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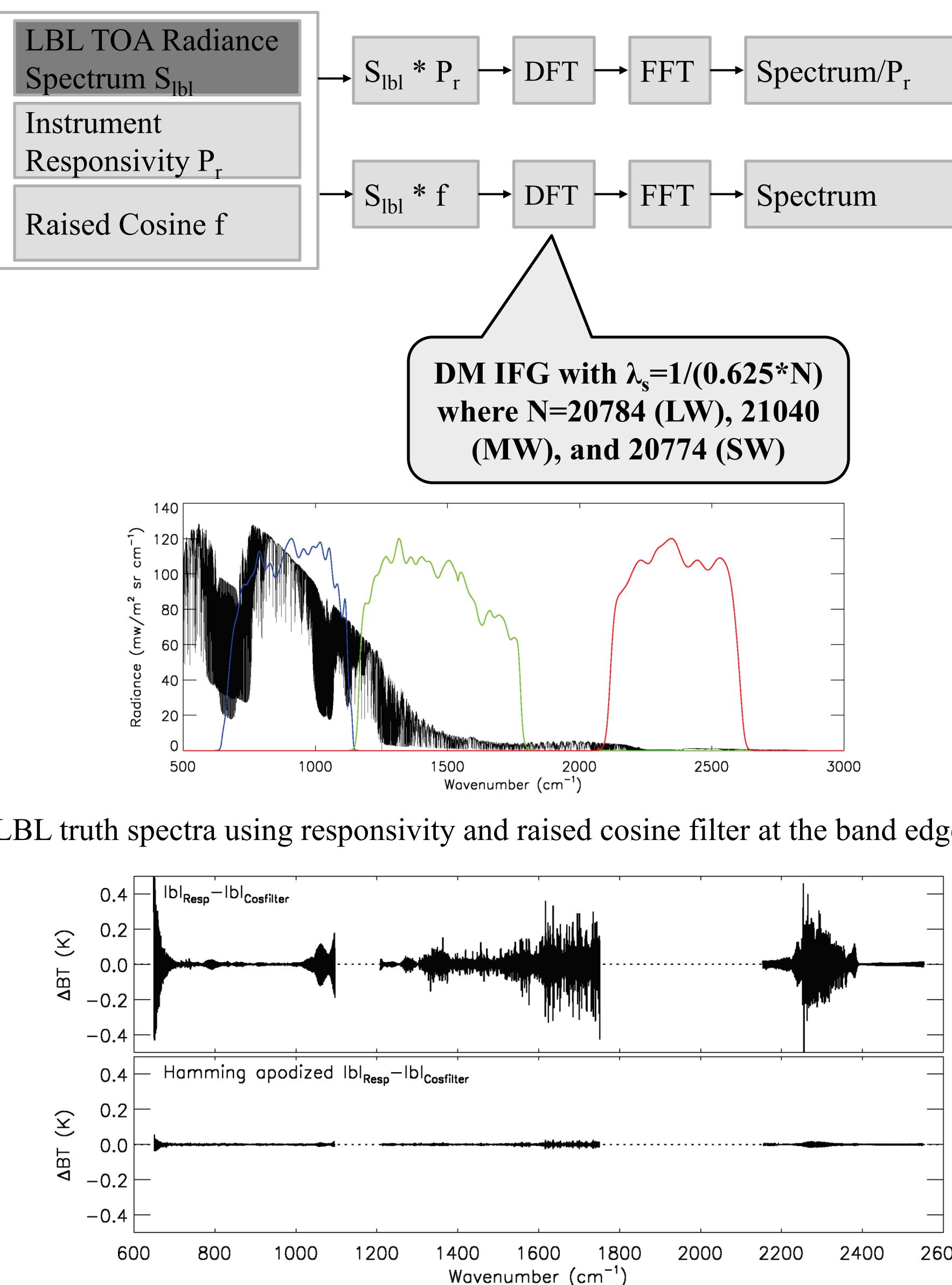
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## Abstract

The Cross-track Infrared Sounder (CrIS) on Suomi National Polar-orbiting Partnership Satellite (S-NPP) is a Fourier transform spectrometer and provides a total of 1305 and 2211 channels in normal mode and full spectral resolution (FSR) mode, respectively, for sounding the atmosphere. NOAA operated CrIS in FSR mode on December 4, 2014 for SNPP. Based on CrIS Algorithm Development Library (ADL), CrIS full resolution Processing System (CRPS) has been developed to generate the FSR Sensor Data Record (SDR). This code can also be run for normal mode and truncation mode SDRs.

