Validated Maturity Science Review for NOAA-20 CrIS SDR

Presented by Flavio Iturbide-Sanchez

Date: 2018/10/02

THE NOAA-20 CrIS SDR VALIDATED MATURITY REVIEW

CrIS SDR Team

October 2, 2018

Outline

- CrIS SDR Algorithm Cal/Val Team Members
- CrIS SDR Specifications
- Evaluation of the NOAA-20 CrIS SDR Performance
  - Noise (NEdN)
  - Radiometric Calibration Uncertainty
  - Spectral Calibration Uncertainty
  - Geolocation Uncertainty
  - Error Budget
- Risks, Actions, and Mitigations
- Documentation
- Caveats
- Conclusion
- Path Forward

Summary from Provisional Review

- 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

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 Team Members

PI	Organization	Team	Major Task
Flavio Iturbide-Sanchez	NOAA/STAR	Yong Chen, Likun Wang, Denis Tremblay, Andrew Wald	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 Deslover	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
Deron Scott	Space Dynamic Lab (SDL)	Joe Kristl, Kori Moore, Ben Esplin	Noise characterization, bit trim and impulse noise mask, anomaly analysis
Dan Mooney	MIT/LL	Mark Tolman	Correlated/uncorrelated noise characterization, residual analysis and ringing, simulation
Dave Johnson	NASA Langley	Yana Williams	NASA flight support, instrument science
Lawrence Suwinski	Harris	Clayton Buttles	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	Cole Rossiter	Coordination with JPSS Flight Project
Banghua Yan	NOAA/STAR	Xin Jin	CrIS SDR data quality and monitoring

CrIS SDR Maturity Level Timeline

S-NPP CrIS SDR

Beta — 04/19/2012

~9.5 mos.

Provisional — 01/31/2013

~10.8 mos.

Validated — 12/20/2013

S-NPP Launch:10/28/2011.
First Science Data:01/18/2012.
Transition to FSR mode:12/04/2014

~20 mos.

NOAA-20 CrIS SDR

Beta — 01/17/2018

1 mos.

Provisional — 02/16/2018

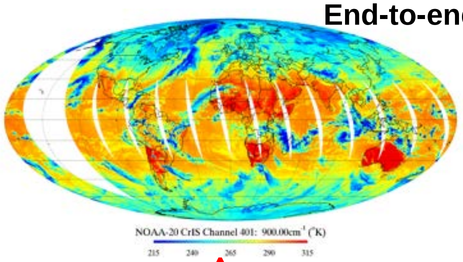
6 mos.

Validated — 08/14/2018
Expected Effective Date

NOAA-20 Launch:11/18/2017
First Science Data:01/04/2018

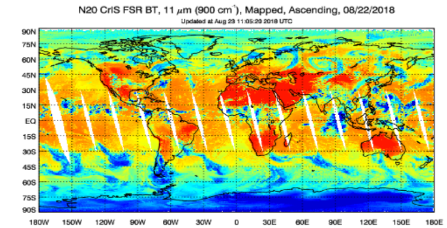
7 mos.

NOAA-20 CrIS Major Events and Milestones



End-to-end System (Flight/Ground) demonstration

Optimally Calibrated and Validated Observations



1/5/2018
FIRST LIGHT
GLOBAL IMAGES

1/17/2018
BETA MATURITY
ENGPKT V113

2/16/2018
PROVISIONAL MATURITY
ENGPKT V114

2/2/2018 - 2/16/2018
BIAS TILTS ANOMALY

3/5/2018
IDPS BLOCK 2.1 MX0
DR 8399: CRIS ICT PRT3, TELEMETRY

4/30/2018
IDPS BLOCK 2.1 MX1
DR 8444: USING EXTENDED INTERFEROGRAMS
DR 8361: ENGPKT OUTPUT FREQUENCY
DR 8445: FSR LONGWAVE RADIANCE ANOMALY (FOLDING INDEX)

5/24/2018
DR 8653: N-20 SDR ANOMALIES RELATED TO MISSING RDR PACKETS

7/2/2018
IDPS BLOCK 2.1 MX2
DR 8489: MISSING DS CAL PACKETS
DR 8490: OVERALL QUALITY FLAG FOR NAN
DR 8491: METROLOGY LASER WAVELENGTH AS NAN

8/14/2018
VALIDATED MATURITY
ENGPKT V115

7/19/2018 - 7/26/2018
BIAS TILTS ANOMALY

11/18/2017 - 1/3/2018 OUTGASSING PHASE	1/4/2018 - 1/17/2018 EARLY CHECK	1/17/2018 - 2/16/2018 INTENSIVE CAL/VAL	2/16/2018 - 8/14/2018 CONTINUING INTENSIVE CAL/VAL

18 November 2017 — 1/1/2018 — 14 August 2018

Planned Improvements

9/24/2018
IDPS BLOCK 2.1 MX3
DR 8013: CRIS INTERFEROGRAMS SPIKES DETECTION AND CORRECTION
DR 8629: N-20 SWEEP DIRECTION INDICATORS AND QUALITY FLAGS

12/17/2018
IDPS BLOCK 2.1 MX4
DR 8631: CRIS LUNAR INTRUSION DETECTION ALGORITHM UPDATE AND PCT UPDATE

Implementation delayed to October 2, 2018 due to Severe Weather Conditions Associated to Florence Hurricane

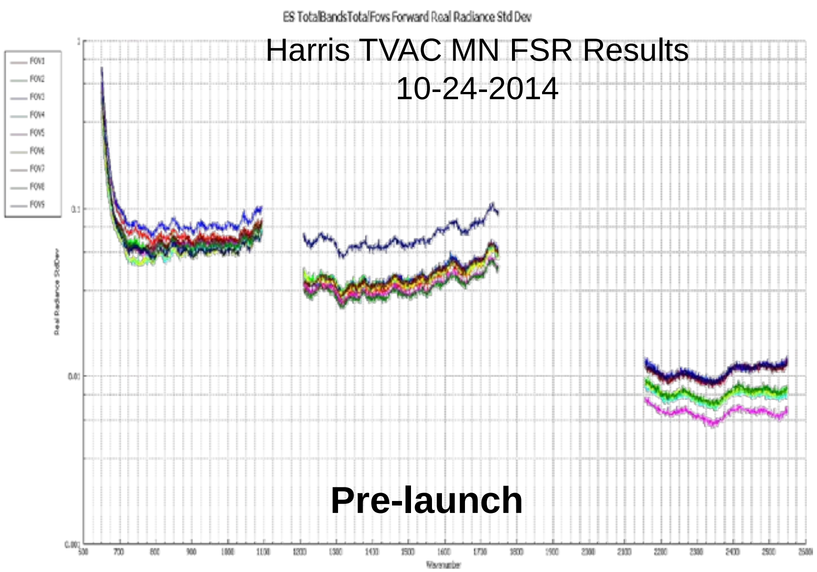
Provided by Yong Chen

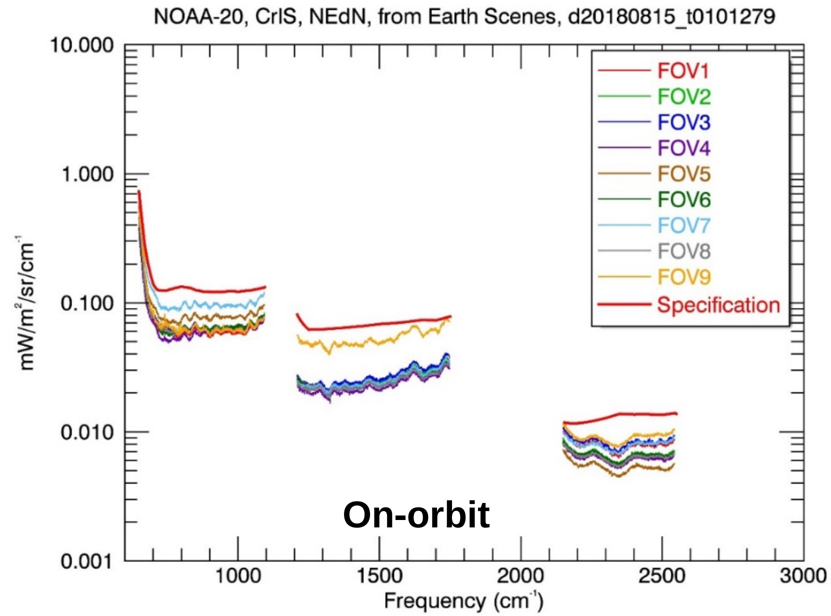
Discrepancy Reports Related to NOAA-20 CrIS

Title	DR #	Date	Description	Status
J2 PCT update for mounting matrix coefficients	8762	9/4/18	3x3 transformation matrix to compute LOS pointing vector relative to spacecraft	open No Related to NOAA-20
Turn off the CrIS truncated data products (NSR)	8761	9/4/18	Turn off NSR product production	open
CrIS SDR Radiances Polarization Correction	8760	9/4/18	Implement polarization correction	open
Upload EngPkt v115 for N20 CrIS SDR validated maturity	8708	6/25/18	Engineering Packet Version 115 upload	Closed, EngPkt v115 upload 08/14/18
MWIR bit trim mask saturation for N20	8654	4/2/18	MWIR bit trim mask saturation for N20 for hot scenes, increasing one bit in MWIR	Closed, EngPkt v115 upload 08/14/18
N20 CrIS SDR anomalies related to missing RDR packets	8653	4/2/18	Noticed bad SDR products while having good RDR but with missing packets.	Closed, out of cycle LUT update 05/24/18
Invalid radiances caused by contaminated deep space by lunar intrusion	8631	3/8/18	Contaminated radiance due to lunar intrusion	Closed, Block 2.1 Mx4 12/17/2018
Sweep direction bug in IDPS impacting N20 CrIS SDR DQF and DQI.	8629	3/5/18	Sweep direction bug in IDPS	Closed, Block 2.1 Mx3 10/02/2018
Metrology laser wavelength as NaN	8491	9/13/17	Use the previous valid metrology laser wavelength in the CrIS SDR processing to process the SDR data	Closed, Block 2.1 Mx2 07/02/2018
Overall Quality Flag for NaN	8490	9/13/17	Overall quality flag should be invalid for NaN cases	Closed, Block 2.1 Mx2 07/02/2018
Missing DS cal packets	8489	9/13/17	Correct the unsigned integer to signed integer when dealing negative number to improve performance	Closed, Block 2.1 Mx2 07/02/2018
FSR LW radiance anomaly [folding index]	8445	7/17/17	Folding index inconsistent between calibration targets and earth scene due to the changing of metrology laser wavelength	Closed, Block 2.1 Mx1 04/30/2018
Using extended interferograms	8444	6/21/17	PCT update to use all the CrIS extended interferogram data points and to further reduce the spectral ringing in the CrIS LWIR radiance	Closed, Block 2.1 Mx1 04/30/2018
CrIS ICT PRT3 telemetry	8399	4/4/17	Separation of J1 and NPP telemetry configuration due to ICT PRT3	Closed, Block 2.1 Mx0 03/05/2018
Eng Pckt Output Frequency	8361	2/23/17	Control generation frequency of SDR-ENGPKT-BACKUP-AUX using checksum	Closed, Block 2.1 Mx1 04/30/2018
CrIS Interferograms spikes detection and correction	8013	06/22/15	Detect and correct interferogram spikes	Closed, Block 2.1 Mx3 10/02/2018

NOAA-20 CrIS pre-launch and on-orbit performance: Noise

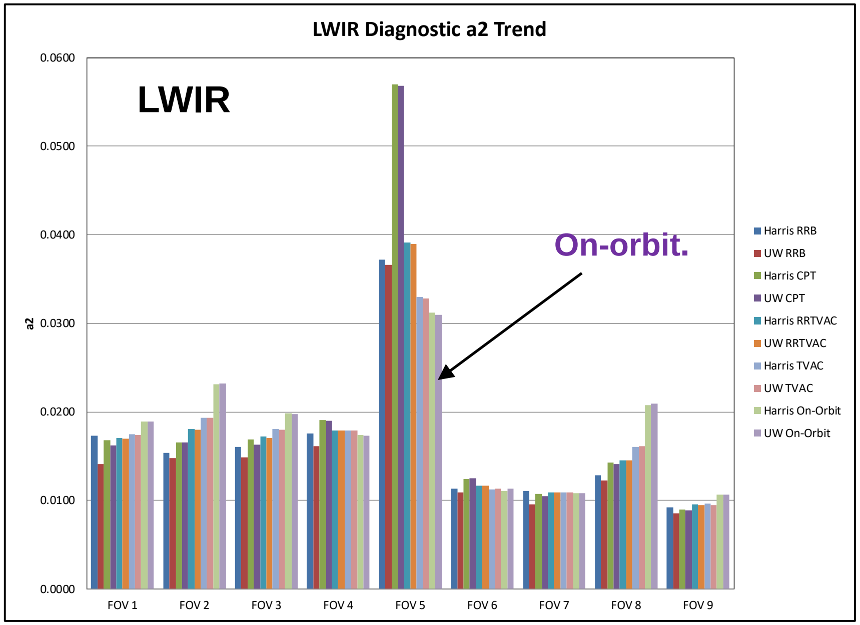
On orbit NEdN Compares well to 287K ECT TVAC NEdN CrIS at Full Spectral Resolution

