Evaluation of Different Calibration Approaches for JPSS CrIS

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Acknowledgement: CrIS SDR science team for the development and improvement of J1 CrIS SDR algorithm

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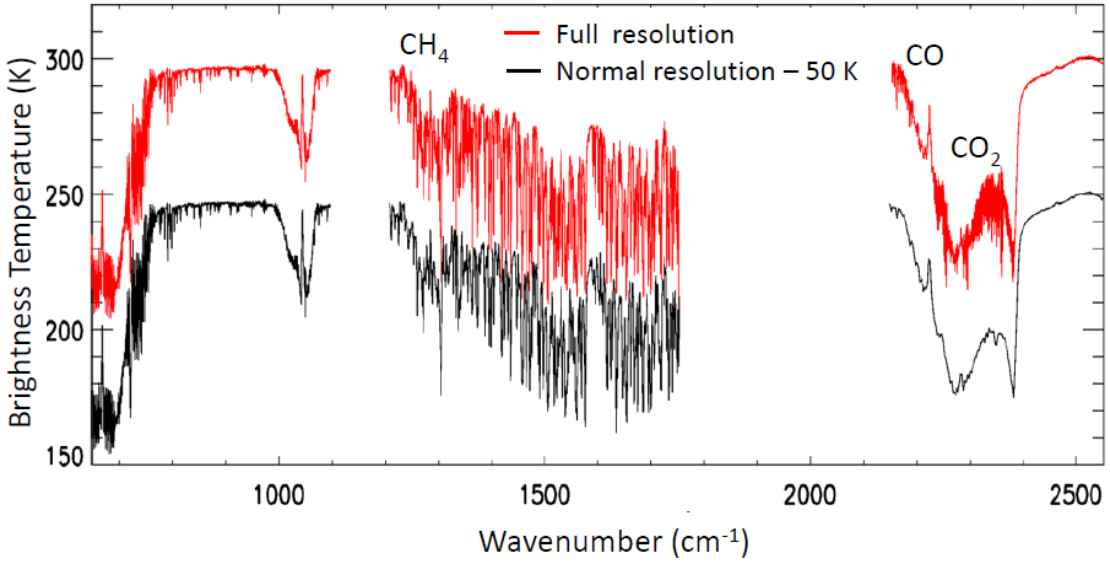
Outline

- S-NPP CrIS full spectral resolution measurements and SDRs
- J1 CrIS SDR algorithm/software baseline version
- Calibration algorithm improvements and evaluations
- Summary and future work

S-NPP CrIS Normal & Full Resolution SDRs

Spectral resolution modes:

