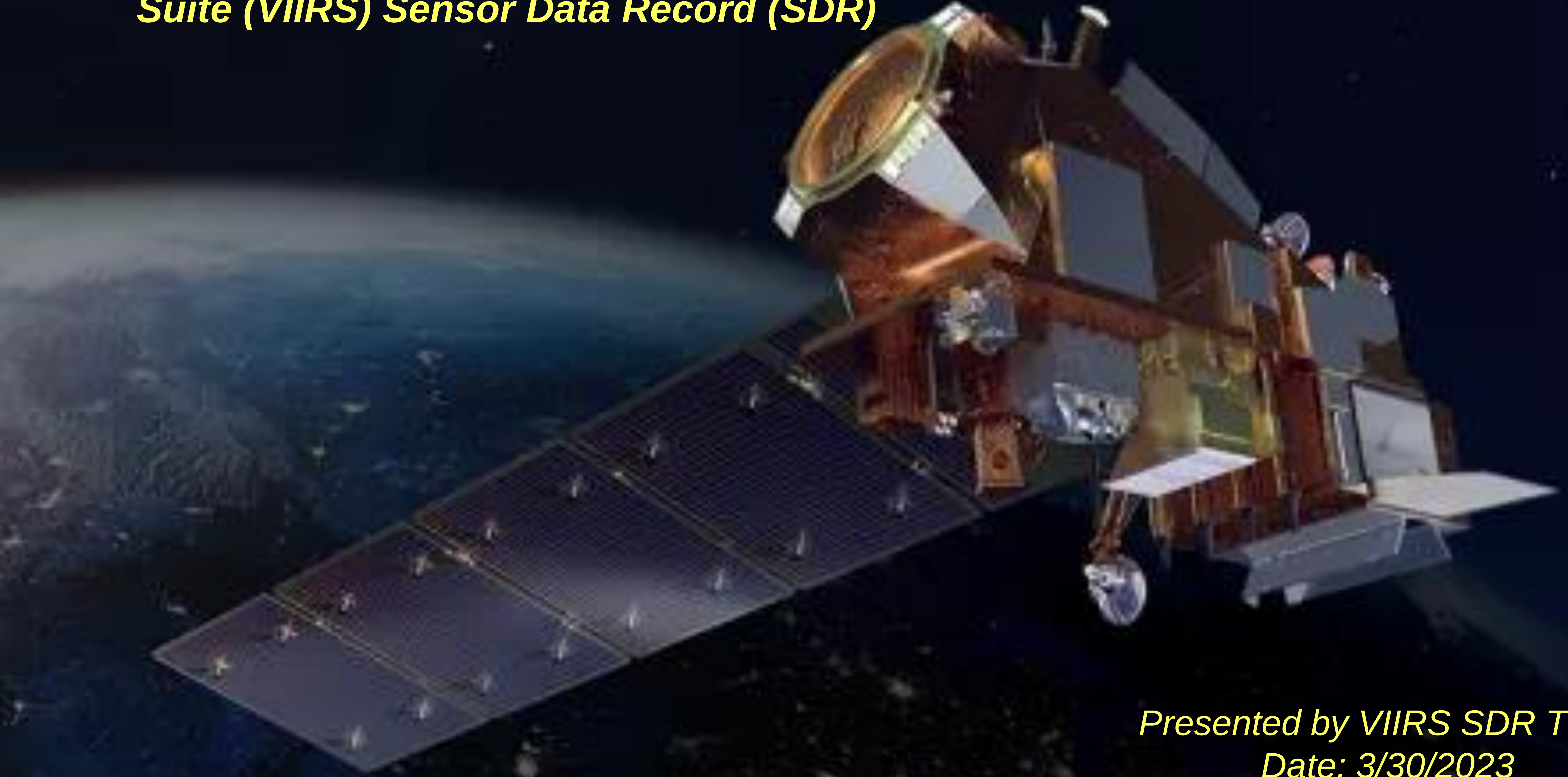
Provisional Maturity Science Review For NOAA-21 Visible Infrared Imaging Radiometer Suite (VIIRS) Sensor Data Record (SDR)



Presented by VIIRS SDR Team

Date: 3/30/2023

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

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.

Provisional Maturity Review - Entry Criteria (provided by JSTAR)

- Product Requirements
- Pre-launch Performance Matrix/Waivers
- Provisional Maturity Performance Validation
  - On-orbit instrument performance assessment
    - instrument and product characteristics verified/validated
    - pre-launch concerns/waivers, mitigation and evaluation attempts with on-orbit data
- Users/Downstream-Products feedback
- Risks, Actions, Mitigations
  - Potential issues, concerns
- Path forward to Validated Maturity
- Summary

Provisional Maturity Review - Exit Criteria (provided by JSTAR)

- Provisional Maturity Performance is well characterized and meets/exceeds the requirements:
  - On-orbit instrument performance assessment
    - Summary for NOAA-21 VIIRS instrument and product characteristics you we have validated/verified as part of the entry criteria
    - Provide summary of pre-launch concerns/waivers mitigations/evaluation and address whether any of them are still a concern that raises any risk.
- Updated Maturity Review Slide Package addressing review committee's comments for:
  - Calibration/Validation (Cal/Val) Plan and Schedules
  - Product Requirements
  - Provisional Maturity Performance
  - Risks, Actions, Mitigations
  - Path forward to Validated Maturity

NOAA-21 Visible Infrared Imaging Radiometer Suite (VIIRS) Sensor Data Record (SDR)

Provisional MATURITY REVIEW

Outline

- Algorithm Cal/Val Team Members
- Product Overview and Requirements
- Evaluation of NOAA-21 VIIRS instrument/algorithm performance to specification requirements
  - Instrument performance
  - Algorithm version, processing environment
  - Evaluation of the effect of required algorithm inputs
  - Quality flag analysis/validation
  - Error Budget
- User Feedback
- Downstream Product Feedback
- Risks, Actions, and Mitigations
- Documentation (Science Maturity Check List)
- Conclusion
- Path Forward

JPSS VIIRS Cal/Val Team

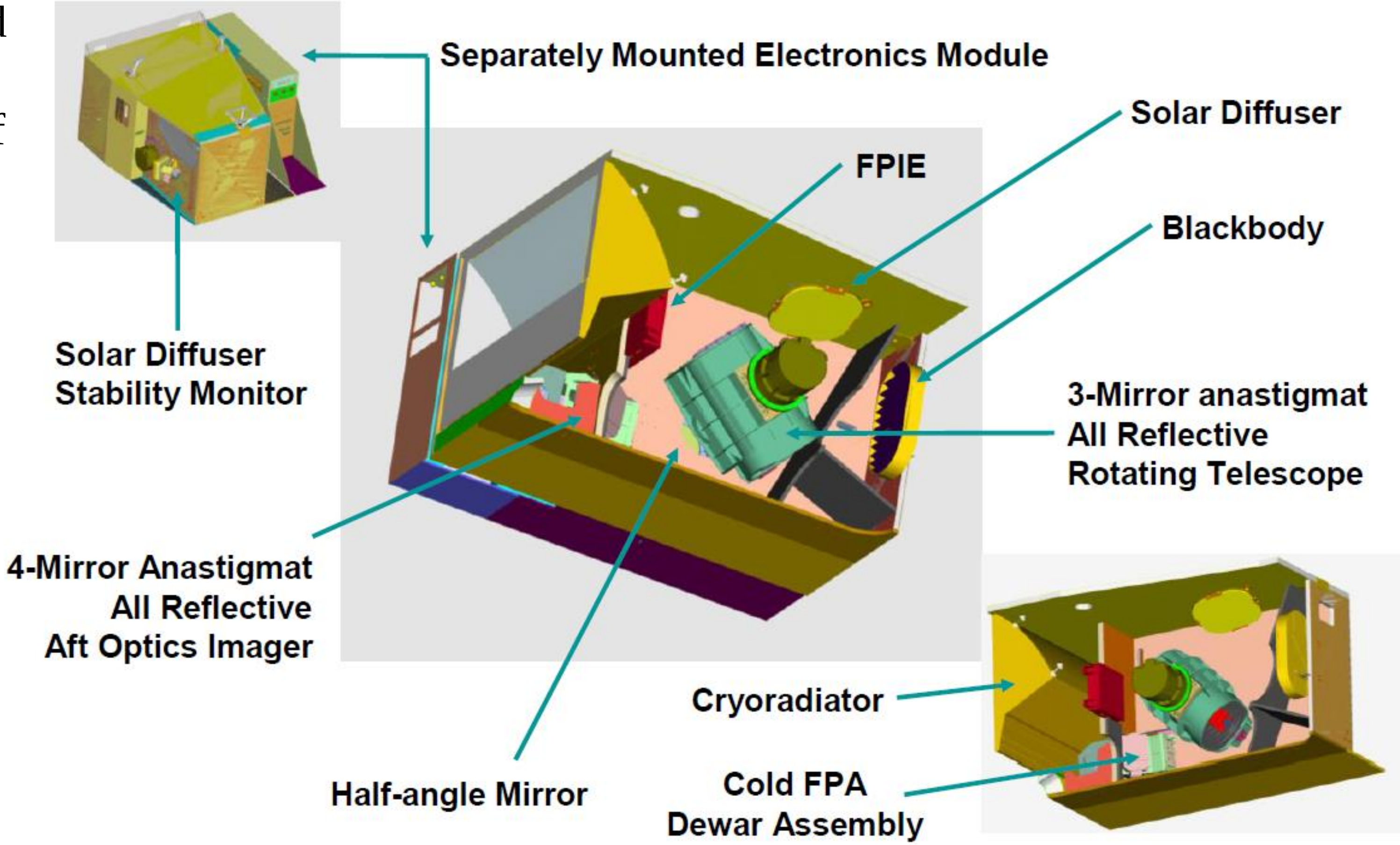
Name	Organization	Major Task
Changyong Cao	NOAA/STAR	NOAA STAR VIIRS Cal/Val Team Lead
Slawomir Blonski	GST, Inc. @ NOAA/STAR	Instrument science; POC for operations; STAR VIIRS Cal/Val Team
Wenhui Wang	UMD/CISESS @ NOAA/STAR	TEB cal/val/CPM; STAR VIIRS Cal/Val Team
Xi (Sean) Shao	UMD/CISESS @ NOAA/STAR	DNB/lunar cal/orbits; STAR VIIRS Cal/Val Team
Taeyoung (Jason) Choi	GST, Inc. @ NOAA/STAR	Solar/lunar cal; STAR VIIRS Cal/Val Team
Bin Zhang	UMD/CISESS @ NOAA/STAR	NOAA STAR VIIRS Cal/Val Team
Yan Bai	UMD/CISESS @ NOAA/STAR	Image quality/Envi/web; STAR VIIRS Cal/Val Team
Khalil Ahmad	GST, Inc. @ NOAA/STAR	Data analysis/Image quality/reprocessing; VIIRS Cal/Val Team
Priya Pillai	GST, Inc. @ NOAA/STAR	Cloud/RTM/data quality; STAR VIIRS Cal/Val Team
Tom Liu	UMD/CISESS @ NOAA/STAR	Data analysis/anomaly; STAR VIIRS Cal/Val Team
Dave Moyer & Team	Aerospace	Postlaunch to prelaunch traceability
Jack Xiong/R. Wolfe & team	NASA	NASA VIIRS Characterization Support Team
Chris Moeller & team	CIMSS	VIIRS RSR development, TEB validation, RTM, User interaction

