CrIS SDR Team Report

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2014 STAR JPSS Science Teams Annual Meeting
NOAA Center for Weather and Climate Prediction (NCWCP)
5830 University Research Park, College Park, Maryland
May 12-16, 2014

Outlines

- Team Membership
- Overview of last year's Cal/Val activities and achievements
- Ongoing calibration algorithm/code improvements
- Challenges and risks
- Next year's activities
- Summary

CrIS SDR Team

PI Name	Organization
Yong Han	NOAA/STAR
Deron Scott	SDL
Hank Revercomb	UW
Larrabee Strow	UMBC
Dan Mooney	MIT/LL
Degui Gu	NGAS
Joe Predina	Logistikos Engineering LLC.
Mike Cromp	Exelis
Dave Johnson	NASA
Wael Ibrahim	Raytheon
Carrie Root	JPSS/DPA

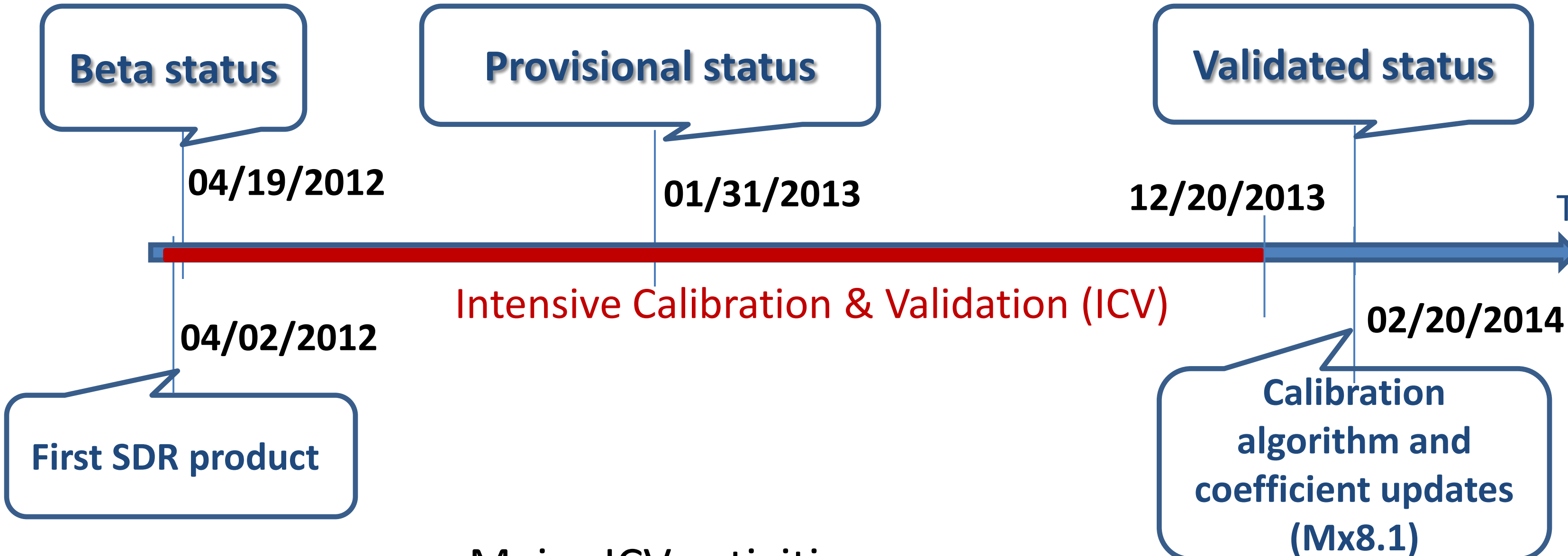
Team Activities
(May 2013 – May 2014)

- S-NPP
  - Intensive Cal/Val (ICV) activities (ended in Dec 2013) – great success; SDR product reached Validated status
  - Long-Term Monitoring (LTM) activities, covering all areas that are significant to the data quality
  - Preparation for processing full spectral resolution data
- JPSS-1
  - Calibration algorithm/code improvements
  - J1 test data analysis
  - Proxy data development for Ops software tests

Accomplishment Highlights

CrIS SDR CalVal Milestones

SDR validated in three stages: Beta, Provisional, and Validated



- Major ICV activities
  - SDR algorithm and software improvement
  - CrIS performance characterization
  - Radiometric CalVal
  - Spectral CalVal
  - Geolocation CalVal
  - CrIS instrument and SDR trending and monitoring

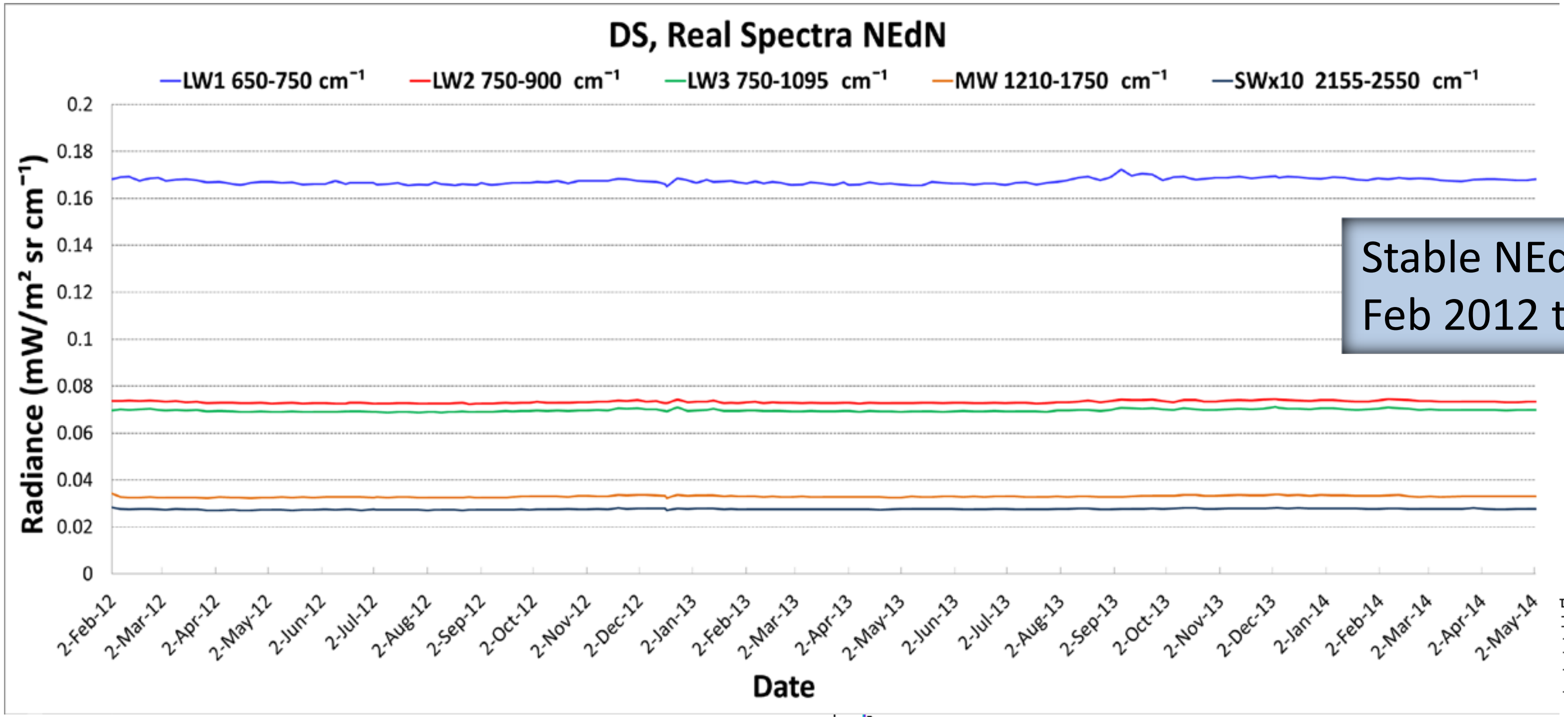
Validated CrIS SDR Product

CrIS SDR uncertainties (**blue**) vs. specifications (black)