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



Beginning S-NPP CrIS measurements
March, 2012

CrIS transition to FSR mode
Dec. 4, 2014

NOAA IDPS Processing Data on CLASS

Normal mode SDRs

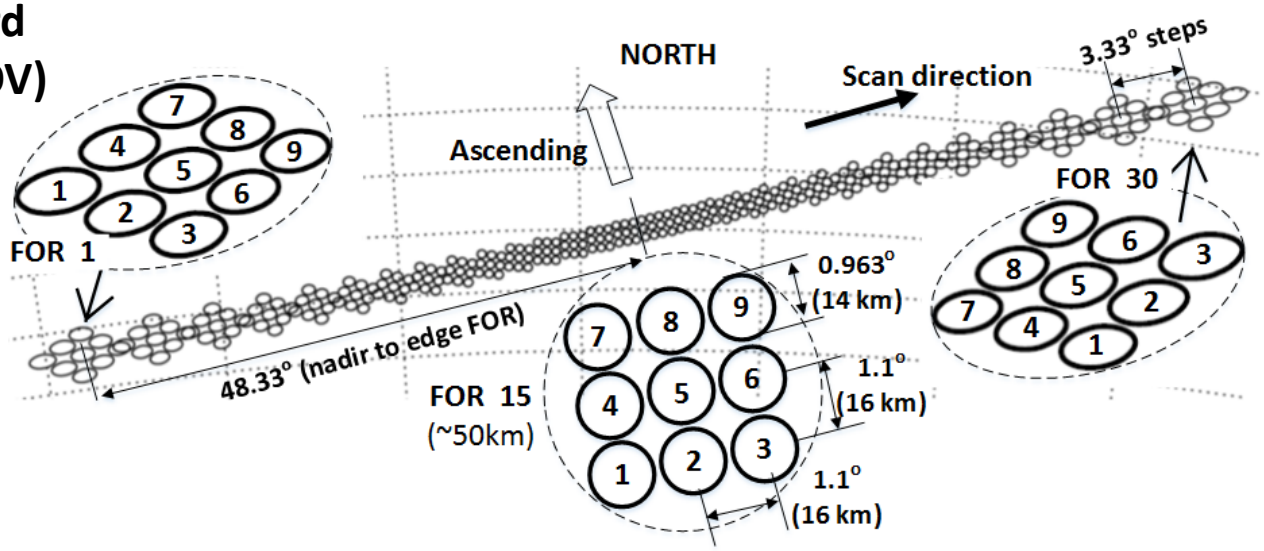
NOAA STAR offline processing

FSR mode SDRs

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

S-NPP/JPSS1 CrIS SDR Specifications

CrIS scan, field-of-regard (FOR), field-of-view (FOV)



CrIS SDR specifications. Black – normal spectral resolution (NSR); Red – full spectral resolution (FSR)

Band	Spectral Range (cm^{-1})	# of Chan.	Spectral Res. (cm^{-1})	NEdN @287K BB ($mW/m^2/sr/cm^{-1}$)	Radiometric Uncertainty @287K (%)	Frequency Uncertainty (ppm)	Geolocation Uncertainty (km)
LWIR	650-1095	713	0.625	0.14	0.45	10	1.5
	650-1095	713	0.625	0.14	0.45	10	1.5
MWIR	1210-1750	433	1.25	0.06	0.58	10	1.5
	1210-1750	865	0.625	0.085	0.58	10	1.5
SWIR	2155-2550	159	2.50	0.007	0.77	10	1.5
	2155-2550	633	0.625	0.014	0.77	10	1.5

Number of FSR channels: 2211; Number of NSR channels: 1305

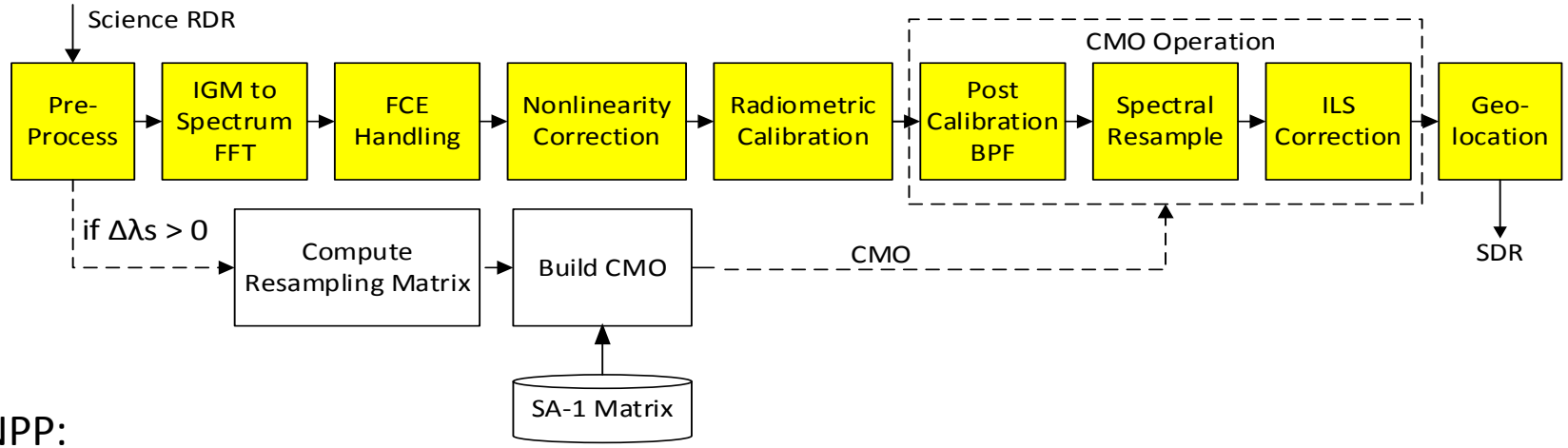
J1 CrIS SDR Algorithm/Software Baseline Version

