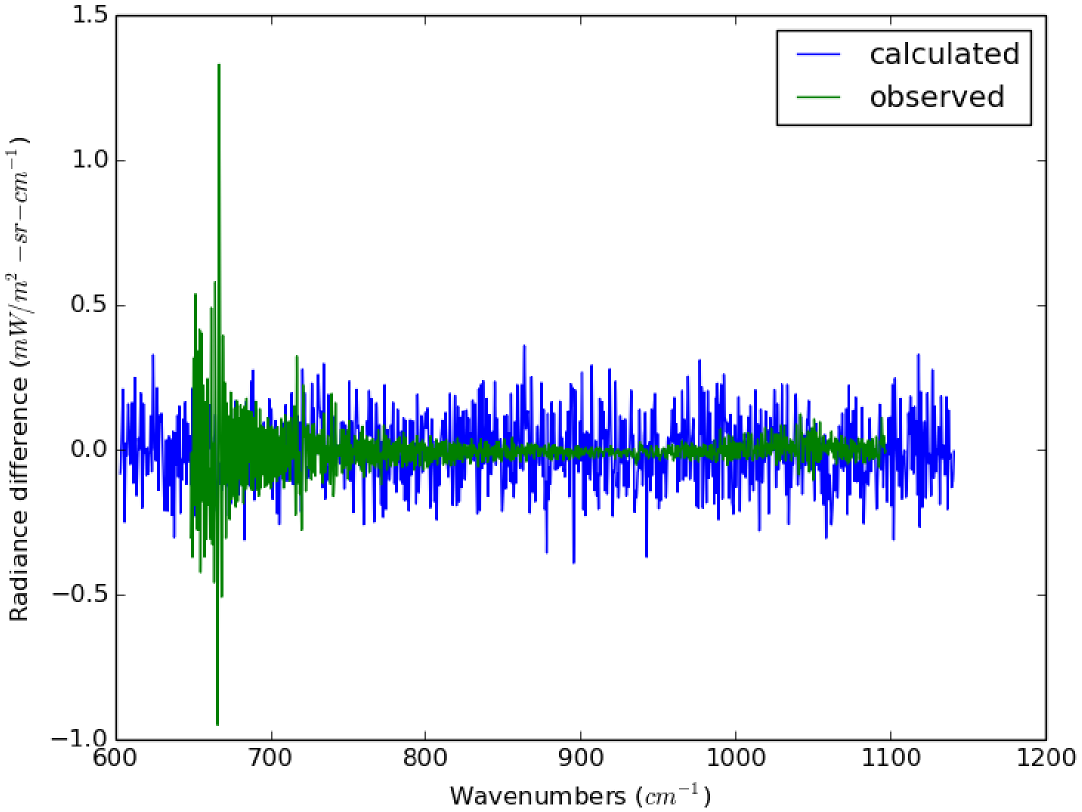




- 0.07 of FOV1 & FOV2 added to FOV5
- Biggest effect in 720 to 760 cm^{-1} region not 668 cm^{-1}
- Other combination of cross-talk also not a good fit

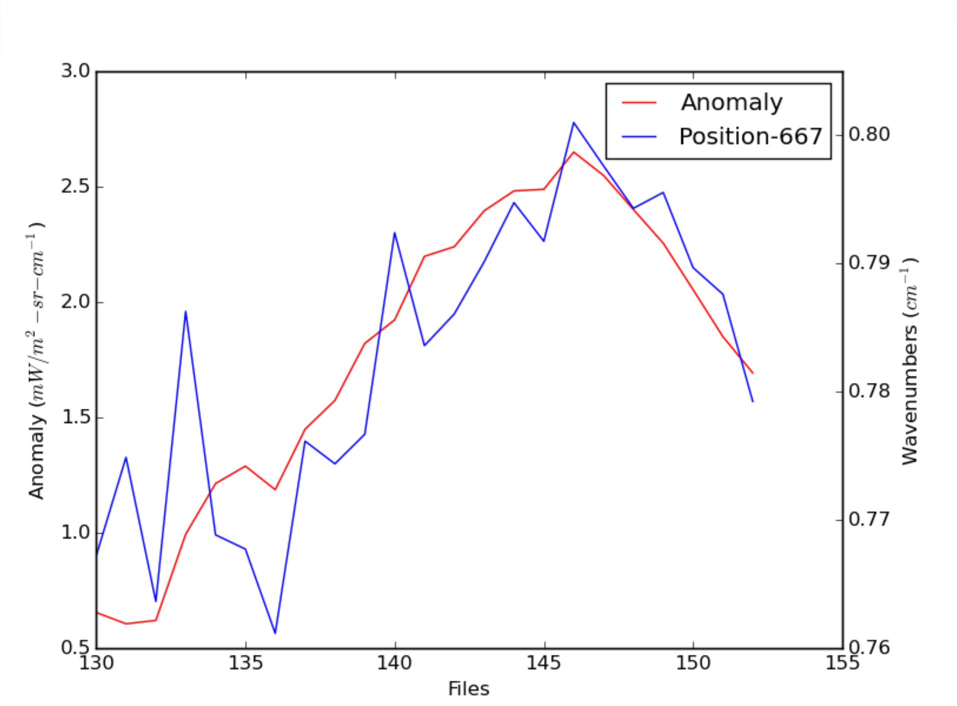
BACKUP

How Large is Anomaly?



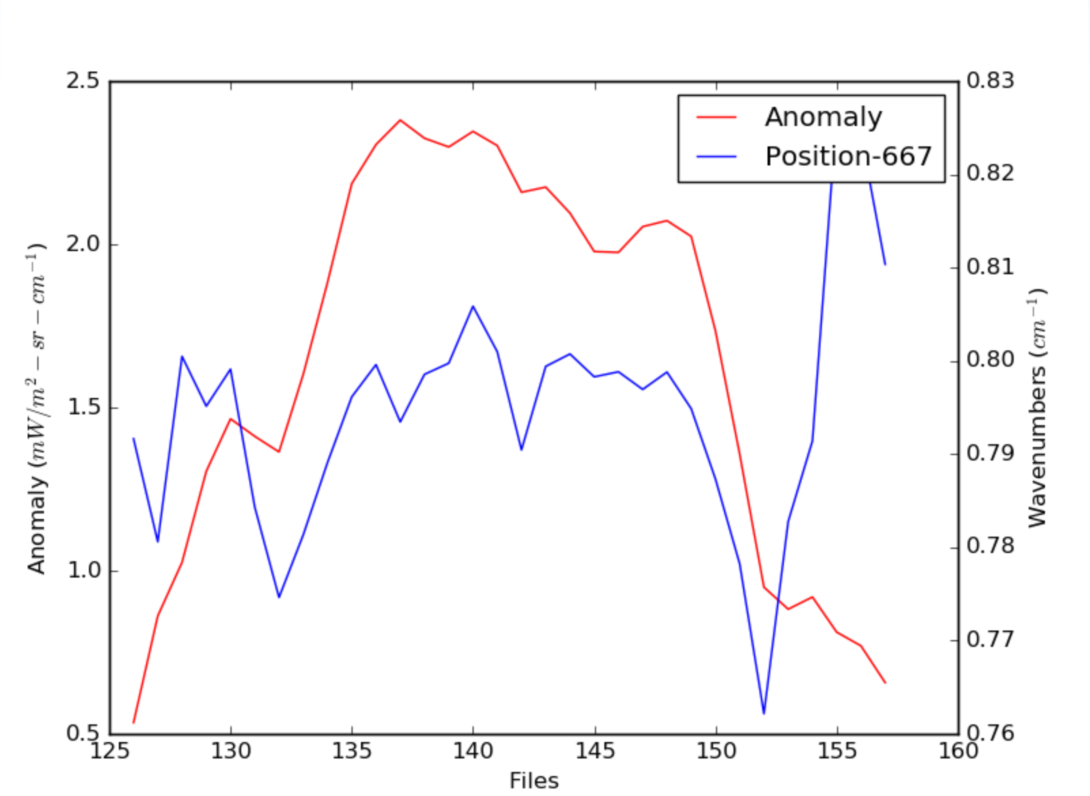
- Anomaly compared to a single pixel noise
- Anomaly was averaged over a granule