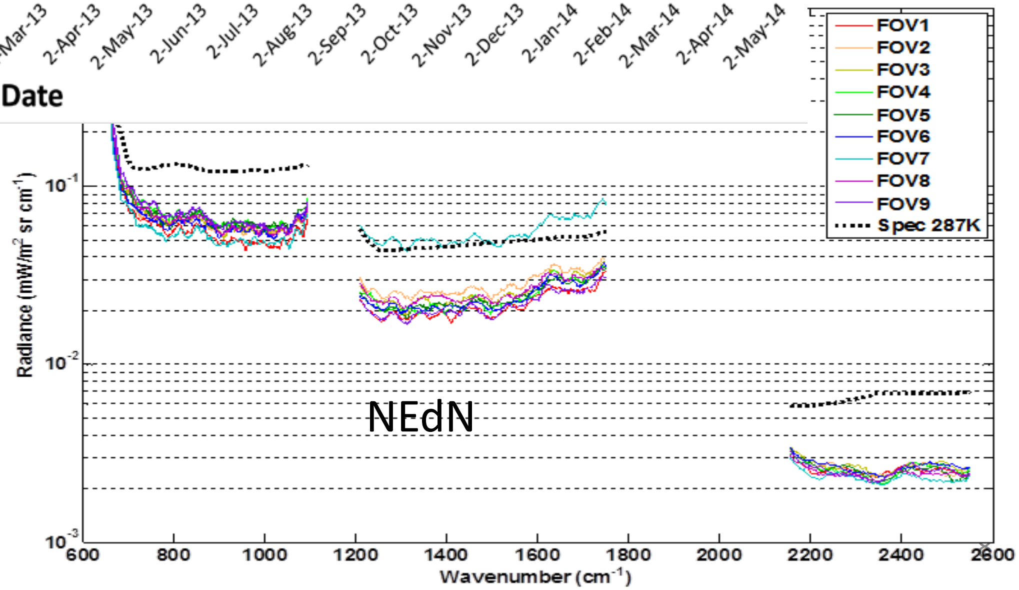
Band	NEdN @287K BB mW/m²/sr/cm⁻¹	Radiometric Uncertainty @287K BB (%)	Frequency Uncertainty (ppm)	Geolocation Uncertainty (km) *
LW	**0.098** (0.14)	**0.12** (0.45)	**3** (10)	**1.2** (1.5)
MW	**0.036** (0.06)	**0.15**(0.58)	**3** (10)	**1.2** (1.5)
SW	**0.003** (0.007)	**0.2** (0.77)	**3** (10)	**1.2** (1.5)

- Requirements
  - **Instrument & SDR performances exceed requirements by large margins**
- SDR software
  - **Stable & free of errors that could impact data quality since 11/14/2013 (Mx8.0)**
- Documentation
  - **SDR User's Guide (55 pages)**
  - **Revised ATBD**
  - **Peer-review Journal papers**

Stable Instrument Performance



Stable NEdN
Feb 2012 to May 2014



The noise levels substantially better than specification

CrIS Data Quality

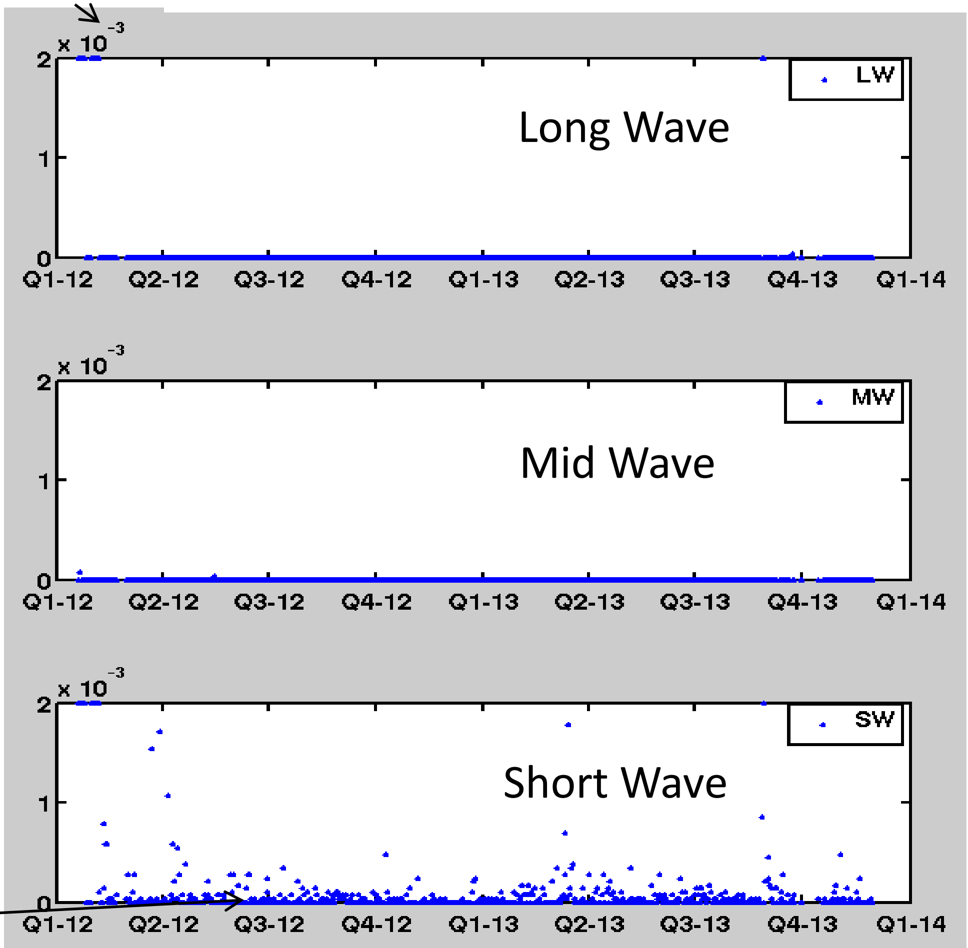
Daily occurrence of Good SDR spectra

LW	99.9817%
MW	99.9817%
SW	99.9816%

- **No ice contamination on detector so far**
- **No significant South Atlantic Anomaly (SAA) impact**
- **No Fringe Count Error (FCE) so far**

Daily Percentage of Invalid interferogram measurements (RDRs)