- Delivered on January 30, 2015

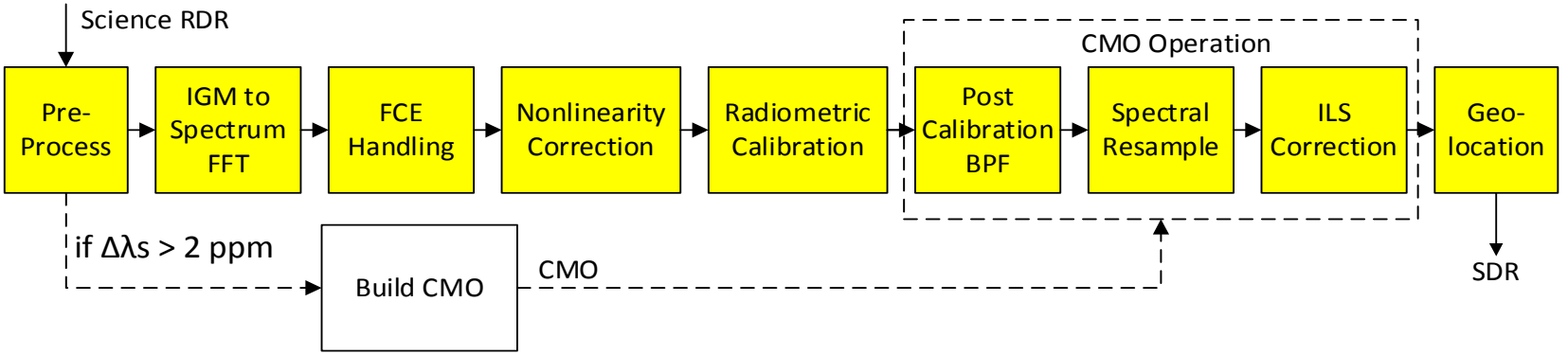
- Software/software changes
  - Capable to process both normal and full spectral resolution SDRs
  - Backward compatibility (multiple calibration algorithms implemented)
  - Correction Matrix Operator (CMO) file separated into two files: 1) SA-1 matrix; 2) backup of Engineering packet
  - Resampling matrix calculation following neon calibration
  - Resampling and self-apodization matrix algorithms are modified to reduce spectral ringing artifacts
  - Spectral calibration (CMO) applied to radiance noise (NEdN) calculation
  - New FCE detection/correction module

Processing Flow

JPSS-1:



