CrIS Full Spectral Resolution SDR and S-NPP/JPSS-1 CrIS Performance Status

Yong Han

NOAA Center for Satellite Applications and Research, College Park, MD, USA

and

CrIS SDR Science Team

ITSC-20
October 27 – November 3, 2015
Lake Geneva, Wisconsin, USA

CrIS SDR Science Team

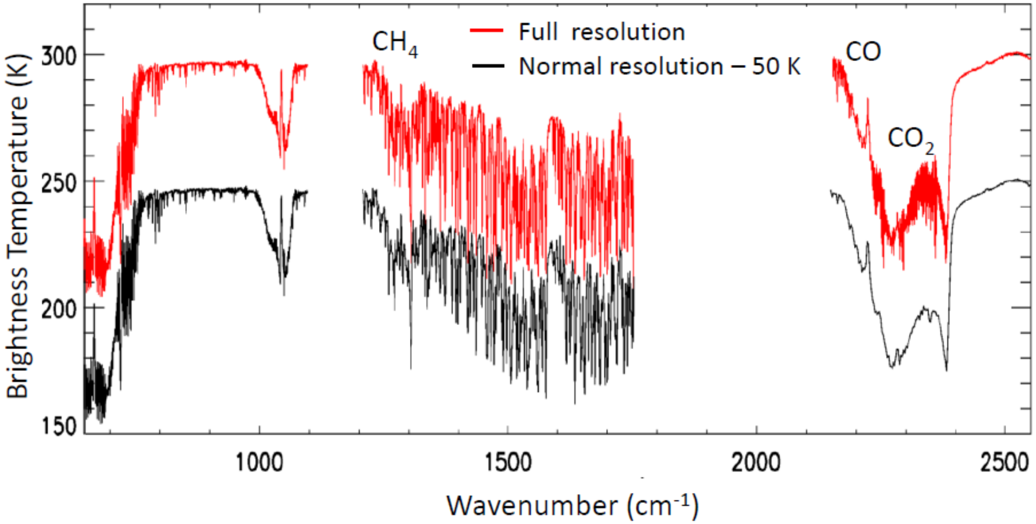
PI	Organization
Yong Han	NOAA/STAR
Hank Revercomb	U. of Wisconsin (UW)
Larrabee Strow	U. of Maryland Baltimore County (UMBC)
Deron Scott	Space Dynamic Lab (SDL)
Dan Mooney	MIT/LL
Dave Jonson	NASA Langley
Lawrence Suwinski	Harris
Joe Predina	Logistikos
Carrie Root	JPSS/DPA
Wael Ibrahim	Raytheon

Outline

- S-NPP CrIS performance status
- S-NPP CrIS full spectral resolution measurements and SDRs
- SDR algorithm improvements
- JPSS-1 CrIS status
- Summary

S-NPP CrIS Normal & Full Resolution SDRs

- **Spectral resolution modes**:
  - Full spectral resolution (FSR):
    - 0.625 cm^{-1} all three bands
    - 2211 channels
  - Normal spectral resolution (NSR):
    - 0.625 cm^{-1}(LW), 1.25 cm^{-1}(MW), 2.5 cm^{-1}(SW)
    - 1305 channels