NOAA-21 VIIRS Instrument

- VIIRS is a scanning imaging radiometer onboard Suomi NPP and JPSS satellites that produces global imagery and radiometric measurements of land, atmosphere, cryosphere, and oceans in the visible and infrared bands with moderate spatial resolutions at 22 spectral bands;

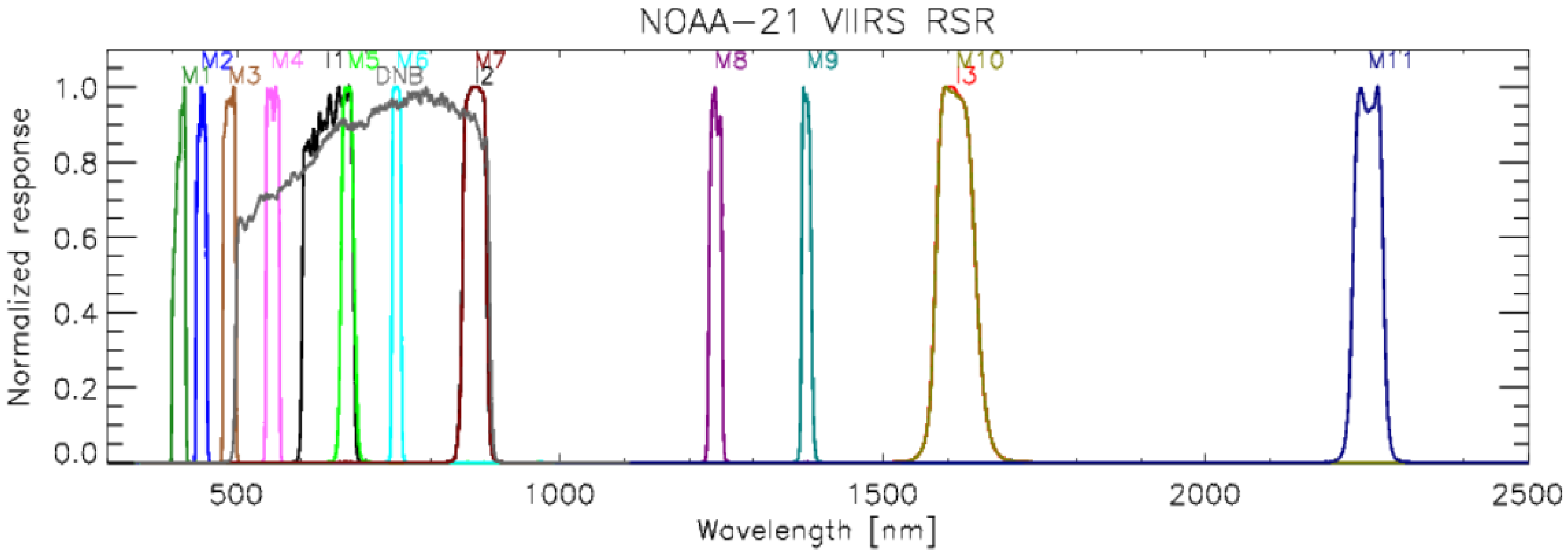
- The operationally produced VIIRS data are widely used globally to monitor hurricanes/typhoons, cloud and aerosol properties, ocean color, sea and land surface temperature, ice motion and temperature, active fires, and Earth's albedo.

- The VIIRS data support the operational production of at least 26 Environmental Data Records(EDRs);



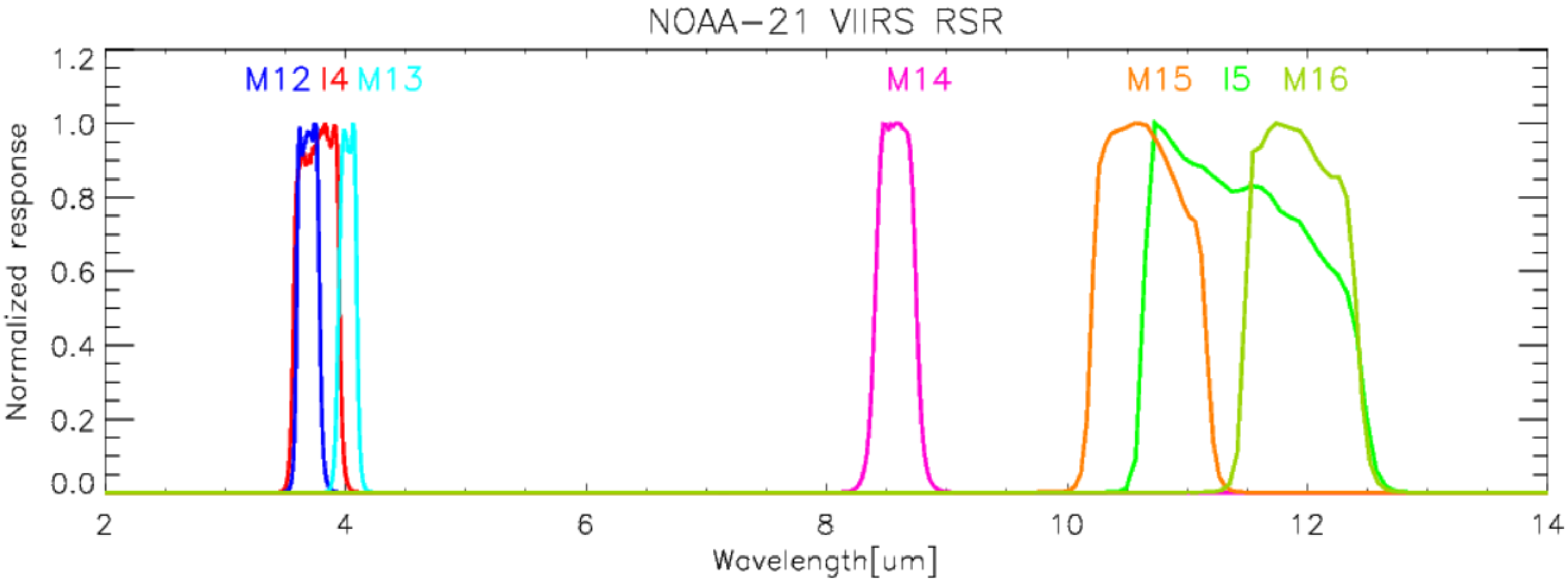
VIIRS Spectral Bands: Reflective Solar Bands (RSB)/ Day/Night Band (DNB)

- Spectral Bands of VIIRS RSBs and DNB
  - RSBs cover a spectral range from 0.412 μm to 2.25 μm
  - There are 14 RSBs with 3 image bands (I1-I3) and 11 moderate bands (M1-M11)
  - RSB band calibration is dependent on Solar Diffuser (SD) and Solar Diffuser Stability Monitor (SDSM) observations
  - The required RSB calibration uncertainty is within 2%
  - DNB is a panchromatic band with spectral range 0.5μm - 0.9 μm



VIIRS Spectral Bands: Thermal Emissive Bands (TEB)

- Spectral Responses of VIIRS TEBs
  - There are 7 bands with 2 image band (I4, I5) and 5 moderate bands (M12-M16)
  - Calibration sources are Onboard Blackbody (BB) with six thermistors and space view



VIIRS Sensor Data Record (SDR) Requirements

Band		Center Wavelength (nm)	Maximum FOV @ Nadir (km)	Maximum FOV @ Edge-of-Scan (km)	Ltyp or Ttyp (spec)	Specification SNR (RSB & DNB) NEDT (TEB)	Accuracy Specification
RSB	M1	412	0.8	1.6	155, 44.9 (LG, HG)	316, 352 (LG,HG)	2%
	M2	445	0.8	1.6	146, 40 (LG, HG)	409, 380 (LG,HG)	2%
	M3	488	0.8	1.6	123, 32 (LG, HG)	414, 416 (LG,HG)	2%
	M4	555	0.8	1.6	90, 21 (LG, HG)	315, 362 (LG,HG)	2%
	M5	672	0.8	1.6	68, 10 (LG, HG)	360, 242 (LG,HG)	2%
	M6	746	0.8	1.6	9.6	199	2%
	M7	865	0.8	1.6	33.4, 6.4(LG, HG)	340, 215 (LG,HG)	2%
	M8	1240	0.8	1.6	5.4	74	2%
	M9	1378	0.8	1.6	6	83	2%
	M10	1610	0.8	1.6	7.3	342	2%
	M11	2250	0.8	1.6	1.0	90	2%
	I1	640	0.4	0.8	22	119	2%
	I2	865	0.4	0.8	25	150	2%
	I3	1610	0.4	0.8	7.3	6	2%
TEB	M12	3700	0.8	1.6	270	0.396	0.7% (0.13 K)
	M13	4050	0.8	1.6	380, 300 (LG, HG)	0.107, 0.423 (LG, HG)	0.7% (0.13 K)
	M14	8550	0.8	1.6	270	0.091	0.6% (0.26 K)
	M15	10763	0.8	1.6	300	0.07	0.4% (0.22 K)
	M16	12013	0.8	1.6	300	0.072	0.4% (0.24 K)
	I4	3740	0.4	0.8	270	2.5	5% (0.97 K)
	I5	11450	0.4	0.8	210	1.5	2.5% (1.5 K)
DNB	DNB	700	0.8	0.8	3×10^{-9} (w/cm^2-sr)) (HG)	6	5%, 10%,30% (LG,MG,HG)

NOAA-21 VIIRS SDR Provisional Review Highlights

Since Beta review on Feb. 23, 2023

Thermal Emissive Bands (TEB)

- Mid-Mission Outgassing (MMOG) completed on 2/26, to mitigate instrument contamination within dewar
- Cold focal plane temperature (CFPA) lowed to 80 K on 3/3
  - Blackbody Warm-up cool-downs (WUCD) between 3/10 and 3/18 completed
- TEB Nominal performance since 3/19/2023
- Comparison with CrIS show 0.1 K agreement (M13: 0.2 K)
- M13 Spectral Response change Impact assessed using CRTM
- No other major issues expected

Feedbacks from fire team

Day/Night Band (DNB)