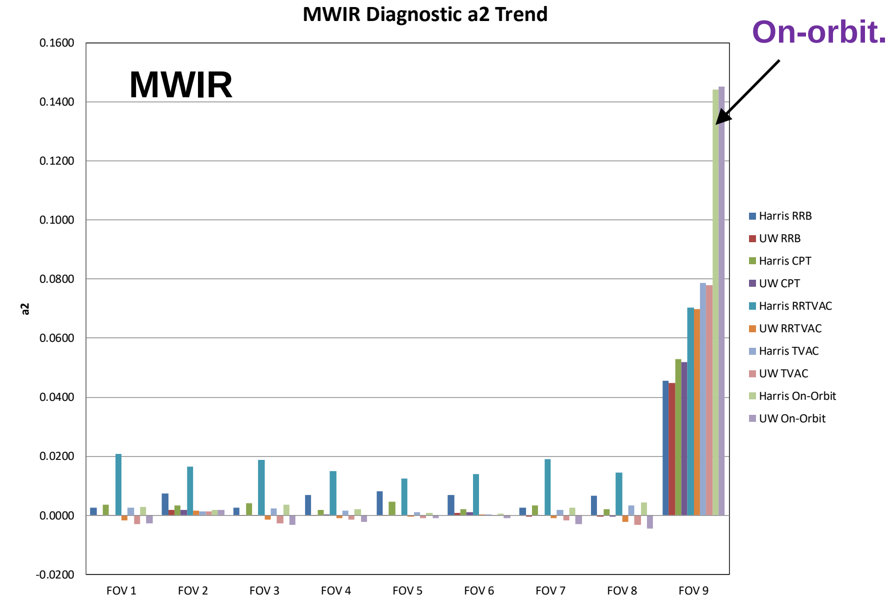


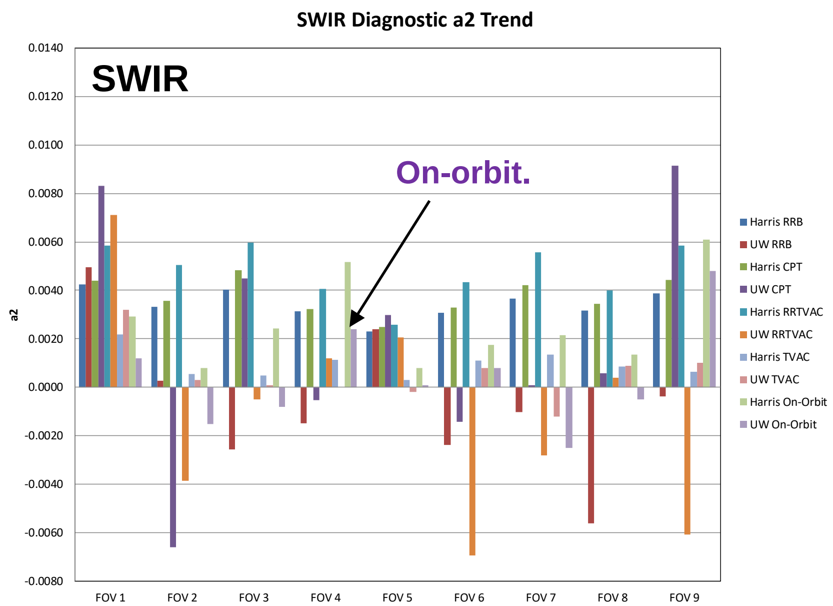


- Pre and Post launch NEdN are consistent.
- MW9 NEdN elevated as expected from prelaunch TVAC measurements but within specification .
- LW7 NEdN elevated (high noise had been seen once before during EMI test phase).
- Full resolution spectra compared against the NOAA full resolution SDR specification.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

NOAA-20 CrIS Pre-launch and On-orbit performance: Non-linearity







On-orbit detector non-linearity trends are consistent with ground tests for NOAA-20 CrIS LWIR, MWIR and SWIR bands.

Provided by Harris Corporation

Upload of the NOAA-20 CrIS EP v115 on August 14, 2018

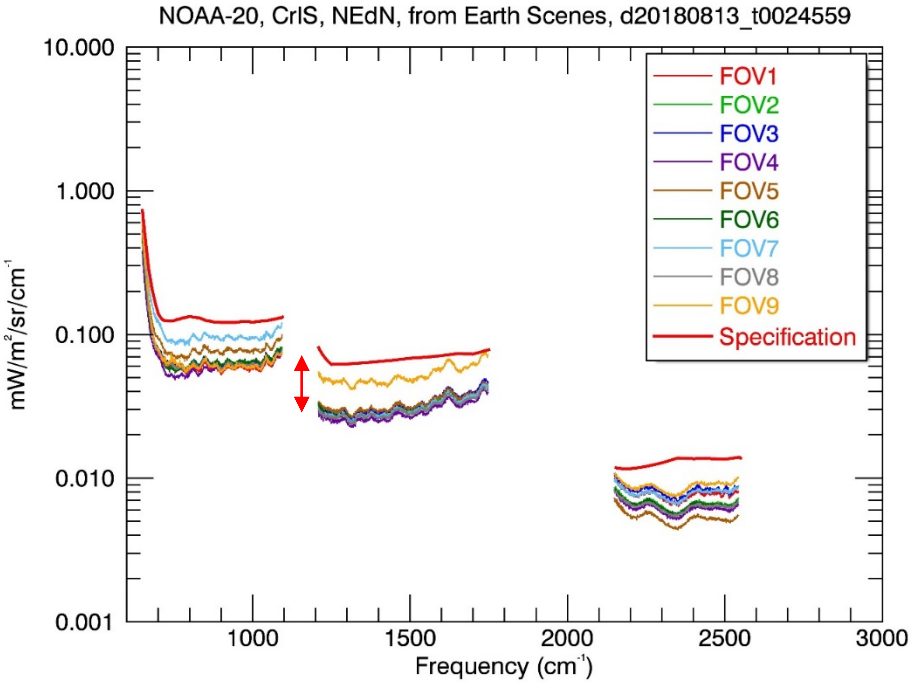
The calibration table and configuration files for NOAA-20 CrIS were successfully uploaded on August 14, 2018. The calibration table (v115) was successfully uploaded at 17:40:16 UTC, the DSP4M configuration (Bit-Trim-Mask) and setup was performed at 17:40:48 UTC, and the DSP8S (PGA gain) was performed at 17:41:20 UTC. Summary of major updates:

a) Update of the ILS parameters for the Short Wave (SW) FOV 5 position to reduce the spectral spread among FOVs.
b) Update of Geolocation parameters to further adjust the geolocation parameters.
c) Update of the PGA gain (50% increase) setting on all FOVs (except FOV9) for MWIR band to improve further the MWIR NEdN.

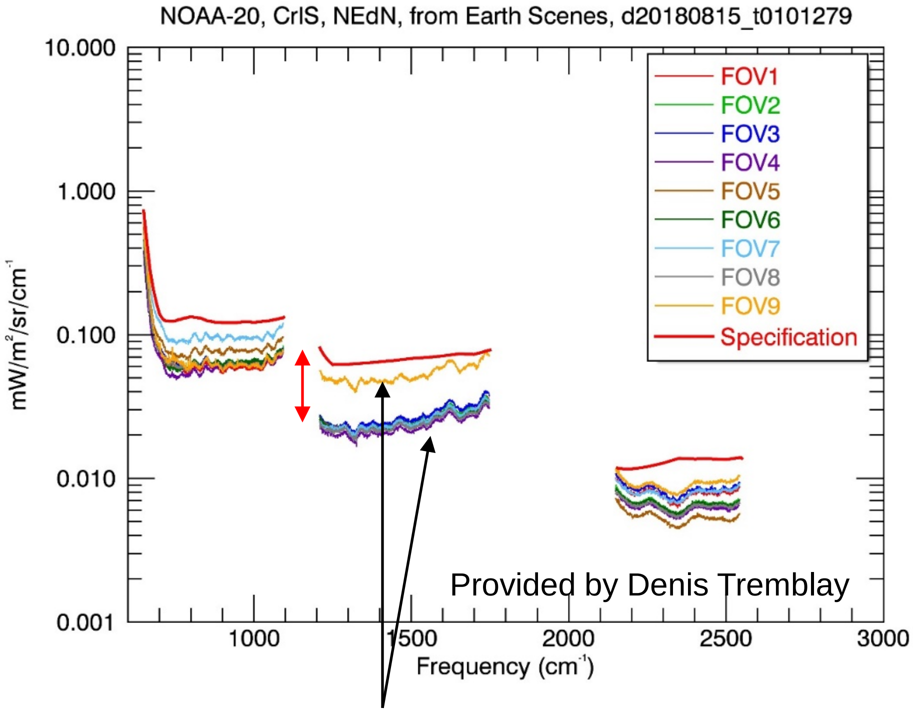
d) Update of the Bit-Trim-Mask by adjusting the mask one bit higher in order to avoid the saturation of very hot MWIR earth scenes.

NOAA-20 CrIS NEdN: After EP v115 Upload on Aug 14, 2018

NEdN on 8/13/2018 (EP v114)



NEdN on 8/15/2018 (EP v115)
For Validated Maturity Level

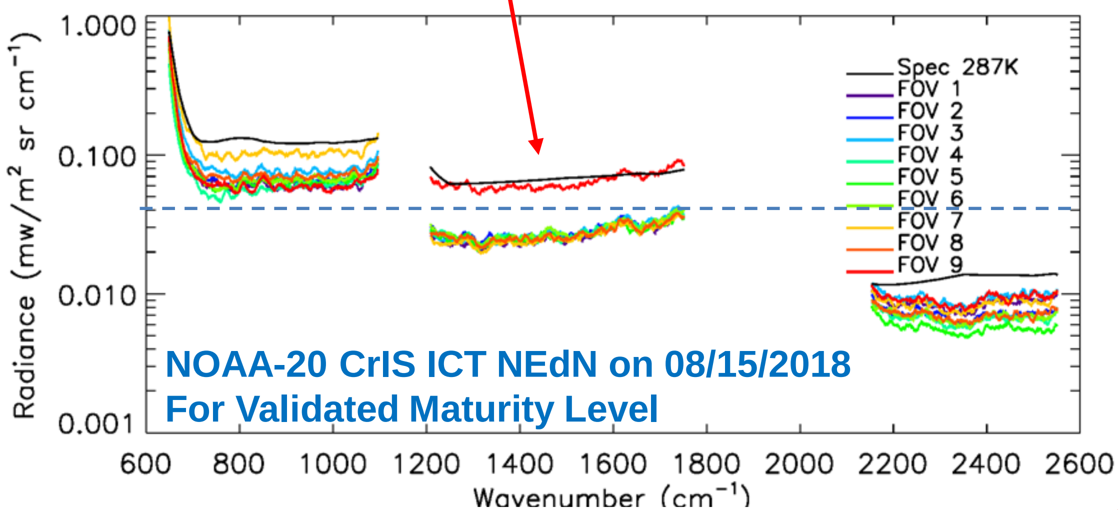


- MWIR NEdN has decreased ~15% due to PGA gain increase (FOV9 stays the same due to no gain change).
- All FOVs are below the specification.
- Based on the Principal Component Analysis methodology.

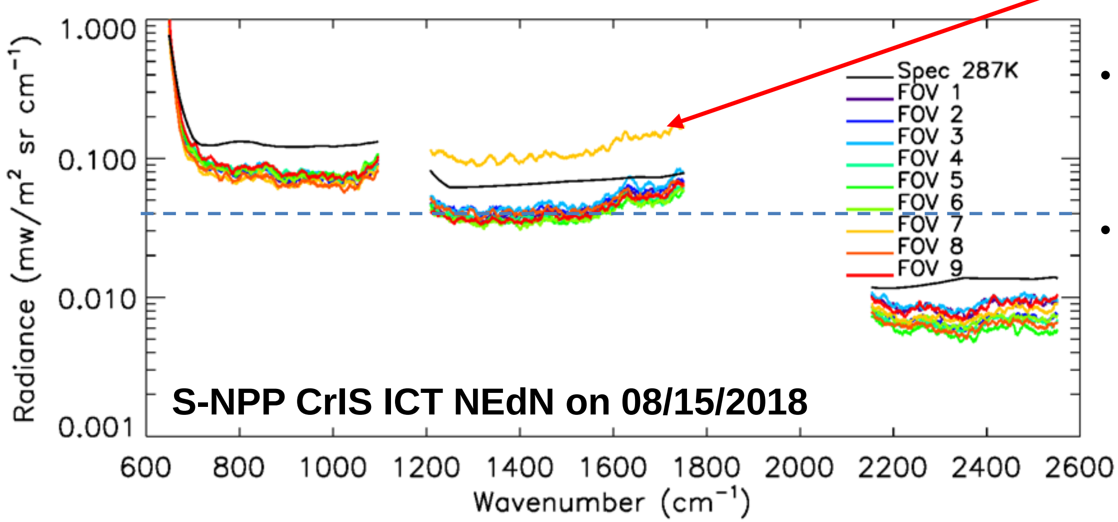
CrIS NEdN performance is a key parameter for the mission success. Defines instrument sensitivity (lowest measured radiance), consequently the SNR. Lower noise gives more weight to the observations in the NWP or retrieval applications.

NEdN Performance: NOAA-20 vs S-NPP

NOAA-20 CrIS MWIR NEdN shows better performance than S-NPP for FOVs 1-8



S-NPP and NOAA-20 are meeting the NEdN specifications (except NPP FOV7)



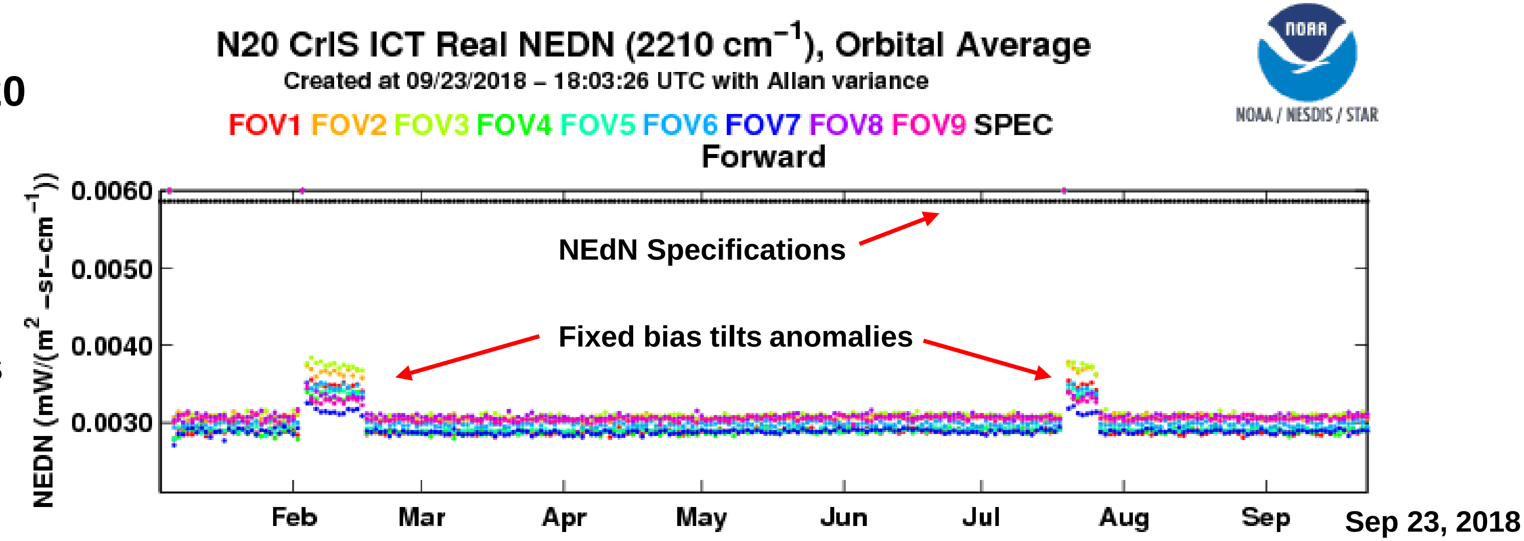
- Generated based on the CrIS SDR NEDN averaged over 4 scans using unapodized radiances with self-apodization correction.
- CrPRD-11270: The maximum allowed NEdN values for the best 8 FOV in the FOR, for any data set, at mission nominal shall be less than those given in Table 4.4-1, Table 4.4-2, and Table 4.4-3.