- **NOAA CrIS SDR processing:**

Beginning S-NPP measurements (NSR mode)
March, 2012

transition to FSR mode
Dec. 4, 2014

NOAA IDPS Processing Data on CLASS

Normal mode SDRs

NOAA STAR offline processing

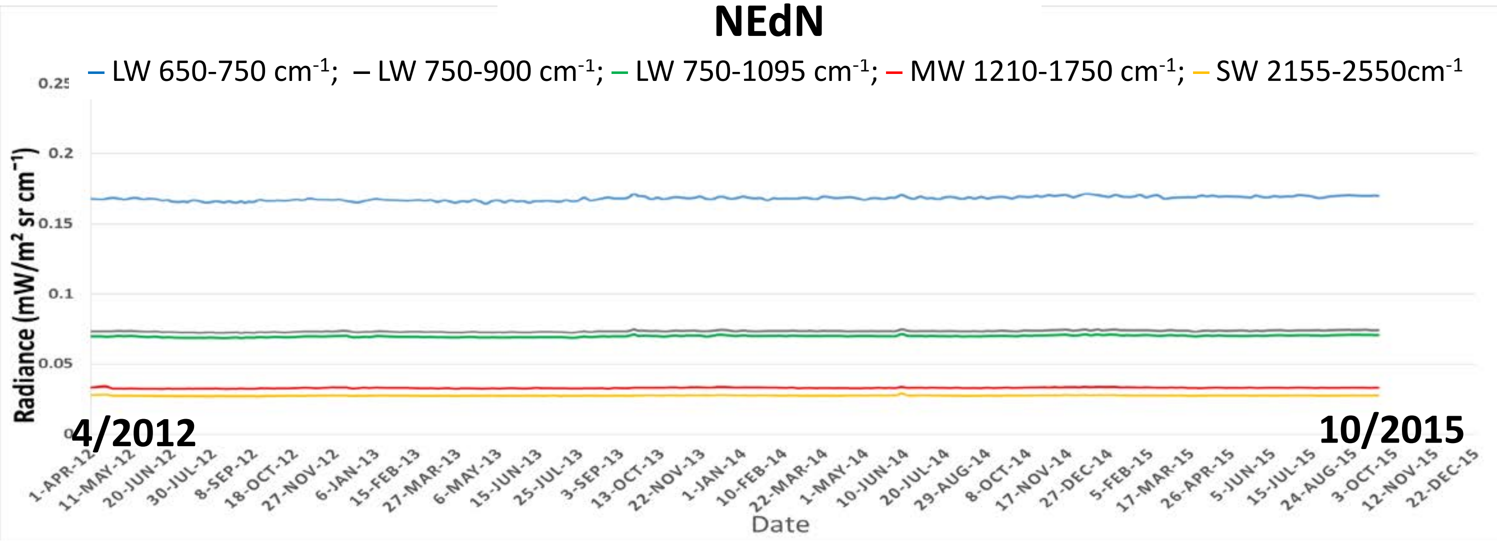
FSR mode SDRs

Data: ftp://ftp2.star.nesdis.noaa.gov/smcd/xxiong

- **Planned reprocessing:**

NOAA will reprocess CrIS data with latest ADL Block-2.0 5.x code in early 2016

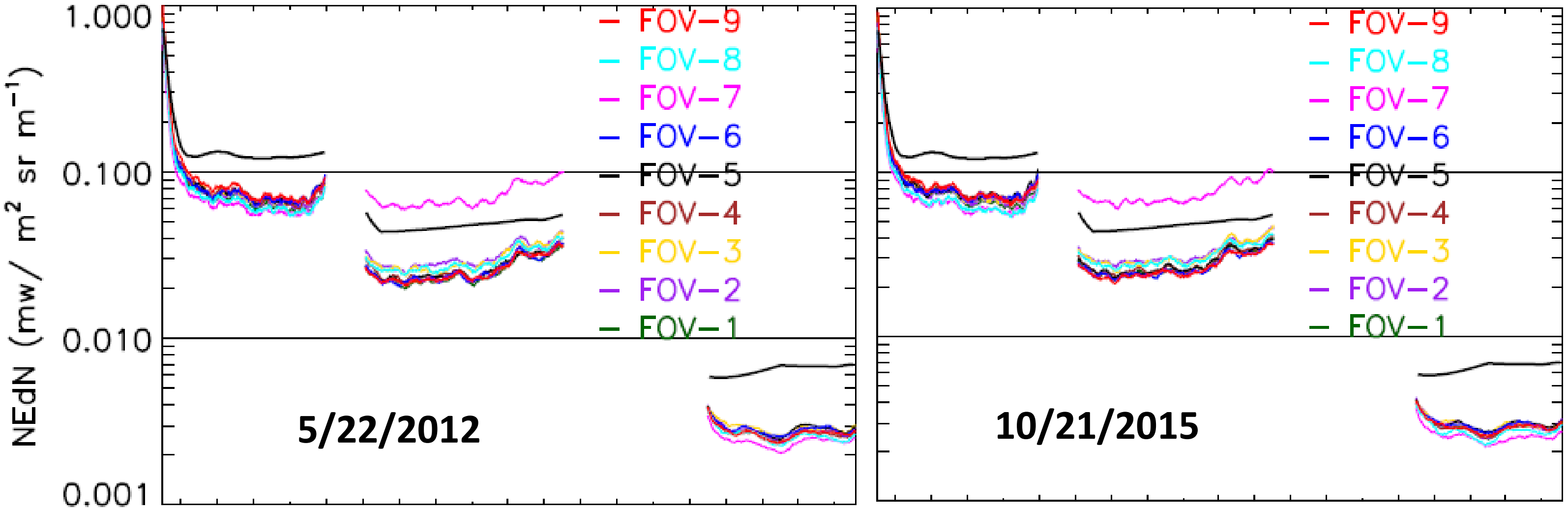
S-NPP CrIS NEdN


NEdN

4/2012

10/2015

From SDL

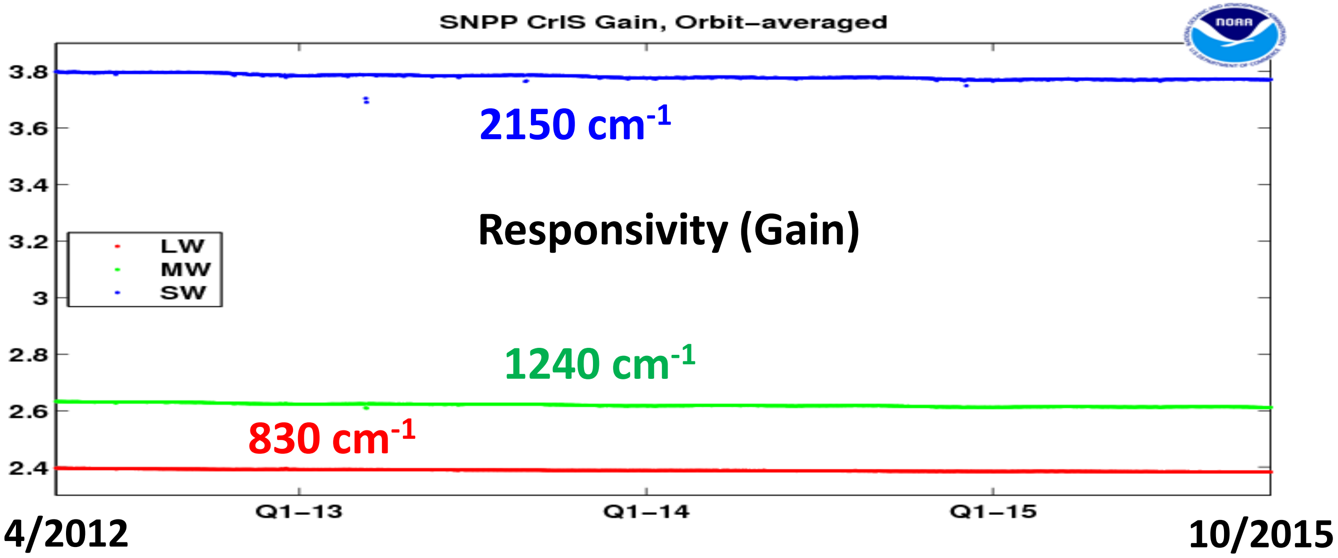

5/22/2012

10/21/2015

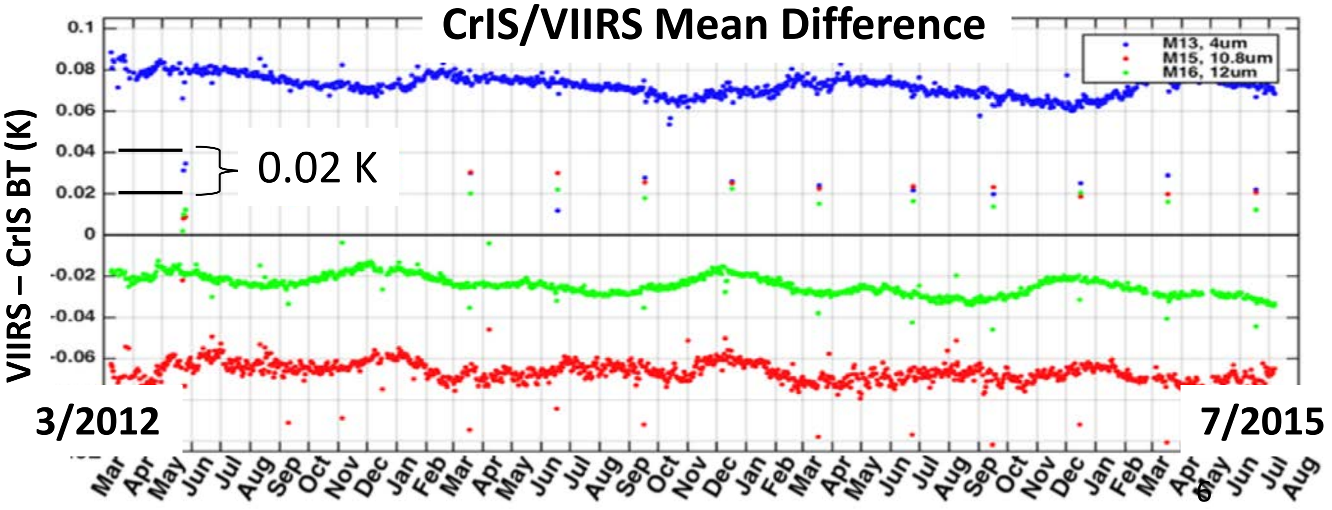
Stable NEdN performance

S-NPP CrIS Gain & Performance Stability

Less than 1% change of instrument responsivity over 3.5 years



