NOAA-20 CrIS SDR Performance Overview

February 20, 2018

Yong Chen, Changyong Cao
and CrIS SDR Team

With contributions from NOAA/STAR, NASA/GSFC, Harris, UW/SSEC, UMBC, UMD/CICS, SDL/USU, MIT/LL, Logistikos, Raytheon

Outline

- Algorithm Cal/Val Team Members
- NOAA-20 CrIS SDR Specification
- CrIS SDR Performance
  - Noise NEdN
  - Radiometric Calibration Accuracy
  - Spectral Calibration Accuracy
  - Geolocation Accuracy
- Summary and Path Forward

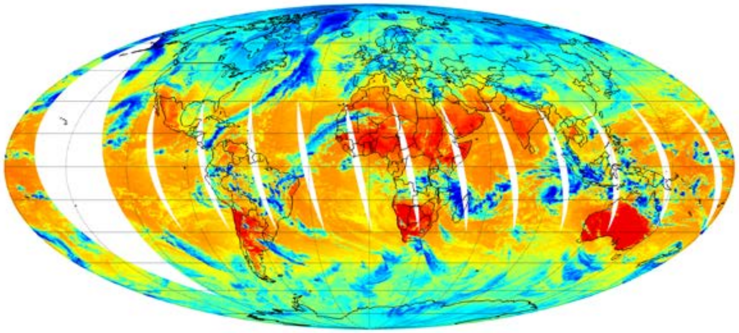
Cal/Val Team Members

PI	Organization	Major Task
Changyong Cao (acting)	NOAA/STAR	Project management, SDR team coordination and algorithm test in IDPS, calibration and geolocation science support, inter-comparison, CrIS SDR data quality and monitoring
Dave Tobin	U. of Wisconsin (UW)	Radiometric calibration, non-linearity coefficients, polarization, inter-comparison, simulation
Larrabee Strow	U. of Maryland Baltimore County (UMBC)	Spectral calibration, ILS parameters, inter-comparison, simulation
Deron Scott	Space Dynamic Lab (SDL)	Noise characterization, bit trim and impulse noise mask, anomaly analysis
Dan Mooney	MIT/LL	Correlated/uncorrelated noise characterization, residual analysis and ringing, simulation
Dave Johnson	NASA Langley	NASA flight support, instrument science
Lawrence Suwinski	Harris	PLT tests, on-orbit instrument performance
Joe Predina	Logistikos	Optimal laser wavelength setting, noise, calibration algorithm
Deirdre Bolen	JPSS/JAM	DR support
Wael Ibrahim	Raytheon	IDPS support

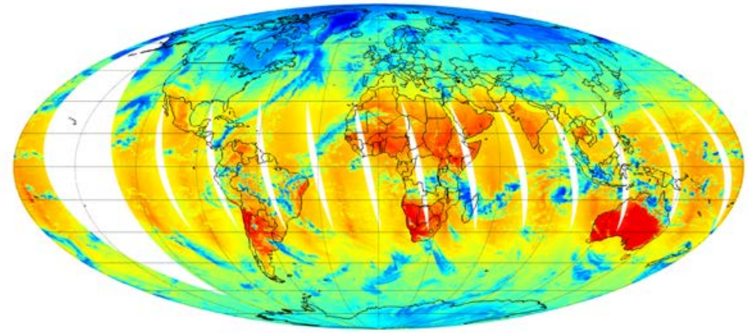
- **Big thanks for the dedicated and hard work of each of the contributing organizations**
- **Team work has been and continues to be exceptional**

NOAA-20 CrIS SDR Cal/Val Timeline

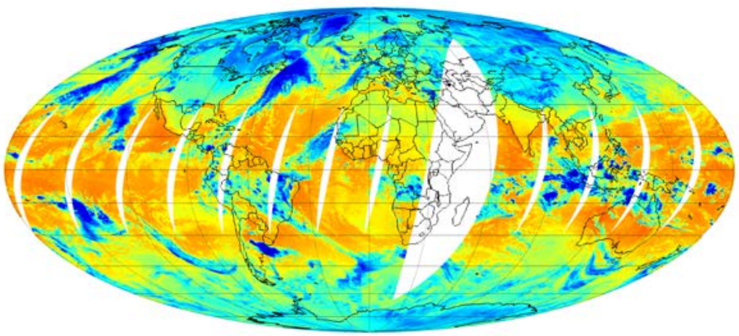
	Flight Activity	Ground Activity
L + 0 (11/18/17)	JPSS-1 Launch	
L + 11 (11/29/17)	Begin Outgassing	
L + 46 (1/3/18)	End Outgassing; Deploy Cooler Door; **Initial Cal Table upload(v112)** Instrument Stable	
L + 47 (1/4/18)	First Earth view science data available	Science Data Available (L+48) CrIS Diode Temp, IR Gain Check, BTM, Impulse Noise Mask Check, Jitter Performance, etc
L + 60 (1/17/18)	**Second Cal Table (v113)** upload with PGA gain and new Neon Wavelength and ILS parameters	SDR data available (Beta Maturity L+68), Spectral Cal/Laser Stability, Detector Noise/Linearity, Full Res Diagnostic, Geolocation a2, ILS parameters Delivered w/STAR input (L+85)
L + 90 (2/16/18)	**Third Cal Table Upload v114**	Provisional Maturity



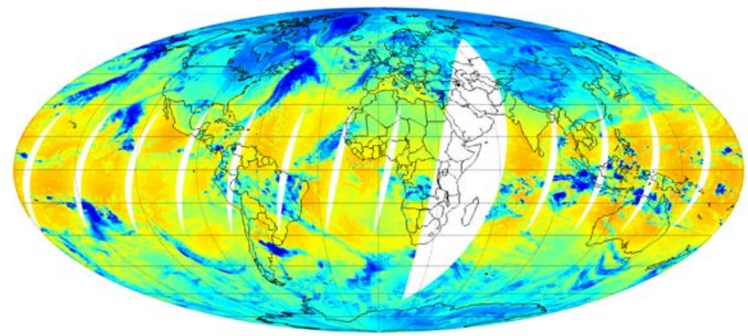
NOAA-20 CrIS Channel 401: 900.00cm^{-1} (°K)



NOAA-20 CrIS Channel 1267: 2455.00cm^{-1} (°K)



NOAA-20 CrIS Channel 401: 900.00cm^{-1} (°K)



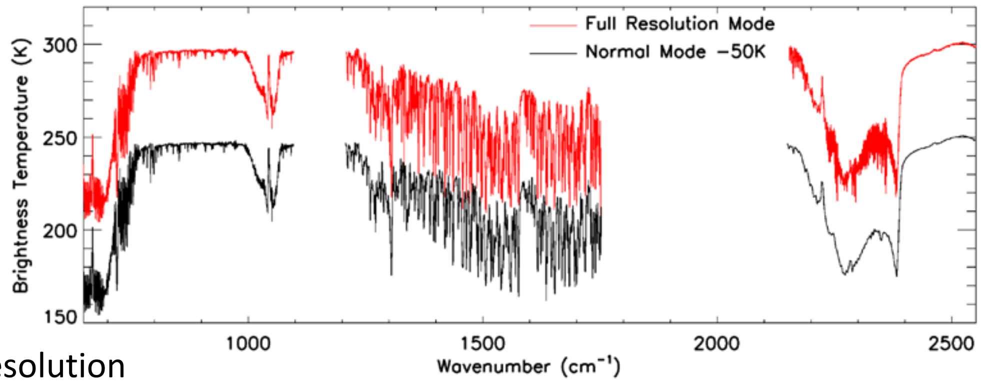
NOAA-20 CrIS Channel 1267: 2455.00cm^{-1} (°K)

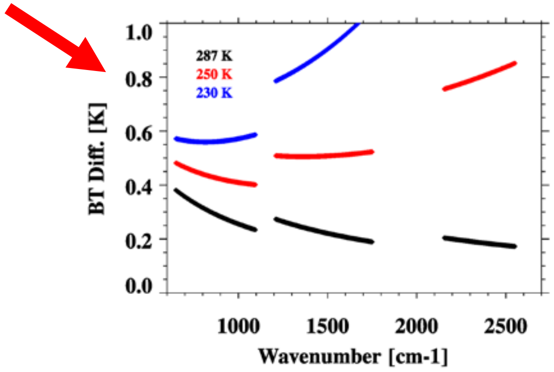
- Cooler door opened on 1/3
- First science data produced at 22:08 on 1/4; detectors still cooling
- IDPS immediately produced SDR products suitable for analysis
- End-to-end demonstration that system (Flight + Ground) is working

NOAA-20 SDR Calibration Uncertainty Specifications

Normal Spectral Resolution

Band	Spectral range (cm^{-1})	N. of chan.	Resolution (cm^{-1})	FORs per Scan	FOVs per FOR	NEdN @287K BB $mW/m^2/sr/cm^{-1}$	Radiometric Uncertainty @287K BB (%)	Spectral (chan center) uncertainty ppm	Geolocation uncertainty Km (Nadir)
LW	650-1095	713	0.625	30	9	**0.14**	**0.45**	**10**	**1.5**
MW	1210-1750	433	1.25	30	9	**0.06**	**0.58**	**10**	**1.5**
SW	2155-2550	159	2.5	30	9	**0.007**	**0.77**	**10**	**1.5**





Full Spectral Resolution

Band	Spectral range (cm^{-1})	N. of chan.	Resolution (cm^{-1})	FORs per Scan	FOVs per FOR	NEdN @287K BB $mW/m^2/sr/cm^{-1}$	Radiometric Uncertainty @287K BB (%)	Spectral (chan center) uncertainty ppm	Geolocation uncertainty Km (Nadir)
LW	650-1095	713	0.625	30	9	**0.14**	**0.45**	**10**	**1.5**
MW	1210-1750	865	0.625	30	9	**0.084**	**0.58**	**10**	**1.5**
SW	2155-2550	633	0.625	30	9	**0.014**	**0.77**	**10**	**1.5**

Beta Maturity Definition

JPSS/GOES-R Data Product Validation Maturity Stages –
COMMON DEFINITIONS (Nominal Mission)

1. Beta

- Product is minimally validated, and may still contain significant identified and unidentified errors.
- Information/data from validation efforts can be used to make initial qualitative or very limited quantitative assessments regarding product fitness-for-purpose.
- Documentation of product performance and identified product performance anomalies, including recommended remediation strategies, exists.