Provided by Yong Chen

Noise Performance Trending:NOAA-20 and S-NPP

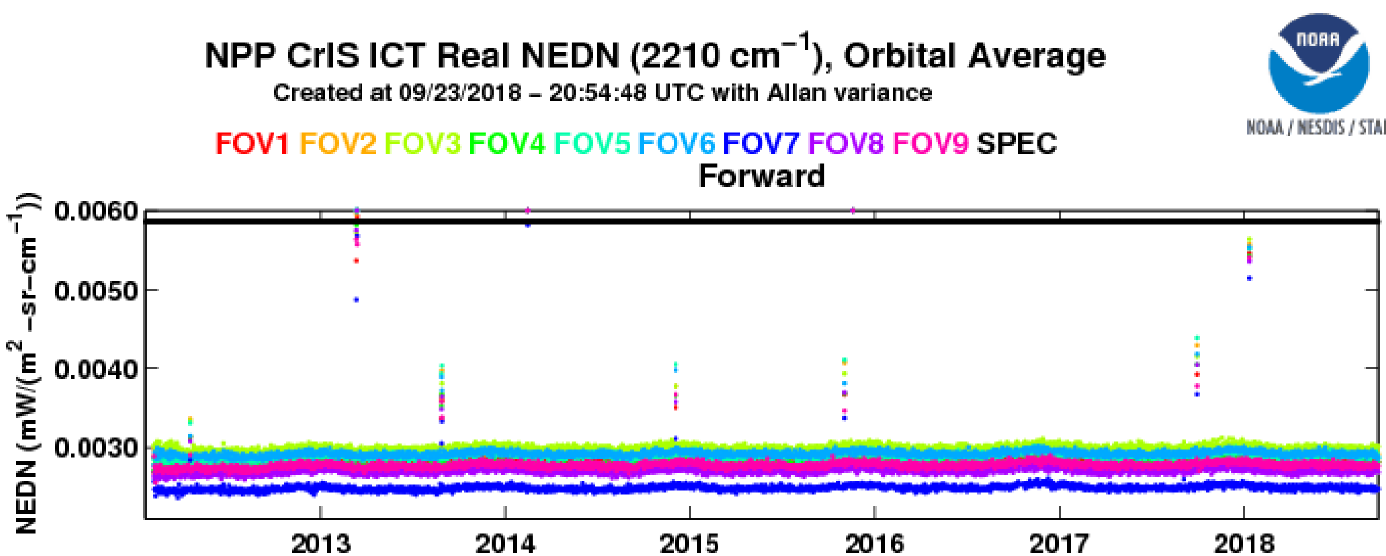
NOAA-20

From STAR/ICVS

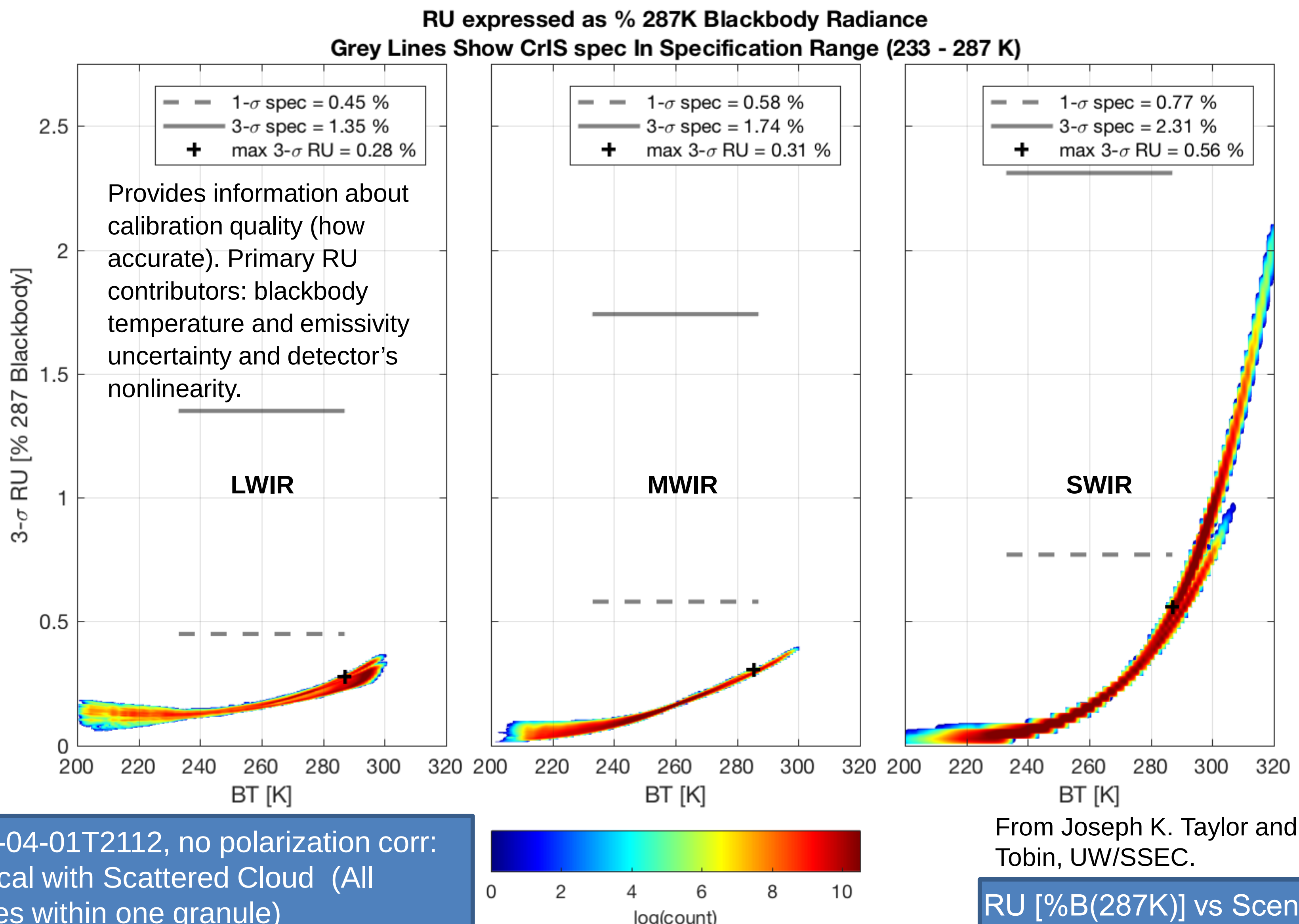


S-NPP and NOAA-20 are showing long term noise stability

S-NPP



NOAA-20 CrIS Radiometric Calibration Uncertainty as Percent of the 287K Blackbody Radiance

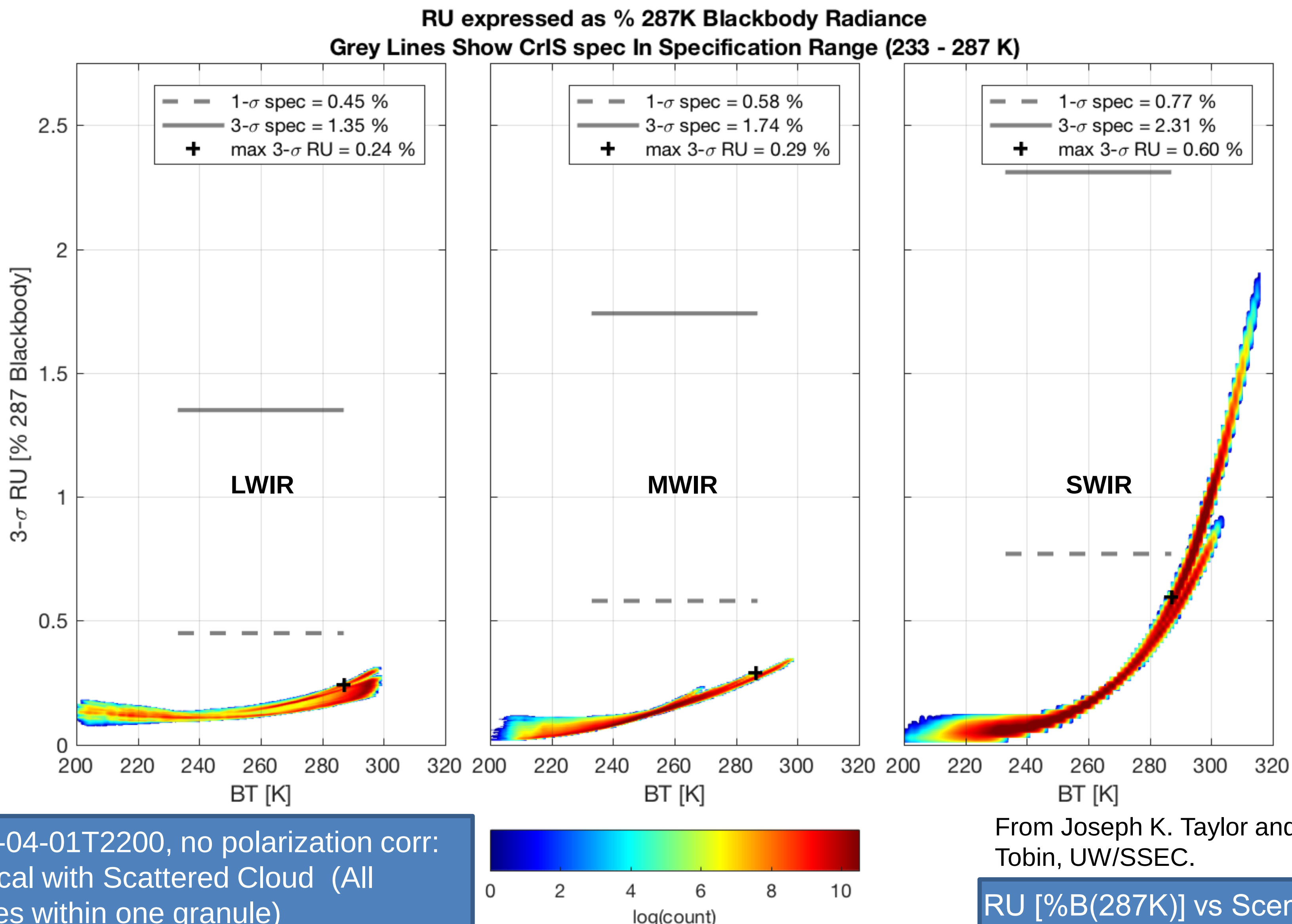


2018-04-01T2112, no polarization corr: Tropical with Scattered Cloud (All scenes within one granule)

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

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

S-NPP CrIS 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]

NOAA-20 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	0.0933%	0.1033%	0.1867%
Case 2: Typical Antarctic cold scene	0.0633%	0.0633%	0.0733%
RU estimate*	**0.19%**	**0.21%**	**0.37%**

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

RU characterization and understanding is required for NWP and Climate applications and for its use in satellite intercalibration efforts.

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

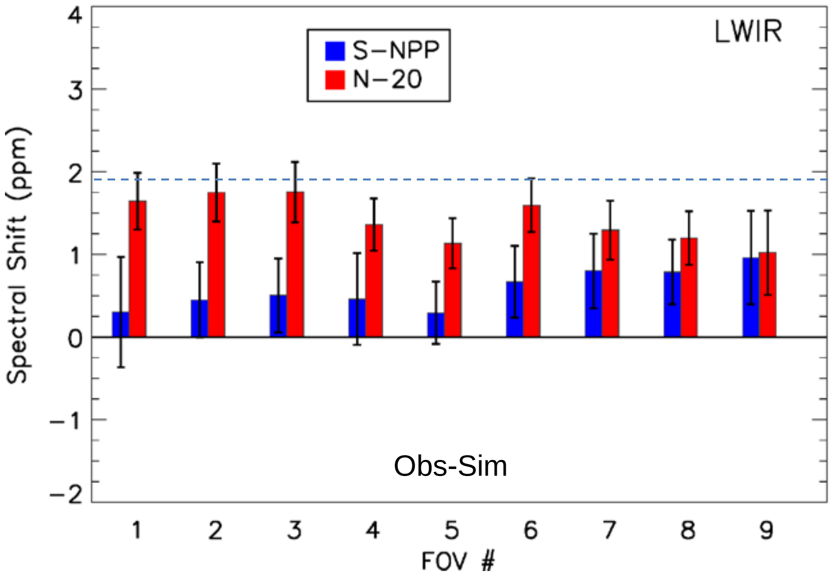
	LW (1-σ)	MW (1-σ)	SW (1-σ)
Specification	0.45%	0.58%	0.77%
Case 1: Typical Tropical ocean with scattered cloud scene	0.0800%	0.0967%	0.2000%
Case 2: Typical Antarctic cold scene	0.0600%	0.0633%	0.0867%
RU estimate*	**0.16%**	**0.19%**	**0.40%**

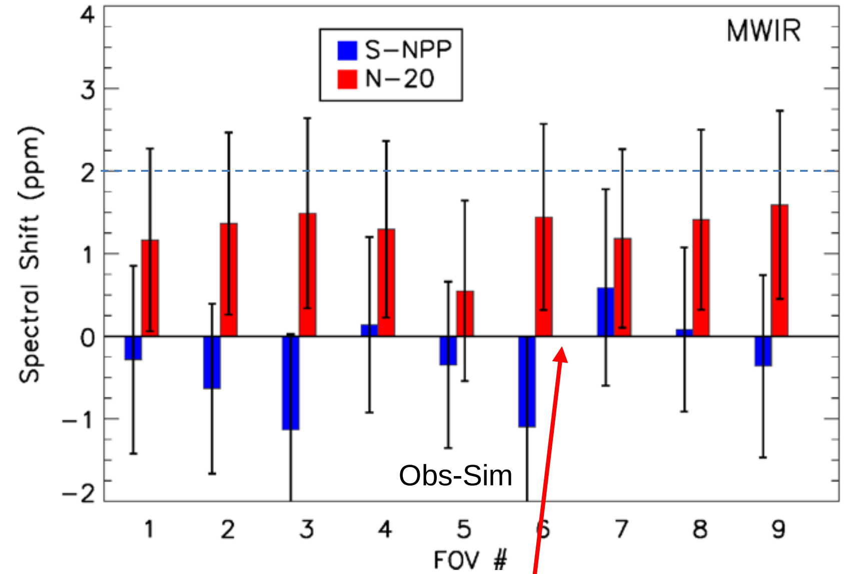
From Joseph K. Taylor and David Tobin, UW/SSEC.