- **Variation of the difference is less than ±0.01**
- Large outliers are due to VIIRS quarterly nonlinearity tests



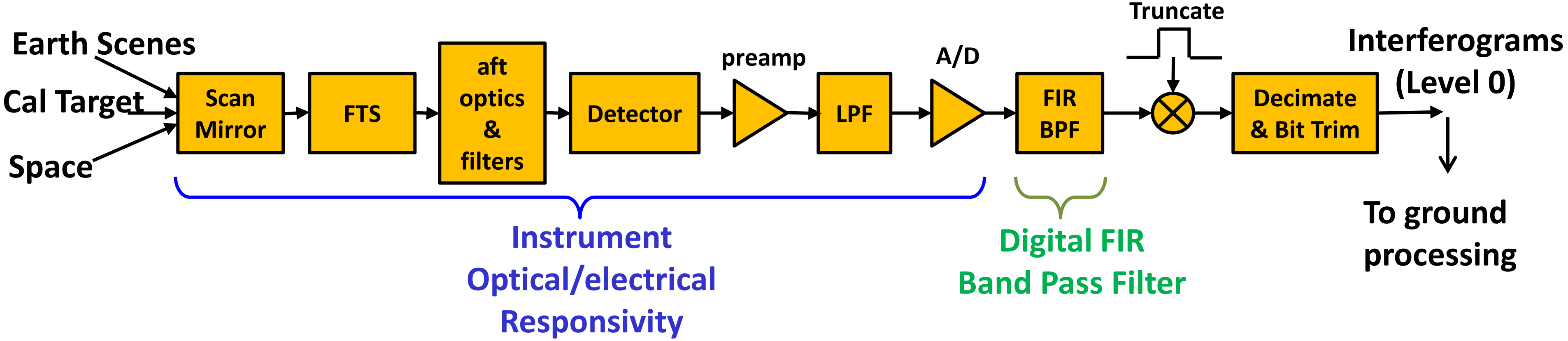
From UW

Calibration Algorithm Improvement

- CrIS SDR radiance spectra are un-apodized
- Ringing artifacts appeared when spectra are compared among the 9 FOVs, between forward and reverse sweep direction, and between observed and simulated spectra
- These ringing artifacts are due to
  - Non-circular onboard digital FIR filtering (non-circular convolution)
  - Spectral calibration applied to radiometrical ratio, which distorts information for spectral calibration.
  - Channel response model in radiance simulation that does not take into account the instrument responsivity
- Progress has been made in addressing these issues