2. Provisional

- Product performance has been demonstrated through analysis of a large, but still limited (i.e., not necessarily globally or seasonally representative) number of independent measurements obtained from selected locations, time periods, or field campaign efforts.
- Product analyses are sufficient for qualitative, and limited quantitative, determination of product fitness-for-purpose.
- Documentation of product performance, testing involving product fixes, identified product performance anomalies, including recommended remediation strategies, exists.
- Product is recommended for potential operational use (user decision) and in scientific publications after consulting product status documents.

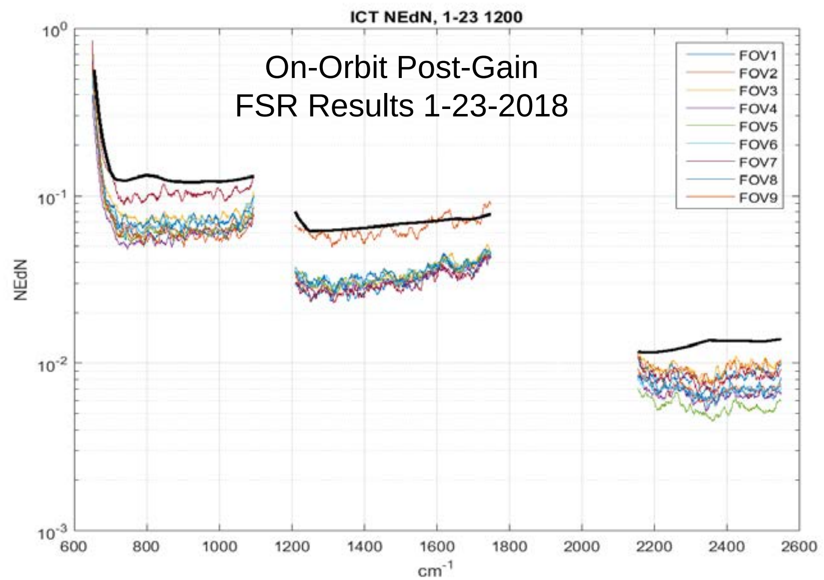
3. Validated

- Product performance has been demonstrated over a large and wide range of representative conditions (i.e., global, seasonal).
- Comprehensive documentation of product performance exists that includes all known product anomalies and their recommended remediation strategies for a full range of retrieval conditions and severity level.
- Product analyses are sufficient for full qualitative and quantitative determination of product fitness-for-purpose.
- Product is ready for operational use based on documented validation findings and user feedback.
- Product validation, quality assurance, and algorithm stewardship continue through the lifetime of the instrument.

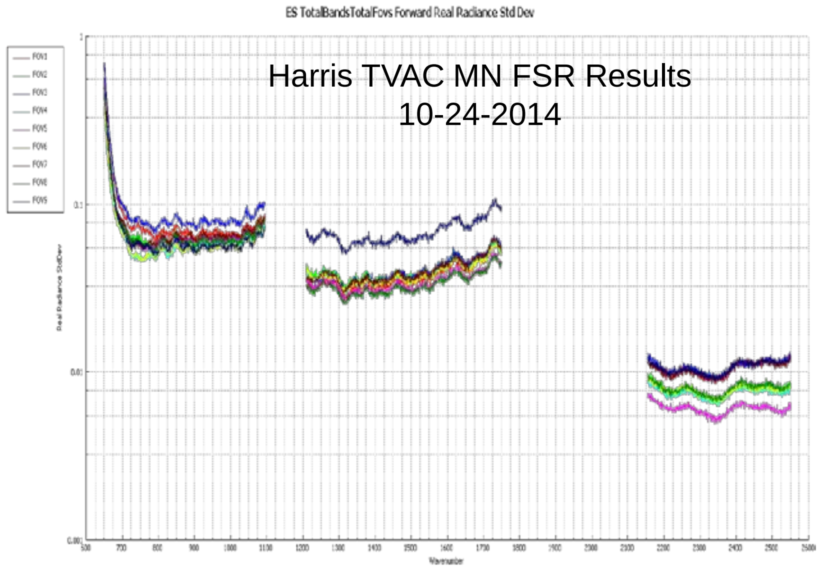
Major Improvements since Beta Review

- Major NOAA-20 CrIS SDR performance from Beta Review:
  - NEdN: all FOVs and bands within the specification (except for MW FOV9), comparable well to S-NPP
  - Radiometric uncertainty: within the specification, all channels (except one) are with ±0.2 K with S-NPP (global averaged), showing very good agreement with VIIRS, AIRS, and IASI (less than 0.5 K)
  - Spectral uncertainty: within the specification, FOV 5 absolute spectral shift within 1 ppm, relative shift within 3 ppm for all bands after EngPkt v113
  - Geolocation uncertainty: within the specification, in-track geolocation having up to about 6% FOV size error
- Major CrIS SDR improvements after uploading EngPkt v114
  - Radiometric uncertainty: radiometric FOV2FOV consistency improved for LW and MW bands
  - Spectral uncertainty: spectral offsets for relative and absolute for all three bands are all within ±1ppm
  - Geolocation uncertainty: in-track geolocation accuracy significantly improved after updating mapping angles in v114 relative to VIIRS

NEdN Compares well to
287K ECT TVAC NEdN – Full Spectral Resolution



On Orbit

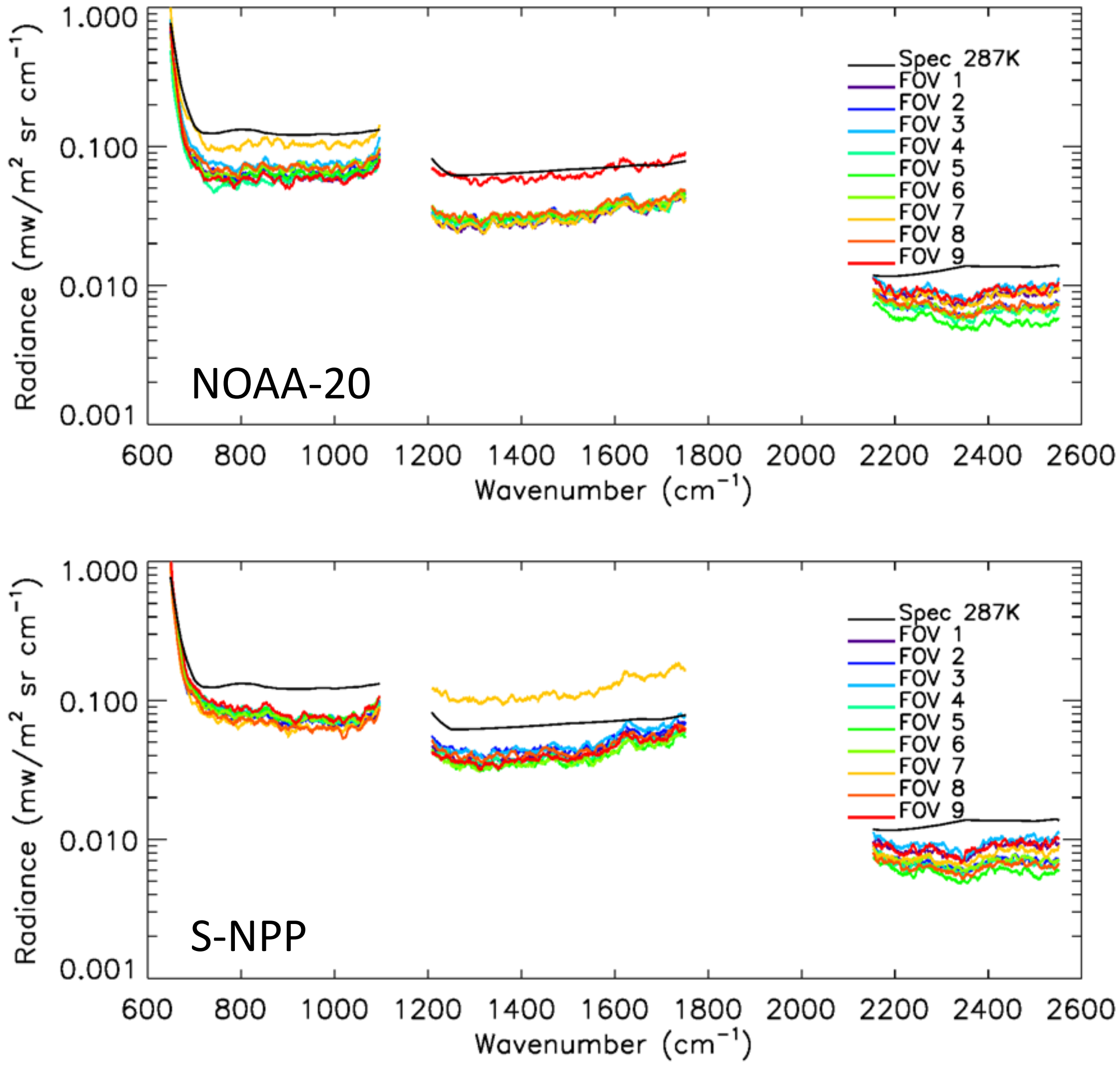


Ground Testing

- Full resolution spectra compared against the NOAA full resolution SDR specification
- Spread in SW is a known result of the algorithm (SA correction) when applied to full resolution spectra
- Pre and Post launch NEdN are consistent
- MW9 NEdN elevated as expected from prelaunch TVAC measurements but within specification
- LW7 NEdN elevated (high noise had been seen once before during EMI test phase)

