The JPSS Beta/Provisional Maturity Science Review For Suomi-NPP CrIS SDR Side-2 Data

POC: Flavio Iturbide-Sanchez

Date: 2019/07/25

Performance Overview of the SNPP/CrIS SDR Product After the Switch to Side-2 Electronics: Recovery of the Full Capabilities of the SNPP/CrIS Instrument

Flavio Iturbide-Sanchez
Larrabee Strow
Dave Tobin
On behalf of the **CrIS SDR Science Team**
July 25, 2019

Outline

- CrIS SDR Algorithm Cal/Val Team Members
- CrIS SDR Specifications
- Evaluation of the SNPP CrIS SDR Performance
  - Noise (NEdN)
  - Radiometric Calibration Uncertainty
  - Spectral Calibration Uncertainty
  - Geolocation Uncertainty
- User Feedback
- Error Budget
- Risks, Actions, and Mitigations
- Documentation
- Conclusion
- Path Forward

JPSS Data Products Maturity Definition

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.

CrIS Cal/Val Science Team Members

Name	Organization	Team	Major Task
Flavio Iturbide-Sanchez	NOAA/STAR	Yong Chen, Denis Tremblay, Erin Lynch, Peter Beierle	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)	Hank Revercomb, Joe Taylor, Bob Knuteson, Lori Borg, Michelle Feltz, Dan Desolver	Radiometric calibration, non-linearity coefficients, polarization, inter-comparison, simulation
Larrabee Strow	U. of Maryland Baltimore County (UMBC)	Howard Motteler, Sergio de Souza-Machado, Chris Hepplewhite, Steven Buczkowski	Spectral calibration, ILS parameters, inter-comparison, simulation
Dan Mooney	MIT/LL	Mark Tolman	Correlated and uncorrelated noise characterization, residual analysis and ringing, simulation
Dave Johnson	NASA Langley	Yana Williams	NASA flight support, instrument science
Clayton Buttles	Harris	Lawrence Suwinski, Don Ripplinger, Sara Glass, Jeff Garr, and Rebecca Malloy.	PLT tests, on-orbit instrument performance
Joe Predina	Logistikos	Richard Hertel, James Isaacs, Shankar Atre	Optimal laser wavelength setting, noise, calibration algorithm
Deirdre Bolen	JPSS/JAM		DR support
Bruce Guenther	JPSS/AMP	Susan Venter	Coordination with JPSS Flight Project
Banghua Yan	NOAA/STAR	Xin Jin, Warren Porter, Ninghai Sun	CrIS SDR data quality and monitoring

The Loss of the Midwave-IR (MWIR) Band

- **Loss of the MWIR Band:**
  - On March 23, 2019, missing SNPP/CrIS MWIR Interferograms were detected. IDPS stopped producing SNPP/CrIS SDR data since 18:27 UTC on March 26.
- **Root Source:**
  - Mid-wave (MW) IR Signal Processor Field Programmable Gate Array (FPGA) and associated support circuitry.
- **Option to Rectify the Anomaly:**
  - Switch to Side-2 Electronics: Very High Probability of Success.
- **Impacted Users:**
  - Weather Forecast centers, Environmental data record developers and users, Participants of field campaign experiments.
- **Impacted Operational Products in IDPS:**
  - Thermodynamic profiles, Outgoing Longwave Radiation, Trace Gases, MWIR Radiances.

Recovery Cal/Val Plan of the SNPP/CrIS Instrument Operating under the Side-2 Electronics Configuration

Activity No.	Cal/Val Activities in the Event of Switching to SNPP/CrIS Side-2 Electronics	Main Responsible(s)	Completion Date[1]	Deliveries	Delivery Status: Completed, In Progress, Not Initiated	Timeline (weeks)													
						1 6/21/2019	2 6/28/2019	3 7/5/2019	4 7/12/2019	5 7/19/2019	6 7/26/2019	7 8/02/2019	8 8/09/2019	9 8/16/2019	10 8/23/2019	11 8/30/2019	12 9/06/2019	13 9/13/2019	14 9/20/2019
1	Prepare Initial Engineering Packet (EP)	STAR/Harris/NASA LaRC	6/24/2019	Upload Initial EPv38	Completed														
2	Instrument Tuning	Harris/NASA LaRC	6/28/2019 (7/05/2019)	Upload First EPv39	Completed														
3	Generation of new ILS parameters, as part of the Spectral Calibration	UMBC	7/08/2019 (7/19/2019)	Technical Report	Completed														
4	Bit Trim Mask Verification, as part of the PGA gain setting	STAR	7/03/2019 (7/19/2019)	Technical Report	Completed			Beta Level 7/03/2019											
5	Evaluation of Non-linearity	UW	7/03/2019 (8/2/2019)	Technical Report	Completed														
6	Evaluation of Spectral Uncertainty	UMBC/UW/STAR	7/17/2019 (8/2/2019)	Technical Report	Completed														
6	Evaluation of Geolocation Uncertainty	STAR/UW	7/17/2019 (8/2/2019)	Technical Report	Completed														
8	Evaluation of Radiometric Calibration Uncertainty	UW	7/17/2019 (8/2/2019)	Technical Report	Completed														
9	Evaluation of Instrument Noise Performance	STAR	7/17/2019 (8/2/2019)	Technical Report	Completed														
10	FOV-to-FOV Radiometric Consistency	UW/UMBC/STAR	7/17/2019 (8/2/2019)	Technical Report	Completed														
11	**Beta Maturity Level Review**	CrIS SDR Team	7/25/2019 (7/24/2019)	Technical Report	Scheduled						Beta and Provisional Review								
12	Generation of a 3-day SDR dataset with Updated ILS Parameters to Share with Team for Evaluation	STAR	7/09/2019 (7/26/2019)	SDR at NSR/FSR in HDF	Completed														
13	Generation of new mapping angles and assessment of the Geolocation Calibration	STAR	7/10/2019 (8/2/2019)	Technical Report	Completed														
14	Generation of a 3-day SDR dataset, with optimized calibration coefficients for Verification in Preparation for Second EP. Distribute data to Users.	STAR	7/10/2019 (8/9/2019)	SDR at NSR/FSR in HDF	Completed														
15	Evaluation of SDRs Using Offline ADL with Second EP Information	STAR	7/17/2019 (8/23/2019)	Technical Report	Completed					Provisional Level 7/17/2019					Provisional Level (Planned)				
16	**Beta/Provisional Maturity Level Review**	CrIS SDR Team/Users	7/25/2019 (8/28/2019)	Technical Report	Scheduled						Beta and Provisional Review					Provisional Review (Planned)			
17	Prepare Second Engineering Packet for uploading (xml file and documentation)	STAR	7/18/2019 (8/30/2019)	Second EP	Completed														
18	Approval and Upload of Second Engineering Packet	Fligth Working Group/OSPO	7/29/2019 (9/20/2019)	Upload Second EPv40	In Progress							Toward Validated Level							Toward Validated Level (Planned)

Instrument Reconfiguration to Operate using Side-2 Circuitry

Original Plan

Cal/Val Process for calibrated CrIS Observations to Meet Radiometric, Spectral and Geolocation Specifications.

Planned dates in parenthesis

About 1 month ahead

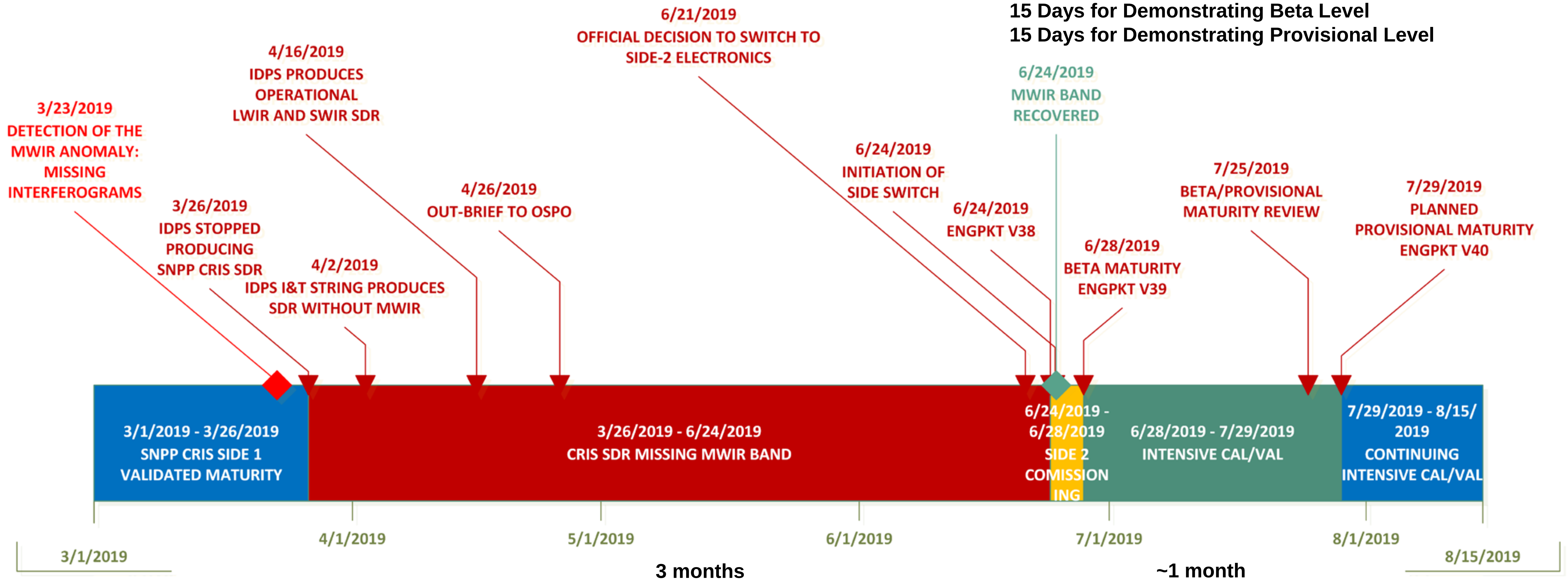
About 2 month ahead

Process to Upload Engineering Packet with Optimized Parameters

- **The plan accounts for the calibration of the three SNPP/CrIS spectral bands: LWIR, MWIR and SWIR.**
- **Milestones (Product Maturity Level): *Beta* (Minimally validated), *Provisional* (Meeting specifications with limited validation), *Validated* (Demonstrated long-term stability performance).**
- **SNPP/CrIS Science data will be available during the Cal/Val process, except during a specific period within the Instrument Tuning (Activity No. 2).**

SNPP/CrIS Major Events and Milestones: Recovery Timeline

1 Day to Recover the MWIR Band
5 Days for Instrument Tuning
15 Days for Demonstrating Beta Level
15 Days for Demonstrating Provisional Level



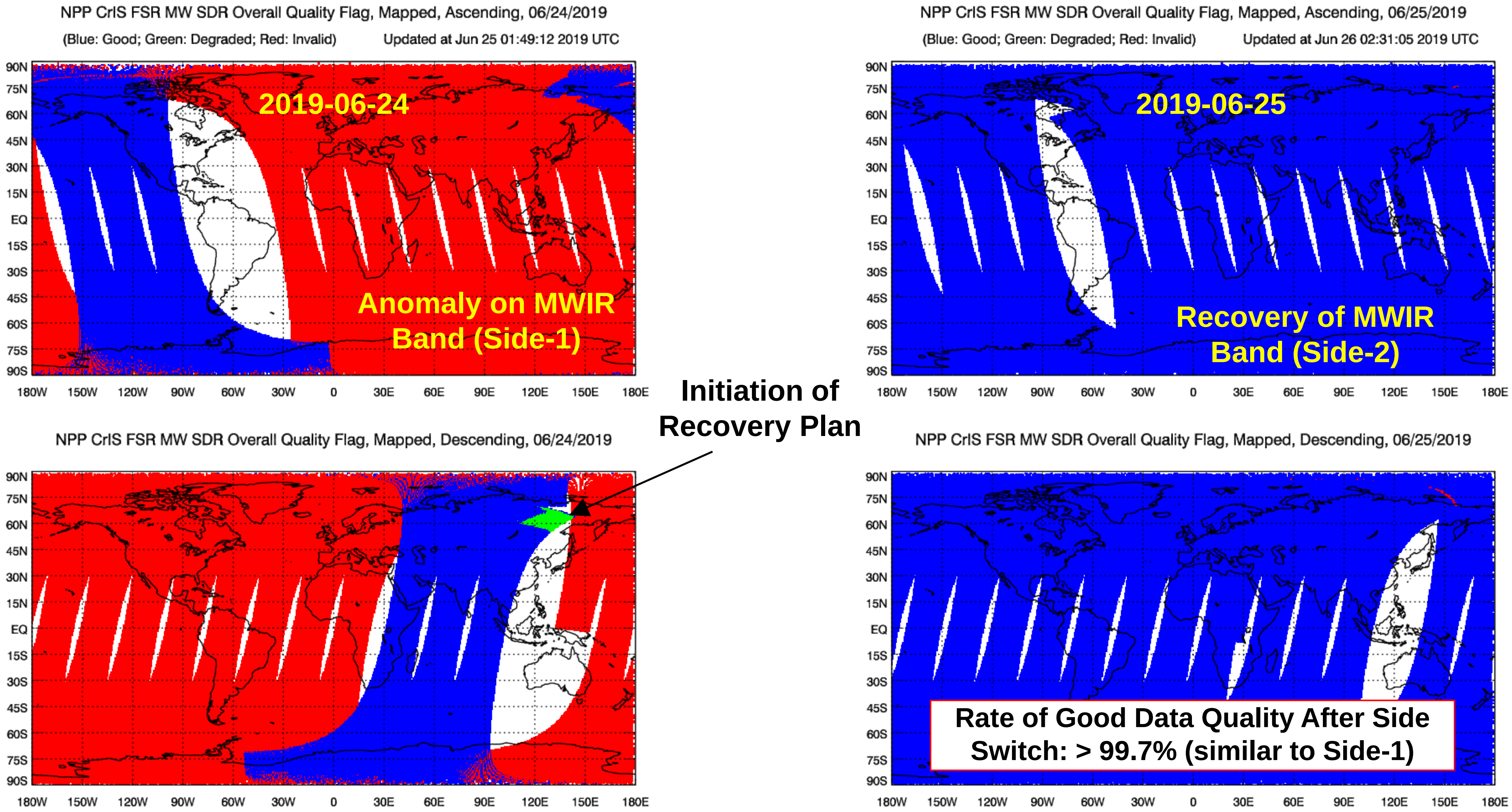
- **Date of Side-2 Meetings:** 2019-03-29, 2019-04-12, 2019-05-01, 2019-05-15, 2019-05-29, 2019-06-26, 2019-07-03, 2019-07-17, 2019-07-25.
- **Delivered daily reports to the JPSS Managers after side switch.**

Timeline for Initial Instrument Commissioning and Calibration Activities

1. **Load Initial Calibration Table** (Engineering Packet v38).
2. Switch sides: Science data for all 3-bands available after activity completion.
3. Interferometer Optimization.
4. PGA Gain Check.
5. *Vinst* Check (nonlinearity) and *SSM Null Torque Position* (Geolocation).
6. Bit Trim Mask Verification.
7. Metrology Laser Stability.
8. NEdN Check.
9. Responsivity Check.
10. **New Calibration Table Upload** (Engineering Packet v39).

Provided by Harris/Dave Johnson

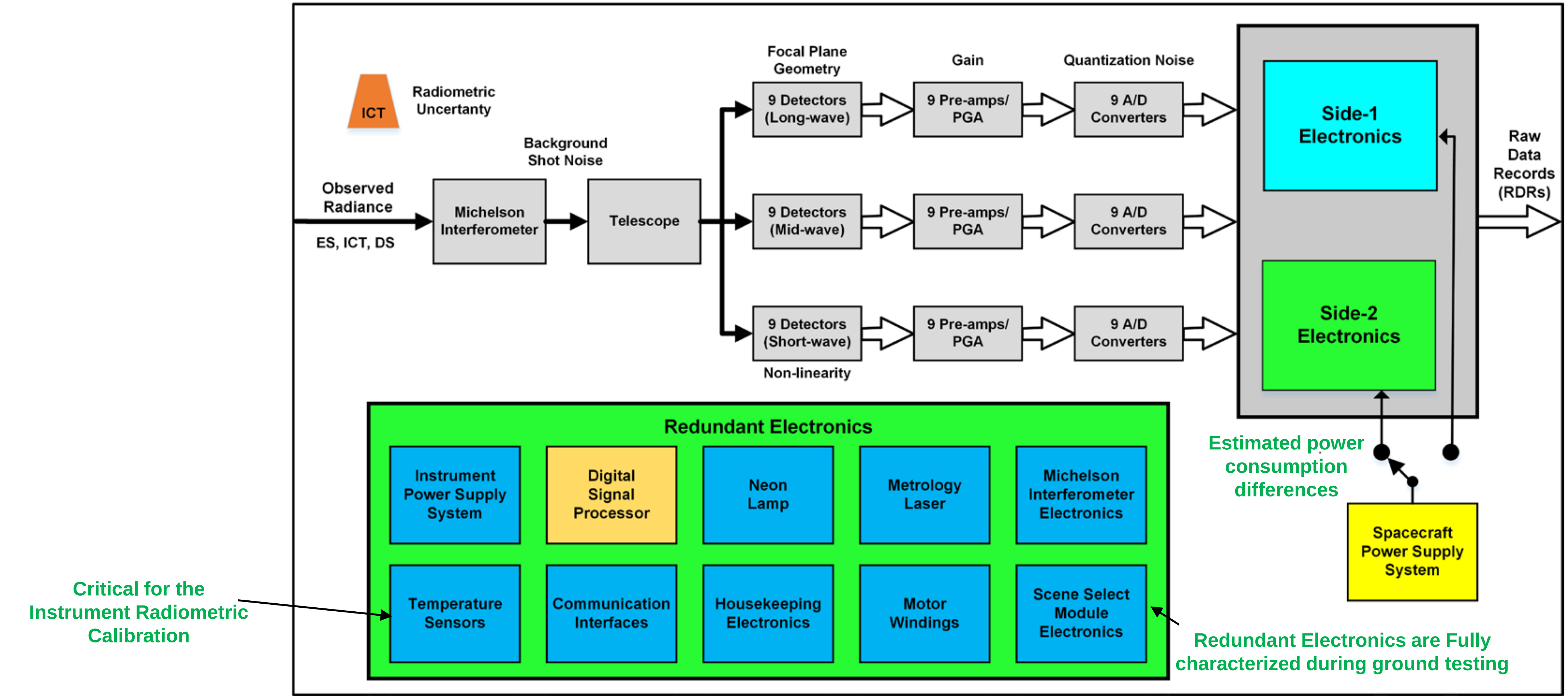
SNPP/CrIS Data Quality: Recovery of the MWIR Band



SNPP/CrIS MWIR band quality flags indicating good (blue), degraded (green), and invalid (red) quality during the implementation of the switch to Side-2 on June 24, 2019 (left panels) and on June 25, 2019, following the switch (right panels).