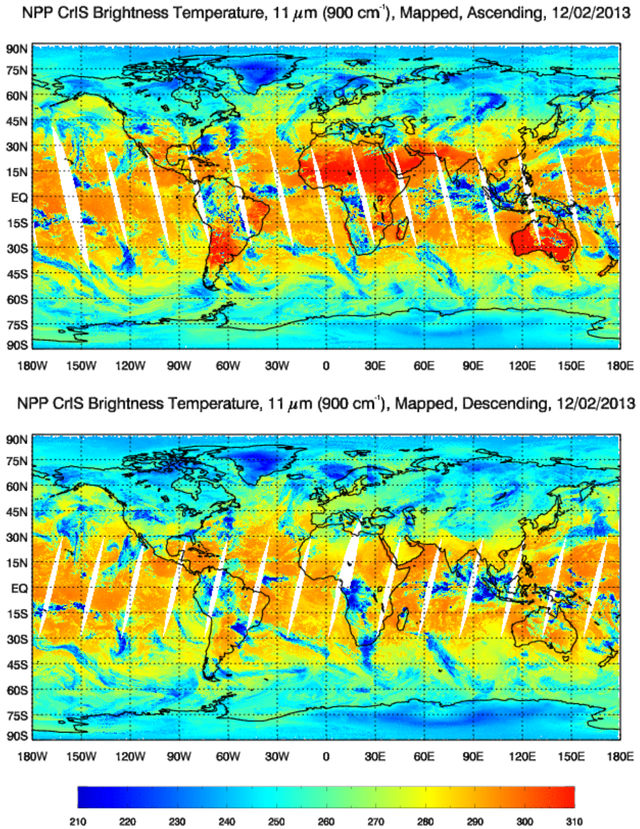
10^{-3}



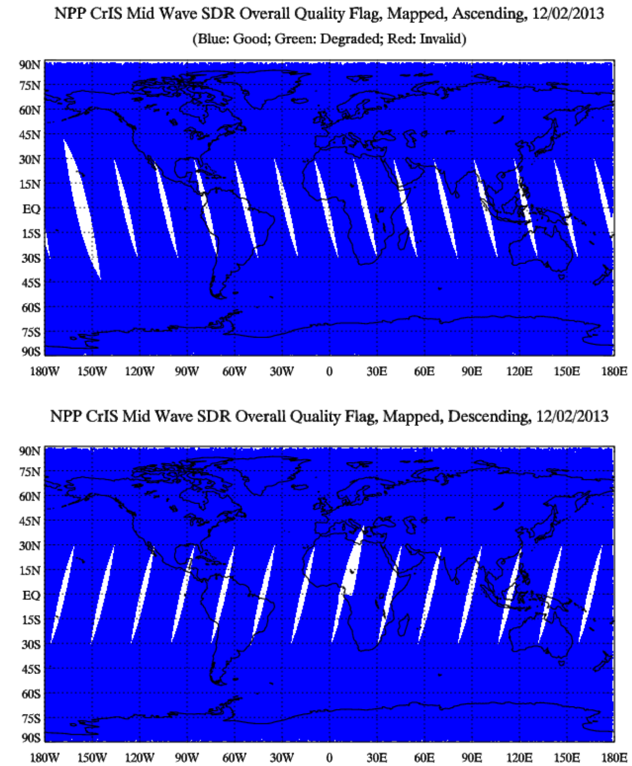
Mainly due to sun-glint saturation

Example of Data Quality after Mx8.0

Radiance (900 cm^{-1})



Overall SDR quality flag (Blue – good)



CrIS data monitoring website:

http://www.star.nesdis.noaa.gov/icvs/status_NPP_CrIS.php

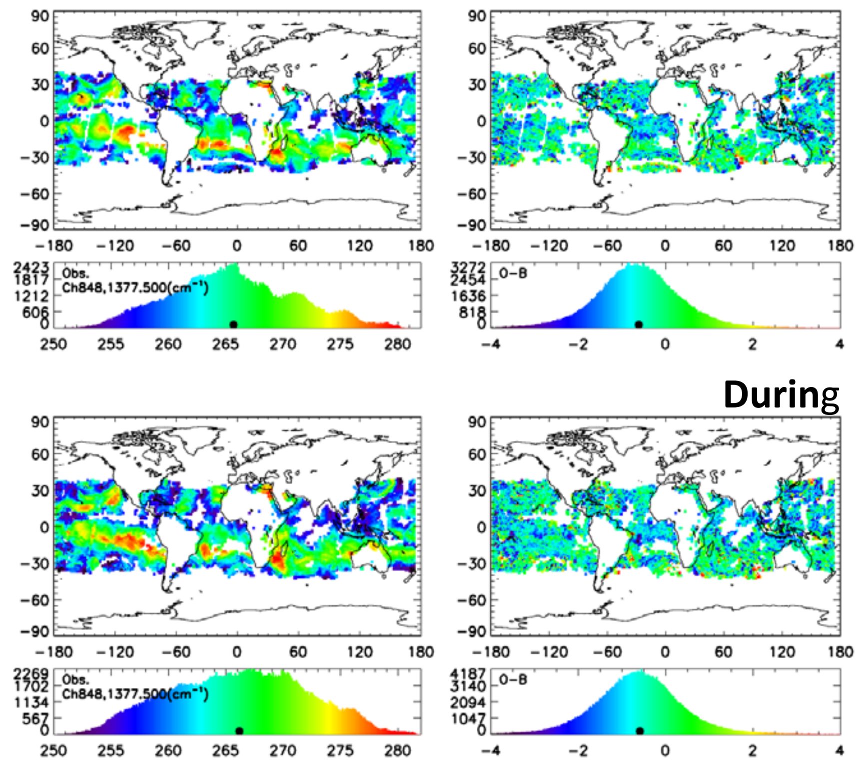
A RDR Truncation Module Implemented and Validated for IDPS to Process Full Spectral Resolution RDRs

- Activities
  - IDPS RDR truncation module development
  - IDPS SDR evaluation/validation for 2 on-orbit full resolution tests
  - Bit trim mask evaluation/adjustment to meet data rate
  - Full resolution SDR processing experiments
  - 25 telecon meeting presentations
- Results
  - IDPS RDR truncation module was implemented & validated (Mx7.1)
  - Proposed Bit trim mask meets the data rate requirement
  - The noise impulse masks need to be lifted by 1 bit (no impact to the data rate)

The Software truncation module works as expected: Obs – Calc results showing no difference before and during 8/27 FSR test

Before

During



BT (K)

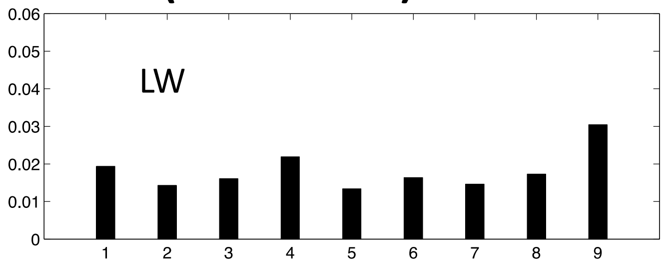
ΔBT (K)

IDPS CrIS SDR code is ready to process full resolution RDRs and produce normal mode SDRs