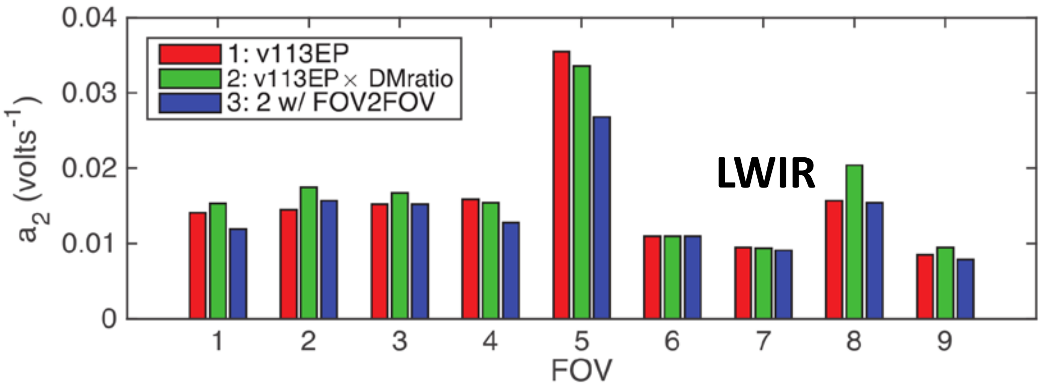
NOAA-20 NEdN Comparable to S-NPP

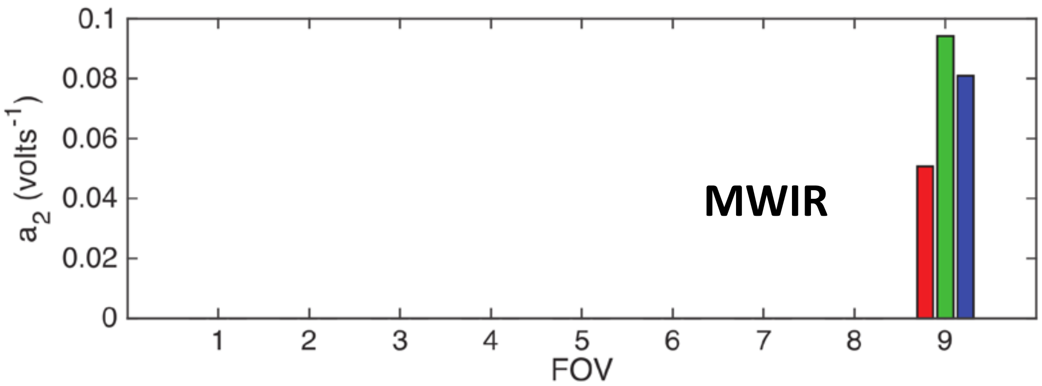
ICT NEdN on 01/21/2018



NOAA-20 MW NEdN are better than S-NPP for FOVs 1-8

Non-Linearity Coefficients Adjustment





- SW and other MW 1-8 are linear
- Most significant changes in LW FOV 5 and MW FOV 9

Set 1: v113 EP (based on TVAC NM ECT view residuals)

FOV	LW	MW	SW
1	0.0141	0	0
2	0.0145	0	0
3	0.0152	0	0
4	0.0159	0	0
5	0.0355	0	0
6	0.0110	0	0
7	0.0095	0	0
8	0.0157	0	0
9	0.0085	0.0507	0

Set 2: v113 EP x (in-orbit DM)/(TVAC DM)

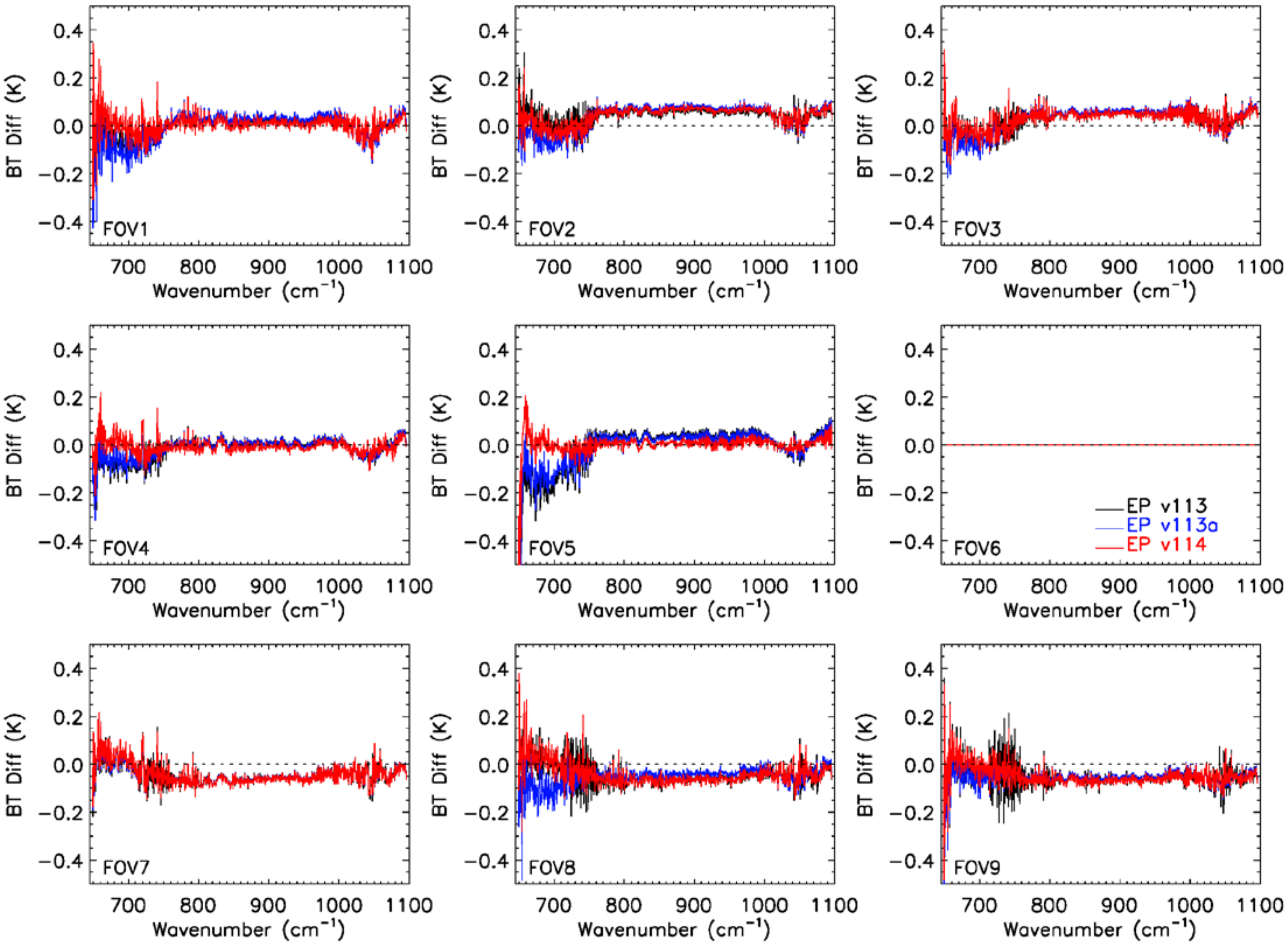
FOV	LW	MW	SW
1	0.0153	0	0
2	0.0175	0	0
3	0.0167	0	0
4	0.0154	0	0
5	0.0336	0	0
6	0.0110	0	0
7	0.0094	0	0
8	0.0204	0	0
9	0.0095	0.0943	0

Set 3: Set 2 w/ adjustments to minimize FOV2FOV differences

FOV	LW	MW	SW
1	0.0119	0	0
2	0.0157	0	0
3	0.0152	0	0
4	0.0128	0	0
5	0.0268	**0**	0
6	**0.0110**	0	0
7	0.0091	0	0
8	0.0154	0	0
9	0.0079	0.0811	0

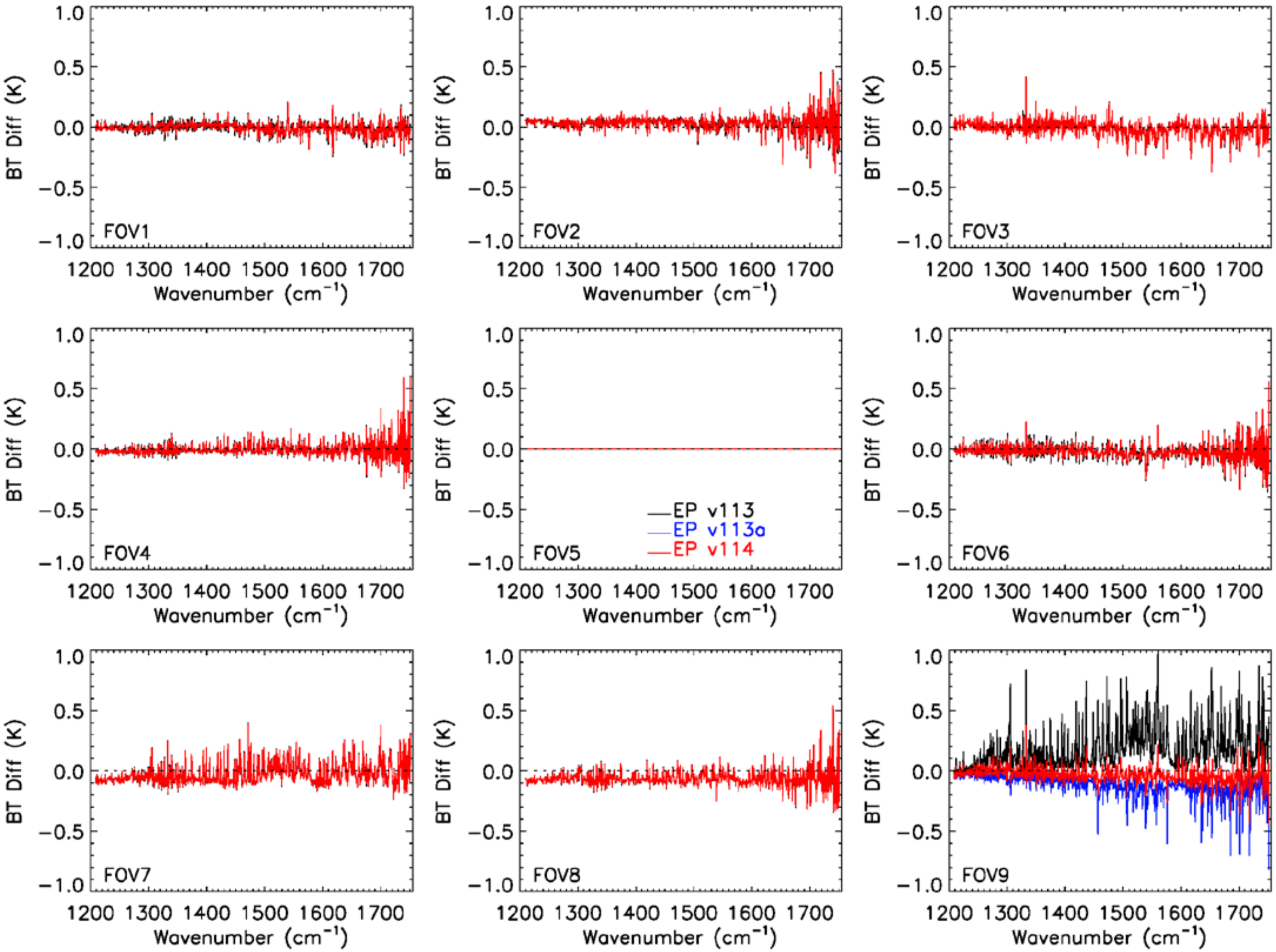
Reference FOVs are LW6 and MW5

Radiometric FOV2FOV Comparison (LWIR)