Figures from STAR/ICVS Website

SNPP/CrIS Operating Under the Side-2 Electronics Configuration



Switching to Side-2 electronics:

- Spectral calibration expected to be slightly impacted by the new Side-2 metrology laser, Neon lamp and change in instrument temperature, but optimization of the focal plane characterization will be needed due to shifts occurring over the lifetime of the mission.
- No major impact on the Instrument Noise and Gain (Bit Trim Mask definition) was expected.
- Low impact on the Radiometric Uncertainty is expected due to minor changes in the ICT temperature, no changes in the detector’s nonlinearity, and the use of new Side-2 temperature sensors for radiometric calibration.

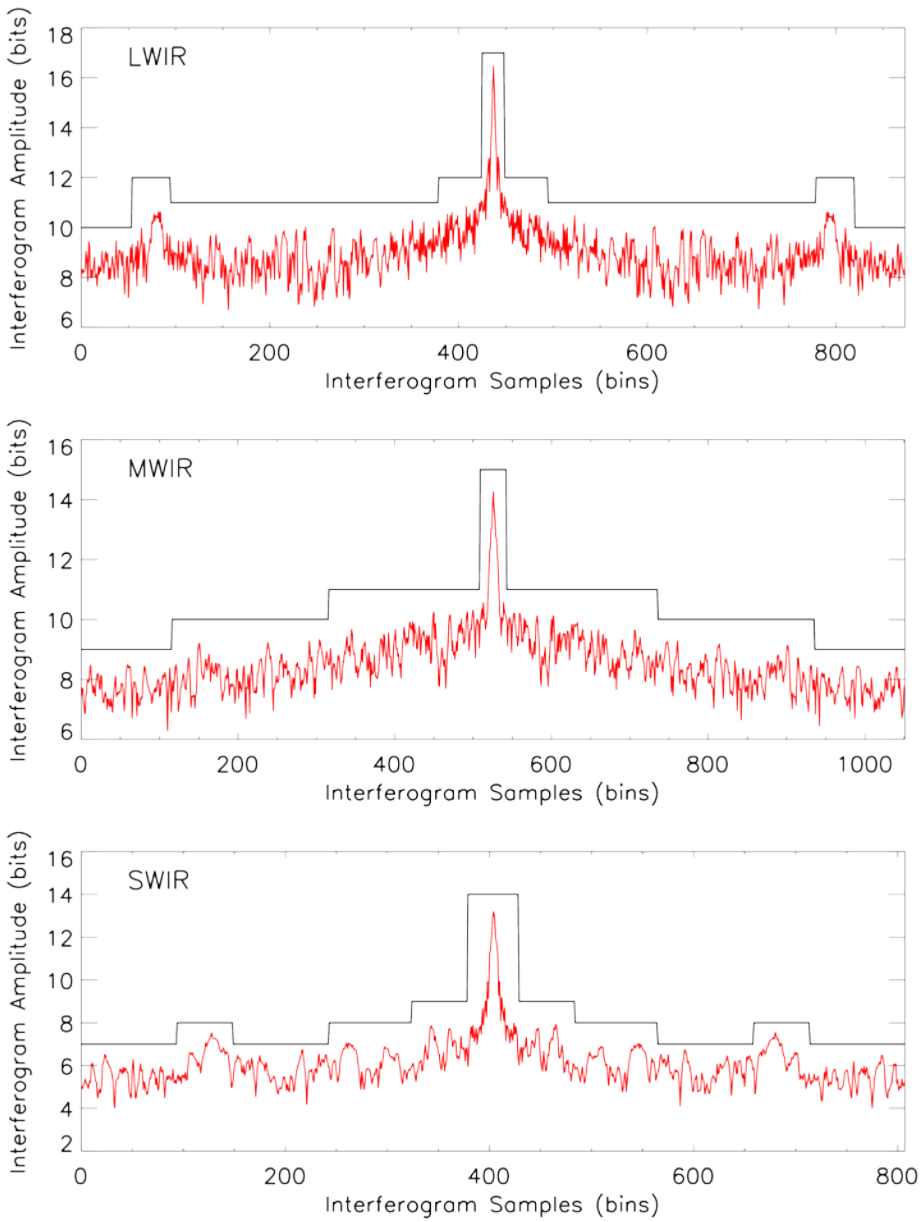
SNPP/CrIS Side-2 Calibration Table Timeline

- Engineering Packet v38. **Initial calibration table after Side Switch.**
  - Based on Engineering Packet v37 (from Validated Side-1) and uploaded on June, 24 2019.
- Engineering Packet v39.
  - Upload completed on June 28, 2019 at about uploaded around 19:00UTC. Included mapping angles (in-track torque null position) and Vinst values (needed for non-linearity correction), for the all detectors and over the three spectral bands (9 FOVs x 3 bands). The SDR product demonstrated **Beta Maturity Level**.
- Engineering Packet 40. Three major calibration changes were proposed:
  1) Update the effective Neon wavelength, by adjusting it 0.4 ppm.
  2) Use new optimized focal plane parameters (Instrument Line Shape fit parameters).
  3) Use improved mapping in-track and cross-track angle parameters.

  Expected to be delivered on the week of July 22, 2019, and uploaded during the week of July 29. This calibration coefficients are proposed to reach the **Provisional Maturity Level**.

"*Calibration parameters were adjusted to maintain SDR data continuity between Side-1 and Side-2 rather than to minimize calibration errors*".

SNPP/CrIS Bit Trim Mask Verification



- The maximum absolute amplitude of the interferogram at each bin (including real and imaginary parts) on 06/26/2019 for all three bands
- **The current bit-trim-mask in the Engineering Packet v40 (EP v38) is sufficient to handle all the atmospheric conditions** without violation, except for occasional high or saturated single sample in SW FOVs from sun-glint or extremely hot scenes, or strong spikes

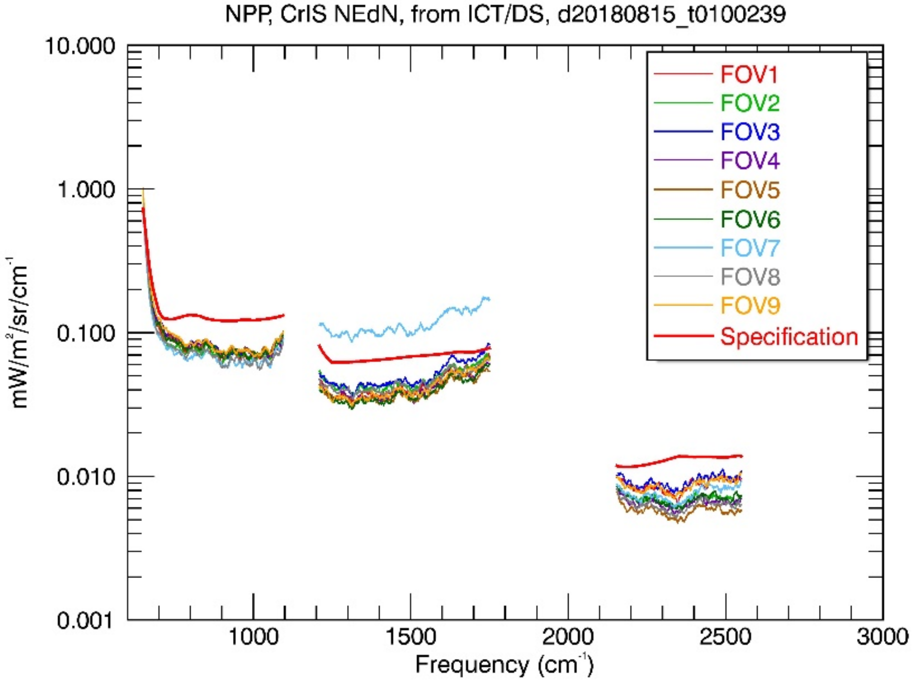
All the BTM violation from 06/24/2019 to 07/01/2019

RDR data	band	FOV	FOR	I failure	Q failure
RCRIS-RNSCA_npp_d20190627_t0426409_e0427129_b39708_c20190627055741888446_noau_ops.h5	3	1	8	1	1
RCRIS-RNSCA_npp_d20190628_t0703519_e0704239_b39724_c20190628073420826868_noau_ops.h5	3	8	12	1	1
RCRIS-RNSCA_npp_d20190628_t0704239_e0704559_b39724_c20190628073430549023_noau_ops.h5	3	5	12	1	1
RCRIS-RNSCA_npp_d20190629_t0826554_e0827274_b39739_c20190629085409405135_noau_ops.h5	3	2	12	1	1
RCRIS-RNSCA_npp_d20190629_t1102385_e1103105_b39740_c20190629121157443683_noau_ops.h5	3	9	17	1	0
RCRIS-RNSCA_npp_d20190629_t2016434_e2017154_b39746_c20190629205036908322_noau_ops.h5	3	5	12	1	1
RCRIS-RNSCA_npp_d20190701_t0606240_e0606560_b39766_c20190701063837472921_noau_ops.h5	3	8	12	1	1
RCRIS-RNSCA_npp_d20190701_t0930388_e0931108_b39768_c20190701095755013491_noau_ops.h5	3	8	25	0	1

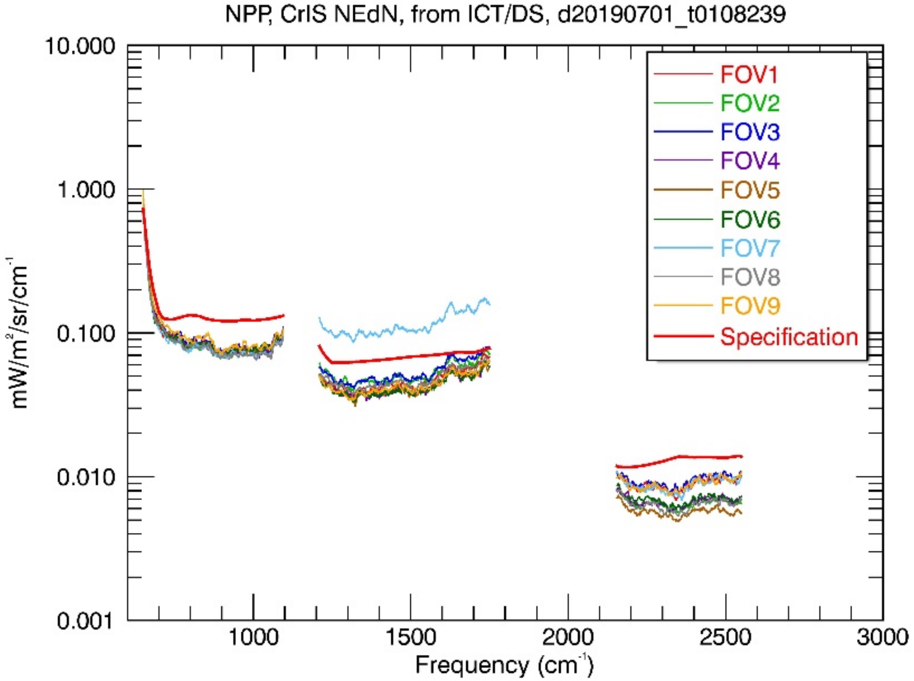
Provided by Yong Chen

SNPP/CrIS NEdN: Comparison of Side-1 vs Side-2 (ICT/DS Method)

08/15/2018
(EPv37, Side-1)



07/01/2019
(EPv40, Side-2)

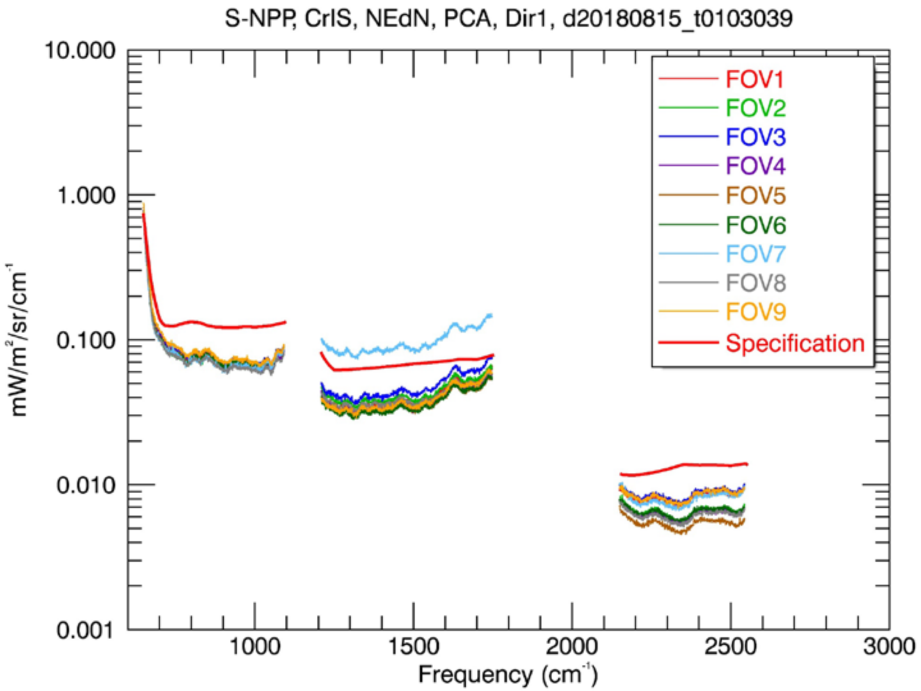


Side-1 and Side-2 NEdN are consistent

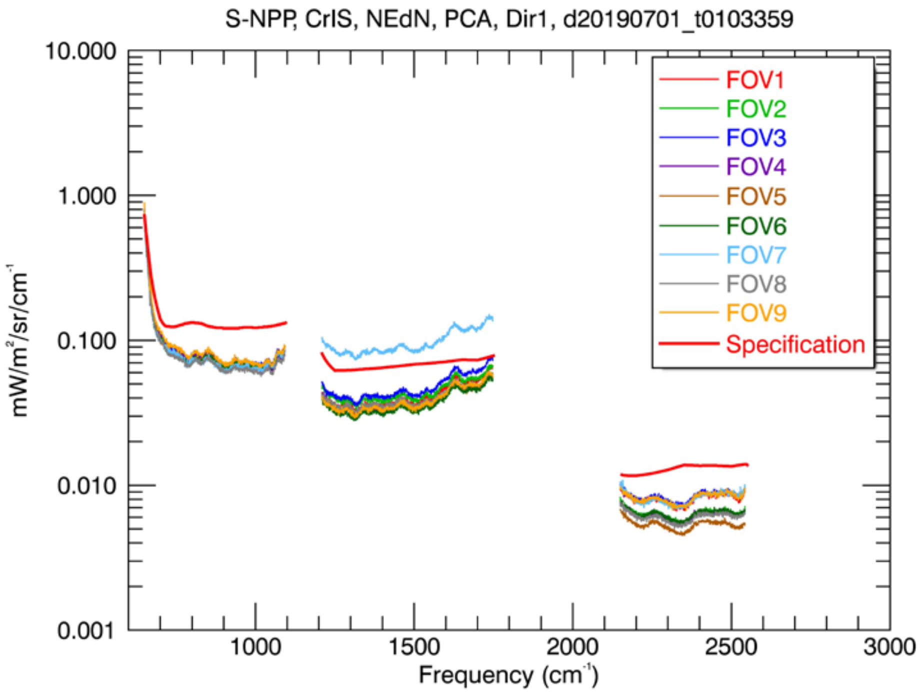
Provided by Denis Tremblay

SNPP/CrIS NEdN: Comparison of Side-1 vs Side-2 (PCA Method)

06/15/2018
(EPv37, Side-1)



07/01/2019
(EPv40, Side-2)