Preliminary J1 NL Correction Coefficients Derived from Bench DM Data

FM1 (Suomi-NPP) EPv36

a_2 values

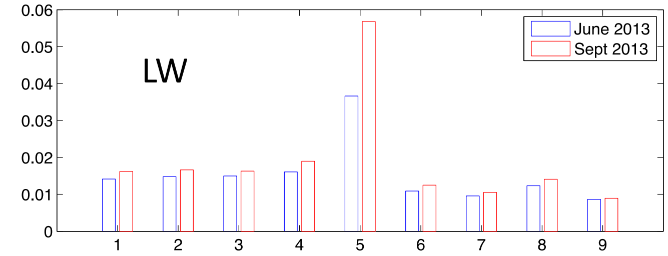


MW

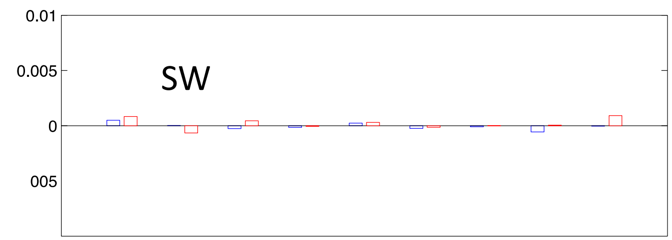
SW

J1 Bench DM

a_2 values



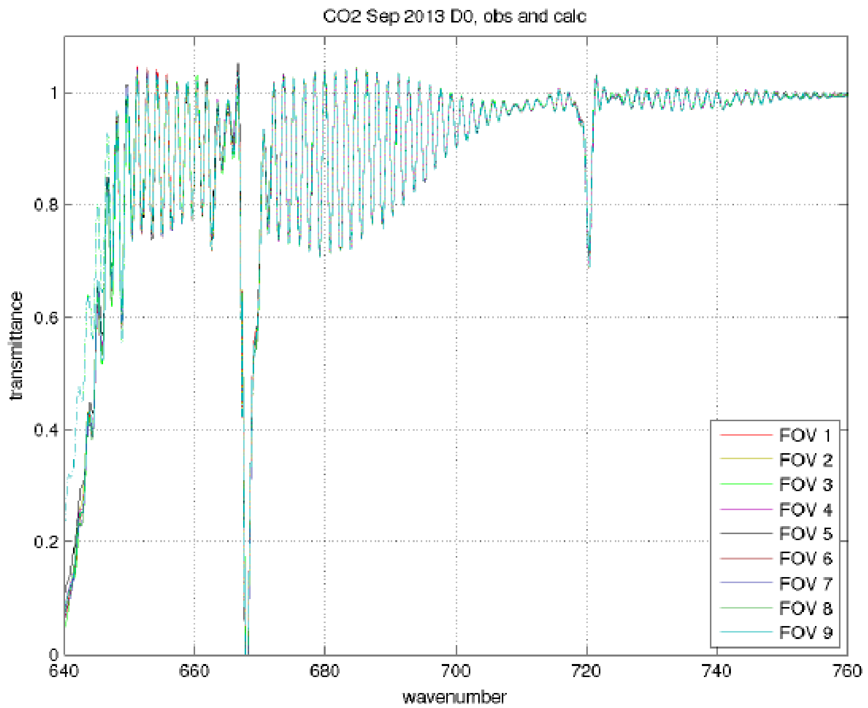
MW



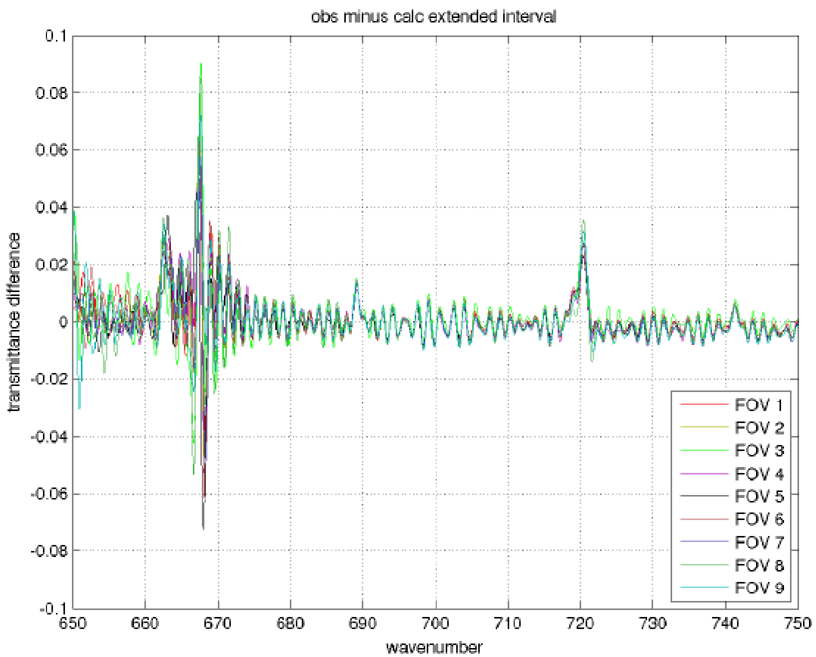
- The preliminary DM results for J1 are qualitatively similar to FM1 (SW is linear, some linear MW FOVs, all LW FOVs are nonlinear) and the same type of NL correction and TVAC and on-orbit a_2 analysis techniques will be needed for J1.
- Compared to FM-1, the J1 LW FOVs are more linear (except FOV5), and 8 of the J1 MW FOVs are very linear.
- Results are very similar to results found by Exelis (Lawrence S.)
- The difference between the June and Sept DM results (e.g. FOV5) are similar to inconsistent results seen for FM1 DM data analysis, which is still under investigation.

Preliminary Analysis of J1 Gas Cell Bench Test

Test results show good agreement with calculated data



Observed and calculated transmittance for all FOVs



Observed minus calculated transmittance spectra for all FOVs

Ongoing Calibration Algorithm and Software Improvements

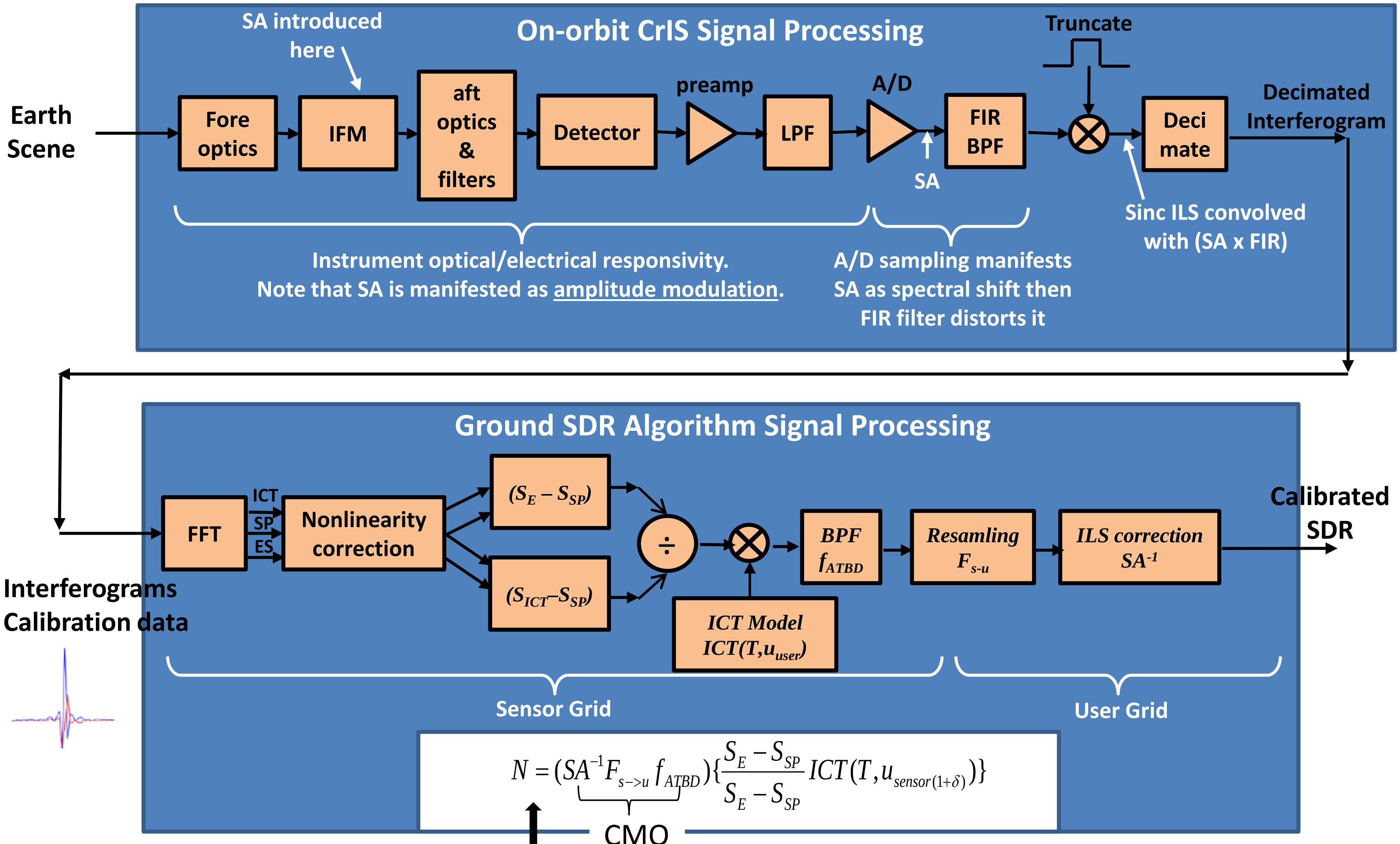
Why Need to Improve Calibration Algorithm/Software

- Recent progress in the investigation of spectral ringing artifacts indicates the current IDPS CrIS SDR calibration algorithms may not be optimal, especially for full spectral resolution SDR processing
- The NWP/Sounding community is interested in using unapodized CrIS data. However, the ringing artifacts in the unapodized data are not negligible
- The current implementation of the spectral Correction Matrix Operator (CMO) is not optimal and may be difficult to apply for some of the calibration algorithms under considerations