- Using LW FOV 6 as a reference, unapodized mean spectra
- FOV2FOV consistency significantly improved after non-linearity coefficients adjustment in EP v114

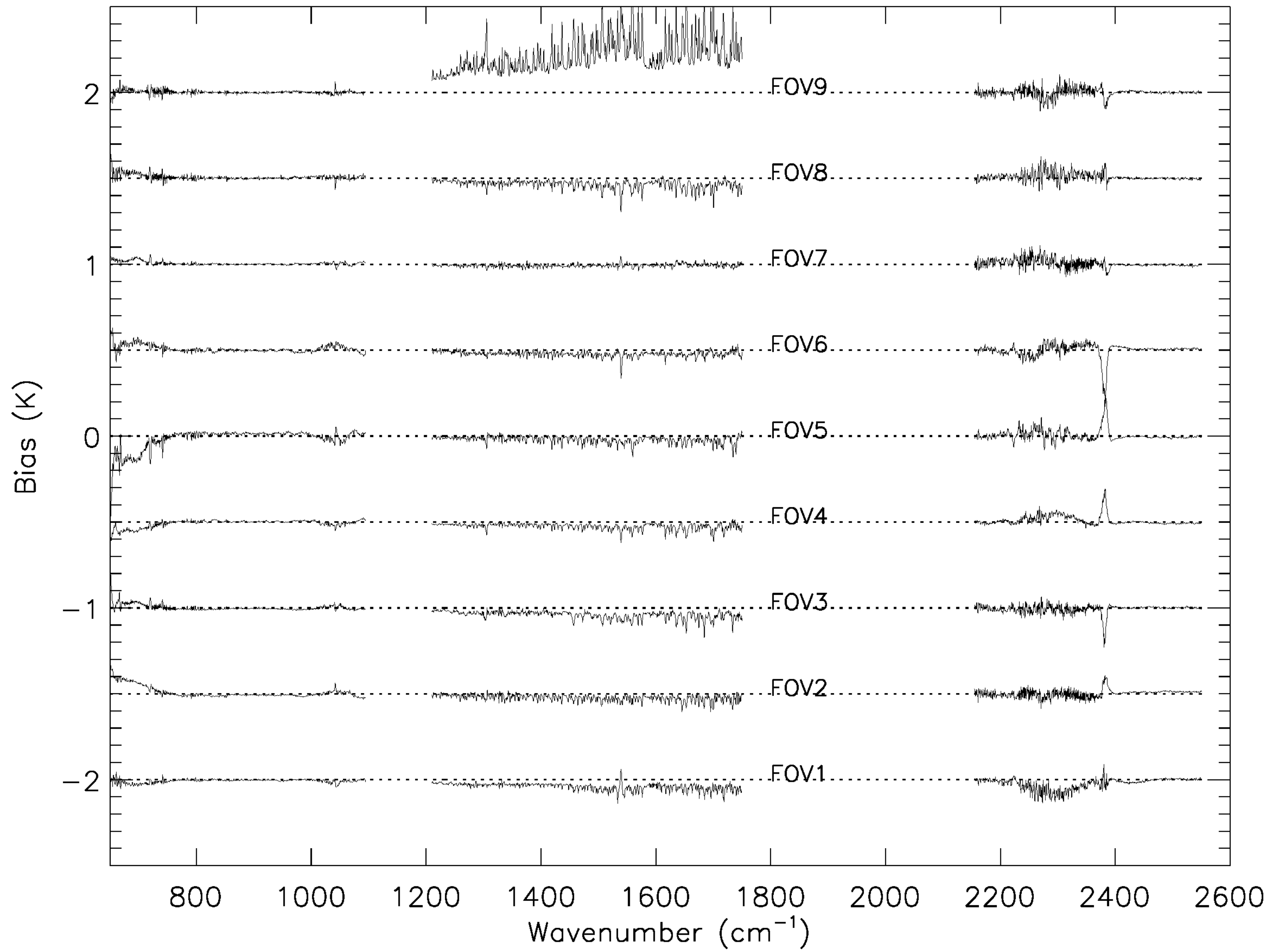
Radiometric FOV2FOV Comparison (MWIR)



- Using MW FOV 5 as a reference, unapodized mean spectra
- MW FOV 9 non-linearity significantly improved after non-linearity coefficients adjustment in EP v114

