Beta Maturity Science Review
For NOAA-21 CrIS SDR

Presented by Flavio Iturbide-Sanchez and
the CrIS SDR Cal/Val Science Team
Date: 02/23/2023

Outline

- Executive Summary
- Product Overview, Requirements and Waivers
- Quality flag analysis and validation
- Cal/Val Timeline
- EP Update
- Evaluation of the NOAA-21 CrIS SDR Performance
  - NOAA-21 Telemetry Analysis (ICT, OMA, Scan Baffle temperatures and detector coolers)
  - Bit Trim Mask verification
  - NEdN noise performance
  - Radiometric performance (from CrIS SDR team, UW and UMBC)
  - Spectral performance (from CrIS SDR team, UW and UMBC)
  - Geolocation Accuracy
  - Downstream User Feedback (NUCAPS)
  - Analysis of Imaginary and Real Radiances
- Risks, actions and mitigations
- Justification, Caveats and Path Forward
- Potential Benefits of 3 JPSS Satellites

The CrIS SDR Cal/Val Science Team and Collaborators

Team Lead	Organization	Team	Major Tasks
Flavio Iturbide-Sanchez (Science Team Lead)	**NOAA/STAR** Cal/Val Team	**GST:** Kun Zhang, Denis Tremblay, Arun Ravindranath **UMD:** Peter Beierle, Lin Lin	Science Lead and Project Management; SDR Team Coordination and Algorithm Test in IDPS; Algorithm/Software Sustainment and Maintenance; Noise, Geolocation, Radiometric and Spectral Characterization; Inter-comparison; Long-term SDR Data Quality and Monitoring; Science Support
Dave Tobin	**U. of Wisconsin (UW)** Cal/Val Team	Hank Revercomb, Joe Taylor, Bob Knuteson, Lori Borg, Michelle Loveless, Dan Desolver	Radiometric Calibration; Radiometric Error Budget and Uncertainty; Noise Characterization; Non-linearity Correction; Polarization Correction; Inter-comparison; Science Support
Larrabee Strow	**U. of Maryland Baltimore County (UMBC)** Cal/Val Team	Howard Motteler, Sergio de Souza-Machado, Chris Hepplewhite, Steven Buczkowski	Spectral Calibration; Neon Calibration System; Self-Apodization Correction (e.g. ILS parameters); Inter-FOV Variability; Inter-comparison; Radiometric Stability; Science Support
Dave Johnson	**NASA Langley**	Yana Williams	NASA Flight Support; Instrument Science
Joe Predina	**Logistikos**	Richard Hertel, James Isaacs, Glen White, Mark Searfoss, Perry Falk & Fred Williams	Anomaly Resolution and Instrument Science
Sara Glass	**L3Harris**	Lawrence Suwinski, Jeff Garr, Rebecca Malloy, Mike Pries, Brian Case, Chad Eviston, Kris Kombrink	Instrument Manufacturer; On-ground and On-orbit Instrument Characterization and Support
Deirdre Bolen	**NOAA/JPSS**		Algorithm Manager; Discrepancy Report Support

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.

Executive Summary for Beta Review

- From assessments, the CrIS cal/val team has shown that the NOAA-21 CrIS SDR data meets the Beta Maturity Requirements in terms of:
  - Noise (NEdN) performance: All FOVs and bands within the specification, compares well to S-NPP and NOAA-20, no out-of-family detectors showing high NEdN values.
  - Radiometric performance: radiometric FOV2FOV consistency improved for LW and MW bands (within 0.1 K).
  - Spectral performance: spectral offsets for relative and absolute for all three bands are all within ±6 ppm.
  - Geolocation performance: Geolocation meets the requirements using EP V208 but further improvements will be made following the upload of EP v211, at which point the uncertainty will be expected to be comparable to S-NPP and NOAA-20.
- NOAA-21 CrIS SDR products have been reliably produced by IDPS since first science data on February 10, 2023. No Discrepancy or Risk Reports have been submitted during this period associate with the CrIS SDR Algorithm.

CrIS SDR JPSS L1-Requirements

Product Requirements from JPSS L1RD

Band	Minimum Wavenumber Range[1] (cm^{-1})	# of Channels[4]	Spectral Resolution (cm^{-1})[1,3]	Maximum NEdN @287K BB[2] ($mW/m^2/sr/cm^{-1}$)	Radiometric Accuracy @287K[1,2] (%)	Maximum FOV Footprint at Nadir FOV (km)	Maximum Spectral Uncertainty[1] (ppm)	Geolocation Mapping Uncertainty (3σ)[1] (km)
LWIR	650-1095	713	0.625	0.45 @ 670 cm-1, 0.15 @ 700 cm-1, 0.15 @ 850 cm-1, 0.15 @ 1050 cm-1	0.45	15	10	5
MWIR	1210-1750	865	0.625	0.078 @ 1225 cm-1 0.064 @ 1250 cm-1 0.069 @ 1500 cm-1 0.075 @ 1700 cm-1	0.58	15	10	5
SWIR	2155-2550	633	0.625	0.013 @ 2200 cm-1 0.014 @ 2350 cm-1 0.014 @ 2550 cm-1	0.77	15	10	5

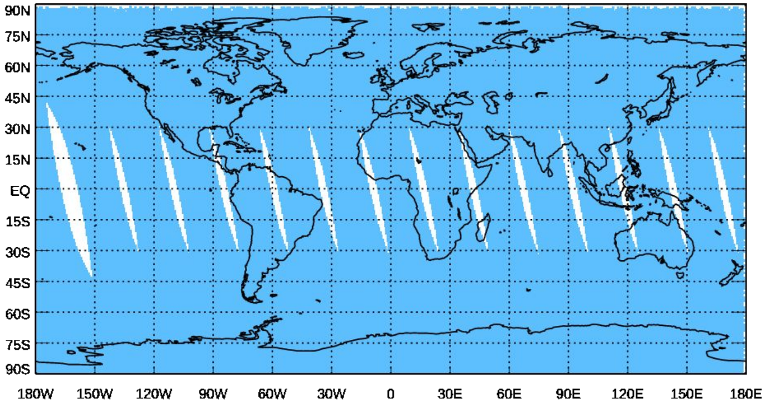
[1]JPSS Algorithm Specification Volume I: Software Requirement Specification (SRS) for the CrIS RDR/SDR, 474-00448-01-03, Revision I, October 24, 2019.
[2]JPSS Level 1 Requirements Document Supplement (L1RDS) – Final, JPSS-REQ-1002/470-00032, Revision 2.11, Rev. 2.1, 02/07/2019. The NEdN Maximum values for the MWIR and SWIR are the result of scaling the NEDN values, defined in Table 4.3, by a factor of $\sqrt{2}$ and 2, respectively.
[3]JPSS-2 CrIS Performance Requirements Document (PRD), 472-00346, Revision B, 03/10/2016.
[4]JPSS CrIS SDR ATBD) for Full Spectral Resolution, June 14, 2018.

Overall Data Quality Flag (2/21/2023)

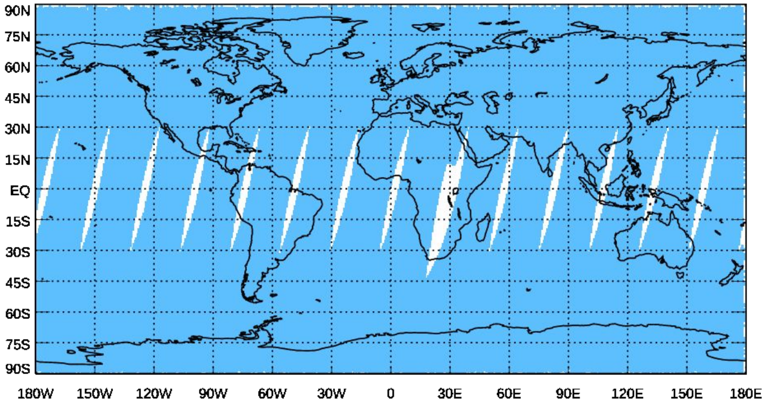
Long-Wave

NOAA-21 CrIS Long Wave SDR Overall Quality Flag, Mapped, Ascending, 02/21/2023

(Sky Blue: Good; Green: Degraded; Red: Invalid)



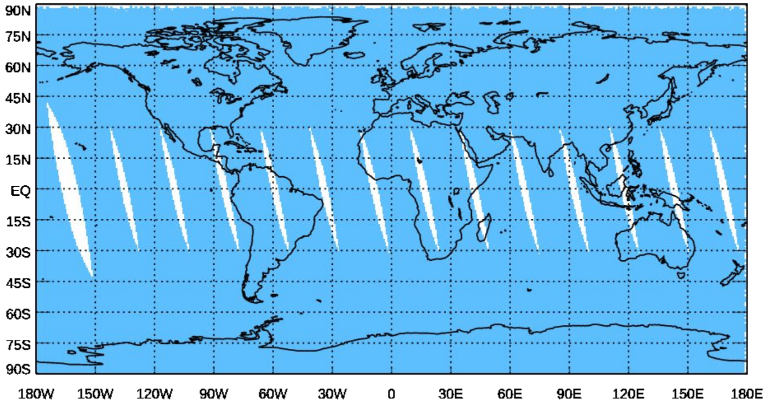
NOAA-21 CrIS Long Wave SDR Overall Quality Flag, Mapped, Descending, 02/21/2023



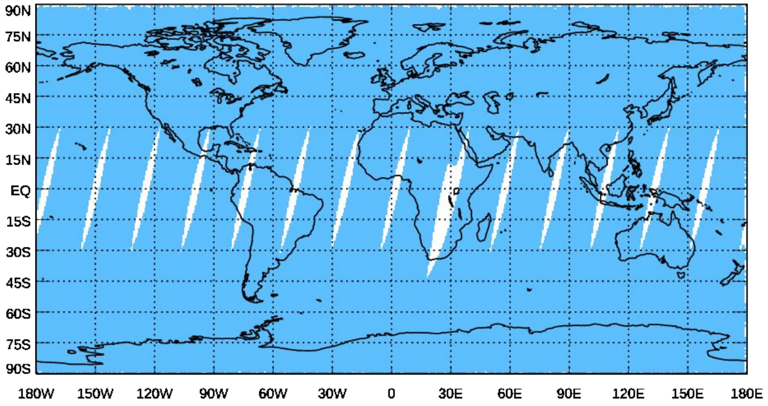
Mid-Wave

NOAA-21 CrIS Mid Wave SDR Overall Quality Flag, Mapped, Ascending, 02/21/2023

(Sky Blue: Good; Green: Degraded; Red: Invalid)



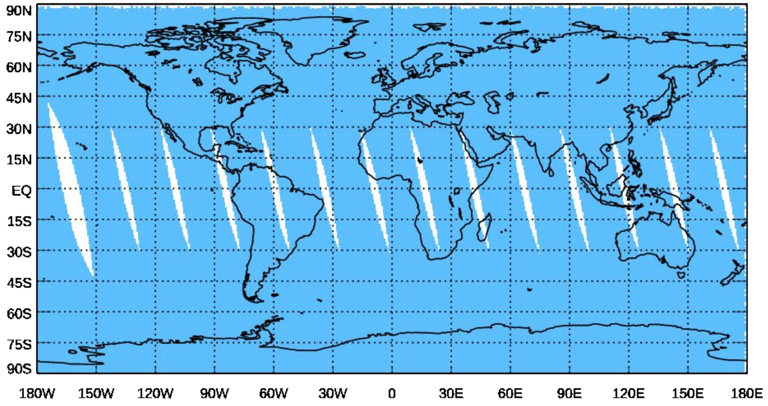
NOAA-21 CrIS Mid Wave SDR Overall Quality Flag, Mapped, Descending, 02/21/2023



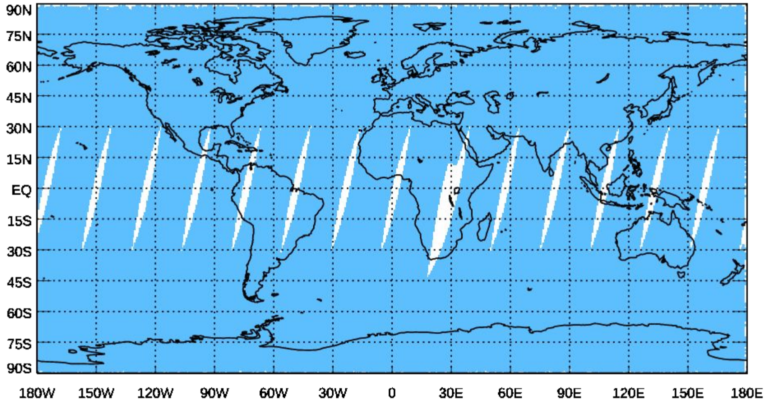
Short-Wave

NOAA-21 CrIS Short Wave SDR Overall Quality Flag, Mapped, Ascending, 02/21/2023

(Sky Blue: Good; Green: Degraded; Red: Invalid)

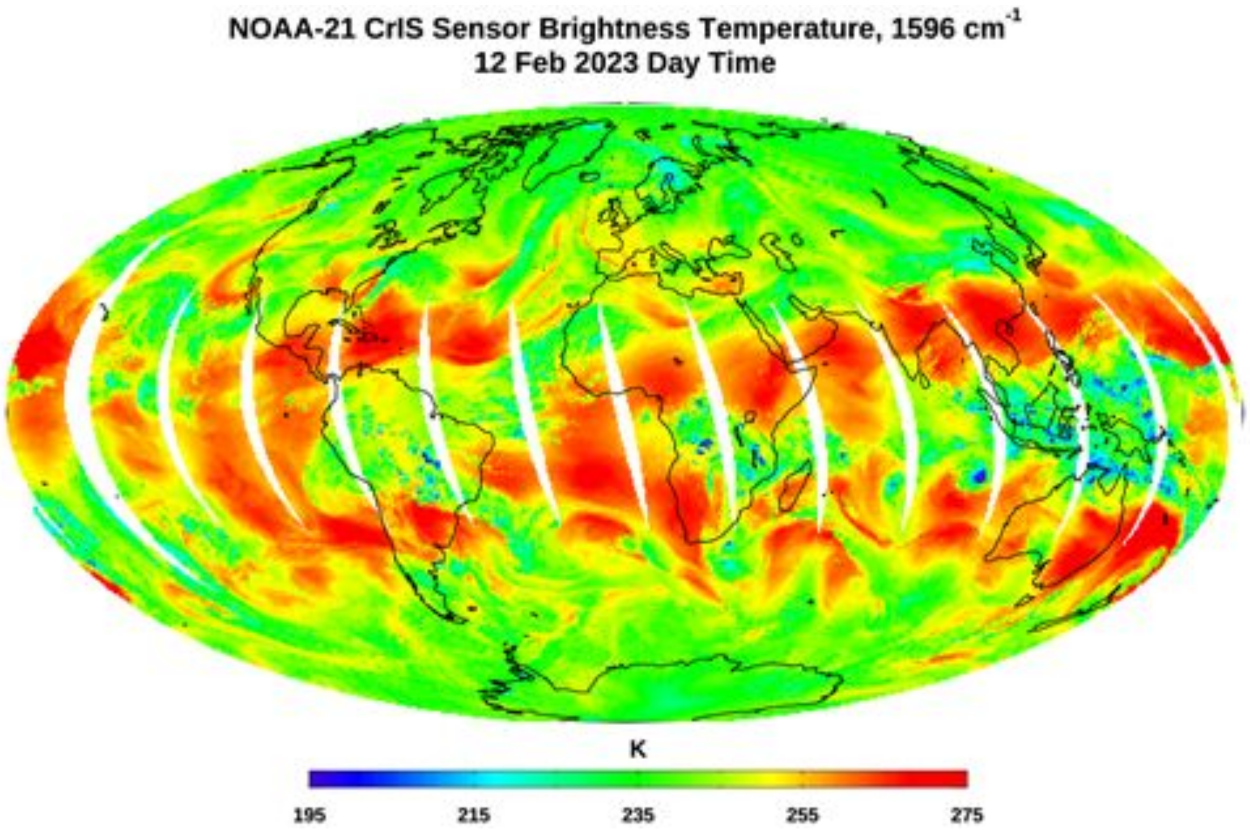


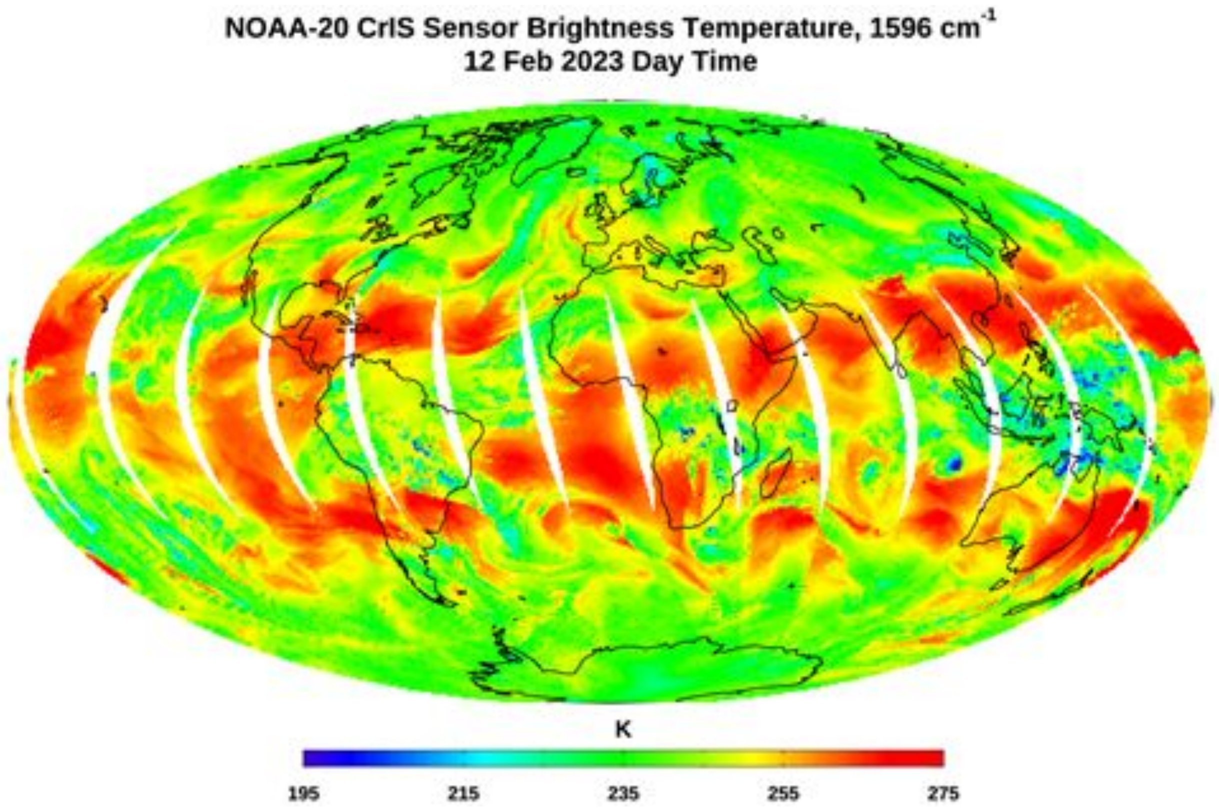
NOAA-21 CrIS Short Wave SDR Overall Quality Flag, Mapped, Descending, 02/21/2023



Since First Science Data and After the Upload of EP v210 on February 21, 2023, there has not been major Data gaps and signs or consistent Degraded or Invalid Spectra (Quality Flags indicate good data)

NOAA-21 vs NOAA-20 CrIS BT Map Comparison from First Light





Good global agreement between the CrIS sensor observations from NOAA-21 and NOAA-20 CrIS has been found. Radiances observed at the 1569 cm^{-1} water vapor channel on February 12, 2023

NOAA-21 CrIS

NOAA-20 CrIS

NOAA-21 CrIS Post-Launch Commissioning and Cal/Val Timeline

Launch day (date)	Flight Activity	Ground Activity
L + 0 (11/10/22)	Activation Process Starts (CrIS Warm Up Heaters Activation)	
L + 10 (11/20/22)		
L + 11 (11/21/22)	Begin CrIS Outgassing	
L + 88 (2/06/23)		OMPS Stray light maneuver
L + 90 (2/08/23)	End CrIS Outgassing; Deploy Cooler Door, **Initial Calibration Table Upload EP v208 (L3Harris and MOST)**	
L + 92 (2/10/23)	Cryoradiator Cooled, Instrument Stable, Power up Signal Processors and Detectors	**First Earth View Science Data is expected** CrIS Diode Temp, Infrared (IR) Gain Check, Bit Trim Mask, Impulse Noise Mask Check, Geolocation (In-track zero position, Pointing Accuracy), etc.
L + 99 (2/17/23)		Cal/Val Science Team and L3Harris Prepare and Deliver 1st Calibration Table (in the form of Eng. Packet) to MOST.
L + 103 (2/21/23)	**First Calibration Table upload EP v210* (L3Harris and MOST)** with Vinst, PGA gain, TVAC param**. (ILS and Nonlinearity), and Geolocation parameters (adjusted for in-track zero position)	**Effective Beta Maturity Level on L+103** Jitter Performance, Spectral Cal/Laser Stability, Detector Noise/Linearity, Full Spectral Resolution Diagnostic, Geolocation (Pointing Accuracy)
L + 121 (3/11/23)		Cal/Val Science Team and L3Harris Prepare and Deliver 2nd Calibration Table (in the form of Eng. Packet) to MOST
L + 126 (3/16/23)	**Second Calibration Table Upload EP v211* (L3Harris and MOST)** with optimized Nonlinearity, Geolocation and ILS parameters	**Effective Provisional Maturity Level on L+126**

We are Here →

- **Tentative Engineering Packet Version Number **TVAC Parameters provided by UW and UMBC.**
- Replanning after SMD transmitter switch has not proceeded into March, so timeline is estimated.

Upload of the NOAA-21 CrIS EP v210 on February 21, 2023

The Calibration Table for NOAA-21 CrIS was successfully uploaded on February 21, 2023 at 16:03 UTC (EP v210). A summary of the major updates include:

a) Update of Vinst values.

b) Updated Bit Trim Mask.

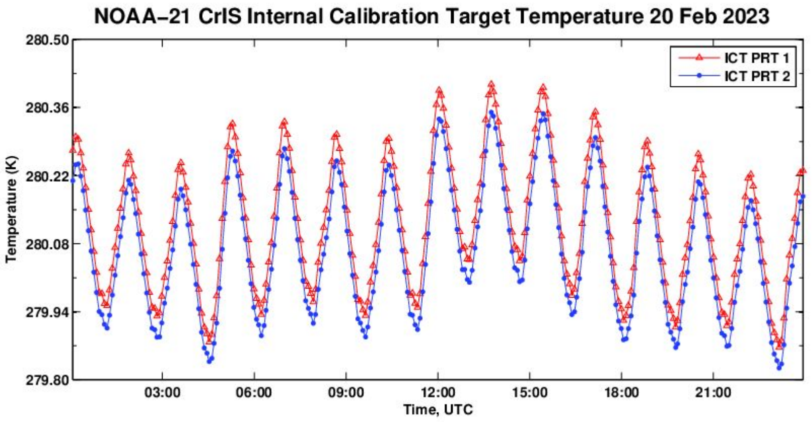
c) Updated of PGA Gain values.

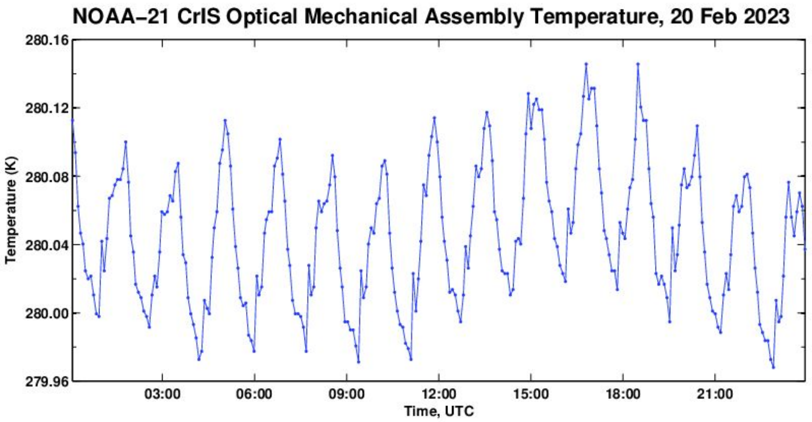
d) Update of ILS and Nonlinearity coefficients based on TVAC-derived values.

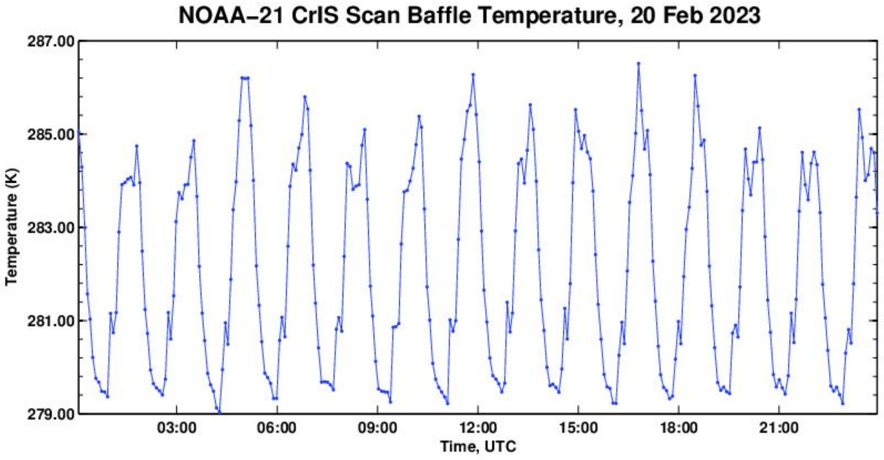
e) Updated Geolocation Pointing accuracy (in-track only, adjusted for in-track null position).