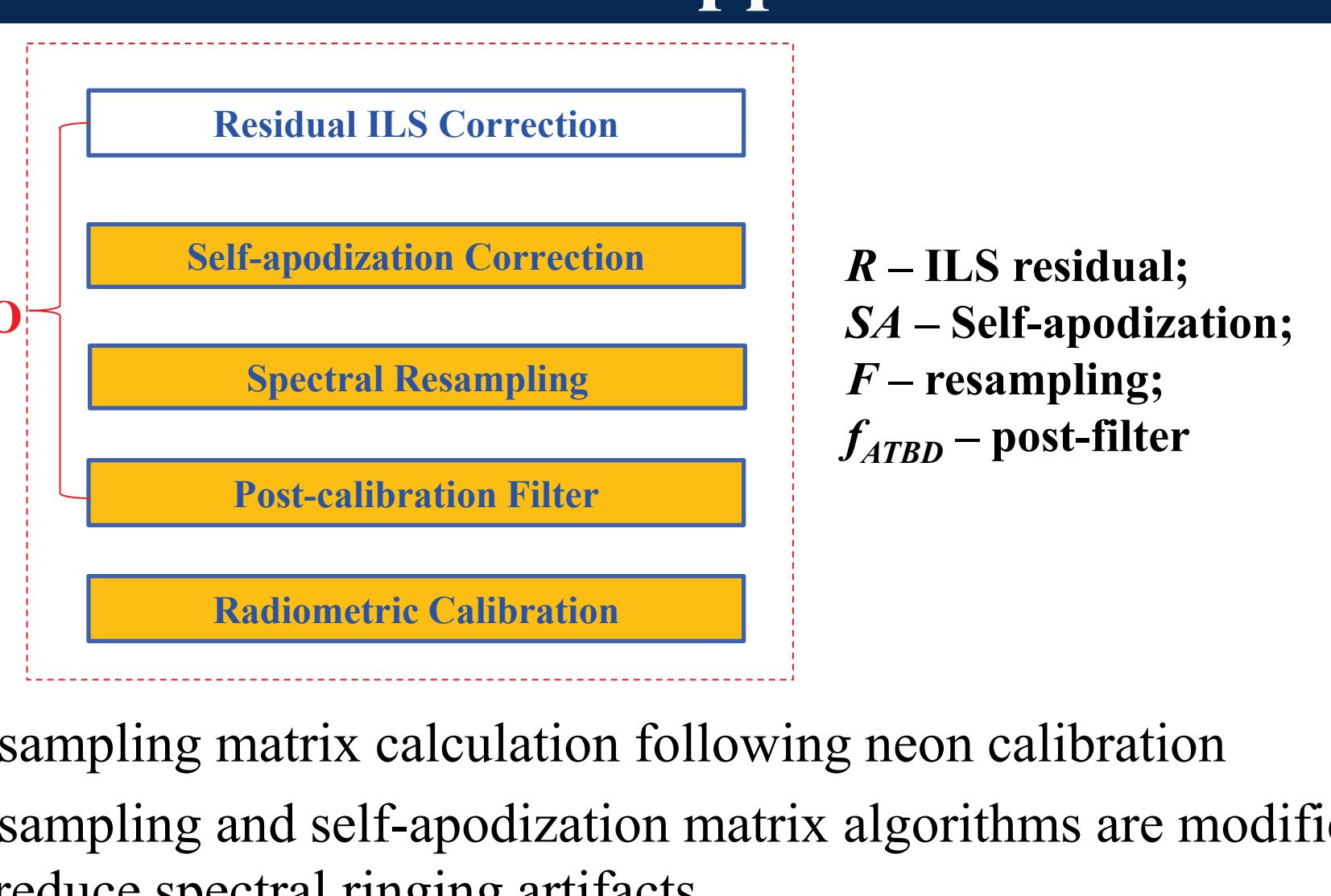
There are ringing artifacts appeared from current SDR unapodized spectra when spectra are compared among the 9 FOVs, between forward and reverse sweep directions, and between observed and simulated spectra. Major sources of these ringing artifacts are due to non-circular onboard Finite Impulse Response (FIR) digital filter, suboptimal calibration equation, and missing the instrument responsivity function for simulating CrIS spectra using radiative transfer models. The solutions to address these issues have been developed and implemented in the CrIS JPSS SDR processing, and will improve the SDR calibration accuracy for CrIS on JPSS.