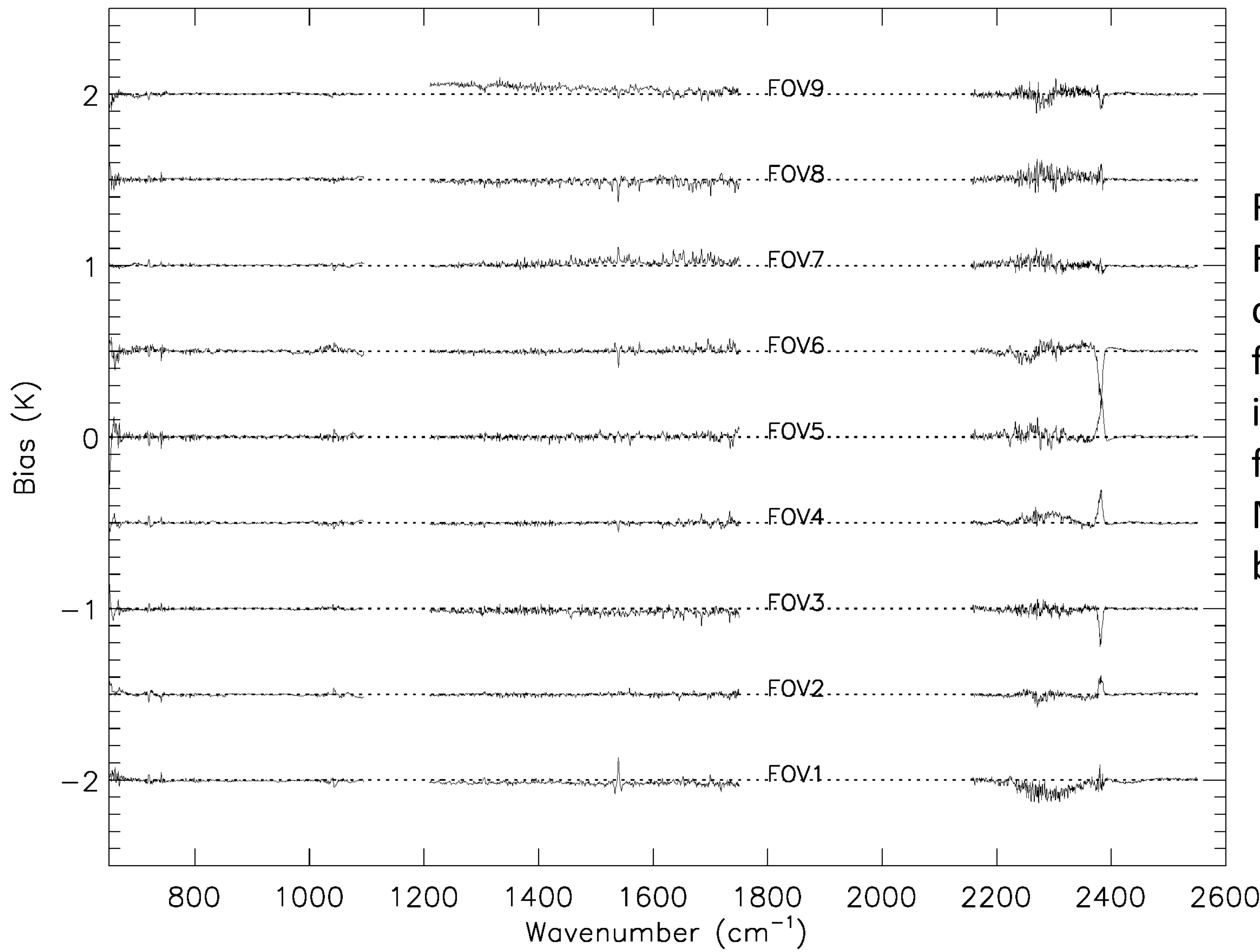
FOV2FOV Radiometric Consistency

NOAA-20 with EP v113, apodized mean spectra, and removed O-B bias for each FOV



FOV2FOV Radiometric Consistency

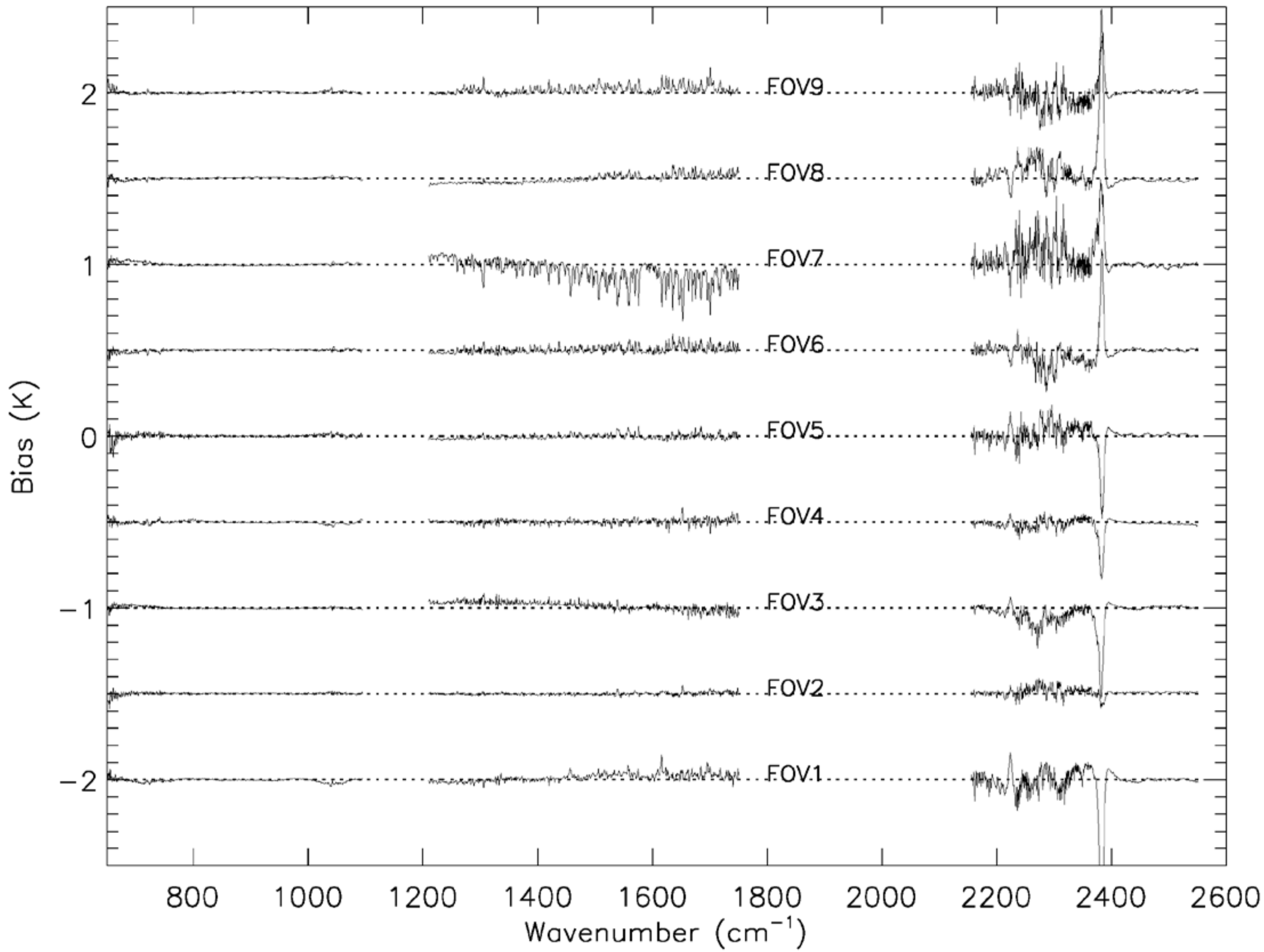
NOAA-20 with EP v114, apodized mean spectra, and removed O-B bias for each FOV



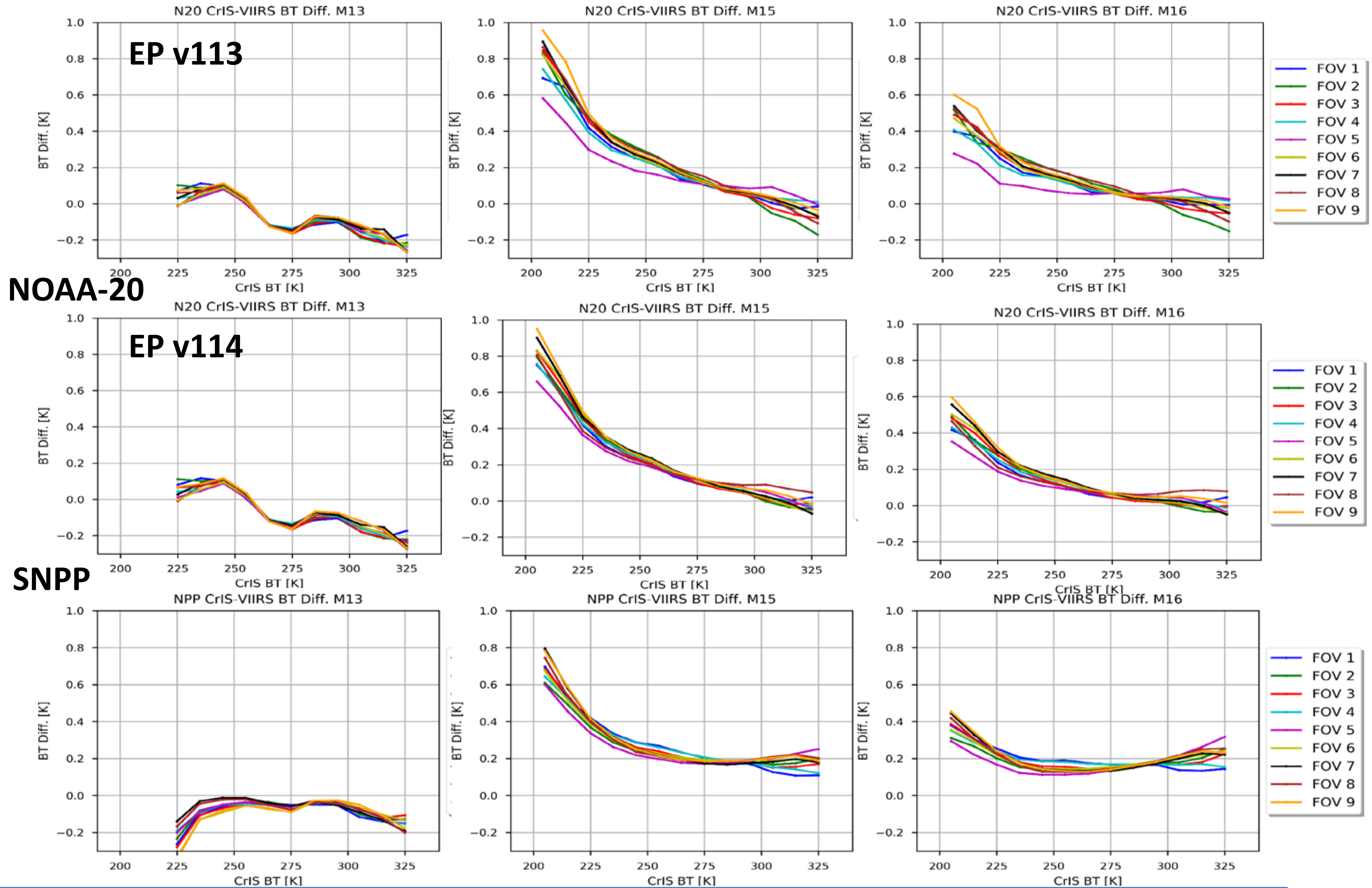
FOV2FOV Radiometric consistency for NOAA-20 is better than for SNPP for MW and SW bands

FOV2FOV Radiometric Consistency

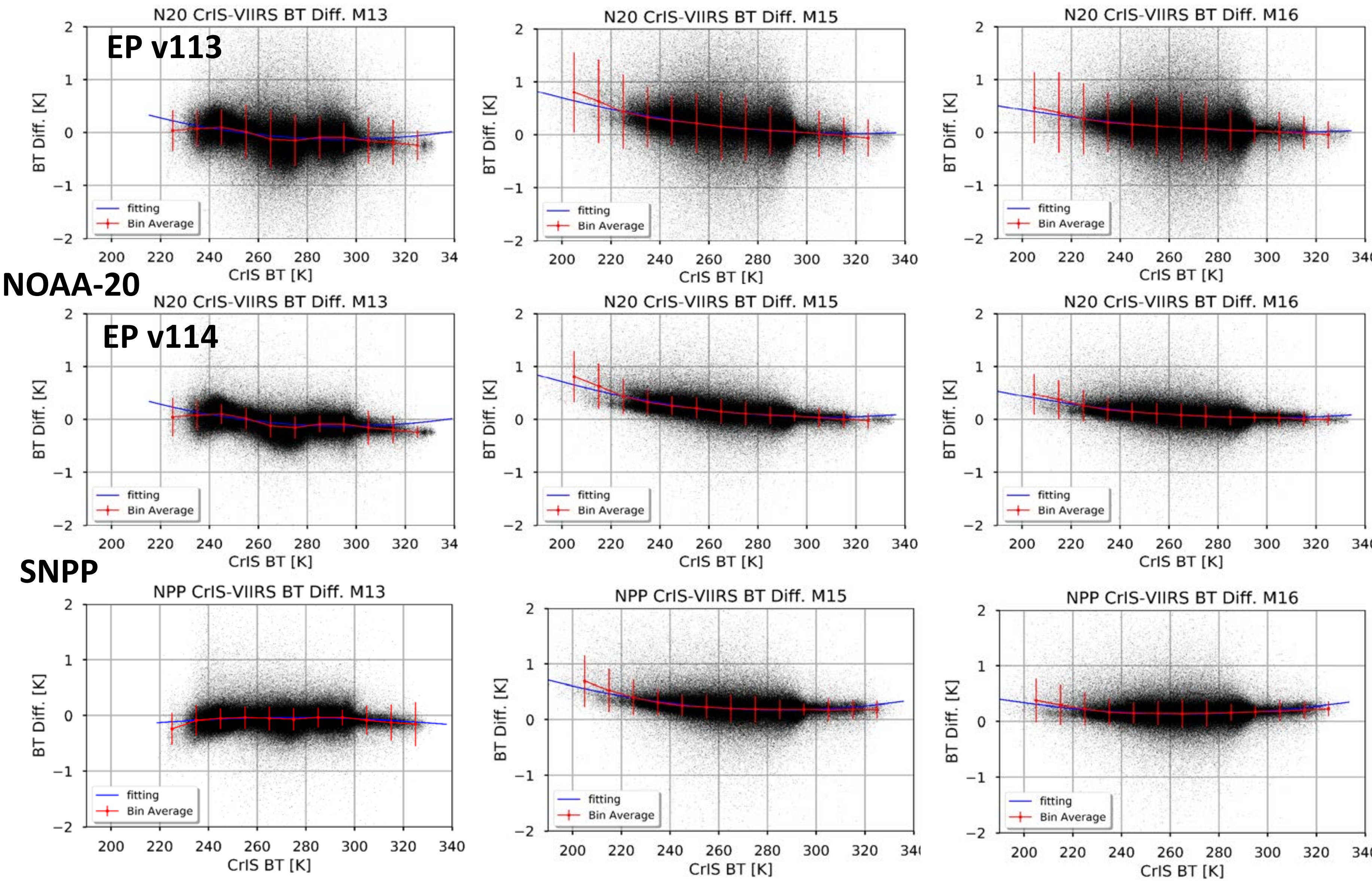
S-NPP, apodized mean spectra, and removed O-B bias for each FOV