- Required new moon data to update calibration coefficients and straylight correction
- New moon occurred on 3/21; Lookup tables (LUTs) developed and delivered to operations(suggest accelerated ops)
- The updated LUTs shall address straylight, striping, and negative radiances, especially in the Alaska region
- DNB trailing scan response tail found as described in waiver, which affects both radiometric and geolocation accuracy for demanding applications

Feedbacks from imagery team and NWS

Reflective Solar Bands (RSB)

- Lunar calibration on 3/2
- Spacecraft yaw maneuvers to quantify solar diffuser BRDF on 3/6-3/7
- Updated RSB LUTs became operational on 3/23
- Radiometric biases relative to NOAA-20 reduced to within 2% for all channels, except shortwave infrared (SWIR) bands
- SWIR band gain change faster than expected, requires close monitoring going forward
- Next Lunar cal on 4/1/2023

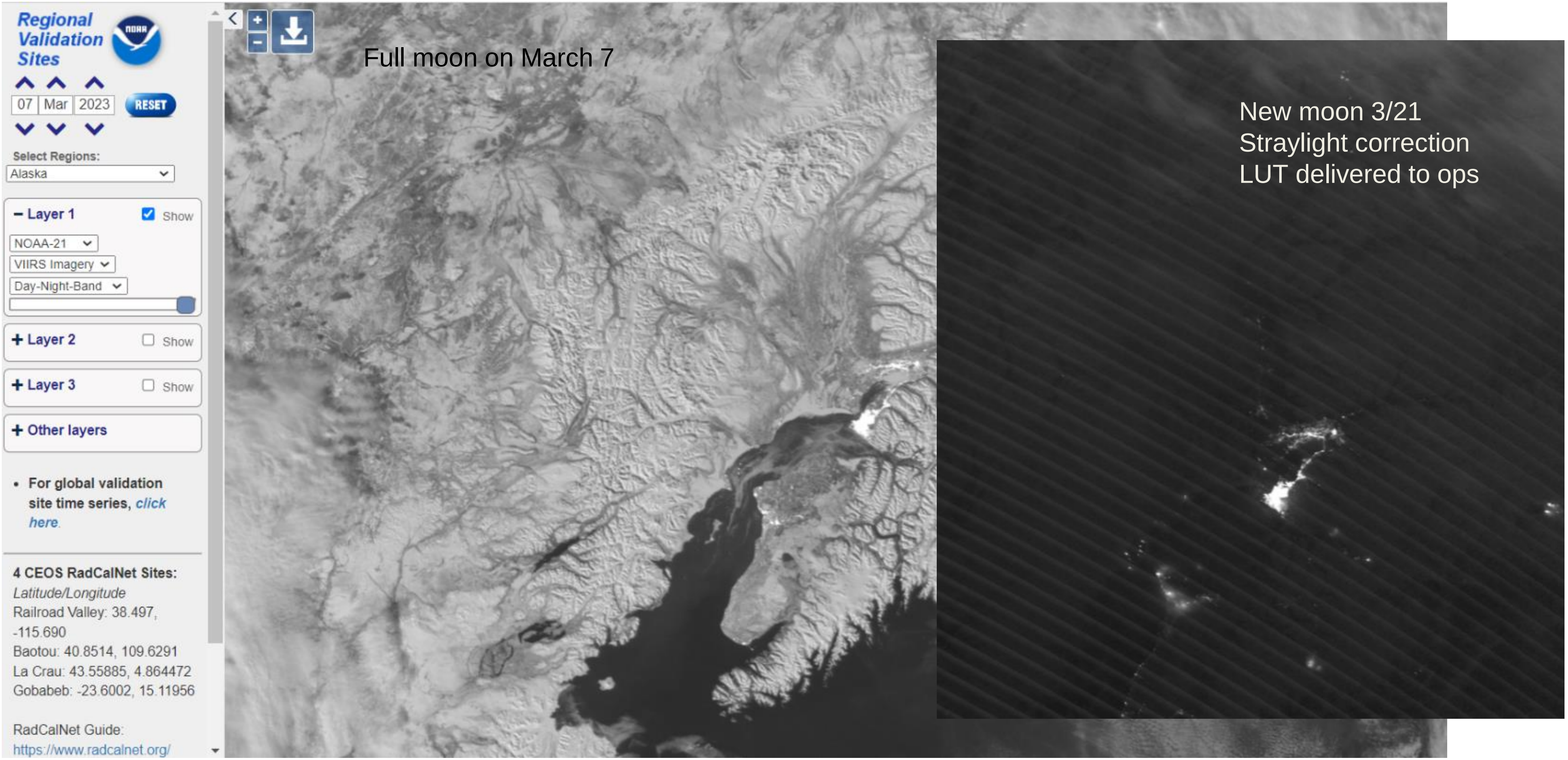
Feedbacks from Ocean Color team

Geolocation

- Comparable to that of NOAA20 VIIRS, after mounting matrix update on 1/12

Latest LUTs for DB community: anonymous@ftp.star.nesdis.noaa.gov /pub/smcd/VIIRS_SDR/J2_LUTs/CURRENT_IDPS_LUTs/

Added Alaska to our Regional Validation Sites



Challenges with multiple passes per day; will make it available soon

Processing Environment and Algorithms

- Description of processing environment and algorithms used to achieve the provisional maturity stage:

	Description	Effective Date
Algorithm version	IDPS Block 2.3 Release Mx 7	July 18, 2022
Version of LUTs	VIIRS LUT Updates from ADR 8821-8823, 10038	Aug.-Sep. 2022
Updated LUTs	4 LUTs (VNIR F factor, geolocation)	January 12, 2023
	DNB onboard offset	Mar. 17, 2023 (21:00)
	SWIR Band F factor, DNB LGS gain	Mar. 23, 2023 (18:14)
	TEB Delta-C LUT	Mar. 30, 2023 (0:10)
	DNB DN0 and gain ratio	Mar 9, 2023 and Mar. 30, 2023 (0:10)
	DNB Stray Light Correction LUT	Mar. 30, 2023 (0:10)

Post-Launch NOAA-21 VIIRS Cal/Val Timeline

Day (date)	Flight Activity
L + 0 (11/10/2022)	JPSS-2 Launch
L + 10 (11/20/2022)	VIIRS Activation
L + 21 (12/1/2022)	DNB Straylight Test
L + 25 (12/5/2022)	Nadir Doors Open
L + 40 (12/20/2022)	Final Orbit
L + 90 (2/8/2023)	Cryoradiator Door Open
L + 92 (2/10/2023)	All Detectors Stable
L + 102 (2/20/2023)	DNB Calibration (new moon)
L + 105 (2/23/2023)	MMOG (3 days)
L + 112 (3/2/2023)	Lunar Calibration
L + 113 (3/3/2023)	TEB Detectors 82K → 80K
L + 116 (3/6/2023)	Yaw Maneuvers (2 days)
L + 120 (3/10/2023)	Pitch Maneuver ("backflip")
L + 122 (3/12/2023)	OBC BB WUCDs (3 + 2 days)
L + 127 (3/17/2023)	DNB Onboard Update
L + 131 (3/21/2023)	DNB Calibration (new moon)
L + 140 (3/30/2023)	
L + 245 (7/13/2023)	

Dates in red imposed by moon phase

Ground Activity

- Begin Cal/Val Tasks: Onboard Calibrators & SDSM, Basic Functionality, DNB Straylight, Image Quality, VNIR Calibration, Orbit & Geolocation
- Begin VIIRS SDR Production
- VIIRS First Light Image for VNIR Data
- 1st Delivery of Updated LUTs: VNIR Cal., GEO
- VIIRS First Light Images for DNB/SWIR/TEB Data
- Beta Maturity
- Continue Cal/Val Tasks: SWIR and TEB Calibration, DNB Calibration, Inter-Satellite Comparisons
- 2nd Delivery of Updated LUTs: SWIR/DNB Cal.
- Provisional Maturity
- Validated Maturity

VIIRS Post-launch Cal/Val Tasks

Successfully performed Post Launch Tests (PLTs) are highlighted in Green..

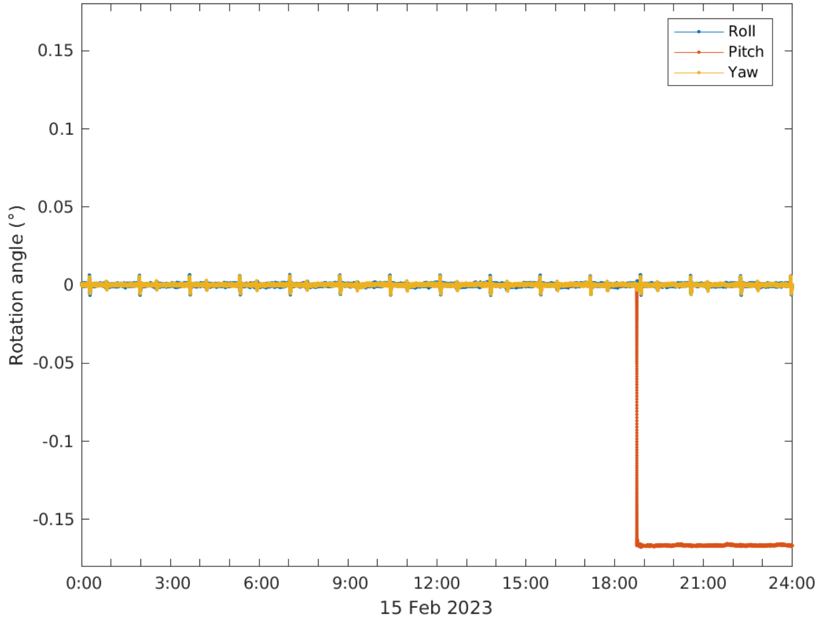
Long-term monitoring required PLTs are highlighted in yellow.