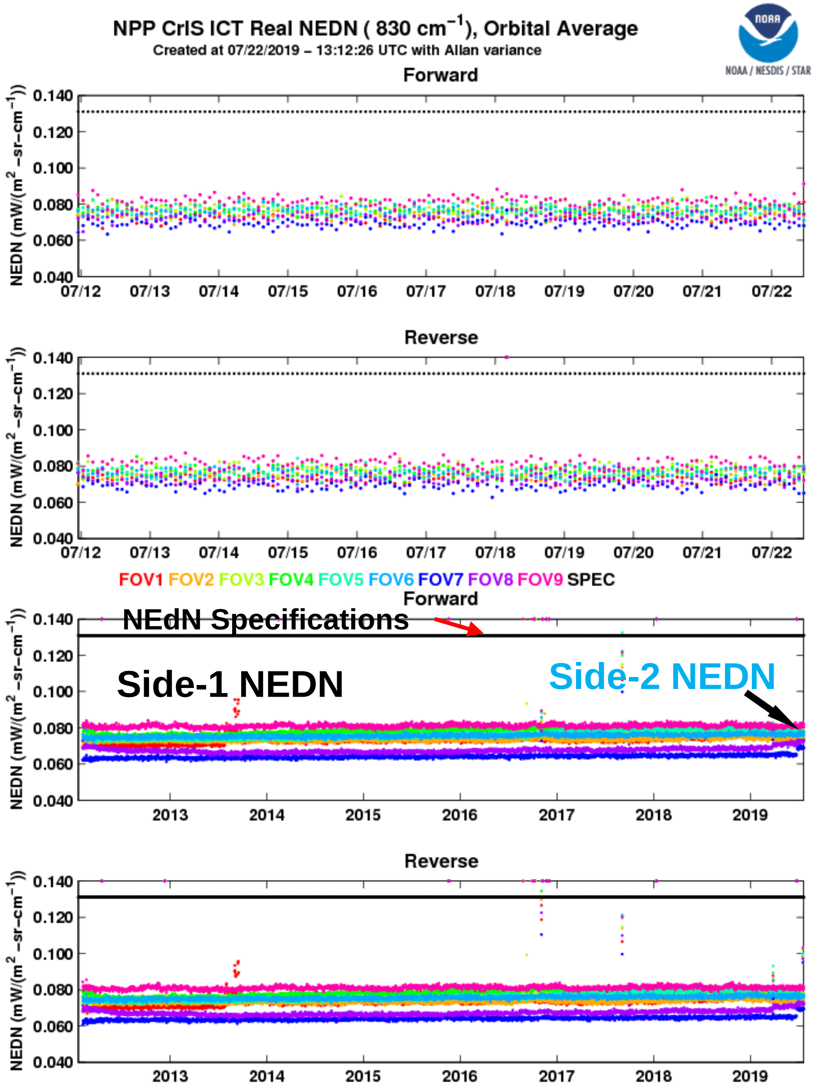


Side-1 and Side-2 NEdN are consistent

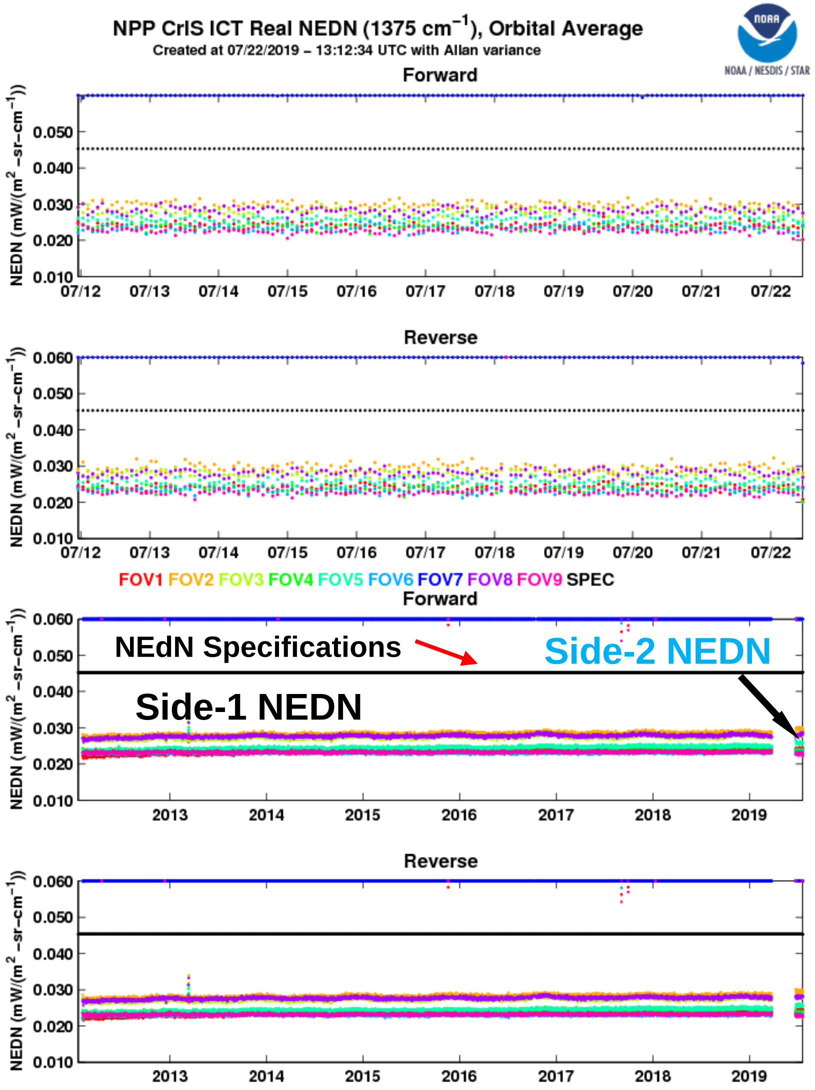
Provided by Denis Tremblay

SNPP/CrIS NEdN Consistency Between Side-1 and Side-2

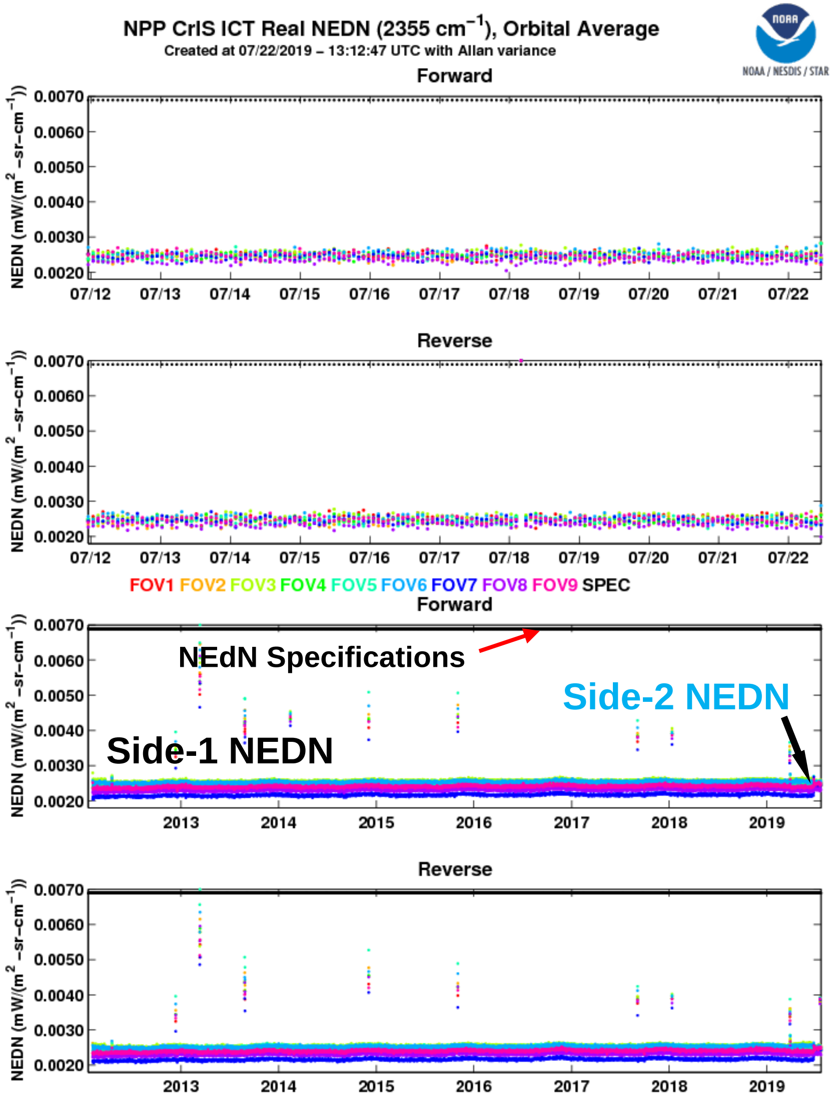
LWIR



MWIR

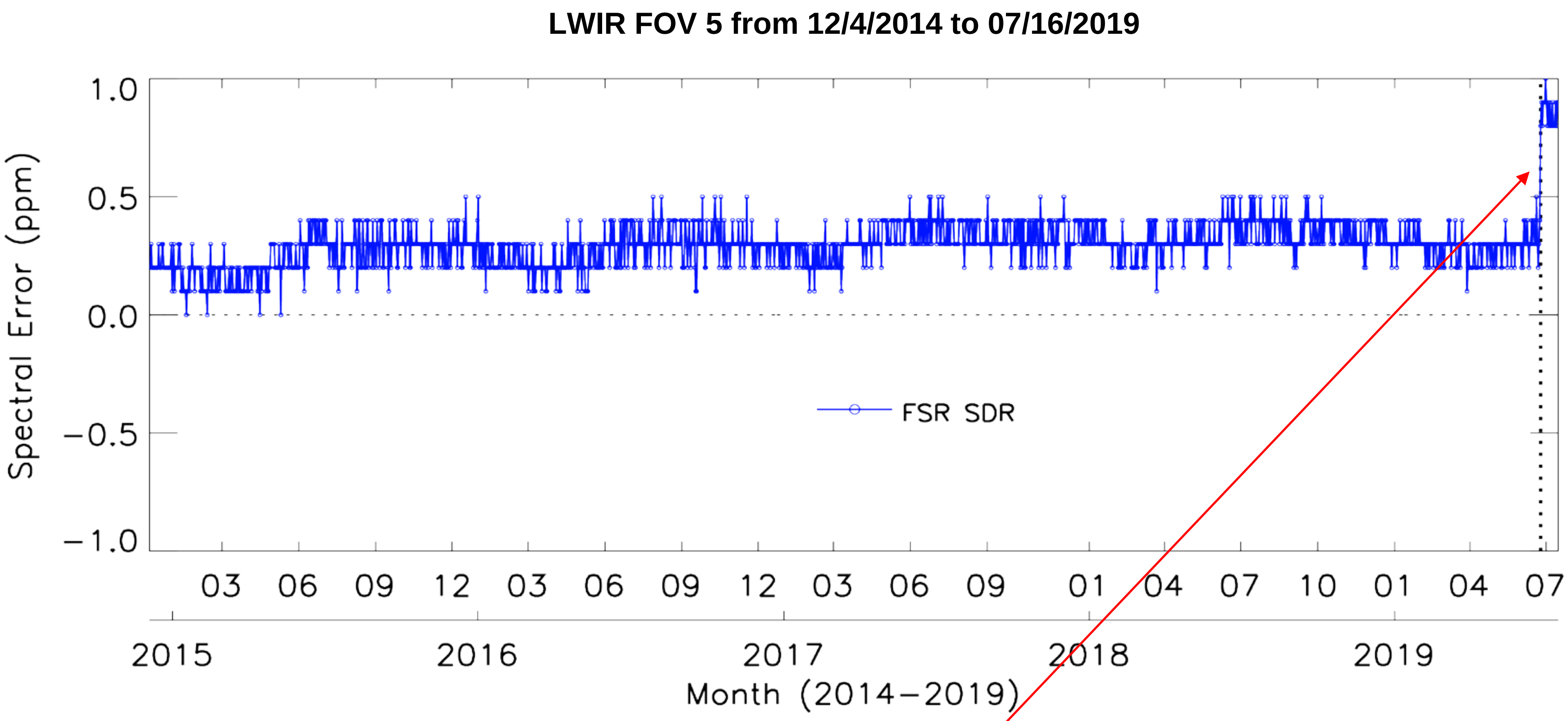


SWIR



From the STAR ICVS website

S-NPP Long-term Trending of Absolute Spectral Accuracy



1. Switch from Side 1 to Side 2 on 06/24/2019. Neon wavelength adjusted **by -4.15 ppm** during instrument tuning.
2. The spectral shift jumps about **0.4 ppm** after instrument tuning.
3. **Spectral shift will be reduced by 0.4 ppm** after Engineering Packet V40 upload, **by increasing the Neon Wavelength by 0.4 ppm.**

Provided by Yong Chen

Summary of Side-2 Changes Impacting the Spectral Calibration

Only Expected changes to SNPP-CrIS Optical/Performance.

- New Neon lamp, with slightly different alignment, implies new Neon value.
  - Harris Neon value changed Neon by 4.15 ppm.
  - Appears accurate to 0.1 ppm ± 0.*x* ppm (*x* is estimated around 0.3 ppm).
  - Shifted in EP v40 to agree with March 2019 effective value (by 0.4 ppm).
- Focal plane shifts
  - Possible due to slight changes in the thermal environment.
  - But, focal plane shifts have not been monitored in the past, so may be drifting, but at VERY low levels.
- No other parameters were expected to change and to date none have been observed.

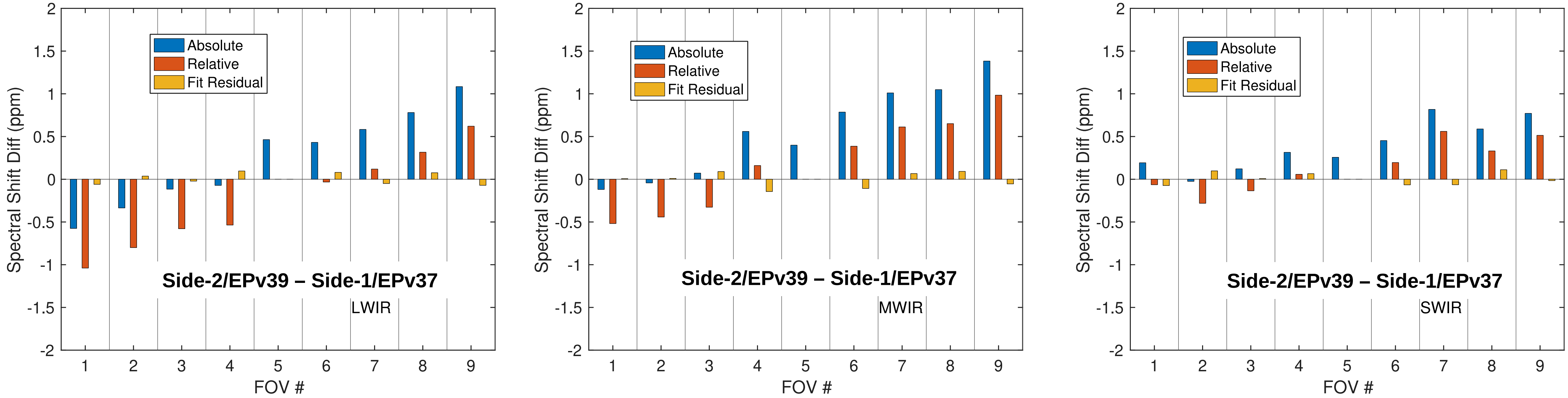
Scientific Spectral Calibration Timeline

- Focal Plane Alignment and Neon Calibration.
  - Assessed in 2-3 days with 1-day's worth of data.
  - Approximately 1 week needed for ADL testing and validation (by NOAA, UW, and UMBC).
- No other Physical Parameters in CrIS Changed.
  - Subsequent validation period not expected to produce any surprises, and it did not.
  - User community (NWP) can easily adjust to small undetected changes using dynamic bias correction.
  - NUCAPS may be sensitive to ~4.2 ppm level adjustments.

Spectral Accuracy: Post-June 2019 (Side-2) vs March 2019 (Side-1)

- March 2019 Side-1 Neon and ILS parameters not perfect (ILS: < 1ppm except for FOV 6 in MW, Neon off by ~0.5 ppm).
- EP 39: Uploaded by Harris with a ~4.15 ppm change to Neon wavelength based on TVAC testing. NO CHANGE to ILS parameters.
- EP v40 adjustments force continuity with March 2019 and earlier.
  - Adjusts Side-2 focal plane ILS parameters to match March 2019 Side-1.
  - Adjusts Neon by ~0.4 ppm.

Spectral Differences of (June 2019 - March 2019) for EP v39



Pattern of frequency calibration errors with FOV ID suggests a rigid x,y displacement of the focal planes. Fairly similar among the three spectral bands

Focal Plane Adjustments and Uncertainties

- The changes in ppm of FOV 1-4, 6-9 (previous slide) are least-squares fit to an x,y translation of the focal plane for each band.
- These new focal plane positions are inserted into EP v40 to ensure spectral continuity (implies radiometric continuity)
- The table below shows these changes, the key parameter is the 2-sigma uncertainty associated with each change.

dx **(μrad)**	***dy*** **(μrad)**	***dr*** **(μrad)**
Longwave Band		
-12.7 ± 4.0	-30.2 ± 4.0	-10.0 ± 2.8
Midwave Band		
-6.8 ± 5.0	-30.7 ± 5.0	7.9 ± 3.6
Shortwave Band		
-0.2 ± 4.3	-16.4 ± 4.3	6.7 ± 3.0

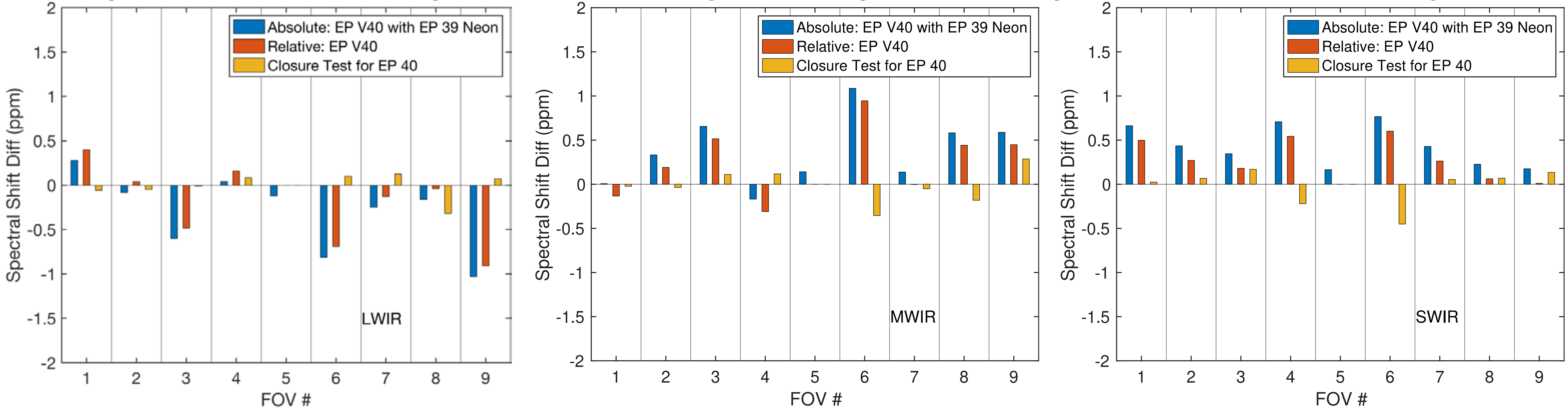
- There is a common, clear *dy* offset in all focal planes.
- Some agreement for a *dx* offset.
- Radial offset (*dr*) small and variable.

- **Root Cause for Shifts**: Possibly slight thermal changes due to higher heat load of side-2 electronics.
- **Recommendation for Long Term**: Continue to monitor focal plane shifts, not previously done.