Anomaly Spectral Position not Constant



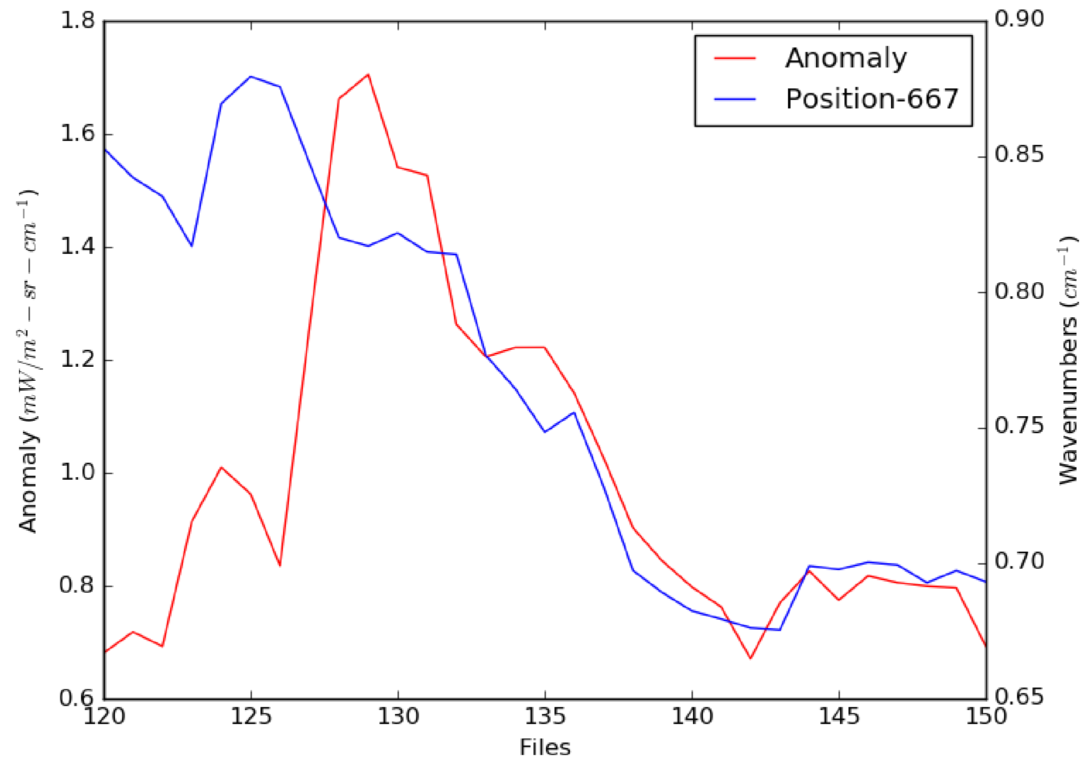
- Spectral position of anomaly correlated with amplitude
- Anomaly amplitude uses left axis, position right axis
- South pole region, averaged over each granule
- August 1, 2015 orbit 19480

Anomaly Spectral Position not Constant



- Spectral position of anomaly correlated with amplitude
- Anomaly amplitude uses left axis, position right axis
- South pole region, averaged over each granule
- June 21, 2015 orbit 18900

Anomaly Spectral Position not Constant



- Spectral position of anomaly correlated with amplitude
- Anomaly amplitude uses left axis, position right axis
- South pole region, averaged over each granule
- December 21, 2015 orbit 21496

J1 CrIS System Level Testing, Results and Preparation for Launch

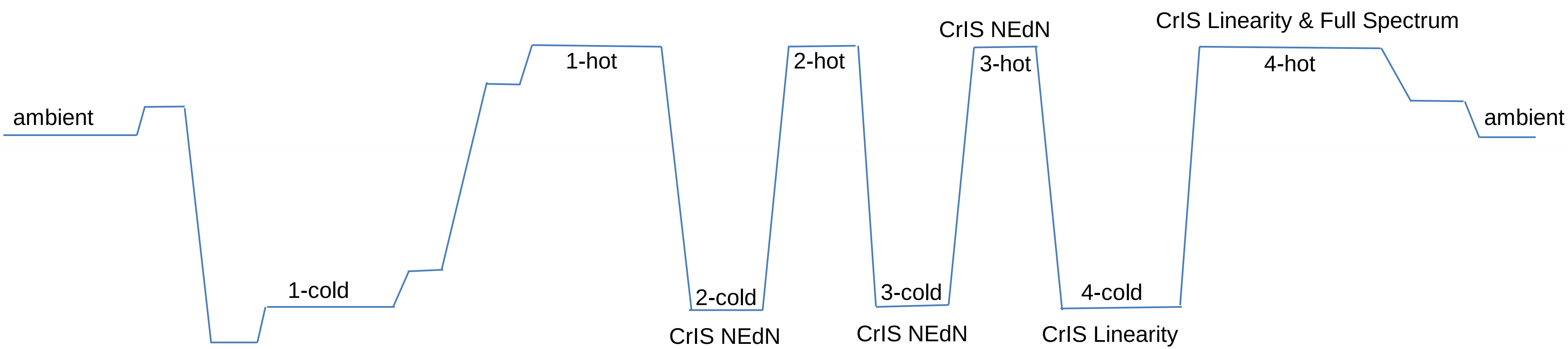
Mark Esplin, Deron Scott, Kori Moore, and Ben Esplin

Outline

- Preparations for J1 CrIS Spacecraft level test and early on orbit checkout
  - Differences in data format since sensor TVAC
  - Reading J1 test data
  - Exercising analysis software
- J1 CrIS sensor level TVAC performance
- S-NPP on-orbit status
  - Typical NEdN
  - Standard deviation verses Allan deviation
  - Response trending
  - Bit-trim errors due to bright scenes
  - Extended interferogram operation

PREPARATIONS FOR J1 CRIS SPACECRAFT LEVEL TEST AND EARLY ON ORBIT CHECKOUT

Plan for CrIS Spacecraft TVAC Test



- Four hot and cold cycles planned during TVAC
- Several opportunities to evaluate CrIS NEdN and linearity
- CrIS will be active during other times as well

J1 CrIS Planned Activities

- During Spacecraft TVAC
  - Verify proper functionality of CrIS sensor
  - Investigate any unexpected behavior
  - Determine NEdN at high and low temperature plateaus
  - Check for ice buildup on optical surfaces
  - Evaluate nonlinearity changes from diagnostic mode data
  - Compare sensor performance with previous sensor level TVAC
- Early on orbit checkout in addition to above tasks
  - Evaluate occurrences of radiation spikes
  - Optimize bit-trim mask
  - Trend degradation of system responsivity

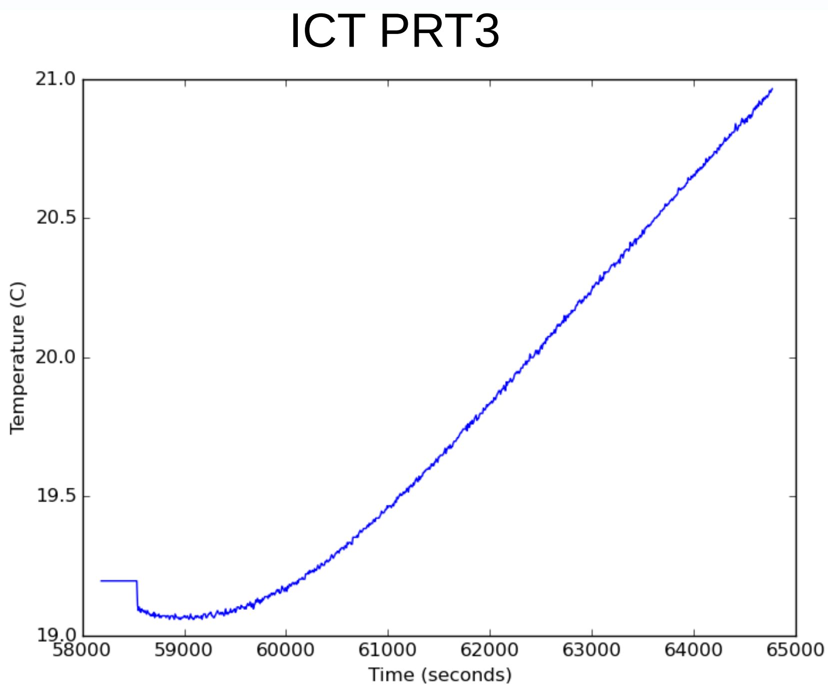
Software Tools Ready for Spacecraft TVAC