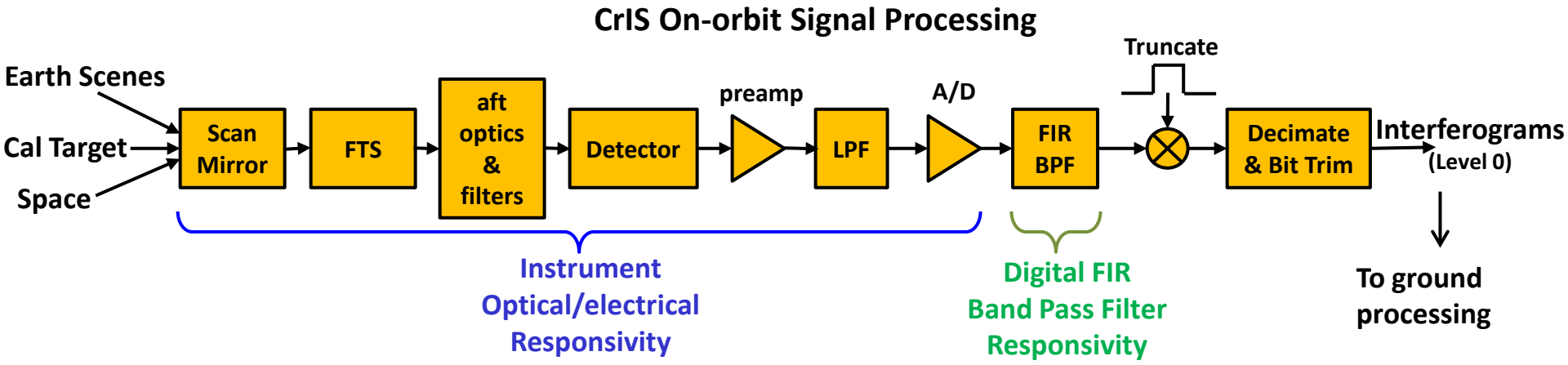
S-NPP:

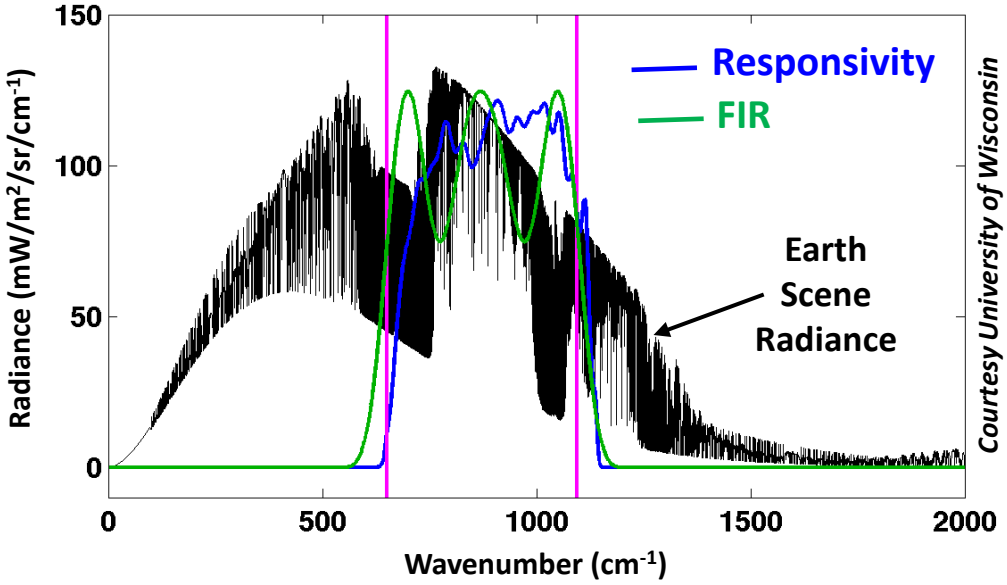


Calibration Algorithm Improvement

- 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 FIR filtering
  - Spectral calibration applied to radiometrically calibrated spectrum, not the raw spectrum.
  - Channel response model in radiance simulation not taking into account the instrument responsivity
- Progress has been made in addressing these issues and reducing these ringing artifacts

FTS Optical & Electrical Responsivity Modifies Shape of Scene Spectrum





Predina et al, OSA HISE, 2015

Optimizing Calibration Equation

Current algorithm: **Radiometric calibration removes the effect of optical/electrical responsivity. If radiometric calibration precedes ILS spectral correction, then the ILS correction is actually performed on the wrong spectrum.**

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

Spectral calibration

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

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

FIR filter removal

New algorithm:

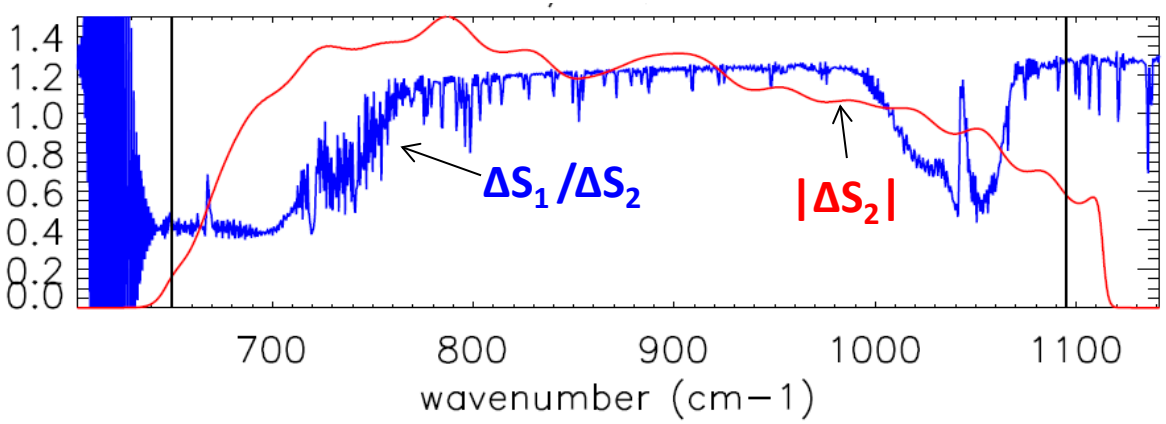
$$S_{Cal} = B_{ICT} \cdot \frac{F \cdot SA^{-1} \cdot f \cdot \{\frac{\Delta S_1}{Phase(\Delta S_2)}\}}{F \cdot SA^{-1} \cdot f \cdot \{\frac{\Delta S_2}{Phase(\Delta S_2)}\}} = B_{ICT} \cdot \frac{F \cdot SA^{-1} \cdot f \cdot \{\frac{\Delta S_2}{|\Delta S_2|}|\Delta S_2|\}}{F \cdot SA^{-1} \cdot f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

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

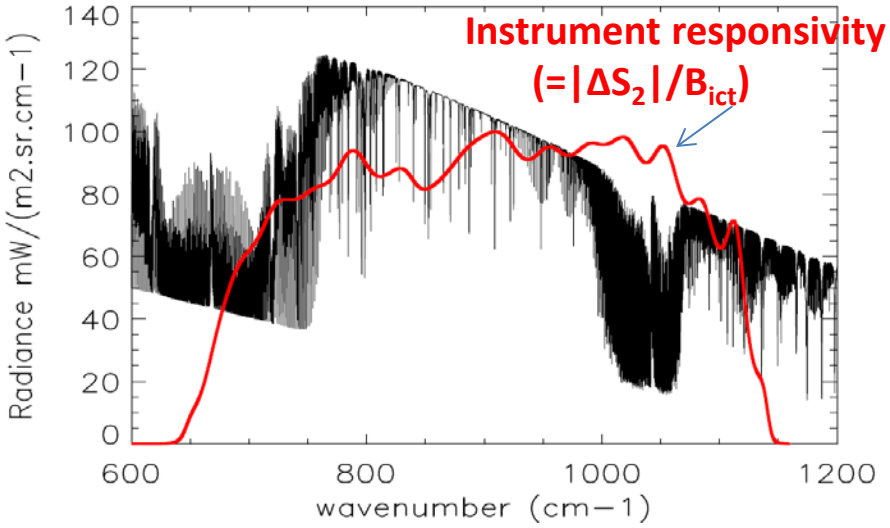
S_e , S_{DS}, S_{ict} – raw spectra of earth scene, deep space & internal calibration target
B_{ICT} – calculated ICT spectrum
SA^{-1} – self-apodization correction matrix
F – spectral resampling matrix
f – post-calibration filter