- 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

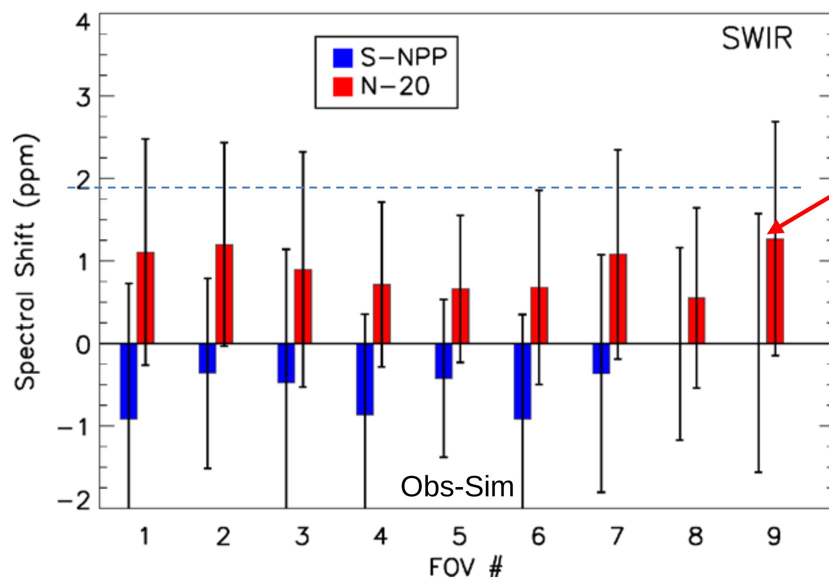
Absolute Spectral Accuracy: NOAA-20 and S-NPP





S-NPP and NOAA-20 are ~5 times below the Spectral Uncertainty Requirement (10 ppm)

Spectral calibration has the major task 1) to assigning the absolute frequency values to the observations and 2) to minimize the corresponding frequency uncertainty. Its major impact can be observed on NWP, Climate and Rerieval applications.



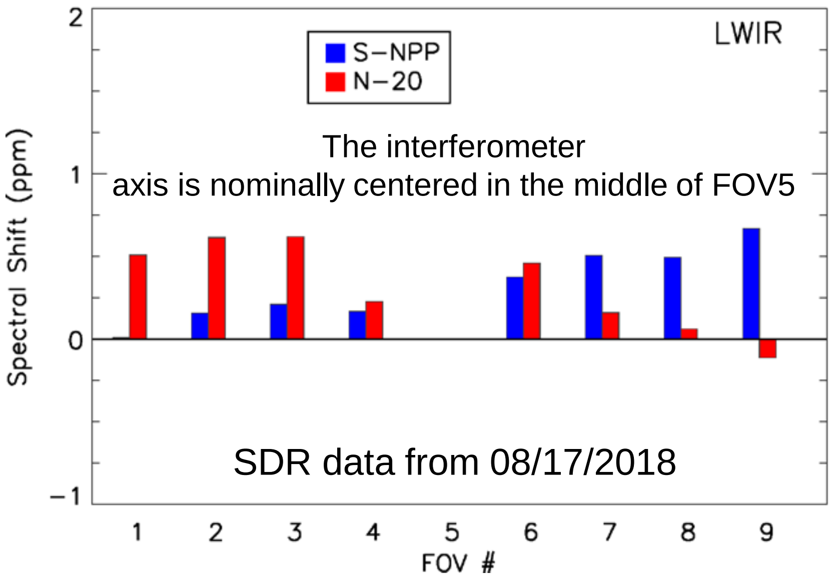
NOAA-20 shows similar performance over all FOVs and IR bands

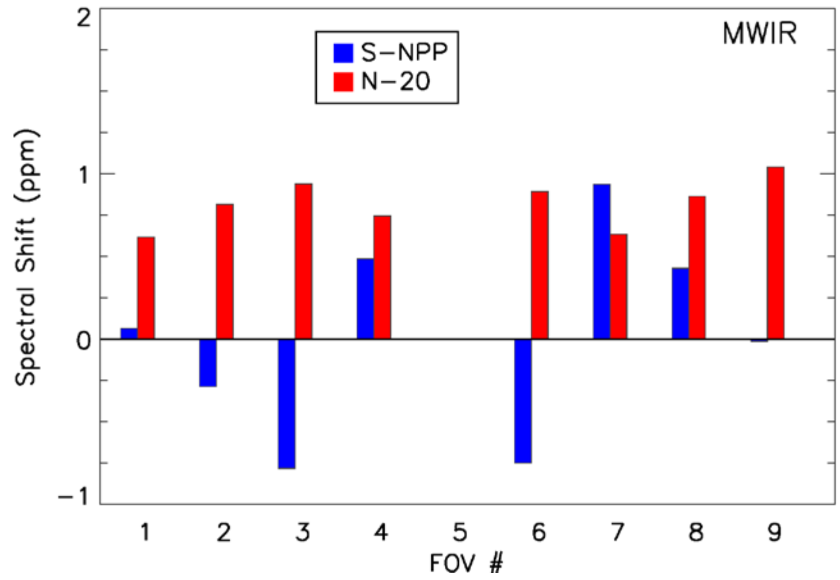
SDR data from 08/17/2018

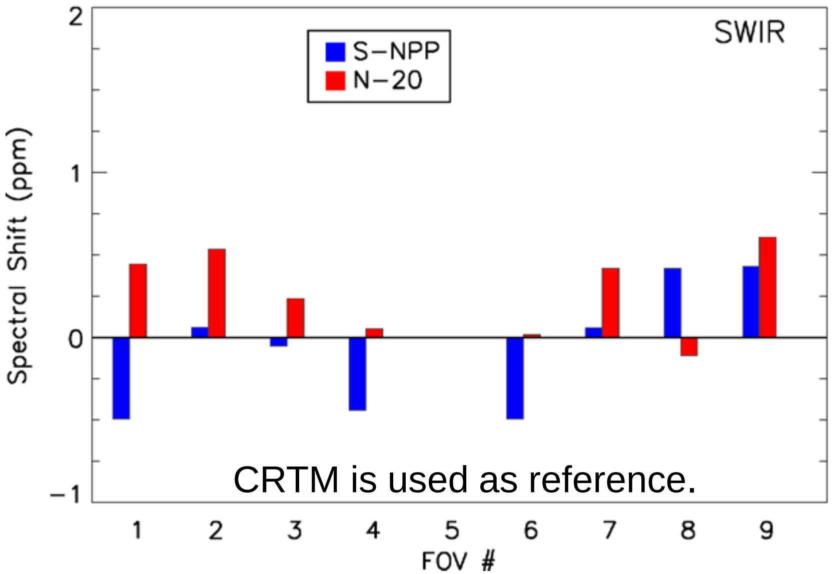
Simulated observations are based on CRTM and ECMWF data.

Provided by Yong Chen

Relative Spectral Accuracy: NOAA-20 and S-NPP



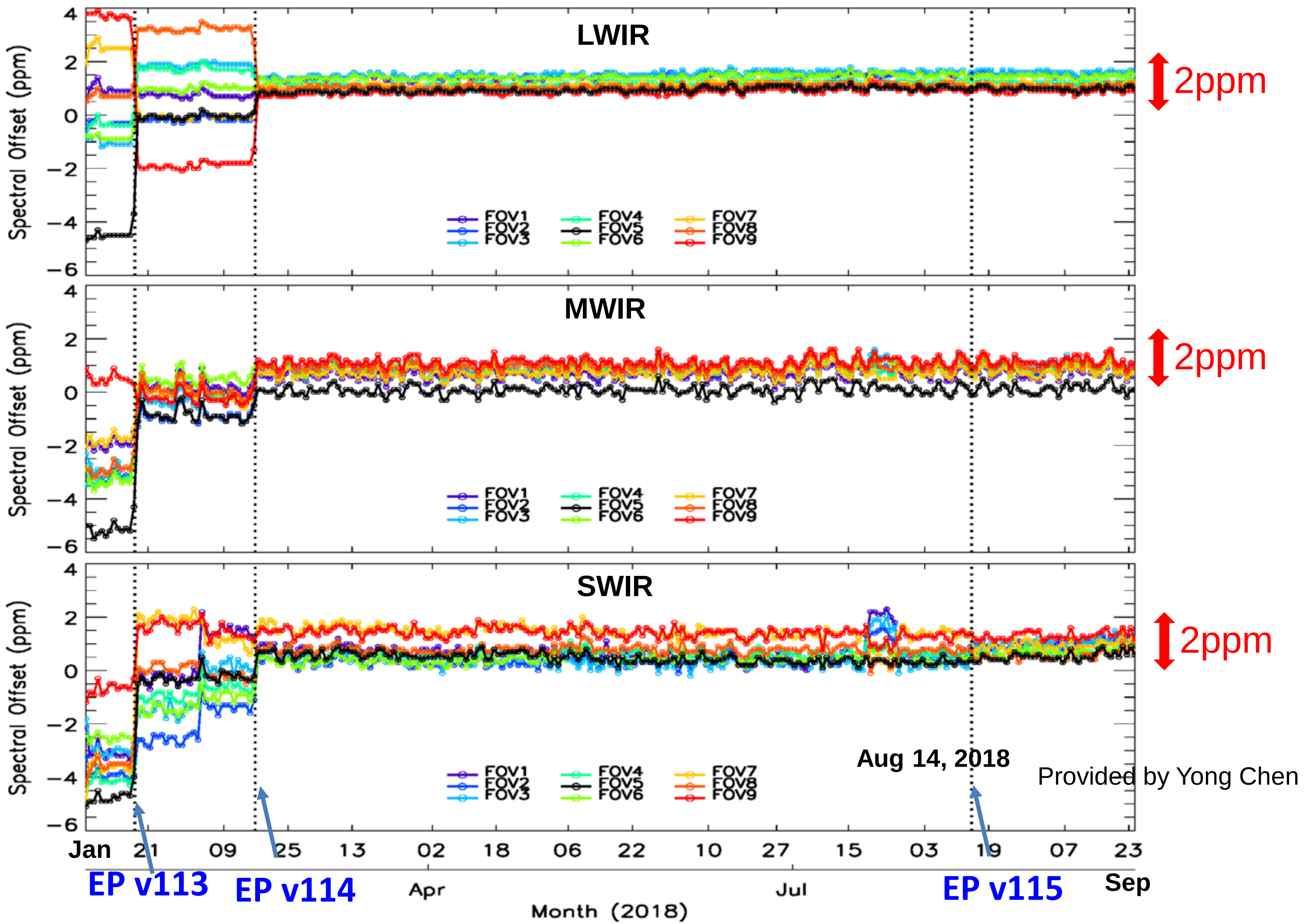




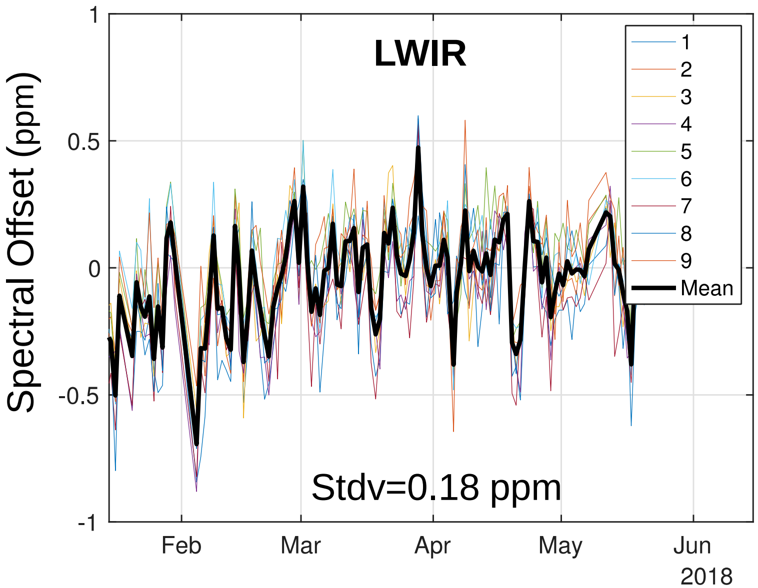
Provided by Yong Chen

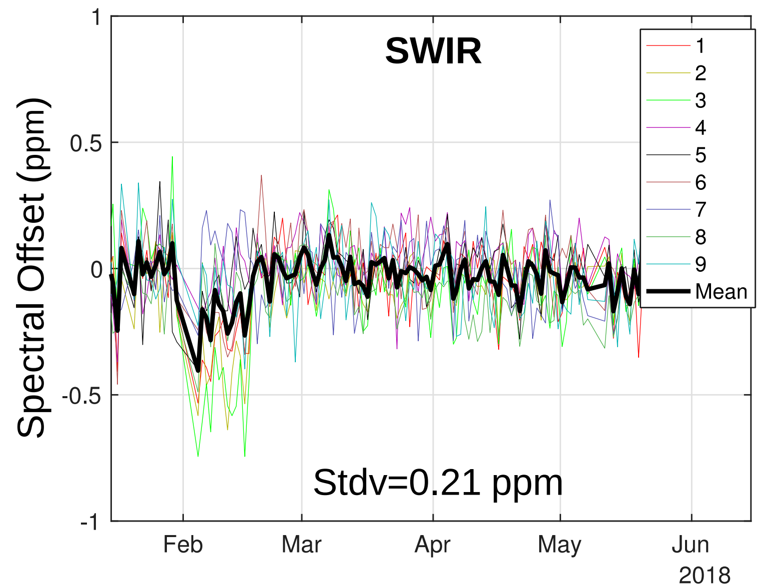
- Spectral calibration quality depends on the accuracy of the CrIS Focal Plane Geometry definition (SA correction) and Wavelength of the Metroogy laser (sampling).
- Spectral calibration determines the off-axis positions of the 9 detectors on each focal plane (main input for the self-apodization corrections to the observed un-corrected radiances) relative to FOV5.
- The apodization corrections affect both the Instrument Line Shape (ILS) and channel center frequencies (by as large as 500 ppm).
- During launch, the off-axis positions of the detectors always move, requiring on-orbit optimization.
- Spectral uncertainty is important because it impacts the radiometric uncertainty (2ppm uncertainty could cause a 0.12K error), particular for unapodized spectra.
- RTA or EWFW performance improvements impact CrIS Calibration.