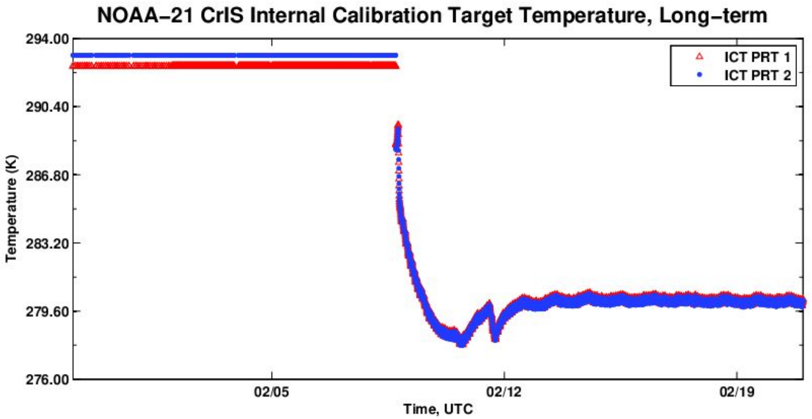
NOAA-21 CrIS Science Telemetry: ICT, OMA & Scan Baffle Temperatures

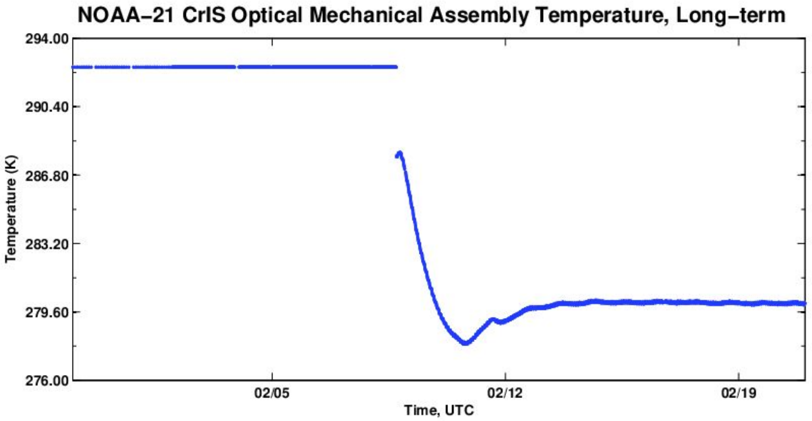
- **Critical CrIS modules have cooled down, reached nominal temperatures, and stabilized**
- Includes Internal Calibration Target, Optical Mechanical Assembly, and Scan Baffle/SSM Mirror Temperatures

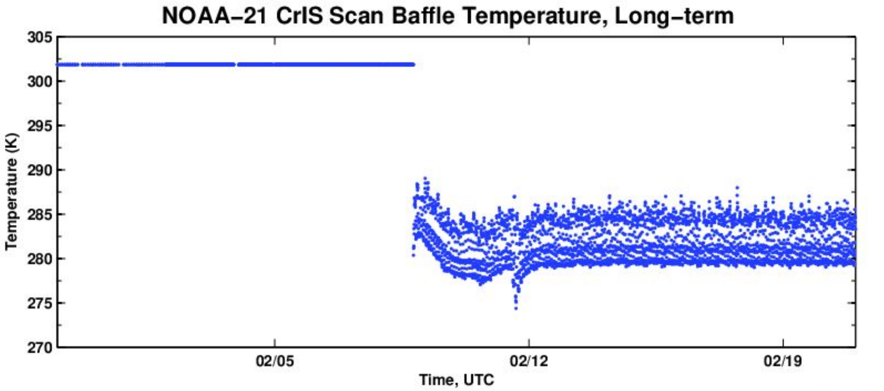








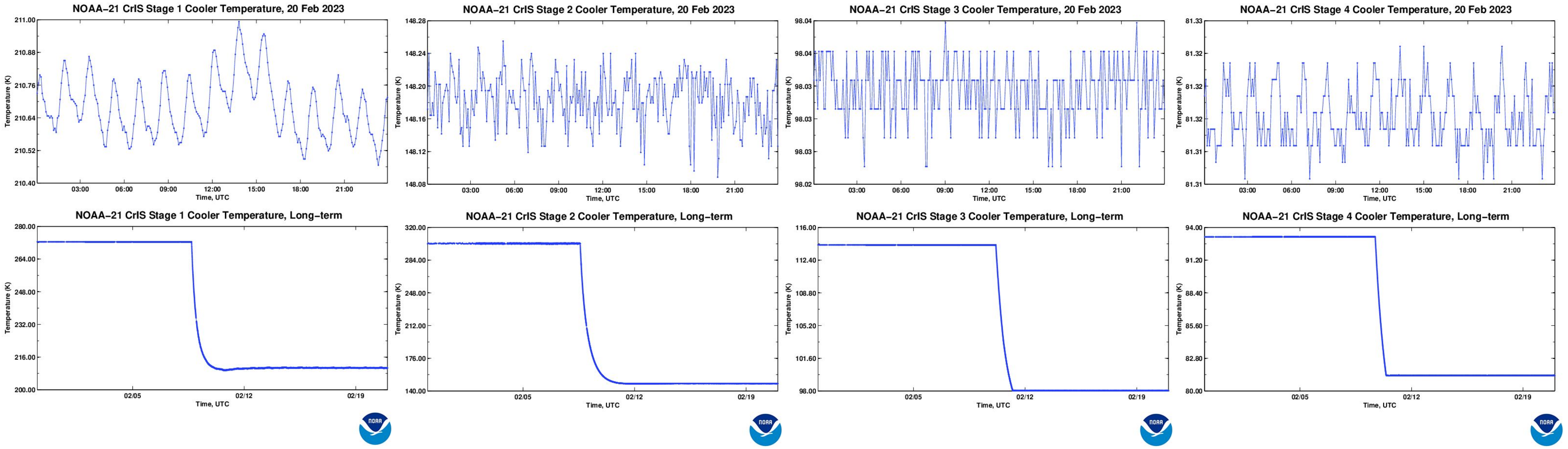




Provided by Peter Beierle

NOAA-21 Detector Cooler System Telemetry

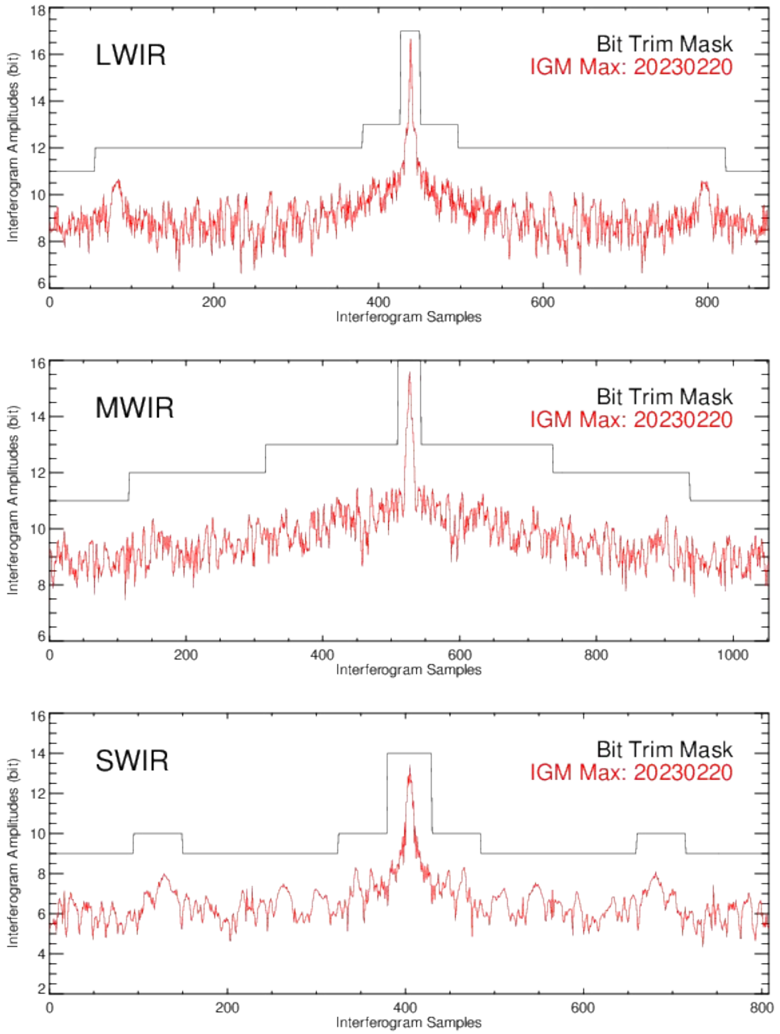
Detector Stage Coolers have cooled down, reached nominal temperatures, and stabilized



Provided by Peter Beierle

NOAA-21 CrIS Bit Trim Mask Verification

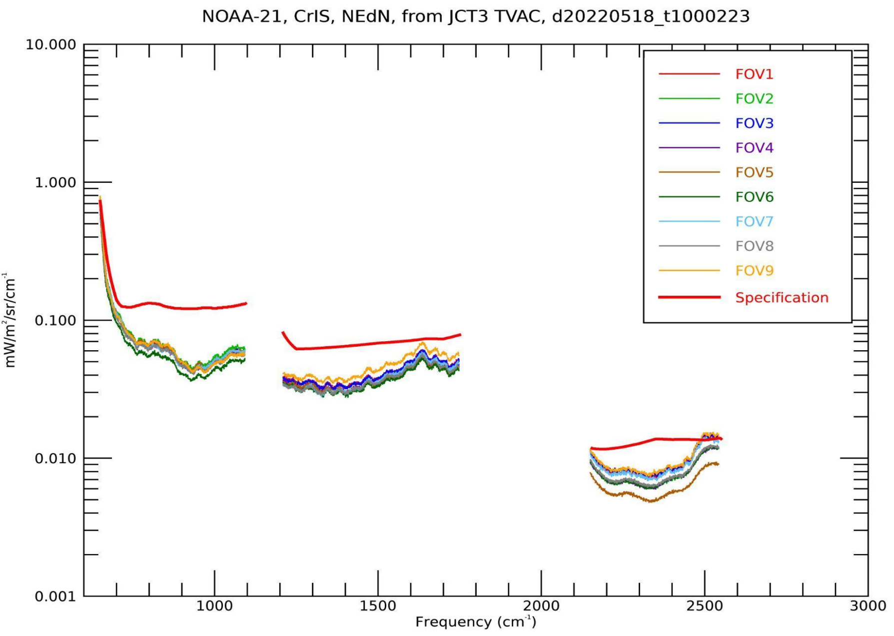
The bit-trim mask was validated using 20 February, 2023 SDR as inputs using the **Bit Trim Mask** from **EP v210**. The results confirm the **sizes of the masks of the 3 CrIS Spectral Bands exceed the maximum bits needed to transmit the Earth View Scenes (No signs of saturated interograms).**



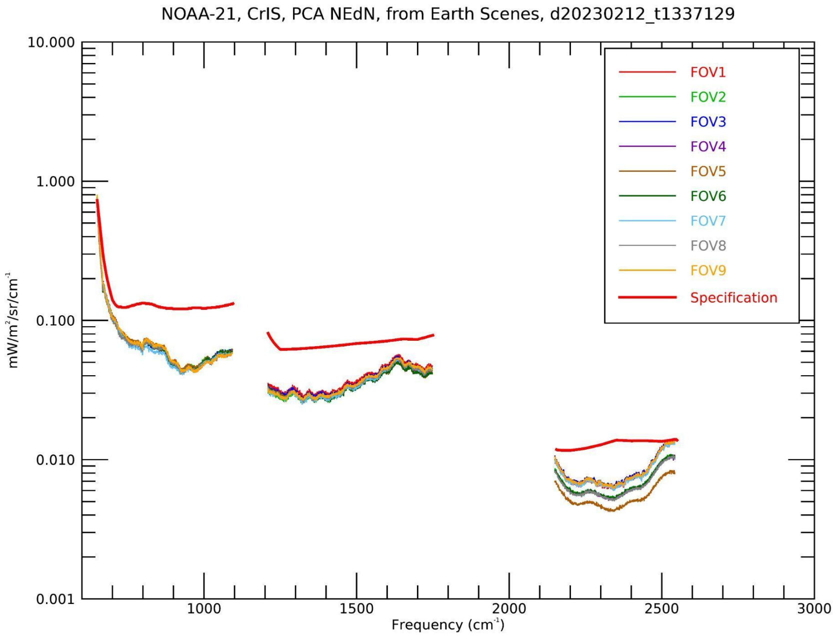
Provided by Peter Beierle

NOAA-21 CrIS Pre-launch and On-orbit Performance: Noise

NOAA-21 JCT3 TVAC, 5/18/2022



NOAA-21 On-Orbit, 2/12/2023



PCA NEdN (Turner Method) on 5/18/2022 (JCT3 TVAC), and from SDR on-orbit Earth Scenes on 2/12/2023

NEdN meets the requirements.

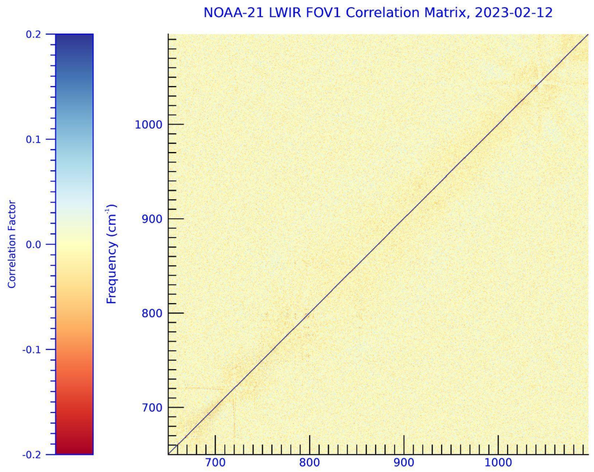
- **On orbit NEdN Compares well to 287K ECT TVAC NEdN** CrIS at Full Spectral Resolution
- Pre- and Post-launch NEdN are consistent, and **on-orbit NEdN already meets the requirements.**
- **LWIR and MWIR bands show lower variance in NEdN** for the on-orbit performance vs the TVAC
- **NOAA-21 CrIS shows high consistency noise performance between FOVs..**
- FOV spread in SW is a known effect of the algorithm (ISA correction) when applied to full resolution spectra.

Provided by Denis Tremblay

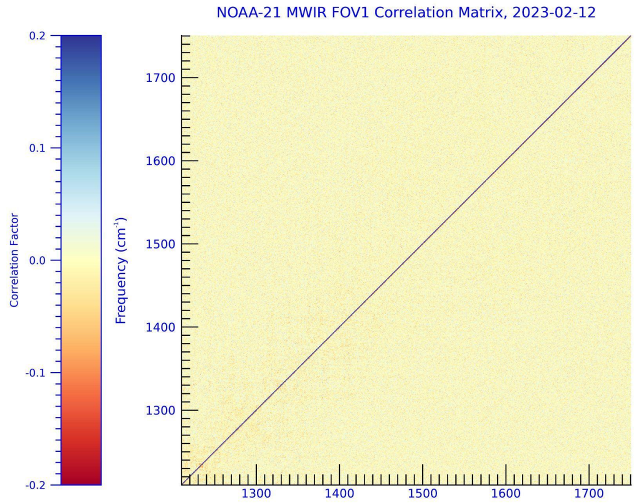
NOAA-21 CrIS on-orbit performance: Full Correlation Matrix

NOAA-21 on-orbit Full Correlation Matrices for FOV 1 (LWIR, MWIR, SWIR) on 2/12/2023

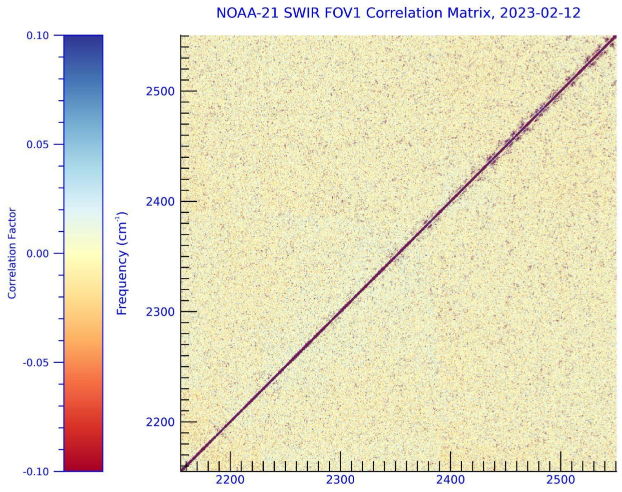
LWIR



MWIR



SWIR



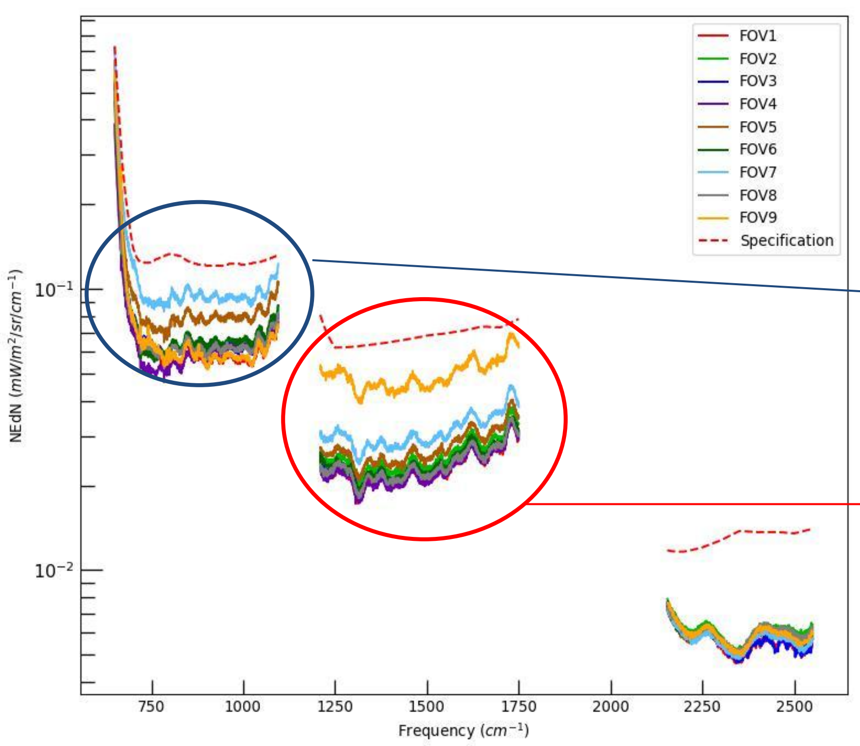
- SWIR near off-diagonal high values are due to SA effect (most for side FOVs, less for side FOVs, lesser for center FOV)
- Otherwise, **there is no sign of high cross correlation in noise between the channels**

Provided by Denis Tremblay

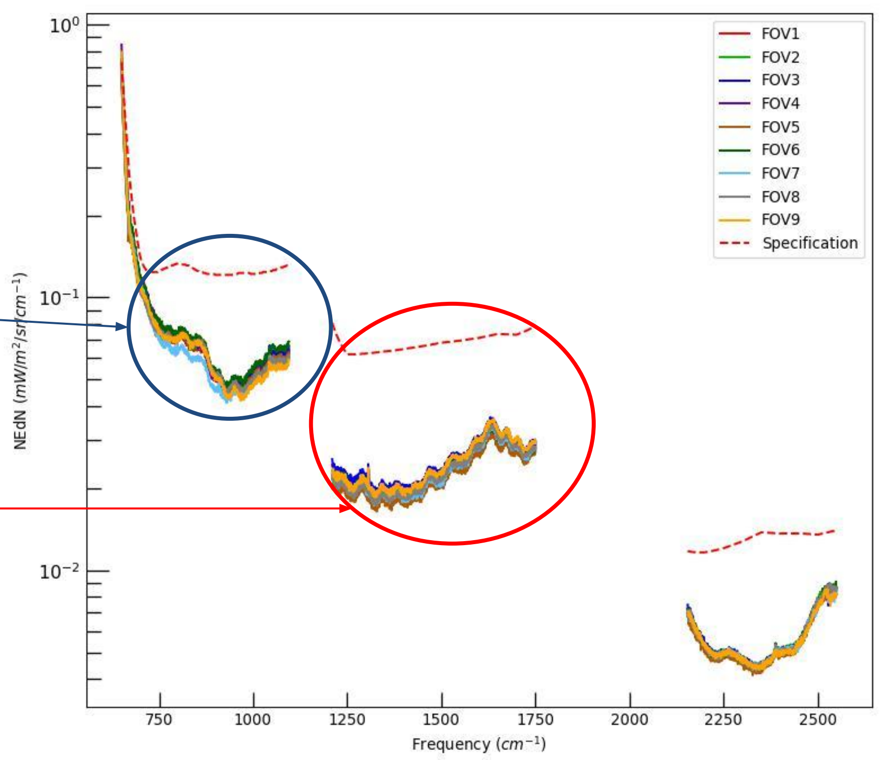
NOAA-20 vs NOAA-21 CrIS On-orbit Noise Performance

PCA NEdN Turner Method on 2/19/2023 (Without SA effect)

NOAA-20



NOAA-21



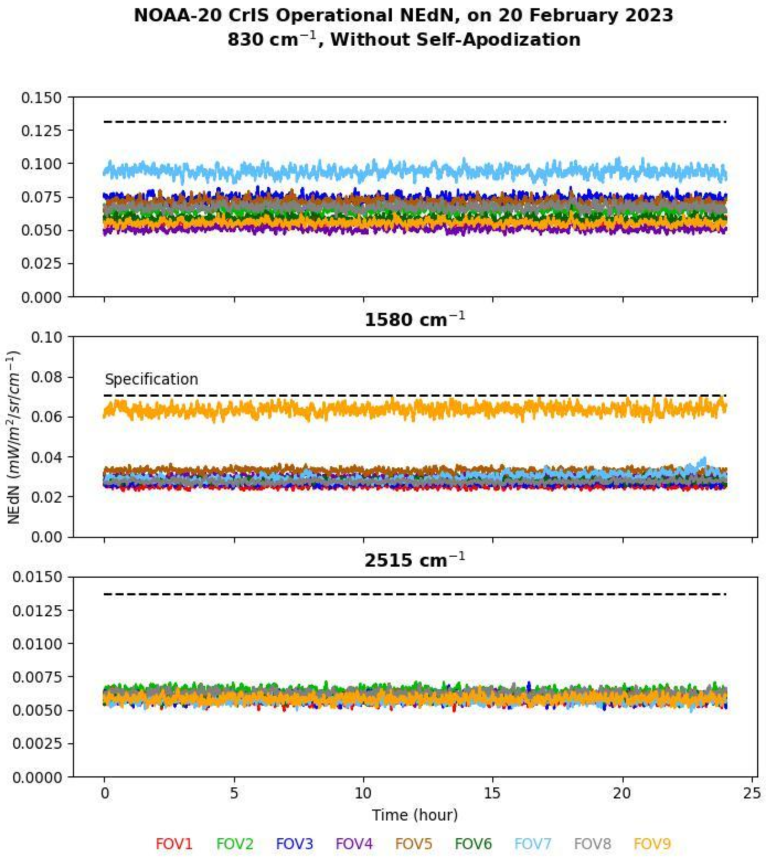
NOAA-21 has **no out outliers in the MWIR** and has **much less variance/spread in the LWIR and MWIR** bands for NEdN (noise). **Improved Consistency in noise levels between the FOVs.**

Provided by Denis Tremblay

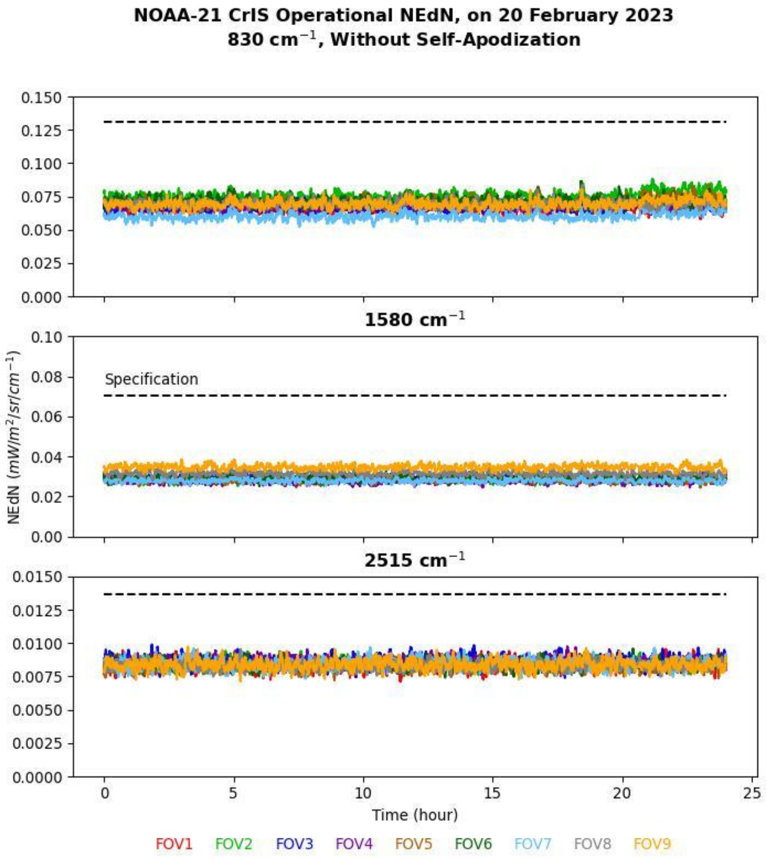
NOAA-21 CrIS post-launch and on-orbit performance: Noise

NEdN at Scan Level (2/20/2023)

NOAA-20



NOAA-21

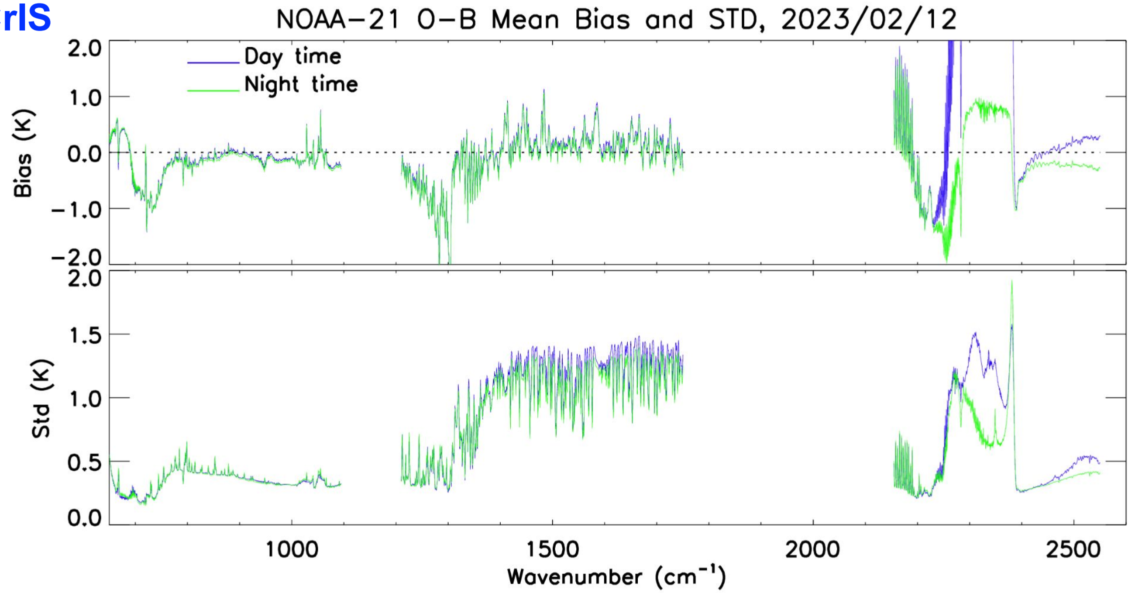


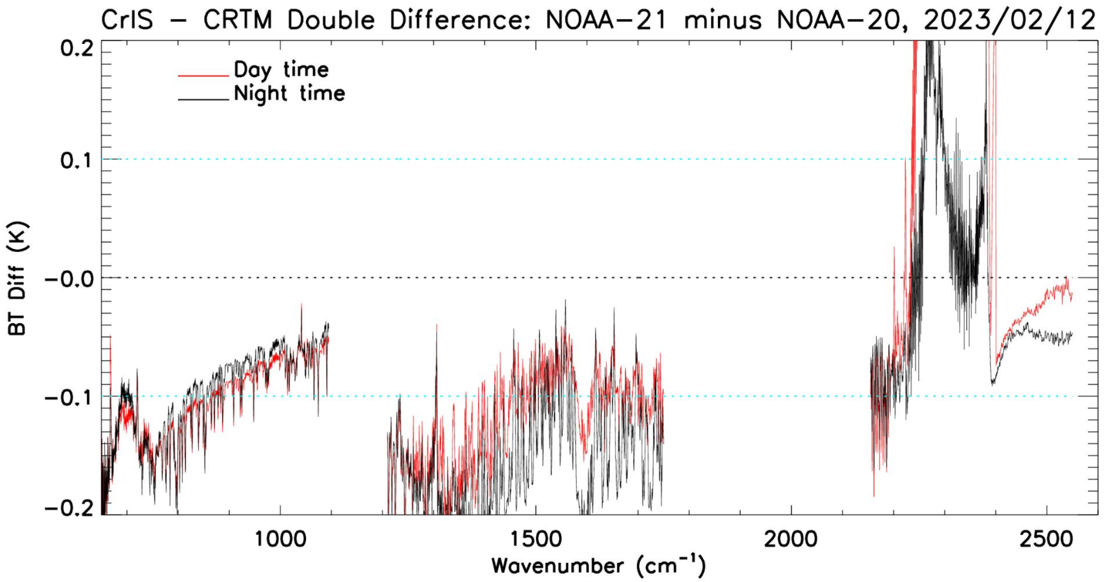
NOAA-21 CrIS Radiometric noise (NEdN) has shown stability of all detectors.