Calibration Algorithms under Evaluations

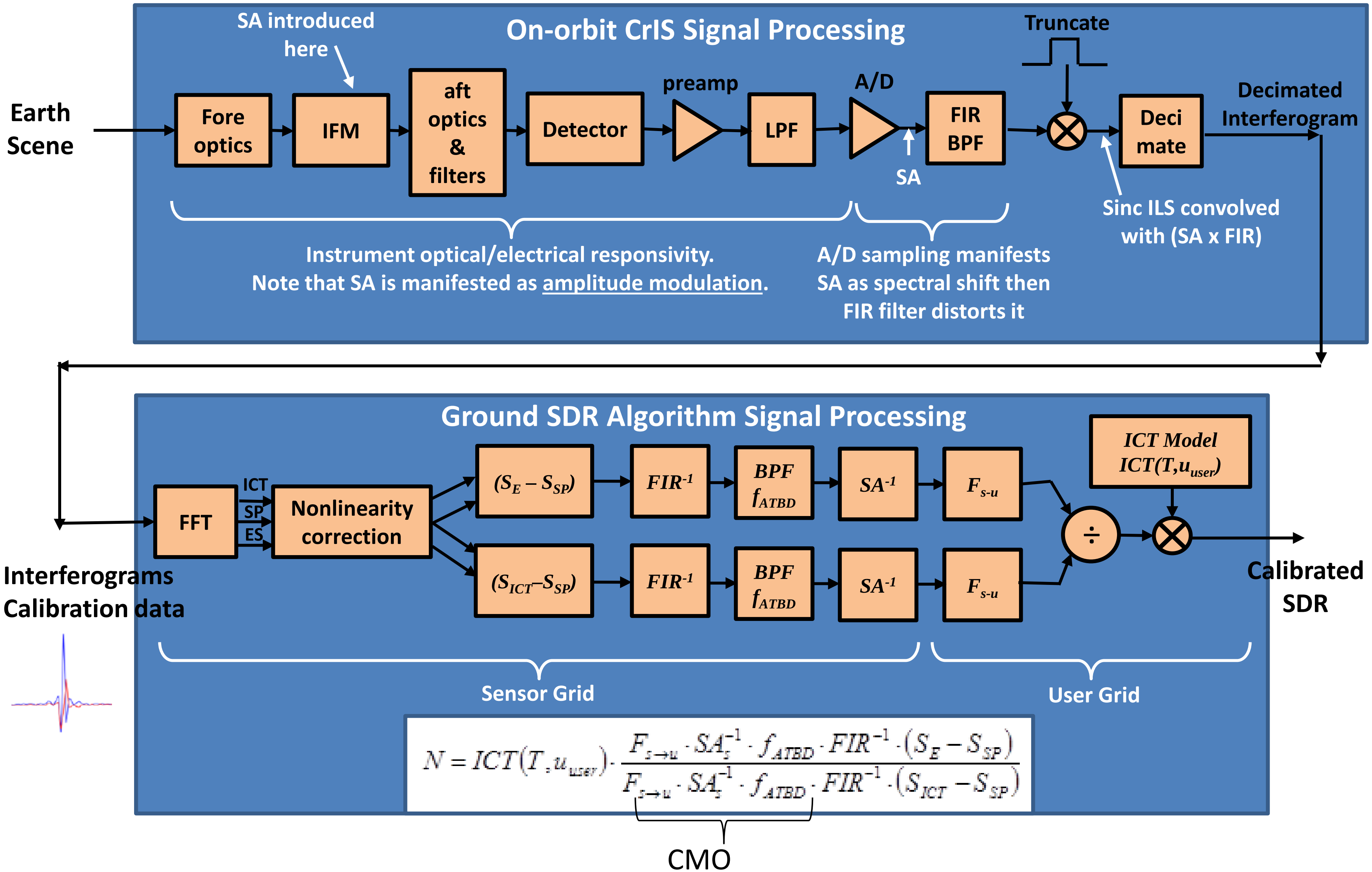
Item	Member	Calibration	CMO Principals	Calibration Order
1	IDPS	$N=(SA_u^{-1}\cdot F_{s\to u}\cdot f_{ATBD})\cdot\left\{\frac{S_E-S_{SP}}{S_{ICT}-S_{SP}}\cdot ICT(T,u_{sensor*(1+delta)})\right\}$		
2	ADL/CSPP	$N=(SA_u^{-1}\cdot F_{s\to u}\cdot f_{ATBD})\cdot\left\{\frac{S_E-S_{SP}}{S_{ICT}-S_{SP}}\cdot ICT(T,u_{sensor*(1+delta)})\right\}$	$SA_u^{-1}\cdot F_{s\to u}$	
3	Exelis (old)	$N=\left(SA_u^{-1}\cdot F_{s\to u}\cdot f_{ATBD}\right)\cdot\left\{\frac{S_E-S_{SP}}{S_{ICT}-S_{SP}} f_{BH}\cdot\left[SA_u^{-1}\cdot F_{s\to u}\right]^{-1}\cdot ICT(T,u_{sensor})\right\}$		
4	UMBC/UW** option A	$N=F_{s\to u}\cdot f\cdot SA_s^{-1}\cdot\left\{f\cdot\frac{FIR^{-1}\cdot(S_E-S_{SP})}{FIR^{-1}\cdot(S_{ICT}-S_{SP})}\cdot ICT(T,u_{sensor\_off\_axis})\right\}$		Calibration first, then CMO
5	CCAST Cal mode 1	$N=F_{s\to u}\cdot f\cdot SA_s^{-1}\cdot\left\{\frac{FIR^{-1}\cdot(S_E-S_{SP})}{FIR^{-1}\cdot(S_{ICT}-S_{SP})}\cdot ICT(T,u_{sensor\_off\_axis})\right\}$		
6	UMBC/UW** option B	$N=F_{s\to u}\cdot\left\{ICT(T,u_{sensor})\cdot f\cdot SA_s^{-1}\cdot\left\{f\cdot\frac{FIR^{-1}\cdot(S_E-S_{SP})}{FIR^{-1}\cdot(S_{ICT}-S_{SP})}\right\}\right\}$		
7	CCAST Cal mode 2	$N=F_{s\to u}\cdot f\cdot\left\{ICT(T,u_{sensor})\cdot SA_s^{-1}\cdot\left\{\mathrm{Re}\left[\frac{FIR^{-1}\cdot(S_E-S_{SP})}{FIR^{-1}\cdot(S_{ICT}-S_{SP})}\right]\right\}\right\}$	$F_{s\to u}\cdot SA_s^{-1}$	
8	LL(old)*	$N=\left\{\frac{M\cdot(FIR^{-1}\cdot(S_E-S_{SP}))}{M\cdot(FIR^{-1}\cdot(S_{ICT}-S_{SP}))}\right\}\cdot ICT(T,u_{user})$		
9	Proposed(1)	$N=F_{s\to u}\cdot f_{ATBD}\cdot\left\{\frac{SA_s^{-1}\cdot(FIR^{-1}\cdot(S_E-S_{SP}))}{SA_s^{-1}\cdot(FIR^{-1}\cdot(S_{ICT}-S_{SP}))}\cdot ICT(T,u_{sensor})\right\}$		CMO first, then Calibration
10	Proposed(2)	$N=ICT(T,u_{user})\cdot\left\{\frac{F_{s\to u}\cdot SA_s^{-1}\cdot f_{ATBD}\cdot(FIR^{-1}\cdot(S_E-S_{SP}))}{F_{s\to u}\cdot SA_s^{-1}\cdot f_{ATBD}\cdot(FIR^{-1}\cdot(S_{ICT}-S_{SP}))}\right\}$		
11	Exelis(new)	$N=\left\{\frac{(SA_u^{-1}\cdot F_{s\to u}\cdot(S_E-S_{SP}))}{(SA_u^{-1}\cdot F_{s\to u}\cdot(S_{ICT}-S_{SP}))}\right\}\cdot ICT(T,u_{user})$	$SA_u^{-1}\cdot F_{s\to u}$	