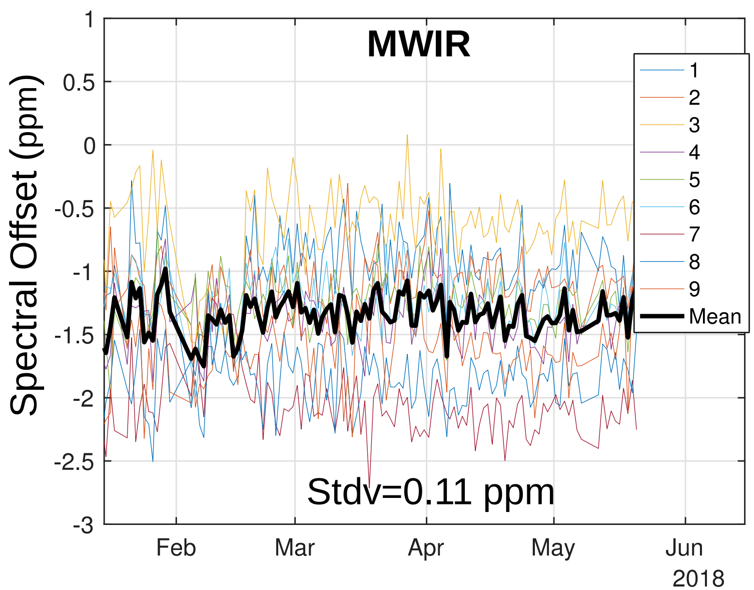
NOAA-20 CrIS Spectral Calibration: Absolute Accuracy Trending



NOAA-20 CrIS Spectral Calibration: Absolute Accuracy Trending





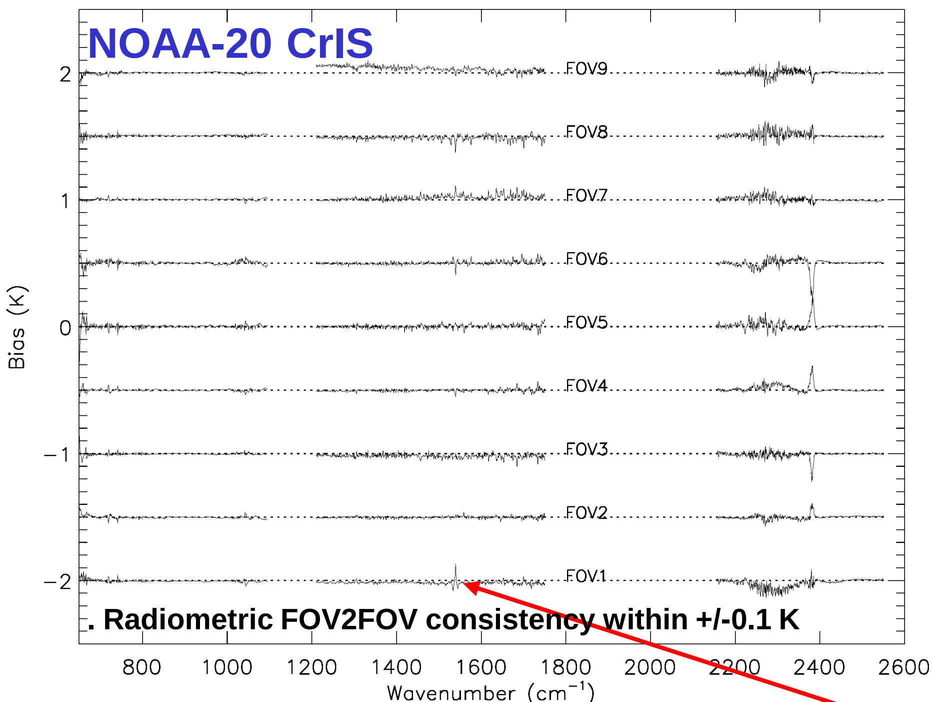


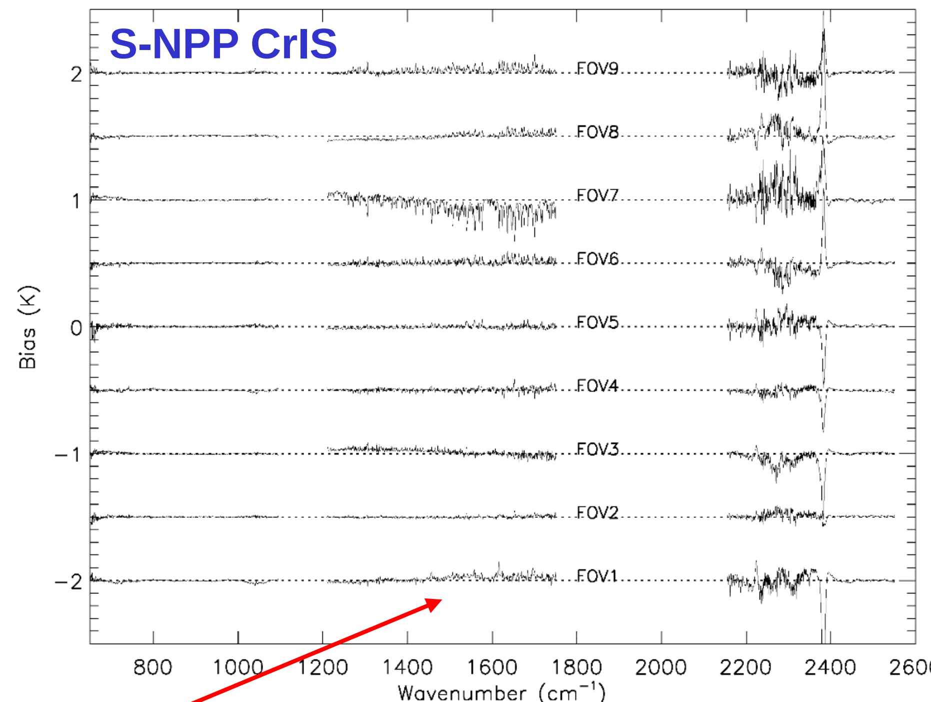
- Charaterization is done for each FOV and each band
- Midwave FOV-5 is chosen as Neon standard due to best performance

Three groups (UMBC, NOAA, UW) all perform relative spectral calibration using different techniques and agree to < 1 ppm relative and < 2 ppm absolute, well within specification.

FOV-to-FOV Radiometric Consistency

Mean Difference of Observed and Simulated (CRTM) Hamming Apodized Spectra (removed O-B bias for each FOV)





Over Clear-Sky/Ocean/No Sea Ice Surfaces

NOAA-20 shows better FOV2FOV Radiometric Consistency than SNPP for MW and SW bands mainly associate to better detectors linearity characteristics

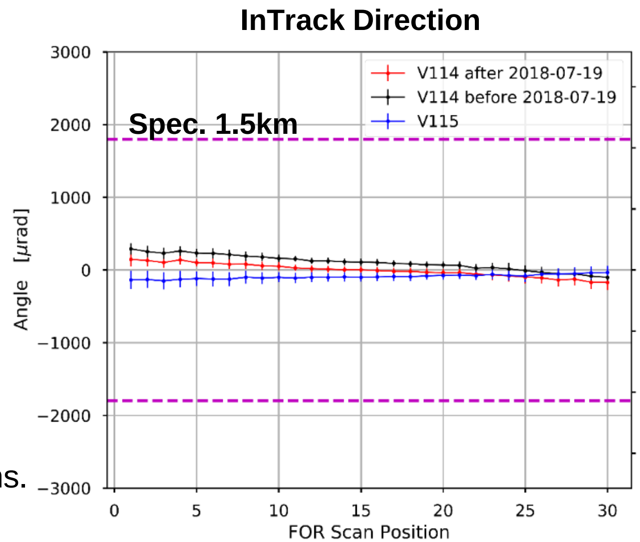
Uniformity of FOV-to-FOV radiometric and spectral performances allows the assimilation of all FOVs without special treatment for particular FOVs

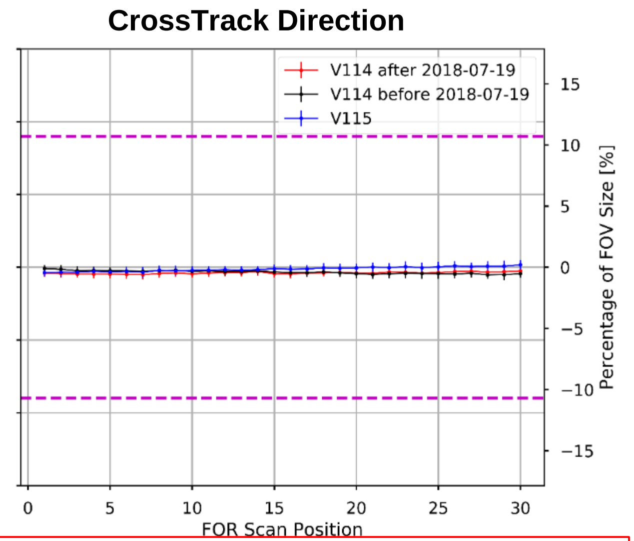
Provided by Yong Chen

Geolocation Uncertainty: S-NPP and NOAA-20

NOAA-20

How well observations are Geolocated. Accurate and precise geolocation is required to collocate CrIS with ATMS observations in order to combine them for retrievals and data assimilation applications.

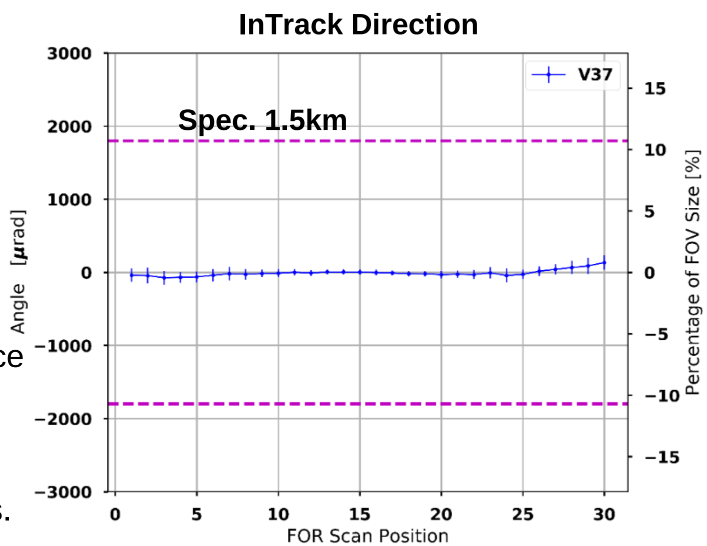


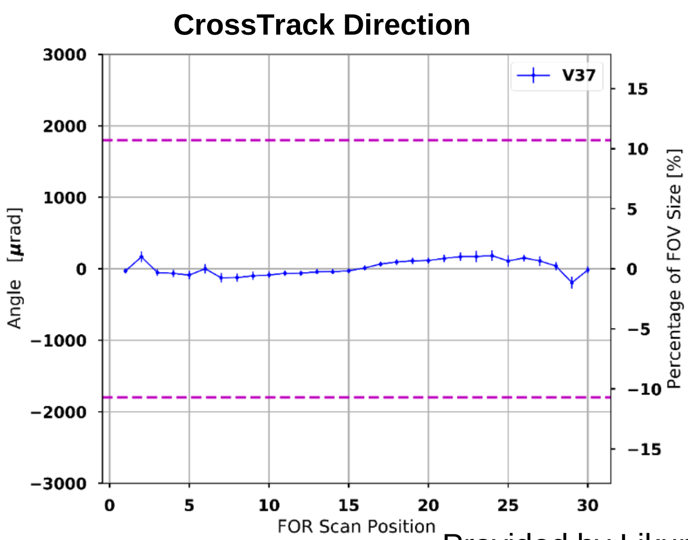


NOAA-20 shows better geolocation uncertainty due to an improvement performed in the method to derived the mapping angles defined in the engineering packet

S-NPP

Using VIIRS as reference (high spatial resolution (375m) and accurate geolocation). Using inhomogeneous regions.