Provided by Denis Tremblay

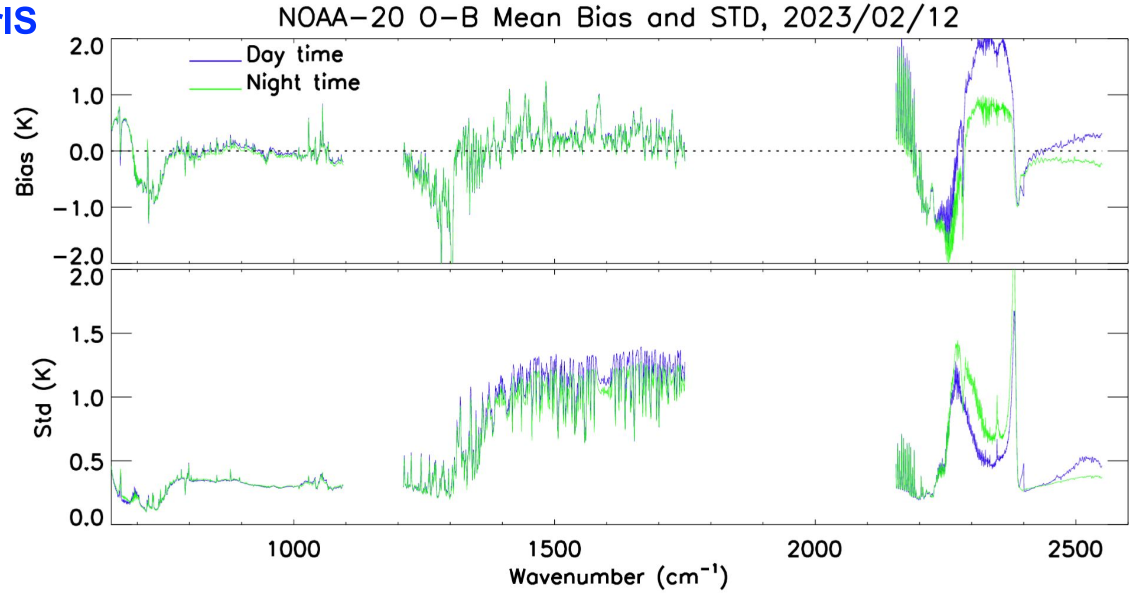
NOAA-21 CrIS Radiometric Comparison with NOAA-20

NOAA-21 CrIS





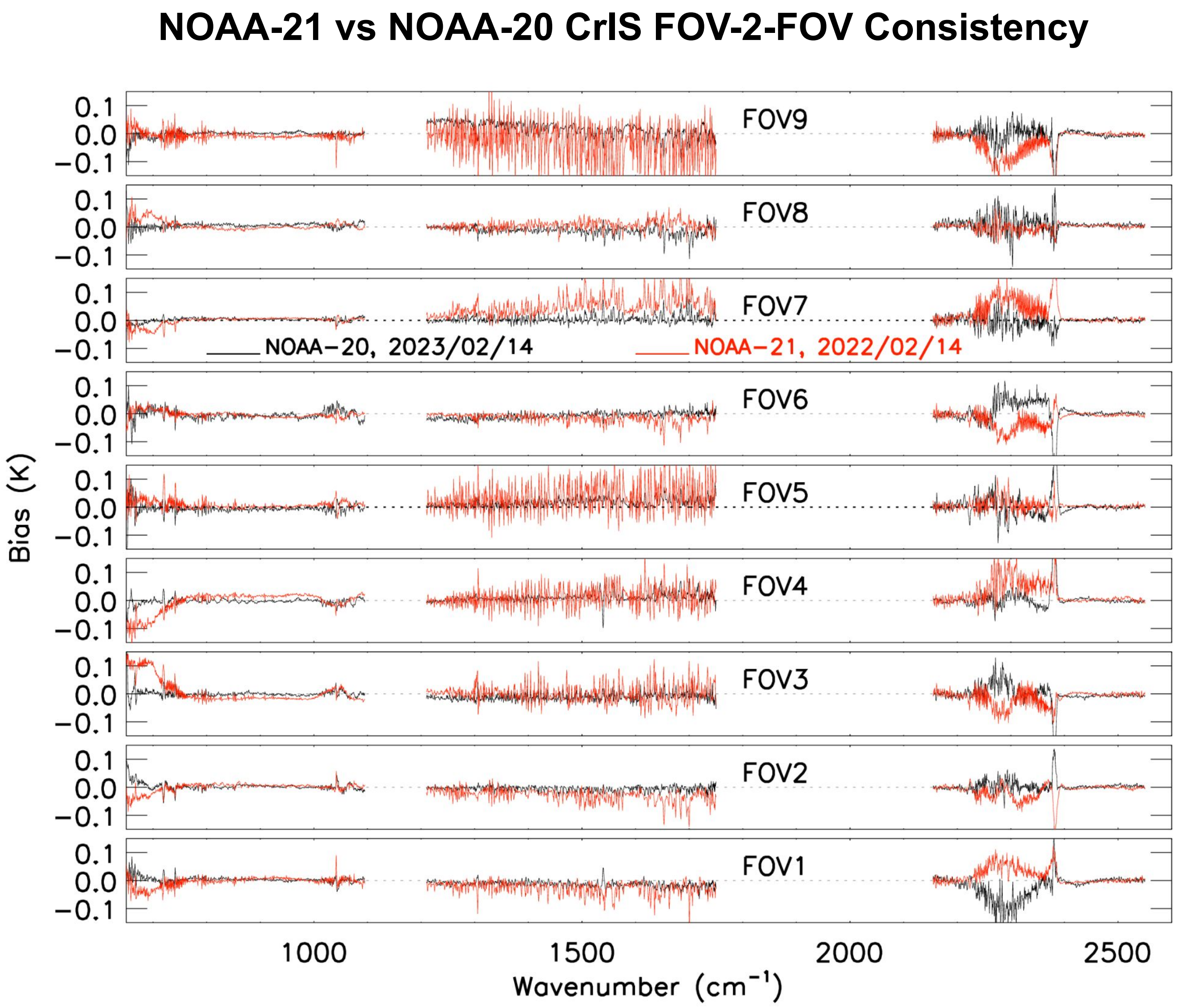
NOAA-20 CrIS



- **Radiometric differences are within +/- 0.2 K for most of channels in three bands.**
- All FOVs and FORs for clear-sky observations over ocean between +/- 65 deg latitude were selected for February 12, 2023.
- NOAA-21 CrIS Calibration Table v208 (prelaunch) was used.

Provided by Kun Zhang

NOAA-21 CrIS FOV-2-FOV Radiometric Consistency



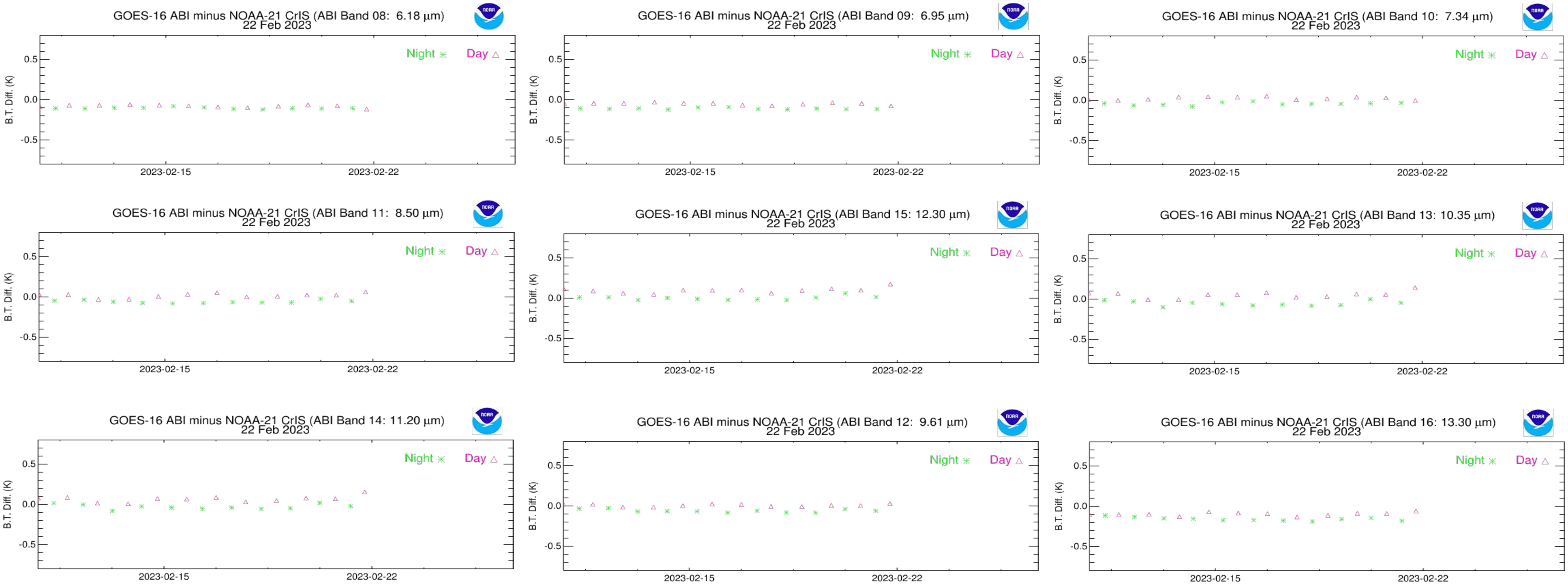
- **The FOV-2-FOV relative radiometric variability is within +/- 0.1 K in all three bands.**
- **The radiometric consistency at the lower end of the LWIR band will be improved by the planned non-linearity parameters optimization in EP v211.**
- The FOV-2-FOV relative radiometric variability was assessed by mean difference of observed and simulated apodized spectra for each FOV relative to the O-B mean bias.
- This result was derived using the NOAA-21 CrIS observations and collocated CRTM simulations over clear-sky and ocean surface for February 14, 2023.

Provided by Kun Zhang

NOAA-21 CrIS SDR/GOES-16 ABI Radiometric Inter-comparisons

- ABI bands 8-11 correspond to CrIS MWIR band and bands 12-16 correspond to CrIS LWIR band.
- **The comparison of the two instruments shows temporally stable brightness temperature biases (within 0.2K), <u>indicating the highly stable calibration of NOAA-21 CrIS Radiances</u>.**

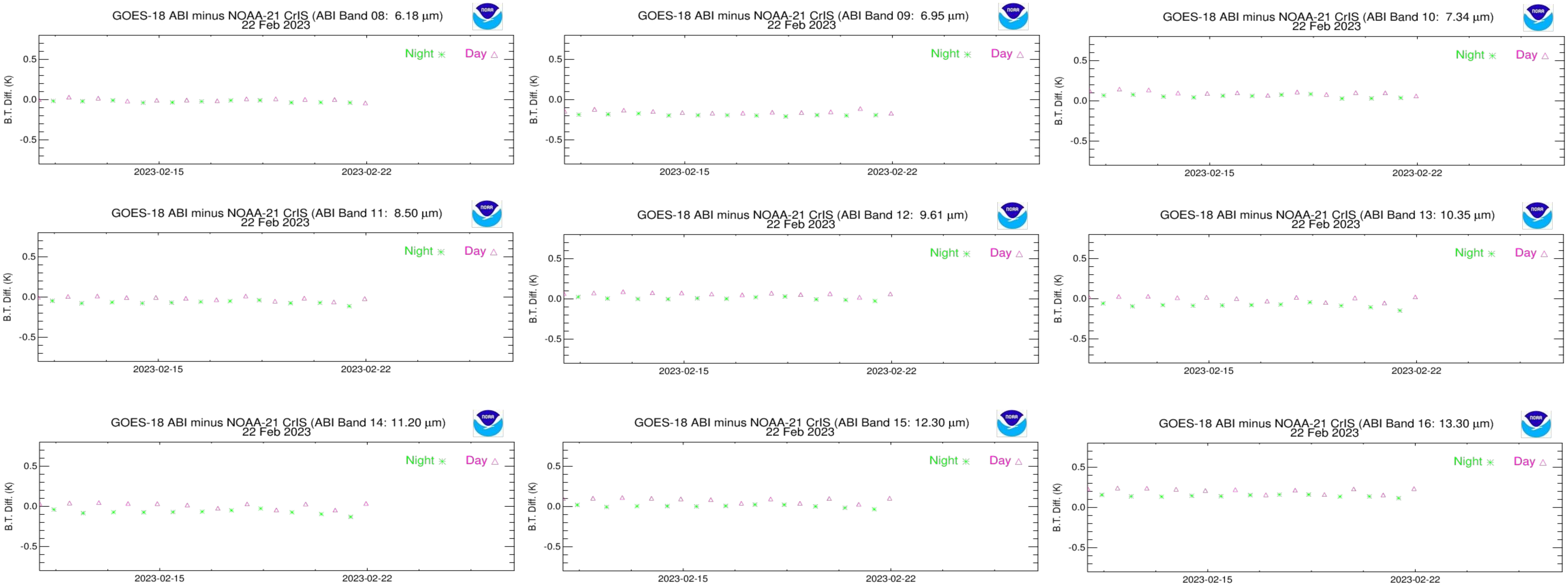
Provided by Lin Lin



NOAA-21 CrIS SDR/GOES-18 ABI Radiometric Inter-comparisons

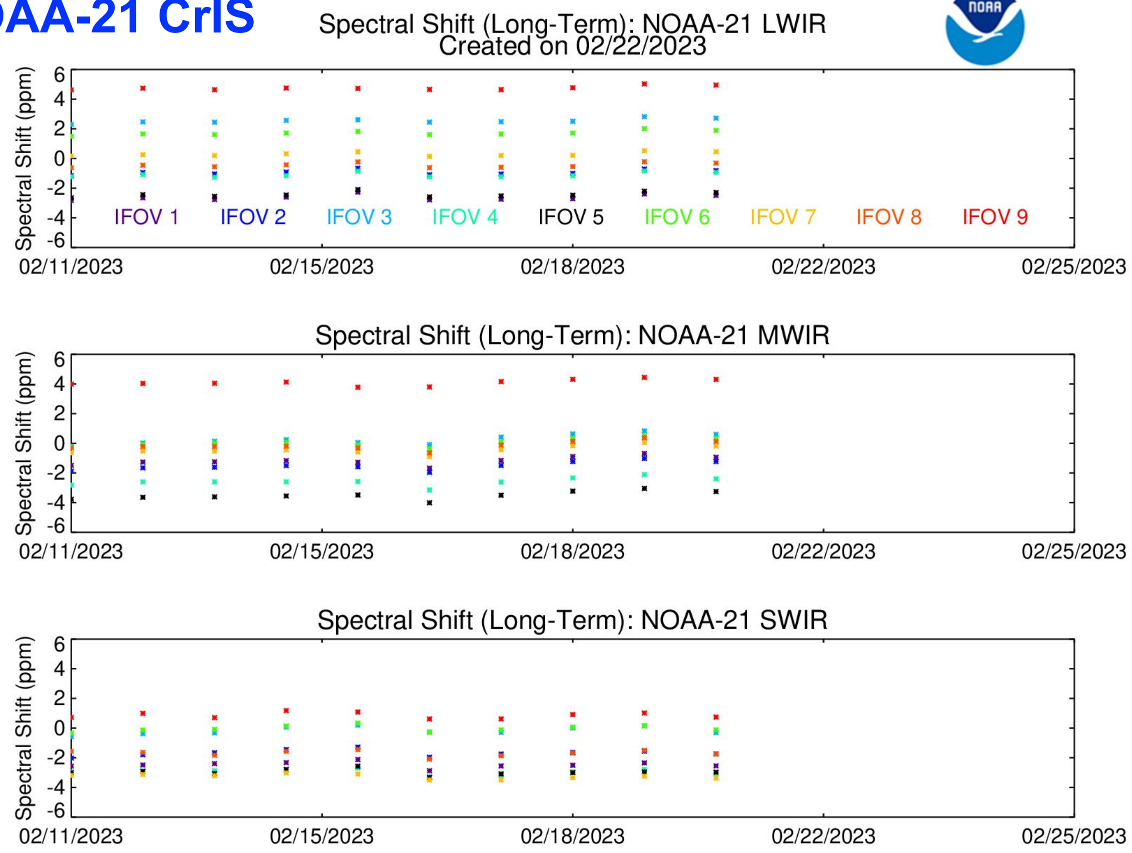
- ABI bands 8-11 correspond to CrIS MWIR band and bands 12-16 correspond to CrIS LWIR band.
- **The comparison of the two instruments shows temporally stable brightness temperature biases (within 0.2K), indicating the highly stable calibration of NOAA-21 CrIS Radiances.**

Provided by Lin Lin

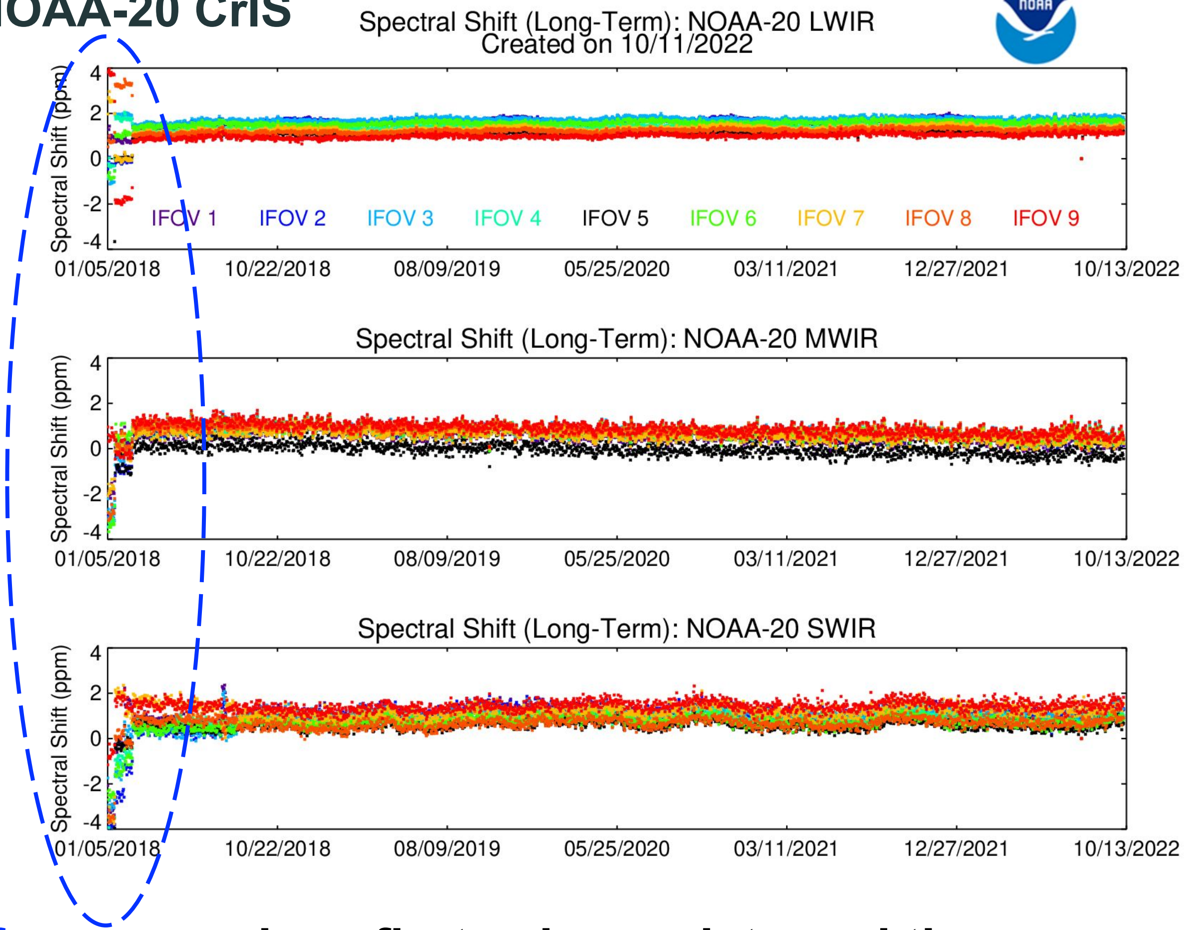


NOAA-21 CrIS Spectral Accuracy Comparisons with NOAA-20

NOAA-21 CrIS



NOAA-20 CrIS

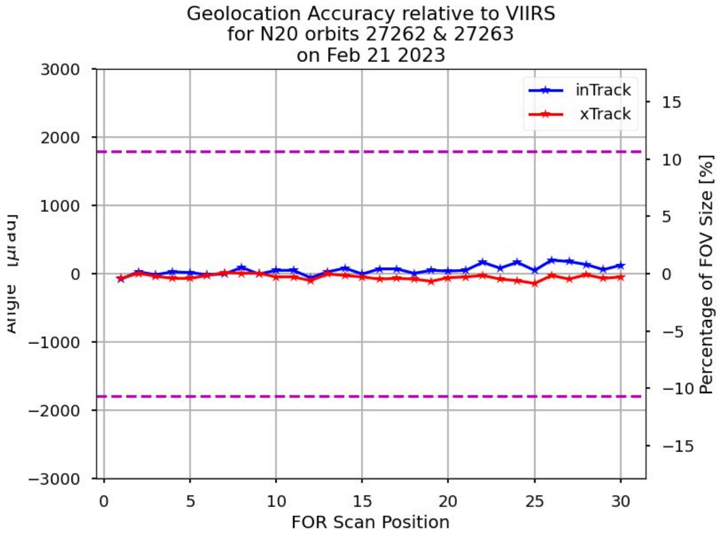


- **The NOAA-21 CrIS shows stable spectral performance since first science data and the absolute spectral accuracy meets the requirement (within 10 ppm).**
- **The spectral performance of NOAA-21 CrIS will be improved to the same level as previous CrIS instruments by the On-Orbit Calibration Table v211.**

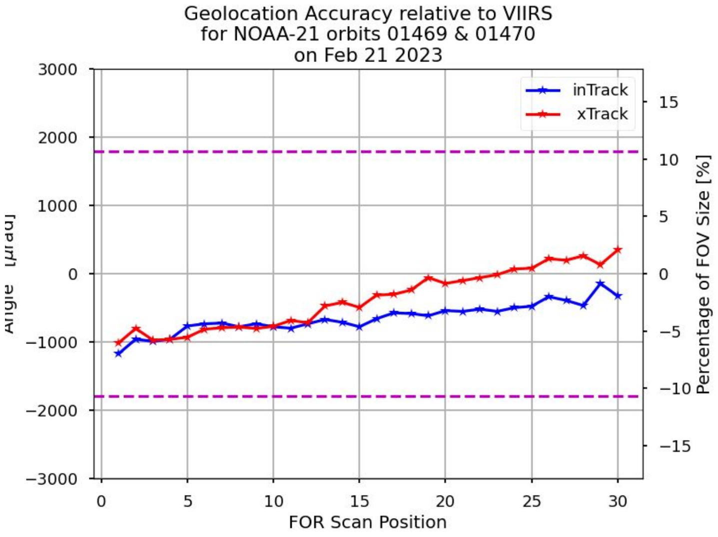
Provided by Kun Zhang

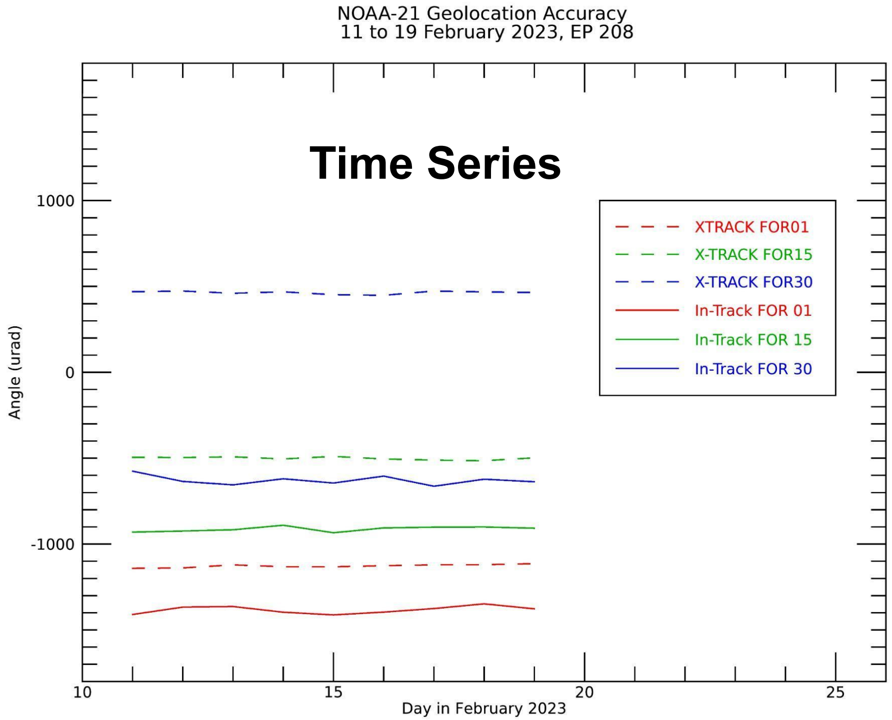
Geolocation Accuracy: NOAA-21 vs NOAA-20 (2/21/2023) and Time Series

NOAA-20



NOAA-21





- **Geolocation meets the requirements; however, the performance still a function of the sensor FOR.**
- Worst case performance: **FOR 1 total geolocation uncertainty amounts to 1.22 Km at nadir** (borderline with requirements) with EP V210.
- **With geolocation adjustment planned for EP V211, it is expected that the geolocation accuracy will be comparable to NOAA-20 (left).**

Geolocation accuracy are stable and within requirements (plot show performance for FOR 1, 15, and 30).

Provided by Denis Tremblay

Imaginary Radiance Observation

- What: **Slightly elevated imaginary radiance levels have been observed between 45-60 deg. S Latitude Region.**
- Why: Results from **heating of the SSM baffle** when illuminated by the Sun at high latitudes **when leaving satellite eclipse**, **causing a thermal transient seen in the Dynamic Alignment System response and Instrument temperatures.**
- **Result: Minimal impact is seen in real radiances, so no impact on downstream products is expected.**

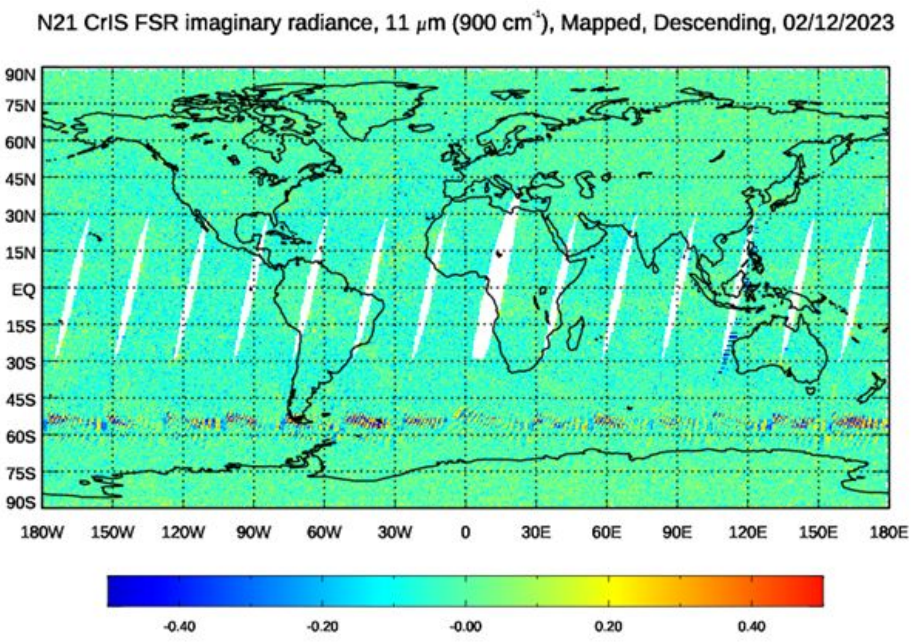
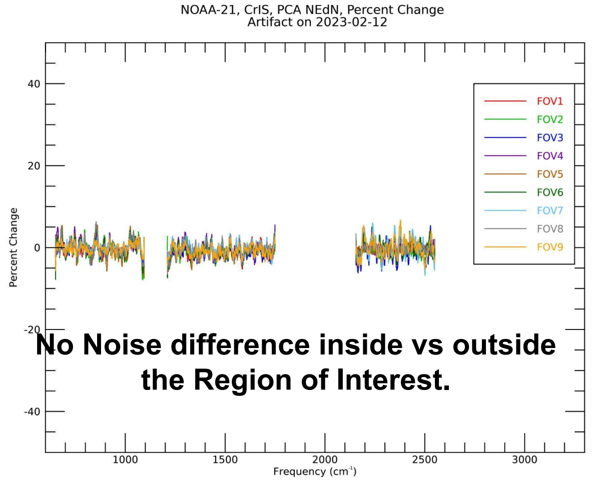
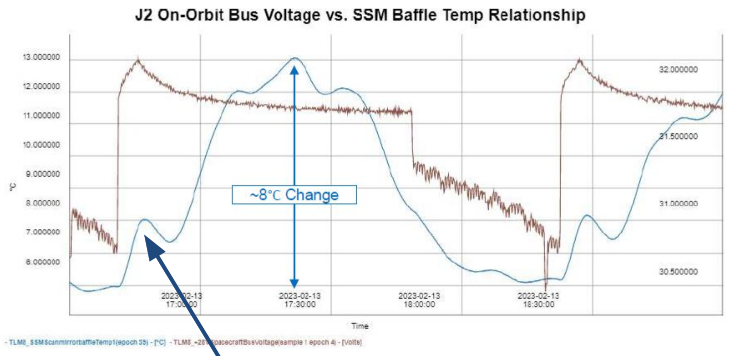


Figure Courtesy of ICVS



No Noise difference inside vs outside the Region of Interest.