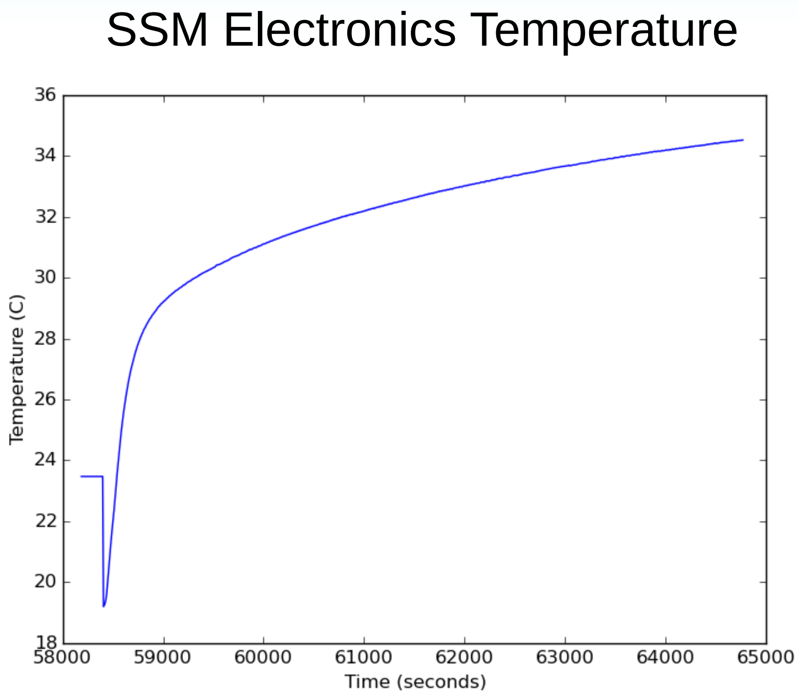
- Ability to unpack CCSDS packets from HDF5 formatted files
- Ability to read and plot telemetry data
- Plot raw interferograms both normal and diagnostic mode
- Determine FOR, FOV, sweep direction etc. from interferogram data (check for missing data)
- Convert raw interferograms into magnitude and phase spectra
- Process raw interferograms into calibrated spectra (Harris SDR generator)
- Determine NEdN and Allan deviation
- Derive nonlinearity coefficients from diagnostic mode data

J1 Preliminary Spacecraft Data

- Files have 15 granules per file
- Interferogram length LW 876, MW 1052, SW 808
- Data from all FOVs present
- For some files there is one less earth scene interferogram than expected (1799 instead of usual 1800)
  - No gaps in time stamps
  - Short granule not missing data
- Packet trackers not consistent with documentation
  - Issue currently being worked
  - Possible to get needed information from binary CCSDS packet headers

Example J1 Telemetry Data



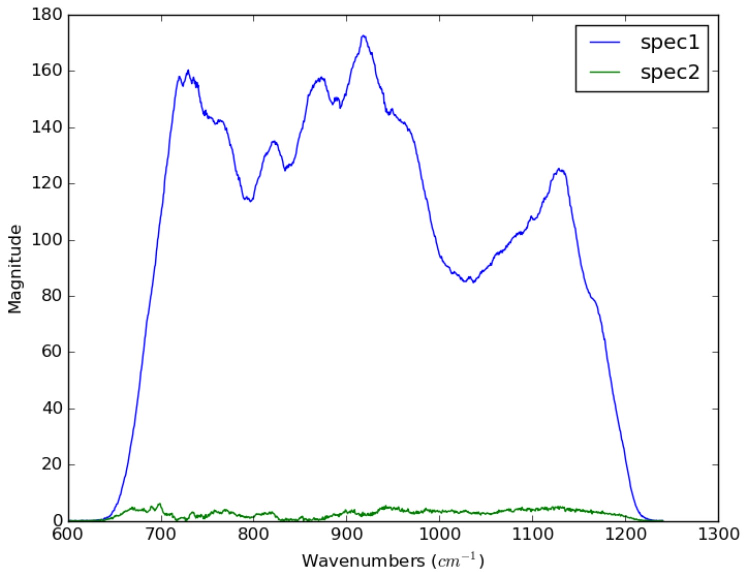


- Software able to read and decode telemetry data
- Telemetry as expected for a CrIS system turn on

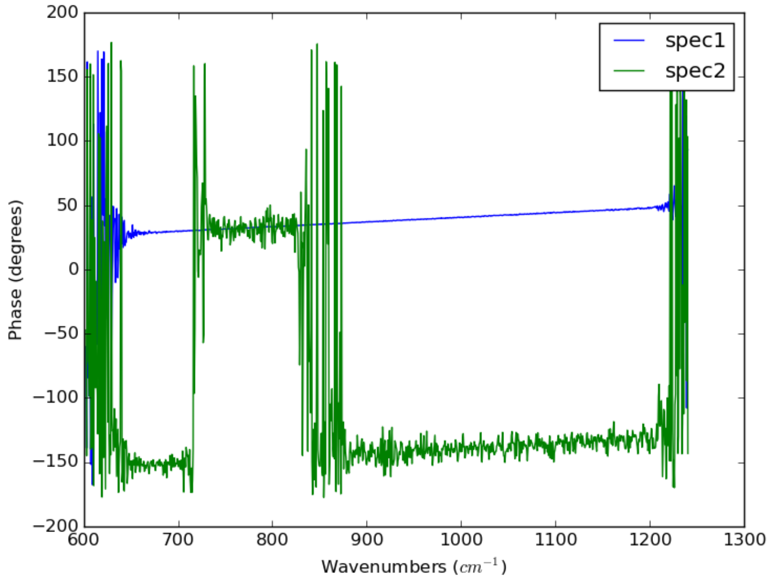
RCRIT_j01_d20151014_t1609422_e1800055_b00001_c20160118222721609000_all-_dev.h5

Uncalibrated Test Spectra

Magnitude



Phase



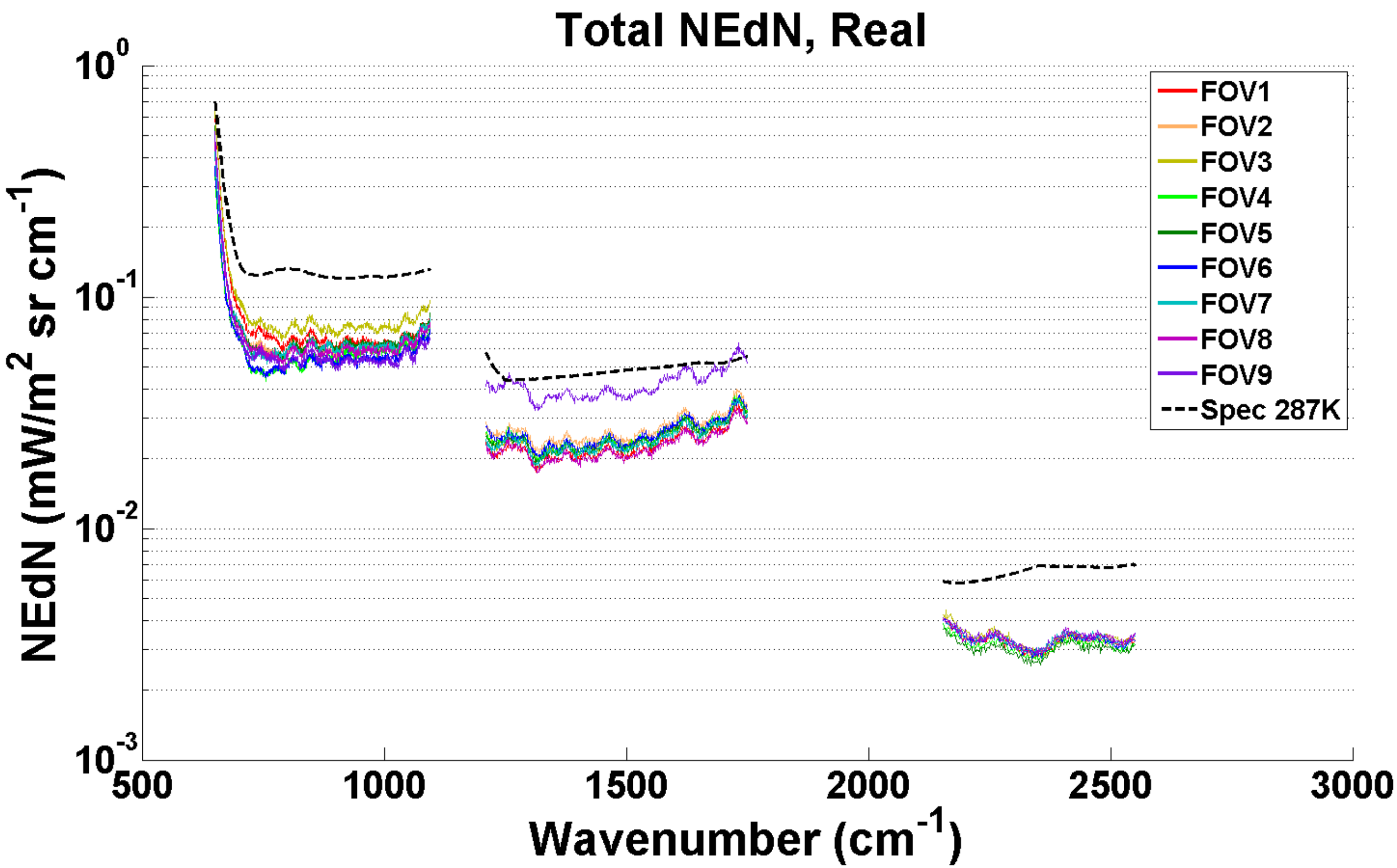
- Playback of representative interferograms
- All FOVs of a given FOR are equal
- Scan direction 1 is small amplitude
- Scan direction 0 is large amplitude
- These two spectra are replicated over and over again