Current Ground SDR Algorithm



Not optimal for full spectral resolution mode processing

A Proposed SDR Algorithm



Example of Cal. Algorithm Difference

Algorithms are implemented in ADL and then compared

Proposed 2

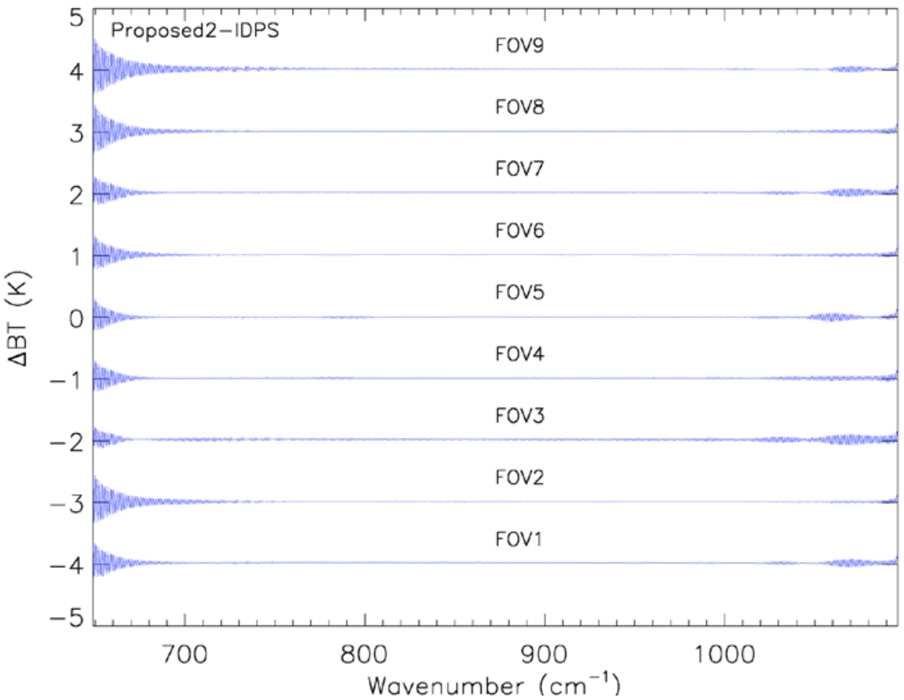
$$N = ICT(T, u_{user}) \cdot \left\{ \frac{F_{s \to u} \cdot SA_s^{-1} \cdot f_{ATBD} \cdot \left(FIR^{-1} \cdot (S_E - S_{SP}) \right)}{F_{s \to u} \cdot SA_s^{-1} \cdot f_{ATBD} \cdot \left(FIR^{-1} \cdot (S_{ICT} - S_{SP}) \right)} \right\}$$

minus

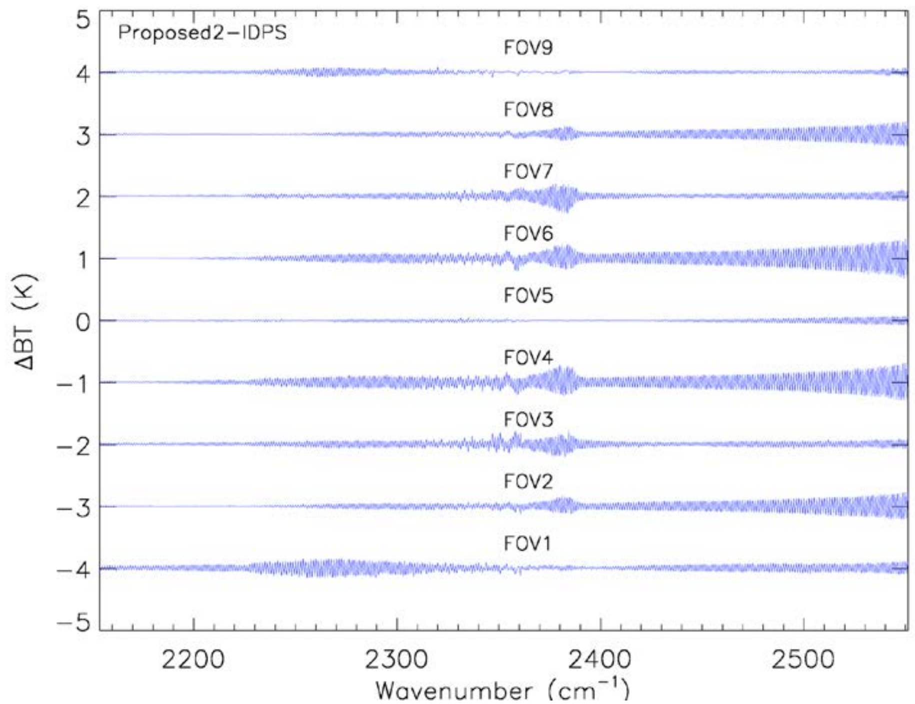
Current IDPS

$$N = (SA^{-1} F_{s->u} f_{ATBD}) \{ \frac{S_E - S_{SP}}{S_E - S_{SP}} ICT(T, u_{sensor(1+\delta)}) \}$$

LW Band (FOR 1)



SW Band (FOR1, full resolution)



Significant difference (ringing) seen in all three bands (unapodized) 0.1 – 0.5 K

Spectral Interpolation before/after the Calibration Ratio Has Big Difference

$$N = ICT(T,u_{user}) \cdot \left\{ \frac{F_{s\to u} \cdot SA_s^{-1} \cdot f_{ATBD} \cdot \left(FIR^{-1} \cdot (S_E - S_{SP})\right)}{F_{s\to u} \cdot SA_s^{-1} \cdot f_{ATBD} \cdot \left(FIR^{-1} \cdot (S_{ICT} - S_{SP})\right)} \right\}$$

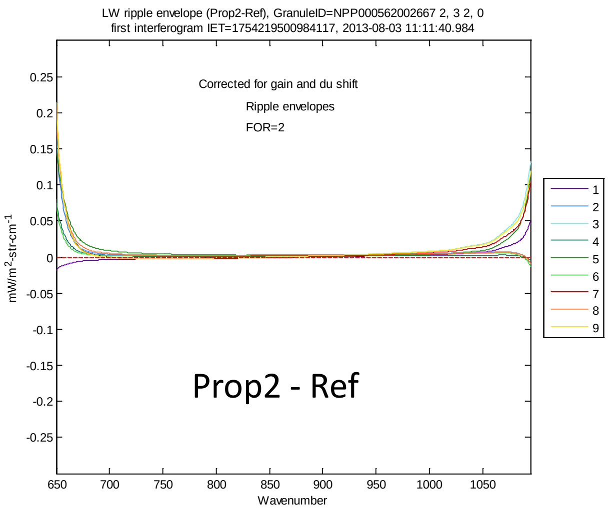
$$N = F_{s\to u} \cdot f \cdot SA_s^{-1} \cdot \left\{ \frac{FIR^{-1} \cdot (S_E - S_{SP})}{FIR^{-1} \cdot (S_{ICT} - S_{SP})} \cdot ICT(T,u_{sensor\_off\_axis}) \right\}$$

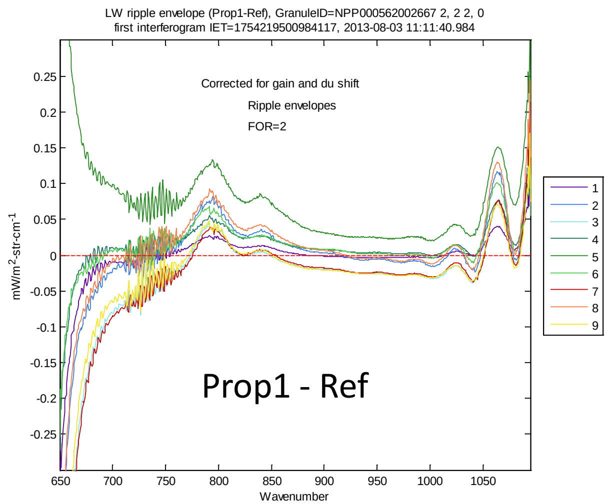
$$N = F_{s\to u} \cdot f_{ATBD} \cdot \left\{ \frac{SA_s^{-1} \cdot \left(FIR^{-1} \cdot (S_E - S_{SP})\right)}{SA_s^{-1} \cdot \left(FIR^{-1} \cdot (S_{ICT} - S_{SP})\right)} \cdot ICT(T,u_{sensor}) \right\}$$