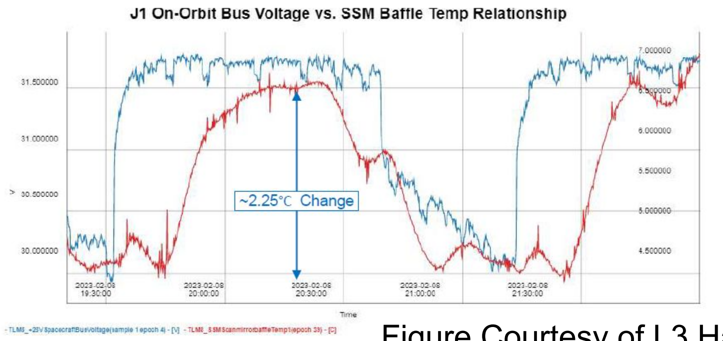
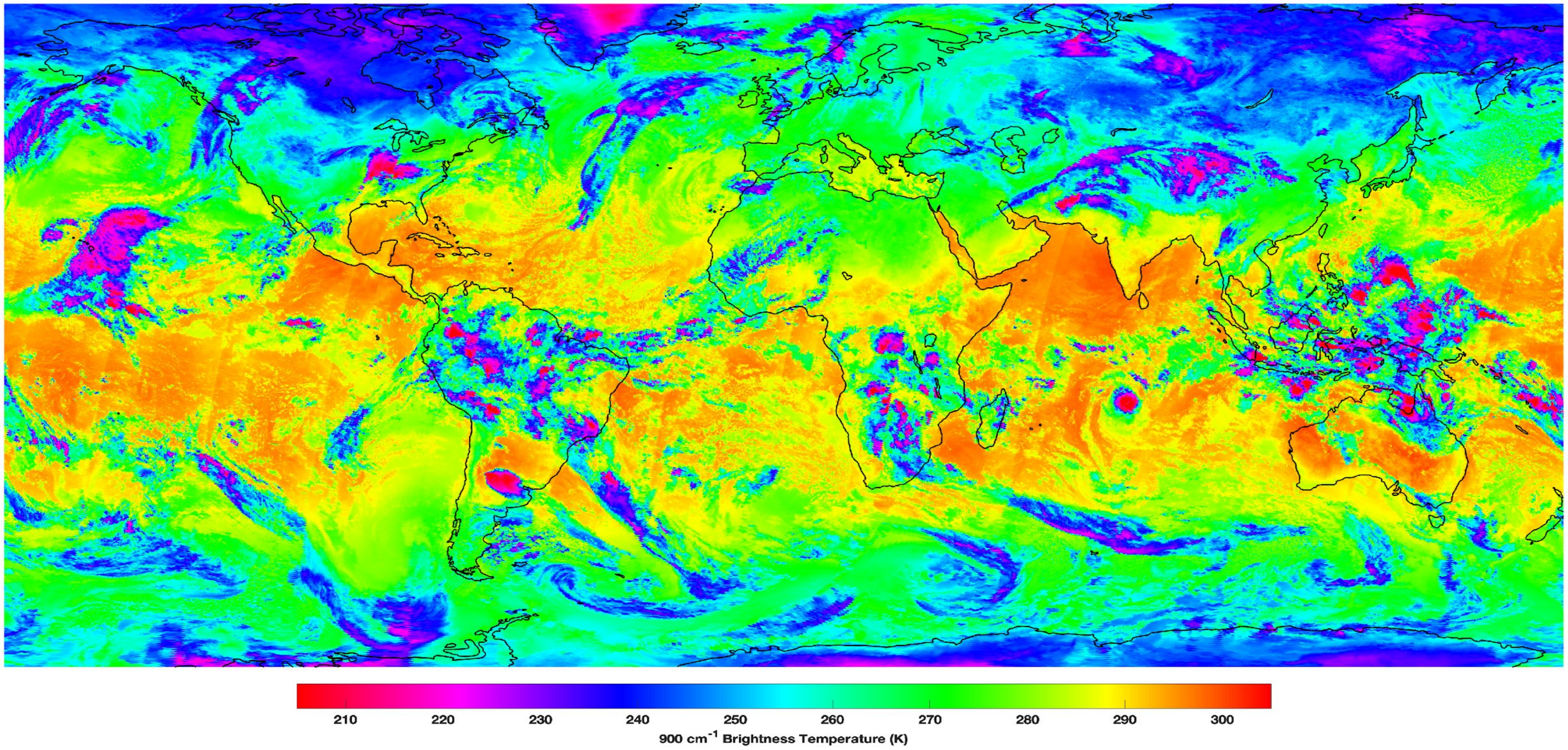


Figure Courtesy of L3 Harris

Heat pulse associated with the removal of a coating from the exterior of the baffle on J2 and forward

NOAA-21 CrIS SDR Calibration and Validation Efforts from University of Wisconsin/SSEC Cal/Val Science Team



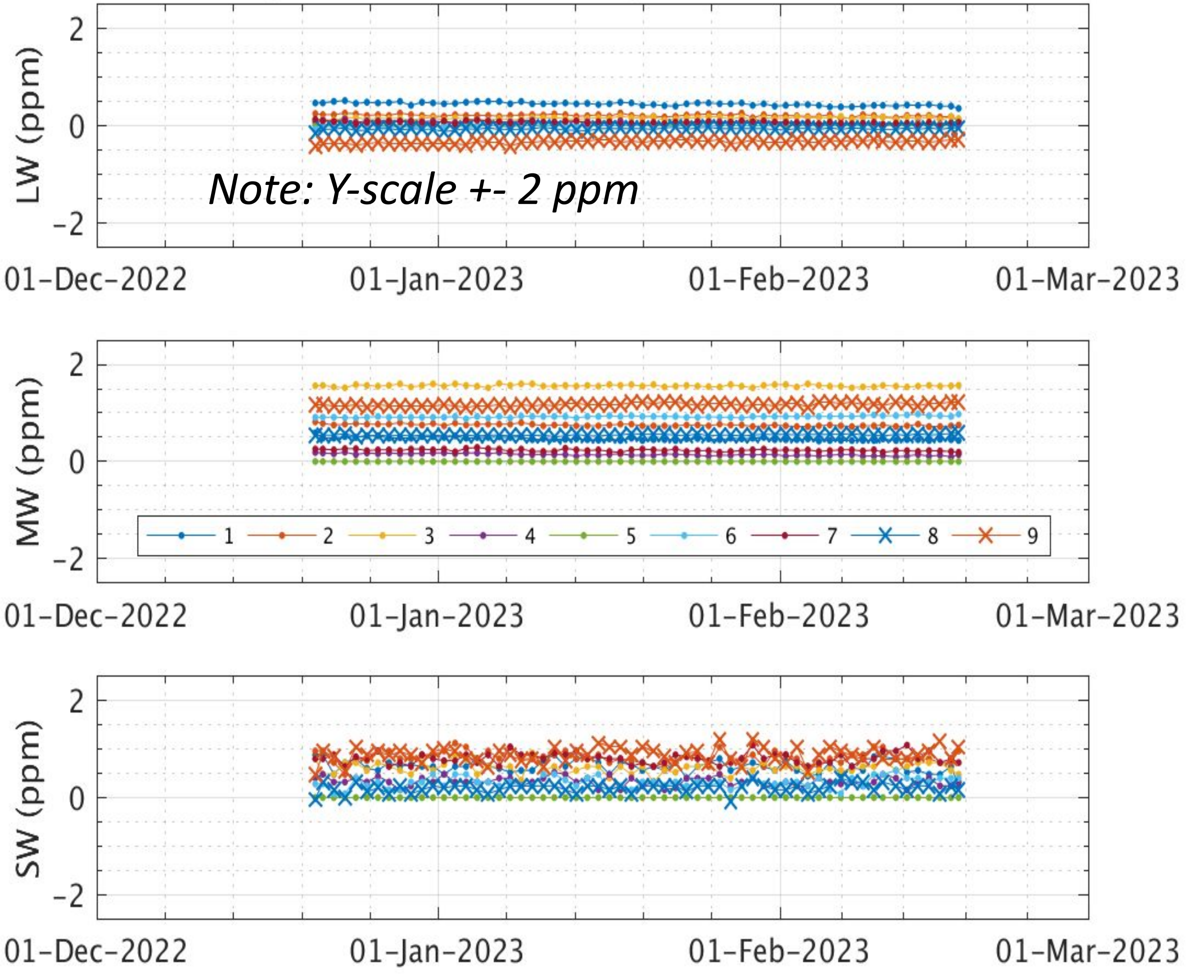
Early Orbit Check-Out Efforts @ UW

- Radiometric Nonlinearity Evaluation
- Radiometric Noise Assessment
- Interferogram Spike Analysis
- Internal Consistency Checks on Spectral Calibration, self- apodization corrections, and Resampling
- FOV-2-FOV spectral calibration assessment
- FOV-2-FOV radiometric calibration assessment
- CrIS/VIIRS radiometric comparisons
- SNOs – SNPP, NOAA-20, NOAA-21, METOP-B, METOP-C
- Clear Sky Obs-Calcs

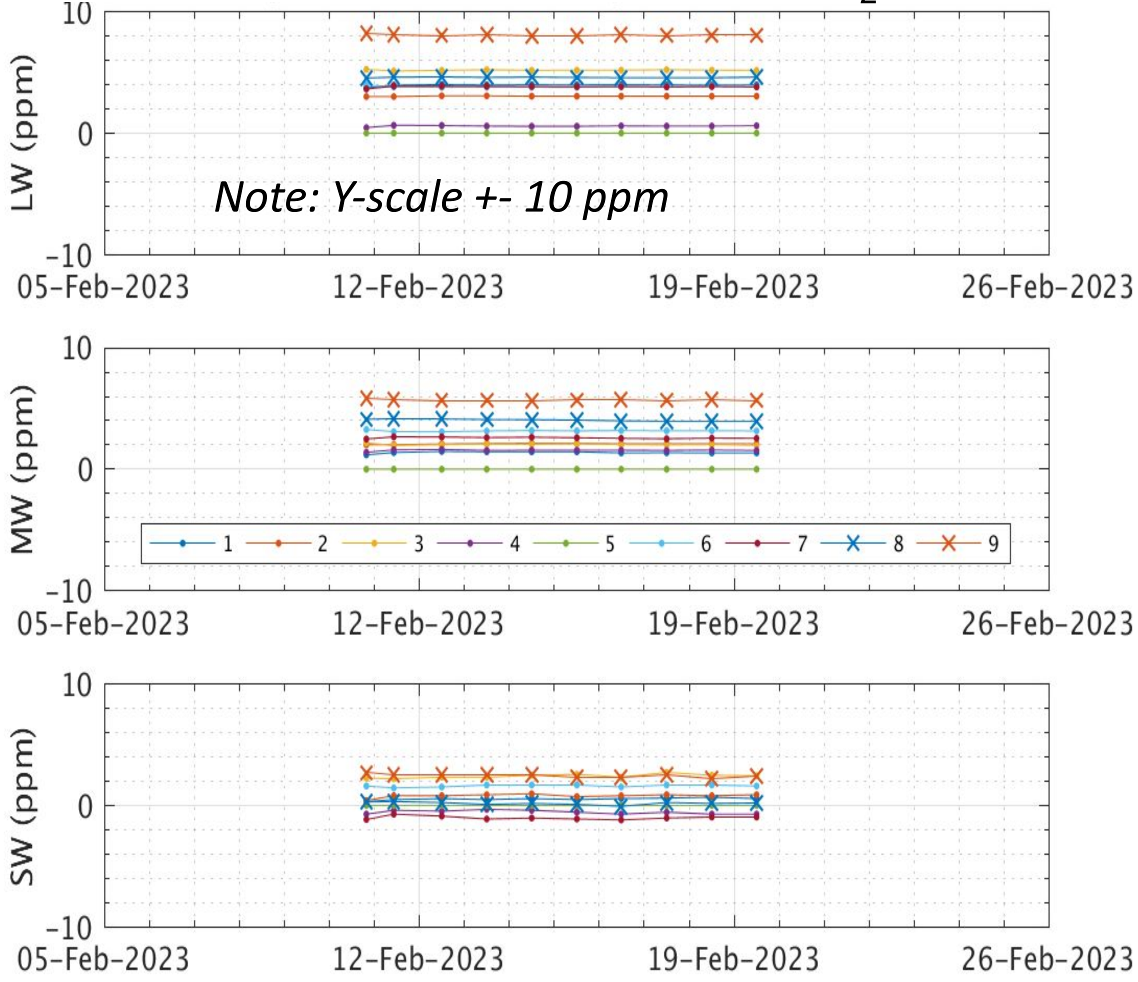
☐ Internal Consistency Checks on Radiometric Calibration

FOV-2-FOV Relative Spectral Daily Time Series

NOAA 20 CrIS (Flight)



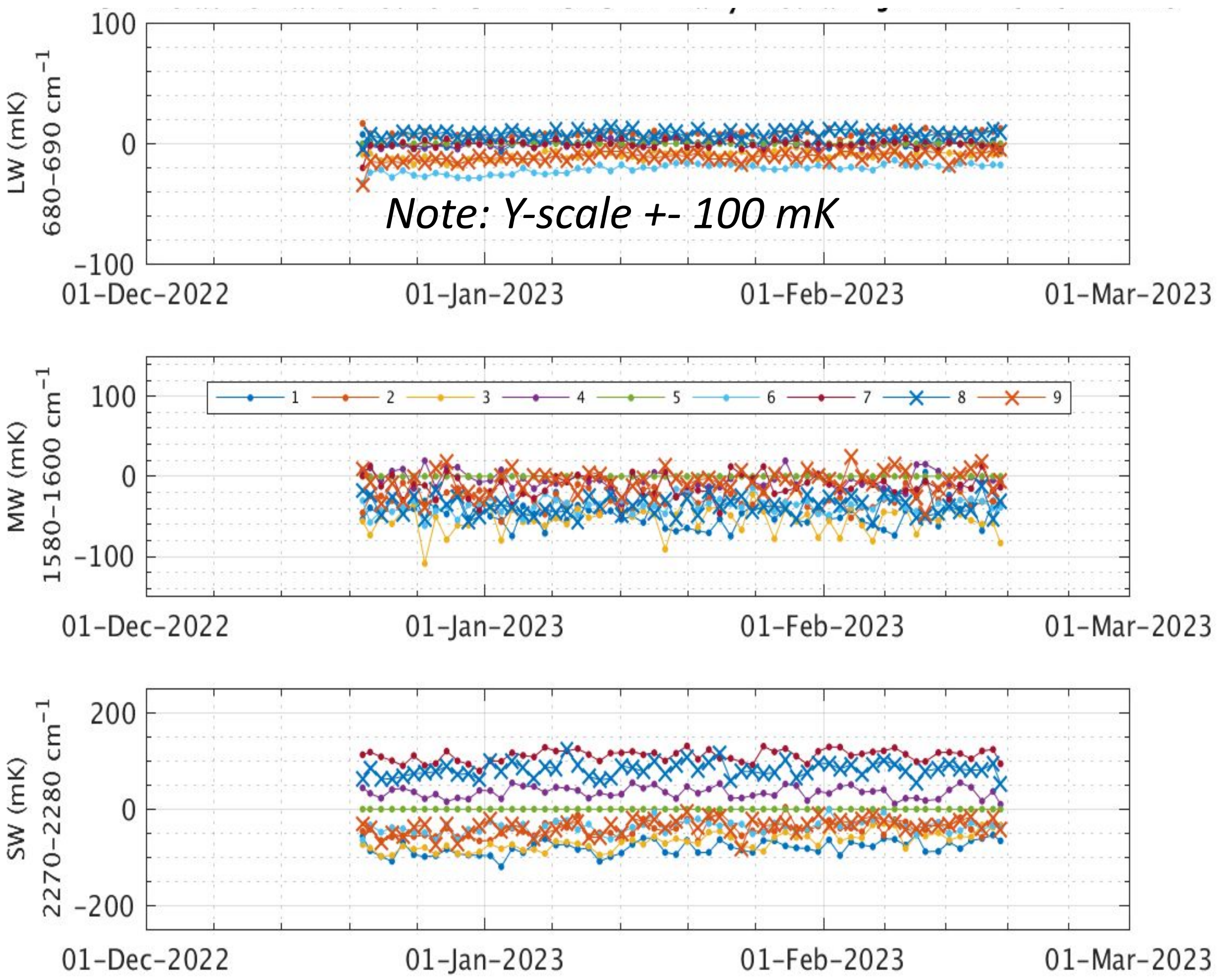
NOAA 21 CrIS
using J2 MN TVAC UMBC ILS and UW a_2 values



Indicates *relatively* large changes from TVAC to in-orbit

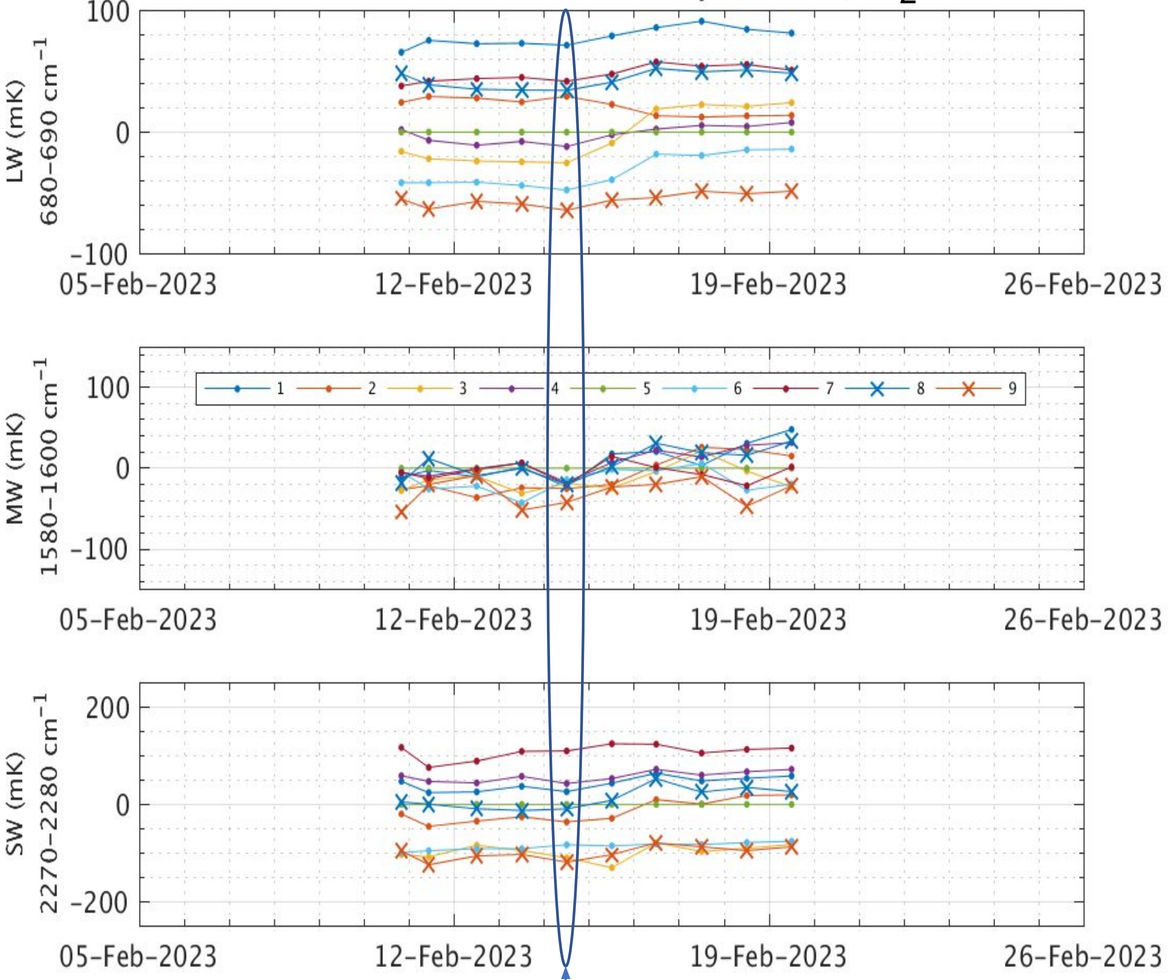
FOV-2-FOV Relative Radiometric Daily Time Series

NOAA 20 CrIS (Flight)



NOAA 21 CrIS

using J2 MN TVAC UMBC ILS and UW a_2 values



14 Feb 2023

Small and consistent FOV-2-FOV differences

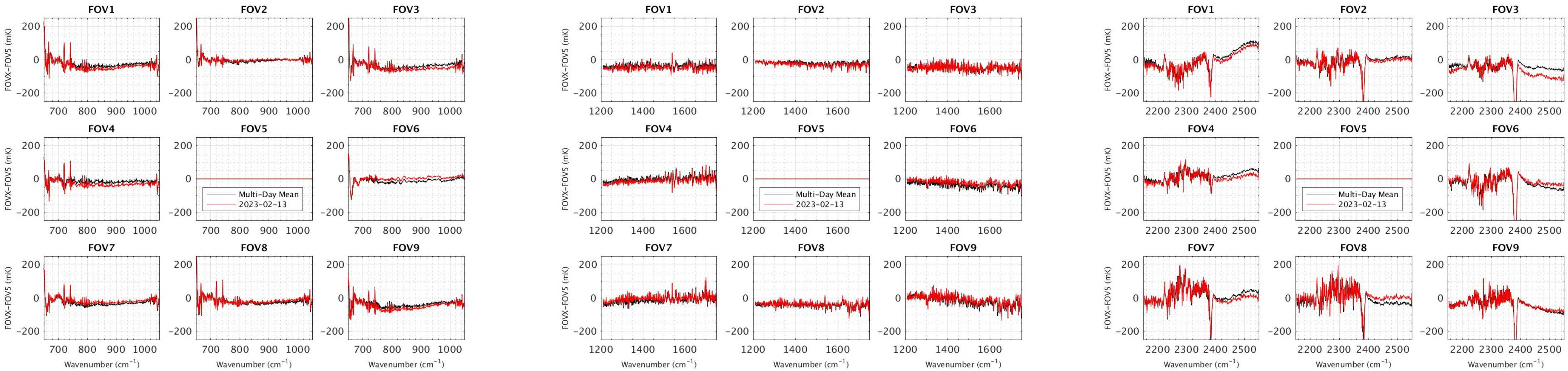
FOV-2-FOV Relative Radiometric Daily Mean

Hamming Apodized

Longwave | **Midwave** | **Shortwave**

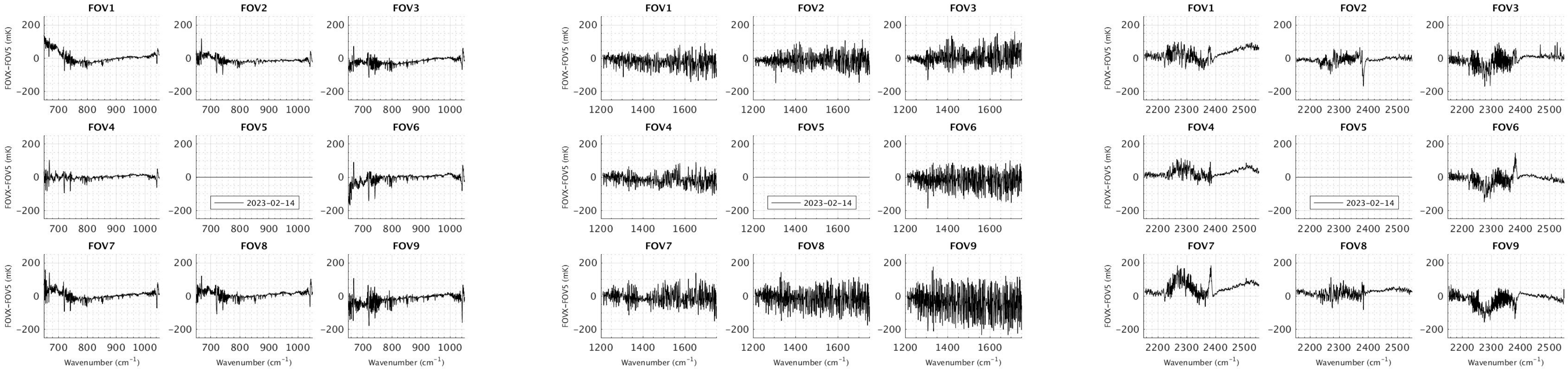
NOAA20

Y-scale: +- 250mK



NOAA21

Feb 14

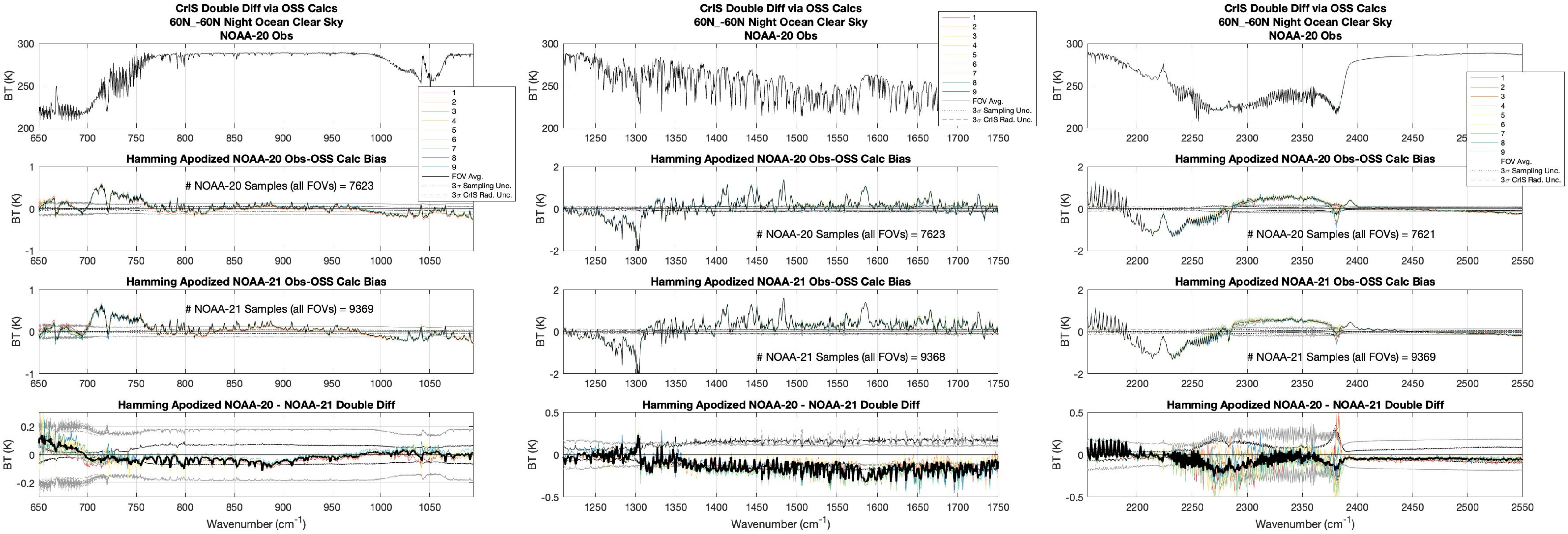


Differences are small and well behaved; MW “hash” is spectral

Clear Sky Observed minus Calculated

NOAA20, NOAA21, and NOAA-20/NOAA-21 Double Difference

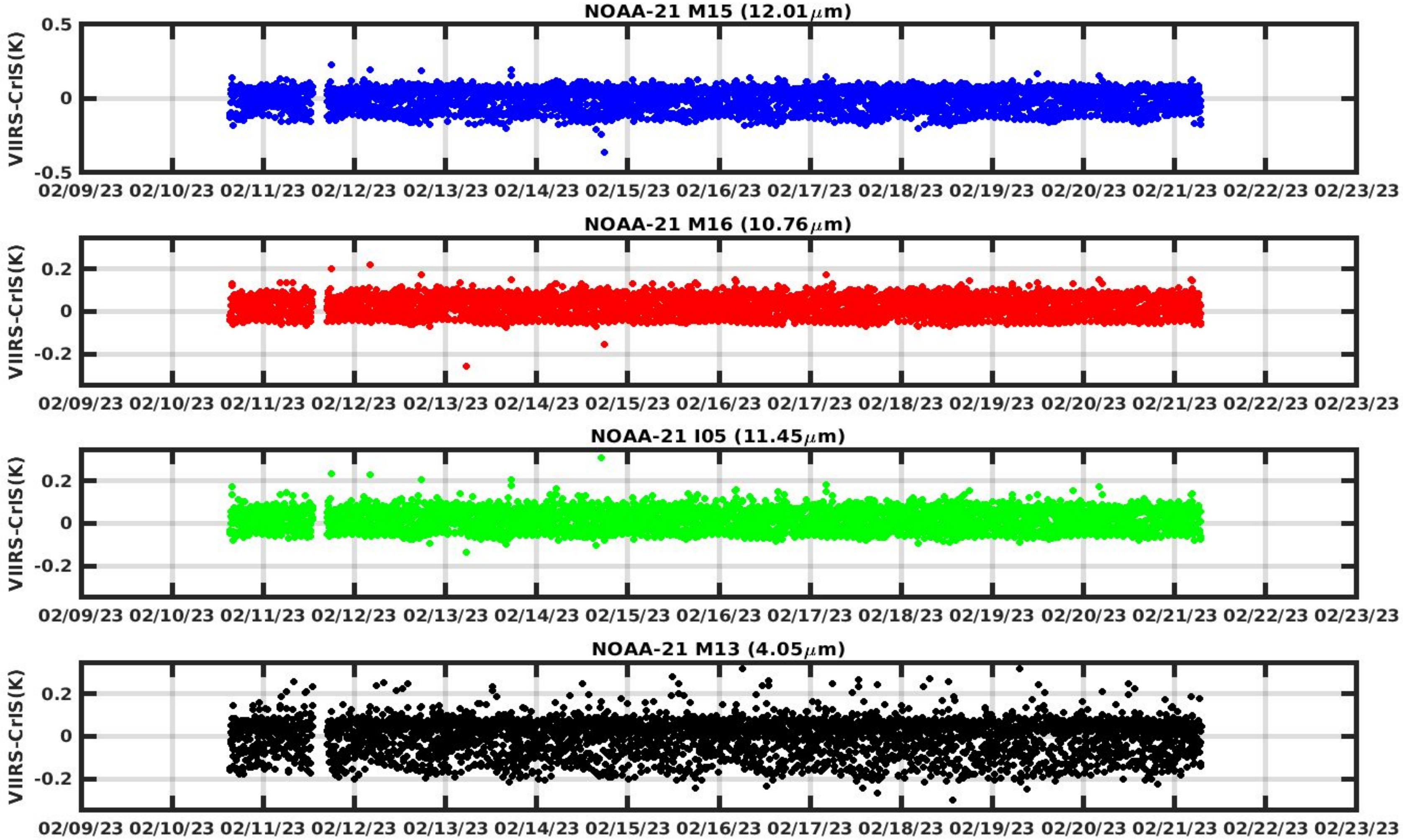
Feb 14



Consistent Obs-Calcs for NOAA-20 and NOAA-21, and small NOAA-20/NOAA-21 differences, with little FOV dependence