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



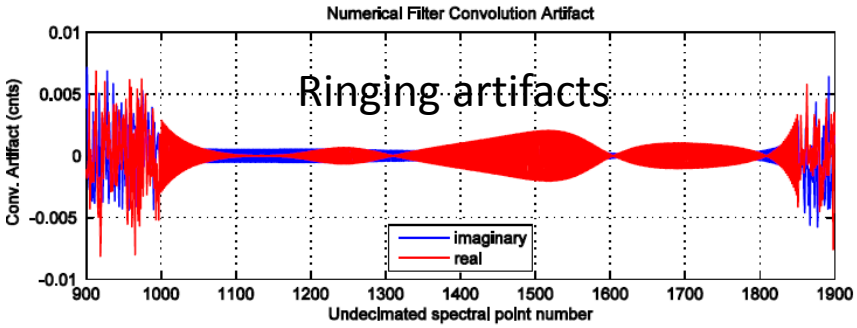
Use of instrument responsivity in CrIS radiance simulation suggested by UW is consistent with the new calibration equation

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

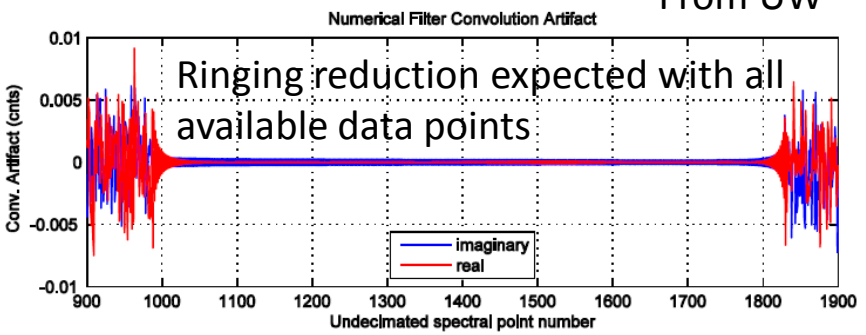
Correction to Error from Non-circular Filtering

- Due to non-circular FIR filtering (convolution), its effect is not completely removed from spectrum *S* by the operation *S*/*FIR*, resulting in ringing artifacts
- A method was developed to reduce ringing artifacts by using longer interferograms