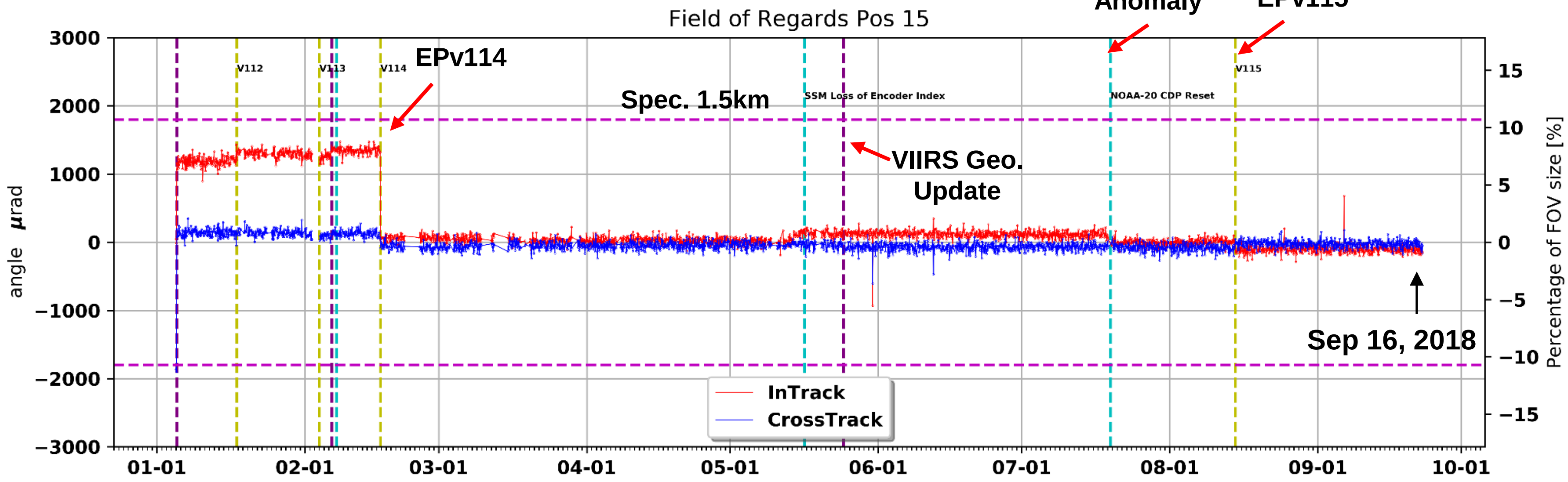




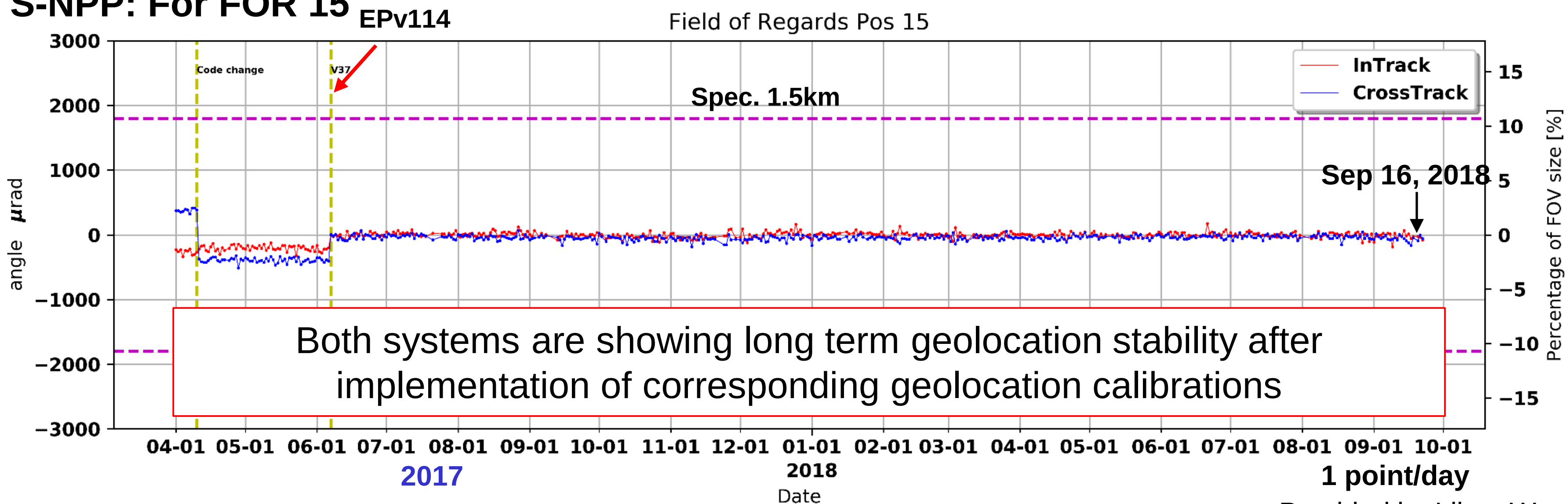
Provided by Likun Wang

Geolocation Uncertainty Trending: NOAA-20 and S-NPP

NOAA-20: For FOR 15 since CrIS turned on



S-NPP: For FOR 15

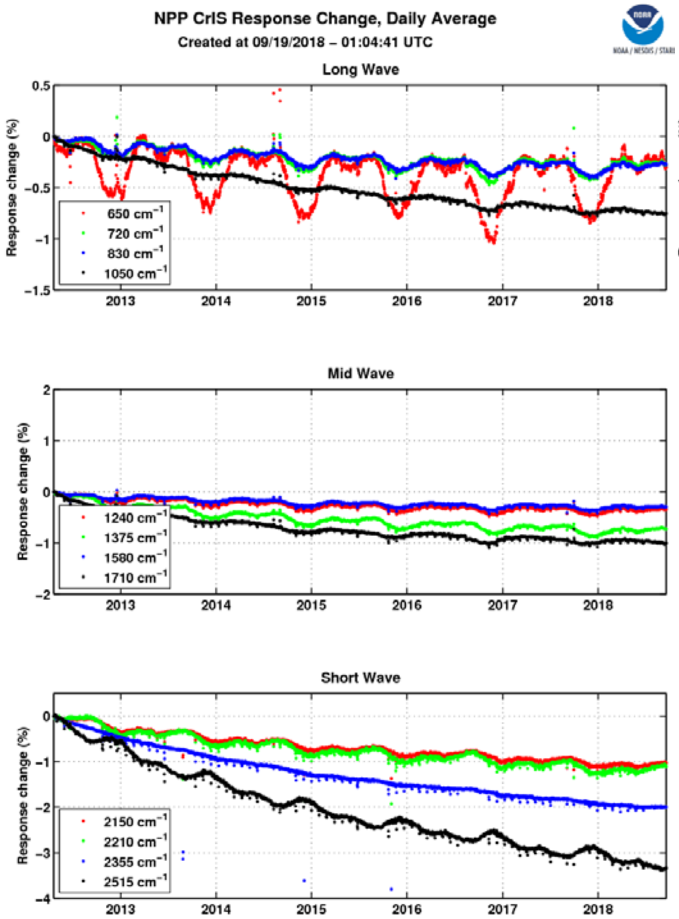


Both systems are showing long term geolocation stability after implementation of corresponding geolocation calibrations

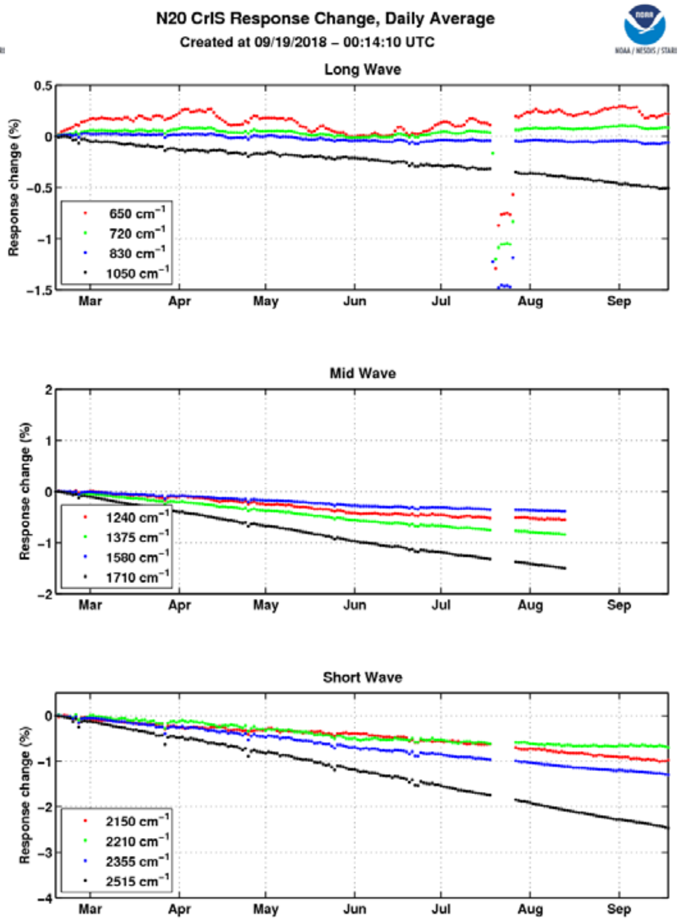
Provided by Likun Wang

CrIS Responsivity (Gain): NOAA-20 and S-NPP

S-NPP



NOAA-20



From STAR/ICVS

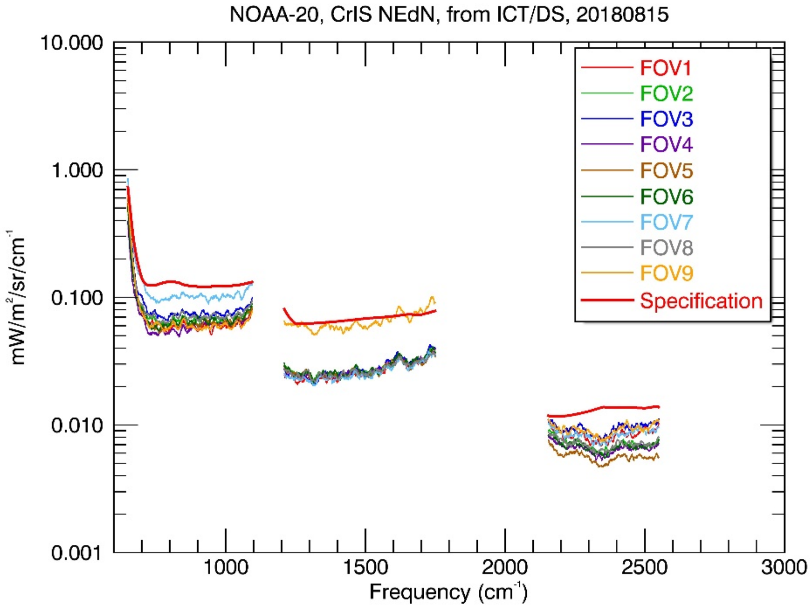
Elapsed Time after NOAA-20 and NPP CrIS Experienced same Responsivity Degradation

Platform/ Band	λ (cm $^{-1}$)	Degradation (%)	Time (months)
N20/SW	2515	-2%	6
NPP/SW	2515	-2%	26
N20 /MW	1710	-1%	3.5
NPP/MW	1710	-1%	54
N20 /LW	1050	-0.4%	6
NPP/LW	1050	-0.4%	24

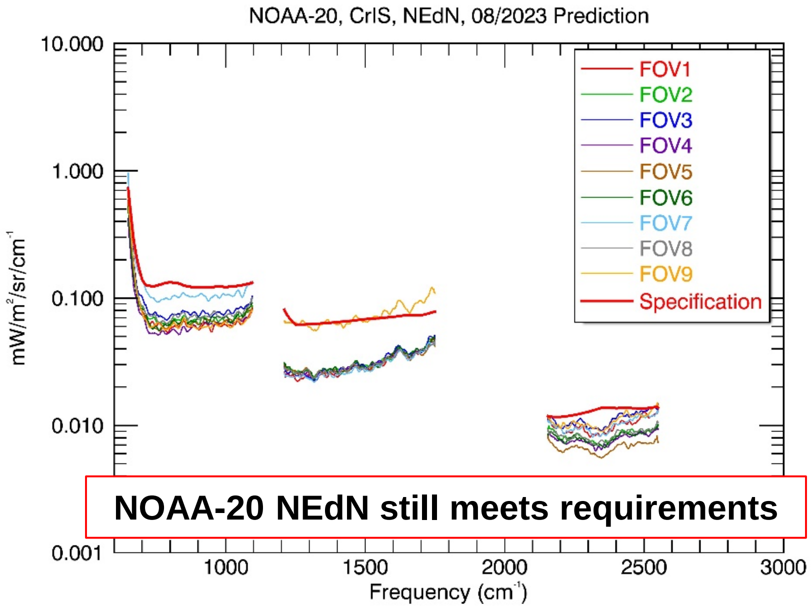
- These changes are calibrated out.
- Interesting to know if other NOAA-20 instruments are experiencing similar responsivity degradation.
- This could be related to contamination (molecular, particulate) of the optical surface.

Estimation of NOAA-20 CrIS NEdN Prediction in Five Years (Worst Case Scenario)

NEdN on 2018-08-15



NEdN Prediction in August 2023

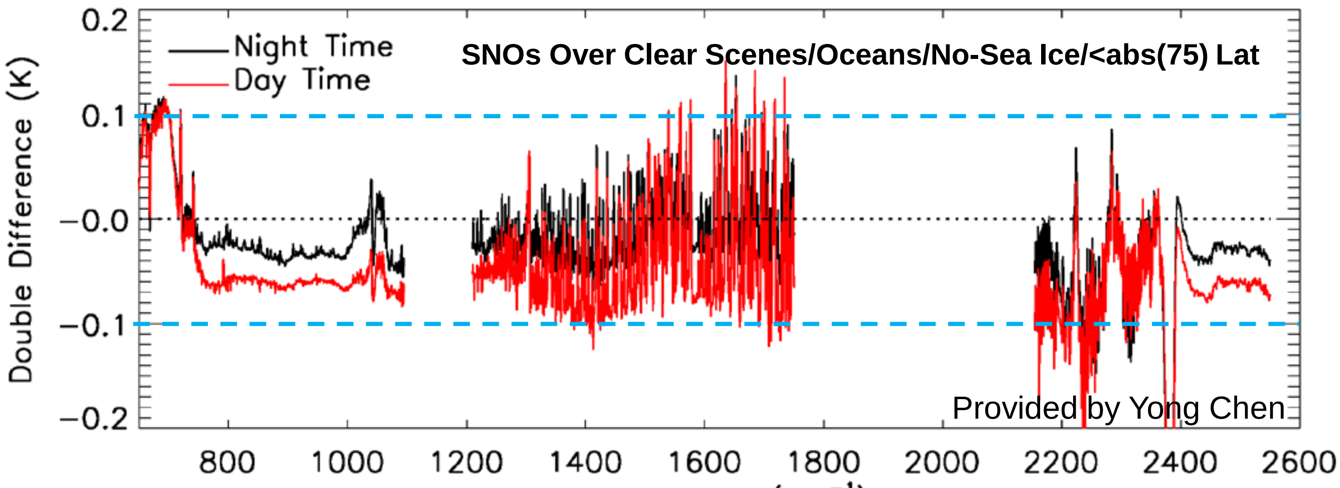


- NEdN prediction assumes:
  - Linear degradation of the response function.
  - Photon noise remains constant (as opposed to photon noise limited detector, where noise decreases with instrument gain decrease).
  - Degradation occurs on the front side of the interferometer.
- The response degradation is expected to become asymptotic, that is less than linear.
- This is worst case scenario. Noise still meets the requirements.