J1 CRIS SENSOR LEVEL TVAC TESTING

J1 CrIS TVAC During Fall of 2014

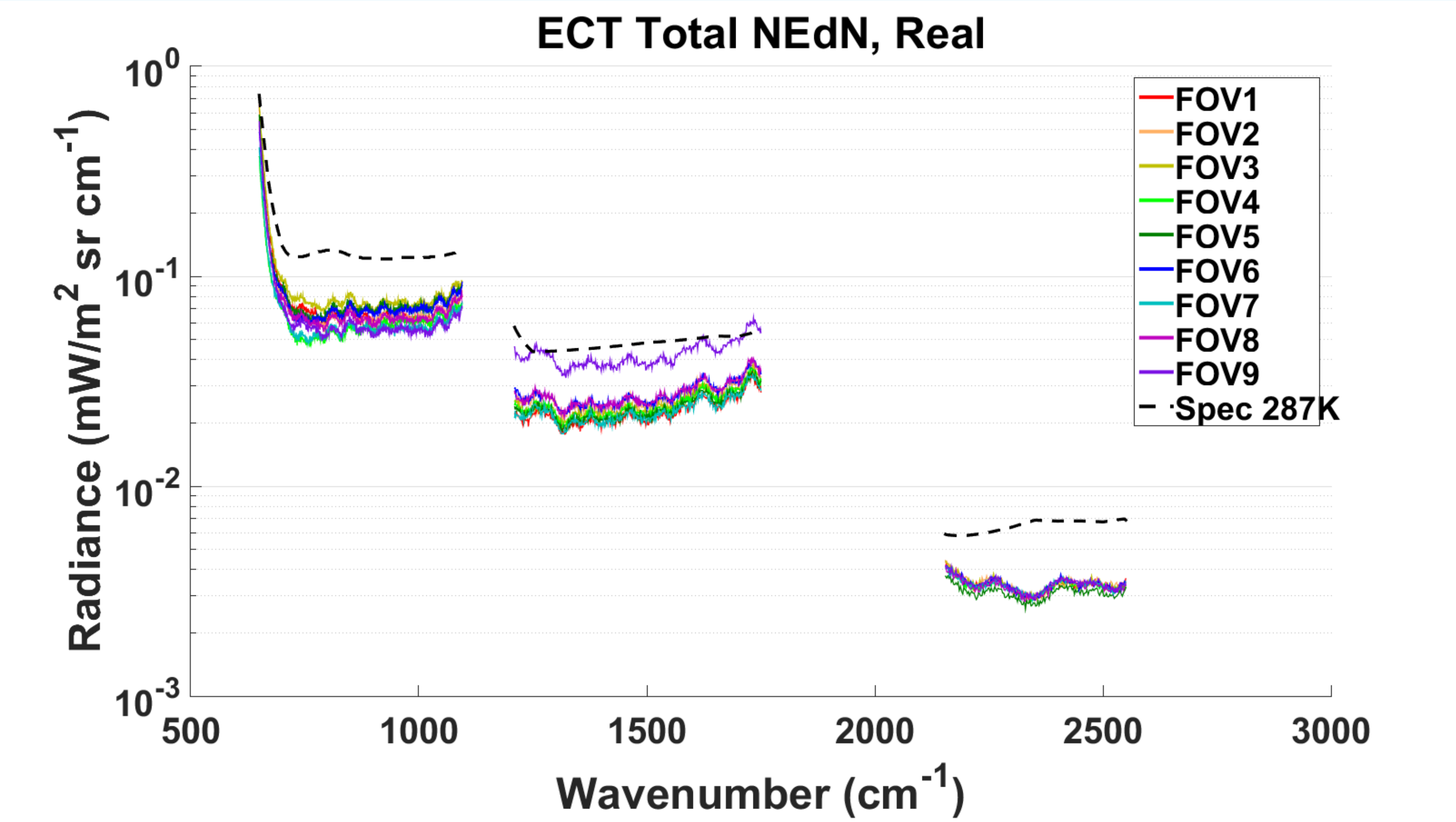
- Basic functionality checks
- NEdN from both operational and staring modes
- Three sensor plateaus
  - (PFL) Proto Flight Low (ICT at about 262 K)
  - (MN) Mission Nominal (ICT at about 287 K)
  - (PFH) Proto Flight high (ICT at about 314 K)
- Both electronic sides and different supply voltages
- NEdN with induced vibration
- Nonlinearity Characterization
  - Diagnostic mode interferograms
  - Normal mode CrIS operation with stepped ECT temperatures

Example Staring MN NEdN



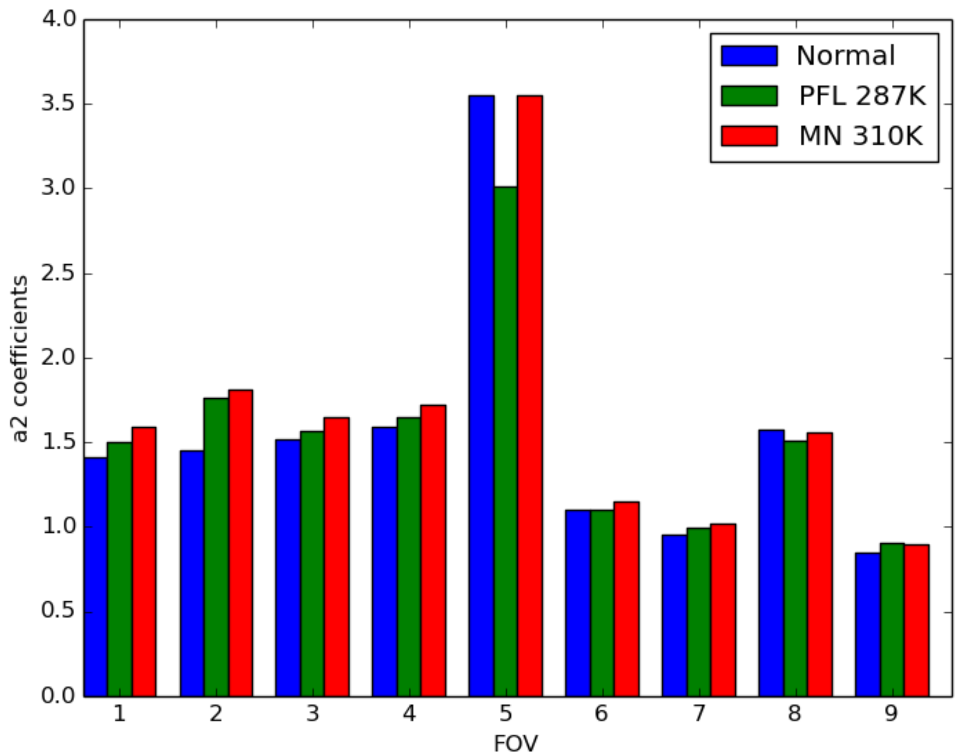
- MW FOV9 out of family with other FOVs
- MW FOV9 slightly above spec value
- MN (Mission Nominal) plateau staring mode