Example CrIS/VIIRS Comparisons

Time Dependence

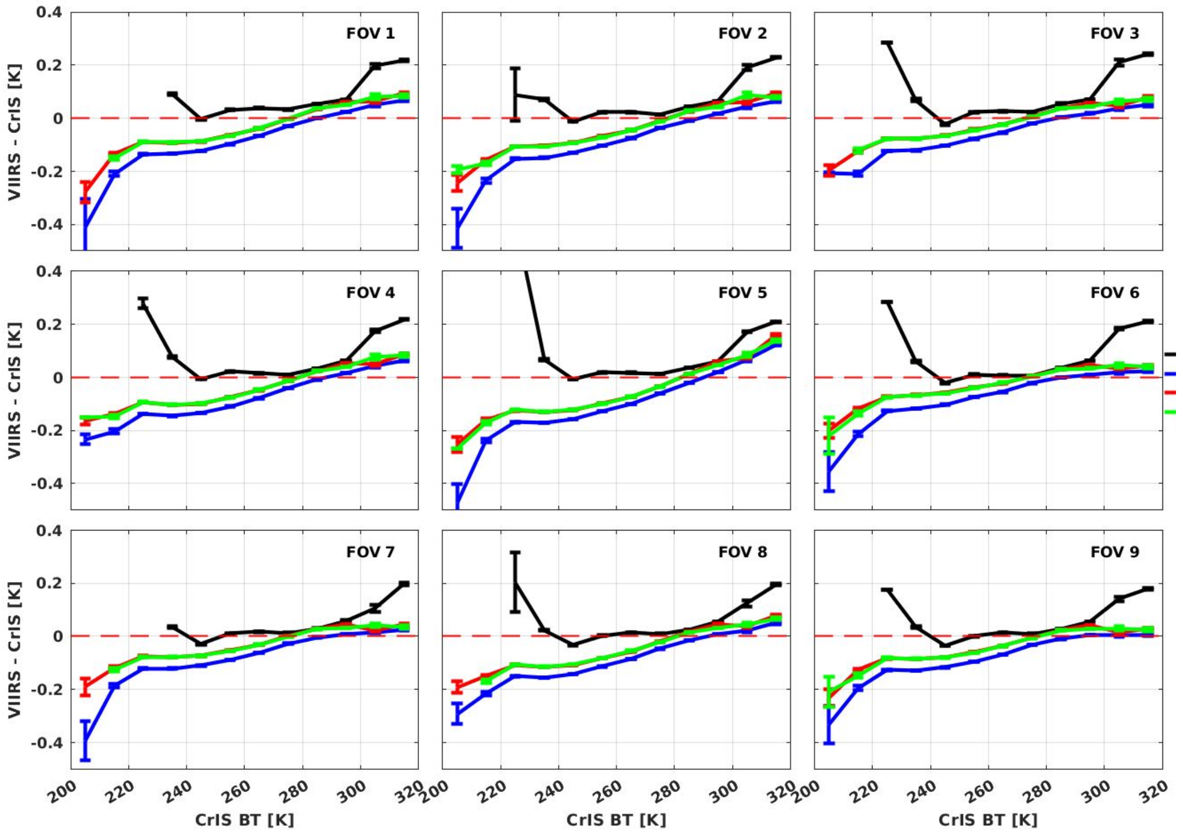


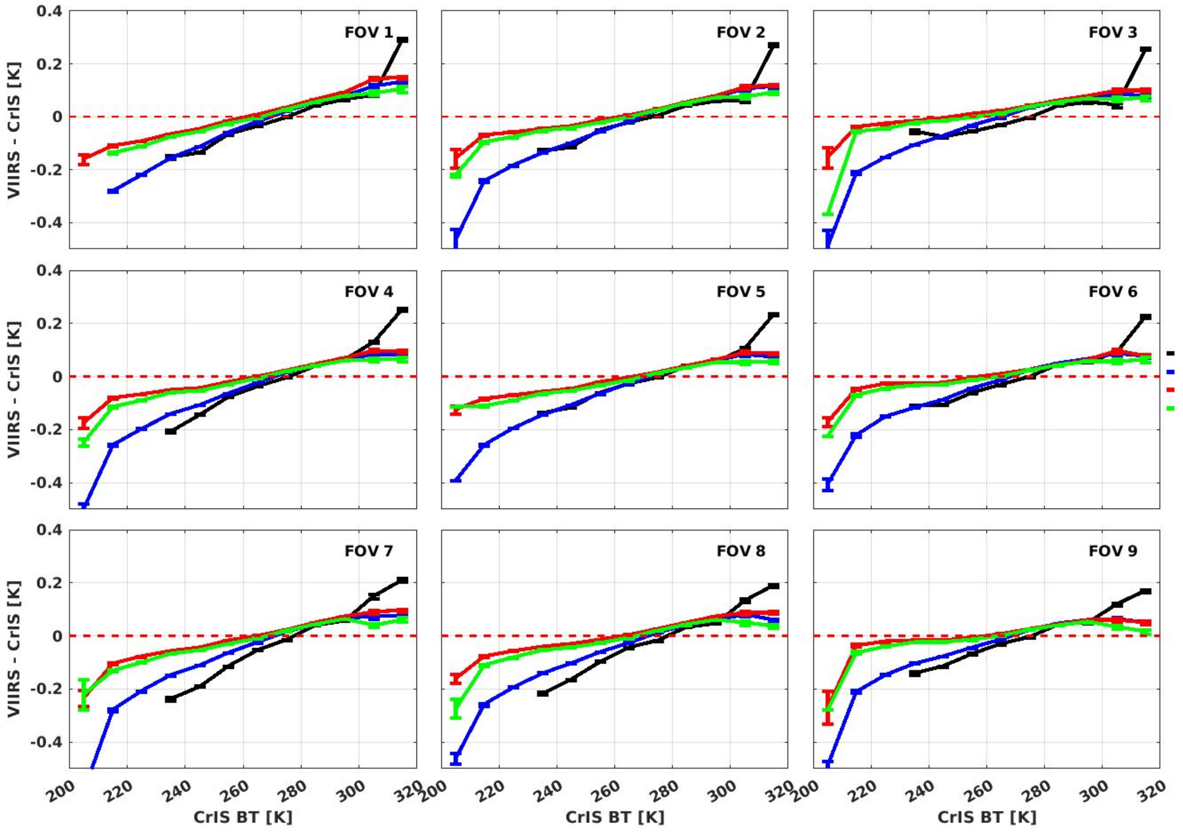
Consistent and small residuals since turn-on

Example CrIS/VIIRS Comparisons

M13 4.05 μm
M15 10.76 μm
M16 12.01 μm
I05 11.45 μm

Signal Level Dependence, by FOV





Similar behavior as NOAA-20, and similar behavior among FOVs

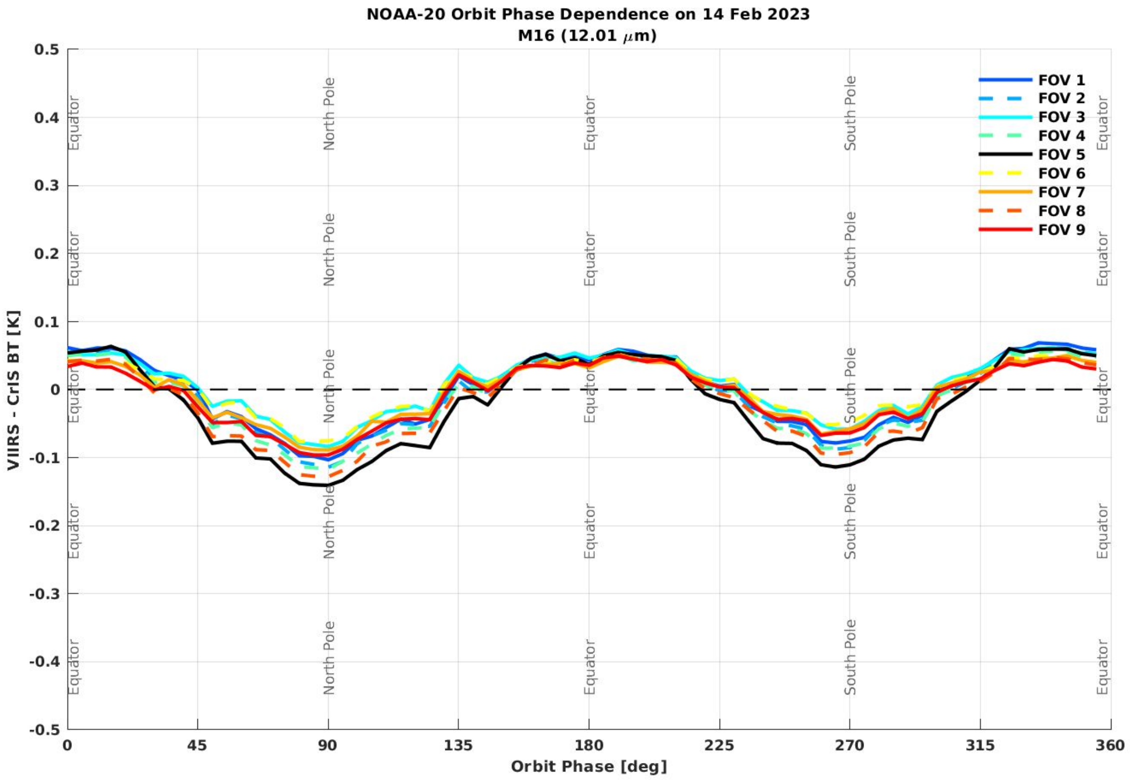
Example CrIS/VIIRS Comparisons

M16 12.01 μm

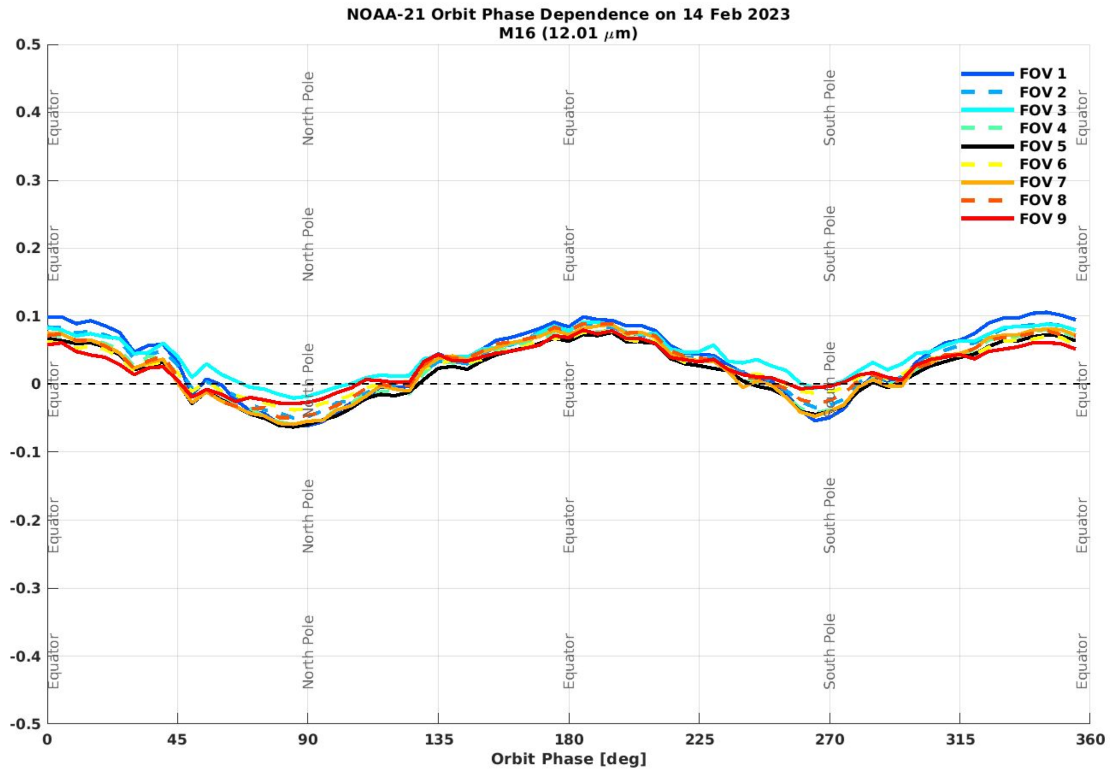
Feb 14

Orbit Phase Dependence, by FOV

NOAA 20



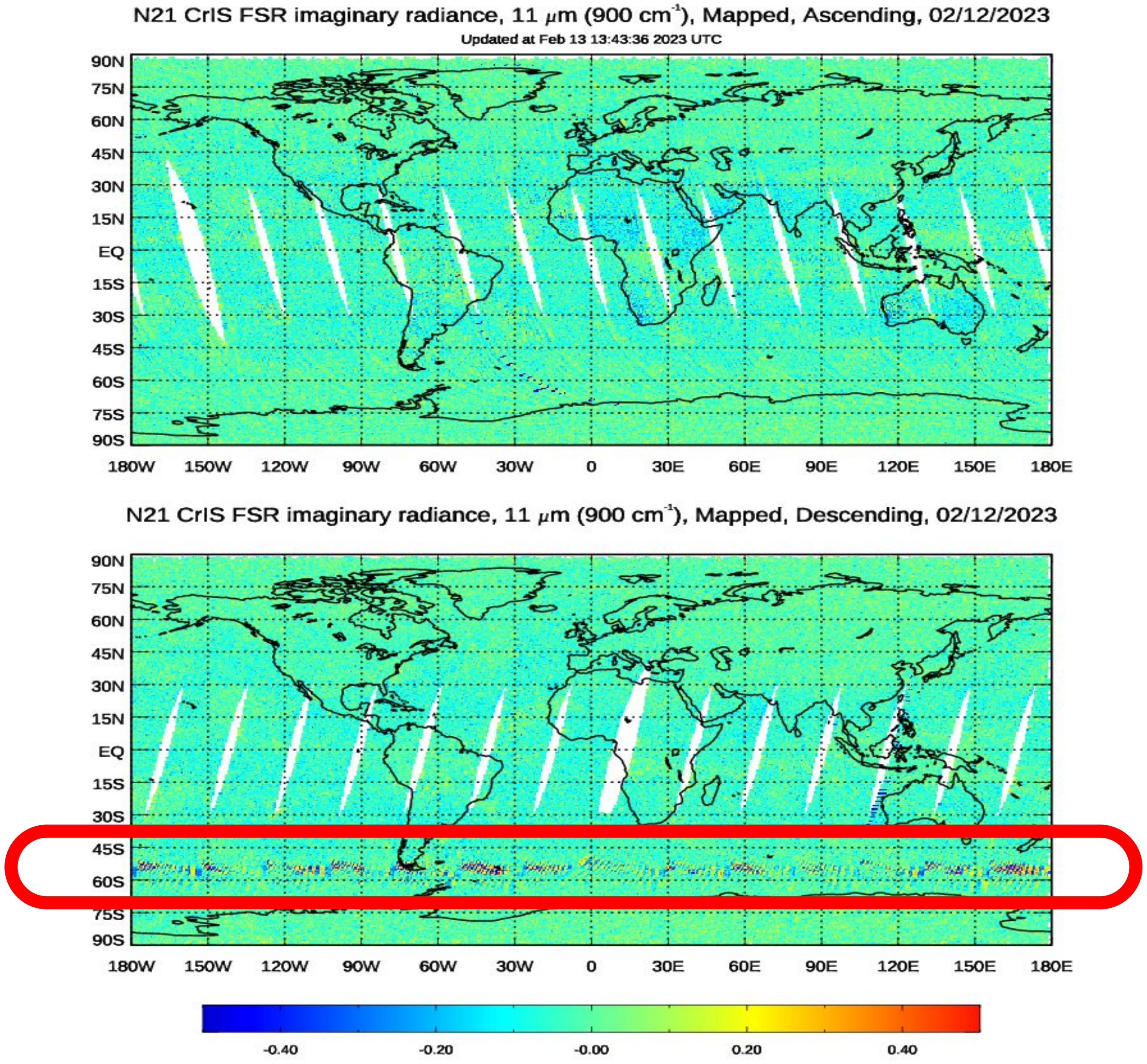
NOAA 21



Consistency with NOAA-20 behavior, and similar behavior among FOVs

Imaginary Radiance Observation

Larger Imaginary Parts of calibrated radiance seen consistently during descending passes at ~-55 to -60 deg latitude, when satellite is coming out of eclipse into sunlight



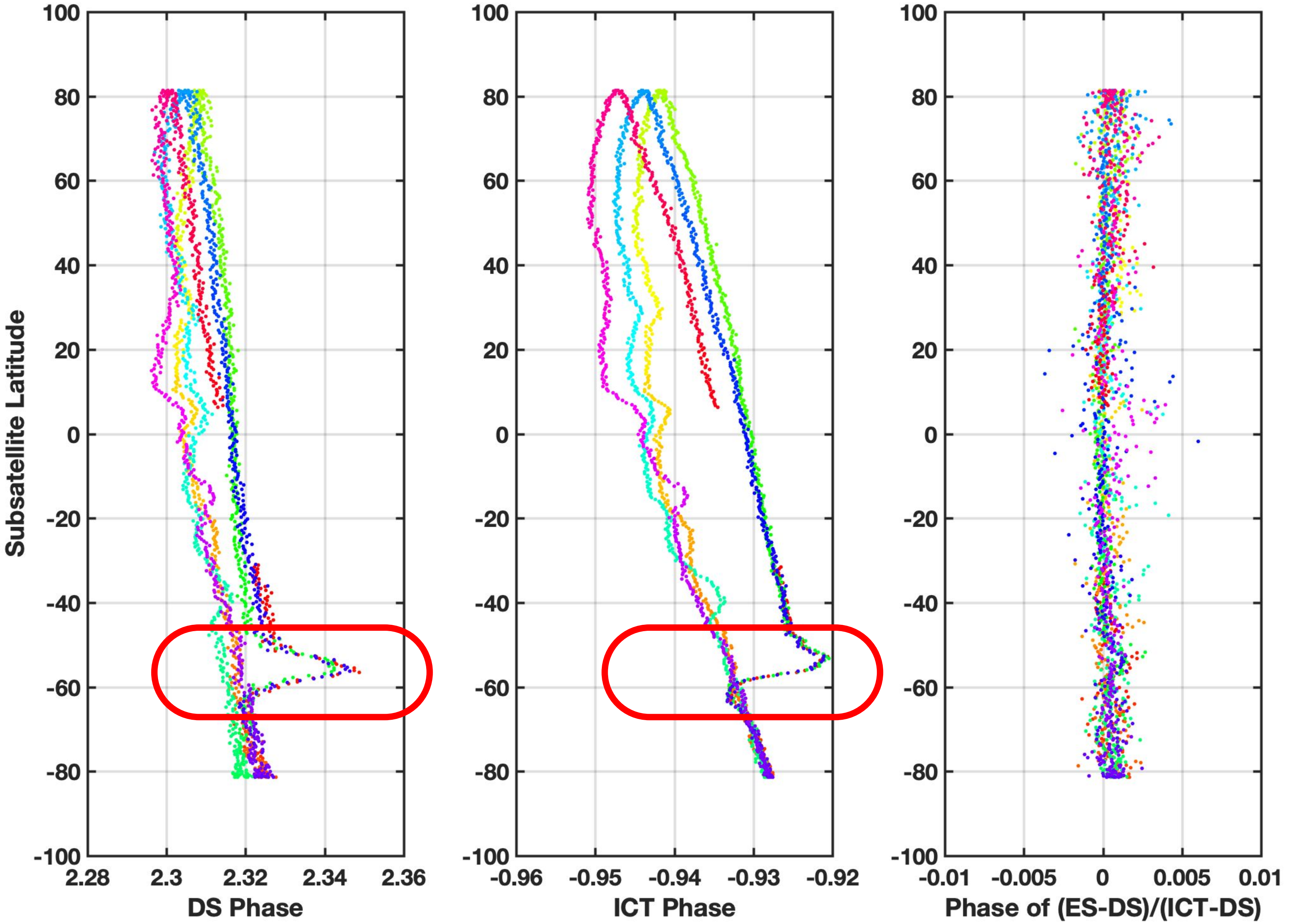
FOV 7 example, Mean values for 900-950 cm^{-1}, on 2023/043 from 0 to 5 UTC

<u>Left:</u> DS SD0 phase
X-axis is C_{DS} phase, Y-axis is Sat Latitude

<u>Middle:</u> ICT SD0 phase vs Sat Latitude
X-axis is C_{DS} phase, Y-axis is Sat Latitude

<u>Right:</u> Mean "Calibration Phase"
X-axis is phase of $(C_{ES}-C_{DS})/(C_{ICT}-C_{DS})$
Y-axis is Sat Latitude

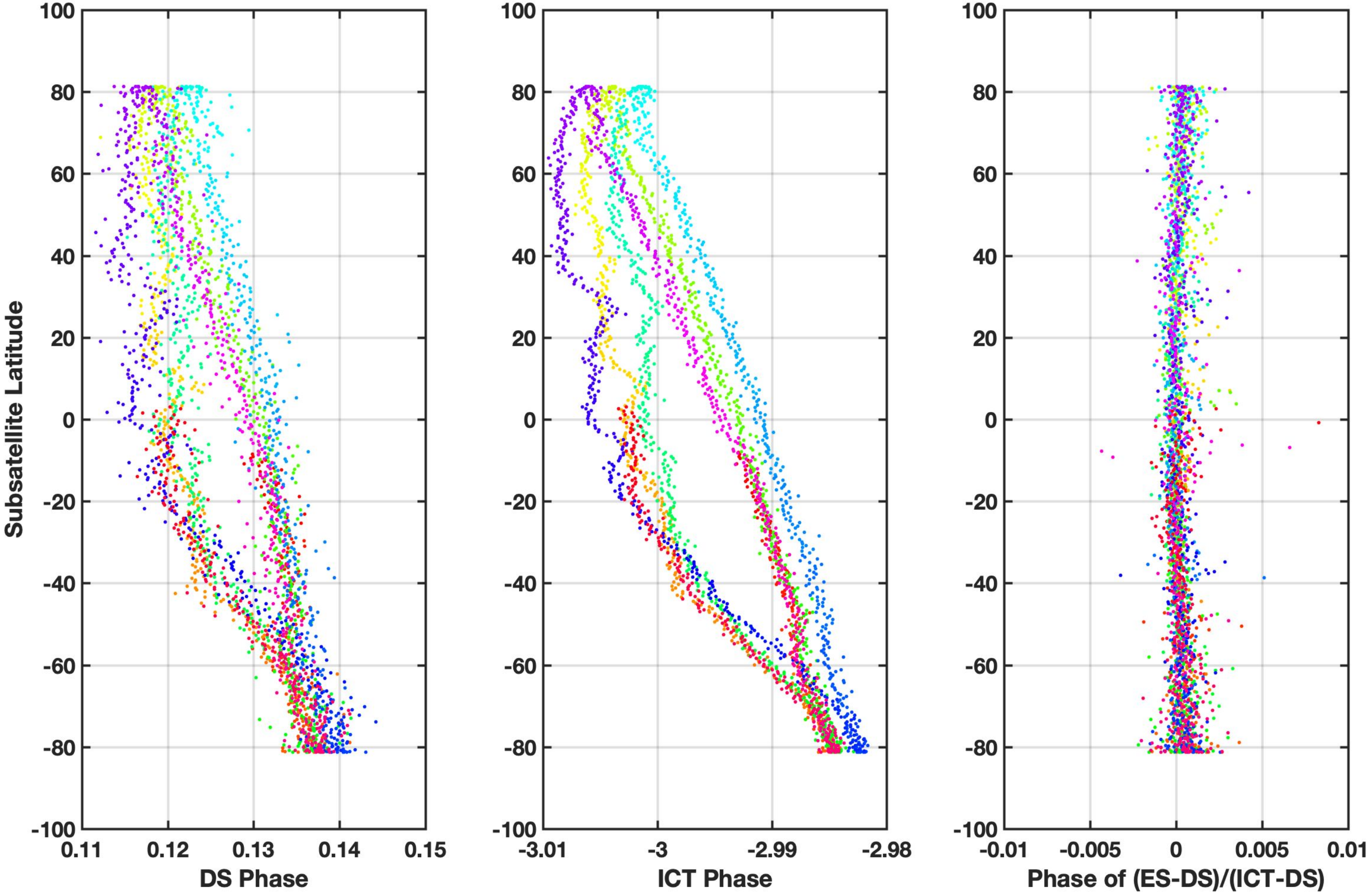
- All evaluated on a scan-line by scan-line basis (no moving window/averaging of cal views)
- Rapid change in phase at ~-50 deg, when coming out of full darkness
- DS phase changes are ~18 scan lines long, and the normal moving window (+/- 14 scan lines) does not fully capture the more rapid variation.
- Therefore, the calibration of ES views can be using C_{DS} and C_{ICT} phases which differ from the ES view for any given scan line.



Analogous Plots for NOAA-20

Displays a similar behavior over the full orbit but not the faster events.