Spectral Accuracy of EP v40

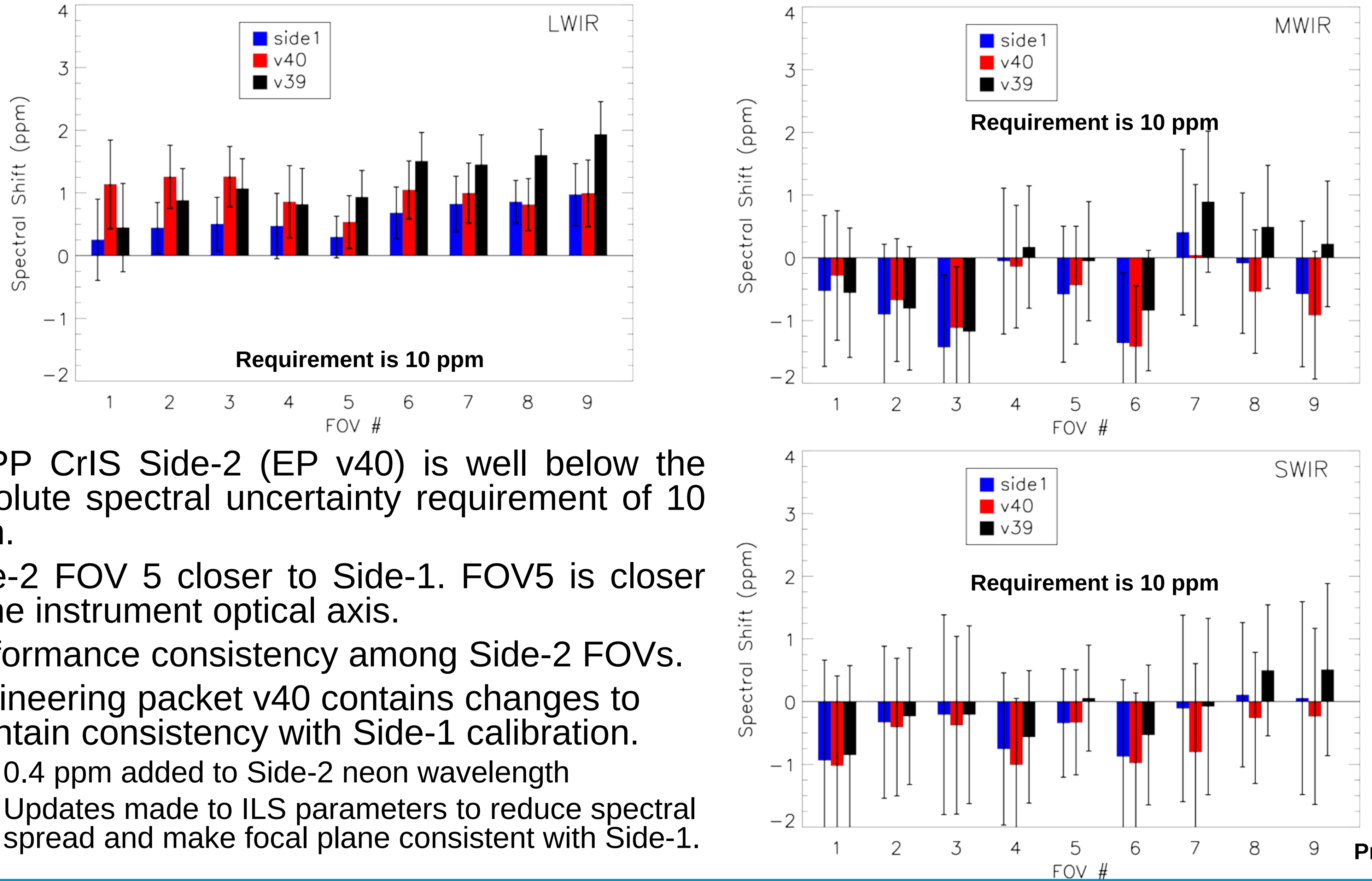
- Continuity implies EP v40 is not perfect, but instead is the same as Side-1 EP v37 (March 2019 and earlier).
- Plots below show spectral errors:
  1. Absolute EP v40 with EP v39: Errors for upcoming EP v40 w/o change in Neon (which is planned).
  2. Same as Absolute except with Neon difference removed (expected EP v40 absolute performance).
  3. Closure Test for EP 40: Expected differences with EP 37 (March 2019 and earlier).

Spectral Differences of: 1) EP 40 w/o Neon Adjustment, 2) EPv40, and 3) Ev40 - EPv40 w/o Neon Adjustment



- **These values generated by UMBC. Independent tests by NOAA. Differences due to use of independent spectral testing algorithms.**
- **Agreement to even 1 ppm is extremely good.**
- **Absolute errors in EP 40 and EP3X translate into max errors of ±0.05K for channels on sides of spectral lines.**

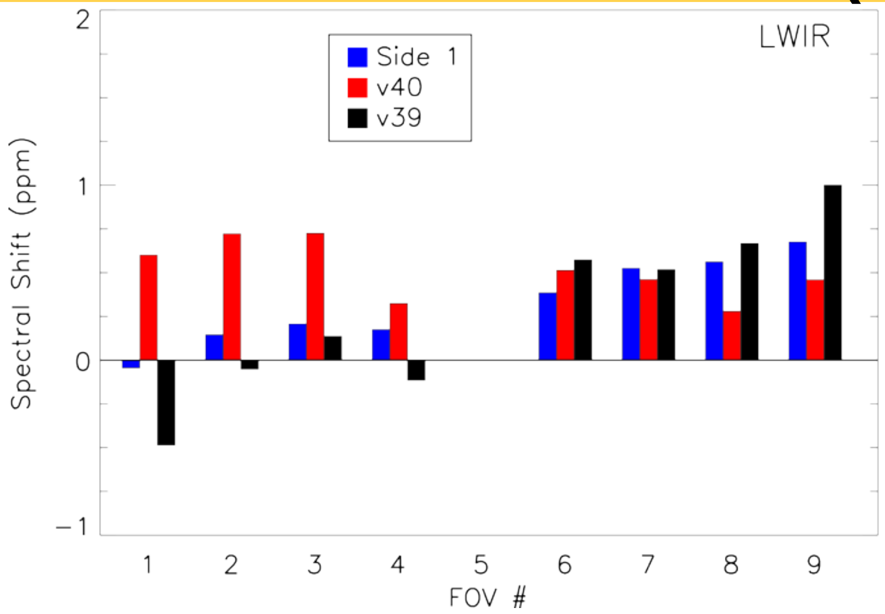
SNPP/CrIS Side-2 (EP v40) Absolute Spectral Accuracy

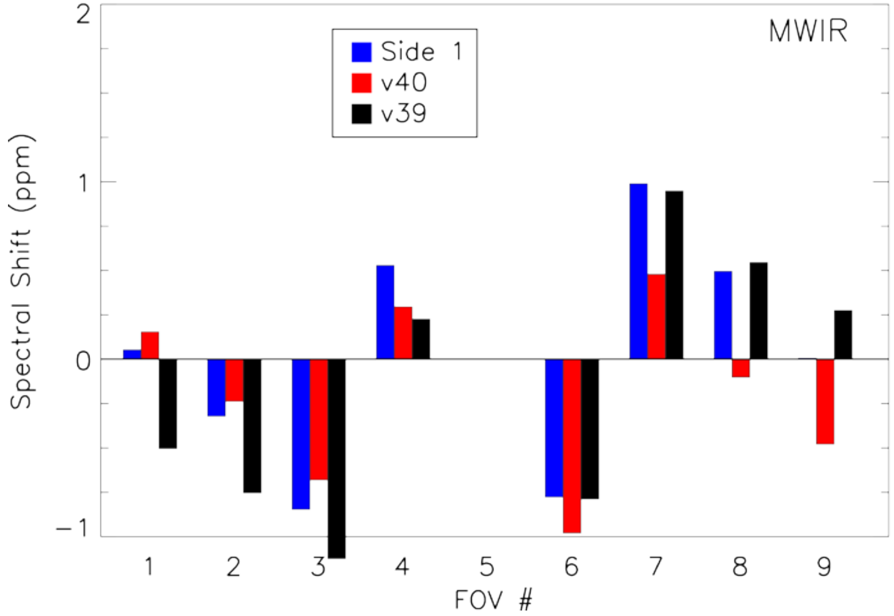


- SNPP CrIS Side-2 (EP v40) is well below the absolute spectral uncertainty requirement of 10 ppm.
- Side-2 FOV 5 closer to Side-1. FOV5 is closer to the instrument optical axis.
- Performance consistency among Side-2 FOVs.
- Engineering packet v40 contains changes to maintain consistency with Side-1 calibration.
  - 0.4 ppm added to Side-2 neon wavelength
  - Updates made to ILS parameters to reduce spectral spread and make focal plane consistent with Side-1.

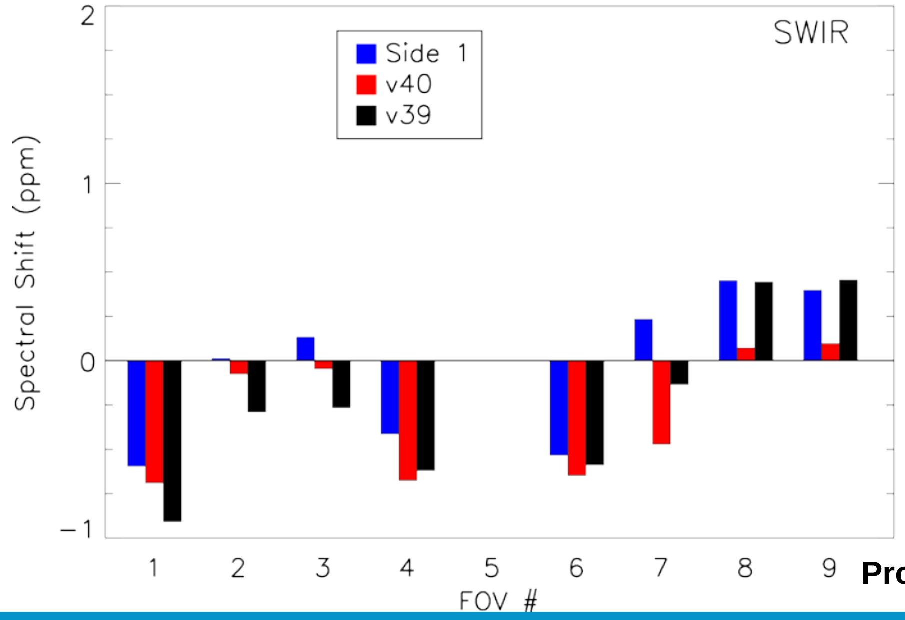
Provided by Yong Chen

SNPP/CrIS Side 2 (EP v40) Relative Spectral Accuracy (compared to FOV5)





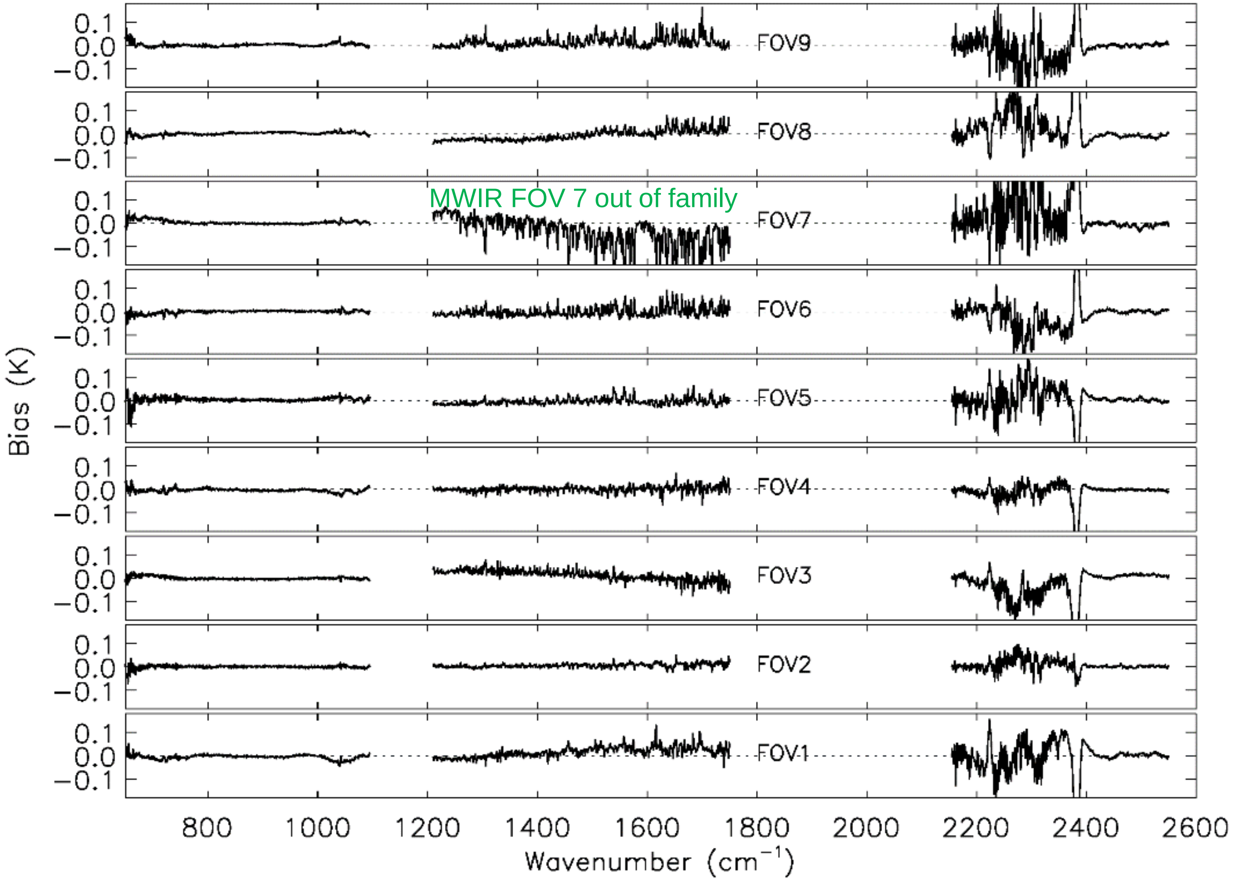
- The LWIR spread is reduced for v40 compared to v39. The MWIR and SWIR spreads are similar for the two engineering packets.
- Performance consistency among Side-2 FOVs.
- Engineering packet v40 contains changes to maintain consistency with Side-1 calibration.
  - 0.4 ppm added to Side-2 neon wavelength
  - Updates made to ILS parameters to reduce spectral spread and make focal plane consistent with Side-1.



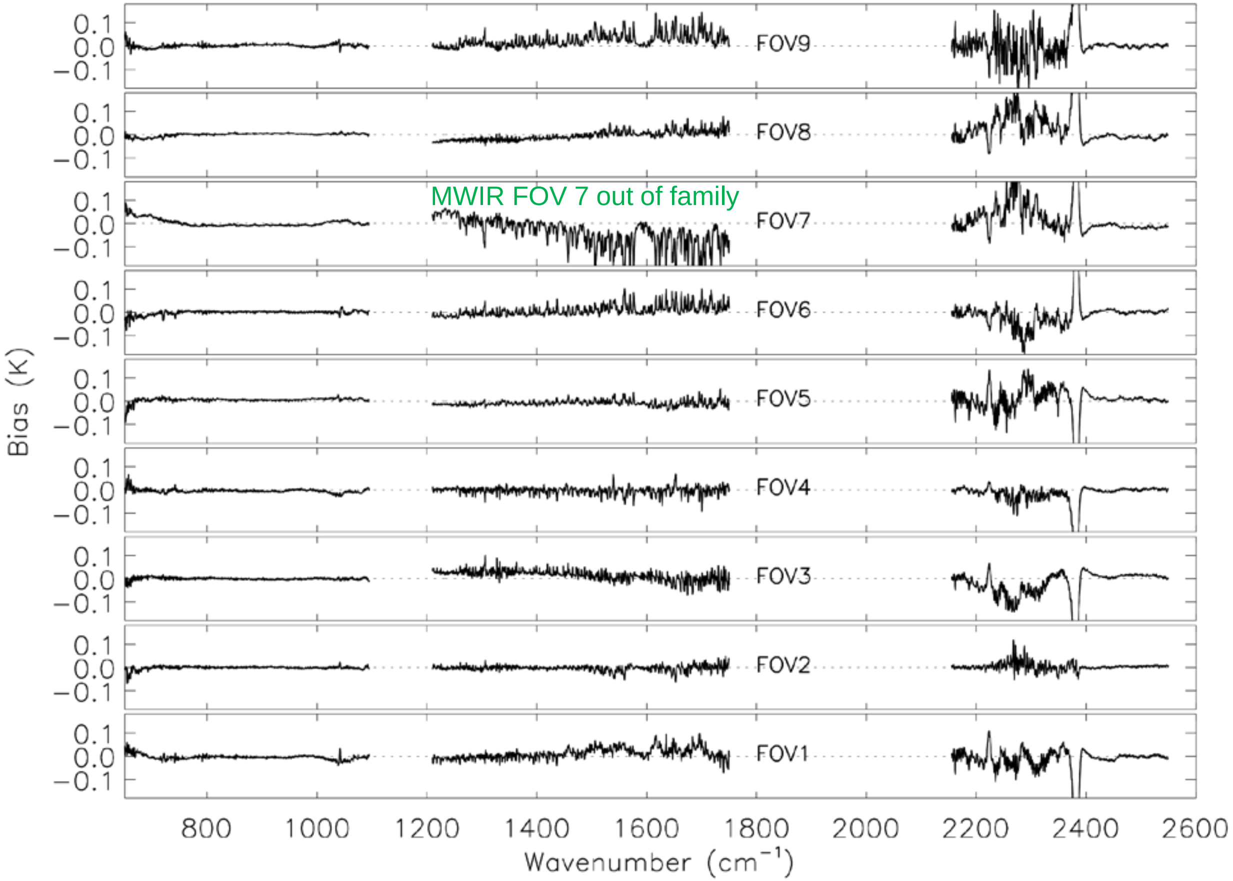
Provided by Yong Chen

FOV-2-FOV Radiometric Consistency: Side-1 vs Side-2

S-NPP/CrIS Side-1
03/15/2019



S-NPP/CrIS Side-2
06/30/2019



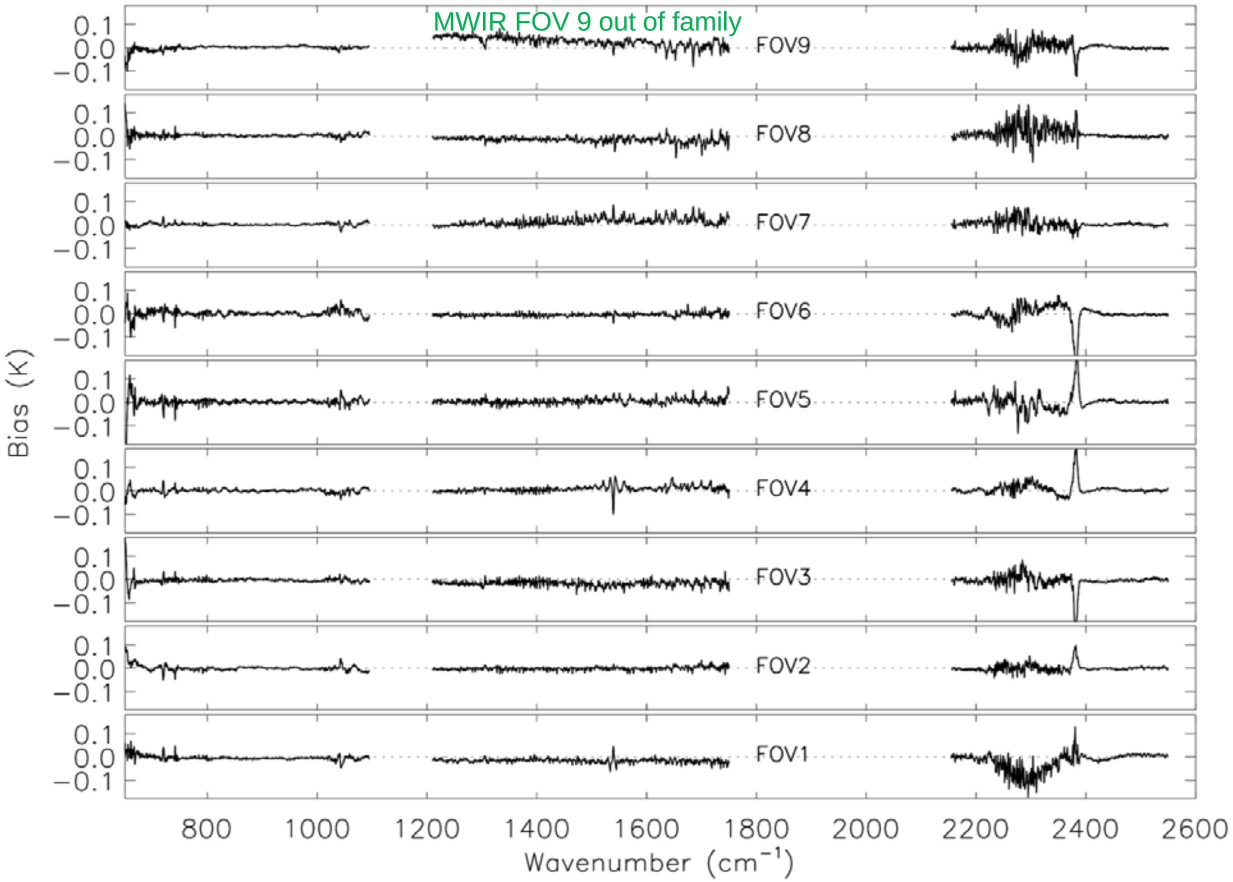
- Based on Observations and Simulated (CRTM) Radiances over Clear Sky and Ocean Surfaces.
- Hamming Apodized Spectra was used and O-B bias removed for each FOV.