Operational Mode MN NEdN



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

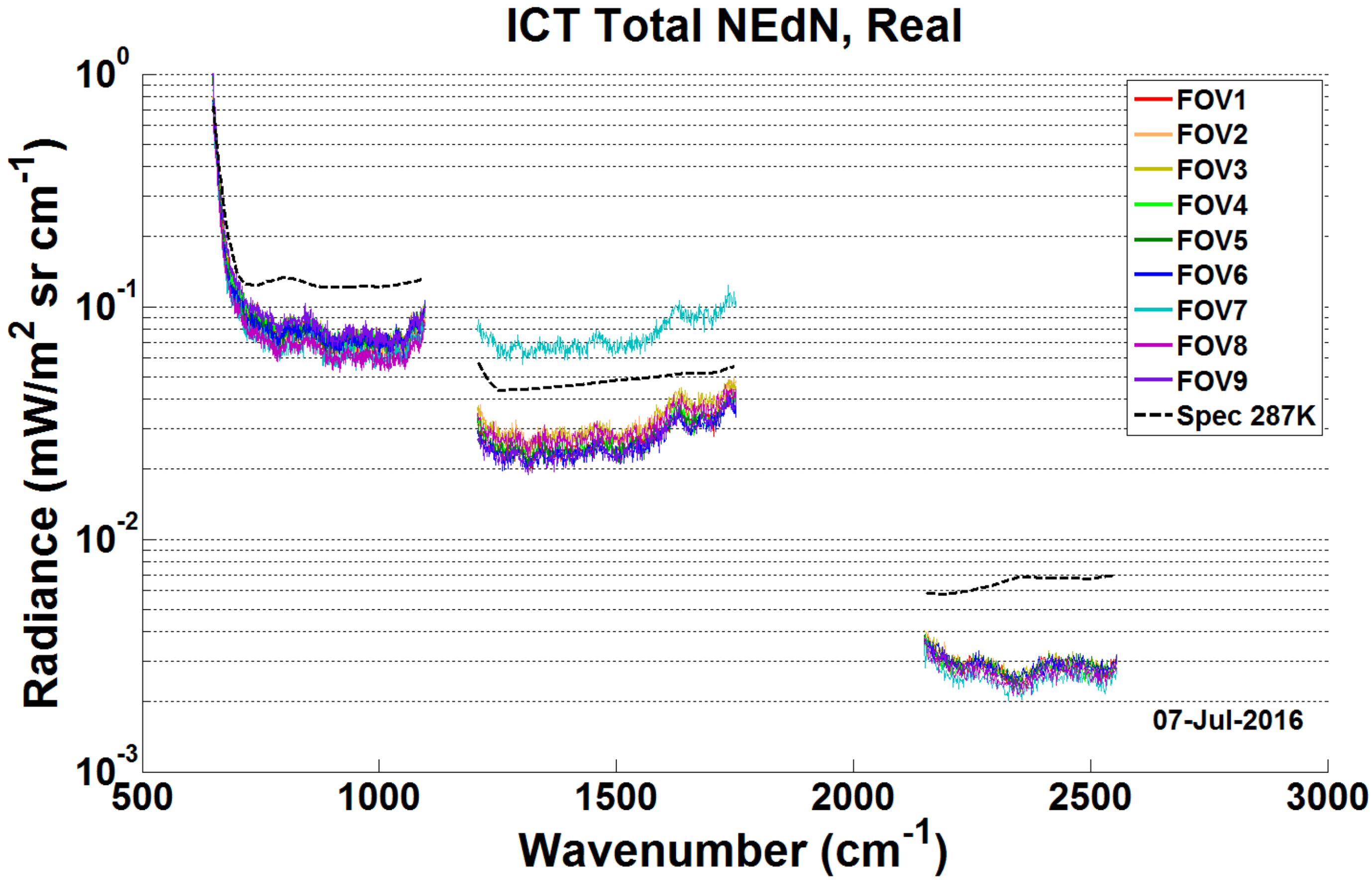
Nonlinearity a_2s Characterized



- Normal is using stepped ECT temperatures
- Relative coefficient magnitude shown
- Diagnostic mode a_2s scaled so MN 310K matched normal FOV5