- **Hypothesis is that NOAA-21 is more susceptible to and/or experiencing faster thermal fluctuations, causing changes to the background instrument emission seen by the detectors, resulting is small changes to the near-ZPD interferogram shape (phase)**
- **This is consistent with the thermal behavior of the NOAA-21 SSM Baffle**



ICT Radiometric model and Temperature Telemetry

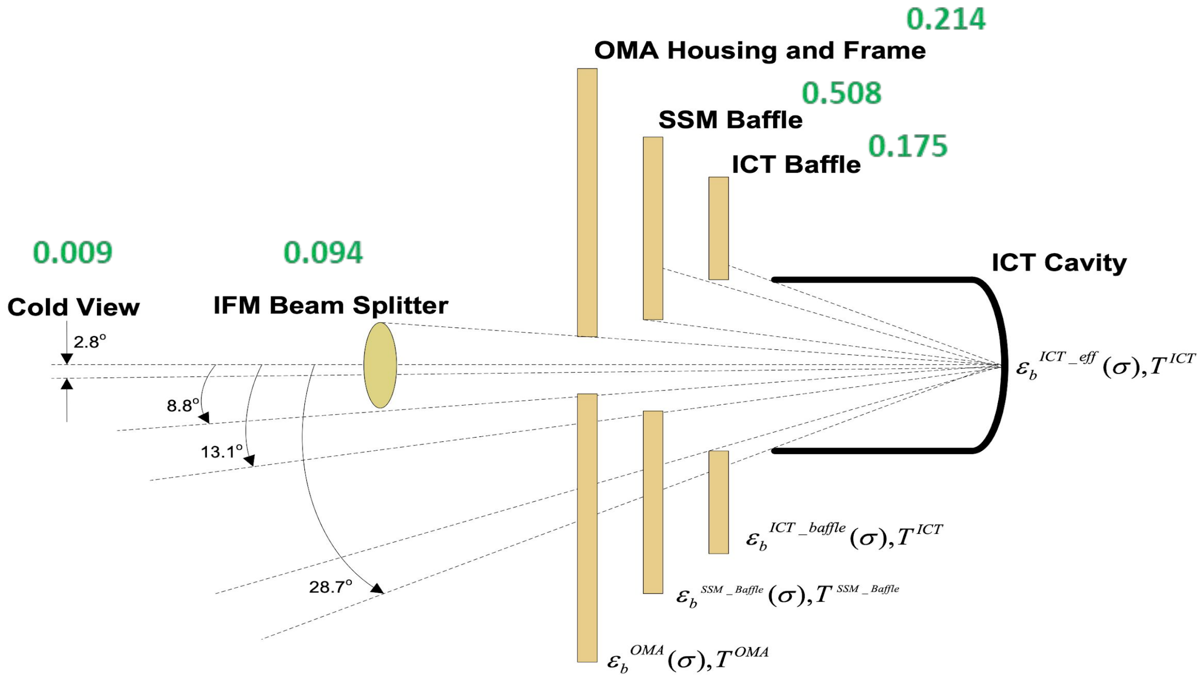
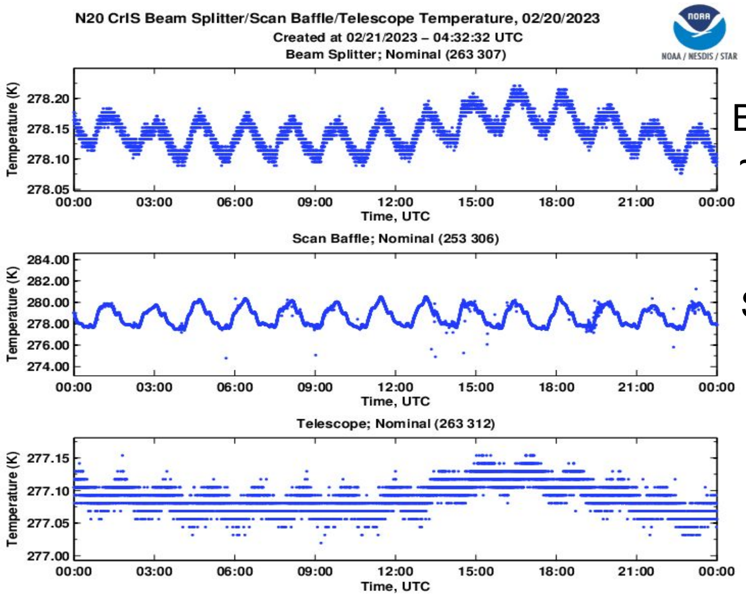


Figure 5-2: Radiometric model when the scene is the ICT

and view fractions

(from SDR ATBD)

NOAA-20

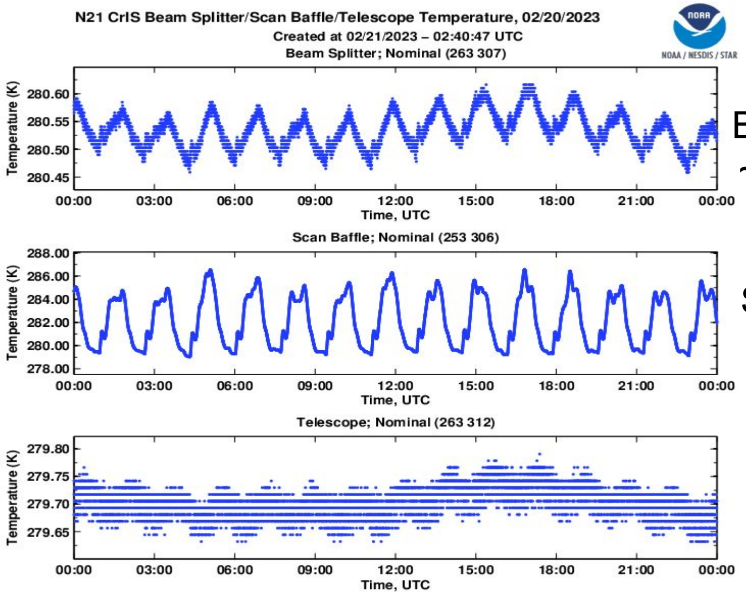


Beamsplitter ~0.10 K p-p

Scan Baffle ~2 K p-p

Telescope ~0.1 K p-p

NOAA-21



Beamsplitter ~0.15 K p-p

Scan Baffle ~7 K p-p

Telescope ~0.1 K p-p

Imaginary and Real Part 900 cm^{-1} Radiances

Imaginary and Real Part 900 cm^{-1} Radiances

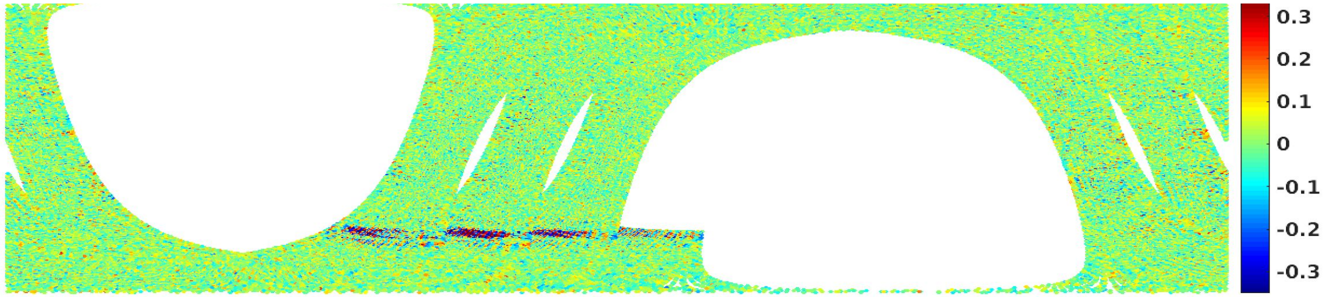
Top: 900 cm^{-1} Imaginary Part using +/-14 scan line window

Middle: 900 cm^{-1} Imaginary Part using +/-4 scan line window

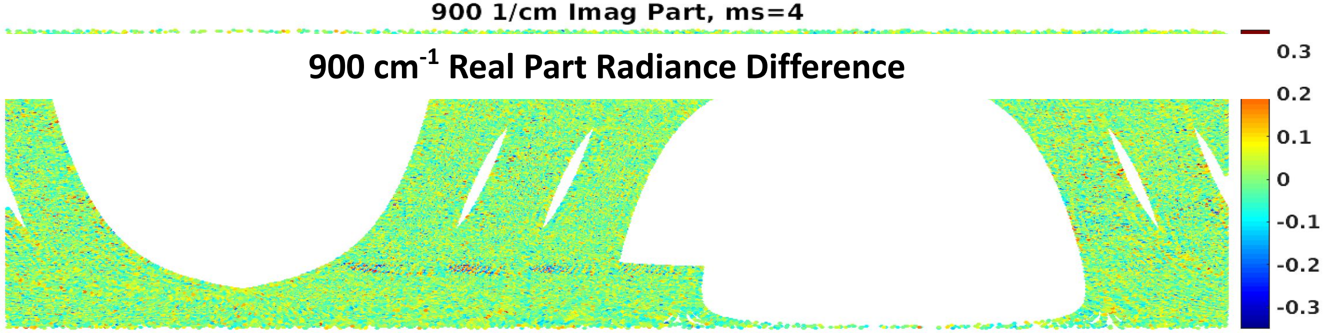
Bottom: 900 cm-1 Real Part Difference (between using +/- 14 and +/-4)

- The reduction in Imaginary Parts with a shorter moving window size is expected given the phase behavior and stated hypothesis
- The lower panel provides a good estimate of the size of the calibration error for the current SDRs with the nominal moving window size, as well as the change in random noise with the smaller window size. **This needs more time to study but the current conclusion is that it appears not much is getting into the real part.**

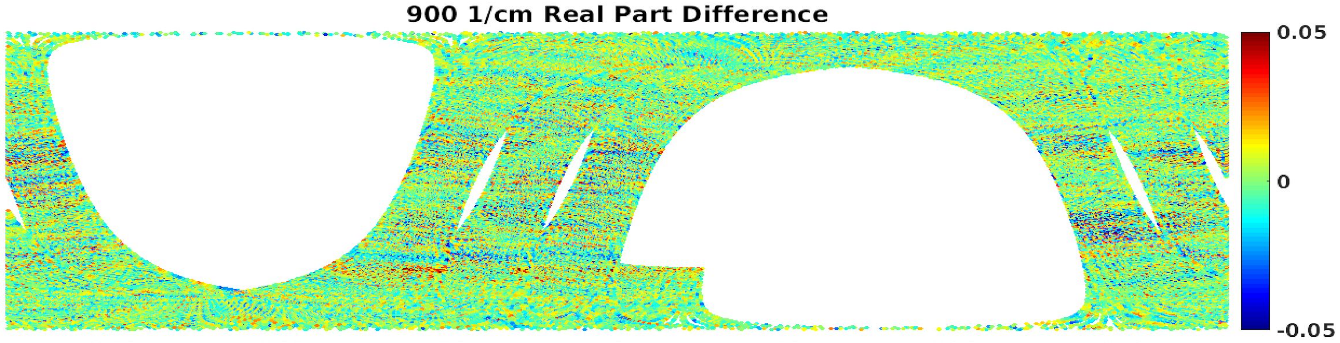
900 cm^{-1} Imaginary Part Radiance, with moving window = 0 +/- 14 scan lines



900 cm^{-1} Imaginary Part Radiance, with moving window = 0 +/- 4 scan lines



900 cm^{-1} Real Part Radiance Difference

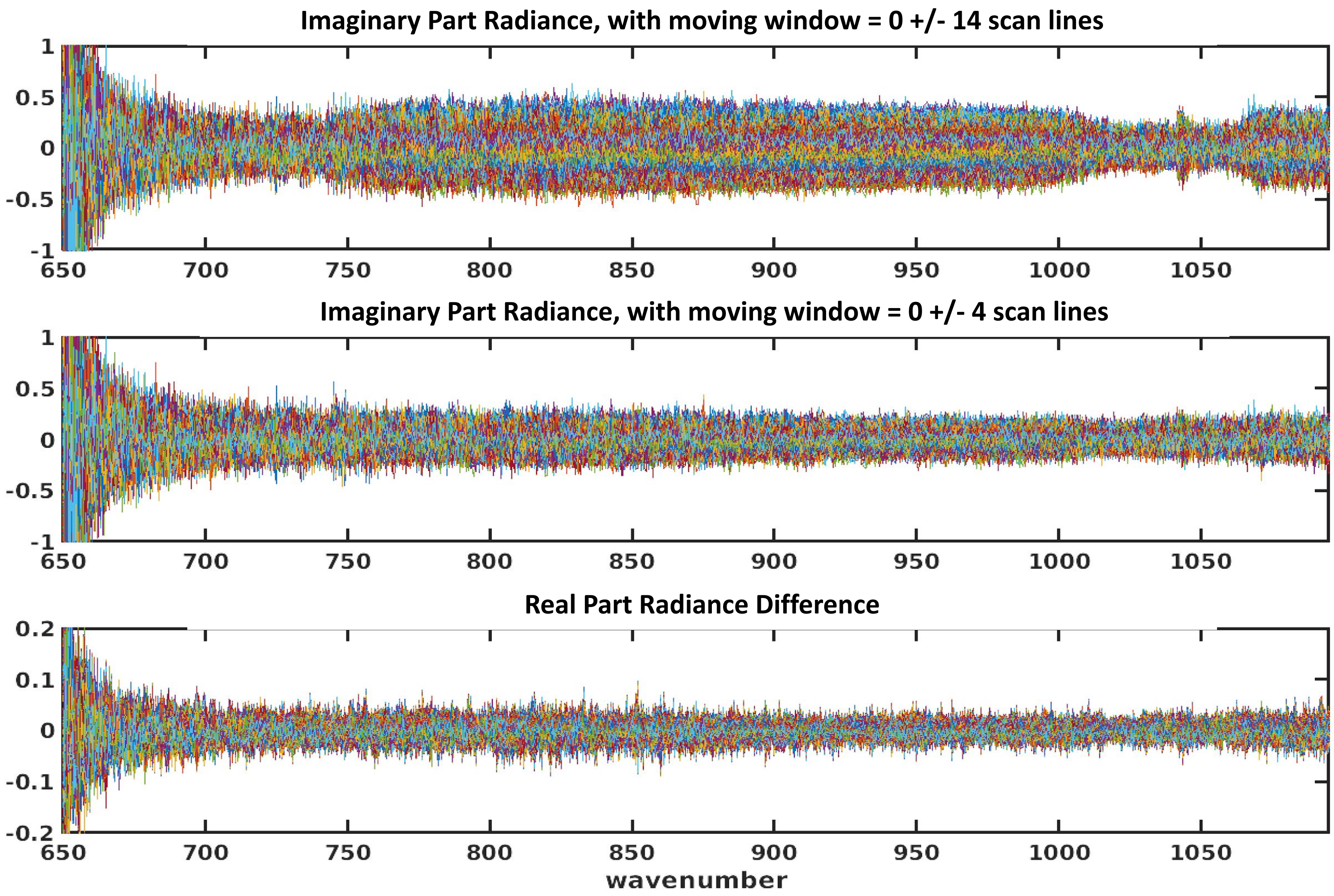


Example LW spectra at ~ -55 degrees

Example LW spectra at ~-55 degrees

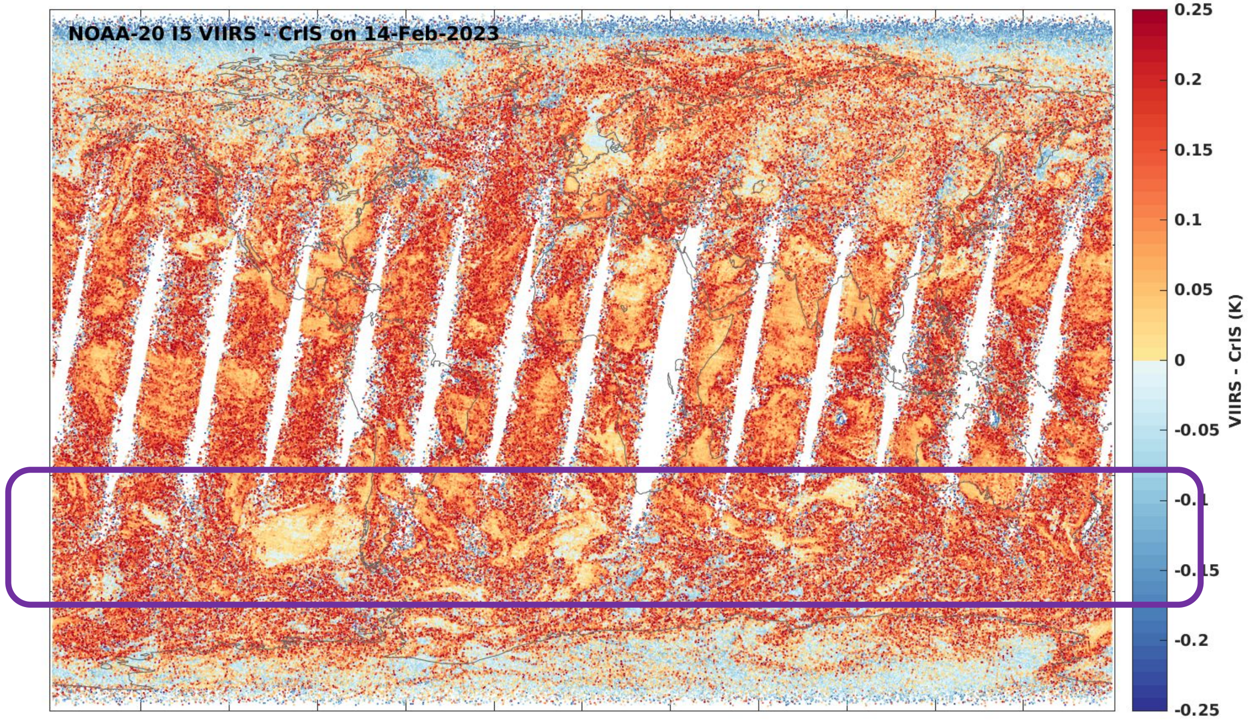
Similar findings as in previous slide, but showing full LW spectra.

Larger imaginary parts, but no significant impact on the (real) calibrated spectra.

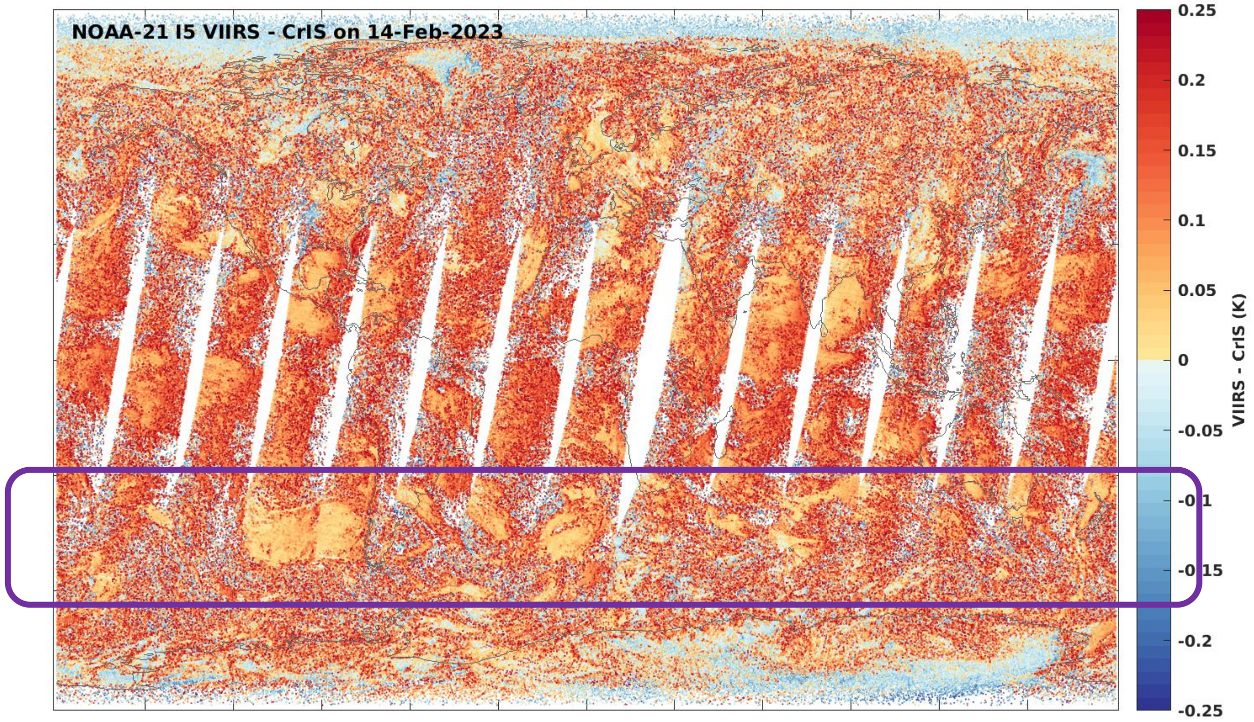


CrIS – VIIRS, I05 @ 11.45 µm

NOAA-20



NOAA-21



Shows no unusual behavior in the region of interest

Early Frequency Calibration and Radiometric Assessment of JPSS-2

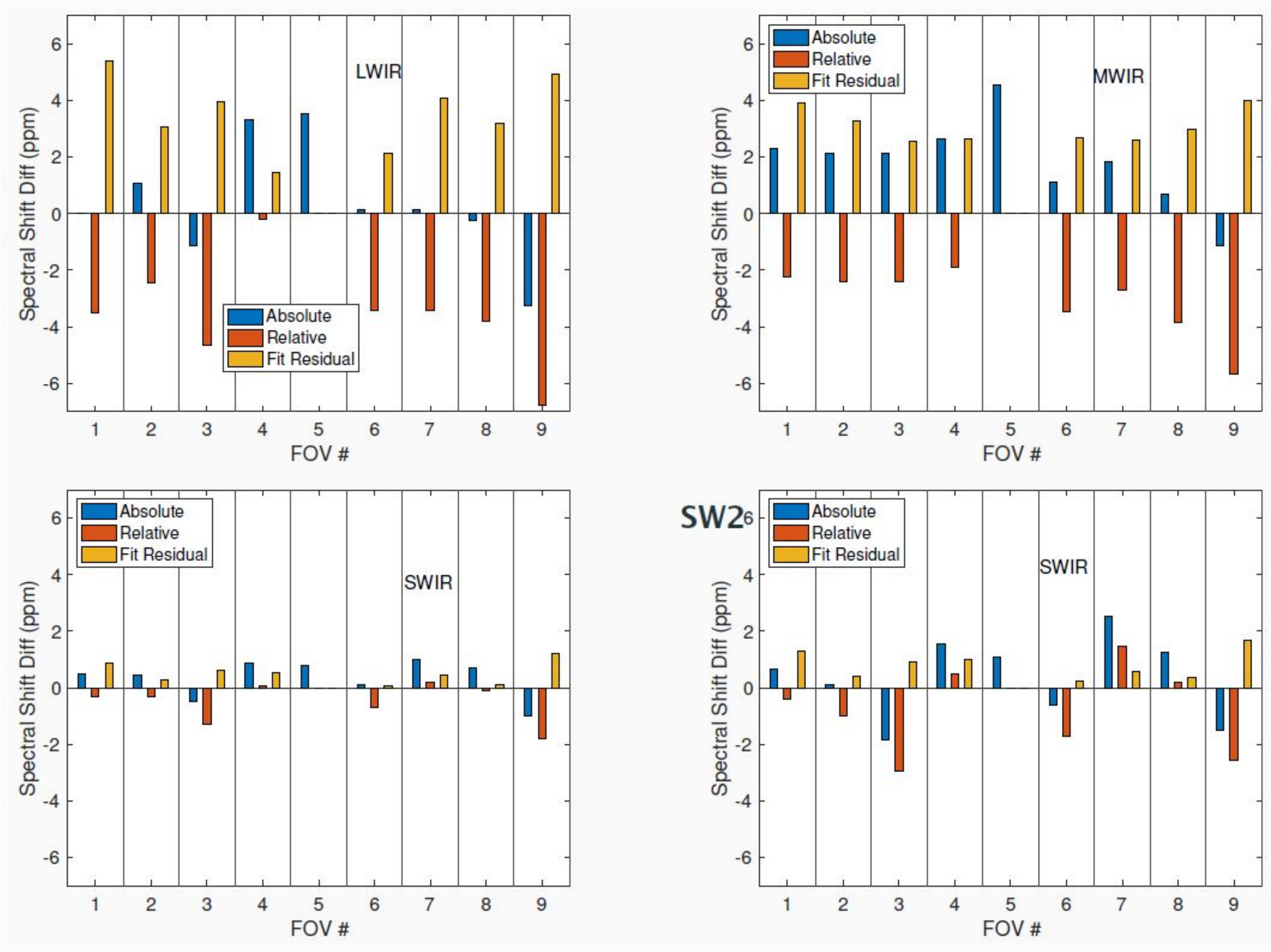
L. Larrabee Strow, Howard Motteler, Chris Hepplwhite, and Steven Buczkowski (UMBC)

Feb 23, 2023

Summary of Results

- Spectral calibration requires effective Neon wavelength and locations of each FOV relative to the interferometer axis for each of the three focal planes.
- Historically the midwave provides the best Neon wavelength estimate.
- Mostly concentrate on Feb. 14, but other days are very similar
- Three SDR algorithms tested: IDPS, UW NASA L1b, and UMBC CCAST
    - All give essentially identical results
    - UMBC CCAST allows quick testing of new ILS parameters and is used here

Spectral Shifts (offline EP 209): Fit Residuals if only in-track/cross-track varies



Fit Results for offline EP 209 (all in microradians)

LW

Fit dx,dy,dr

-67.0	-27.0	144 (0.0063)

Fit unc:

39.2	39.2	25 (0.0011)

MW

Fit dx,dy,dr

-40.9	-44.1	117 (0.0051)

Fit unc

57.2	57.2	36 (0.0016)

SW

Fit dx,dy,dr

-32.2	2.4	23 (0.0010)

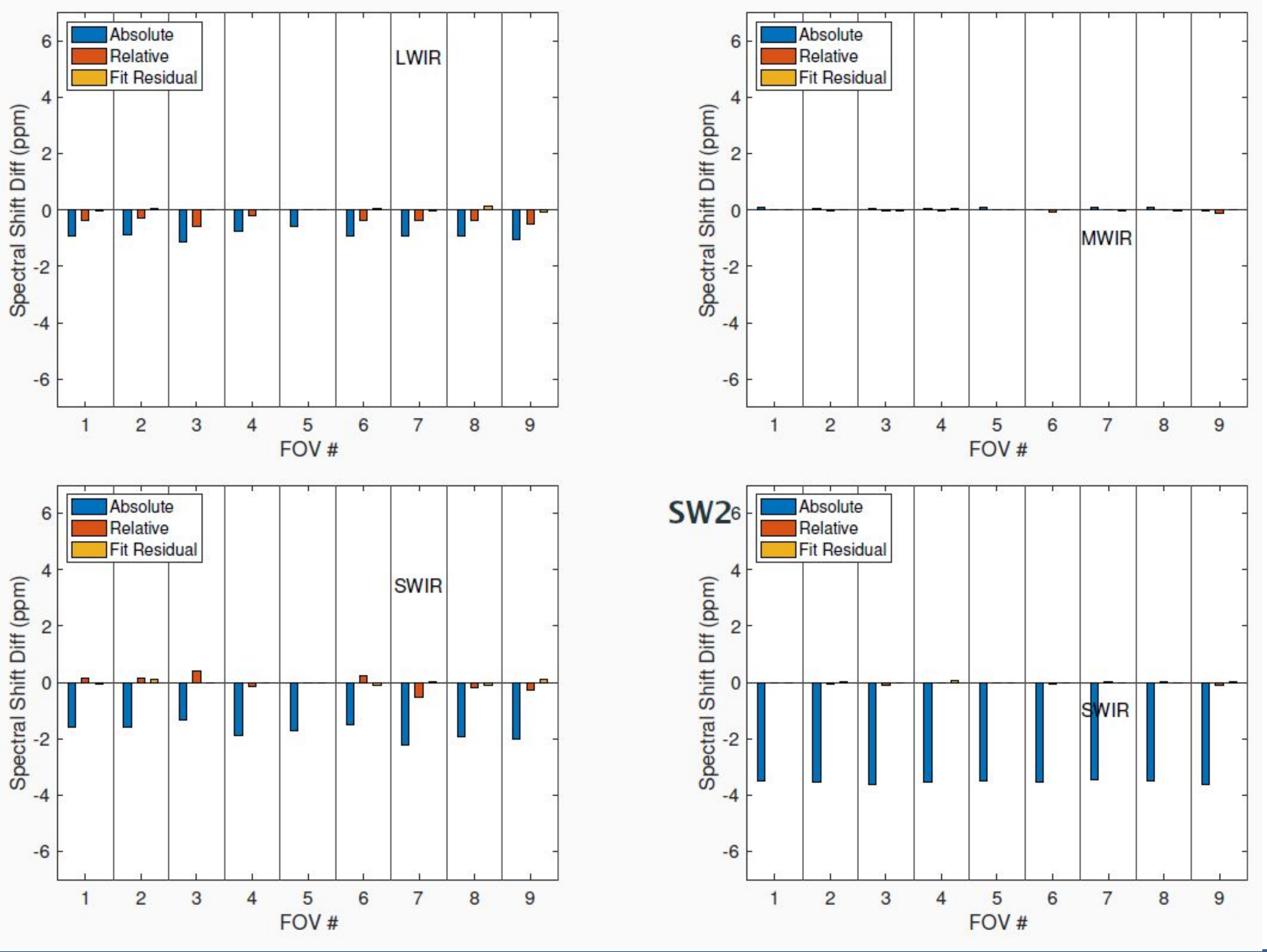
Fit y unc

15.4	15.4	2.3 (0.0004)

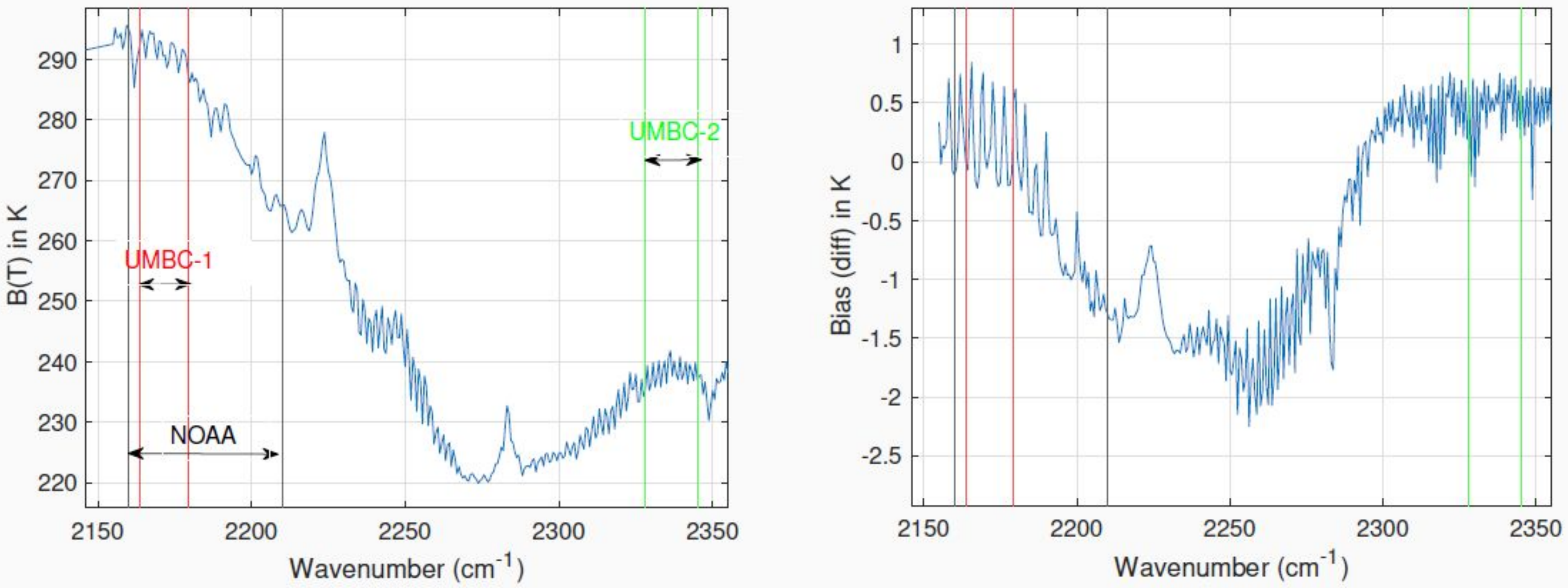
- Small xtrack/atrack shifts (dx/dy)
- Larger "radial" changes (telescope focus?)