FTS Optical & Electrical Responsivity Modifies Shape of Scene Spectrum

CrIS On-orbit Signal Processing



Earth Scenes

Cal Target

Space

Scan Mirror

FTS

aft optics & filters

Detector

preamp

LPF

A/D

FIR BPF

Truncate

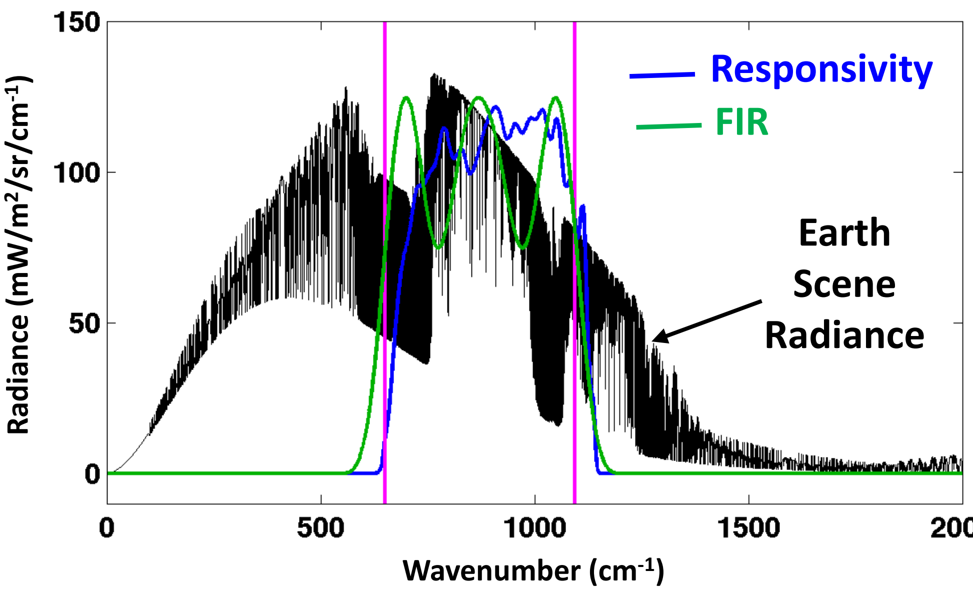
Decimate & Bit Trim

Interferograms (Level 0)

To ground processing

Instrument Optical/electrical Responsivity

Digital FIR Band Pass Filter



Courtesy University of Wisconsin

Predina et al, OSA HISE, 2015

Optimizing Calibration Equation

Current algorithm:

$$S_{Cal} = \underbrace{SA^{-1} \cdot F}_{} \cdot f \cdot \{ \frac{\Delta S_1}{\Delta S_2} (SA \cdot B_{ICT}) \}$$

$$\Delta S_1 = FIR^{-1}(S_e - < S_{DS} >)$$

$$\Delta S_2 = FIR^{-1}(< S_{ICT} > - < S_{DS} >)$$

FIR filter removal

Spectral calibration

New algorithm:

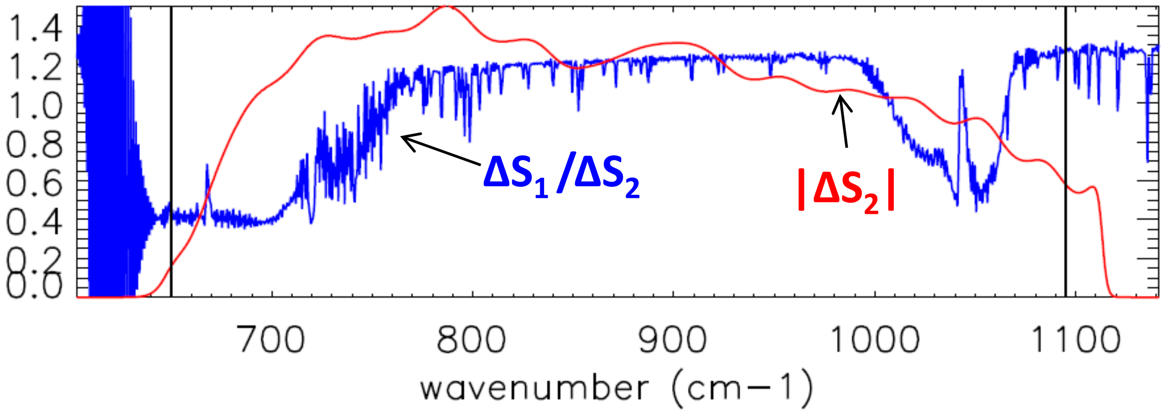
$$S_{Cal} = B_{ICT} \cdot \frac{\overbrace{F \cdot SA^{-1}}^{} \cdot f \cdot \{ \frac{\Delta S_1}{Phase(\Delta S_2)} \}}{F \cdot SA^{-1} \cdot f \cdot \{ \frac{\Delta S_2}{Phase(\Delta S_2)} \}} = B_{ICT} \cdot \frac{F \cdot SA^{-1} \cdot f \cdot \{ \frac{\Delta S_1}{\Delta S_2} |\Delta S_2| \}}{F \cdot SA^{-1} \cdot f \cdot |\Delta S_2|}$$