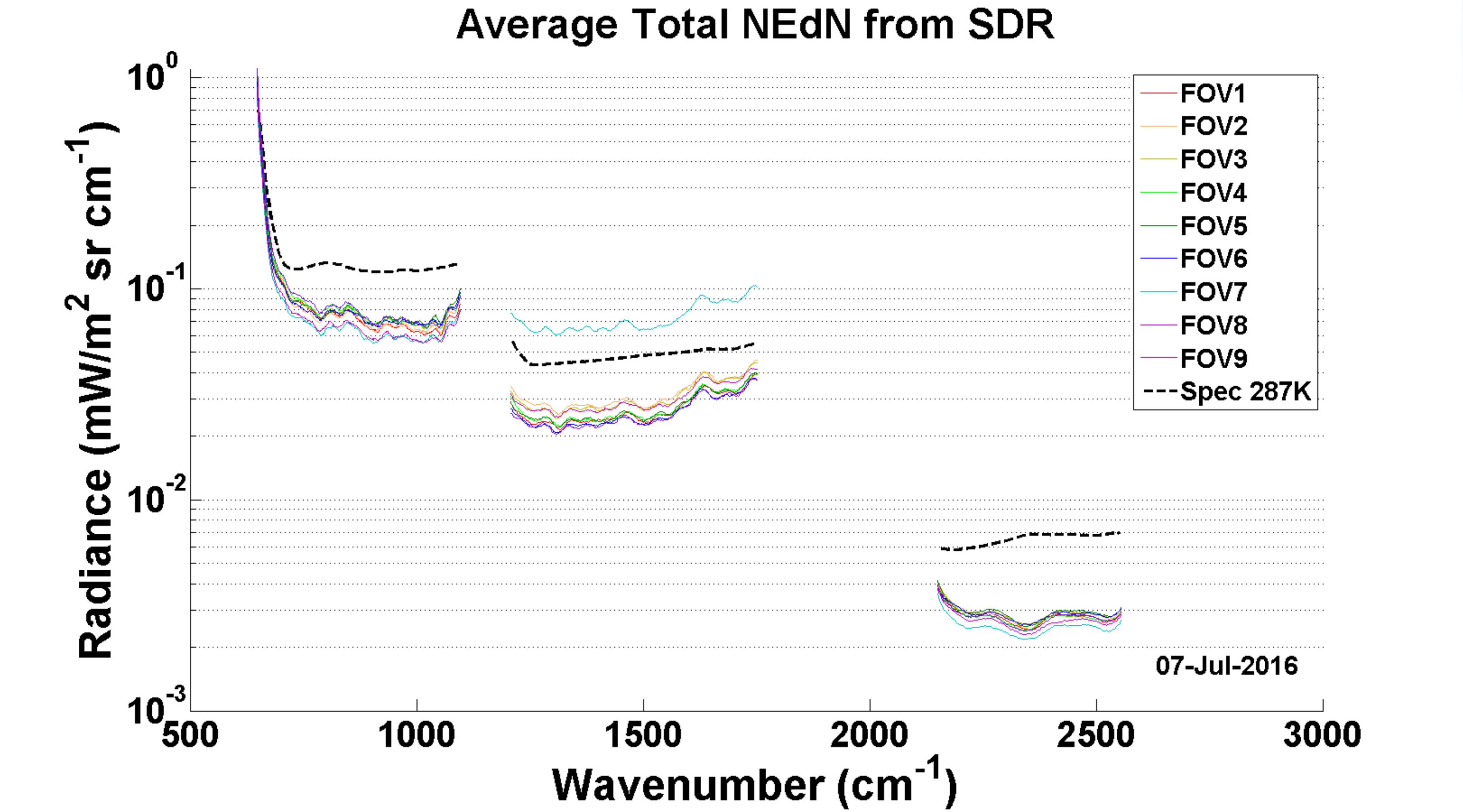
S-NPP ON-ORBIT STATUS

Typical S-NPP On-Orbit NEdN



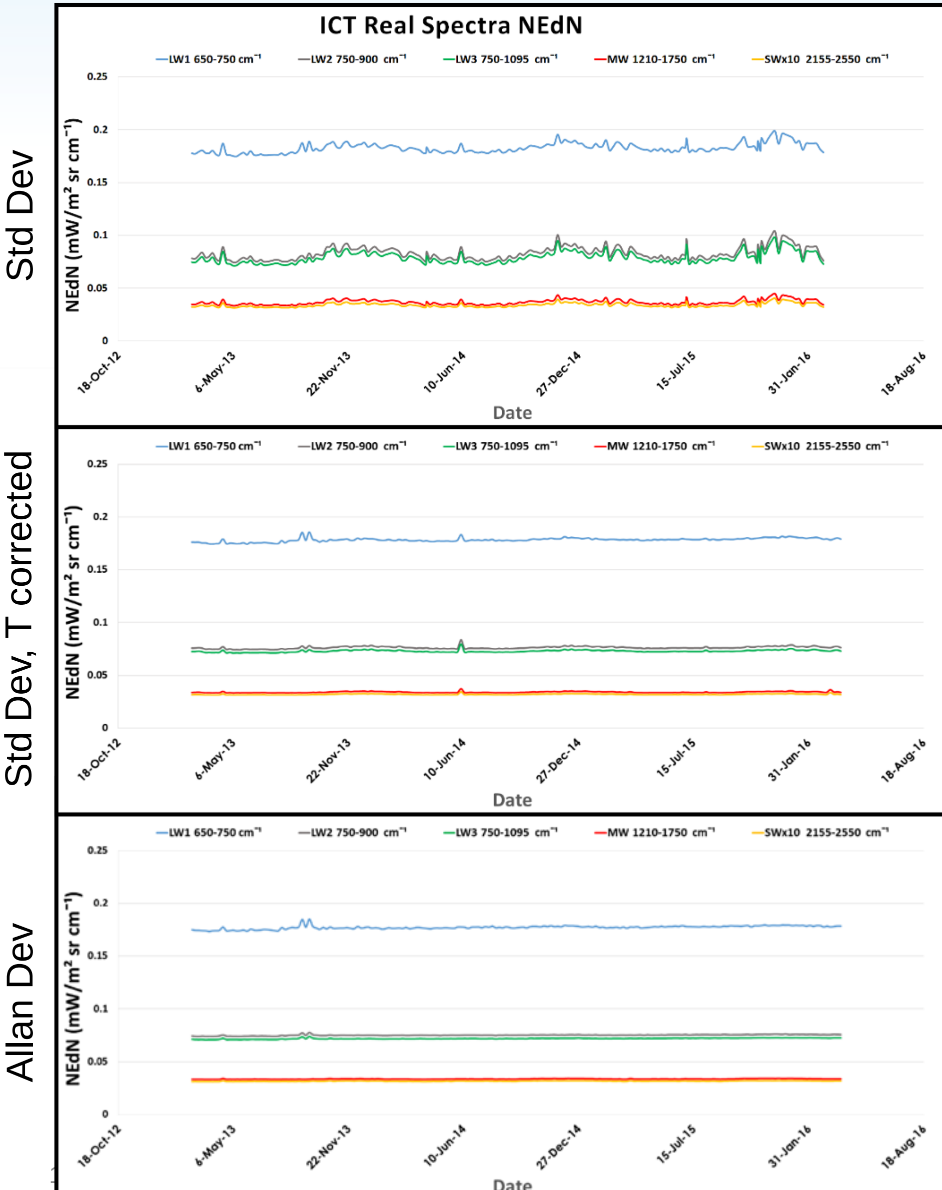
- ICT interferograms substituted for earth scenes
- Nominal resolution
- July 7, 2016

Typical S-NPP On-Orbit NEdN



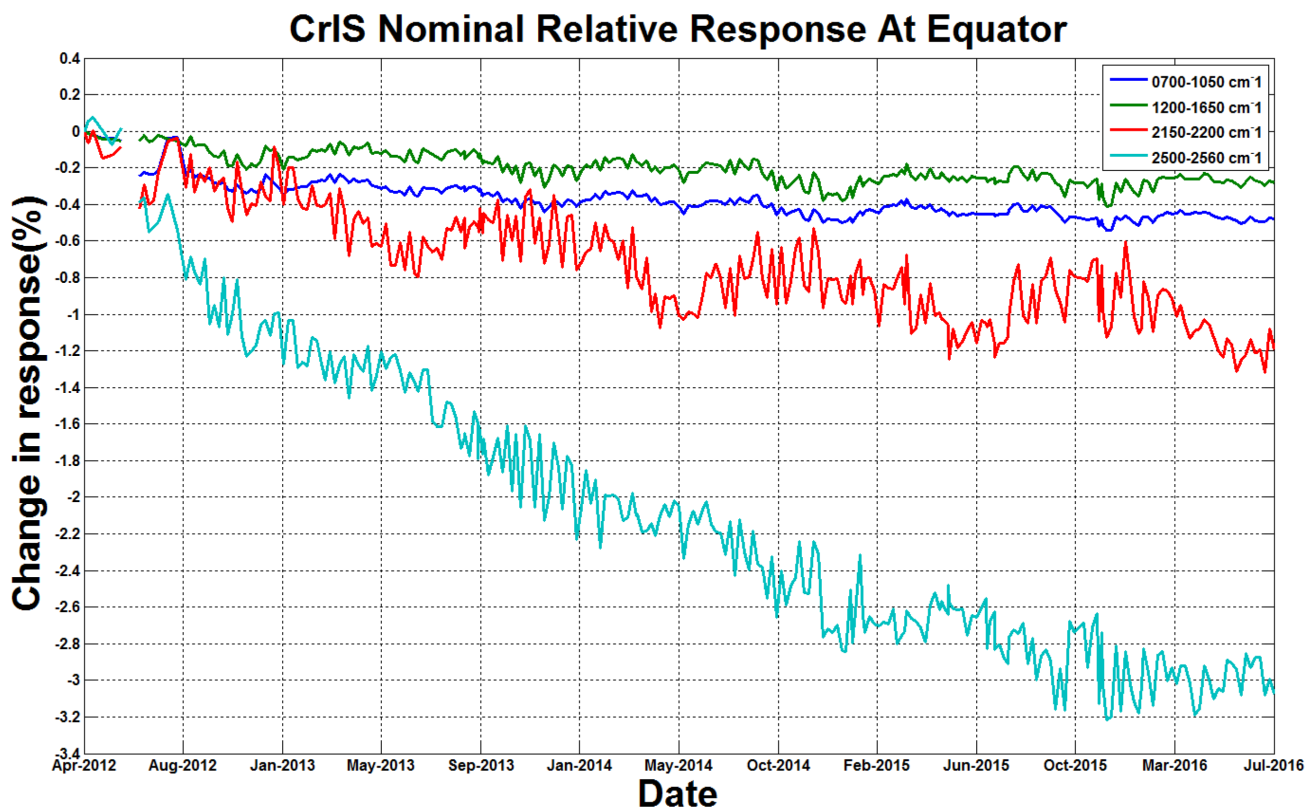
- NEdN produced by IDPS and imbedded in SDR files
- July 7, 2016

Standard Deviation vs. Allan Deviation



- CrIS NEdN is calculated using Std Dev of Internal Calibration Target (ICT) measurements with a temperature (T) correction applied
  - T correction normalizes response with varying ICT T
- Std Dev is sensitive to changing mean, Allan Dev is <u>not</u>
- Std Dev with T correction and Allan Dev are of similar magnitude and show CrIS instrument has been very stable
- ICT T is largest contributor to NEdN variation