## CrIS Radiance Simulation



- LBLRTM version 12.2, with spacing at  $0.001 \text{ cm}^{-1}$  true LBL calculations, using matched ECMWF 3 hour forecast/analysis fields, spatially and temporally interpolated to observed time and location, convolved with CrIS instrument responsivity (Hank et al. 2014), and raised cosine filter through FFT to CrIS user grid.
- Significant differences occur at the beginning edge of band1 and the ending edge of band2.
- When Hamming apodization is applied, the difference are very small ( $\sim 0.02 \text{ K}$ )

## Calibration Approaches



- Four calibration equations based on recommendation from CrIS science team are implemented in the CRPS

- An index in the ADL PCT file (configuration file) configures the code for a particular calibration equation

### Calibration approaches supported by CRPS

Calibration algorithm 1 (the baseline algorithm delivered on January, 2015):

$$S_{Cal} = SA^{-1} \cdot F \cdot f_{ATBD} \cdot \frac{S_e - \langle S_{SP} \rangle}{\langle S_{ICT} \rangle - \langle S_{SP} \rangle}$$

$SA^{-1}$  – computed with the large N and expansion factor 1.4 (LW), 1.6 (MW) and 2 (SW)  
 $F$  – resampling matrix computed with large N  
 $f$  – post-filter

Calibration algorithm 2 & 3: (proposed algorithm 2 in Mooney, D. (2014) algorithm list)

$$S_{Cal} = B_{ICT} \frac{F \cdot f_{ATBD} \cdot SA^{-1} \cdot f_{ATBD} \cdot FIR^{-1} \cdot (S_e - \langle S_{SP} \rangle)}{F \cdot f_{ATBD} \cdot SA^{-1} \cdot f_{ATBD} \cdot FIR^{-1} \cdot (\langle S_{ICT} \rangle - \langle S_{SP} \rangle)}$$

Algorithm 2  
 $SA^{-1}$  – Sincq, small N  
 $F$  – Mooney (small N)  
IFGs are centered by adding Phase to spectra

Algorithm 3  
 $SA^{-1}$  – Sincq, big N  
 $F$  – Mooney (big N)  
f – post-filter

Calibration algorithm 4 (proposed algorithm in Predina and Han (2015)):

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

$\Delta S_1 = FIR^{-1}(S_e - \langle S_{SP} \rangle)$   
 $\Delta S_2 = FIR^{-1}(\langle S_{ICT} \rangle - \langle S_{SP} \rangle)$