The new algorithm applies spectral calibration to raw spectra to take into account the effect of instrument responsivity and allow a wider bandpass post-filter *f*

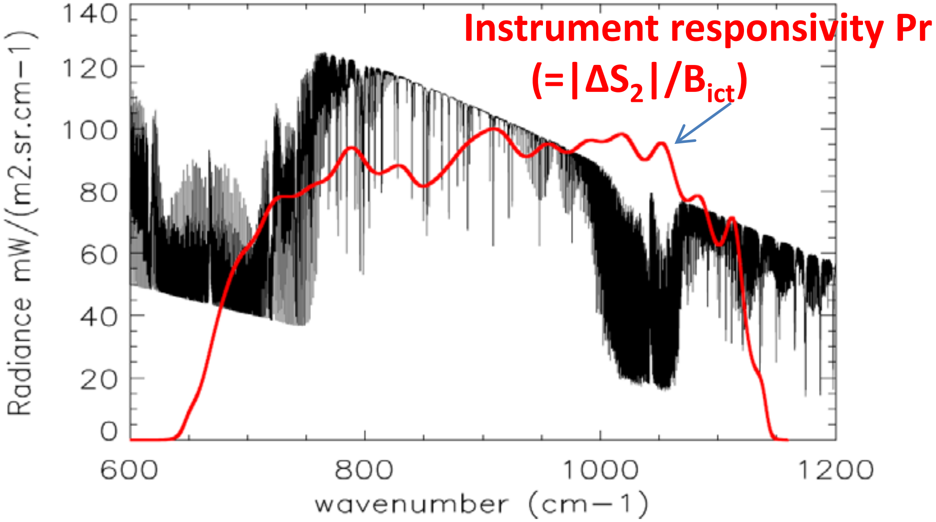
S_e , S_{DS}, S_{ict} – raw spectra of earth scene, deep space & internal calibration target
B_{ICT} – calculated ICT spectrum
SA, SA^{-1} – self-apodization and self-apodization correction matrices
F – spectral resampling matrix
f – bandpass post-calibration filter

Responsivity in Spectrum Simulation

$$S_{Cal} = B_{ICT} \cdot \frac{F \cdot SA^{-1} \cdot f \cdot \{\frac{\Delta S_1}{\Delta S_2}|\Delta S_2|\}}{F \cdot SA^{-1} \cdot f \cdot |\Delta S_2|}$$



RT modeling with instrument responsivity



Use of instrument responsivity in CrIS radiance simulation (suggested by UW) is consistent with the new calibration equation

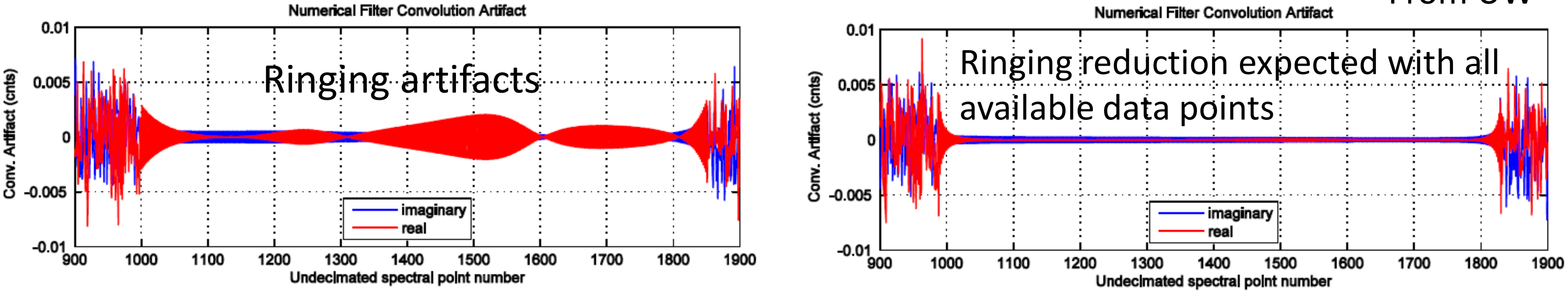
S_{lbl} * P_r → **Double FFT** → **Spectrum/P_r** → CrIS spectrum

Correction to Error due to Non-circular Filtering

- Due to non-circular convolution, the FIR filter can not be completely removed from spectrum *S* by taking *S/FIR*, causing ringing artifacts
- A method was developed to reduce ringing artifacts by using longer interferograms