Provided by Yong Chen

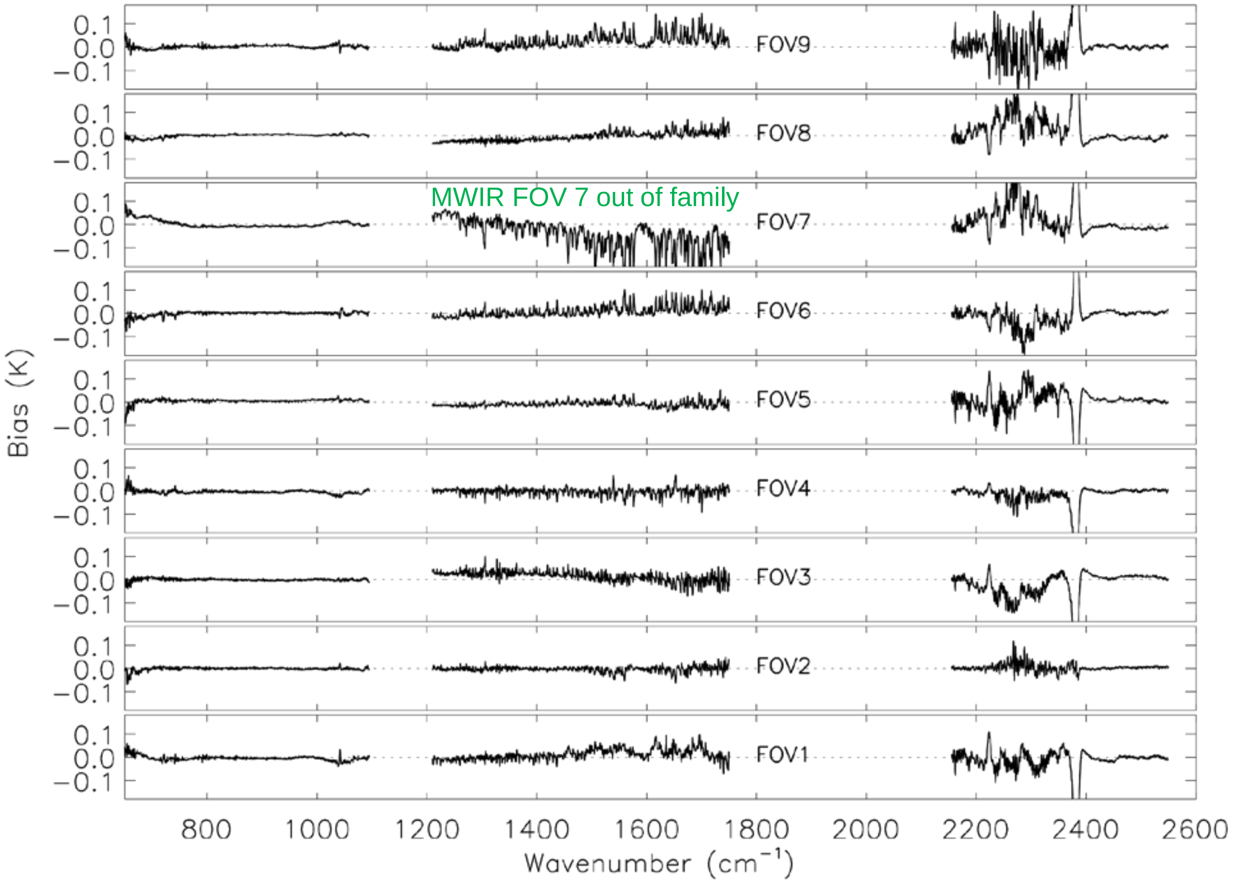
- **FOV's are consistent between Side-1 and Side-2. This indicates no change in the instrument non-linearity.**

FOV-2-FOV Radiometric Consistency: SNPP/Side-2 vs NOAA-20/Side-1

NOAA-20/CrIS Side-1
06/30/2019



S-NPP/CrIS Side-2
06/30/2019

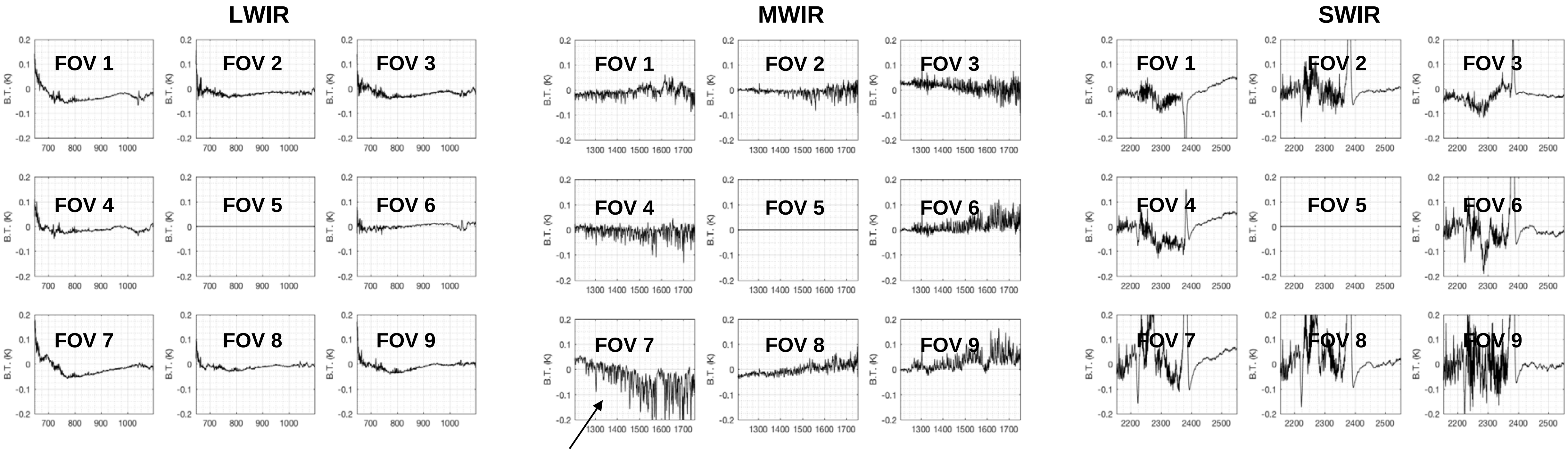


Based on Observations and Simulated (CRTM) Radiances over Clear Sky and Ocean Surfaces.

FOV's are consistent between NOAA-20 and S-NPP Side-2.

Provided by Yong Chen

S-NPP Side-2 EPv40
06/29/2019-07/01/2019



FOV 7 has largest nonlinearity correction in SNPP MW Band

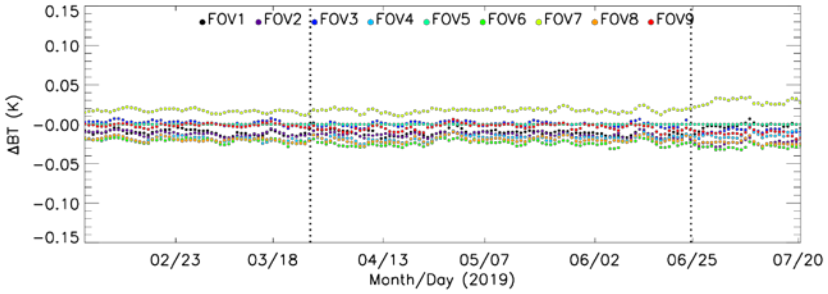
- **FOV-to-FOV consistency over the 3-spectral Bands and within ± 0.2 K.**
- **Verifies that Vinst and a_2 nonlinearity parameters in EP40 are valid.**

Provided by Bob Knuteson

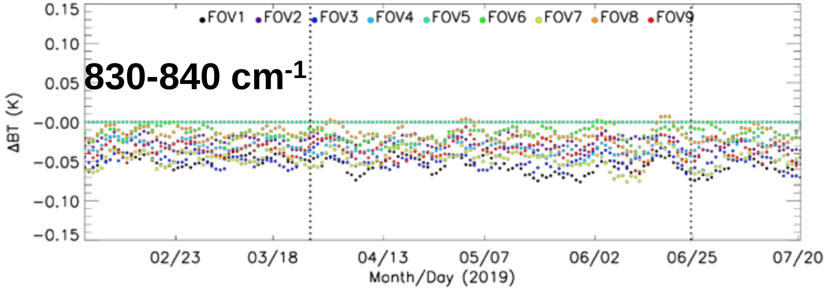
S-NPP Long-term Trending of FOV-2-FOV Radiometric Consistency: Side-1 vs Side-2

LWIR Band

672-682 cm^{-1}



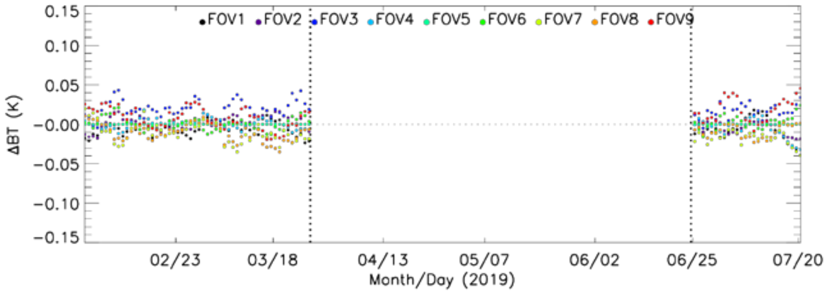
830-840 cm^{-1}



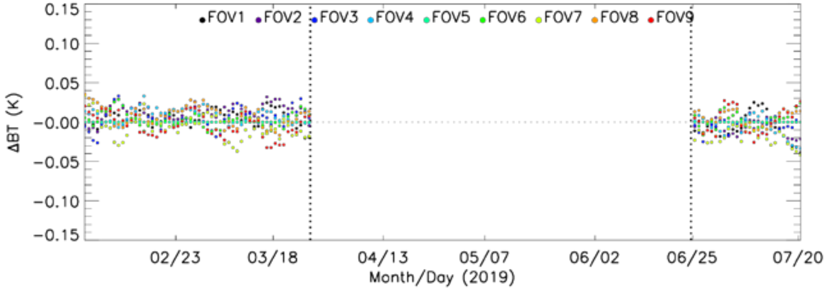
Side-1 | Side-1: MWIR Missing | Side-2

MWIR band

1382-1408 cm^{-1}



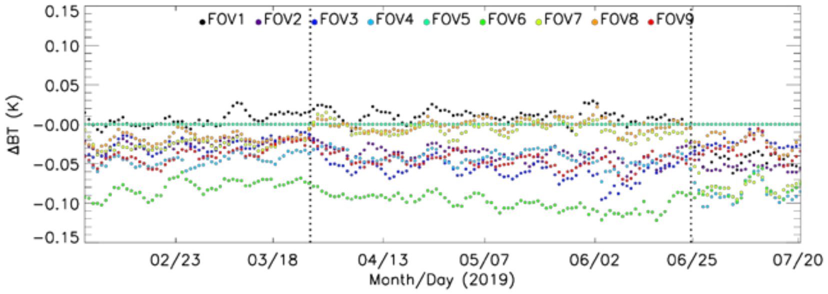
1585-1600 cm^{-1}



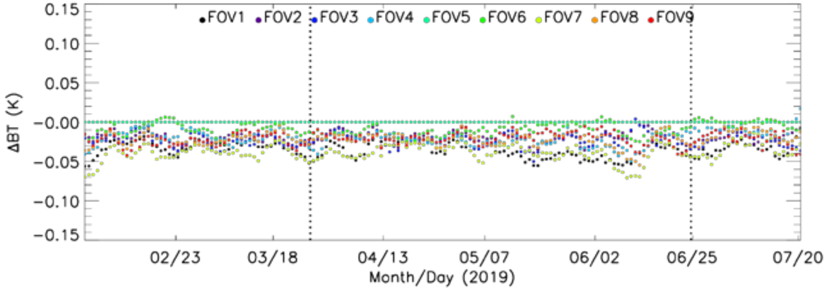
Side-1 | Side-1: MWIR Missing | Side-2

SWIR band

2350-2370 cm^{-1}



2500-2520 cm^{-1}



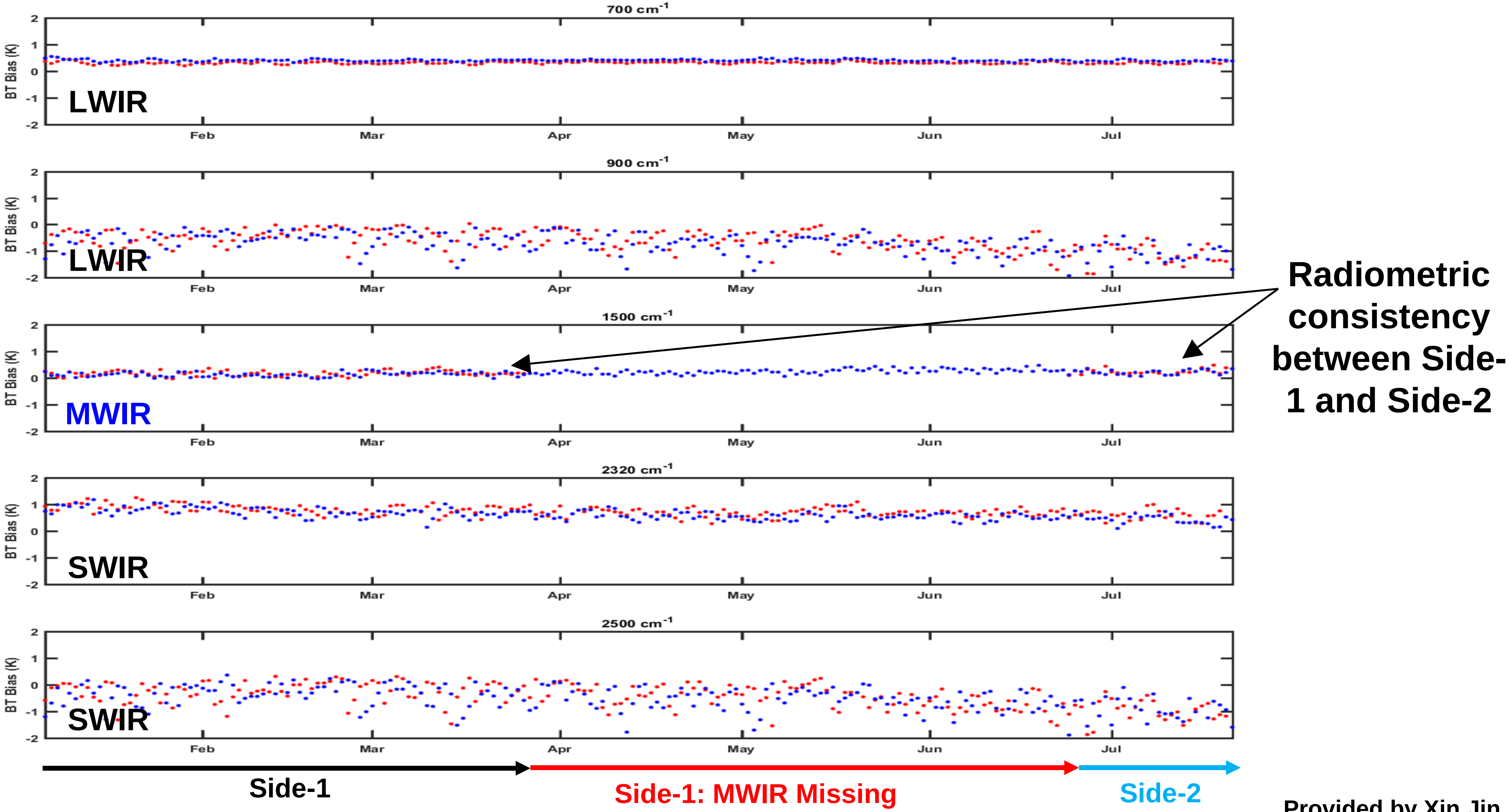
Side-1 | Side-1: MWIR Missing | Side-2

FOV-to-FOV consistency between Side-1 and Side-2 over the 3-spectral Bands. All are within 0.1 K.

Provided by Yong Chen

Long-term (7 months) Trending of Radiometric Accuracy (O-B) for NOAA-20 and SNPP/CrIS: Side-1 vs Side-2

Time series of O-B for SNPP (Red) and NOAA-20 (Blue) from January 2019 to July 22, 2019 for several channels.