### Self-apodization matrix (SA)

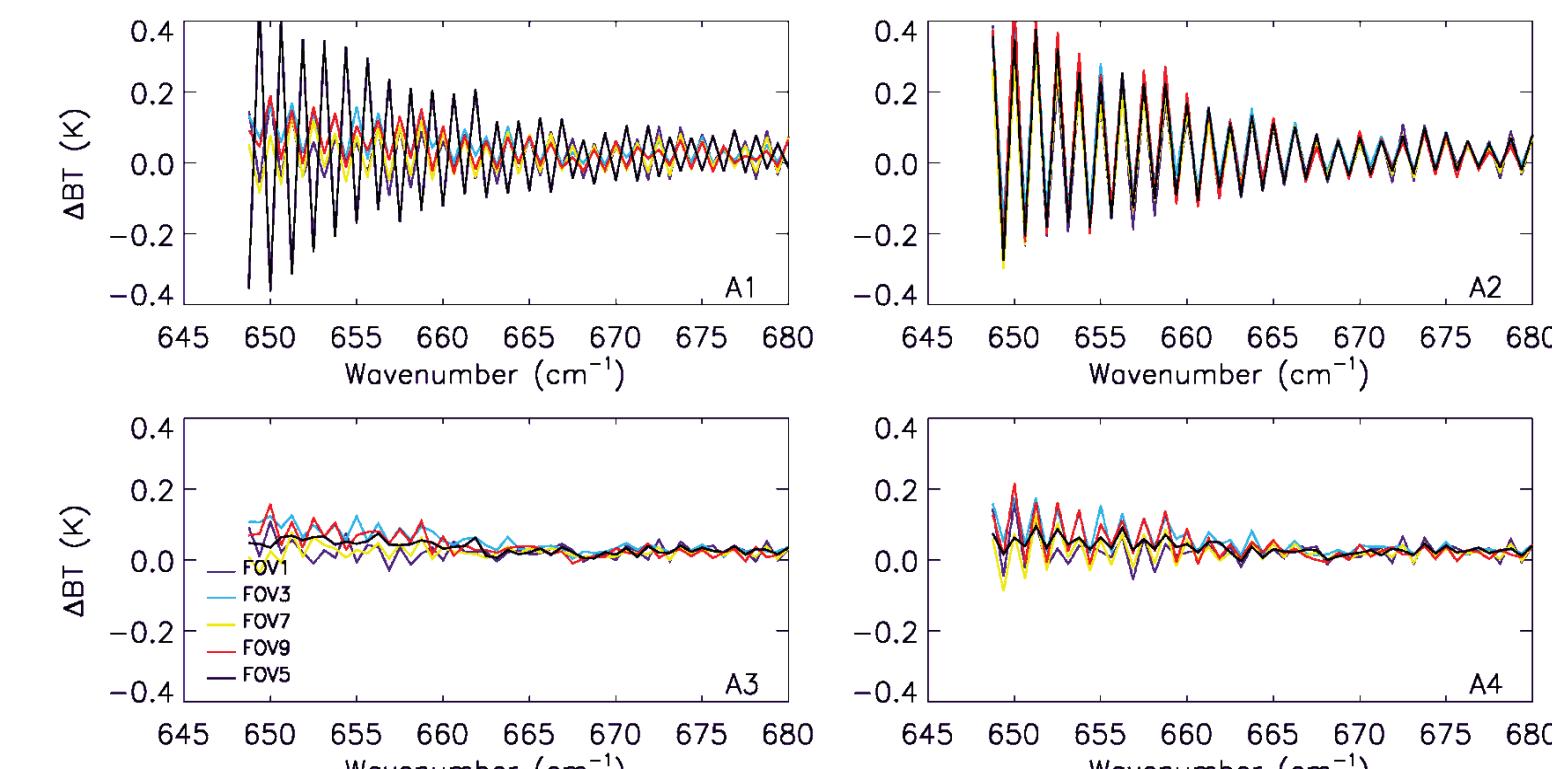
Small N, (N): Number of bins after decimation	$S_d[k, k] = \frac{c_u}{c_m} \text{Psinc}(\frac{\sigma_k - \sigma'_k}{\Delta\sigma}, N) ILS(\sigma, \sigma_k) d\sigma, \quad k=0, N-1, k'=0, N-1$	Expansion factor $\beta=1.0$ for all three bands
Big N, (N <sub>0</sub> ): Number of bins before decimation	$S_d[k, k] = \frac{c_u}{c_m} \text{Psinc}(\frac{\sigma_k - \sigma'_k}{\Delta\sigma}, N_0) ILS(\sigma, \sigma_k) d\sigma, \quad k=0, \beta N-1, k'=0, \beta N-1$	Expansion factor $\beta=1.4$ (LW), 1.6 (MW) and 2.0 (SW), respectively

### Resampling matrix (F)

Small N, (N): Number of bins after decimation	$F[k, k'] = \frac{\sin(\pi \frac{\sigma_z k - \sigma_u k'}{\Delta\sigma_u})}{\Delta\sigma_u N \sin(\pi \frac{\sigma_z k - \sigma_u k'}{\Delta\sigma_u})}, \quad k=0, N-1; k'=0, N-1$
Big N, (N <sub>0</sub> ): Number of bins before decimation	$F[k, k'] = \frac{\sin(\pi \frac{\sigma_z k - \sigma_u k'}{\Delta\sigma_u})}{\Delta\sigma_u N_0 \sin(\pi \frac{\sigma_z k - \sigma_u k'}{\Delta\sigma_u})}, \quad k=0, N-1; k'=0, N-1$