Spectrum difference from truth



From UW

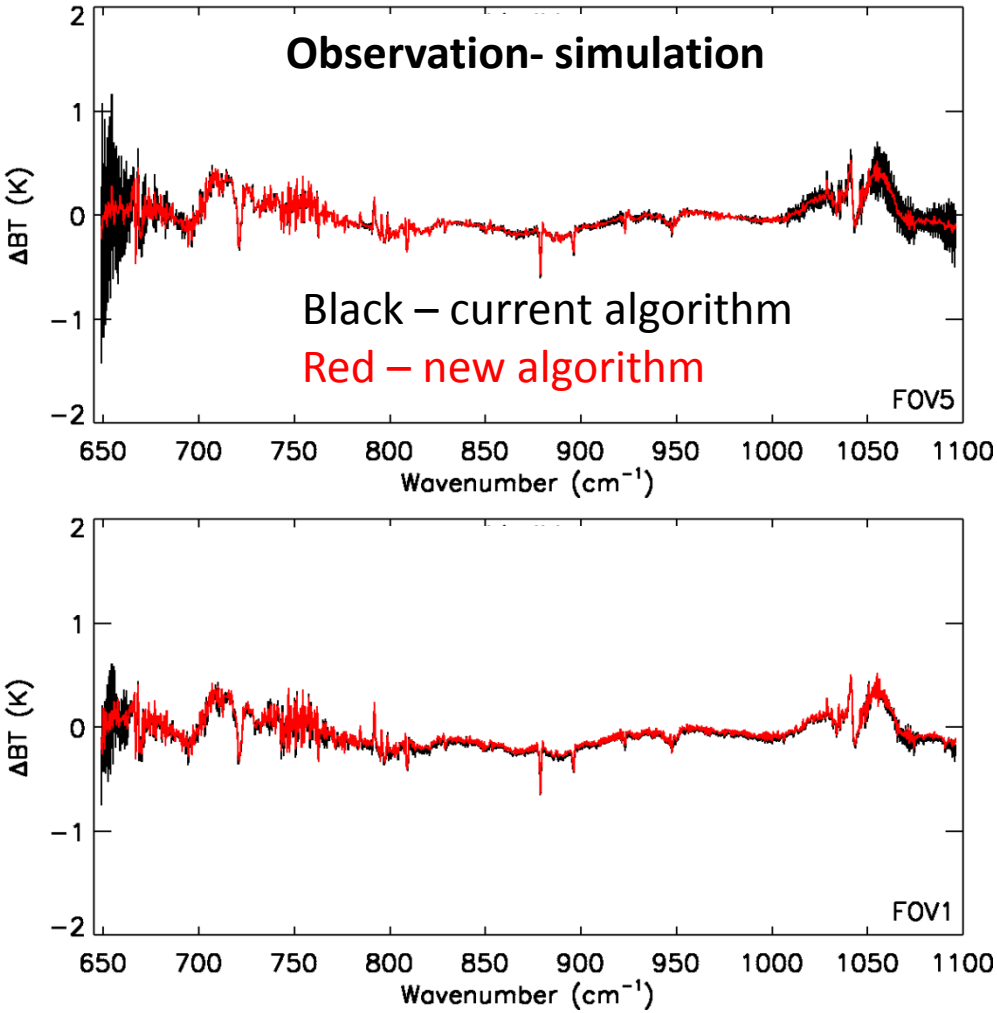


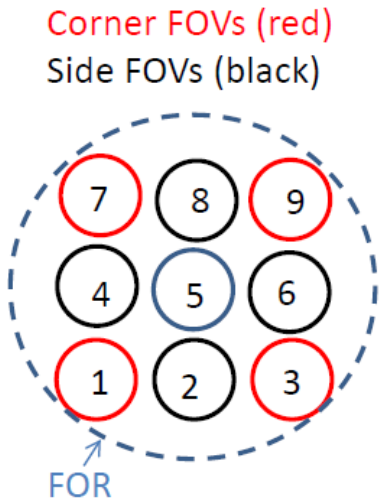
Data points used in calibration:

	LW	MW	SW
Data points used in current algorithm	864	1050	797
Current available data points	866	1052	799
Additional data points available Nov 2, 2015	874	1052	808