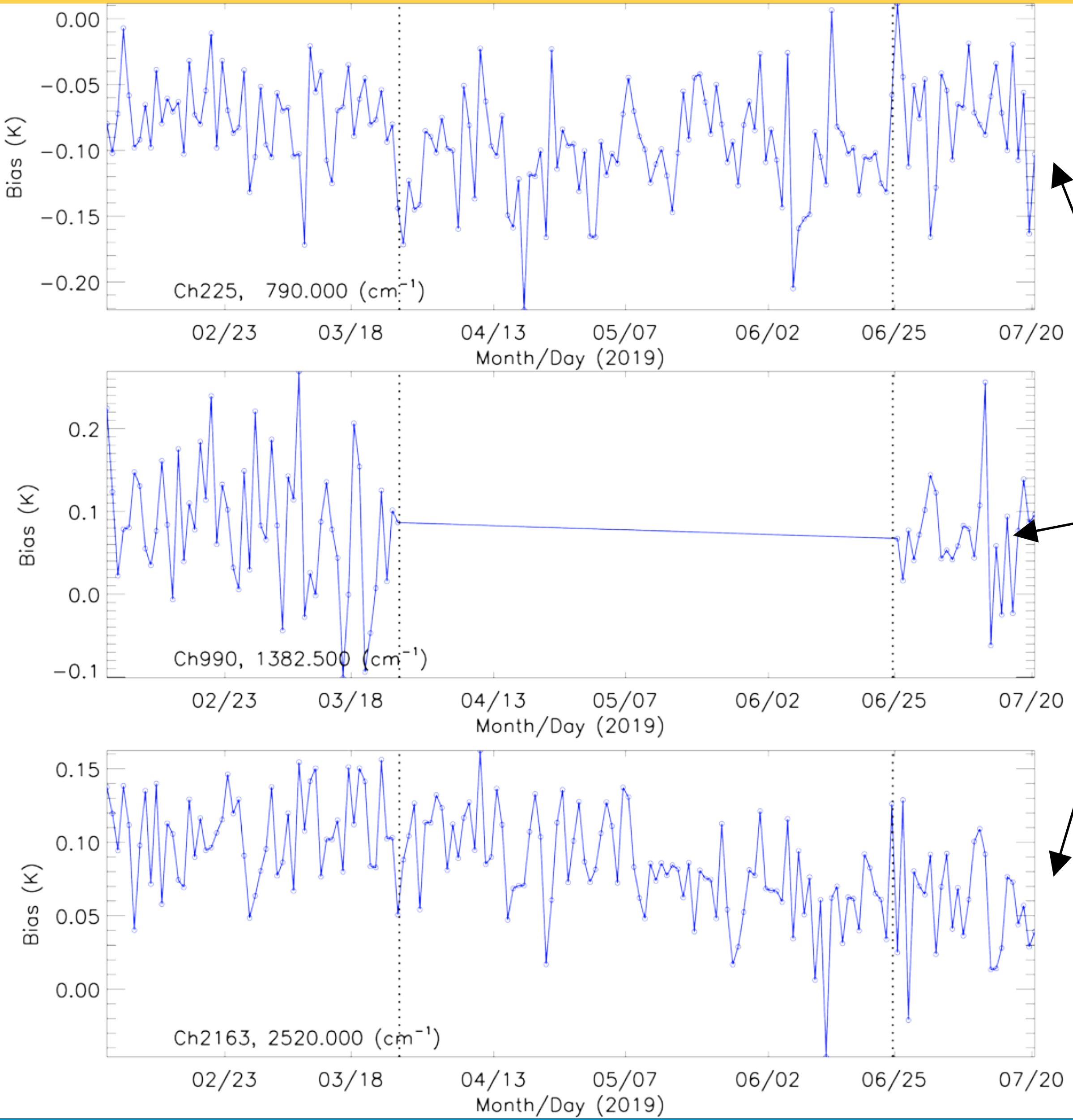
Provided by Xin Jin

S-NPP Long-term (7 months) Trending of Radiometric Accuracy (O-B) for FOV 5: Side-1 vs Side-2

LWIR band

MWIR band

SWIR band

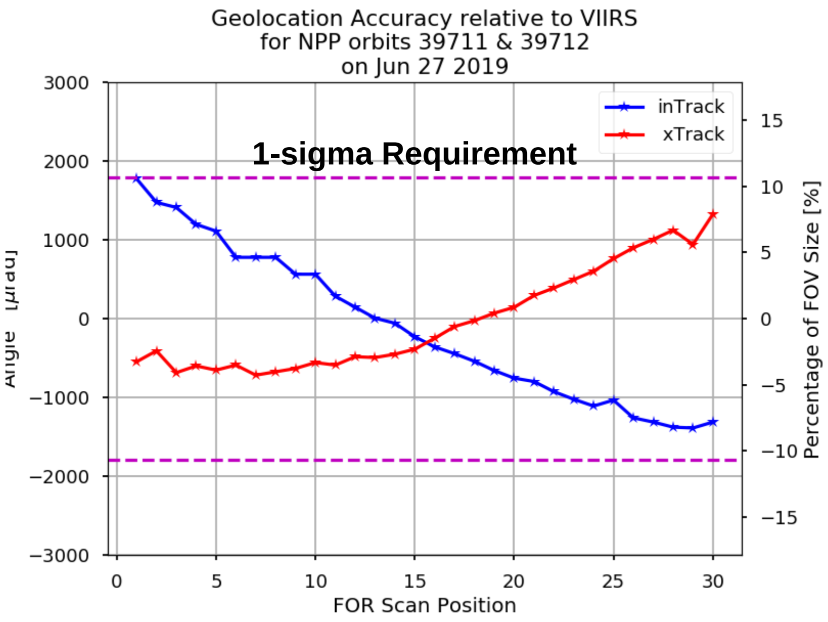


Radiometric consistency between Side-1 and Side-2

Provided by Yong Chen

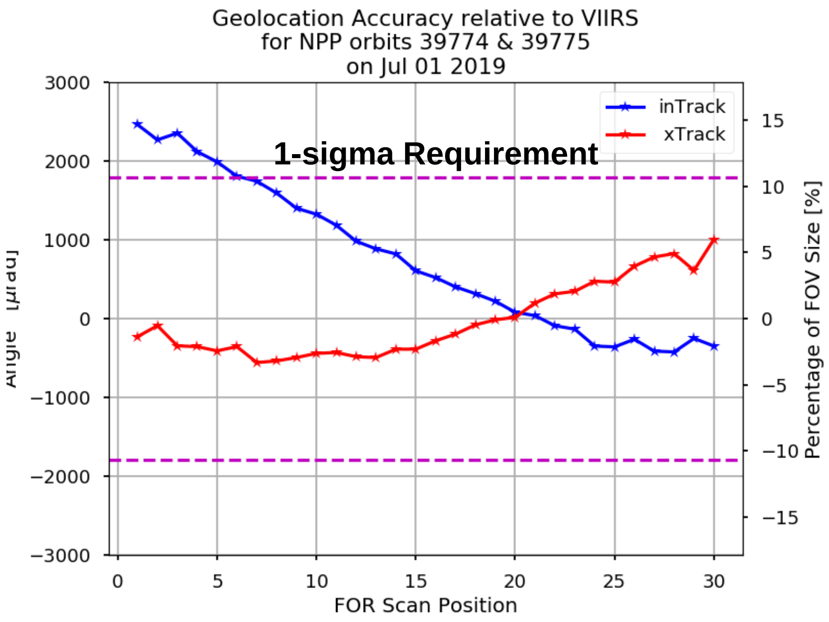
SNPP/CrIS Geolocation Uncertainty for Side-2 Engineering Packets

06/27/2019
(EPv38)



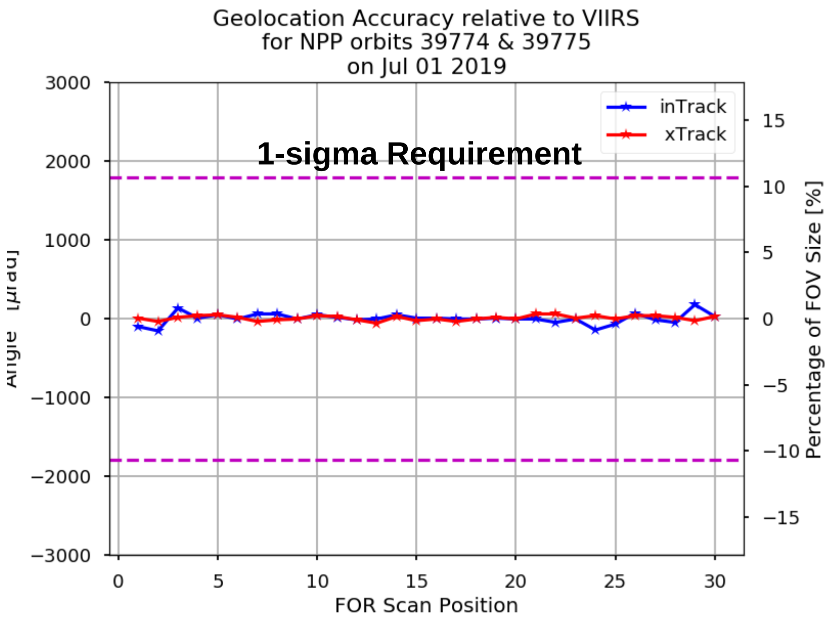
Initial Geolocation Parameters after Side Switch

07/01/2019
(EPv39)



Torque null position Adjustment

07/01/2019
(EPv40)



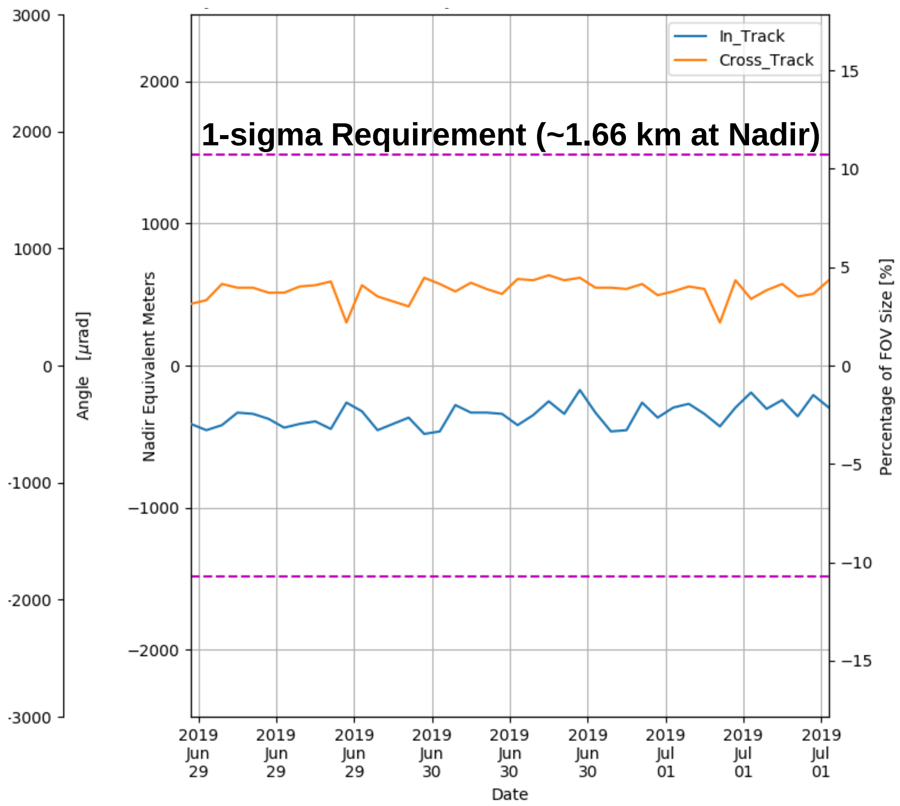
Optimization of in-track and cross-track Geolocation Calibration

Provided by Denis Tremblay/Warren Porter

SNPP/CrIS Side-2 Geolocation Uncertainty: EP v39 vs EP 40

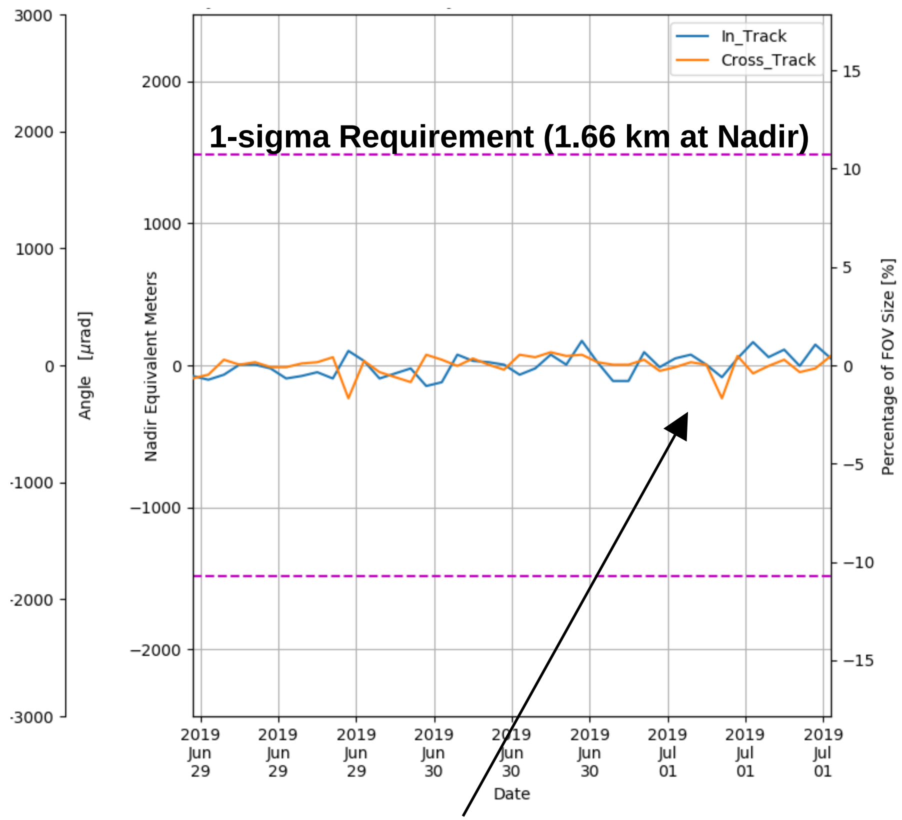
EPv39

3-days Geolocation Uncertainty relative to VIIRS for FOR 29



EPv40

3-days Geolocation Uncertainty relative to VIIRS for FOR 29

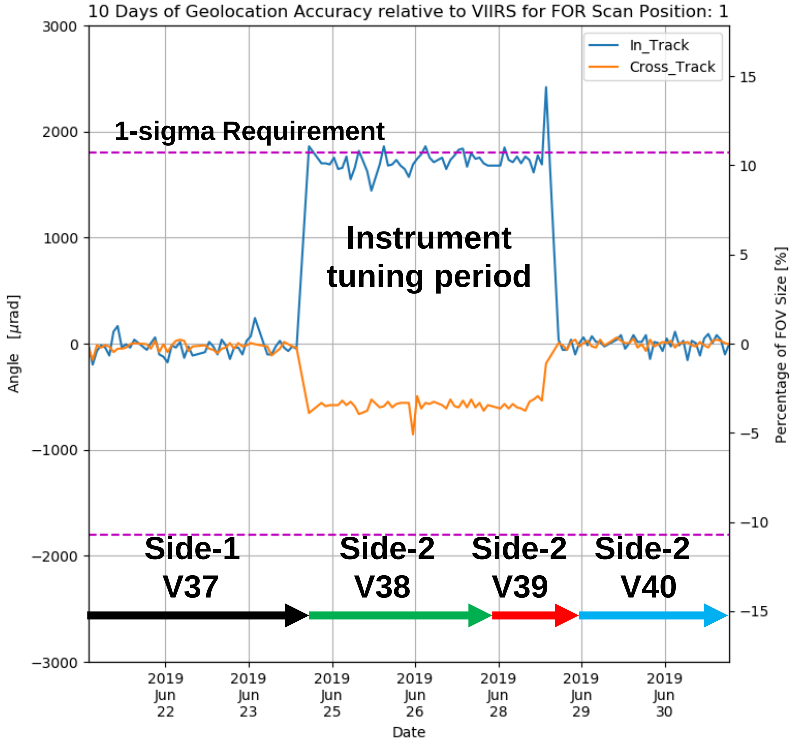


The largest 3-sigma value found over all scan angles for the three day period was about 250 m

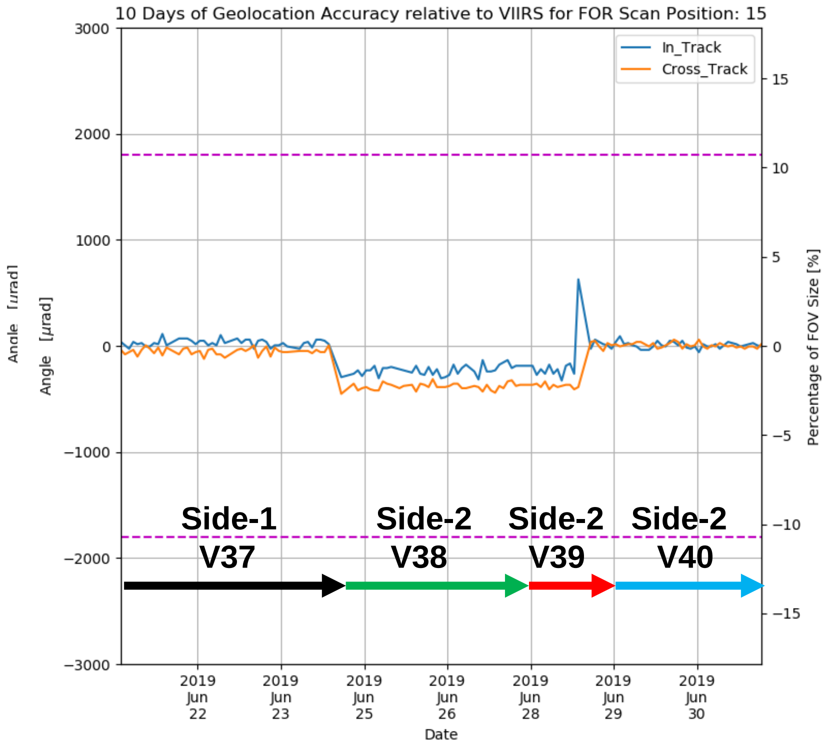
Provided by Warren Porter

Time Series of Geolocation Accuracy Relative to VIIRS for June 21- 30, 2019: Side-1 vs Side-2