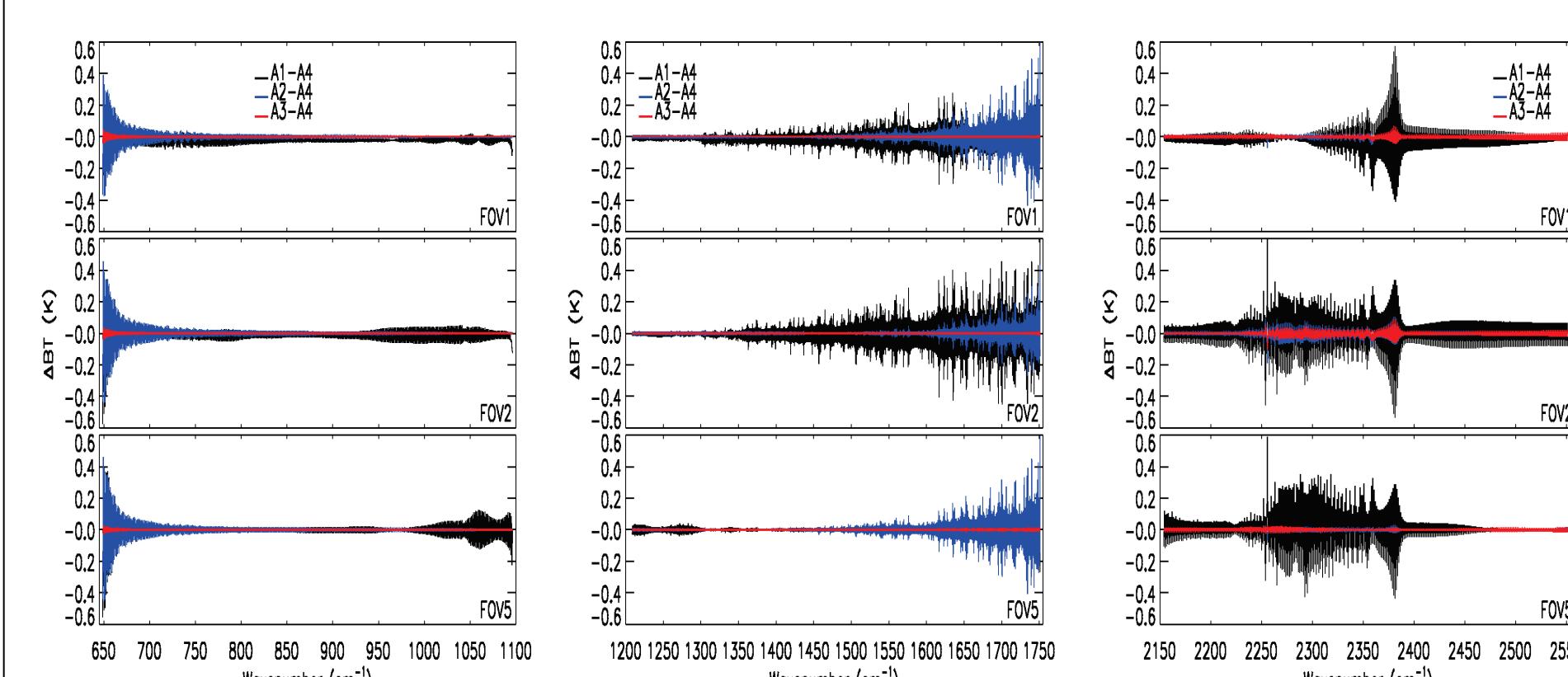
## SDR Radiance Direct Comparison Results

### LW sweep direction differences (ringing) $(BT_{obs})_{fwd} - (BT_{obs})_{rev}$



Sweep direction BT differences (forward sweep BT at FOR 15 minus reverse sweep BT at FOR 16) for all four algorithms at corner FOVs and center FOV 5. The radiance spectra are unapodized.

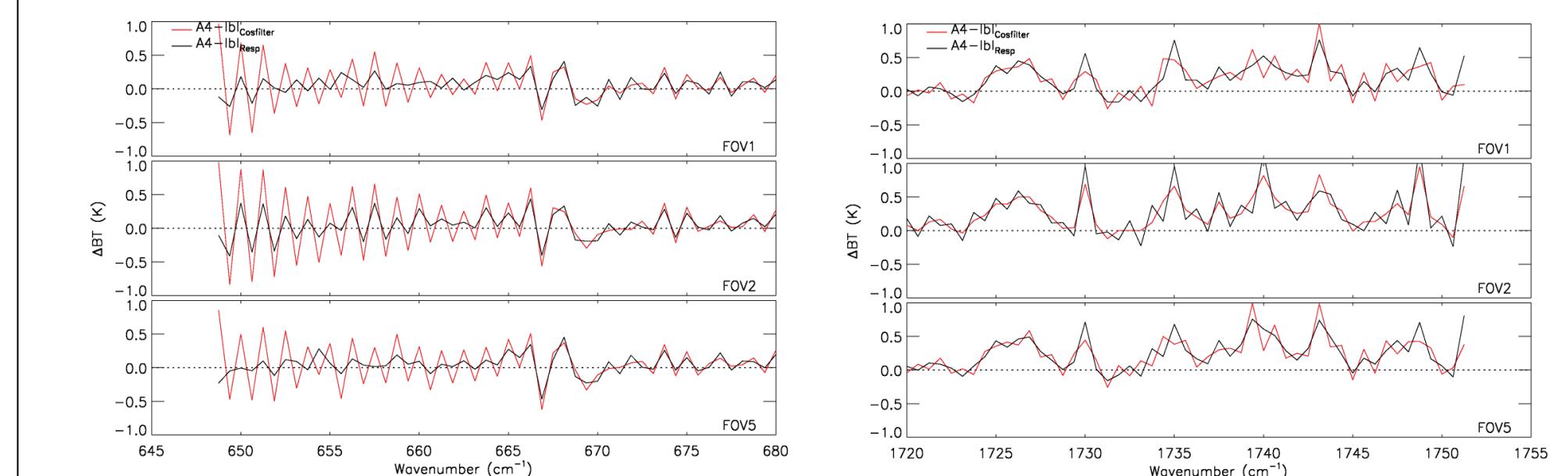
### Mean BT difference between algorithms