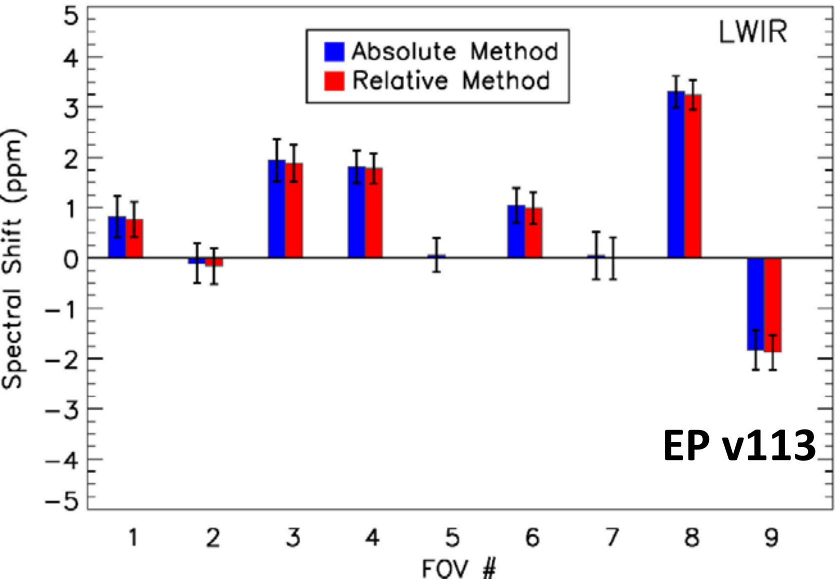


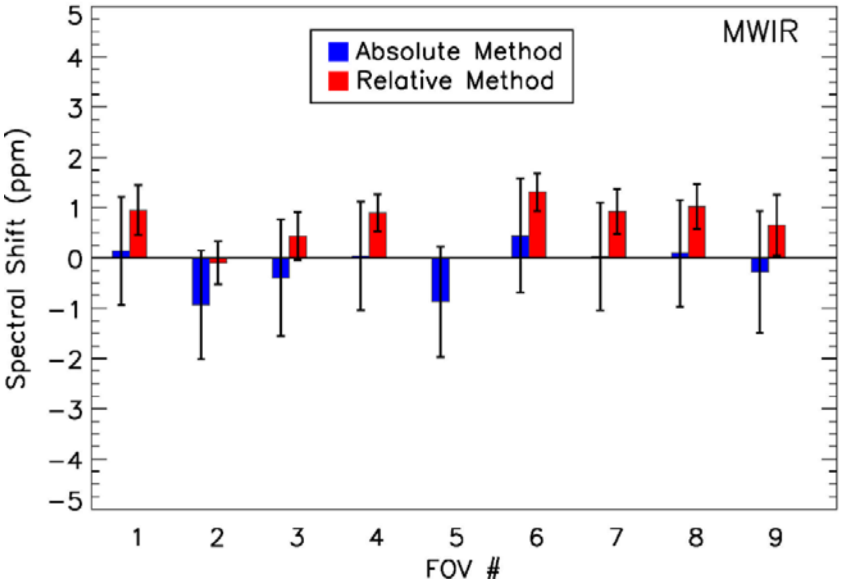
FOV2FOV Dependence Relative to VIIRS

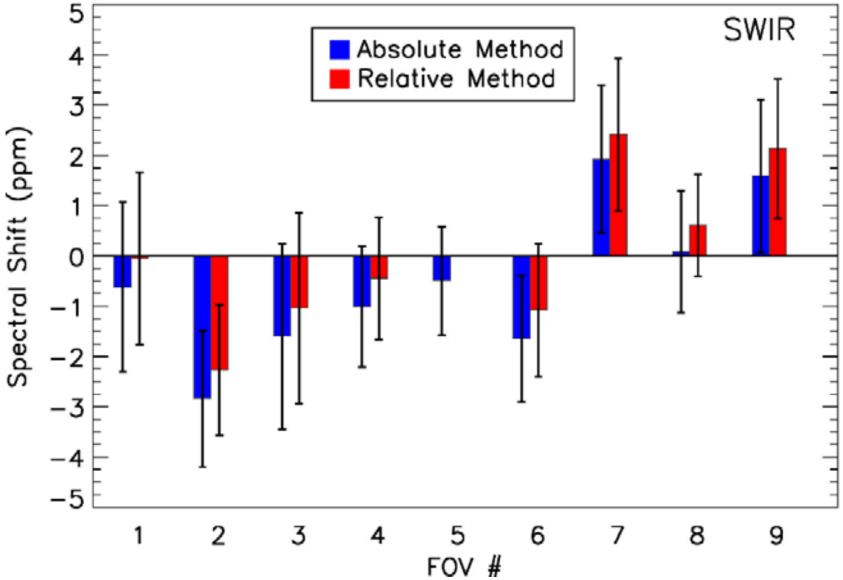


CrIS-VIIRS BT Difference VS Scene Temperature



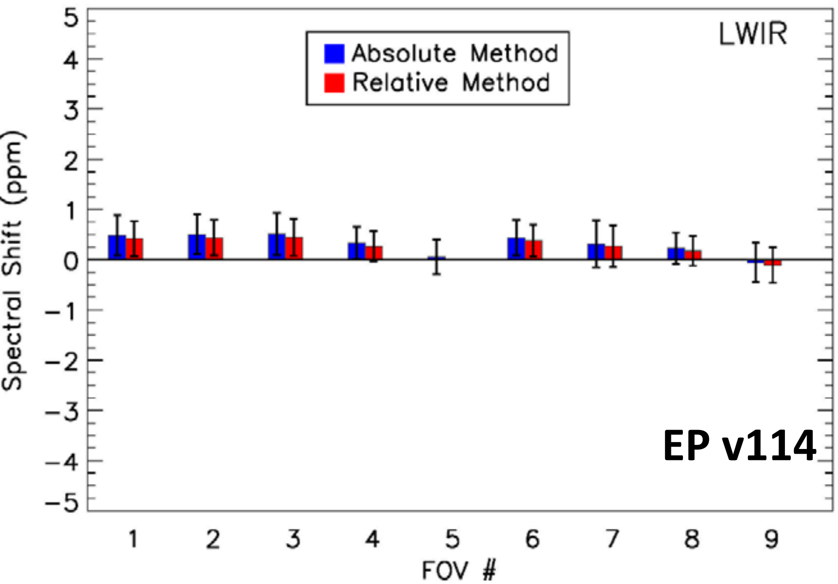


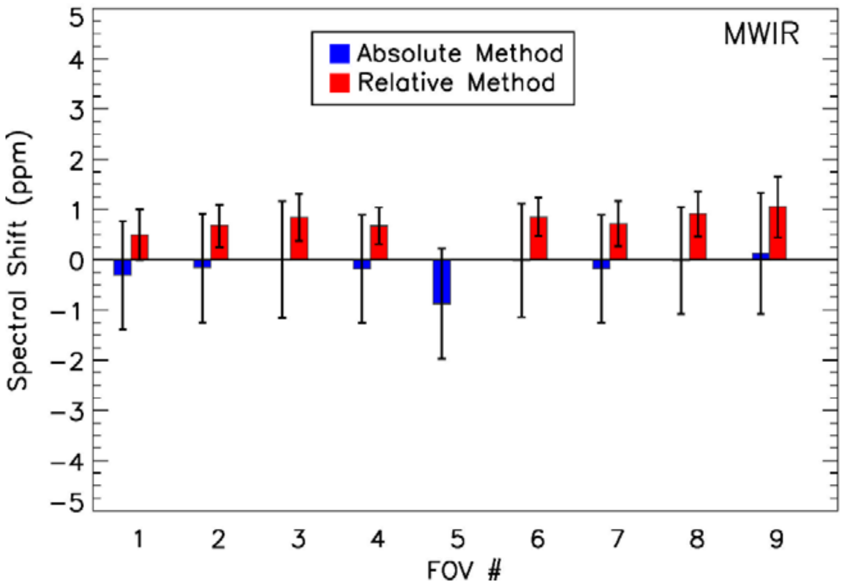


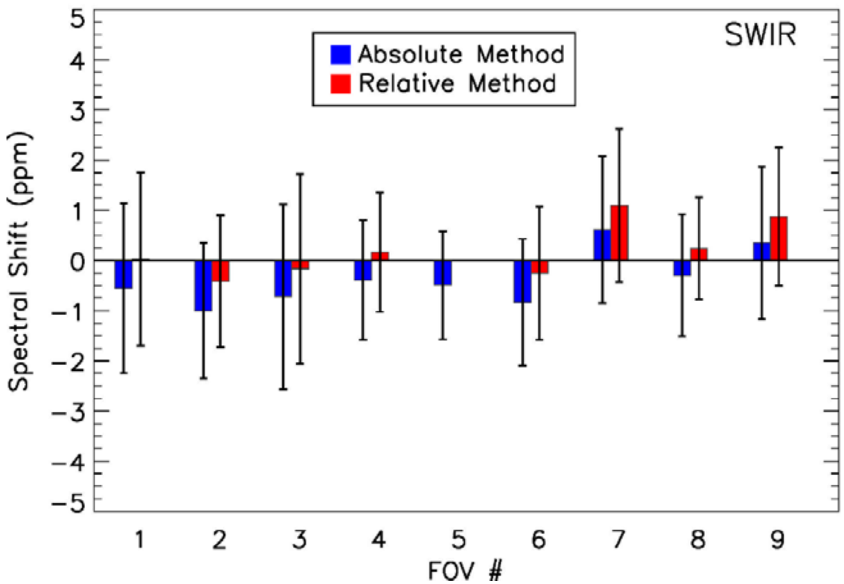


Within the specification, FOV 5 absolute spectral shift within 1 ppm, relative shift within 3 ppm for all bands for EngPkt v113