Spectrum difference from truth

From UW



Ringing artifacts

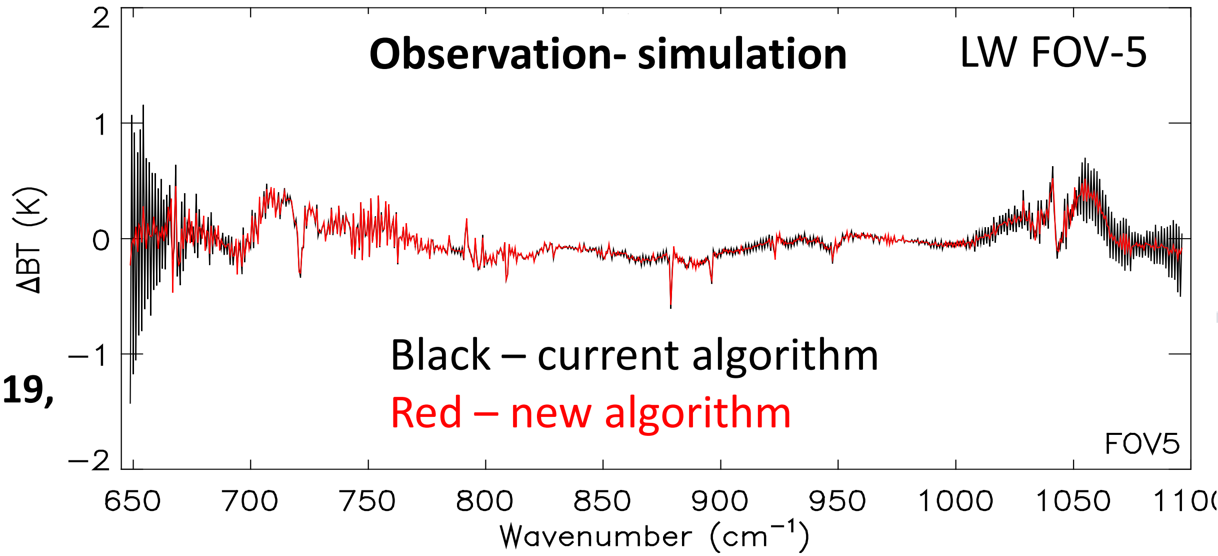
Ringing reduction expected with all available data points

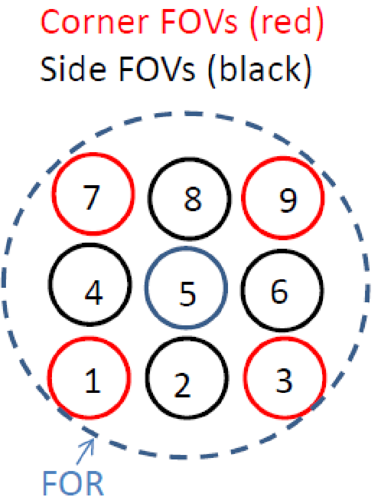
Length of interferograms used in calibration:

	LW	MW	SW
Data points used in current algorithm	864	1050	797
Current available data points used in new algorithm evaluation	866	1052	799
Additional data points available Nov. 2015	874	1052	808