Task ID	Title
	Tasks Started after Instrument Activation
GEO-1	Initial Validation of Spacecraft Ephemeris and Attitude Data
GEO-2	Initial Validation of VIIRS Encoder Data, Scan Time, Scan Period, and Scan Rate Stability
FPF-2	Detector Operability and Noise Verification with Nadir Door Closed: RSB VNIR, DNB
FPF-6	DC-Restore Functionality and Performance Check
FPF-7	Calibrator Visual Inspection
PLT-X	DNB Straylight with Nadir Doors Closed (no sector rotation)
CSE-1	SD and SDSM Characterization
CSE-2	Onboard Calibrator Black Body (OBCBB) Temperature Uniformity
CSE-4	Temporal Analysis of SD Signal over Polar Region
CSE-5	Temporal Analysis of Solar Diffuser Stability Monitor (SDSM) Data
PTT-1	Operability, Noise, SNR Verification
PTT-6	Telemetry Trending Monitoring
PTT-10	RSBAutoCal Calibration Object Trending, Evaluation & LUT Updates
	Tasks Started after Nadir Doors Open
IMG-1	Crosstalk, Echo, and Ghost Investigation
IMG-2	Image Analysis (Striping, Glints and Other Artifacts)
RAD-7	SDR Comparison with S-NPP & N20 VIIRS
RAD-8	SDR Comparison with MODIS
GEO-3	Assess Reasonableness of First-Period SDR Geolocation
GEO-4 to 7	Analyze First-Period VIIRS GCP Residuals
GEO-9	Develop and Test Initial Geolocation LUT Updates
PTT-2	RDR Histogram Analysis

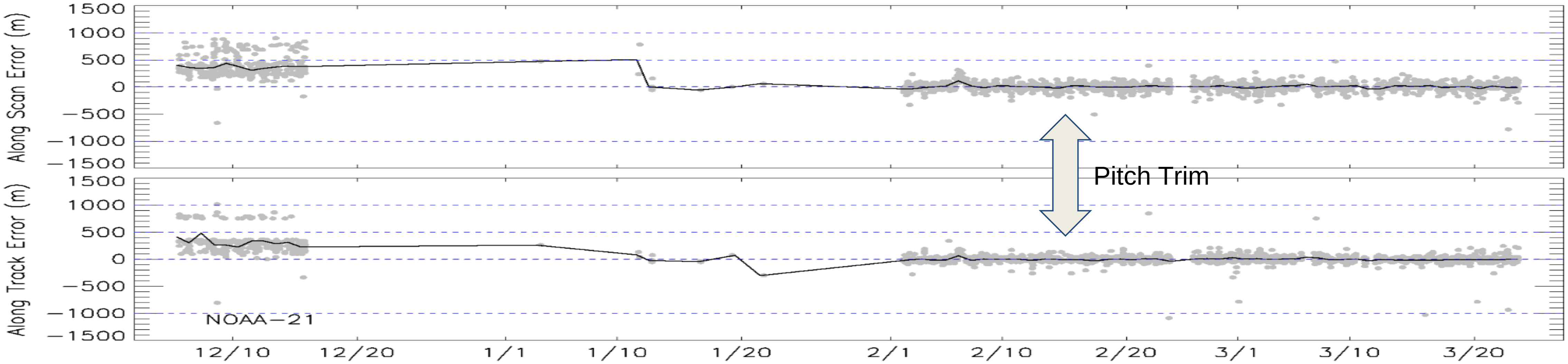
	Tasks Starting after Cryo-radiator Door Open
IMG-3	Moon Echo and Ghost Check
CSE-6	Yaw Maneuver Analysis
RAD-4	Response vs. Scan Angle (RVS)
RAD-9	RSB Radiance/Reflectance Validation – Radiometric Sites
RAD-11	In-Band Spectral Radiance Comparison with CrIS
RAD-14	Emissive Band Response Characterization (WUCD)
RAD-15	Moon in Space View Correction
RAD-18	Lunar Data Analysis - Roll Maneuver
RAD-19	Analysis of Pitch Maneuver Data
RAD-20	SDR Reprocessing and Updates
RAD-24a	Offline F/H Factor Analysis, Prediction and Validation Tool
RAD-24b	Offline TEB F-Factor Monitoring
PTT-4	DNB Offset and Gain Ratios Determination
PTT-7	Update Uploadable Tables ID5, ID33-35: DNB Offsets
WAV-4	DNB straylight assessment and correction LUT development
WAV-5	DNB radiometric/geolocation monitoring using point sources
WAV-6	VIIRS saturation monitoring

GEO	Geolocation/Geometric Evaluation
FPF	Function Performance and Format Evaluation
CSE	Calibration System Evaluation
PTT	Performance and Telemetry Trending
IMG	Image Quality Evaluation
RAD	Radiometric Evaluation

Geolocation Accuracy Monitoring



- All JPSS instruments (CrIS, OMPS, ATMS) rely on accuracy of VIIRS SDR geolocation products
- NOAA-21 VIIRS SDR geolocation errors remain mostly within 200 m (< 400 m required at the 3-sigma, 99.7%, level) after the post-launch mounting matrix update on Jan. 12, 2023
- While the permanent pitch trim of -600 arcsec has been applied to the NOAA-21 spacecraft since Feb. 15, 2023 (to improve OMPS Limb sampling), it did not cause changes in the VIIRS geolocation accuracy

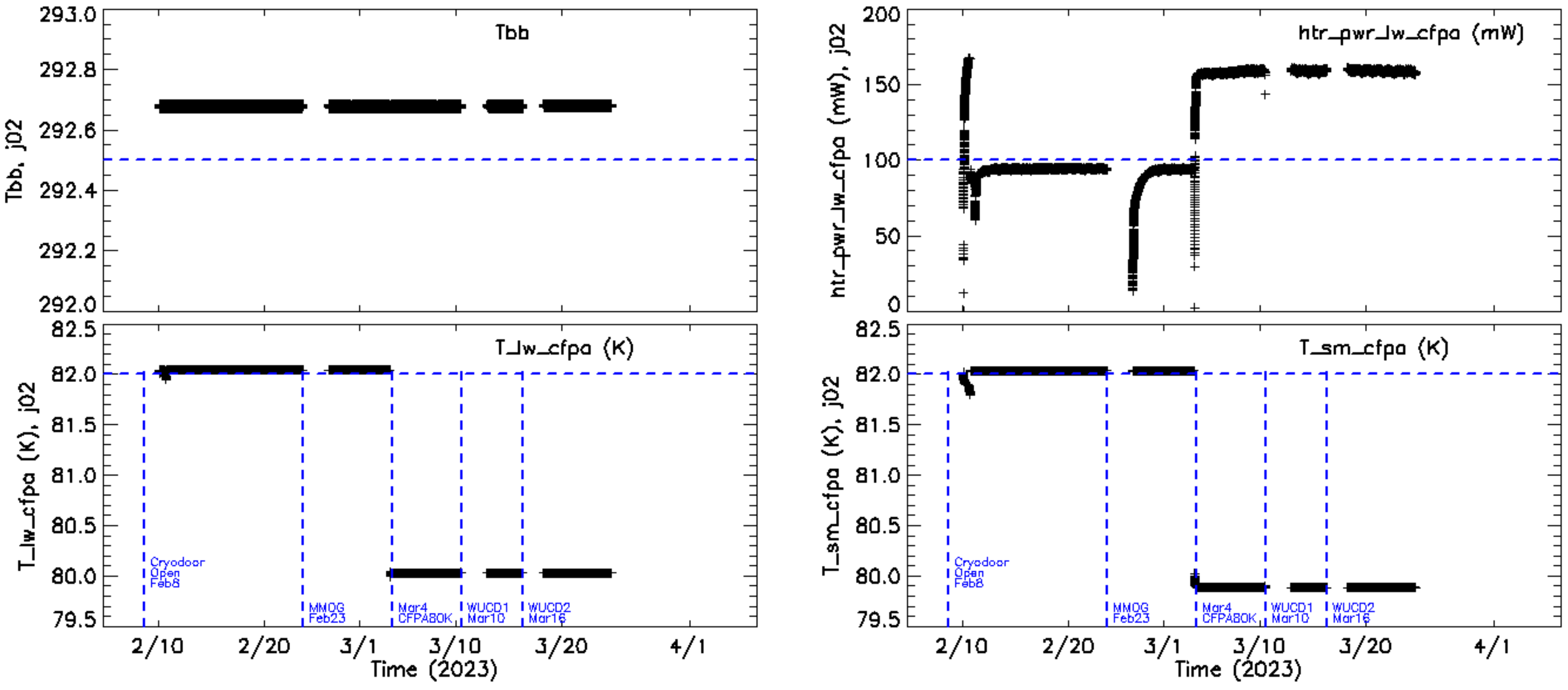


Major TEB Calibration Events and Instrument Temperature Telemetry

- NOAA-21 TEB calibration timeline:
  - Cryo-radiator door opened on Feb. 8, 2023. Cold Focal Plane Temperatures (CFPA) temperatures have stabilized to 82 K on late Feb 10.
  - Mid-mission outgassing (MMOG) was performed on Feb. 23.
  - CFPA setpoint temperatures was switched to 80 K on Mar. 3.
    TEB 80 K Delta-C LUT was developed/delivered, to be implemented.
  - Two blackbody warm-up/cool-down (WUCD) were performed during Mar. 10-13 and 16-18.

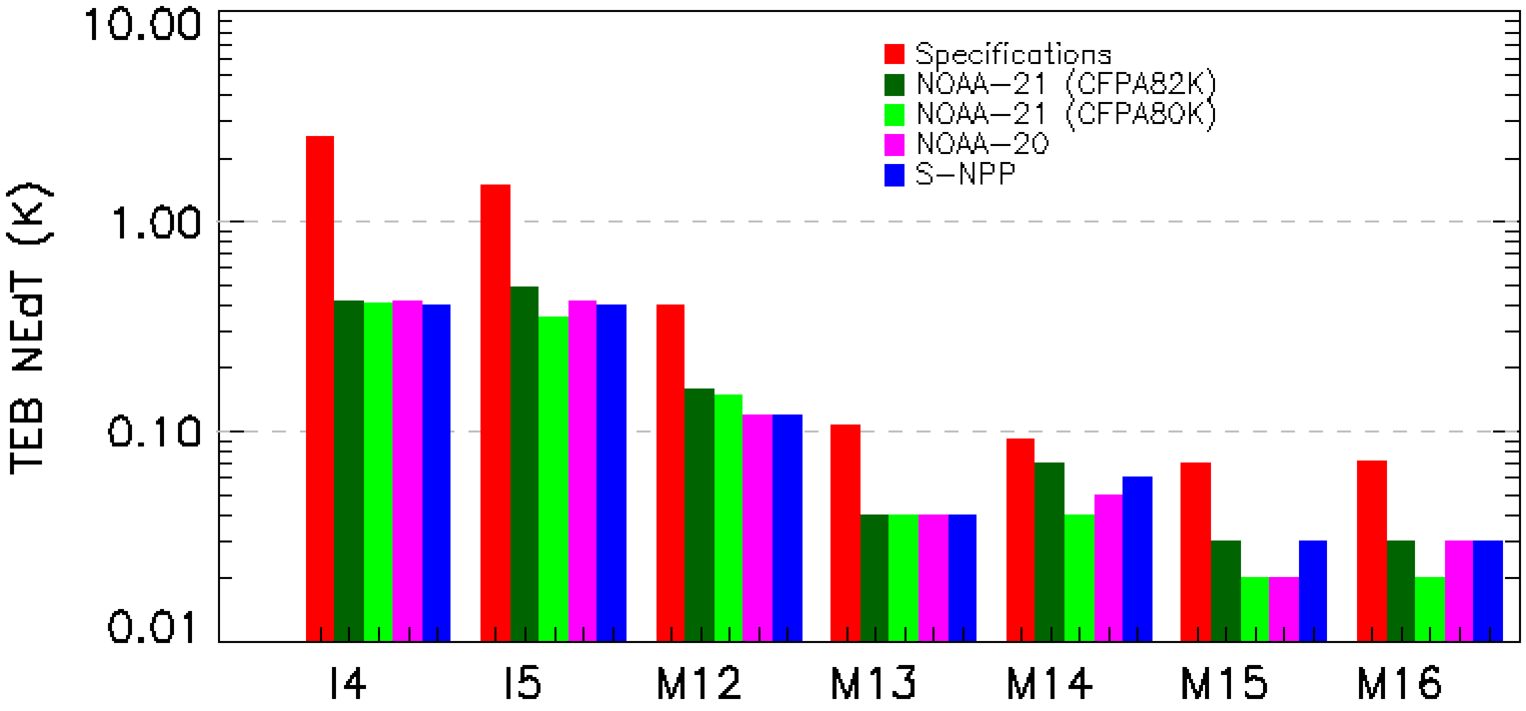
- CFPA and other instrument temperatures have been stable during nominal operations.