Spectral Accuracy: Relative and Absolute

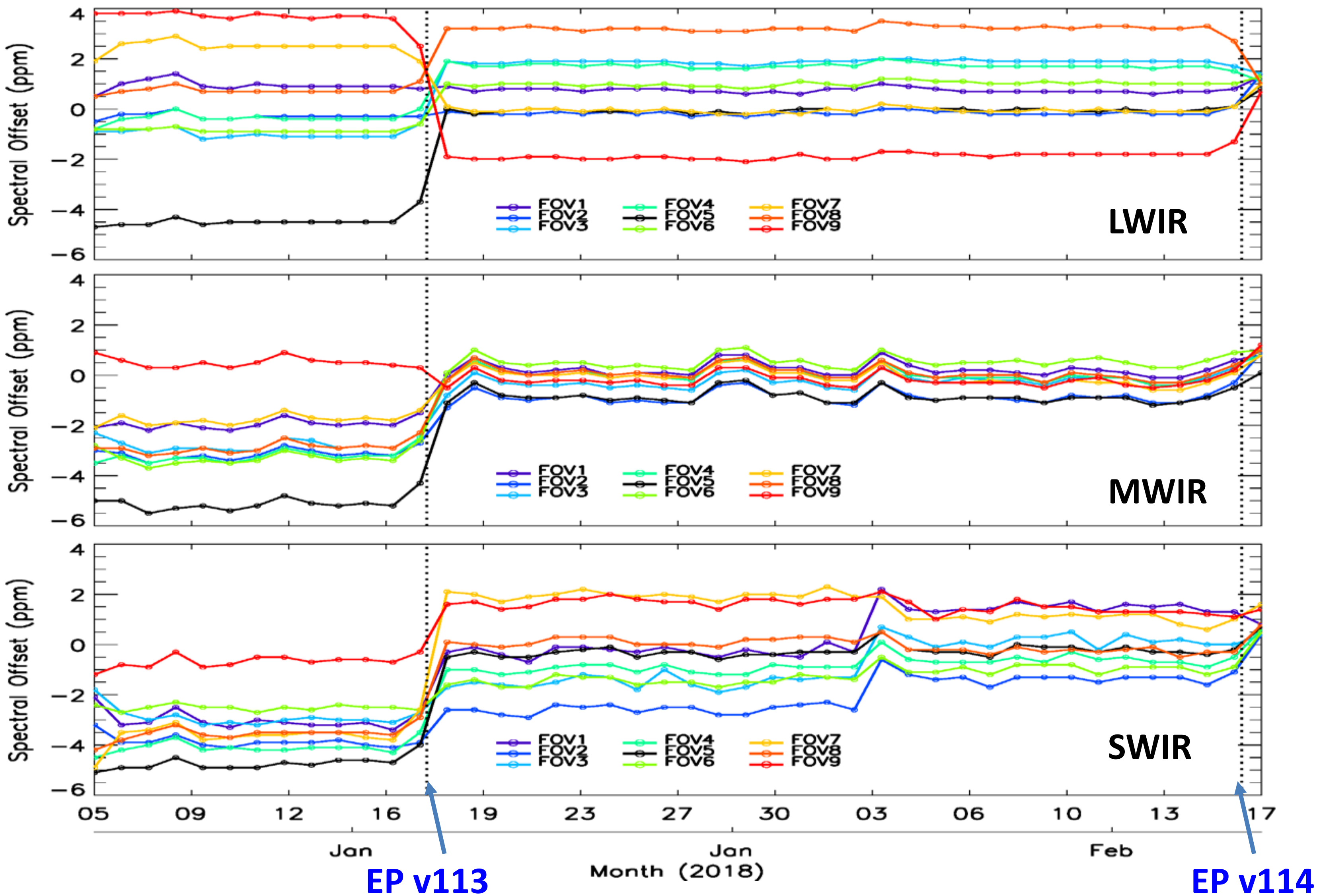




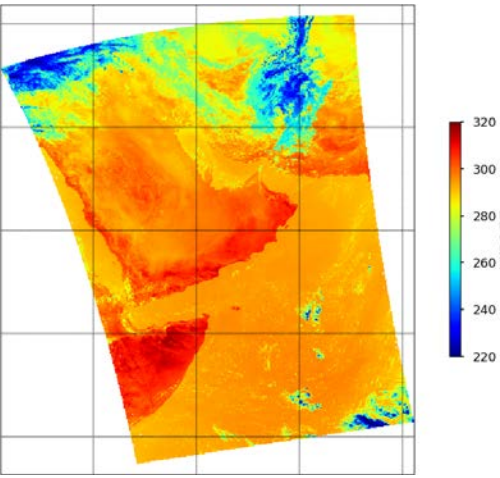


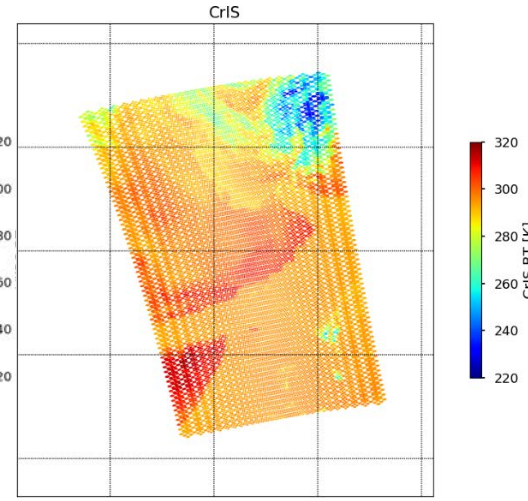
Spectral offsets for relative and absolute for all three bands are all within ±1ppm using Engineering Packet v114