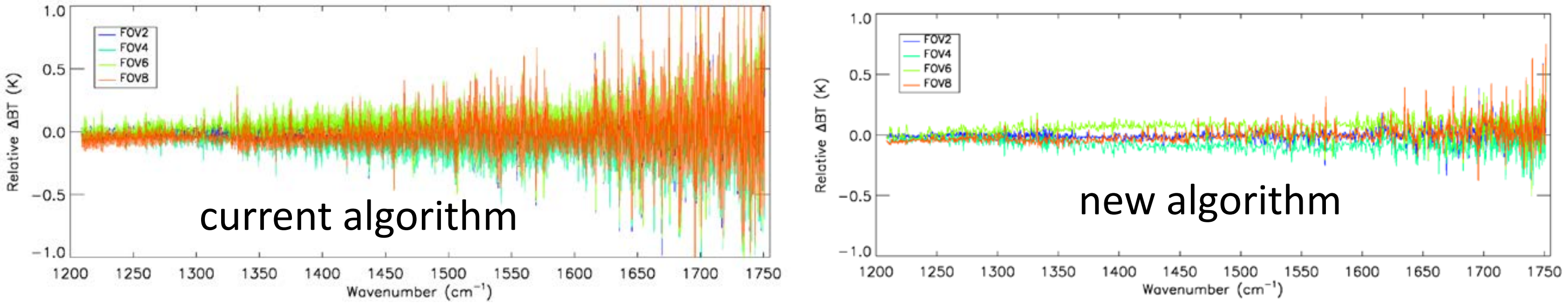
New Calibration Algorithm Evaluation

Clear scenes, Feb. 17, 18 & 19, 2015





MW band FOV-to-FOV difference

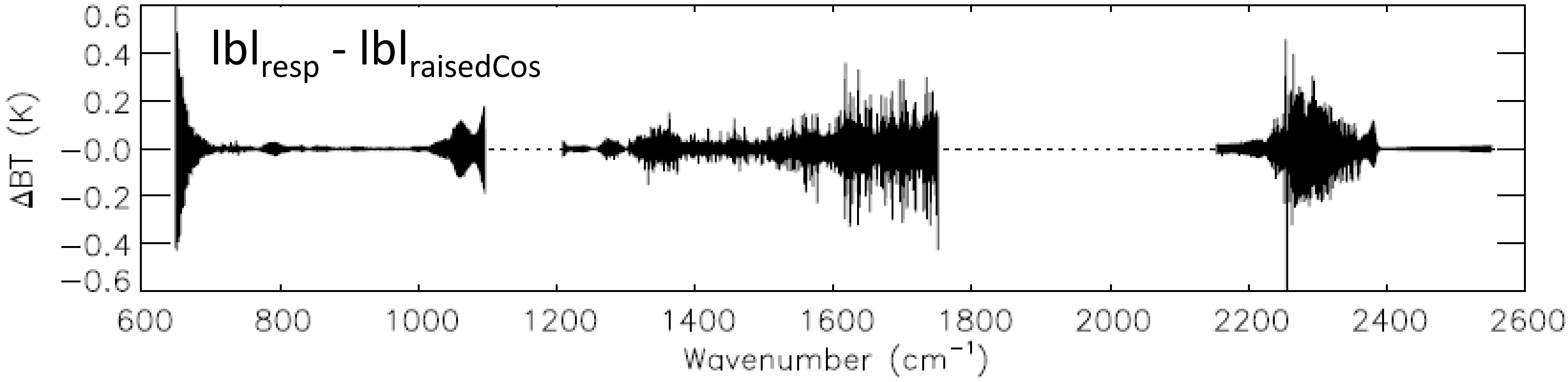


The new algorithm significantly reduces ringing artifacts

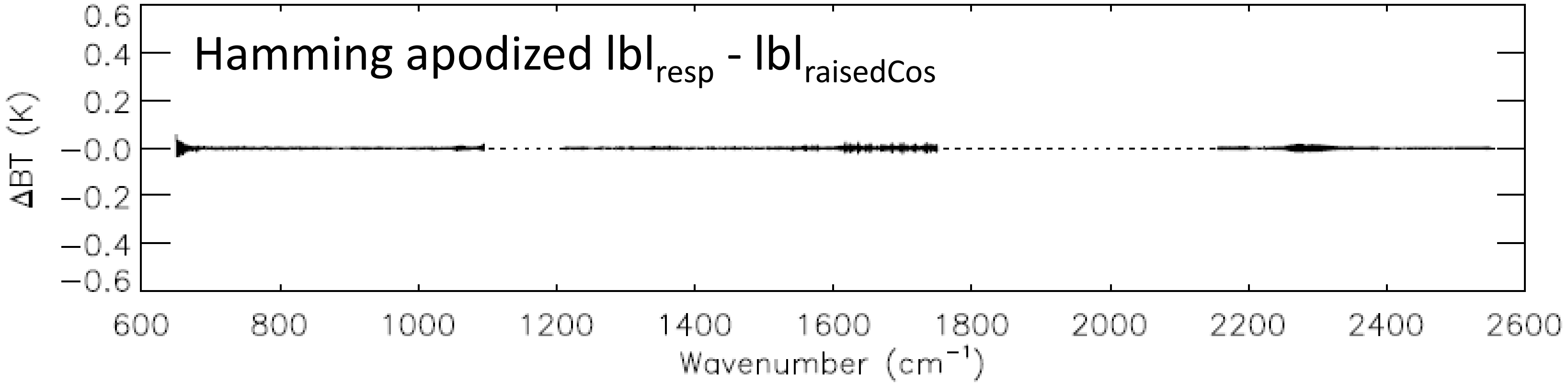
Simulation Issue: Responsivity vs Raised-cosine

lbl_{resp} - CrIS spectrum created with LBL spectrum filtered with responsivity

$lbl_{Cosfilter}$ - CrIS spectrum created with LBL spectrum filtered with a function that is flat in-band and a raised-cosine outside of the band at each end