- Algorithms 3 and 4 significantly reduce the sweep direction differences especially for FOV 5 at the beginning edge of band 1; larger ringing artifacts are showed in Algorithms 1 and 2
- The mean BT differences between other algorithms and algorithm 4 show: For LW, Algorithm 1 has larger difference at the both band edges; Algorithm 2 only has large difference at the beginning of the band edge. For MW, Algorithms 1 and 2 have larger differences towards the end of band. For SW Algorithms 1 has larger differences at the coldest lines and regions. For all bands, Algorithm 3 is basically the same as Algorithm 4.

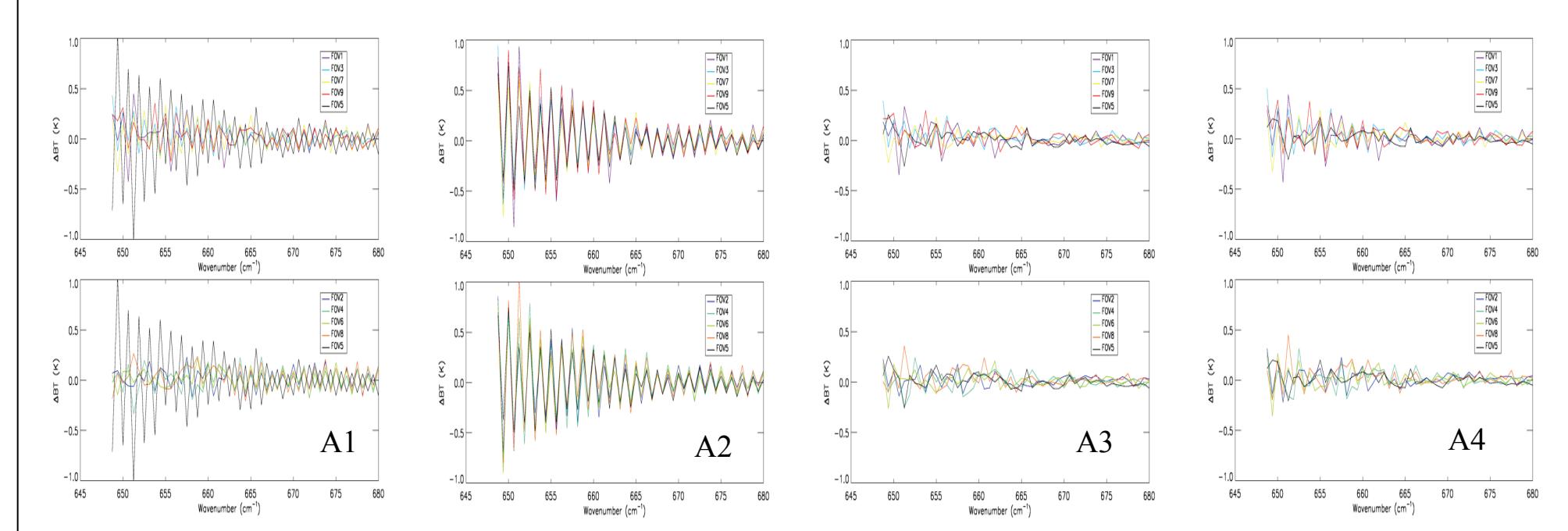
## SDR Radiance Compared with LBL Simulation