Algorithms Evaluation: Observation Compared to LBL Simulation

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

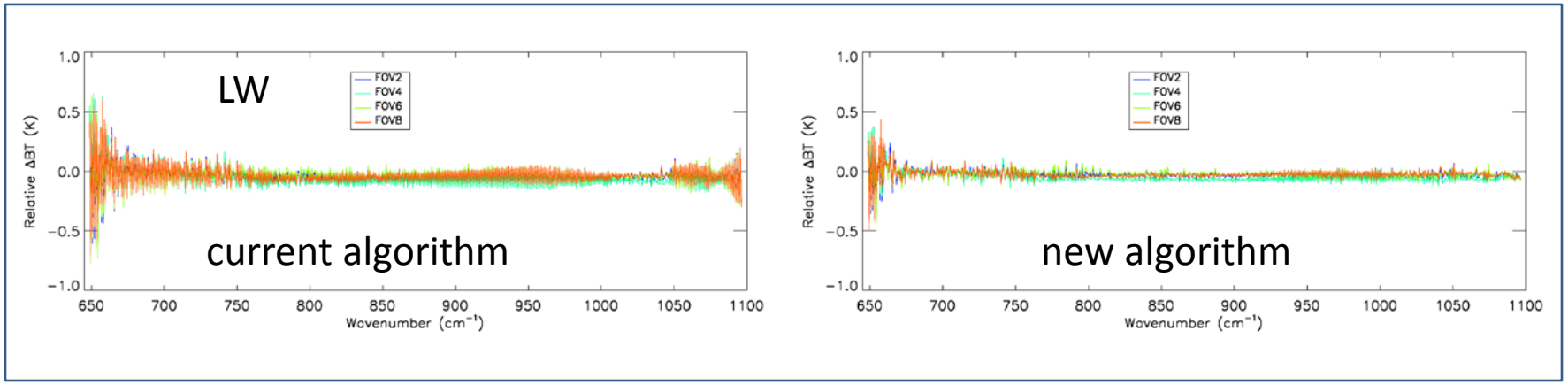




The calibration improvements significantly reduce ringing artifacts

Algorithms Evaluation: FOV-2-FOV Consistency

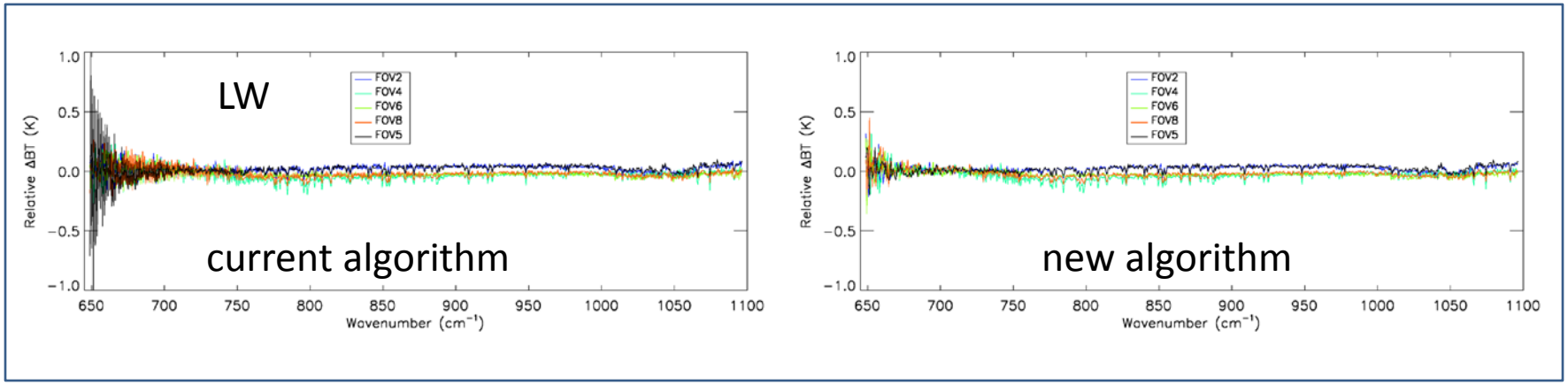
$$(BT_{obs} - BT_{lbl})_{fov\_i} - (BT_{obs} - BT_{lbl})_{fov\_5}$$



The calibration improvements significantly reduce ringing artifacts

Algorithms Evaluation: Sweep Direction Differences

$$(BT_{obs} - BT_{lbl})_{fwd} - (BT_{obs} - BT_{lbl})_{rev}$$



The calibration improvements significantly reduce ringing artifacts

Summary

- The baseline J1 CrIS SDR software was delivered with the capability to process FSR SDRs and the backward compatibility for old data
- S-NPP CrIS full spectral resolution SDRs have been routinely generated since Dec. 4, 2014, available to the public
- The new calibration algorithm improvements significantly reduce radiance ringing artifacts and are being implemented in operational processing
- Future work:
  - Algorithm evaluation for extended interferograms expected to be available before the end of 2015
  - Optimization of the post-filter
  - Continue evaluations of calibration algorithms
  - Lunar intrusion algorithm improvement
  - Impulse noise spike handling