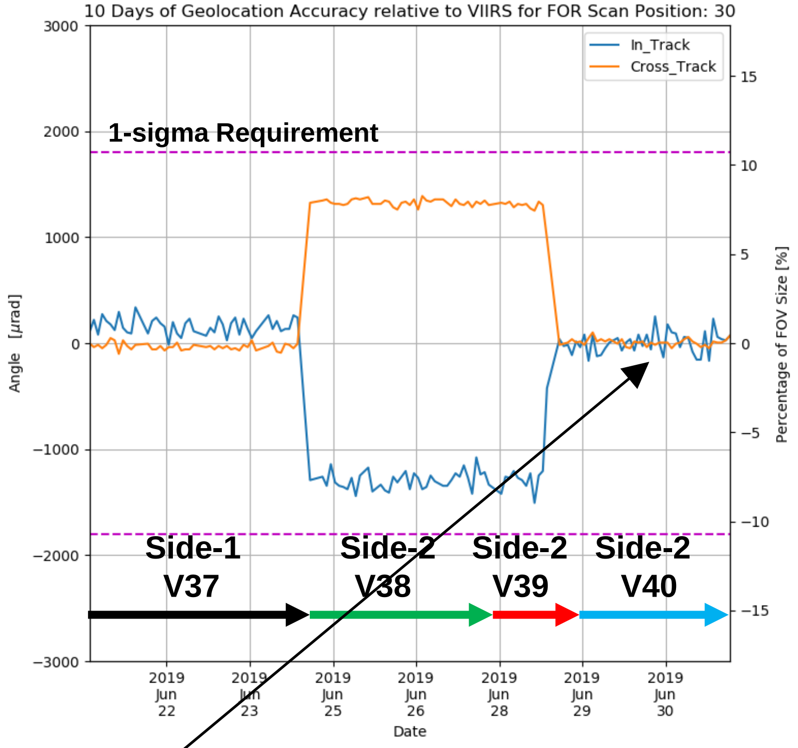
FOR1



FOR15



FOR30

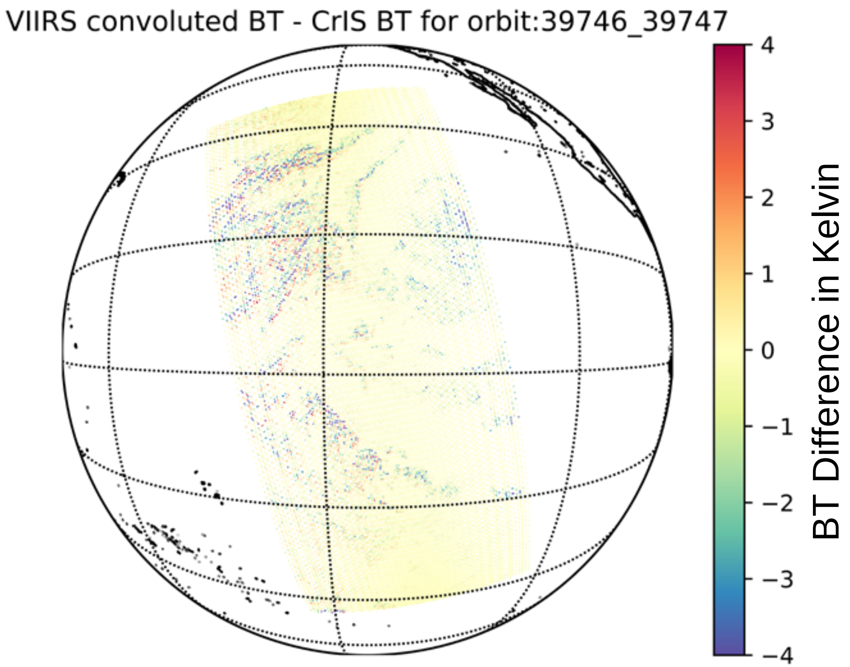


- Initial results show better geolocation performance than before the Switch.

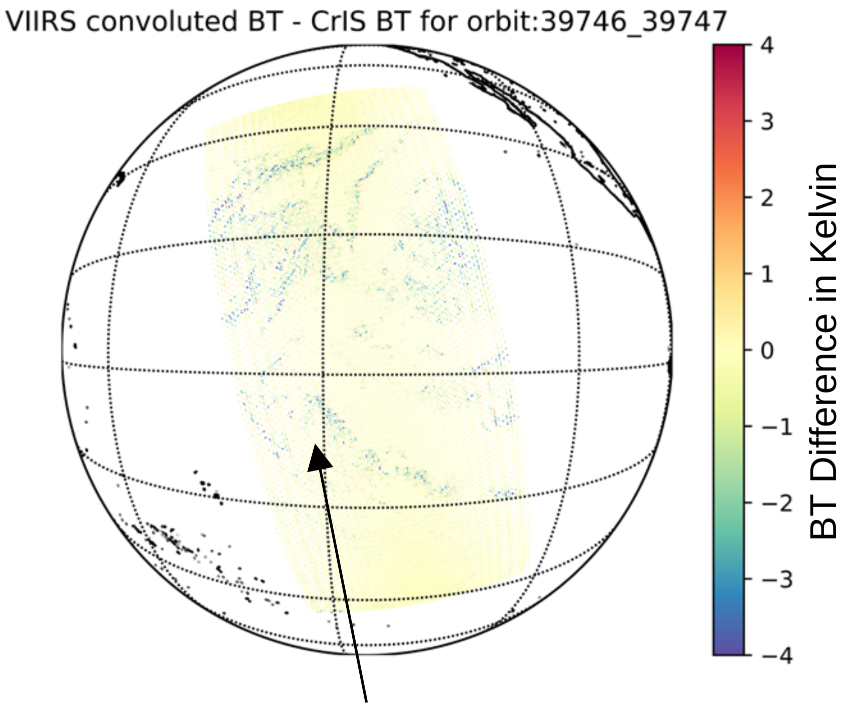
Provided by Warren Porter

SNPP/CrIS Side-2 vs SNPP/VIIRS: Radiometric Comparison

Before Deriving New Mapping Parameters (EP v39)



After Deriving New Mapping Parameters (EP v40)



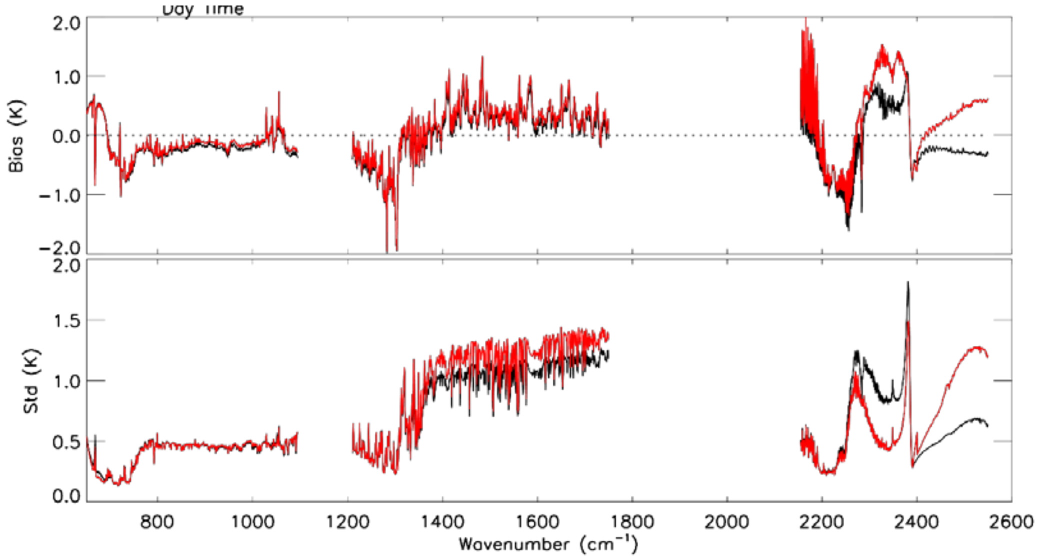
Regions with largest BT differences have been greatly reduced. Major differences occur over cloudy areas

Provided by Warren Porter

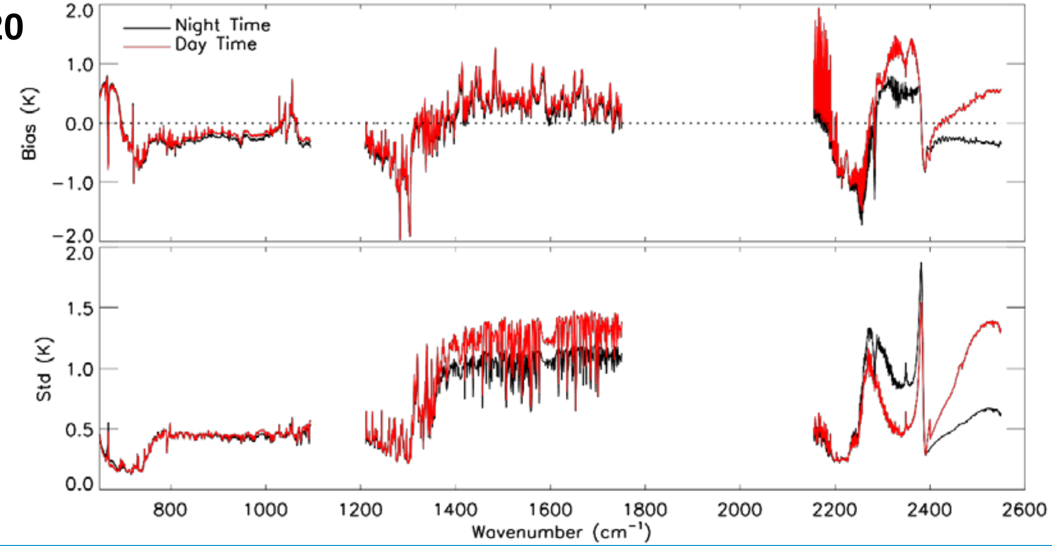
Radiometric Difference Between S-NPP/CrIS Side-2 and NOAA-20/CrIS

Bias/Stdev with respect to Simulated Observations, based on CRTM

S-NPP CrIS Side-2

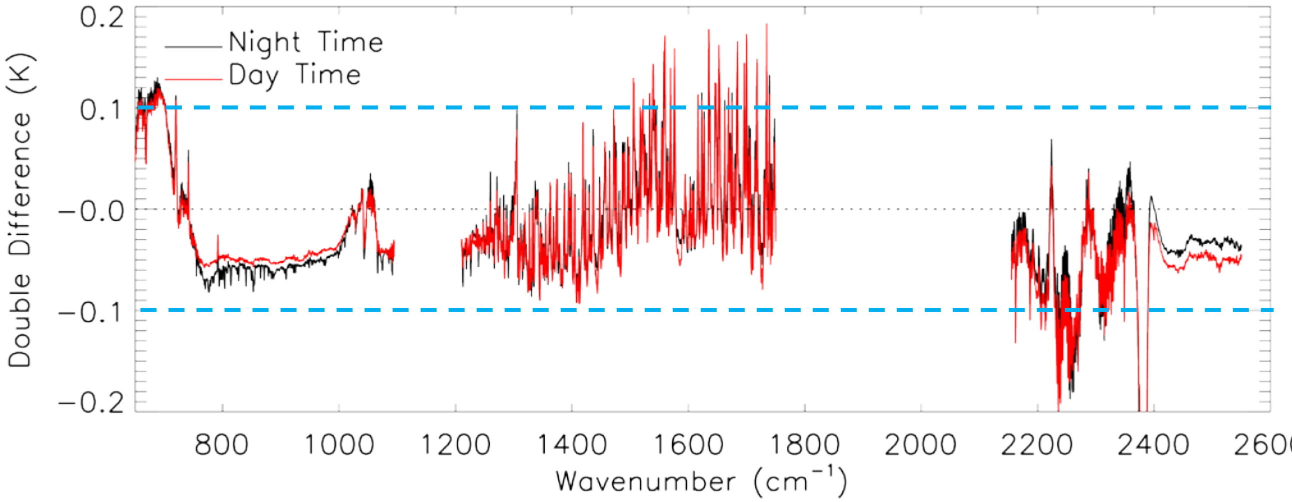


NOAA-20 CrIS



Double Difference:
NOAA-20 CrIS – S-NPP CrIS Side-2 using CRTM simulation as a transfer target

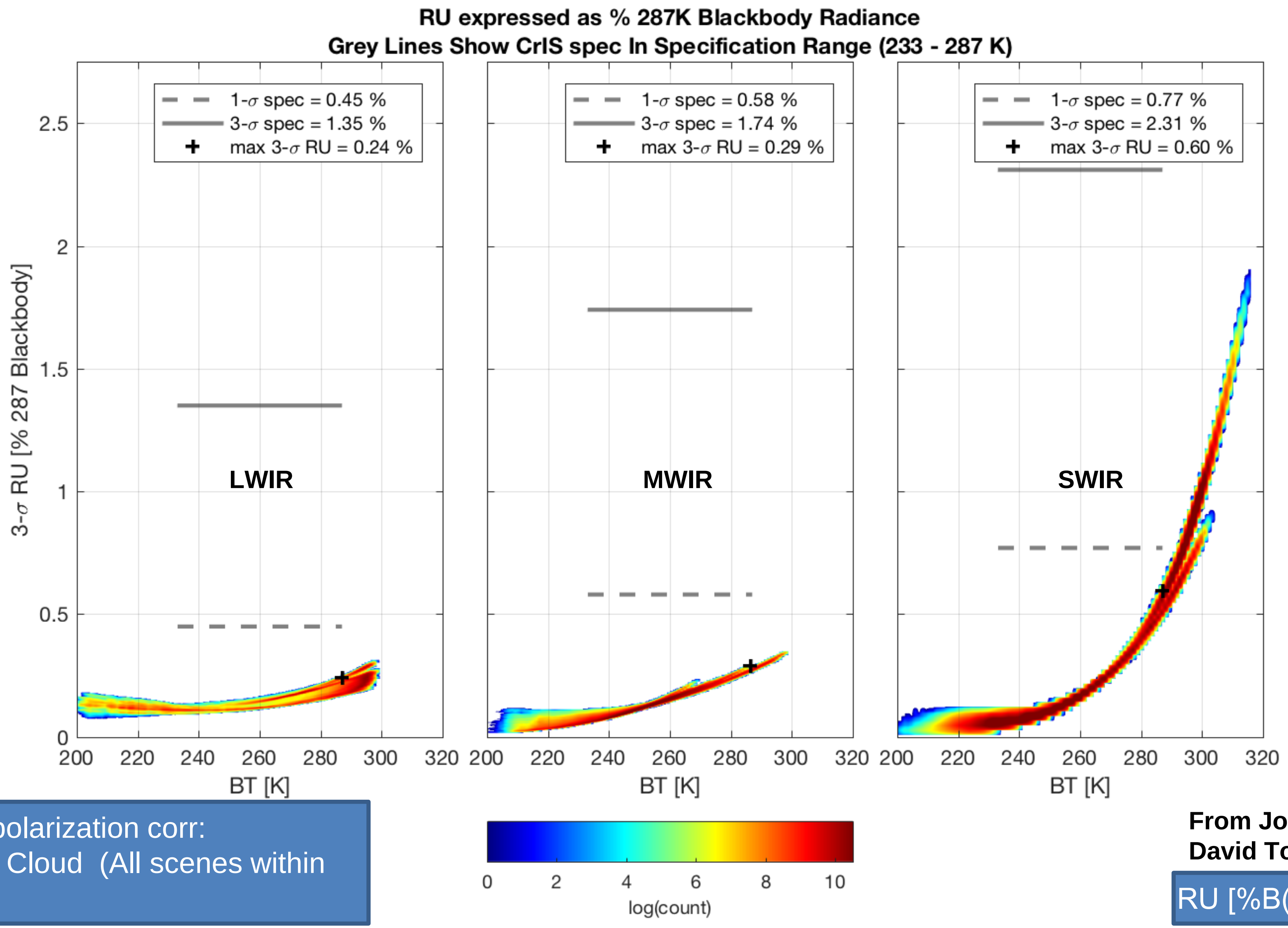
$(BT - BT_{crtm})_{n20} - (BT - BT_{crtm})_{npp}$



- Most channels are within ± 0.2 K with NOAA-20, majority of channels are within ± 0.1 K.
- All FORs and FOVs for clear skies over oceans between ±65° on June 29.
- The effect of the instrument non-linearity is observed in the LWIR, where values above 0.1K are found.

Provided by Yong Chen

S-NPP/CrIS Radiometric Calibration Uncertainty as Percent of the 287K Blackbody Radiance



2018-04-01T2200, no polarization corr:
Tropical with Scattered Cloud (All scenes within one granule)

From Joseph K. Taylor and David Tobin, UW/SSEC.