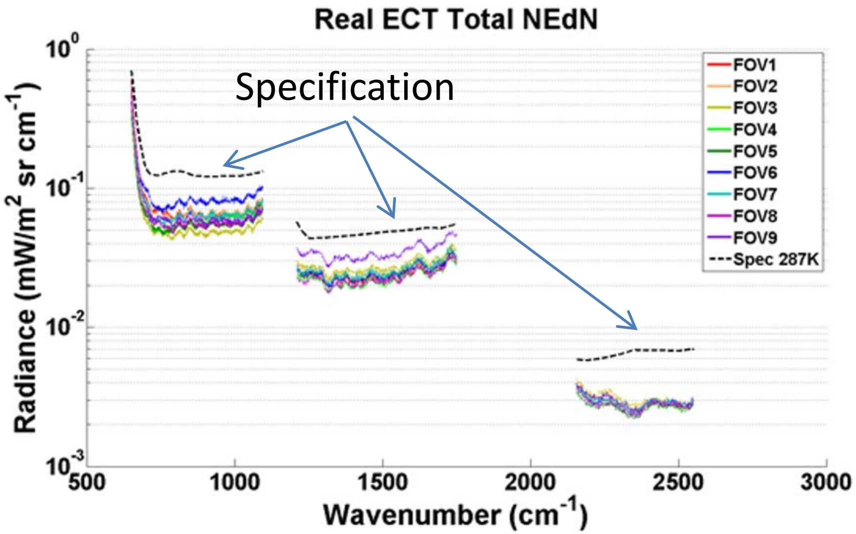
Very small difference after apodization



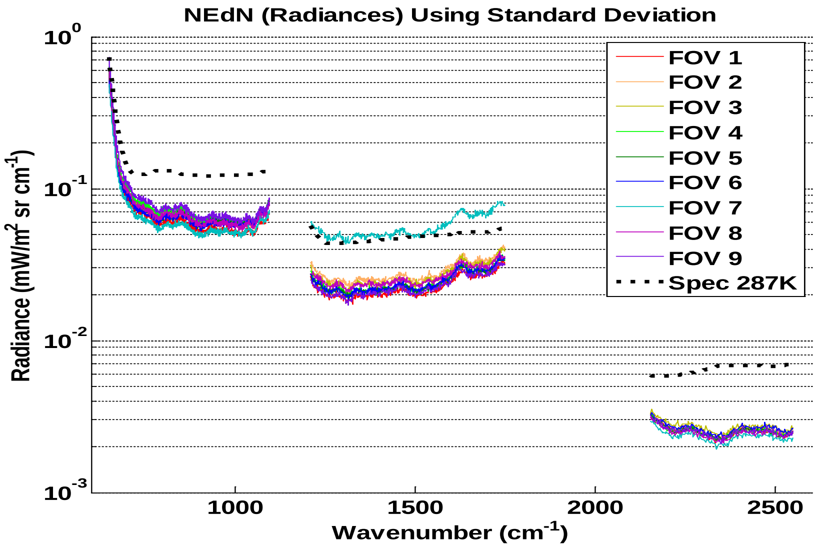
JPSS-1 CrIS Status

- J1 CrIS successfully completed comprehensive pre-launch test program and integrated to J1 for spacecraft level testing
- Calibration LUTs (ILS/nonlinearity/geo-mapping parameters) determined
- J1 CrIS performance as good or better than S-NPP

JPSS-1 NEdN



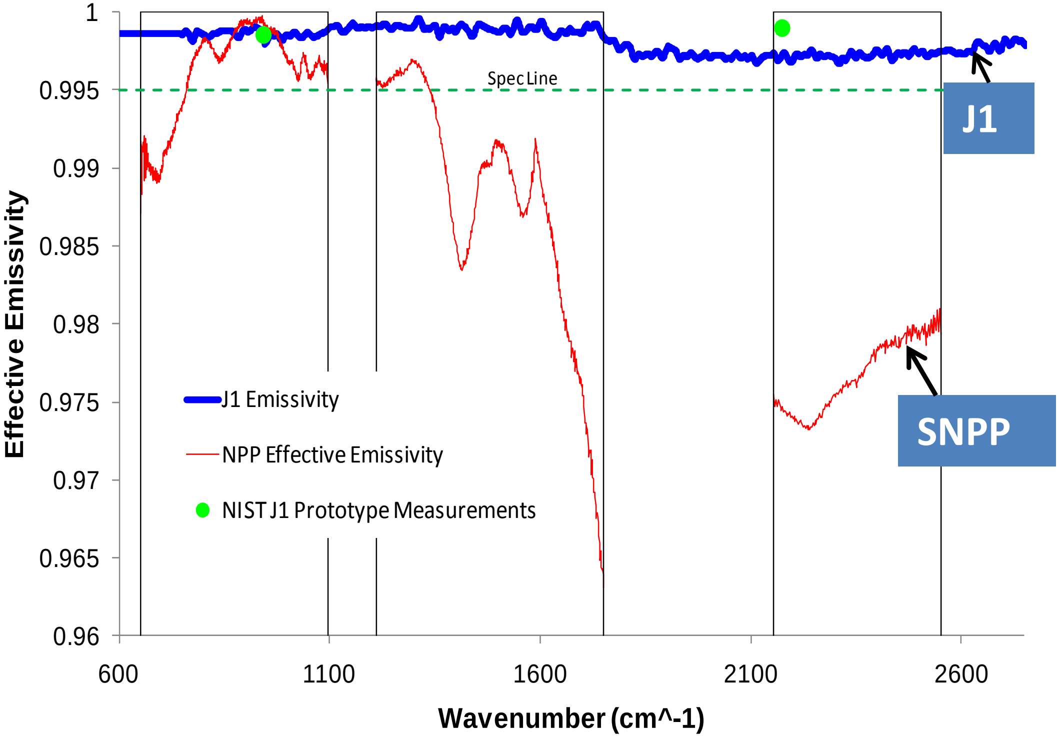
S-NPP NEdN



J1 CrIS ICT Performance Improved From SNPP

- J1 Internal Calibration Target (ICT) redesigned to improve performance
  - Specular coating provides increased emissivity and better stray light rejection
  - Cavity wedge design helps eliminate views to other optical surfaces within instrument
  - Additional PRT provides increased temperature and gradient knowledge
  - Results in simplified SDR processing and more accurate calibration performance

Improved Emissivity



From Harris

Summary

- S-NPP CrIS performance has been stable and consistent; there is no significant performance degradation
- S-NPP CrIS full spectral resolution SDRs have been routinely generated since Dec. 4, 2014, available to the public
- The calibration algorithm improvements significantly reduce radiance ringing artifacts and are being implemented for operational processing
- Pre-launch ground testing program has been successfully completed and results show JPSS-1 CrIS performance as good or better than S-NPP CrIS