- Blackbody temperature and uniformity have also been stable.



TEB Noise/NEdT

- NOAA-21 VIIRS TEB NEdTs are comparable to NOAA-20/S-NPP.
  - All well within specifications.
  - LWIR NEdTs are further reduced after the CFPA temperatures switched to 80K.
  - M12 shows slightly larger NEdT than NOAA-20/S-NPP



NOAA-21 VIIRS TEB Gains

- NOAA-21 TEB calibration has been generally stable during nominal operations.
- The Feb. 23 MMOG successfully removed potential ice contamination.
  - Small degradations observed early in the mission (up to 0.15%).
  - After the MMOG, TEB gains returned to the similar levels as the beginning of the mission.
- After the switch of CFPA to 80 K, LWIR gains increases by 4-11% (M14).
  - MWIR gains don’t change much.

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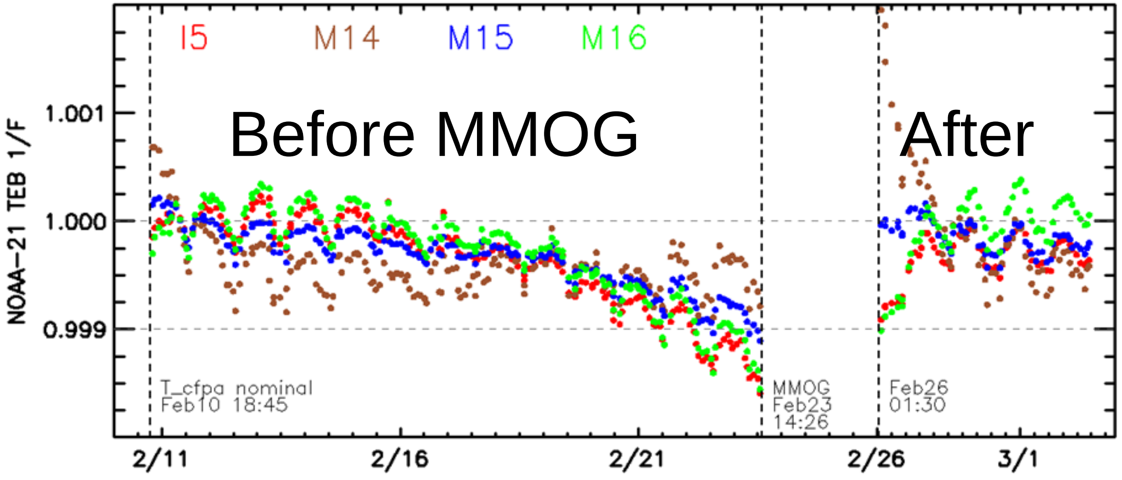
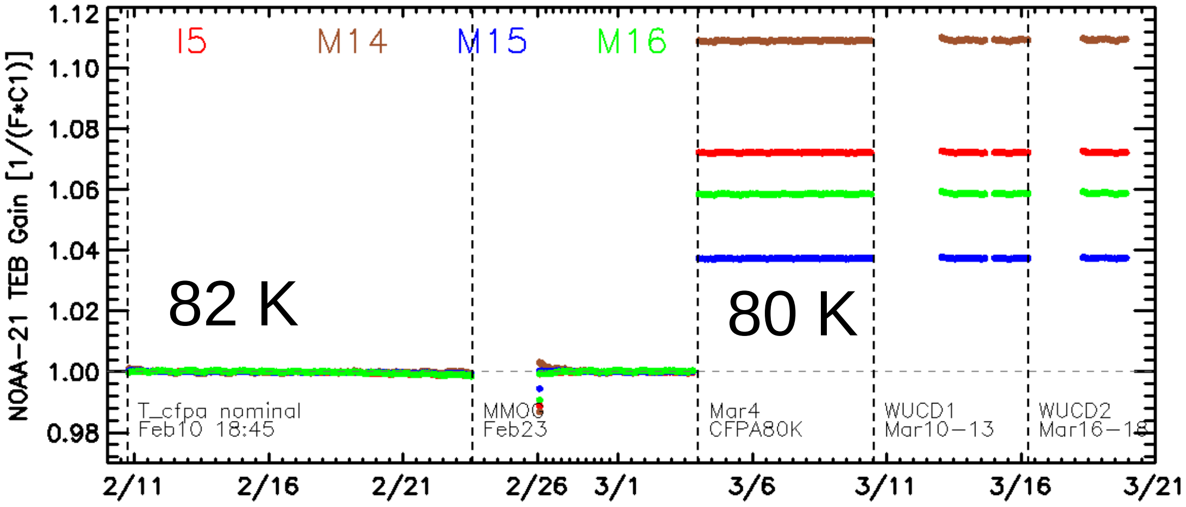
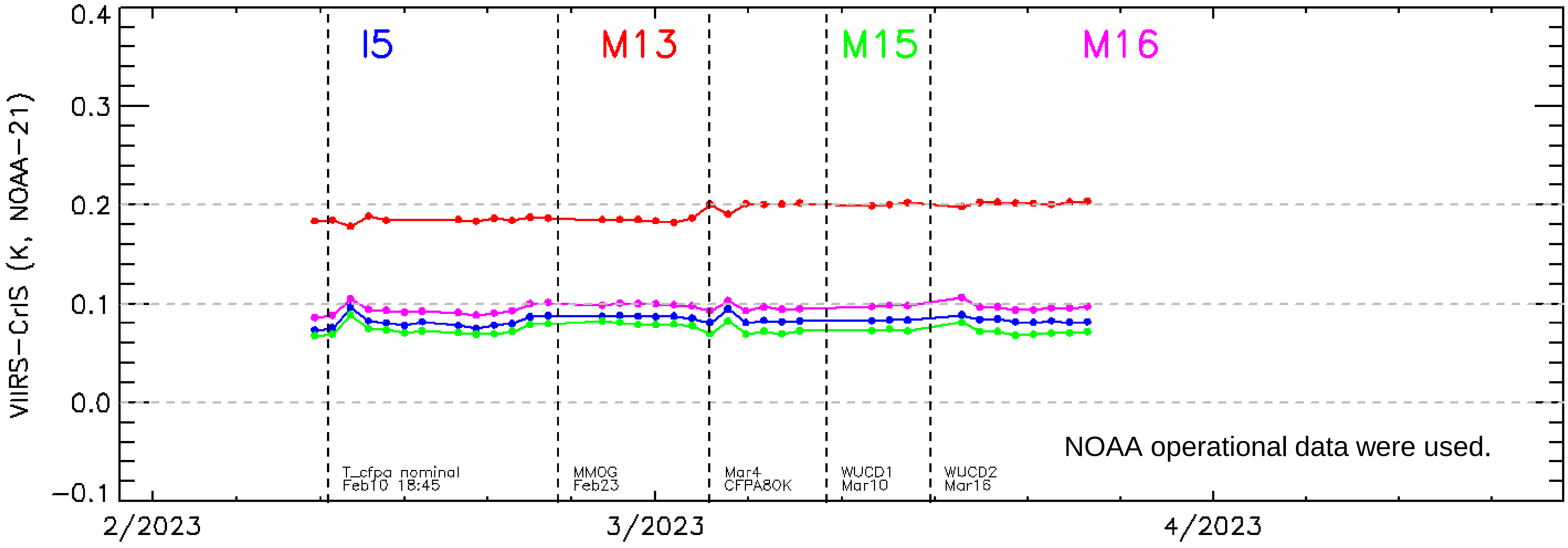




Normalized LWIR Gains

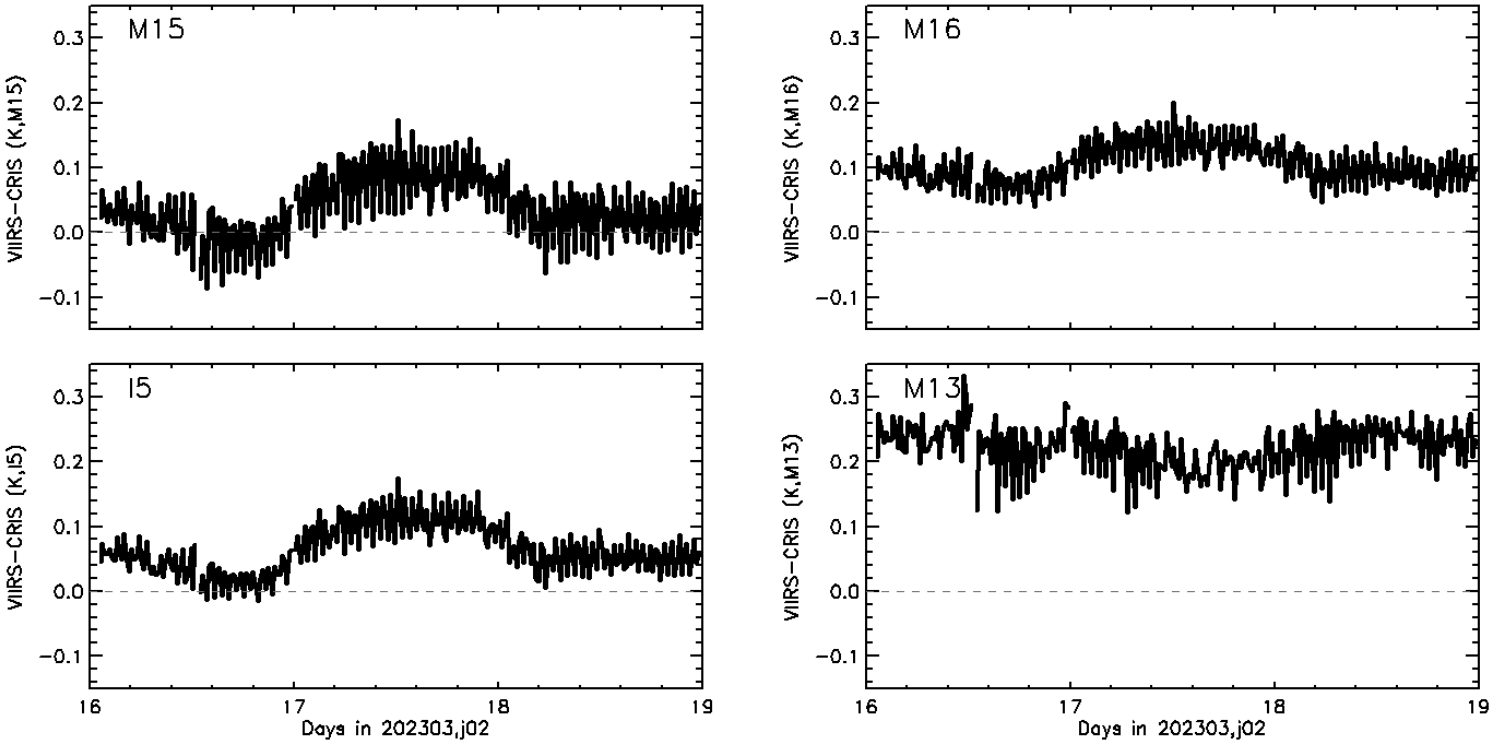
Comparison of VIIRS with Co-Located CrIS Observations