CrIS Relative Response Degradation



- Degradation is only about 3% after 4.5 years at most sensitive wavenumbers
- Response degradation appears to be leveling off

Bit-Trim Check

- CrIS uses bit-trim compression for interferograms
  - Different number of bit are used to encode interferogram zones
  - More bits used near center of interferogram (zero path difference or ZPD) while lower number of bits in the wings of interferogram
- Bit-trim errors occur when interferogram amplitude exceeds allocated number of bits – resulting in loss of information
- Causes of bit-trim errors: hot scenes, fires, sun glints, radiation spikes, etc.
- MW margin for bit-trim errors low for hot dry scenes
- During 2015 three cases found with bit-trim errors caused by bright scenes found (all in Lut desert in Iran)
- No bright scene bit-trim errors found in 2016 through July

Extended Mode Operation

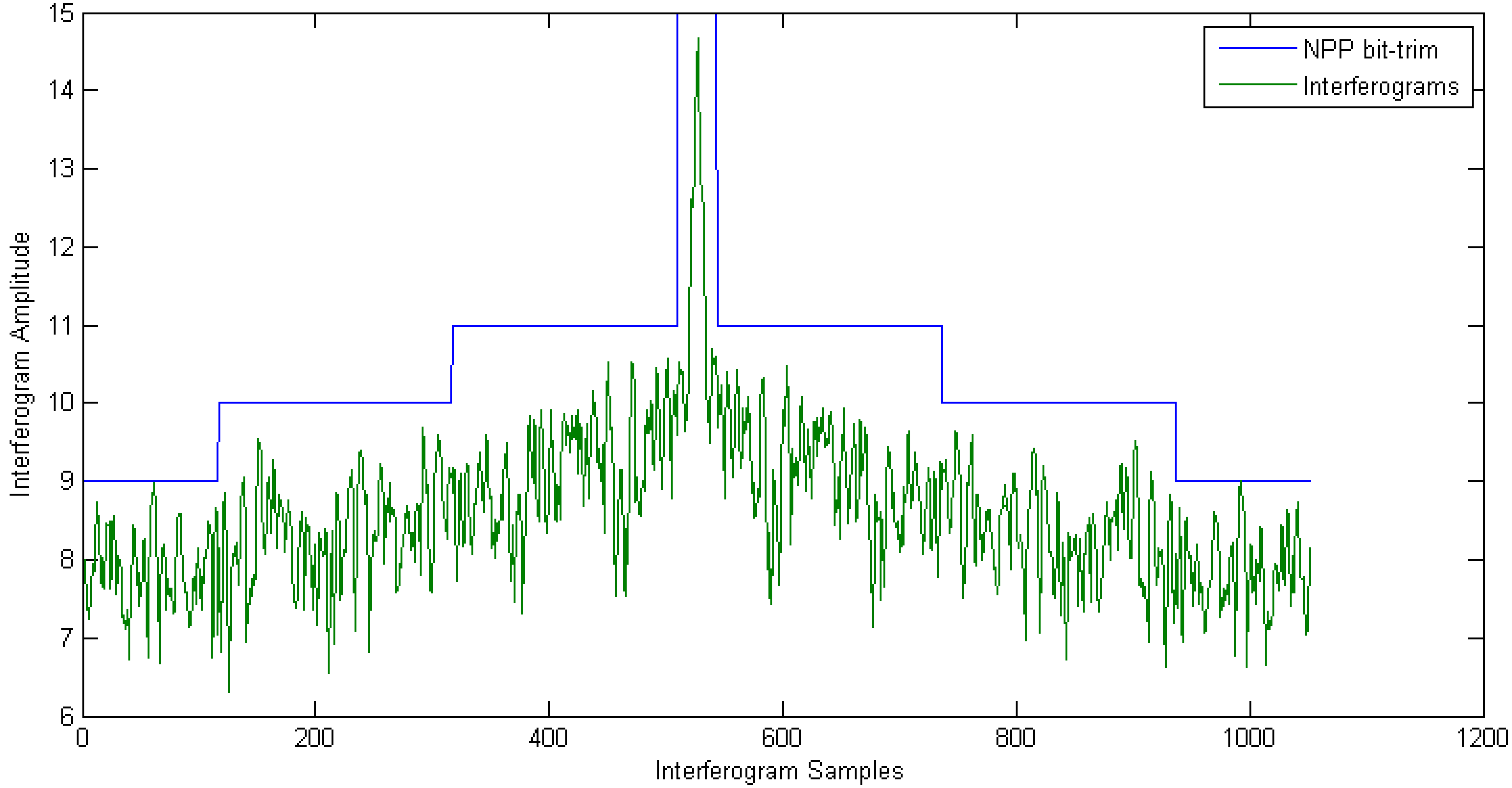
- November 2, 2015 extended lengths of S-NPP interferograms
- Truncating interferogram ends leads to spectral ringing
- Interferogram lengths changed:
  - LW 866 to 874
  - MW 1052 (unchanged)
  - SW 799 to 808
- Additional points can be used to taper interferogram ends while maintaining required spectral resolution
- Ongoing work on optimizing ground based SDR software to take advantage of these additional points

Conclusions

- Software tools and procedures are in place for J1 spacecraft level TVAC
- Practiced reading and analyzing preliminary J1 data
- Results from spacecraft TVAC with be compared with pervious sensor level TVAC results
- S-NPP has been operating very well on orbit
- Standard deviation and Allan deviation produce essentially identical results if an ICT temperature drift correction is used
- S-NPP response degradation very low after 4.5 years
- No bit-trim errors caused by too bright desert scenes in 2016