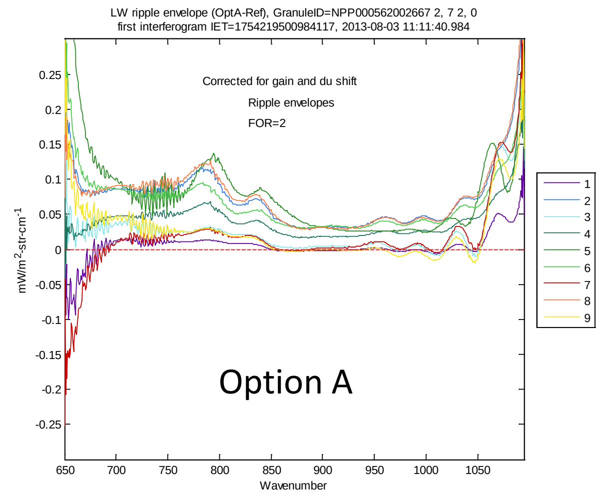
Ratio after interpolation & ISA

Ratio before interpolation

Ratio before interpolation & ISA





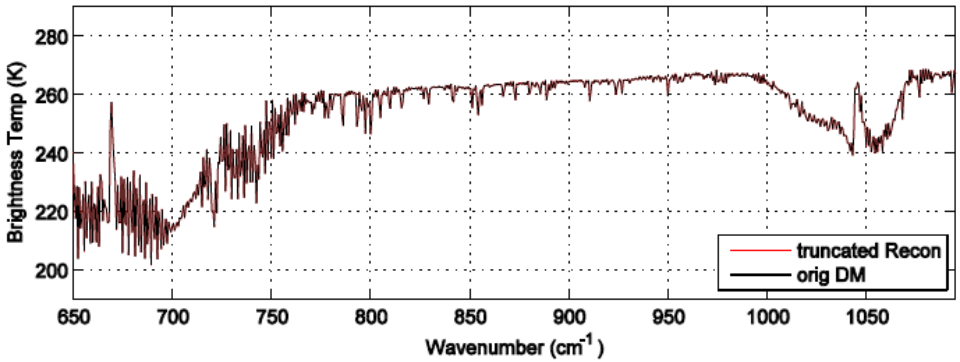


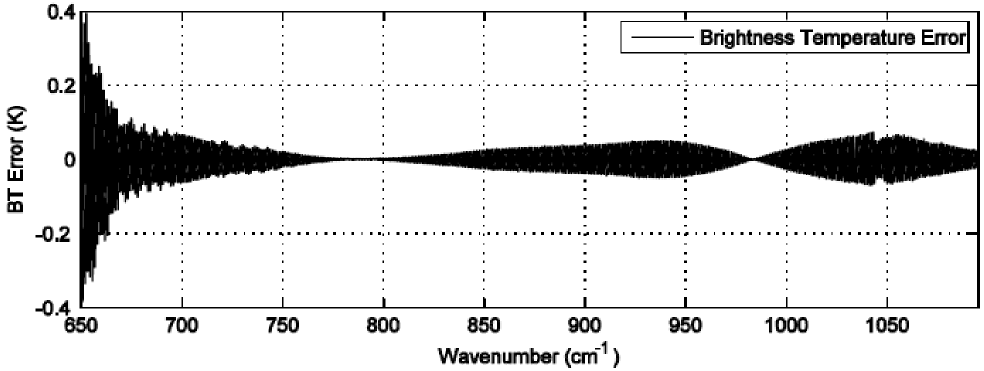
Ref

$$N = \left\{ \frac{M \cdot \left(FIR^{-1} \cdot (S_E - S_{SP})\right)}{M \cdot \left(FIR^{-1} \cdot (S_{ICT} - S_{SP})\right)} \right\} \cdot ICT(T,u_{user})$$

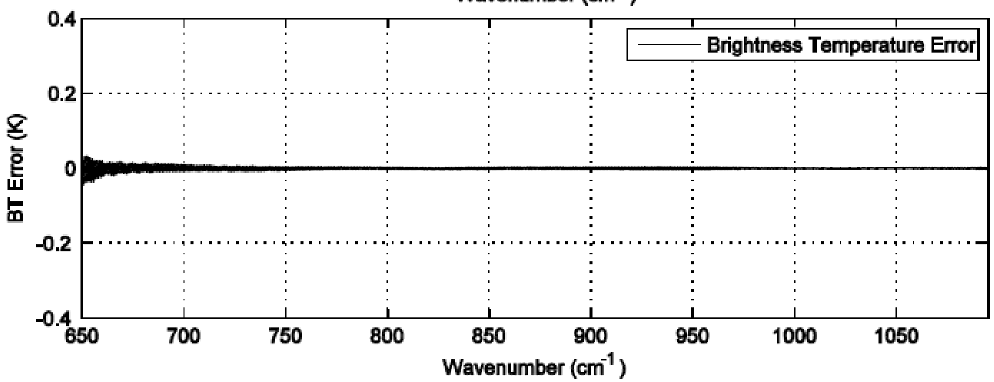
Note: Ref does interpolation before ratio

Ringing Artifact Reduction by Normalizing FIR Gain before Truncation of IGM





Significant ringing if spectrum is not normalized with FIR gain before interferogram (IGM) truncation and spectral interpolation



Ringing artifacts are largely reduced with the algorithm that normalizes S with the FIR gain

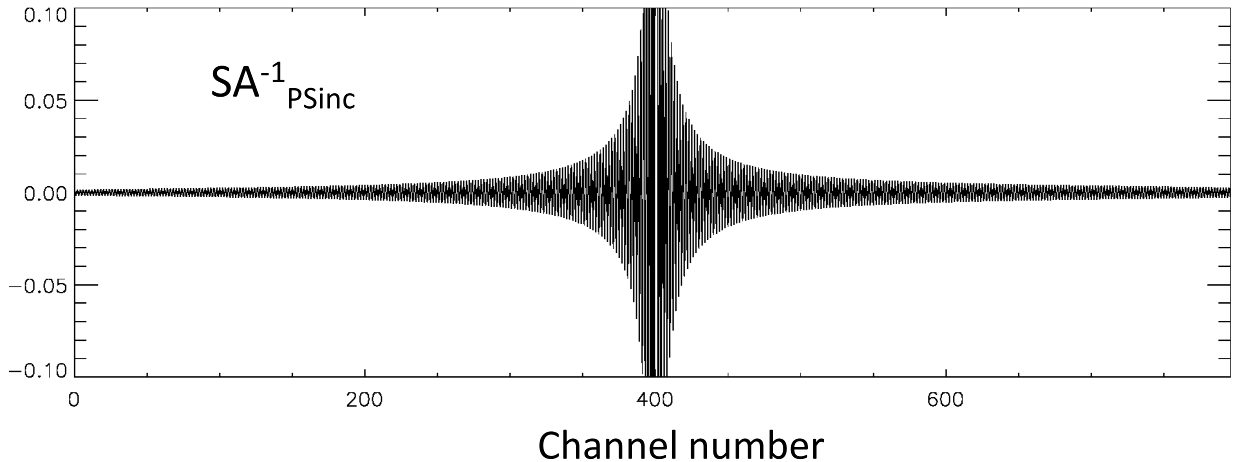
Issue in Self-apodization Correction Matrix SA^{-1}

- Recent investigation indicated the current IDPS SA^{-1} is not optimal and may introduce significant ringing artifacts in full spectral resolution SDR processing
- New algorithms are proposed and are being evaluated
  - Use periodic Sinc function instead of the current Sinc function
  - Double the size of the SA^{-1} matrix in computation
  - Derive the matrix SA^{-1} through minimization