- I5 and M15-M16 agree well with CrIS during nominal operations.
  - Biases are within ~0.1 K, comparable to NOAA-20 and S-NPP
- M13: BT bias ~0.22 K
  - Slightly larger than that of NOAA-20 and S-NPP.
  - NOAA-21 M13 is not fully covered by CrIS spectra, different from NOAA-20 and S-NPP.
- Will be further analyzed after the 80 K TEB Delta-C LUT is deployed in the operations.



TEB Calibration Biases during WUCD events

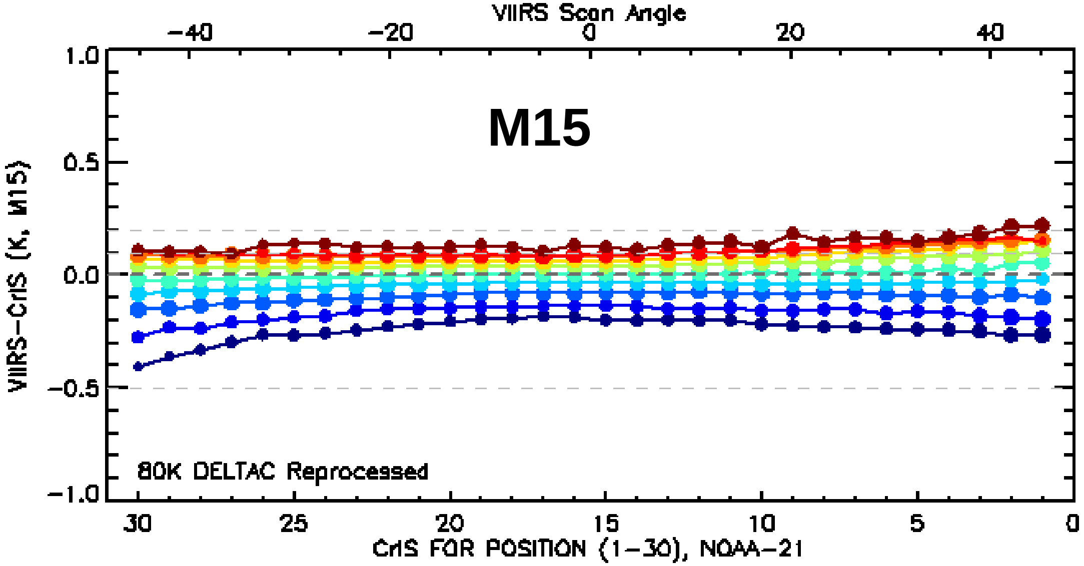
- TEB calibration biases during WUCD were observed, similar to S-NPP/NOAA-20.
  - M15 daily averaged bias: ~0.1 K during the cool-down phase.
  - WUCD bias correction coefficients will be developed and applied operationally.
  - After the PLT, WUCD is performed annually. The next test will be in March 2024.

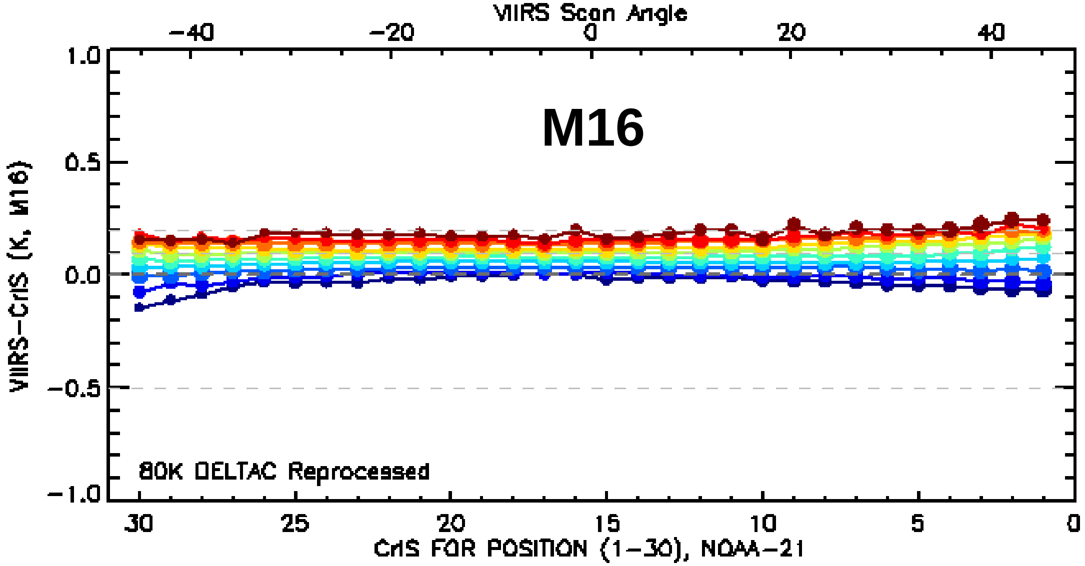


WUCD (March 16-19, 2023, reprocessed using 80 K Delta-C LUT)

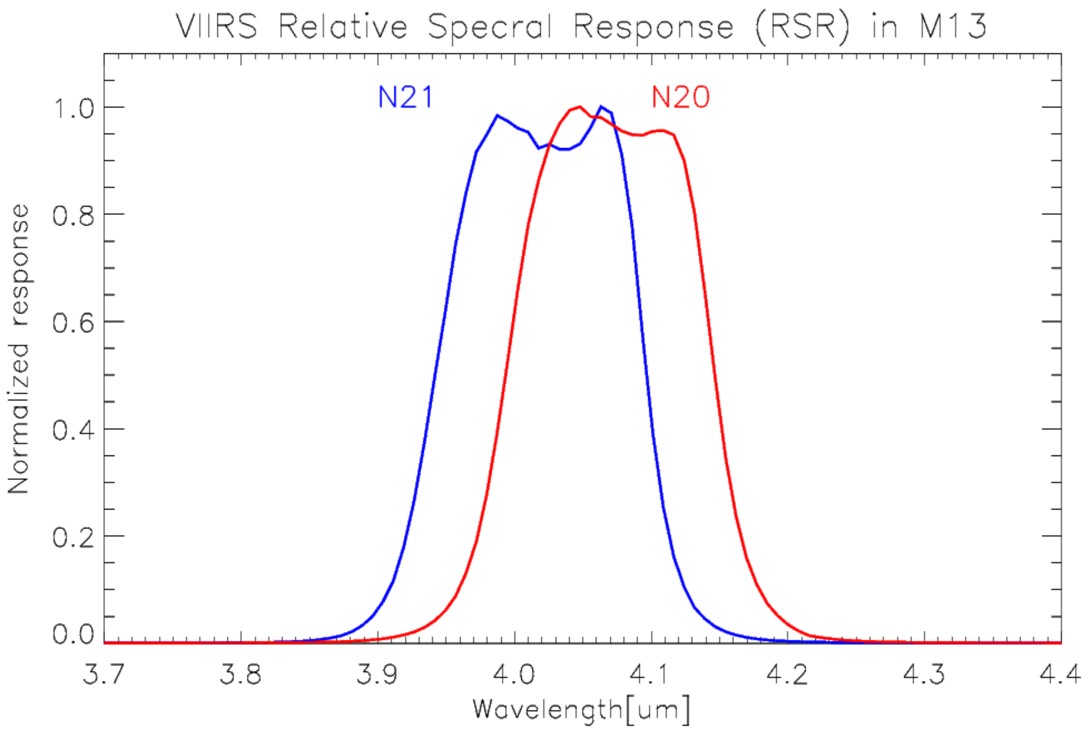
TEB Scan Angle and Scene Temperature Dependent Biases

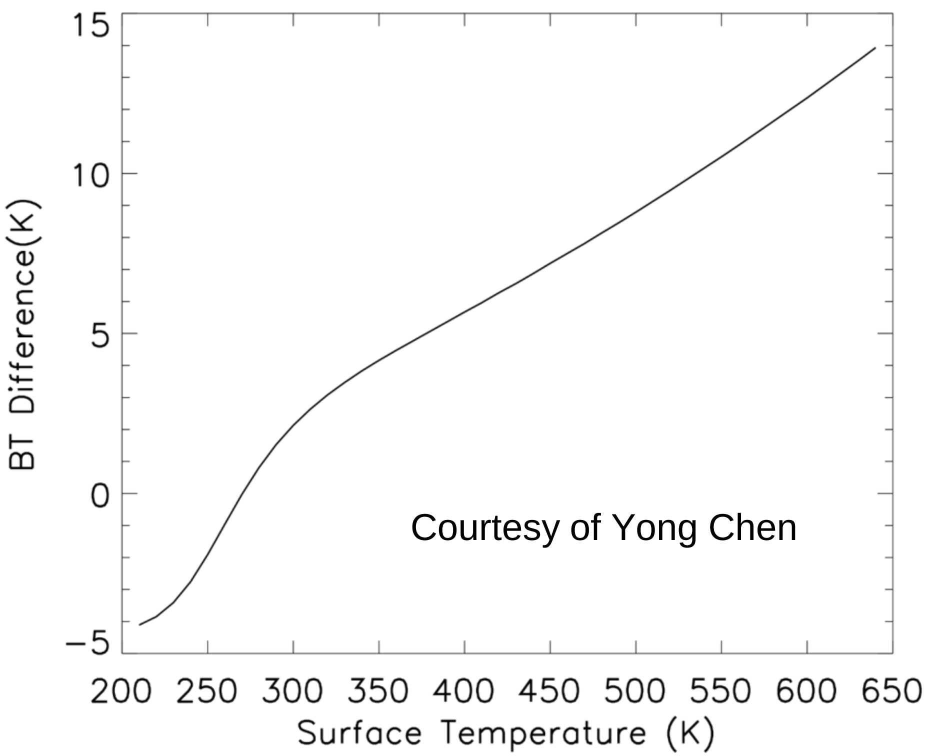
- Small scan angle/scene temperature dependent biases were observed in NOAA-21 LWIRs, relative to CrIS observations.
  - M15: up to ~0.5 K at 220 K scene temperature near the beginning of scan.
  - Smaller than those in NOAA-20, but larger than those in S-NPP.
  - Confirmed by on-orbit pitch maneuver data analysis results.
  - Can be mitigated using pitch maneuver data derived calibration parameters.