Provided by Denis Tremblay

Radiometric Differences Between NOAA-20 and S-NPP

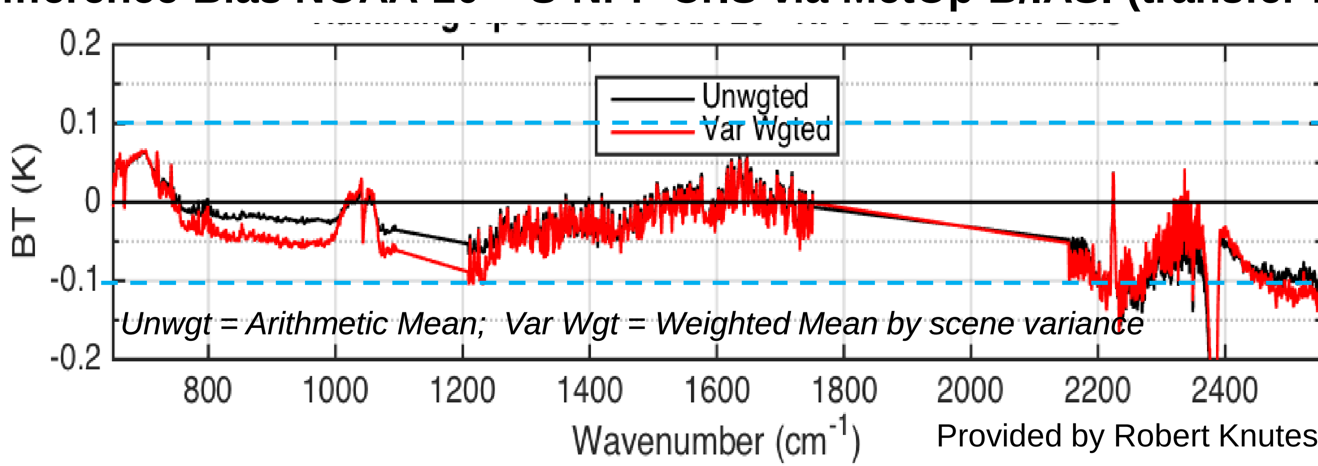
Double-difference Bias NOAA-20 – S-NPP CrIS via Radiative Transfer Calculations (transfer target)



Provided by Yong Chen

Radiometric differences between SNPP and NOAA-20 are within ±0.1 K

Double-difference Bias NOAA-20 – S-NPP CrIS via MetOp-B/IASI (transfer radiometer)

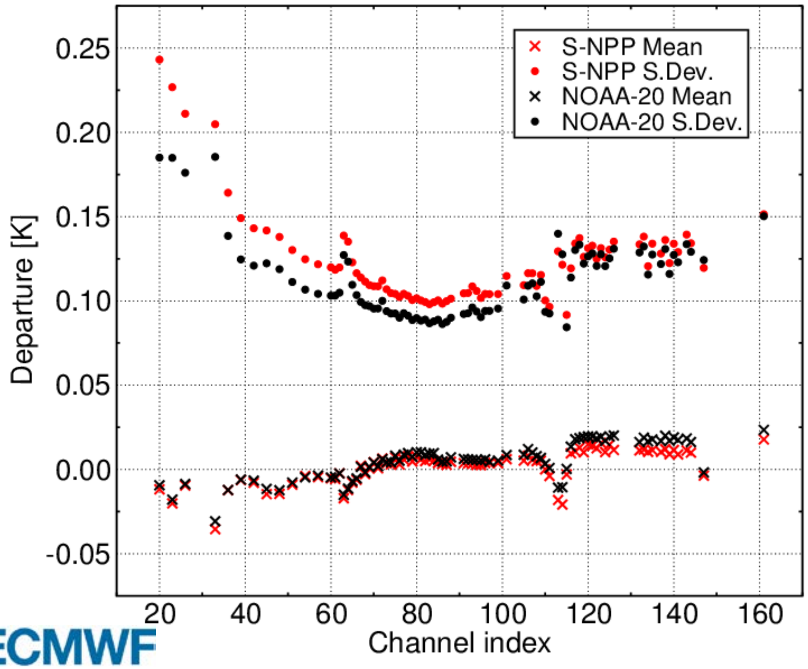


SNOs Over Clear Scenes/Oceans/Land /<Abs(78) Lat

Provided by Robert Knuteson

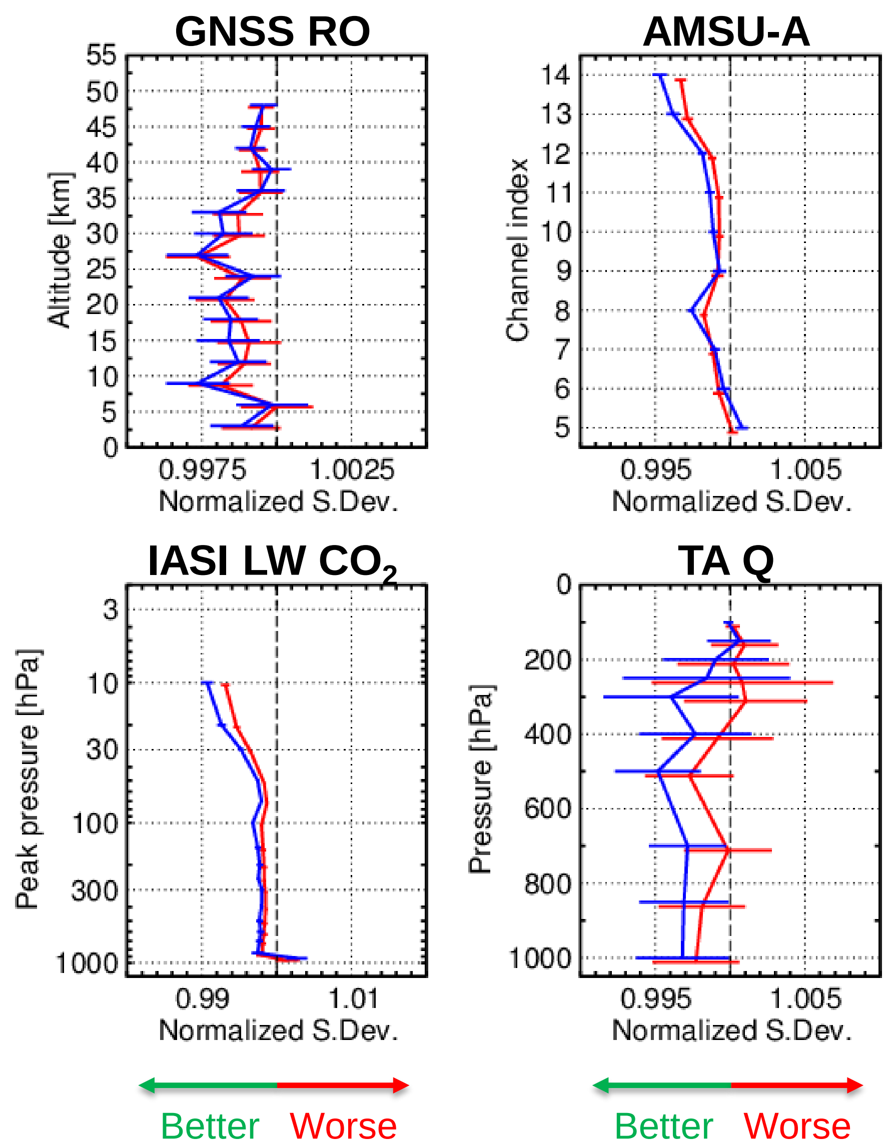
Impact of NOAA-20 CrIS SDR Assimilation at ECMWF

- Using 111 LWIR channels
  - Ongoing work to introduce humidity sounding channels
- Operational monitoring from 1st August 2018
  - Slightly different biases and lower noise than Suomi-NPP CrIS
- Research experiments from 1st May 2018
  - ***Incrementally improved short range temperature forecasts***
- **Operational assimilation introduced from 11th September 2018**



Adding S-NPP CrIS only

Adding S-NPP and NOAA-20 CrIS



Provided by Peter Weston

NOAA-20 and SNPP CrIS SDR Overall Performance

NOAA-20 CrIS FSR SDR 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	0.086 (0.14)	2 (10)	0.22 (1.6)	0.19 (0.45)	0.27 (0.40)
MWIR	1210-1750	0.625	865	0.0315 (0.084)	2 (10)	0.22 (1.6)	0.21 (0.58)	0.30 (0.50)
SWIR	2155-2550	0.625	633	0.00766 (0.014)	2 (10)	0.22 (1.6)	0.37 (0.77)	0.52 (0.64)

S-NPP CrIS FSR SDR 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 Uncertainty @287K BB (%)
LWIR	650-1095	0.625	713	0.101 (0.14)	2 (10)	0.25 (1.6)	0.16 (0.45)	0.17 (0.45)
MWIR	1210-1750	0.625	865	0.0522 (0.084)	2 (10)	0.25 (1.6)	0.19 (0.58)	0.21 (0.58)
SWIR	2155-2550	0.625	633	0.00741 (0.014)	2 (10)	0.25 (1.6)	0.40 (0.77)	0.28 (0.77)

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

** Geolocation uncertainty is based on worst case for all scan angles (Provided by Likun Wang). Specification is based on 3-sigma mapping uncertainty of 5 km (1-sigma=1.66km).

¥ NOAA-20 and S-NPP RU account accounts for the polarization effect.

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

NOAA-20 CrIS SDR User Feedback

Name	Organization	Application	User Feedback - User readiness dates for ingest of data and bringing data to operations
Antonia Gambacorta antonia.gambacorta@noaa.gov	STAR	Atmospheric Soundings*	June 15, 2018
Andrew Collard andrew.collard@noaa.gov	NCEP	NWP	May 30, 2018
Peter Weston peter.weston@ecmwf.int	ECMWF	NWP	September 11, 2018

*A data file containing the new NOAA-20 CrIS FSR NEdN, after EP v115 upload, was provided to NUCAPS team on August 15, 2018. Noise was computed using all FOVs except MWIR FOV7 noise.

NOAA-20 CrIS SDR Risks, Actions, and Mitigations

- No major risks have been identified for the NOAA-20 CrIS SDRs. Fine tuning is being performed to further improve the quality of the NOAA-20 CrIS SDR data.

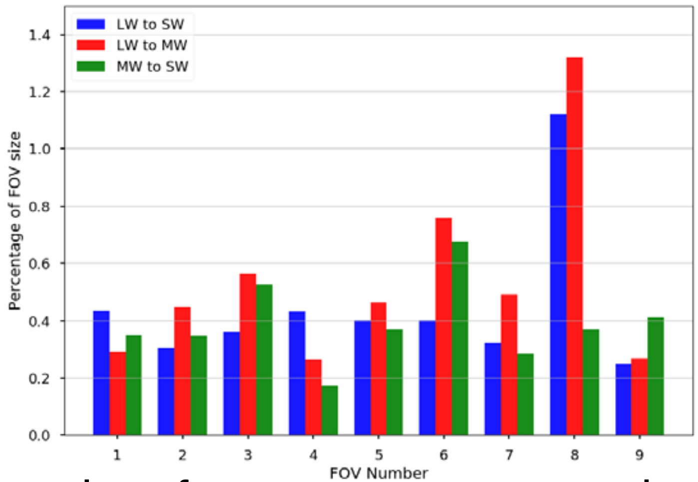
NOAA-20 CrIS Processing Environment and Algorithms

- Description of processing environment and algorithms used to achieve validated maturity stage:
  - Algorithm version (builder): IDPS Block 2.1 MX 2.
  - Version of Look-Up Tables (LUTs) used:
    - CMNGEO-PARAM-LUT_j01_20160331000000Z_20170714135000Z_ee00000000000000Z_PS-1-O-CCR-16-2859-v002-LE-PE_all-_all_all-_ops
    - CrIS-FS-SDR-DQTT_j01_20170918100000Z_20180111000000Z_ee00000000000000Z_PS-1-O-CCR-15-2278-LE-PE_all-_all_all-_ops (FSR)
    - CrIS-FS-SDR-FILL-PACKET-LUT_j01_20180404000000Z_20180430000000Z_ee00000000000000Z_PS-1-O-CCR-3908-LE-PE_all-_all_all-_ops (FSR)
    - CrIS-SDR-DQTT_j01_20170918180000Z_20180111000000Z_ee00000000000000Z_PS-1-O-CCR-14-1791-002-LE-PE_all-_all_all-_ops (NSR)
    - CrIS-SDR-FILL-PACKET-LUT_j01_20180404000000Z_20180430000000Z_ee00000000000000Z_PS-1-O-CCR-3908-LE-PE_all-_all_all-_ops (NSR)
  - Version of Processing Coefficient Tables (PCTs) used:
    - CrIS-FS-SDR-CC_j01_20170926000000Z_20180126000000Z_ee00000000000000Z_PS-1-O-CCR-3661-LE-PE-V001-001_all-_all_all-_ops (FSR)
    - CrIS-SDR-CC_j01_20170926000000Z_20171218160000Z_ee00000000000000Z_PS-1-O-CCR-3540-LE-PE-V001-001_all-_all_all-_ops (NSR)
  - Effective date: August 14, 2018.

NOAA-20 CrIS Waivers

Waiver	CCR	Approval Date	Requirements	Description	Impact
MA-04-027	472-CCR-14-0793	1/8/2015	CrPRD-11202	**The centroid of the FOV of all channels within a band** and also for each band with the same nominal FOV location **shall fall in a circle with a diameter equal to 1.4% of the 50% FOV width specified in Table 4.2.1.1.1-1**. Chromatic aberrations in the optical system are contained inside the 1.4% value.	No Level-1 requirements are affected by the FOV waiver
MA-04-027	472-CCR-14-0793	1/8/2015	CrPRD-11196	The shape of the FOVs shall be inside the tolerance envelope specified in Table 4.2.1.1.1-1. (FOV diameter = 0.944 +/- 0.014º, band-to-band shape match +/- 0.014º)	No Level-1 requirements are affected by the FOV waiver

Both waivers are small and are a result of the FOV 8 shape no longer being circular. The centroid of the FOV of all channels (within a band) match, with a small shift that *does not impact the Level-1 science requirements*.



Provided by Likun Wang

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

Documentation

Science Maturity Check List	Yes ?	Where
ReadMe for Data Product Users	Yes	
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, 2018 STAR JPSS Annual Meeting

Rationales for Validated Maturity

1. Product performance has been demonstrated over a large and wide range of representative conditions

NOAA-20 CrIS SDR performance has been demonstrated globally for more than six months.

2. 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

Comprehensive documentation of instrument status and product performance exists, including: ICVS reports, Algorithm Theoretical Basis Document (ATBD), Operational Algorithm Description (OAD), ReadME file, Cal/Val plan and regular validation reports.

3. Product analyses are sufficient for full qualitative and quantitative determination of product fitness-for-purpose

NOAA-20 CrIS meets or exceeds specification requirements for radiometric, spectral, geolocation, and noise performance; comparable to or better than S-NPP CrIS

4. Product is ready for operational use based on documented validation findings and user feedback

In operations at NOAA/NCEP on May 30, 2018, ECMWF on September 11, 2018 and NUCAPS on June 15, 2018.

5. Product validation, quality assurance, and algorithm stewardship continue through lifetime of the instrument

CrIS SDR team maintains the algorithm and product validation and continues to improve algorithm performance to ensure the quality of the NOAA-20 CrIS SDR product.