- Shortwave results dependent on spectral region used (more later)
- Used midwave Neon in previous missions due to better characterization in midwave

Spectral Shifts (offline EP 211)



Differences in Spectral Fitting Regions



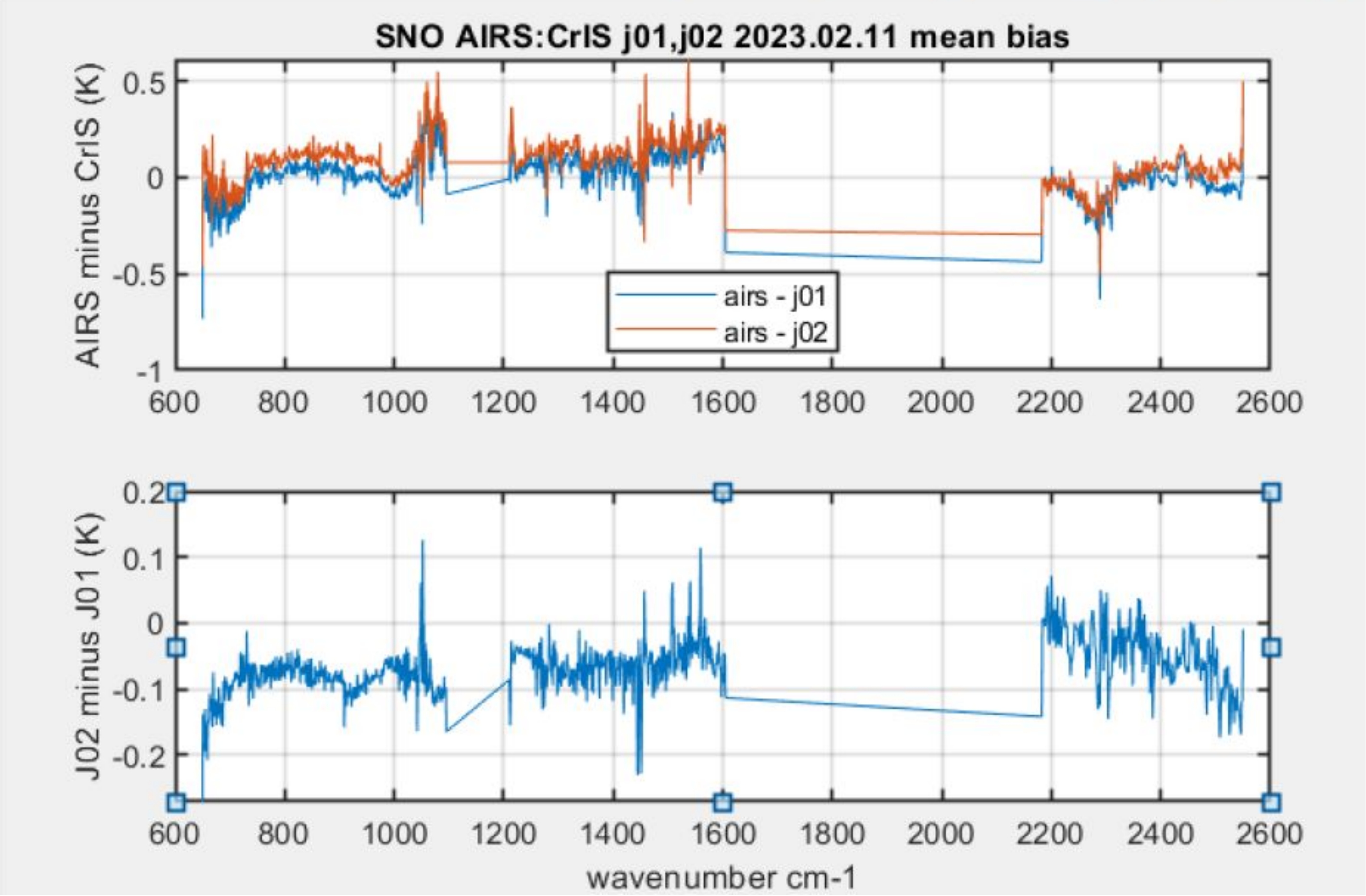
- Left: Shortwave fitting regions for NOAA, UMBC (2 each)
- Right: ECMWF biases in those regions
- I like to avoid regions where BT (and bias?) baselines change a lot
- NOAA has more consistent FOV5 values in SW, mine vary a lot
- Our shortwave relative shifts agree with UW
- Will do similar analysis shown here with NOAA values

Spectral Conclusions

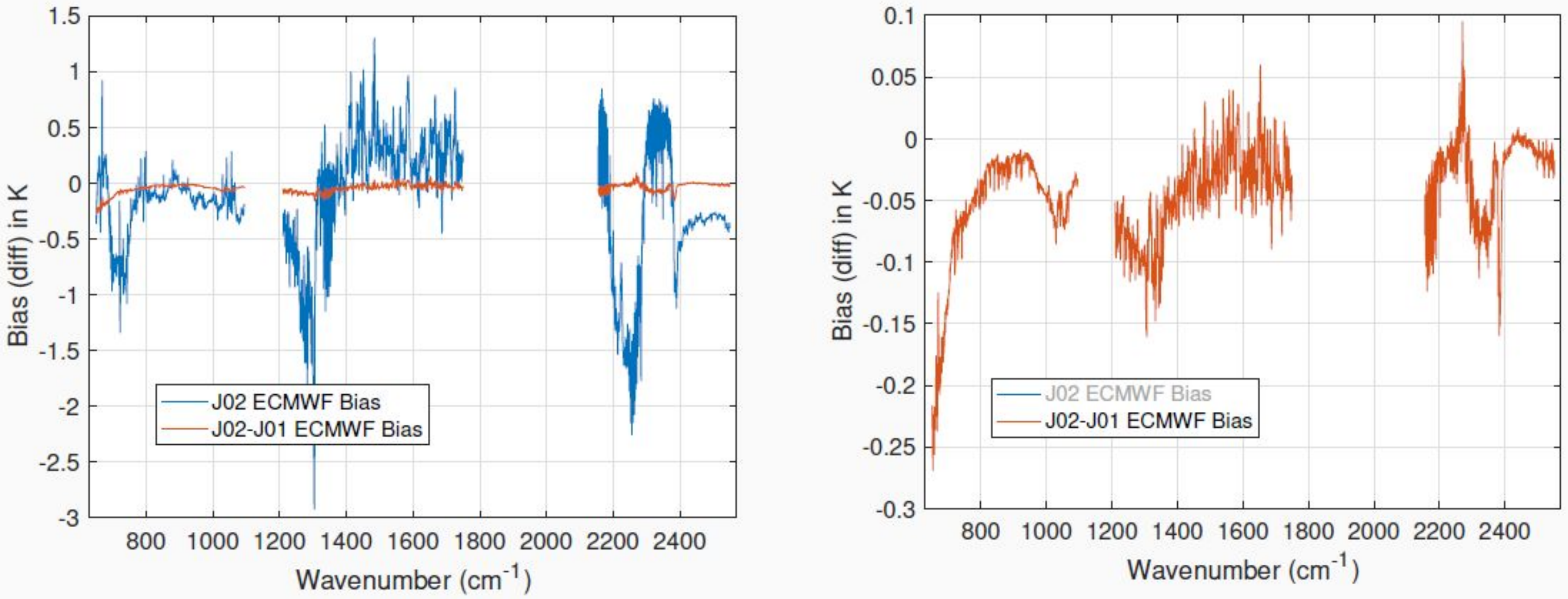
- Quite good V211 ILS parameters now exist
- Small neon differences between LW and MW (not unusual)
- Larger neon differences with shortwave (and with NOAA)
  - Continue to evaluate shortwave issues
- Statistical uncertainties are low, even for 1 day. Systematic errors dominate.
- Since some kind of radial change happened, might be sensitive to diffraction which would vary with band

SNO Double Differences Using CHIRP ILS

- AIRS and NOAA-20,21 converted to CHIRP ILS
- Ignore spikes, they are from AIRS
- SNO single differences on top (statistical errors very low)
- Double SNO diffs remove AIRS: (AIRS - J01) - (AIRS - J02) = J02 - J01



ECMWF Bias Double Differences: NOAA-20 vs NOAA-21



- SNO and ECMWF double differences agree quite well in the longwave where non-linearity is important.
- Non-linearity coefficients for J02 are set to zero here

UMBC Conclusions

- Overall performance is very good
- Spectral offsets will be drastically lower with ENGR PKT 211 ILS coefficients
- J02 behavior different from J01 in terms of TVAC vs in-orbit. Thermal causes?
    - But these are easily handled
- Additional work warranted in shortwave. Possibly switch to sinc RTA rather than Hamming apodized.
- Build up statistics.

User/Downstream Product Feedback (NOAA-21)

Name	Organization	Application	User Feedback - User readiness dates for ingest of data and bringing data to operations
Ken Pryor ken.pryor@noaa.gov	NOAA/STAR NUCAPS Team	Atmospheric Sounding	February 22, 2023

NOAA-21 ATMS/CrIS show high quality with respect to NOAA-20, as demonstrated by no additional tuning needed for the NUCAPS algorithm to generate high quality NOAA-21 NUCAPS EDR products. NUCAPS will work on NOAA-21 tuning specially to improve the EDR results, such as the water vapor RMS in the low levels and the yield number.

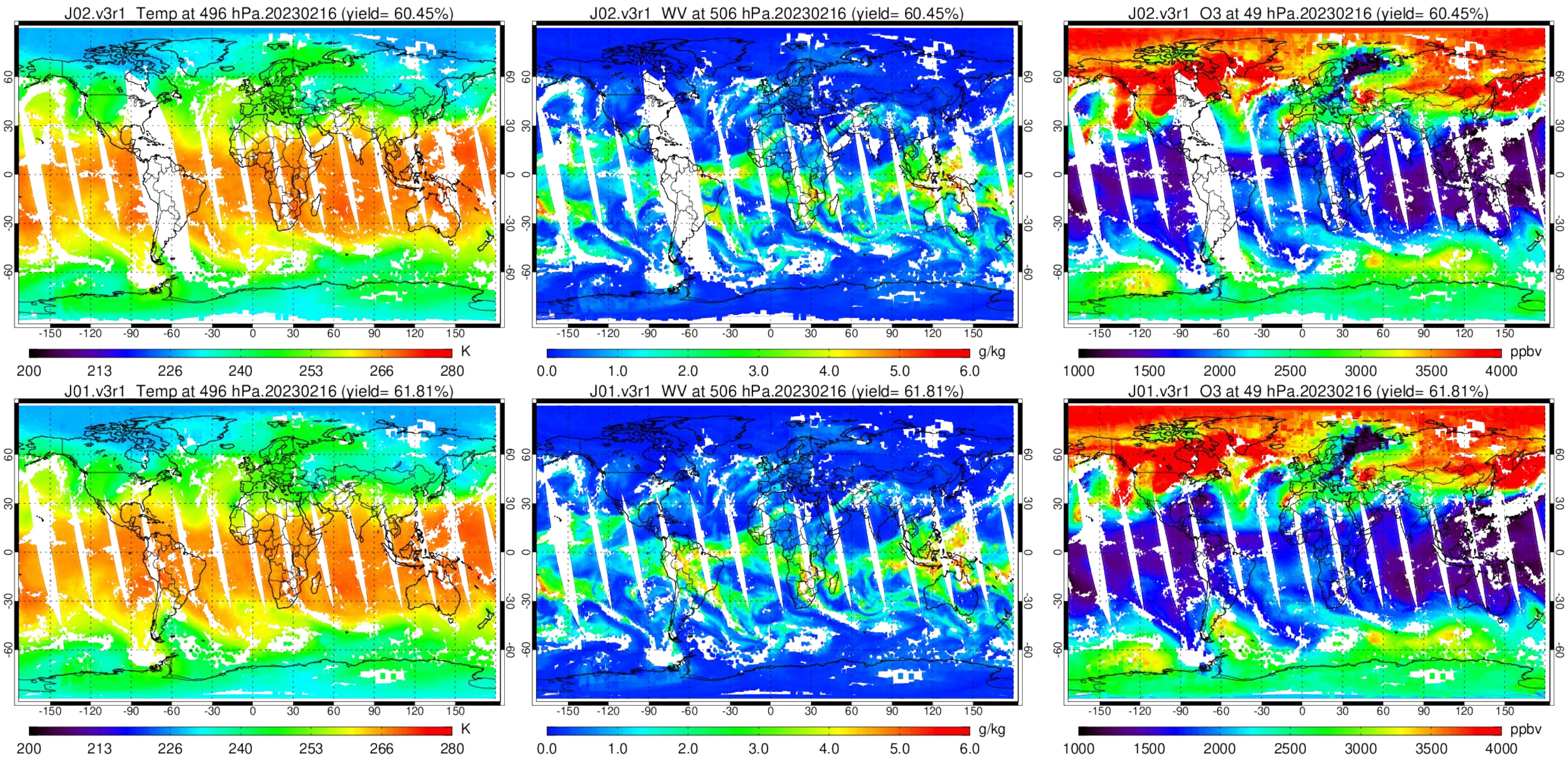
NOAA-21 *vs.* NOAA20 NUCAPS retrievals for 2023/02/16

Temperature at 496 hPa | Water Vapor at 506 hPa | Ozone at 49 hPa

NOAA-21
Yield: 60.5%

NOAA-20
Yield: 62%

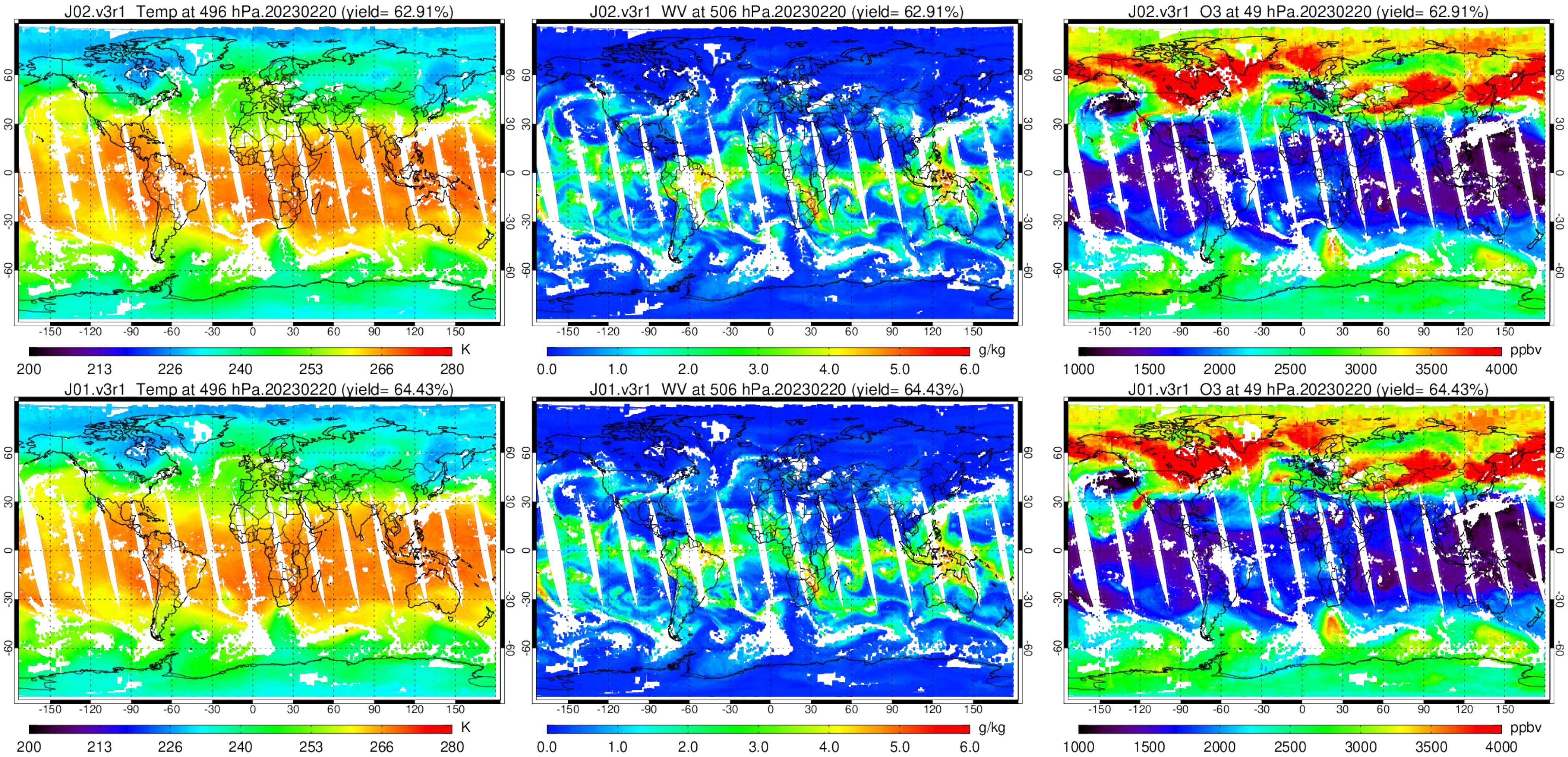
Figures Provided by Tong Zhu, Murty D, and NUCAPS Team Members



NOAA-21 NUCAPS retrievals from J2-Ready algorithm matches very well both qualitatively and quantitatively with the NOAA-21 operational NUCAPS products. The algorithm produces vertical profiles of temperature, water vapor, ozone, CO, CH4, and CO2. Retrieved profiles (100 layers) span from surface to 0.01 hPA.

NOAA-21 *vs.* NOAA20 NUCAPS retrievals for 2023/02/20

Temperature at 496 hPa | **Water Vapor at 506 hPa** | **Ozone at 49 hPa**



NOAA-21
Yield: 63%

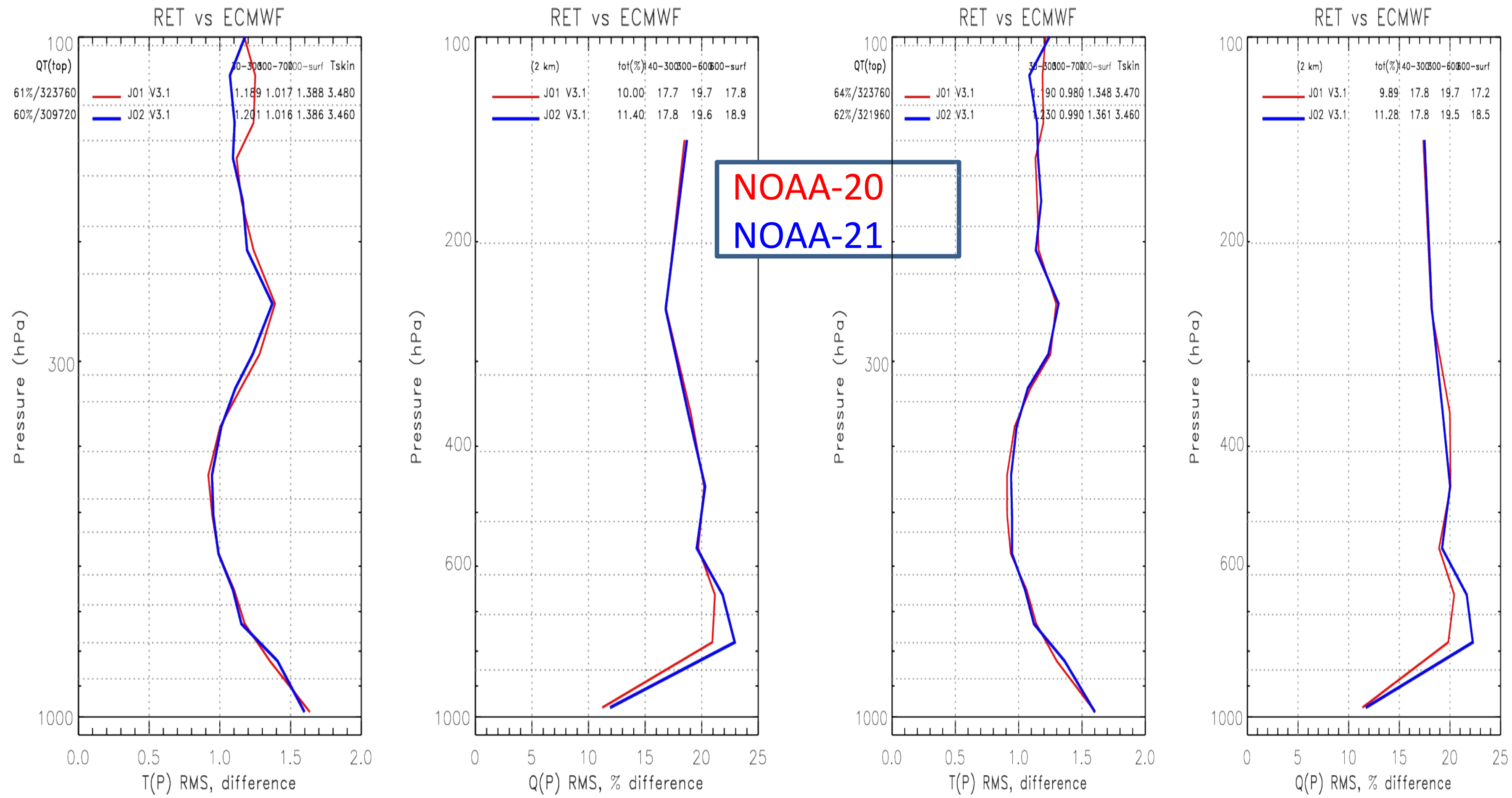
NOAA-20
Yield:65%

Figures Provided by Tong Zhu, Murty D, and NUCAPS Team Members

NOAA-21 NUCAPS retrievals from J2-Ready algorithm matches very well both qualitatively and quantitatively with the NOAA-21 operational NUCAPS products. The algorithm produces vertical profiles of temperature, water vapor, ozone, CO, CH4, and CO2. Retrieved profiles (100 layers) span from surface to 0.01 hPA.

NOAA-21 NUCAPS RMS differences with Matched ECMWF

2023/02/16 RMS Differences with ECMWF		2023/02/20 RMS Differences with ECMWF	
Temperature	Water Vapor	Temperature	Water Vapor



- NOAA-20 and NOAA-21 NUCAPS T(p), q(p) RMS Differences with matched ECMWF show very similar characteristics.
- Currently evaluating CO, CH_4 and CO_2 products with TROPOMI and OCO-2 observations.
- Demonstrates CrIS and ATMS SDRs/TDRs are performing as expected.

Figures Provided by Tong Zhu, Murty D, and NUCAPS Team Members

- **New Improvements for NOAA-21 CrIS**
  - An algorithm update (CCR 6287) has been submitted **for quality control** where **the neon-calibrated laser wavelength** must be between 1540 nm and 1560 nm, or it will be rejected and replaced with the previously valid wavelength value.

NOAA-21 CrIS Pre-Launch Scientific Waivers

There are **no CrIS SDR Pre-Launch Scientific Waivers** for the NOAA-21 beta maturity science review

CrIS Beta Maturity Review - Exit Criteria

- Beta Maturity Performance is well-characterized and meets/exceeds the requirements based on a comprehensive assessment of on on-orbit NOAA-21 CrIS SDR data and comparisons against pre-launch data.
- No major data gaps associated with the performance of the SDR calibration algorithm have been identified.

Risks, Actions, and Mitigations

Identified Risk	Description	Impact	Action/Mitigation and Schedule
None	**No major risks** have been identified for the NOAA-21 CrIS SDRs. Fine-tuning is being performed to further improve the quality of the NOAA-21 CrIS SDR data.	None	None

Documentations (Science Maturity Checklist)

Science Maturity Checklist	Yes ?	Where
ReadMe for Data Product Users	Yes	https://docs.google.com/document/d/1Y-a2NyYlK-4cXm6GWqxl5Yb6djY6lrGx/edit?usp=share_link&ouid=108646070675148611458&rtpof=true&sd=true
Algorithm Theoretical Basis Document (ATBD)	Yes	https://docs.google.com/document/d/14Nqk6b-Ay--dNywRZg8iWA_GZs8NvPyY/edit?usp=share_link&ouid=108646070675148611458&rtpof=true&sd=true
Algorithm Calibration/Validation Plan	Yes	https://docs.google.com/document/d/1Ce4FS8GTtkx-_E50efIRM1mWGxaPK-VX/edit?usp=share_link&ouid=108646070675148611458&rtpof=true&sd=true
(External/Internal) Users Manual	Yes	https://www.star.nesdis.noaa.gov/jpss/documents/UserGuides/CrIS_SDR_Users_Guide1p1_20180405.pdf
System Maintenance Manual (for ESPC products)	Not Applicable	Not Applicable
Peer Reviewed Publications (Demonstrates algorithm is independently reviewed)	In Progress	In Progress
Regular Validation Reports (at least annually) (Demonstrates long-term performance of the algorithm)	In Progress	In Progress

Check List - Beta 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

Product Requirements Met

- Product Overview
- Product performance requirements from JPSS Data Product Specification (DPS)

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	TBD	0.77	YES
Radiometric Stability @ 287K BB (%) (J1MSS-1592)	0.40	YES	0.50	TBD	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

NOAA-21 CrIS SDR Performance vs JPSS L1-Requirements

Band	Minimum Wavenumber Range[1] (cm^{-1})	# of Channels[4]	Spectral Resolution (cm^{-1})[1,3]	Maximum NEdN @287K BB[2] ($mW/m^2/sr/cm^{-1}$)	Radiometric Accuracy @287K[1,2] (%)	Maximum Spectral Uncertainty[1] (ppm)	Geolocation Mapping Uncertainty (3σ)[1] (km)
LWIR	650-1095	713	0.625	(0.189) 0.45 @ 670 cm-1, (0.109) 0.15 @ 700 cm-1, (0.0697) 0.15 @ 850 cm-1, (0.0585) 0.15 @ 1050 cm-1	(0.19) 0.45	(6) 10	(3.7) 5
MWIR	1210-1750	865	0.625	(0.01949) 0.078 @ 1225 cm-1 (0.01826) 0.064 @ 1250 cm-1 (0.02001) 0.069 @ 1500 cm-1 (0.02691) 0.075 @ 1700 cm-1	(0.21) 0.58	(6) 10	(3.7) 5
SWIR	2155-2550	633	0.625	(0.00491) 0.013 @ 2200 cm-1 (0.00416) 0.014 @ 2350 cm-1 (0.00795) 0.014 @ 2550 cm-1	(0.37) 0.77	(6) 10	(3.7) 5

[1]JPSS Algorithm Specification Volume I: Software Requirement Specification (SRS) for the CrIS RDR/SDR, 474-00448-01-03, Revision I, October 24, 2019.
[2]JPSS Level 1 Requirements Document Supplement (L1RDS) – Final, JPSS-REQ-1002/470-00032, Revision 2.11, Rev. 2.1, 02/07/2019. The NEdN Maximum values for the MWIR and SWIR are the result of scaling the NEDN values, defined in Table 4.3, by a factor of $\sqrt{2}$ and 2, respectively.
[3]JPSS-2 CrIS Performance Requirements Document (PRD), 472-00346, Revision B, 03/10/2016.
[4]JPSS CrIS SDR ATBD) for Full Spectral Resolution, June 14, 2018.