M13 Spectral Response Function Effect





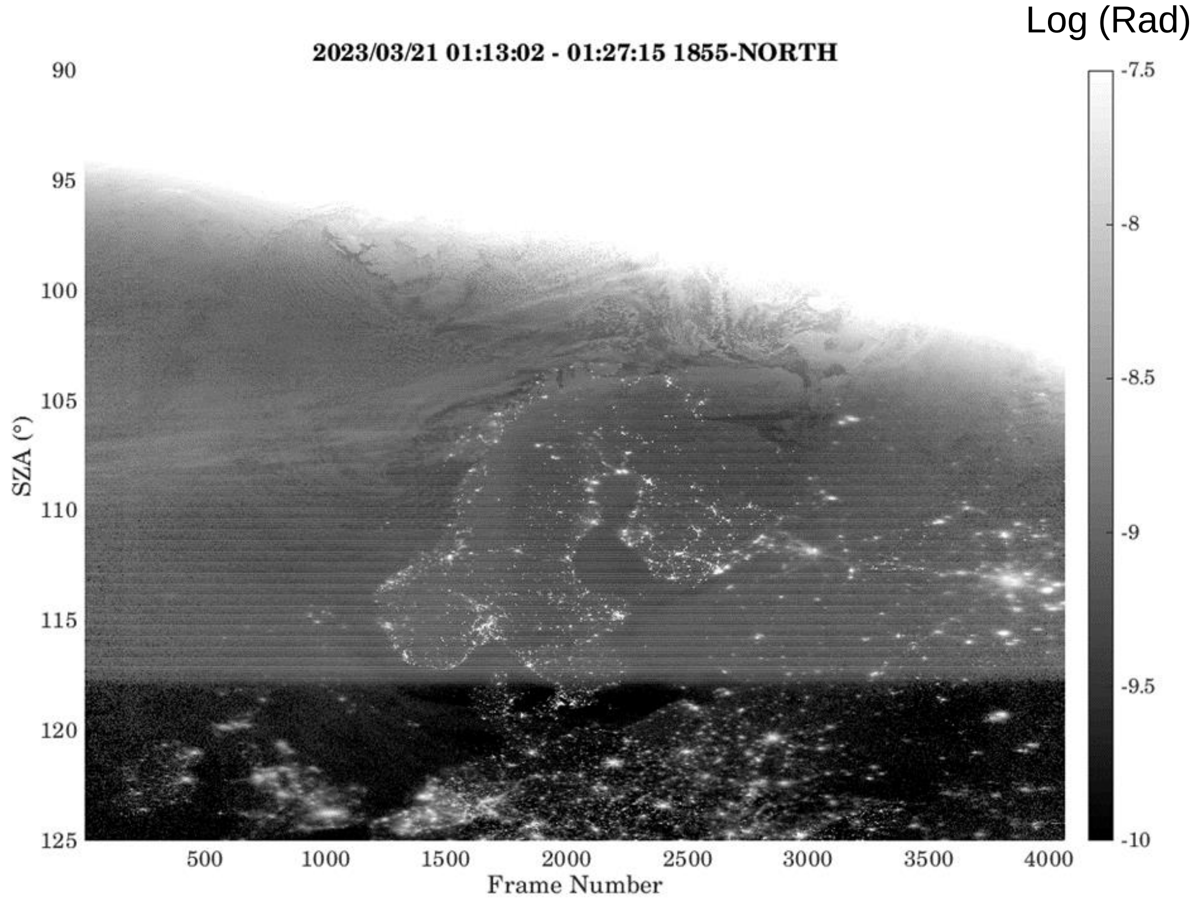
- NOAA-21 M13 spectral response is different from that of NOAA-20 VIIRS
- Fire measurements would be hotter on NOAA-21 (BT21 > BT20)
- May affect saturation level

NOAA-21 DNB Calibration Timeline

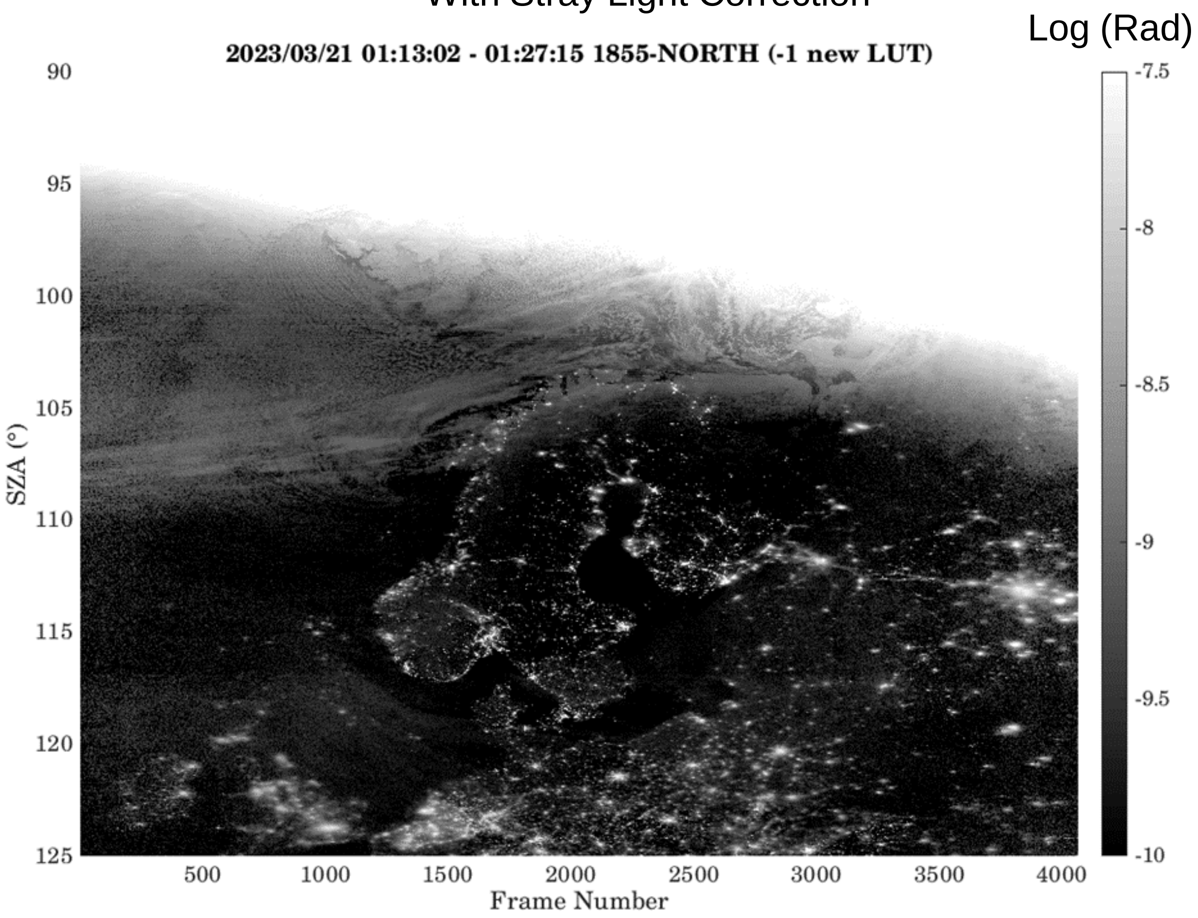
Date	Activities
2/8/2023	DNB FPA started to cool down
2/9/2023	DNB FPA reached operating Temperature around 14:00
2/9-10/2023	First light global DNB image
2/20/2023	First new moon day DNB Calibration
3/9/2023	First DNB calibration (DN0 and Gain Ratio) LUTs implemented at IDPS
3/10/2023	Pitch maneuver for deriving DNB onboard offset
3/17/2023	**DNB onboard offset update on the spacecraft**
3/21/2023	Second new moon day DNB calibration (DN0, Gain Ratio and stray light correction LUT)
3/23/2023	**DNB LGS gain update at IDPS**
3/30/2023	**Second DNB Calibration (DN0 and Gain Ratio) LUTs implemented at IDPS**
3/30/2023	**DNB stray light correction LUT implemented at IDPS**
4/20/2023	Third new moon day DNB calibration