RU [%B(287K)] vs Scene BT [K]

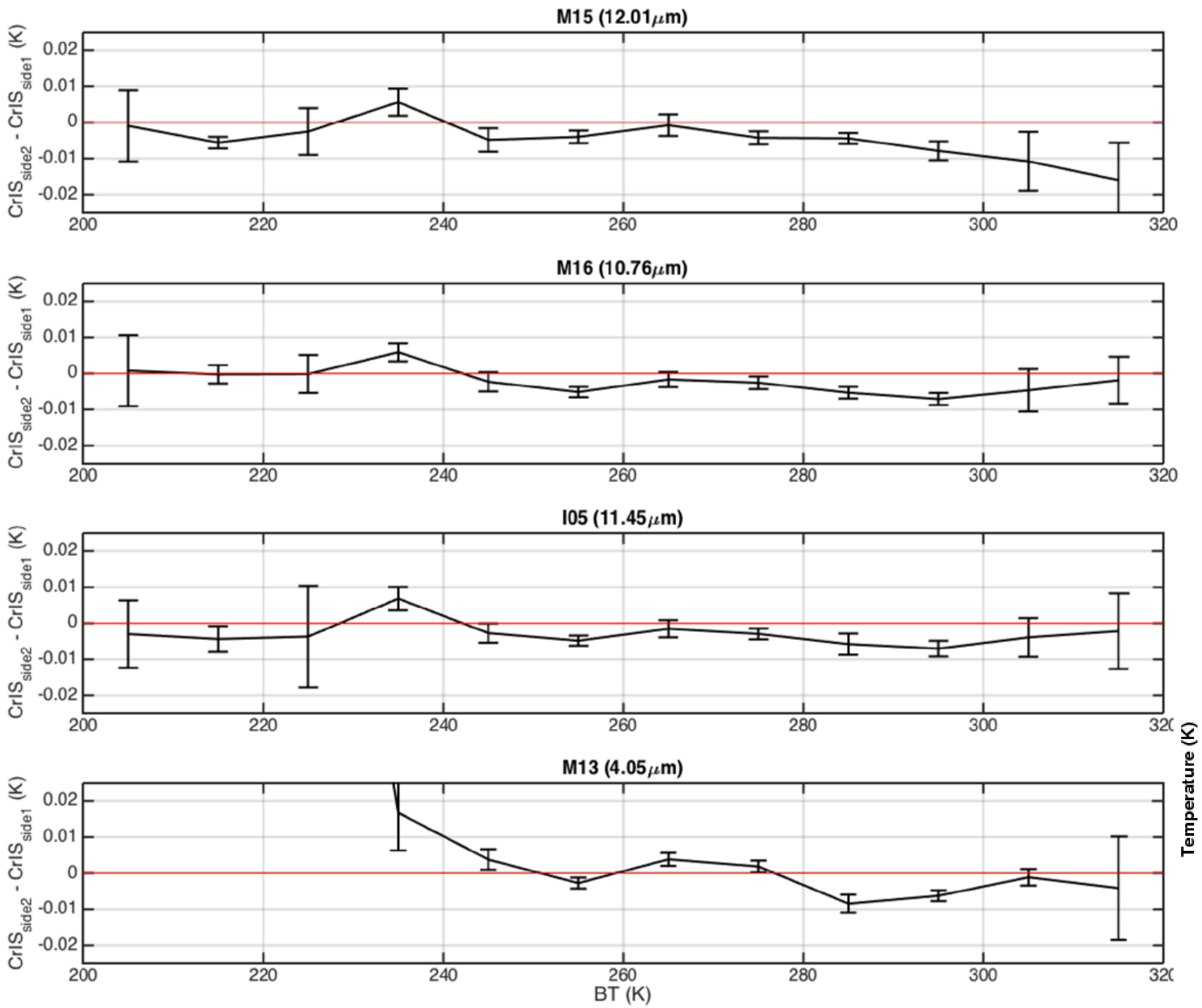
S-NPP/CrIS RU Estimate Summary: Current Operational Processing Expressed as %B(287K) at 1-σ

	LW (1-σ)	MW (1-σ)	SW (1-σ)
Specification	0.45%	0.58%	0.77%
Case 1: Typical Tropical ocean with scattered cloud scene	0.0800%	0.0967%	0.2000%
Case 2: Typical Antarctic cold scene	0.0600%	0.0633%	0.0867%
RU estimate*	**0.16%**	**0.19%**	**0.40%**

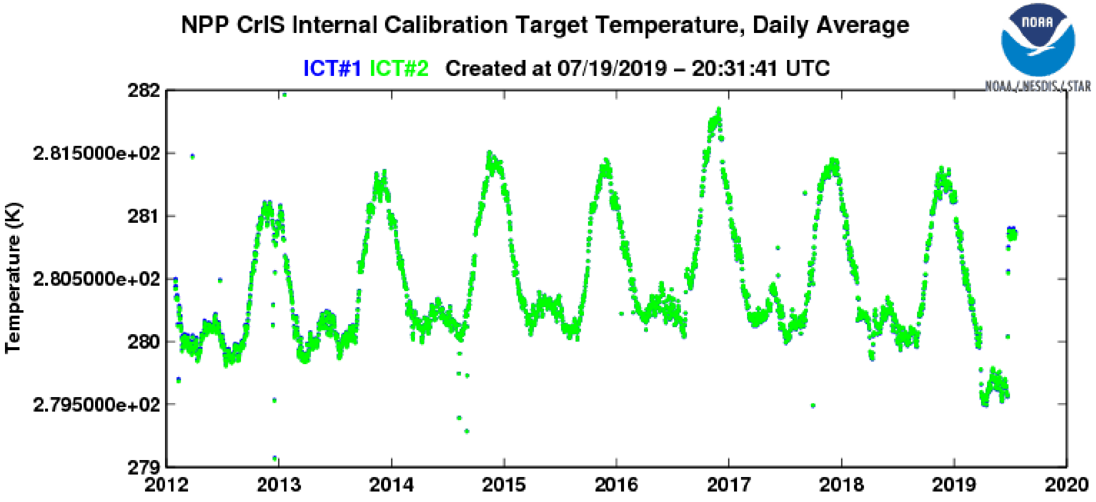
From Joseph K. Taylor and David Tobin, UW/SSEC.

- The current operational processing does not include polarization correction.
- Thus, the calibration bias due to polarization is uncorrected and the associated RU contributor is assumed to be 100% of the uncorrected bias
- Typical tropical ocean with scattered cloud scene case with x2 margin

Comparison of CrIS Side-2 Calibration to Side-1 Calibration



- VIIRS is used as a transfer radiometer to assess the difference in brightness temperatures observed by CrIS Side-1 vs Side-2 as a function of scene temperature.
- VIIRS bands M15 (12.01µm), M16 (10.45µm), I05 (11.45µm), and M13 (4.05µm) covered by CrIS spectra.
- Side-1 data covers the 5 days prior to the 6/24 side switch.
- Side-2 data covers the 5 days after the side switch.
- All scenes are uniform and all FOVs used.
- k=2 error bars shown.
- Differences are very small, with Side-2 calibration 5-7mK colder than Side-1 at the ICT temperature of ~280K.



Provided by Dave Tobin and STAR ICVS

SNPP/CrIS Side-1 and Side-2 Overall Performance

SNPP/CrIS FSR SDR Side-2 uncertainties (blue) vs. specifications (black)

Band	Spectral Range (cm^{-1})	Resolution (cm^{-1})	Number of Channels	NEdN* ($mW/m^2/sr/cm^{-1}$)	Frequency Uncertainty (ppm)	Geolocation Uncertainty** (km)	Radiometric Uncertainty @287K BB¥ (%)	Radiometric Stability @287K BB (%)
LWIR	650-1095	0.625	713	0.099 (0.14)	2 (10)	0.25 (5)	0.16 (0.45)	0.17 (0.40)
MWIR	1210-1750	0.625	865	0.0536 (0.084)	2 (10)	0.25 (5)	0.19 (0.58)	0.21 (0.50)
SWIR	2155-2550	0.625	633	0.00752 (0.014)	2 (10)	0.25 (5)	0.40 (0.77)	0.28 (0.64)

SNPP/CrIS FSR SDR Side-1 uncertainties (blue) vs. specifications (black)

Band	Spectral Range (cm^{-1})	Resolution (cm^{-1})	Number of Channels	NEdN* ($mW/m^2/sr/cm^{-1}$)	Frequency Uncertainty (ppm)	Geolocation Uncertainty** (km)	Radiometric Uncertainty @287K BB¥ (%)	Radiometric Stability @287K BB (%)
LWIR	650-1095	0.625	713	0.101 (0.14)	2 (10)	0.25 (5)	0.16 (0.45)	0.17 (0.40)
MWIR	1210-1750	0.625	865	0.0522 (0.084)	2 (10)	0.25 (5)	0.19 (0.58)	0.21 (0.50)
SWIR	2155-2550	0.625	633	0.00741 (0.014)	2 (10)	0.25 (5)	0.40 (0.77)	0.28 (0.64)

* Mean value averaged over 9 FOVs and over entire band.

** Geolocation uncertainty is based on the largest 3-sigma value found over all scan angles (FORs). Accounts for in-track and cross-track errors. The specification is based on 3-sigma mapping uncertainty of 5 km (474-00448-01-03_JPSS-SRS-Vol-I-Part-3_0200G-2).

¥ S-NPP RU does not accounts for the polarization correction effect. RU values with polarization correction are expected to be lower than those reported in the table.

User Feedback

Name	Organization	Application	User Feedback - User readiness dates for ingest of data and bringing data to operations
Tony Reale tony.reale@noaa.gov	NOAA/STAR	Atmospheric Sounding/Validation	July 29, 2019*
Antonia Gambacorta antonia.gambacorta@noaa.gov	NOAA/STAR	Atmospheric Sounding	July 29, 2019*
Andrew Collard andrew.collard@noaa.gov	NOAA/NCEP	NWP	July 29, 2019* + 30 days
Ben Ruston Ben.Ruston@nrlmry.navy.mil	NRL	NWP	July 29,2019* + 30 days

* July 29, 2019 is the planned date for implementing the provisional Engineering Packet v40.

Data Access Level During the Cal/Val Process

Group 1 Cal/Val Users Full Data Access	Group 2 Beta Users Access to Beta Level Data	Group 3 Provisional Users Access to Provisional Level Data (Everyone not listed in Group 1 or 2, is in Group 3)
NCEP_EMC	NCEP_SPC	NCMRWF (India) International
NCF-SBN	NCEP_SWPC	TWC (Commercial)
NCEP_IDP (NCO)	NCEP_NHC	Accuweather (Commercial)
NCEP_WCOSS (NCO)	NCEP_AWC	Barons (Commercial)
ESPC_SFS	NCF-DD	Blue Sky (Commercial)
ESPC_SAB	EUMETSAT	Roffers (Commercial)
NOAA_STAR	CANADA_MC	KOREA MA
NOAA_NCEI_CO_SPADES	BIG_DATA	BRAZIL_CPTEC
ESPC_HRIT	NAVY_FNMOC	All other users
ESPC_WEB	JAPAN_JMA	
NASA_MSFC_GLM	AF_AFWA (557th, but getting G16 via GRB)	
OSPO_GNC-A	NAVY_NAVO	
~~NOAA_CLASS~~	NOAA_CLASS	
ESPC_NIC		
ESPC_IMS		
NASA_GSFC		
Other ESPC Internals		

Courtesy of Arron Layns

Risks, Actions, and Mitigations

- No major risks have been identified for the SNPP CrIS Side-2 SDRs.

SNPP CrIS Side-2 Provisional Maturity SDR Data Product Caveats

- No major caveats have been identified for the SNPP CrIS Side-2 SDRs.
- No Discrepancy Reports have been entered for SNPP CrIS Side-2.
- Missing data packets in the RDR stream were identified starting on July 10, 2019, due to the annual maintenance on the Ground Station SG4 at Svalbard. This condition was resolved on July 17, 2019. This is not related to the instrument performance.

Requirement Check List – CrIS SDR (FSR)

Band	Longwave		Mid-wave		Shortwave	
Attribute	Requirement	Meet Req?	Requirement	Meet Req?	Requirement	Meet Req?
Wavenumber (cm^{-1})	650-1095	YES	1210-1750	YES	2155-2550	YES
Spectral Range (µm) (J1MSS-1586)	9.13-15.38	YES	5.71-8.26	YES	3.92-4.64	YES
Spectral Resolution (cm^{-1}) (J1MSS-2440)	0.625	YES	0.625	YES	0.625	YES
Polarization	NS	-	NS	-	NS	-
Radiometric Uncertainty @ 287K BB (%) (J1MSS-1584)	0.45	YES	0.58	YES	0.77	YES
Radiometric Stability @ 287K BB (%) (J1MSS-1592)	0.40	YES	0.50	YES	0.64	YES
Maximum NEdN (mW/(m^2-sr-cm^{-1})) (J1MSS-1583)	0.45 @ 670 cm^{-1} 0.15 @ 700 cm^{-1} 0.15 @ 850 cm^{-1} 0.15 @ 1050 cm^{-1}	YES	0.078 @ 1225 cm^{-1} 0.064 @ 1250 cm^{-1} 0.069 @ 1500 cm^{-1} 0.075 @ 1700 cm^{-1}	YES	0.013 @ 2200 cm^{-1} 0.014 @ 2350 cm^{-1} 0.014 @ 2550 cm^{-1}	YES
Nadir FOV (km) (J1MSS-1590)	15	YES	15	YES	15	YES
Spectral Uncertainty (ppm) (J1MSS-1587)	10	YES	10	YES	10	YES

JPSS GSRD Table B-3 + J1MSS (J1 Mission Systems Specification)   NS = Not Specified

Documentations (Check List, 1 slide)

Science Maturity Check List	Yes ?	Where
ReadMe for Data Product Users	Yes	Review Directory
Algorithm Theoretical Basis Document (ATBD)	Yes	https://www.star.nesdis.noaa.gov/jpss/Docs.php
Algorithm Calibration/Validation Plan	Yes	https://www.star.nesdis.noaa.gov/jpss/Docs.php
(External/Internal) Users Manual	Yes	https://www.star.nesdis.noaa.gov/jpss/Docs.php
Operational Algorithm Description Document (OAD)	Yes	https://jointmission.gsfc.nasa.gov/documents.html 474-00071
Peer-Reviewed Publications (Demonstrates algorithm is independently reviewed)	In Progress	
Regular Validation Reports (at least. annually) (Demonstrates long-term performance of the algorithm)	Yes	ICVS and CrIS weekly reports

Check List - Provisional Maturity

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

Rationale for Beta Maturity

1. Product is minimally validated, and may still contain significant identified and unidentified errors.

   Evaluation of the first two weeks of SNPP/CrIS SDR Side-2 data, following the switch to Side-2 electronics, demonstrated the Beta Level quality of the SDR product. The need of new calibration coefficients to improve the spectral and geolocation uncertainty of the SDR data product has been identified.

2. Information/data from validation efforts can be used to make initial qualitative or very limited quantitative assessments regarding product fitness-for-purpose.

   Evaluation results contain qualitative and quantitative assessment of the quality of the SDR data product. Quality monitoring and calibration improvements are in progress. Daily quality monitoring at NCEP and NRL started since side switch.

3. Documentation of product performance and identified product performance anomalies, including recommended remediation strategies, exist.

   Documentation can be found in the material discussed during the CrIS SDR Science Meetings and the daily reports provided to the JPSS managers after the Initiation of the Instrument Recovery Activities on June 24, 2019.

Check List - Provisional Maturity

Provisional Maturity End State	Assessment
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 select locations, periods, and associated ground truth or field campaign efforts.	Yes
Product analysis is sufficient to communicate product performance to users relative to expectations (Performance Baseline).	Yes
Documentation of product performance exists that includes recommended remediation strategies for all anomalies and weaknesses. Any algorithm changes associated with severe anomalies have been documented, implemented, tested, and shared with the user community.	Yes
Product is ready for operational use and for use in comprehensive cal/val activities and product optimization.	Yes

Rationale for Provisional Maturity

1. Product performance has been demonstrated through analysis of 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.

   The performance of the SNPP/CrIS SDR data product has been demonstrated globally over several weeks after successfully switching to Side-2 electronics.

2. Product analyses are sufficient for qualitative, and limited quantitative, determination of product fitness-for-purpose.

   Analysis are sufficient to demonstrate the quality of the SNPP/CrIS SDR data product, meeting or exceeding the JPSS requirements for radiometric, spectral, geolocation, and noise performance.

3. Documentation of product performance, testing involving product fixes, identified product performance anomalies, including recommended remediation strategies, exists.

   No anomalies have been identified in the quality of the SNPP/CrIS SDR data product. In addition to this Review, documentation can be found in the material discussed during the CrIS SDR Science Meetings and the daily reports provided to the JPSS managers after the Initiation of the Instrument Recovery Activities on June 24, 2019).

4. Product is recommended for potential operational use (user decision) and in scientific publications after consulting product status documents.

   The quality of the SNPP/CrIS SDR data product is sufficient to be used in operational environment as confirmed by inputs from NOAA/NCEP, NRL, NUCAPS Team and NPROVS Team.

Lessons Learned from the Science Team (1/2)

1. The operations team **successfully switched SNPP-CrIS from primary to redundant side electronics** without major issues. Full performance was restored following the side switch, with redundant side performance being comparable to that on the primary side. Even though critical calibration electronics, including the internal calibration target temperature sensors, reside in the redundant circuitry, **both sides had been thoroughly checked out during ground testing and calibration constants for both sides were available at launch**.
2. Engineering packet parameters for the redundant side were adjusted after the switch to **optimize SDR continuity over absolute accuracy**. Note that the difference between optimizing continuity versus accuracy is very small.
3. Improvements are needed to the process for transferring updates to the initial geolocation parameters from the primary to the redundant side. The first guess for the on-orbit **redundant side geolocation parameters was not optimal**, and the subsequent update for the in-track torque null position made geolocation worse instead of better.

Lessons Learned from the Science Team (2/2)

4. The time from the loss of the SNPP CrIS MWIR band to the start of the side switch was about 3 months. The Science Team recommends a careful assessment of the timeline to see if it is possible to **reduce the time required to initiate a side switch**. It seems possible that some time could be saved by 1) maintaining up to date configuration files for both primary and redundant sides; 2) maintaining up to date instrument activation procedures for the redundant side; note that these may differ slightly from the procedures for simply restoring power to the primary side due to memory persistence; 3) optimizing the redundant side cal/val plan; 4) documenting the reliability analysis over the life of the mission so that it does not have to be repeated after an on-orbit failure prior to a decision to switch to the redundant side.

Summary of SNPP/CrIS Performance and SDR Product Quality

1. **Recovered the Full Capabilities** of the First CrIS instrument on-orbit, after the successful switch to Side-2 electronics.
2. The quality of the SNPP/CrIS SDR **product is meeting the JPSS requirements**, and no major anomalies or caveats have been identified. The products holds Provisional Level quality: noise, spectral, geolocation and radiometric uncertainty for all three bands are all within the requirements.
3. Provisional quality level was demonstrated **5 weeks ahead the original plan**.
4. Radiometric differences between **SNPP and NOAA-20 are within ±0.1 K** for the majority channels. The estimated differences were derived from the double-difference from radiative transfer calculations.
5. The quality of the **SNPP/CrIS SDR** data products has been monitored after side Switch **at NOAA/NCEP and NRL**. The rate of Good data quality after instrument side switch is greater than 99.7%, which is similar to Side-1 data quality rate.
6. The **assessment** of the SNPP/CrIS SDR Side-2 data in the **geophysical space** has carried out using comparisons between NUCAPS/SNPP Environmental Data Record (EDR) products and **Radiosonde Observations**.

Path Forward for the SNPP/CrIS Instrument

1. Continue monitoring the instrument long-term stability and performance, as well as the SDR data quality.
2. Continue to inter-compare the instrument against other sensors (including the NOAA-20/CrIS, IASI, VIIRS, and ABI), in order to further assess the radiometric calibration (uncertainty/stability). At the Validated review this assessment will be reported to confirm the results reported in this review.
3. Continue assessing the instrument noise, spectral and geolocation calibration, as well as the instrument yield rate.
4. Based on the instrument performance and quality of the SDR products over a long-term validation period, the transition to the Validated maturity level is planned. The initial recommendation is 3 months after reaching the Provisional maturity level.

Acknowledgements

Acknowledgement to all individuals and organizations participating in the Recovery Activities of the SNPP/CrIS Instrument for their Team Effort, Hard Work, Dedication and Professionalism: **NOAA, NASA, HARRIS, University of Wisconsin, University of Maryland Baltimore County, MIT, Logistikos**.