Justification

Based on nearly twelve days of intensive evaluation and monitoring of the NOAA-21 CrIS data, the following assessment of the NOAA-21 CrIS SDR and GEO products are given:

1. **On-orbit SDR radiometric qualit**y on all FOVs and spectral bands has been **well-characterized** using different datasets:
    a. On-orbit SDR spectral calibration and radiometric calibration quality was assessed using FOV-2-FOV difference methodologies.
    b. **On-orbit SDR radiometric quality was assessed based on** preliminary **comparisons** with **observations minus CRTM** simulations using the **ECMWF model data** as input.
    c. On-orbit SDR radiometric quality is stable statistically based on comparisons against simulated observations and satellite observations form NOAA-20/CrIS, AQUA/AIRS and GOES/ABI infrared sensors.
        i. **Intercomparisons with VIIRS** show **consistent and small residuals** since turn-on.
2. **On-orbit radiometric noise** in the form of **NEdN** has shown **consistent performance against pre-launch analysis results**, where all FOVs meet the JPSS Level-1 requirements with margin;
3. **On-orbit SDR absolute and relative spectral calibration shifts** were estimated. Preliminary results show the absolute spectral shifts for **all three bands are within 6 ppm** since the first light observation.
4. **On-orbit GEO accuracy is within requirements**.
5. **NOAA STAR NUCAPS team has performed an initial assessment of the . High quality NOAA-21 NUCAPS EDR products were generated using NOAA-21 CrIS SDR data. No additional tuning was needed for the NUCAPS algorithm.**

Caveats

The following caveats are provided to the Beta NOAA-21 CrIS data product users:

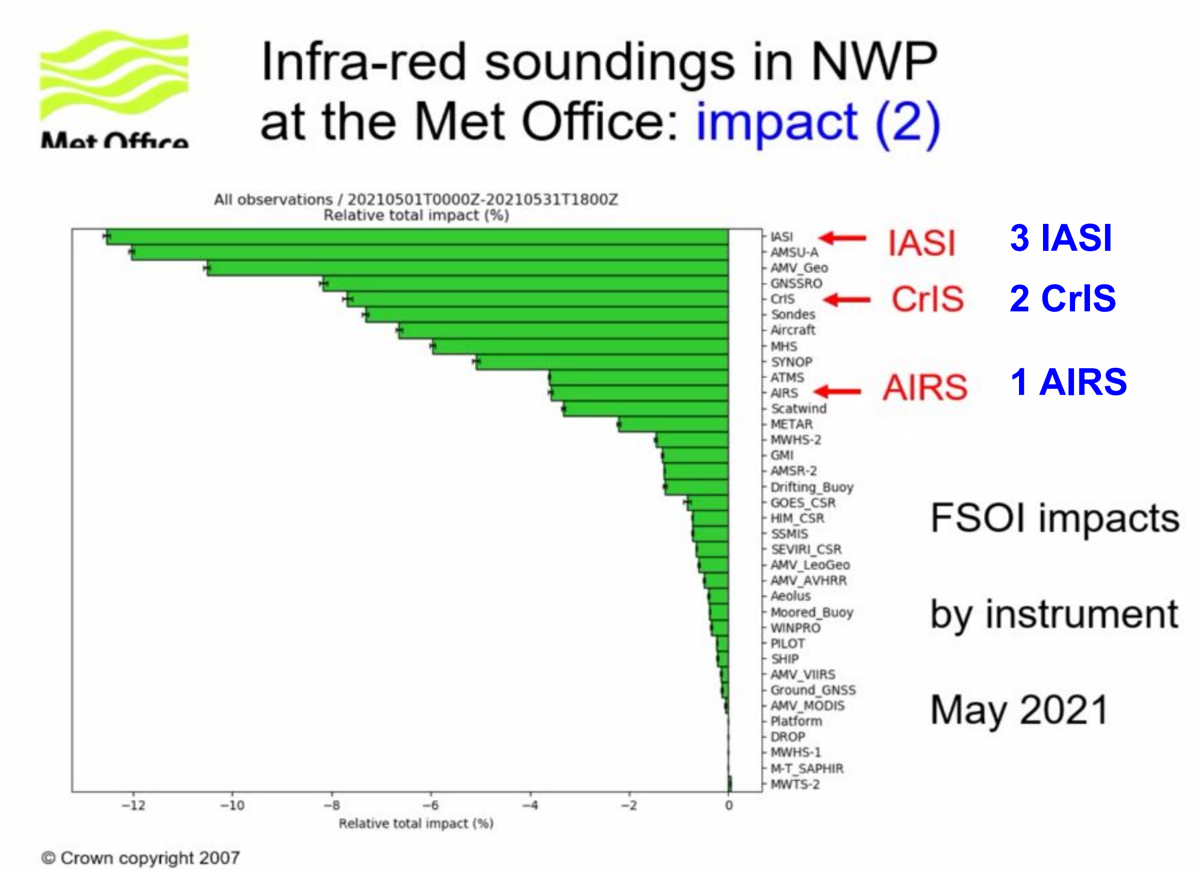
1) Some analyses presented at the Beta review are performed using off-line processing rather than the official SDR product.
2) **Geolocation meets the requirements; however, the performance is still a function of the sensor field of regard.** This dependency is planned to be reduced after the proper optimization of the geolocation parameters planned on the EP v211.
3) **Calibrated radiances have shown a feature on its imaginary component over the 40S-65S latitude region during descending (nighttime) passes.** The impact of this feature has been quantified and does not impact the quality of the NOAA-21 CrIS SDR data. Investigation results show that this is not related to the calibration algorithm, but related to thermal impact on the sensor. Efforts will continue to understand this feature and will be reported toward the provisional maturity review.
4) **Radiometric consistency between FOVs needs to be optimized** and reflected in the EP v211 update. Diagnostic mode data used as part of the **on-orbit nonlinearity characterization has not been collected yet (planned for February 24)**
5) **The spectral calibration parameters** including the Instrument Line Shape (ILS) **need to be optimized** and uploaded in the EP v211 update **for bringing the SDR performance in line with previous instruments.**

Path Forward

The team CrIS Cal/Val Science Team will perform the following intensive calibration and validation activities to enhance the quality and demonstrate the Provisional Maturity level of the NOAA-21 CrIS data:

1) **Monitor the sensor** for short and long-term stability.
2) **Perform** the following **optimizations** as part of the calibration and validations activities as described in the NOAA-21 Calibration Validation Plan, in particular including:
    a) Optimize the non-linearity calibration coefficients.
    b) Optimize the spectral calibration parameters.
    c) Optimize the geolocation calibration parameters.
3) **Test and deliver the engineering packet version 211** after comprehensive characterization of the updated calibration parameters.
4) Continue to **monitor and investigate the 40S-65S latitude imaginary radiance behavior.**
5) Analyze the **pitch maneuver data to derive instrument polarization coefficients.**
6) **Assessed the effect of the permanent spacecraft pitch** offset of -10 arc minutes, performed to optimize OMPS performance.
7) Characterize the instrument performance following the NOAA-21 CrIS Calibration/Validation Plan.

Potential Benefits of 3 JPSS Satellites



John Eyre (Met Office, UK), "Infra-red sounding in NWP at the Met Office: Experience and suggestions for future systems", NOAA Infrared Sounder Workshop, December 6, 2021

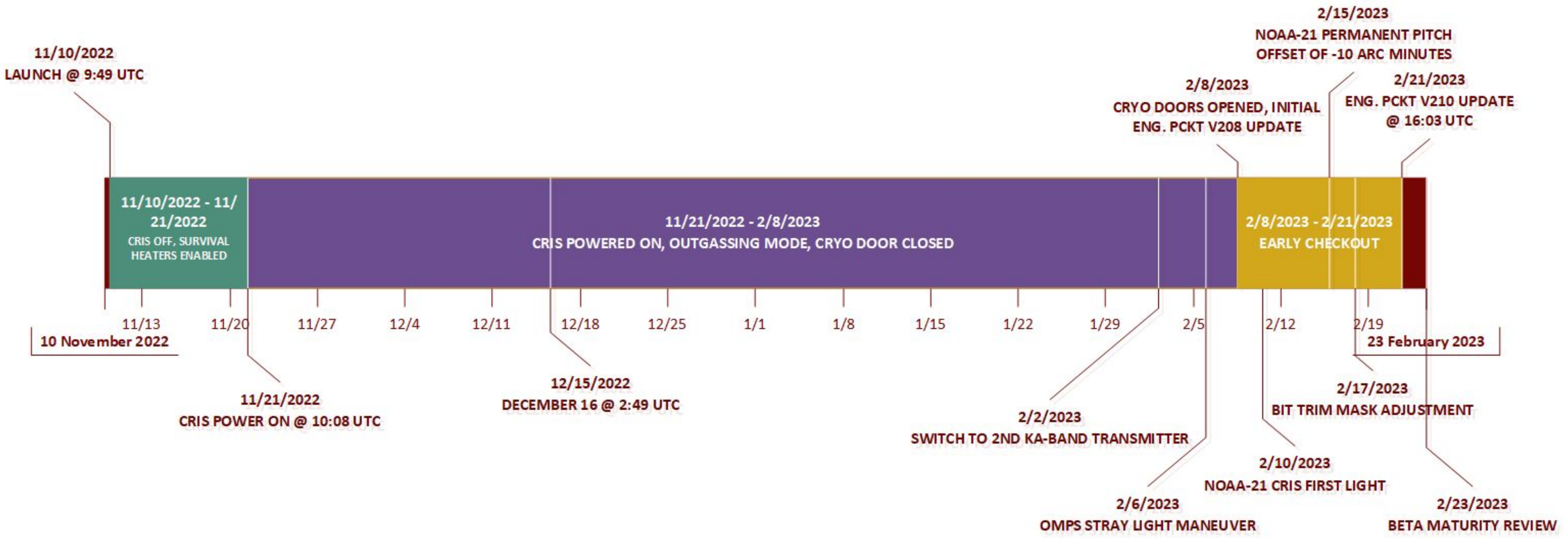
- **IR Sounders have shown to be the most impactful observations for NWP at ECMWF and Met Office.**
- **The addition of a 3rd IR sounder is expected to enhanced the sensing of the Earth's atmosphere dynamics due to improved spatial and temporal coverages.**
- **The information is not saturated with 2 IR sensors (IASI Case); the 3rd satellite has shown to provide significant additional forecast impact.**
- **The very large majority of NWP impact comes from the LW band. One option is to have S-NPP in the current LW+SW configuration to realize these benefits. Then, perform additional experiments (for example deriving wind information) utilizing MW and SW data using the existing NOAA-20, NOAA-21, along with Aqua, MetOp and GOES data.**
- **Study other orbit configurations to explore the benefits in terms of spatial/temporal coverage and reduce correlation between sensor observations.**

Acknowledgements (NOAA-21 CrIS Beta Review)

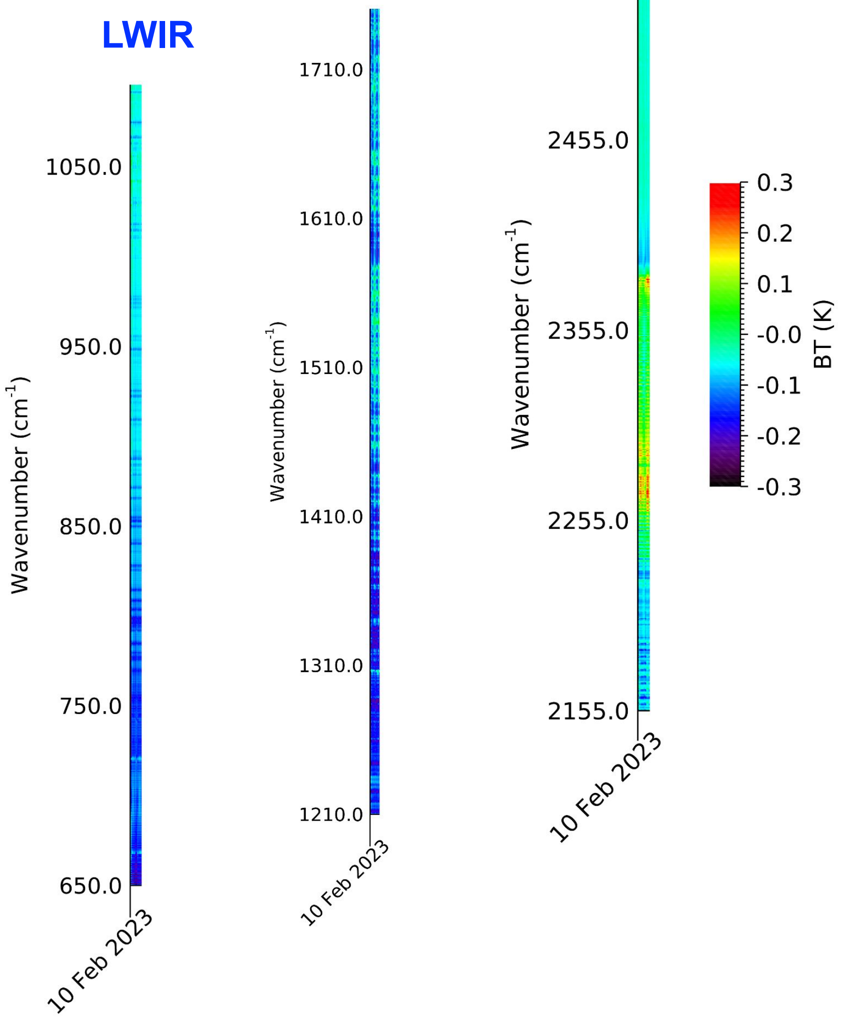
Acknowledgement and thanks are extended to all individuals and organizations participating in the intensive NOAA-21 CrIS Pre-launch analysis, Early Checkout, and Intensive Cal/val toward Beta Maturity, an example of Team Effort, Hard Work, Dedication and Professionalism: **NOAA/STAR, NASA, University of Wisconsin, University of Maryland Baltimore County, L3Harris, Logistikos, Northrop Grumman, and MIT (Pre-Launch Testing)**.

Backup Slides

NOAA-21 CrIS Post-Launch Timeline



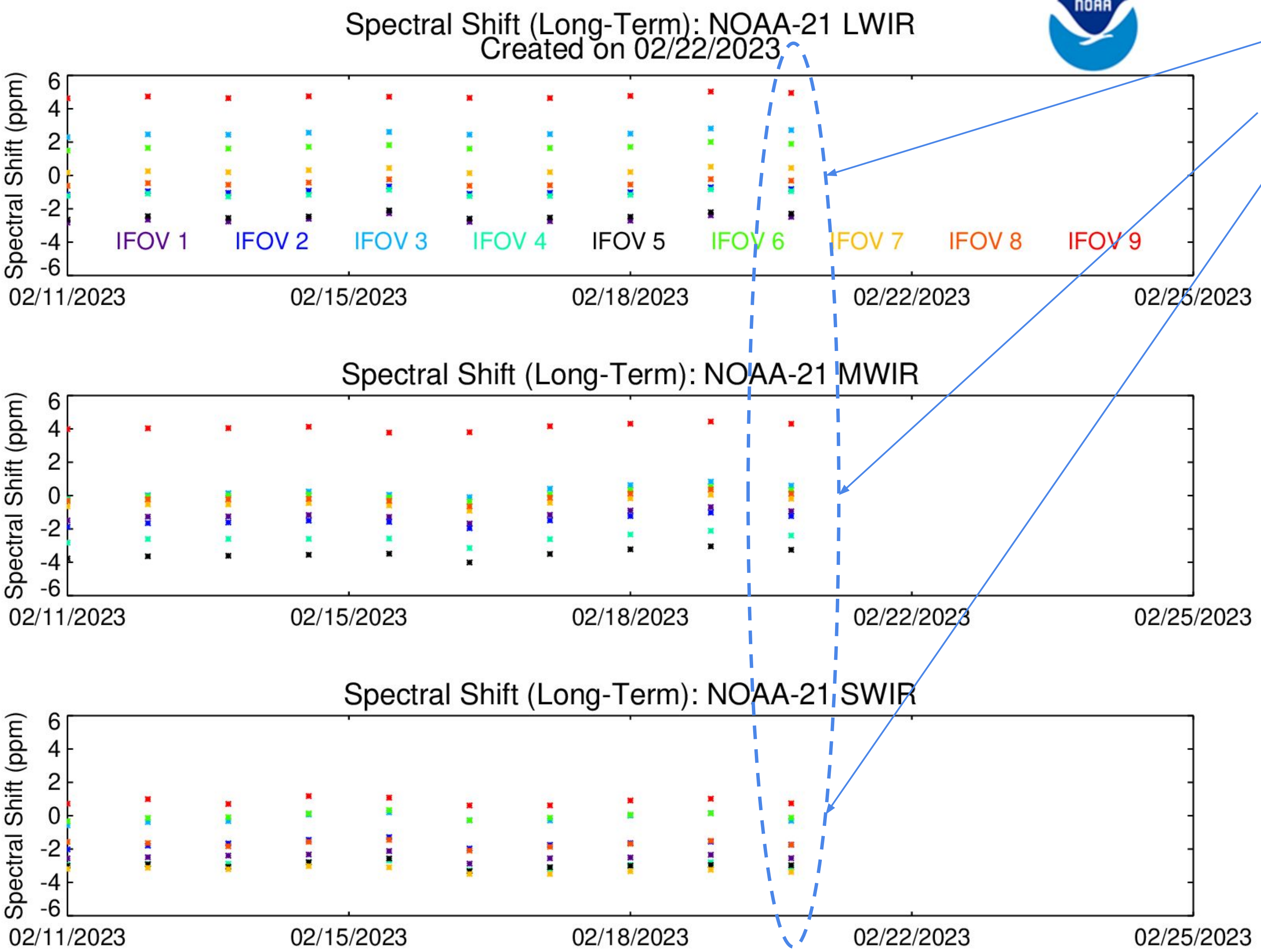
Time Series of Radiometric Comparisons Between NOAA-21 and NOAA-20 CrIS



- NOAA-21 CrIS started to collect science data since February 10, 2023.
- A short time series of NOAA-21 CrIS radiometric comparisons with NOAA-20 CrIS show radiance differences are within 0.3 K for majority of channels since the first light observation.
- NOAA-21 CrIS Calibration Table v208 (TVAC-based) was used in this time series between February 10 and 19, 2023.

Provided by Kun Zhang

Time Series of Absolute Spectral Accuracy for NOAA-21 CrIS

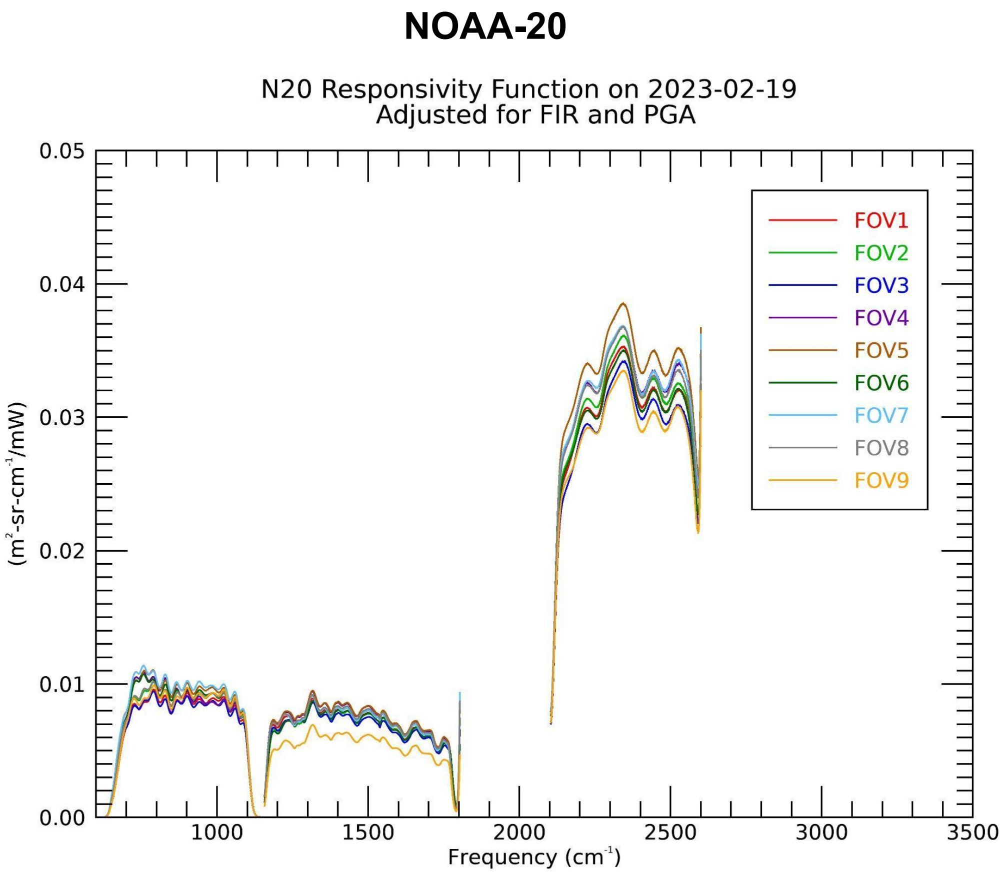


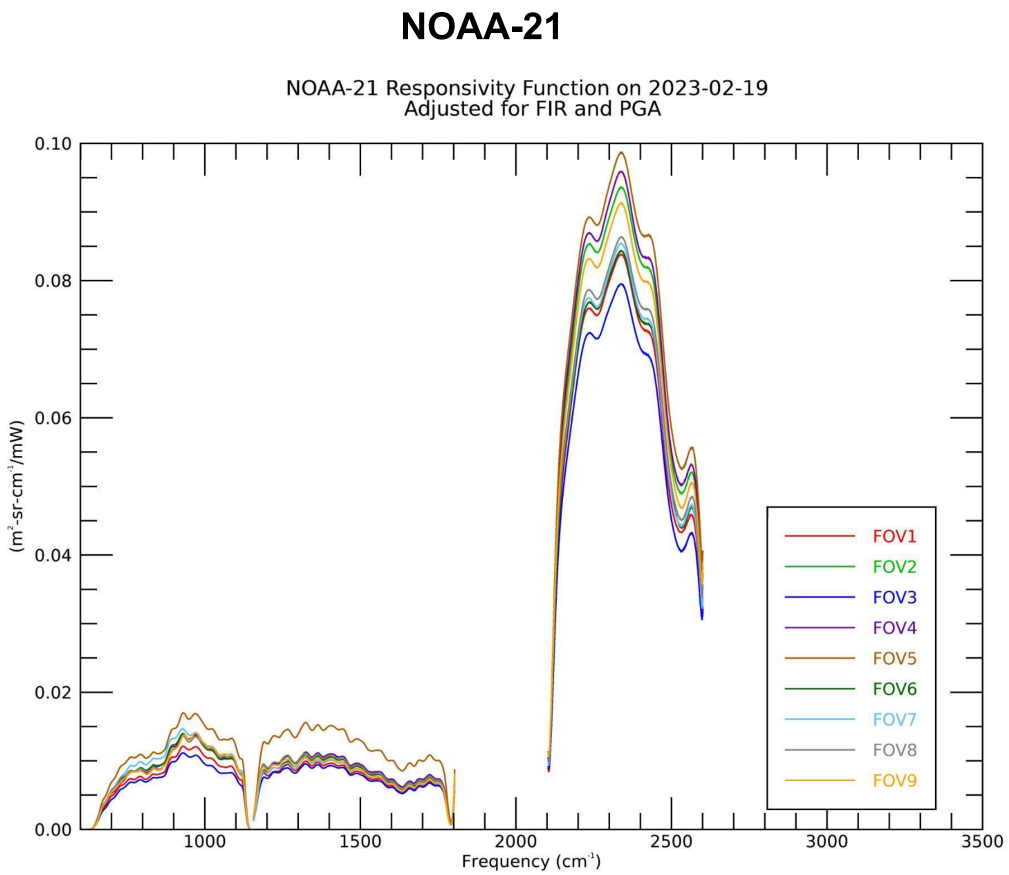
	FOV1	FOV2	FOV3	FOV4	FOV5	FOV6	FOV7	FOV8	FOV9
---LW---									
	-2.484	-0.814	2.720	-0.944	-2.295	1.894	0.452	-0.313	4.949
---MW---									
	-0.939	-1.228	0.598	-2.394	-3.252	0.323	-0.190	0.119	4.307
---SW---									
	-2.545	-1.737	-0.303	-3.085	-2.971	-0.119	-3.377	-1.746	0.742

- The NOAA-21 CrIS shows stable spectral performance since turn-on and the absolute spectral accuracy meets the requirement (within 10 ppm).
- The spectral performance of NOAA-21 CrIS will be improved to the same level as previous CrIS instruments by the On-Orbit Calibration Table v211 update.

Provided by Kun Zhang

CrIS Responsivity: NOAA-21 relative to NOAA-20





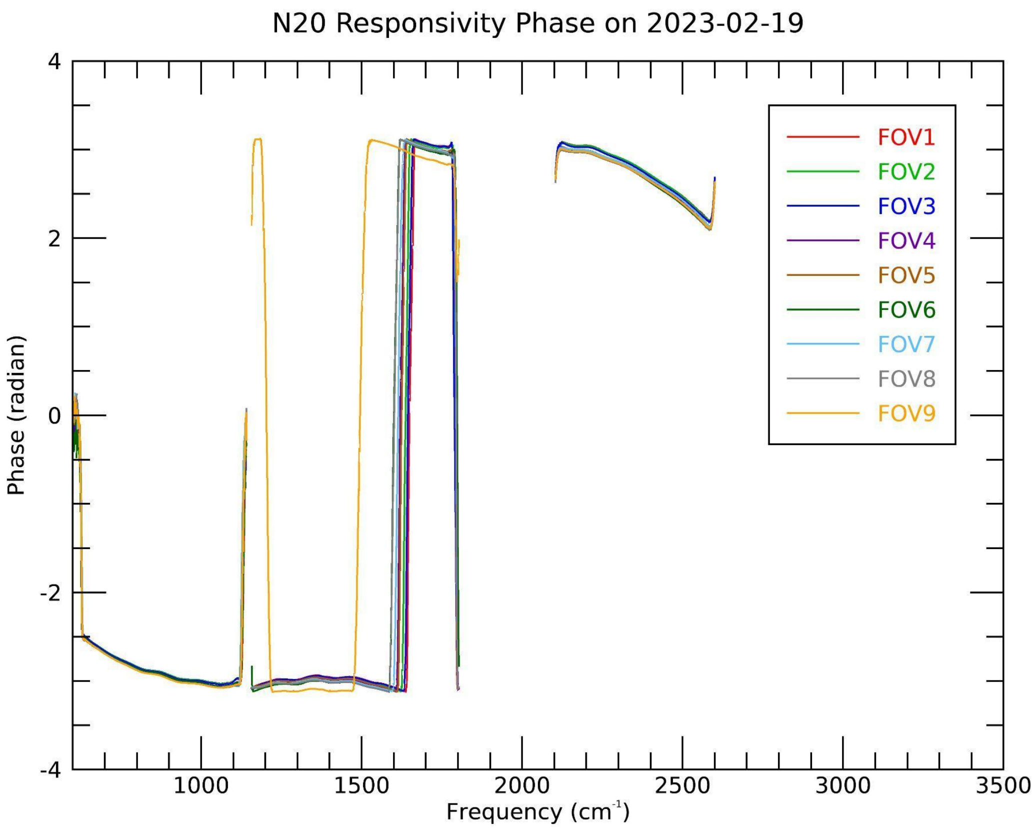
Main point: Responsivity is as high or higher for NOAA-21 than it was for NOAA-20 for all three bands (SWIR, LWIR, MWIR)

- These changes are calibrated out.
- Monitoring tool is developed to track possible degradation due to ice and/or chemical contamination.
- Possible responsivity degradation would increase the NEdN.

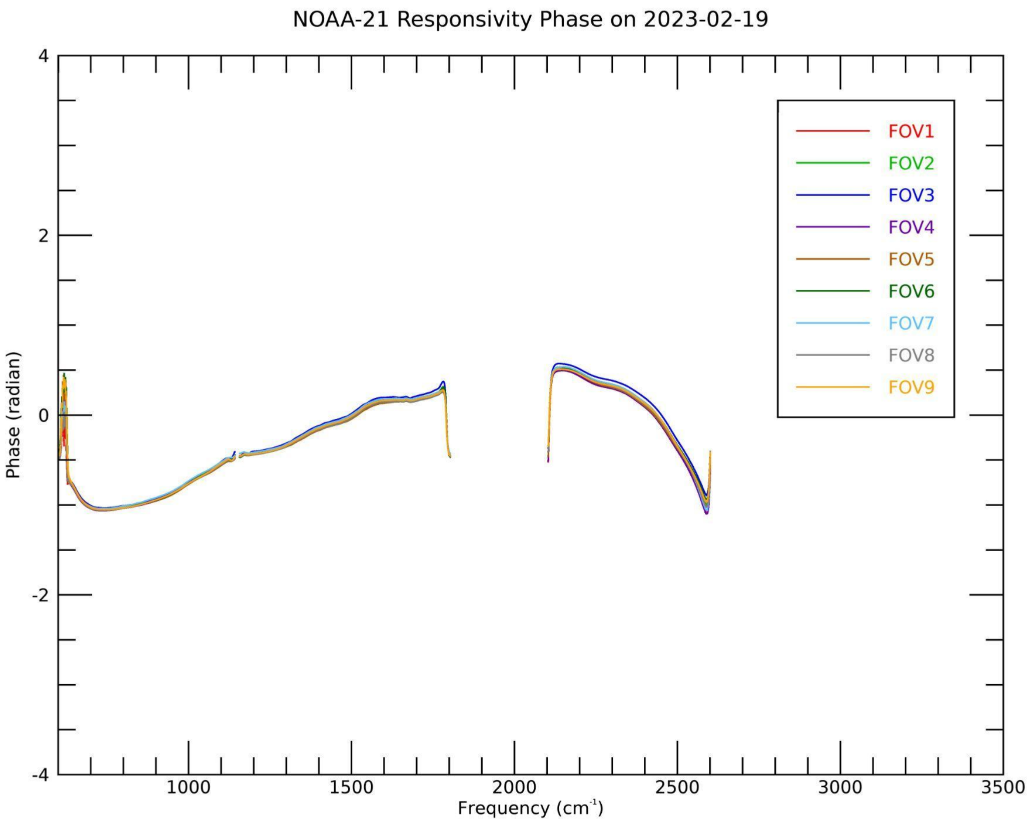
Provided by Denis Tremblay

CrIS Responsivity Phase: NOAA-21 relative to NOAA-20

NOAA-20



NOAA-21



NOAA-21 responsivity phase has better FOV overlay than NOAA-20.

Provided by Denis Tremblay