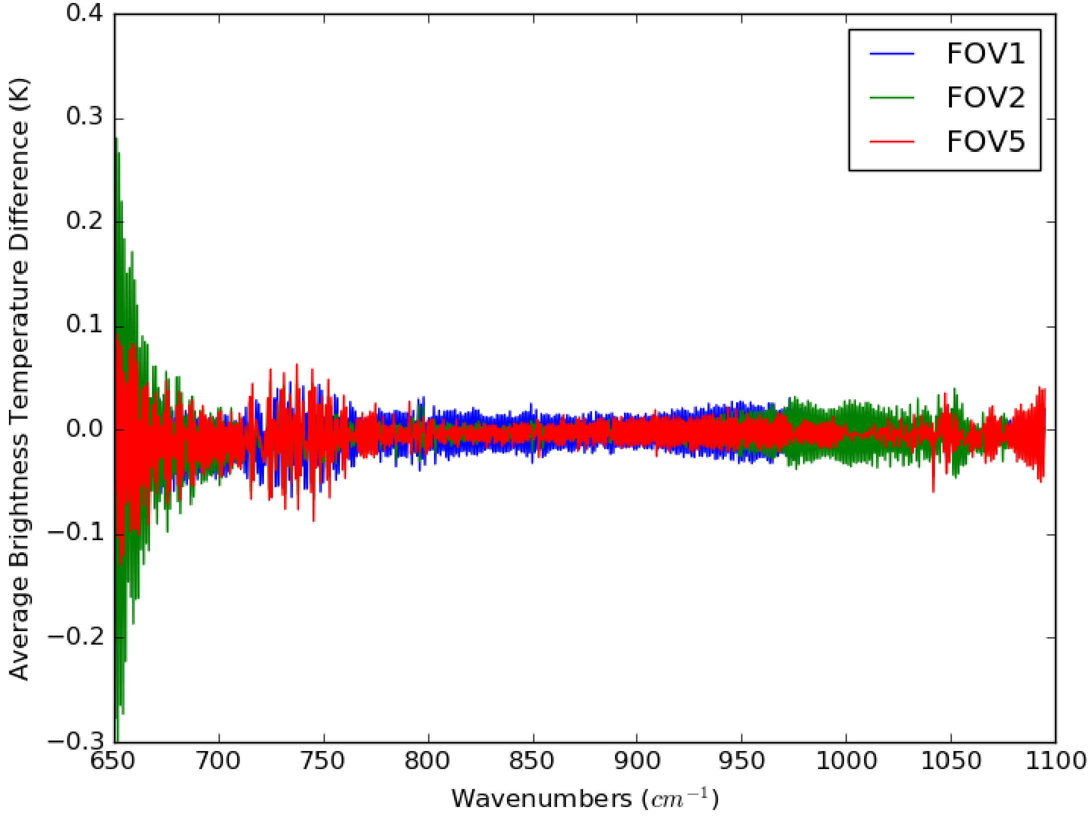
BACKUP

MWIR Bit-Trim Error Caused by Bright Scene



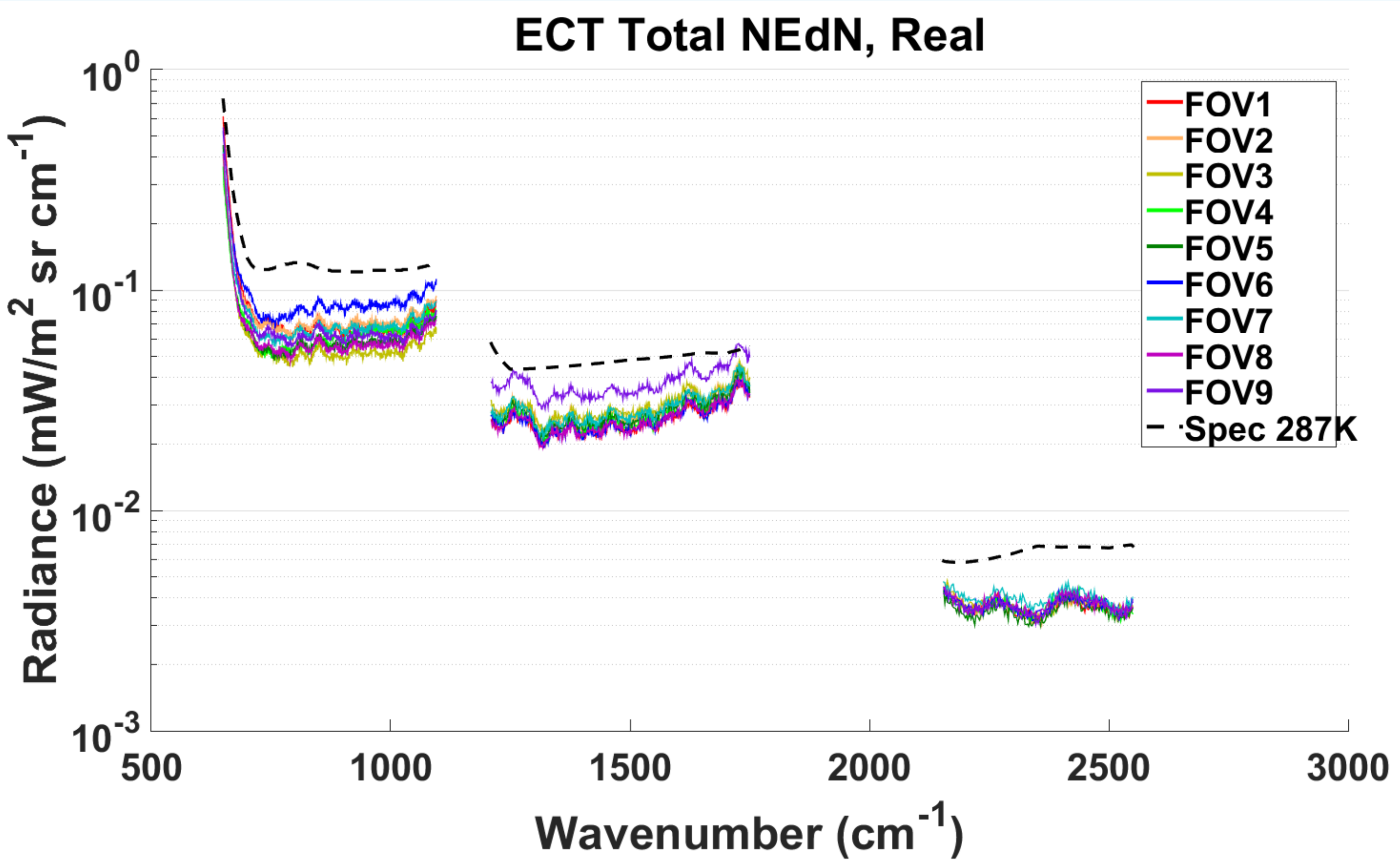
- June 11, 2015 Lut desert Iran
- Bit-trim errors occur in first and last zone

SDR Comparison



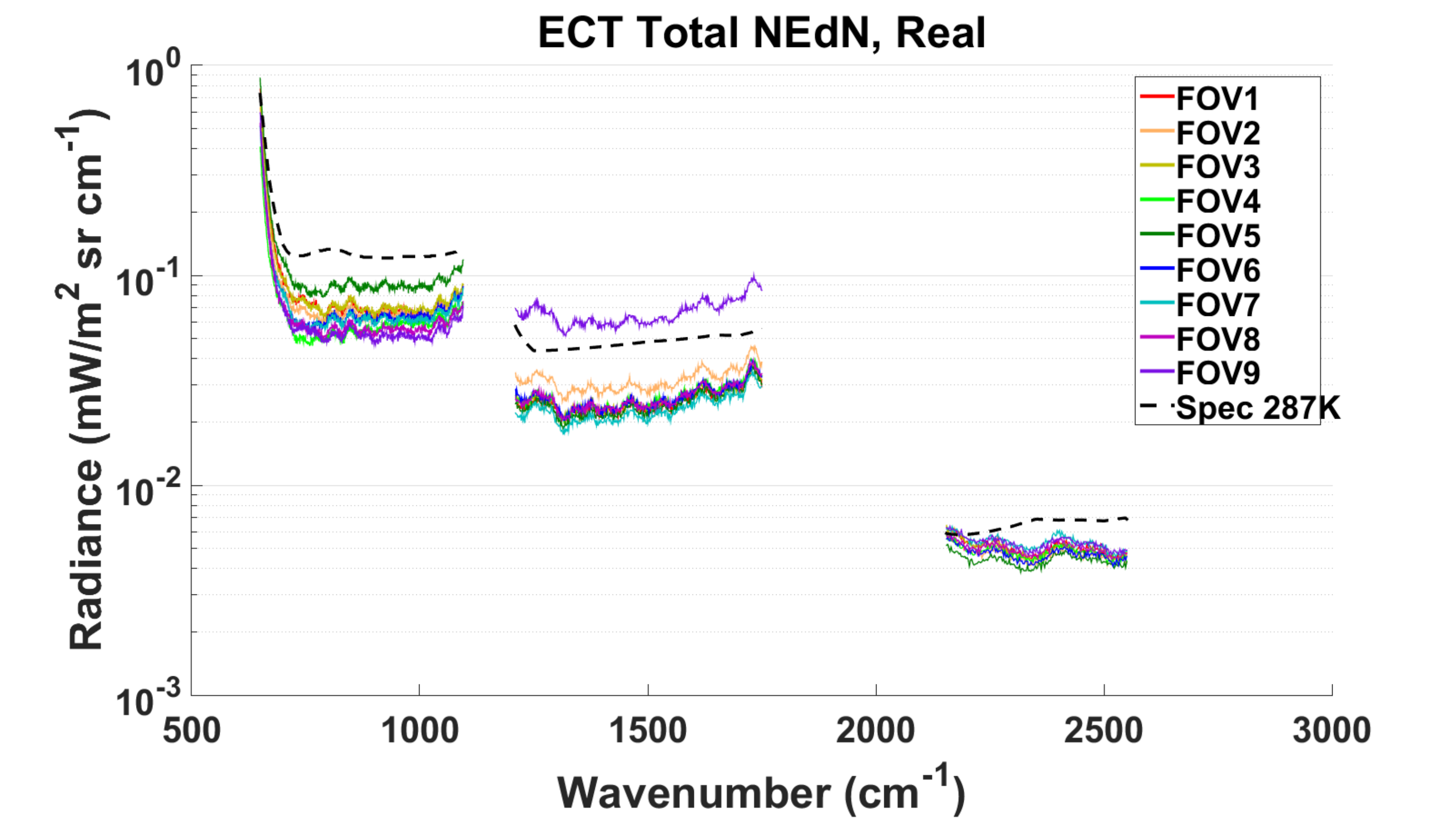
- UMBC A4 algorithm minus STAR A4 algorithm
- Clear Scenes only

PFL NEdN



- PFL (Proto Flight Low) 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