NOAA-20 CrIS Validated Maturity SDR Data Product Caveats (1/2)

1. The MWIR FOV 9 has high NEdN and is out of family. However, the noise performance of this FOV is within specifications and was expected since prelaunch measurements.
2. Due to the flight software update performed on NOAA-20 from 12:07 on February 2, 2018 to 15:59 on February 3, 2018, CrIS data are lost for this period. All instruments were set in safe mode during the flight software update.
3. Due to the incorrect default bias tilts values for Dx and Dy in the flight software, CrIS SDR data have higher NEdN at SWIR (some FOVs increasing 20%, but still meet the specification) compared to pre-flight software update. This issue was corrected around 18:38 GMT on February 16, 2018 when the EP v114 was uploaded and the interferogram (IM) configuration commanding were performed in the flight software. This problem occurred after the flight software update performed during the February 2-3, 2018 period (caveat 2).
4. On July 24, 2018, the CrIS SDR Team informed the Flight Software Working Group (FSWWG) about potential errors in the instrument configuration associated with incorrect bias tilts, after an anomaly experienced on July 19, 2018. Although still meeting the specifications, this increased the NEdN at SWIR channels. The FSWWG confirmed the CrIS SDR team about errors on the bias tilts. On July 26, 2018 at 18:45 UTC the proper instrument configuration (correct bias tilts) and setup commands were uploaded to avoid future incorrect bias tilts occurring after the instrument is set on safe mode (caveat 3 and 4).

NOAA-20 CrIS Validated Maturity SDR Data Product Caveats (2/2)

5. Due to a software bug affecting the determination of the interferometer sweep direction (forward and reverse), the data quality indicators and quality flag with explicit dependence on sweep direction are impacted. These indicators are not employed by users. Affected indicators and flags are: DS_WindowSize, ICT_WindowSize, DS_SpectralStability, ICT_SpectralStability, ICT_TemperatureStability, ICT_TemperatureConsistency, NumberOfValidPRTTemps, and quality flag QF2_CRISSDR. Overall data quality flag (QF3) and radiance products are not impacted. This caveat will be fixed after 10/02/2018, when Block 2.1 Mx 3 goes into operations (DR 8629).
6. There are several anomalies related to missing RDR packets for NOAA-20 CrIS SDR. Earth Scenes (ES) SDRs are found to have bad quality flags and FILLED values on the radiance and Lat/Lon fields. However, corresponding RDRs are not corrupted, when the cross granules (4 before and after of the center granule) have missing ES RDR packets. Another anomaly occurred when Internal Calibration Target (ICT) packets are missing in a moving window. In this case, the SDR radiances are labelled as 'degraded' as a result of excessive thermal drift due to the error to handle the missing ICT packets. Less than 0.01% SDR data expected to be impacted. These anomalies were fixed in IDPS software on May 24, 2018 (DR 8653) by implementing the out-of-cycle LUTs for j01 CrIS-FS-SDR-FILL-PACKET-LUT and CrIS-SDR-FILL-PACKET-LUT.

Summary of NOAA-20 CrIS Performance

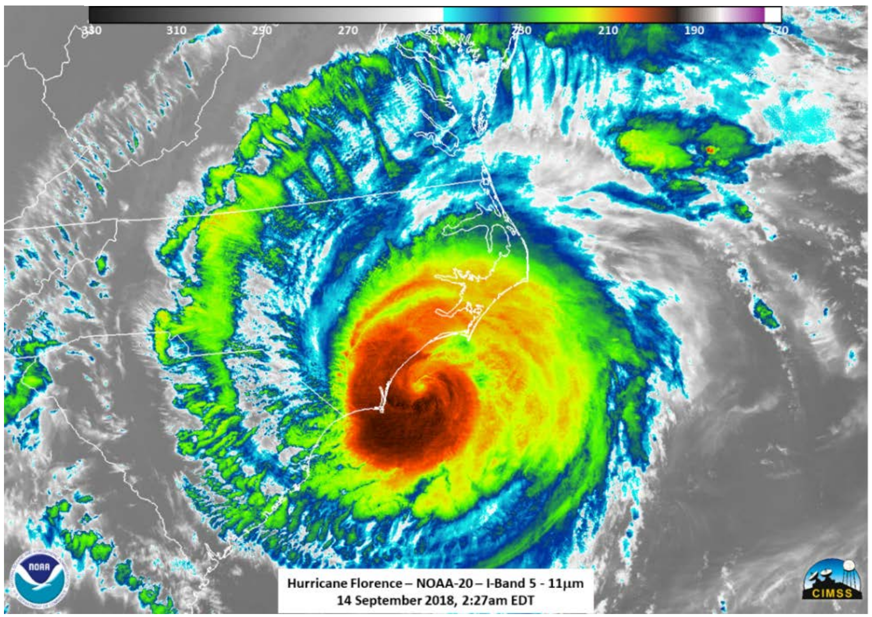
1. NOAA-20 CrIS SDR performance has been demonstrated globally for more than six months, since Provisional Maturity.
2. The on-orbit noise performance of all FOVs and bands are within the specification (MW FOV9 is out of family).
3. The spectral uncertainty, relative and absolute, for all three bands are all within ±2 ppm.
4. The radiometric uncertainty given as a percent of the 287 K blackbody radiance is 0.19%, 0.21% and 0.37% for the long-, mid- and short-wave infrared band, respectively. Radiometric FOV2FOV consistency for LW and MW bands are within 0.1 K.
5. The geolocation uncertainty is within 220 meters for all FORs using VIIRS as the geolocation reference.
6. Radiometric differences between SNPP and NOAA-20 are within ±0.1 K for the majority channels. The estimated differences were derived from the simultaneous nadir overpass (SNO) double-difference approach using MetOp-B/IASI as a transfer radiometer and double-difference from radiative transfer calculations as a transfer target.
7. NOAA-20 CrIS SDR has shown long-term noise, spectral and geolocation stability.
8. The NOAA-20 CrIS SDR data is sufficient for use on qualitative and quantitative assessments, as well as for operational use.
9. NOAA-20 CrIS SDR data has been utilized in NOAA/NCEP operational NWP system since May 30, 2018, and September 11, 2018 in ECMWF.
10. NUCAPS NOAA-20 temperature and water vapor products are being distributed to users after reaching the provisional maturity level on June 15, 2018.

Path Forward for the NOAA-20 CrIS Instrument

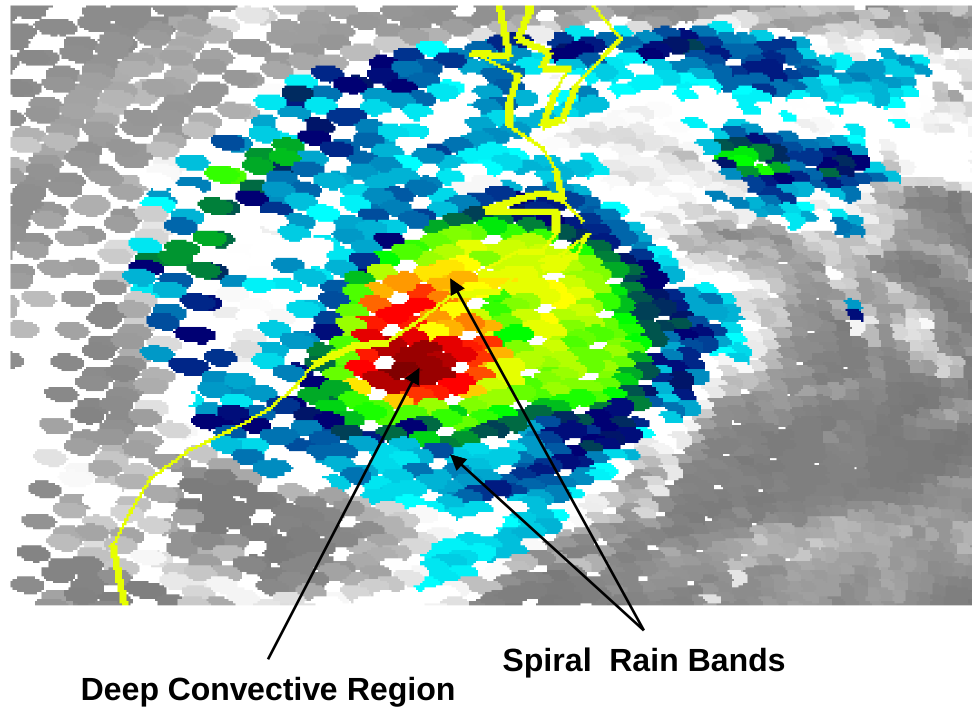
1. Continue to monitor the instrument long term stability and performance (NEdN, responsivity, geolocation, radiometric and spectra accuracy), as well as SDR data quality.
2. Continue to inter-compare the NOAA-20 CrIS instrument with other sensors (IASI, VIIRS, and ABI), and provide the radiometric uncertainty.
3. Implement the polarization correction in IDPS. When and how to turn on this implementation depends on users' request.
4. Reprocessing NOAA-20 CrIS data before EP v115 (August 14, 2018), using the same calibration coefficients and the latest IDPS software to improve the data consistency for the whole mission.
5. Assess the impact of the operational spike detection and correction algorithm on the quality of the CrIS SDR data.
6. Assess the impact of the sweep direction indicator and Quality Flags improvements on the quality of the CrIS SDR data.
7. Include the lunar intrusion algorithm in IDPS Block 2.1 MX4 (12/17/2018) and assess its impact on the quality of the CrIS SDR data.
8. Investigate further the non-linearity of the NOAA-20 CrIS MWIR FOV9.
9. Investigate the potential refinement of the NOAA-20 CrIS ICT Environmental Model.
10. Continue the characterization of the instrument performance following the NOAA-20 CrIS Calibration/Validation Plan.
11. Integrate the lessons learned from NPP and NOAA-20 CrIS into J2 CrIS by using the developed methodologies and procedures for the characterization and calibration of J2 CrIS. As part of the Polar Follow-ON (PFO) planned activities, the CrIS SDR Team is moving toward future higher spatial resolution IR hyperspertral observations by discussing the implementation of a 7 km CrIS FOV size for J4.

Hurricane Florence Landing Observed by NOAA-20 CrIS

NOAA-20 VIIRS Brightness Temperature
I5 Band (5-11µm)
14 September 2:27am EDT

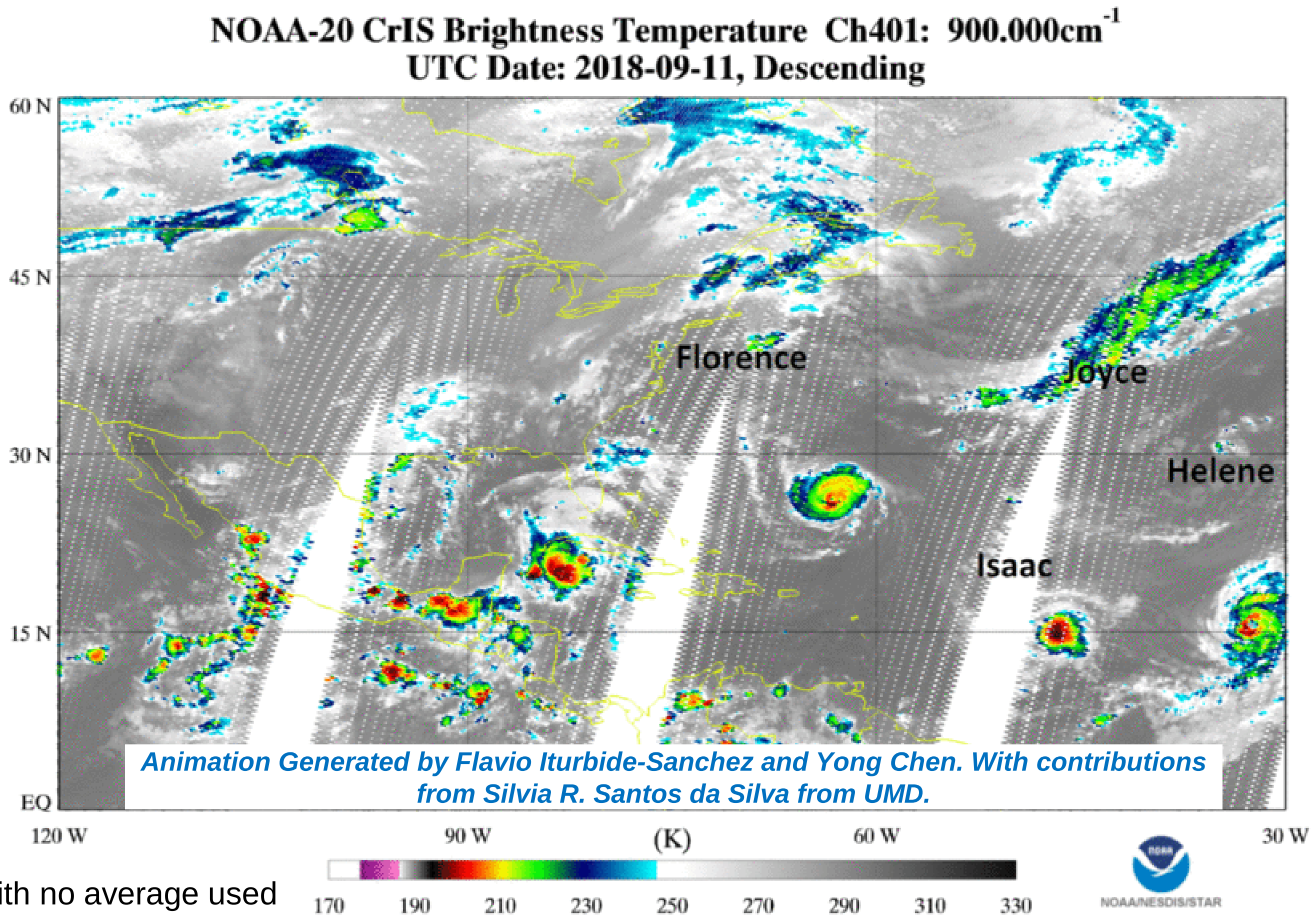


NOAA-20 CrIS Brightness Temperature
at 900 cm^{-1}
14 September 2:27am EDT



Indirect assessment of the quality of the NOAA-20 CrIS SDR Data

Tracking of Atlantic Tropical Cyclones using Combined S-NPP and NOAA-20 CrIS Observation at 900.0 cm^{-1}



9 FOVs with no average used

CrIS observations also help identify different Hurricane development stages: deep organized convection around hurricane Florence, convection around tropical storm Isaac becoming disorganized between Sep/11 and 13, development of tropical storm Joyce on Sep/12 from a low pressure system in the north Atlantic, Helene evolving toward a weaker and disorganized convective pattern on Sep/13.