### A4 compared with different LBL truths

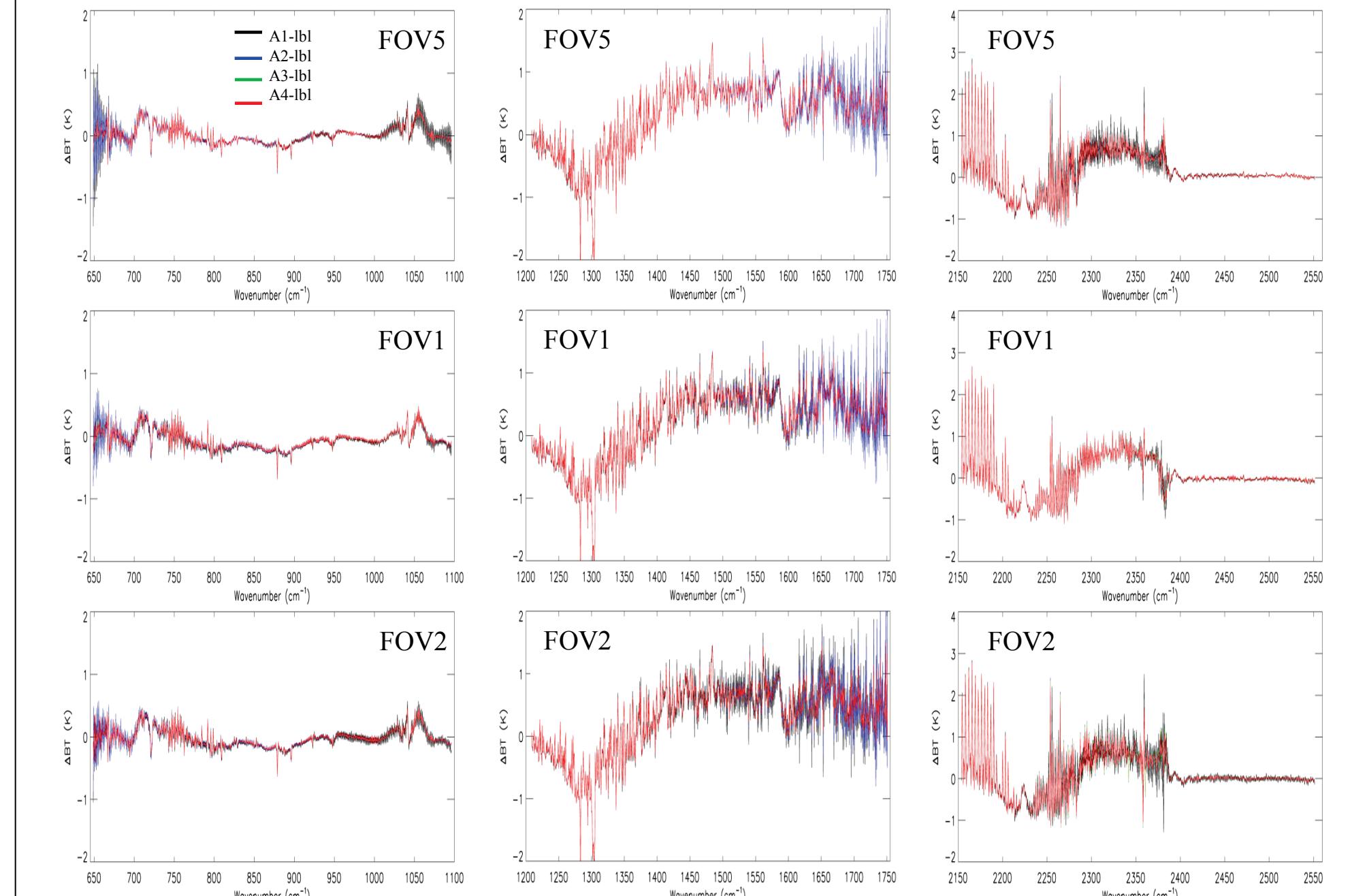


- A4 minus  $lbl_{Resp}$  gives the best results for all FOVs at LWIR band, and mixed results at MWIR band compared to A4 minus  $lbl_{CosFilter}$ . In this study, we use  $lbl_{Resp}$  as truth spectra.