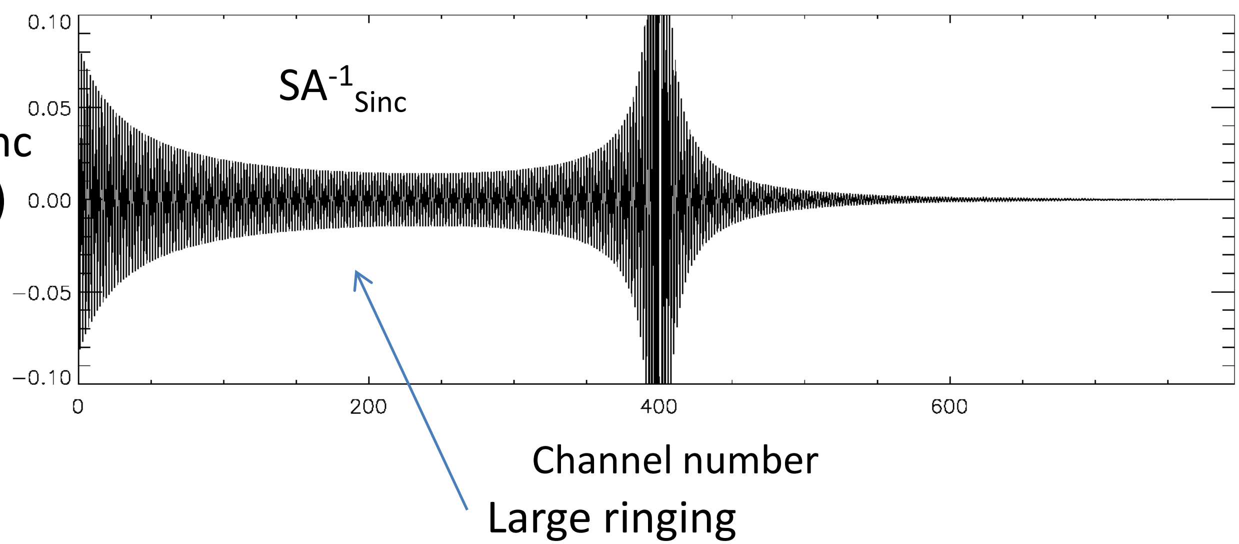
Difference of SA^{-1} Matrixes Calculated with Psinc and Sinc Functions

SW FOV1 SA^{-1} matrix row 400 (full resolution)

SA^{-1} calculated with Periodic Sinc function

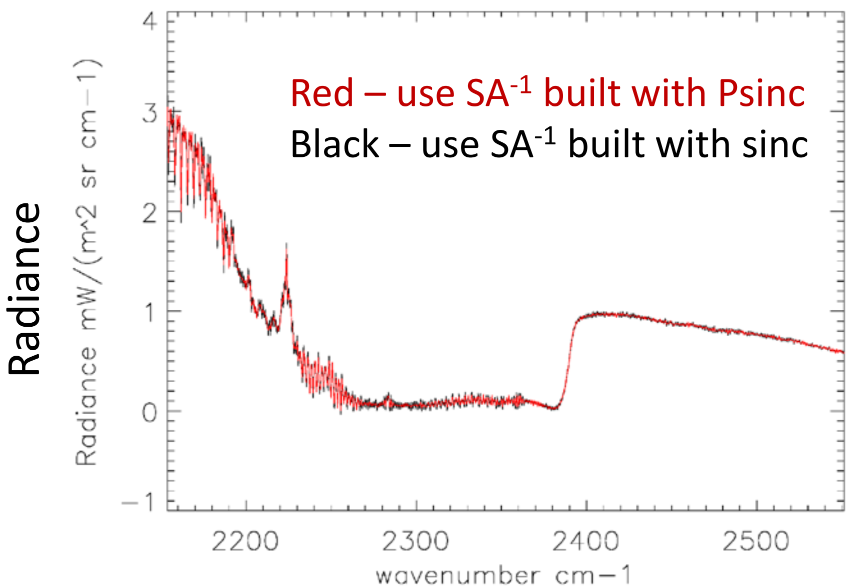


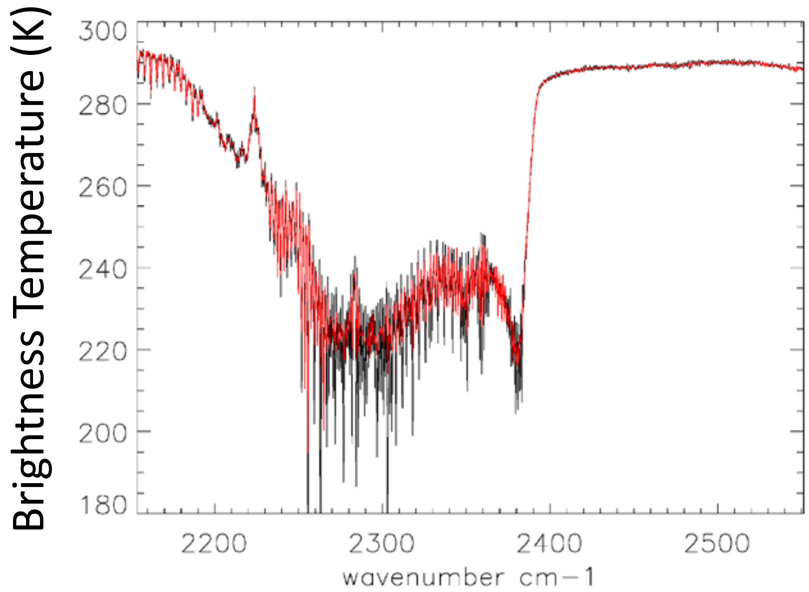
SA^{-1} calculated with Sinc function (current IDPS)

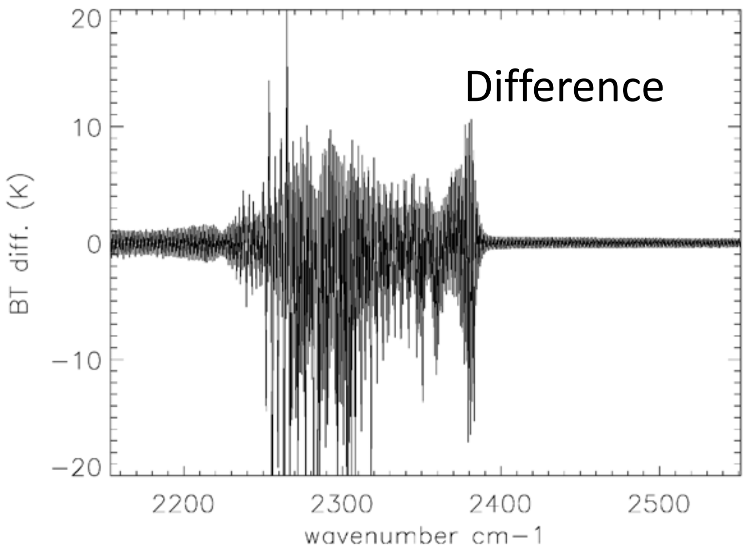


Radiance Difference due to the Difference in SA^{-1}

ADL Full Resolution SW FOV1 Spectrum







Large ringing artifacts produced with the current SA^{-1} algorithm is not acceptable for full spectral resolution processing

Challenges and Risks

- The delivery of CrIS SDR software is scheduled on Jan 15, 2015. However, we still have a large amount of work to do in both algorithm and code changes
- Implementation of the proposed calibration algorithm requires a lot of code changes, which normally start after the algorithm investigations. However, the delivery schedule is pushing us to start working on the code changes before the conclusion of the investigations.
- Current IDPS does not support a dynamic switch between the normal mode and full spectral resolution mode SDR processing; in other words, the switch requires recompiling the software

Work in the Coming Program Year

- Suomi NPP
  - Continuation of RDR and SDR monitoring
  - Fine adjustment of spectral and radiometric calibration parameters and geolocation mapping parameters, if needed.
  - Continuation of Full Spectral Resolution work, if required.
  - SDR algorithm improvement to address the potential issues (e.g. FCE detection/correction, reduction of ringing artifacts and polarization effect correction)
  - Continuation of SDR software improvements to address the remaining and future issues
- JPSS J1
  - Support of and participation in pre-launch testing and instrument characterization
  - Calibration data (LUTs and coefficients) development
  - Algorithm/software development and improvements (full resolution SDR capability, calibration algorithms and FCE detection/correction module), delivering the SDR code in January 2015
  - Development of a comprehensive test data set derived from NPP observations and J1 TVAC tests for J1 algorithm and software development

Summary

- The team has successfully completed the CrIS SDR ICV process and achieved the Validated status for the S-NPP CrIS SDR product
- LTM activities are being routinely carried out to ensure the data product quality
- Work has been successfully completed to add a truncation module to the IDPS CrIS SDR software: the software is ready for handling full spectral resolution RDRs
- The team is making efforts to improve the calibration algorithms and processing software. Progress has been made. However, it is challenging to meet the software delivery schedule.
- Preliminary analysis of the bench test data was performed and the results are within the expectation
- The team has a clear path moving forward for both NPP and J1 missions