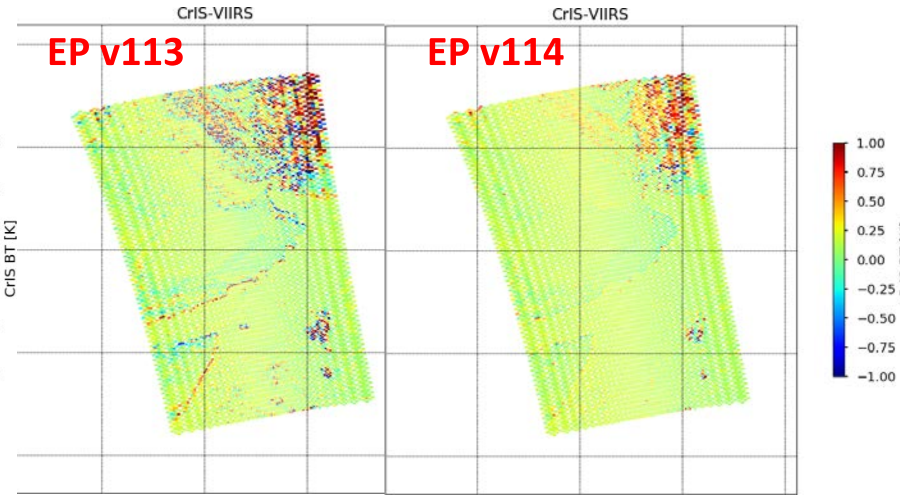
Spectral Accuracy Trending



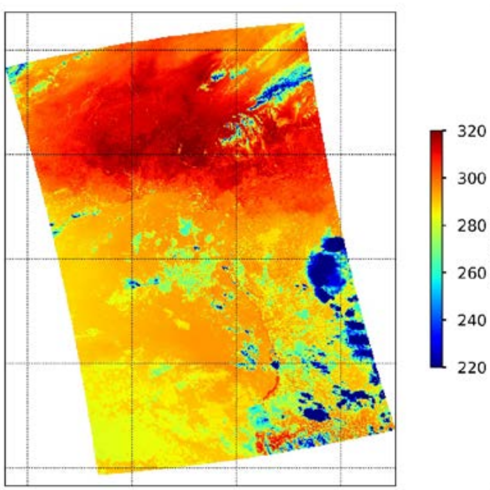
Geolocation Accuracy

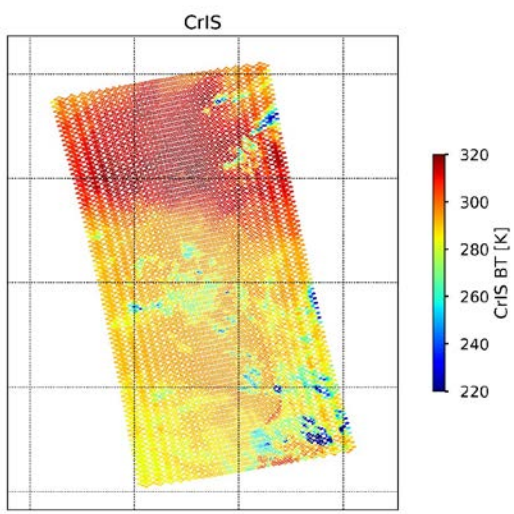


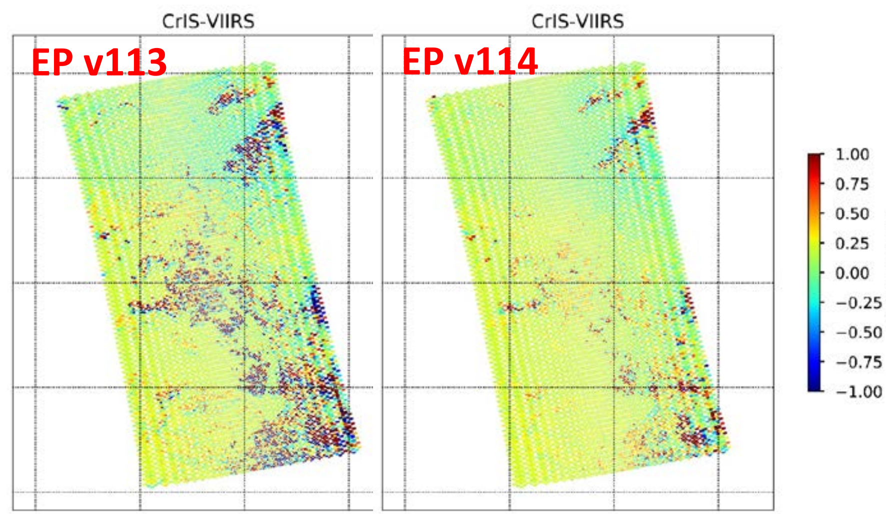




CrIS VIIRS BT Differences for Coastline Case





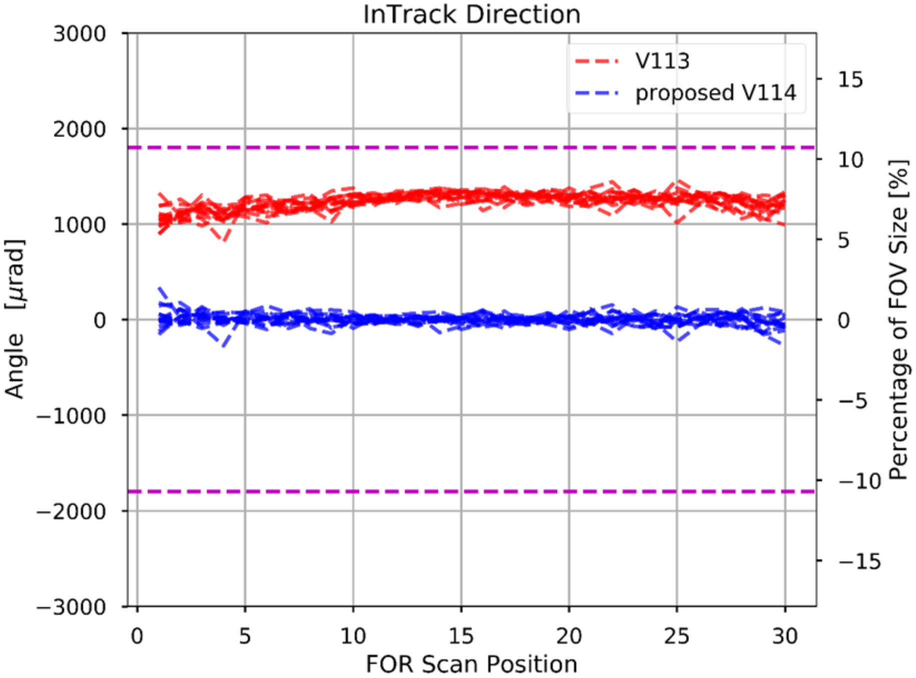


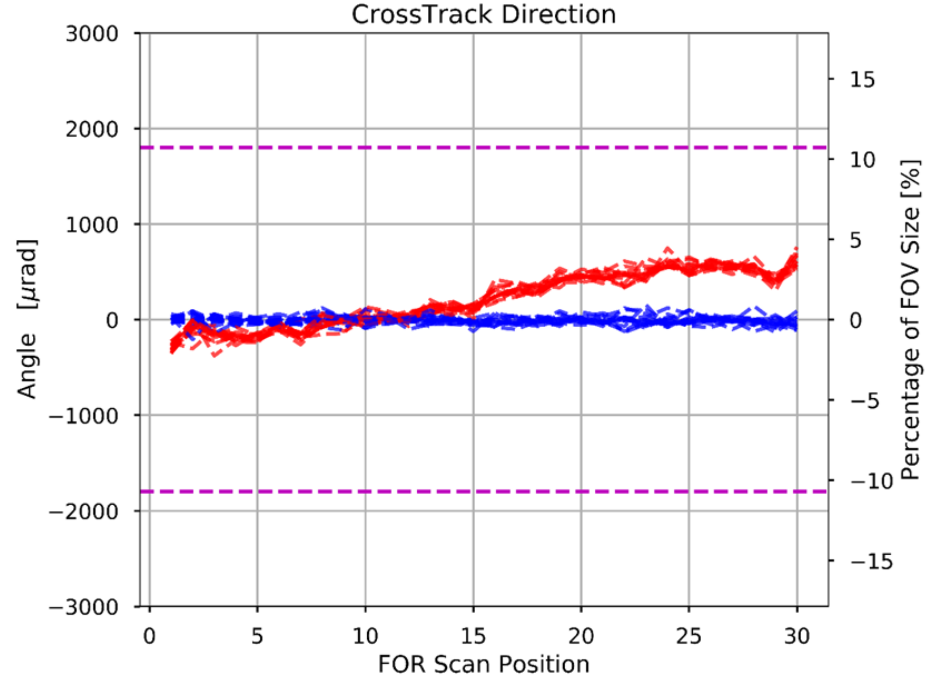
VIIRS M15

CrIS at 900.0 cm^{-1}

CrIS VIIRS BT Differences for Cloud Case

In-track and Cross-track Bias





Overall performance for CrIS geolocation for all FOV positions: requirement is 1.5 km at nadir, 11% of FOV diameter for all scan positions:

- EP v113 based on prelaunch characterization, v114 includes launch shifts and post-launch comparison with VIIRS

CrIS SDR Reached Provisional Maturity Level

- Requirements
  - Instrument & SDR performances exceeded requirements since Beta status declaration 1/17/2018
- SDR software
  - Stable & free of errors that can impact data quality since 7/28/2017 (Block 2.0 Mx 3.0)
- Documentation
  - 5 presentations in this meeting
  - Peer reviewed Journal papers for S-NPP
  - SDR ATBD
  - SDR User Guide
  - ReadMe for Data Product Users
  - Algorithm Calibration/Validation Plan

Provisional Status

SDR Software: Free of Major Error Since Block 2.0 Mx 3.0

Documentation: Complete

Requirements : Exceeded Specifications Since Beta Declaration

CrIS FSR SDR uncertainties (**blue, estimation**) vs. specifications (black)

Band	NEdN @287K BB $mW/m^2/sr/cm^{-1}$	Radiometric Uncertainty @287K BB (%)*	Frequency Uncertainty (ppm)	Geolocation Uncertainty (km)
LW	**0.10** (0.14)	**0.12** (0.45)	**2** (10)	**0.3** (1.5)
MW	**0.04** (0.084)	**0.15**(0.58)	**2** (10)	**0.3** (1.5)
SW	**0.01** (0.014)	**0.2** (0.77)	**2** (10)	**0.3** (1.5)

* Using SNPP radiometric uncertainty here, expect that NOAA-20 has very similar radiometric uncertainty, will provide the uncertainty at the Validated Status

Summary

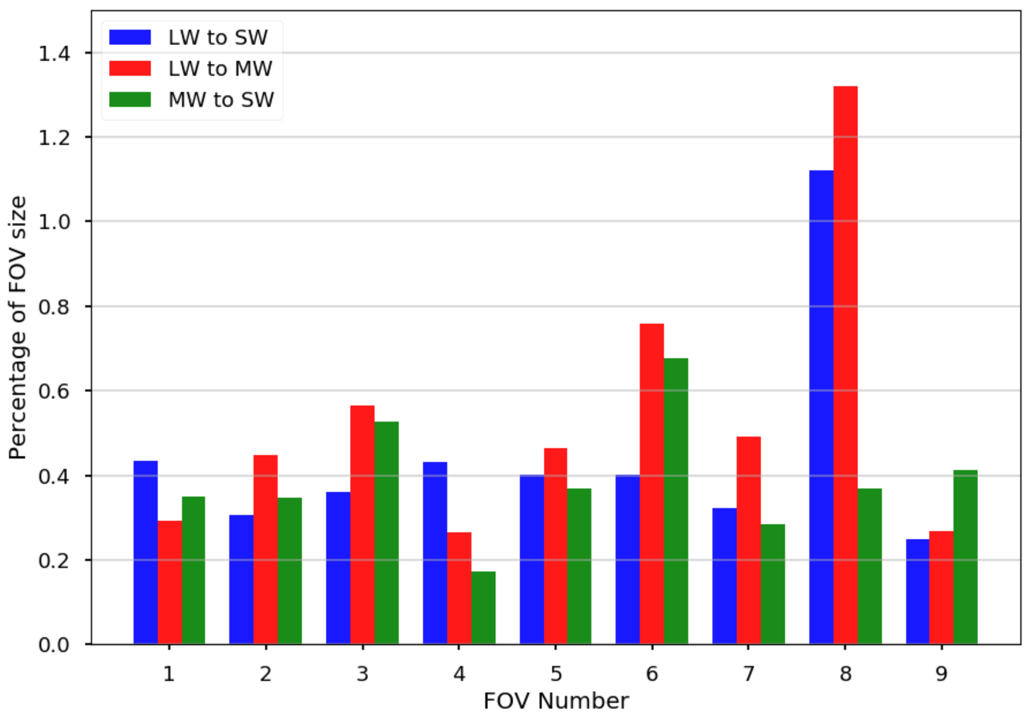
- NOAA-20 CrIS SDR data well meet the Provisional Maturity: The CrIS SDR team recommends the NOAA-20 CrIS SDR data for operational use (user decision)
- Major NOAA-20 CrIS SDR performance and improvements after Beta Maturity:
  - NEdN: all FOVs and bands within the specification (except for MW FOV9), comparable well to S-NPP
  - Radiometric uncertainty: radiometric FOV2FOV consistency improved for LW and MW bands (within 0.1 K)
  - Spectral uncertainty: spectral offsets for relative and absolute for all three bands are all within ±1ppm
  - Geolocation uncertainty: in-track geolocation accuracy significantly improved after updating mapping angles in v114 relative to VIIRS
- NOAA-20 CrIS SDR products have been reliably produced by IDPS since detectors first went cold on 01/04/2018. No DR submitted during this period

Path Forward

- The CrIS SDR team will continue performing the cal/val tasks with NOAA-20 CrIS towards Validated status milestone by August, 2018
  - Radiometric uncertainty: on-orbit error budget analysis, polarization correction, and inter-comparison with other sensors
  - Spectral uncertainty: only very minor adjustment if demanded
  - Geolocation uncertainty: mapping angles may need to be adjusted depending on the VIIRS geolocation updates
  - SDR algorithm improvements to address the potential issues (e.g. polarization effect correction, lunar intrusion detection)
  - Continuation of SDR software improvements to address the remaining and future issues

- While additional minor tuning will take place during the extended validation campaign, there are no open issues
- One science waiver at launch: MA-04—07

  Chipped LW FOV 8 singlet results in minor outage for band-to-band centroid coregistration and shape matching



Band-to-band performance for EP v114, meets requirement (1.4%)