### Sweep direction differences (ringing) $(BT_{obs} - BT_{lbl})_{fwd} - (BT_{obs} - BT_{lbl})_{rev}$

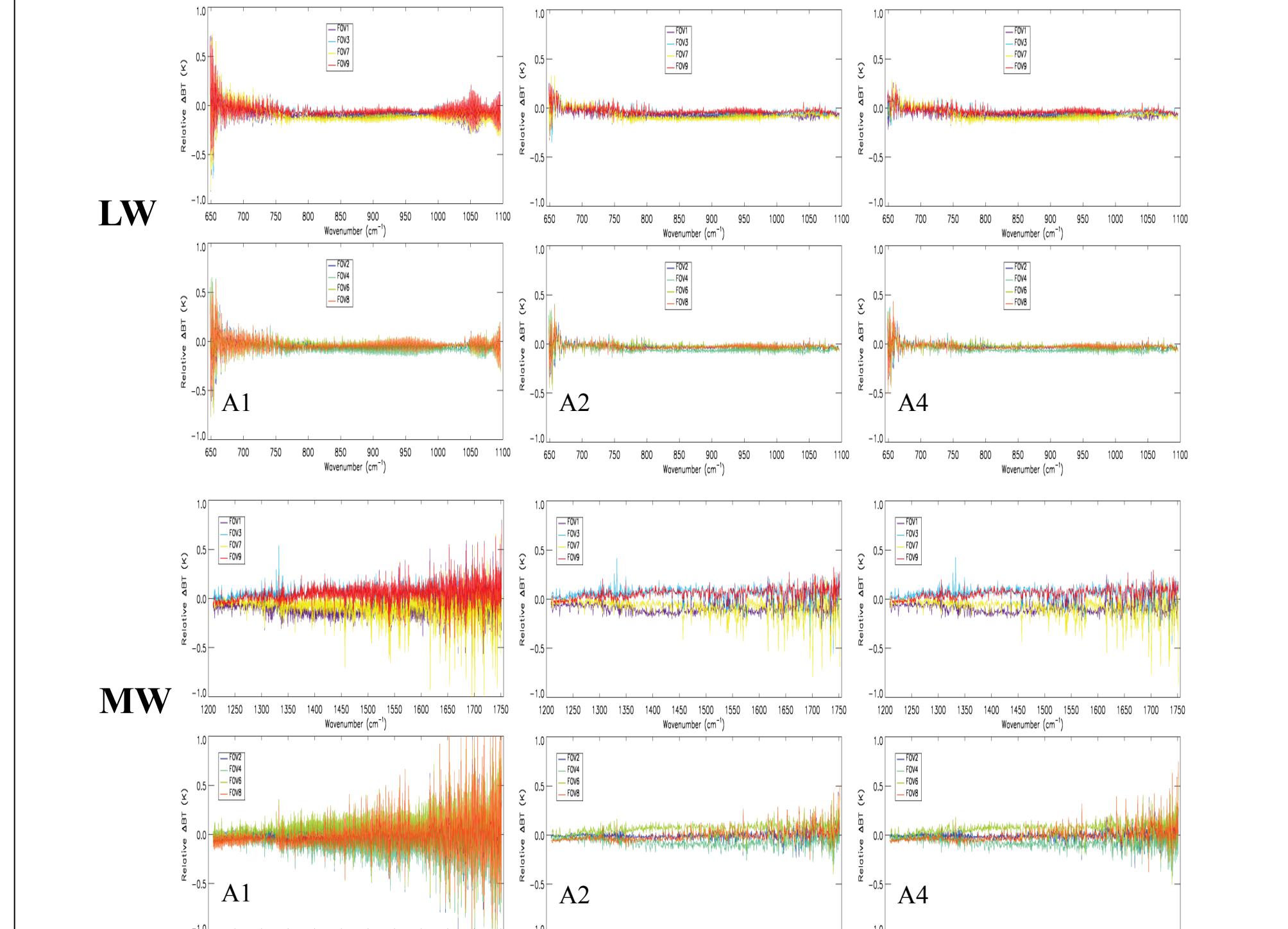


### Calibration bias using LBLRTM simulation $BT_{obs} - BT_{lbl}$



Mean brightness temperature differences between observations in SDR from the four algorithms and Line-by-Line simulation over clear ocean scenes. The radiance spectra are unapodized.

### FOV-2-FOV comparison $(BT_{obs} - BT_{lbl})_{fov\_i} - (BT_{obs} - BT_{lbl})_{fov\_5}$



- CrIS SDR algorithm comparisons using FSR CrIS data and LBL simulation show that Algorithms 3 and 4 are the best choice in term of absolute bias, sweep direction difference (ringing artifact) reduction, and FOV-2-FOV consistency

## Conclusion

- 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 improvements from the new calibration algorithm significantly reduce radiance ringing artifacts observed in CrIS operational unapodized spectra and are being implemented in operational processing
- Future improvements include reducing the non-circular onboard FIR impact by using longer interferograms and optimization of the post-filter

## References and Acknowledgments

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