DNB Stray Light Correction

Northern Hemisphere



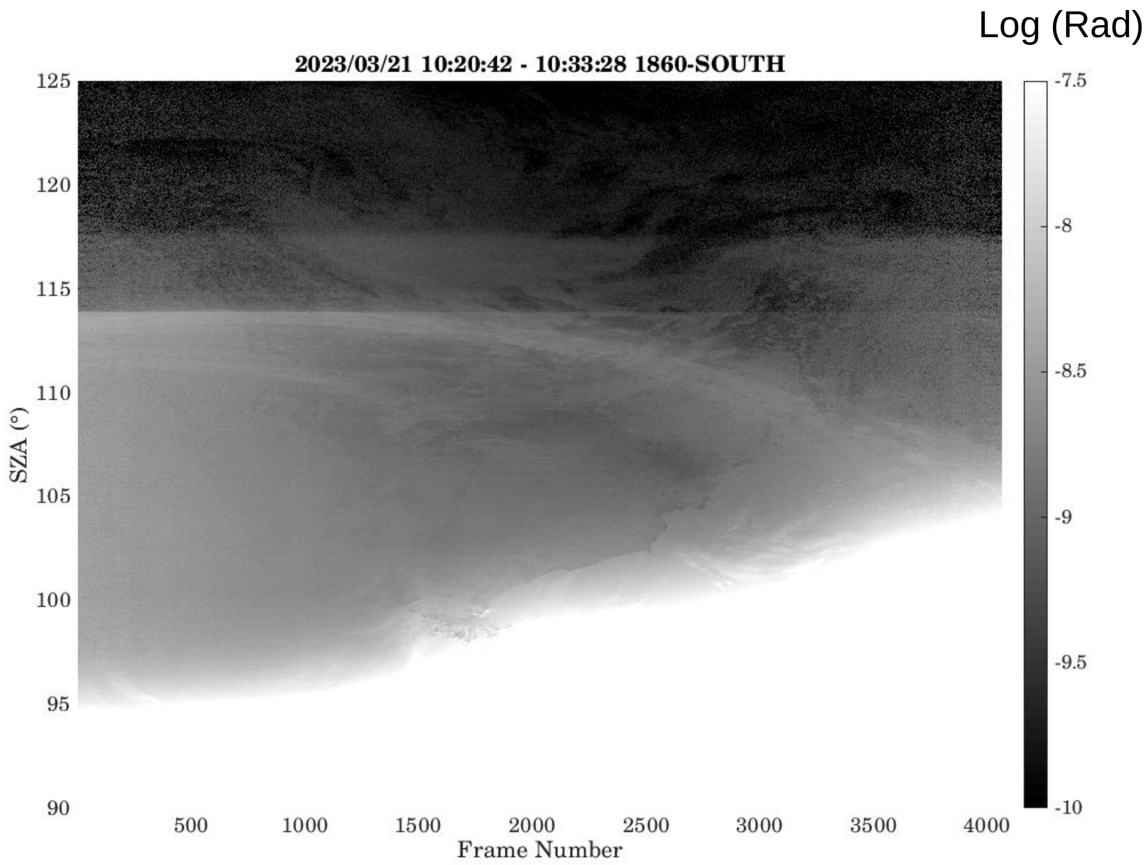
With Stray Light Correction



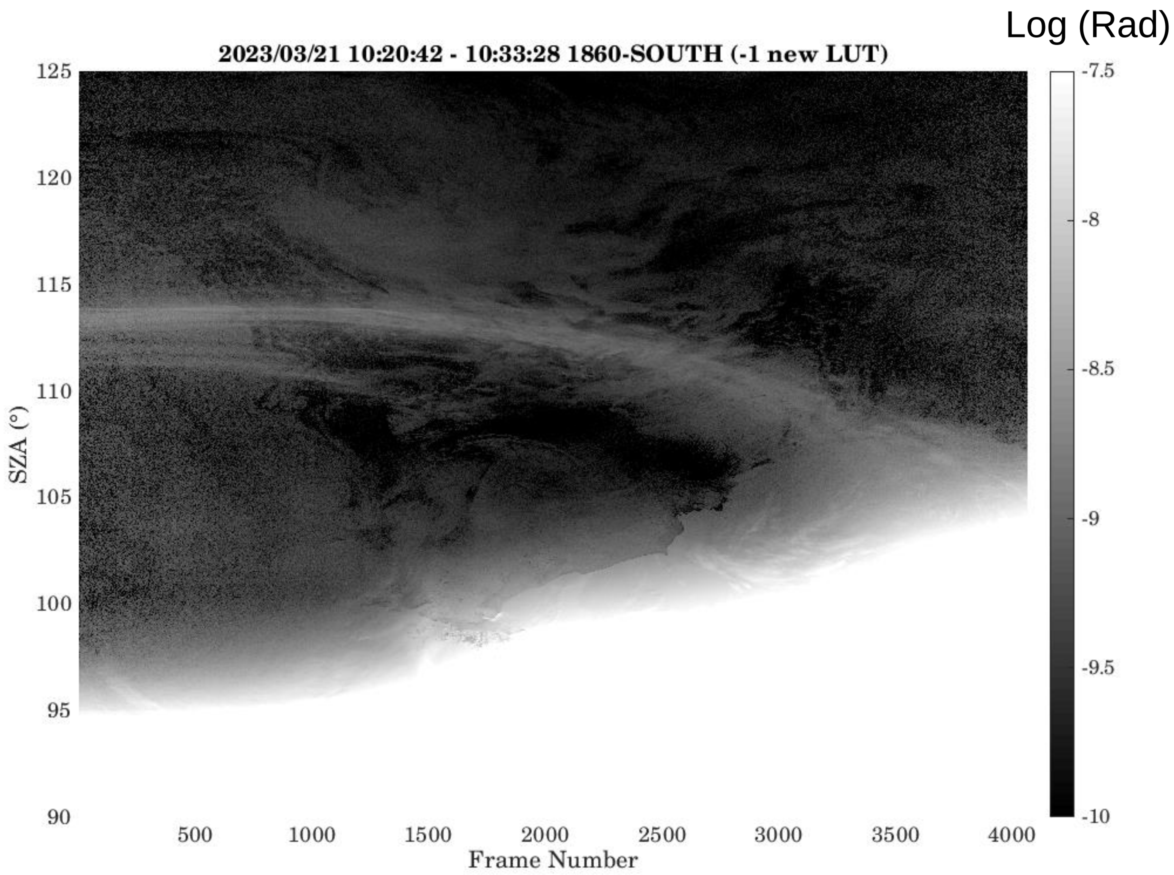
- NOAA-21 DNB stray light observed over both the northern and southern hemispheres.
- Developed stray light correction tables from Mar. 20 new moon day data; Effective in IDPS after 00:10 Mar. 30.
- Twelve monthly DNB stray light correction LUTs will be developed using the following new moon day data.

DNB Stray Light Correction

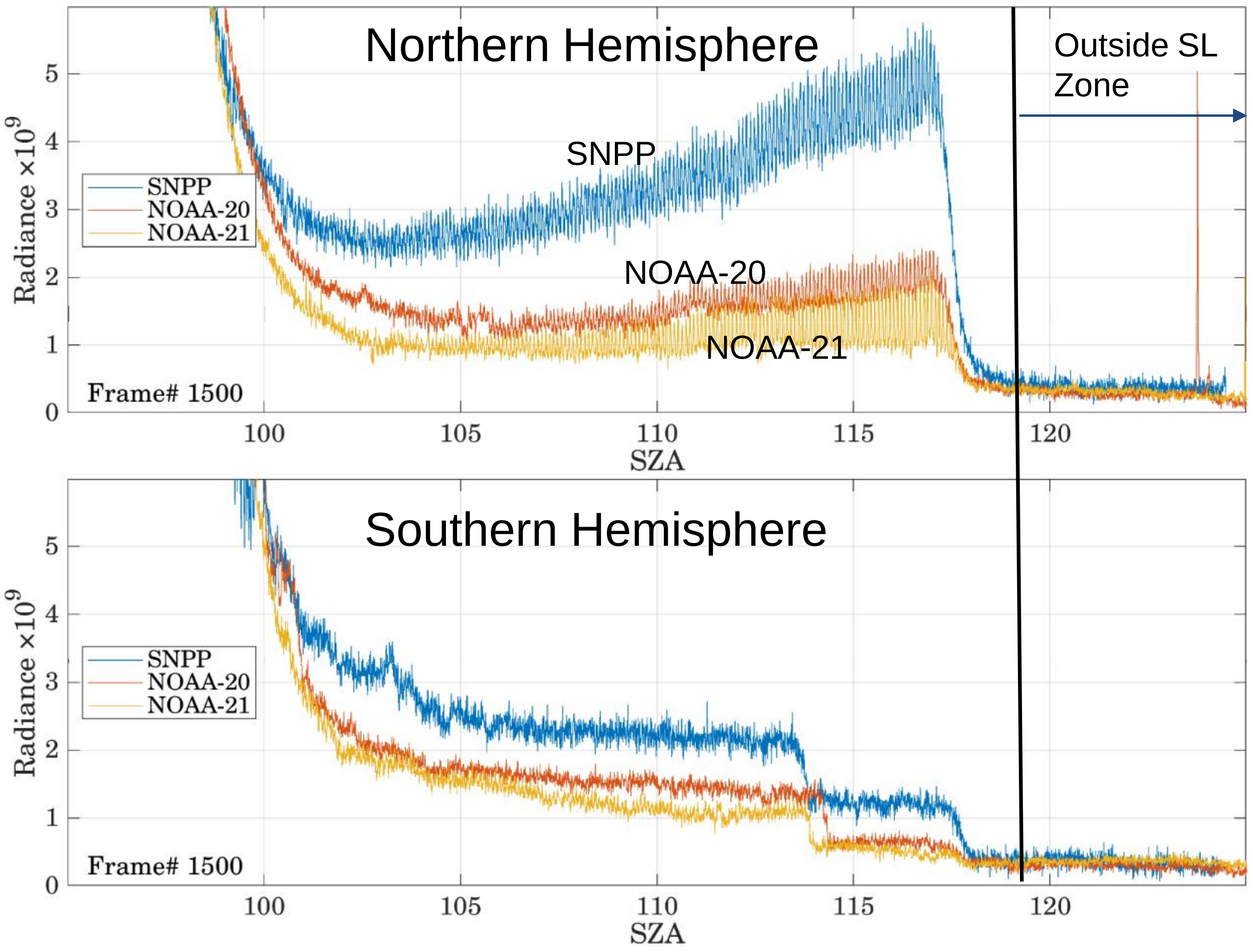
Southern Hemisphere



With Stray Light Correction

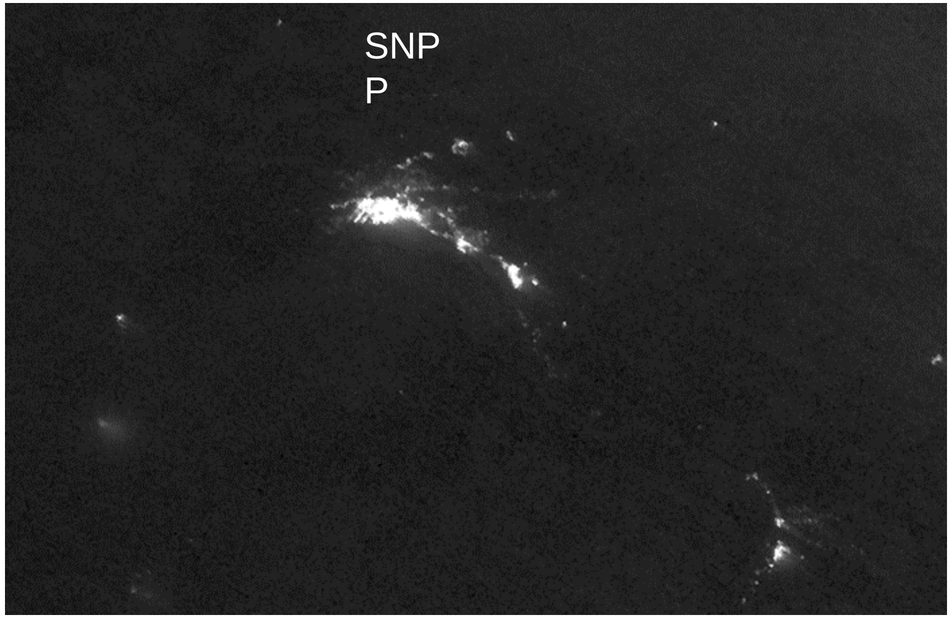


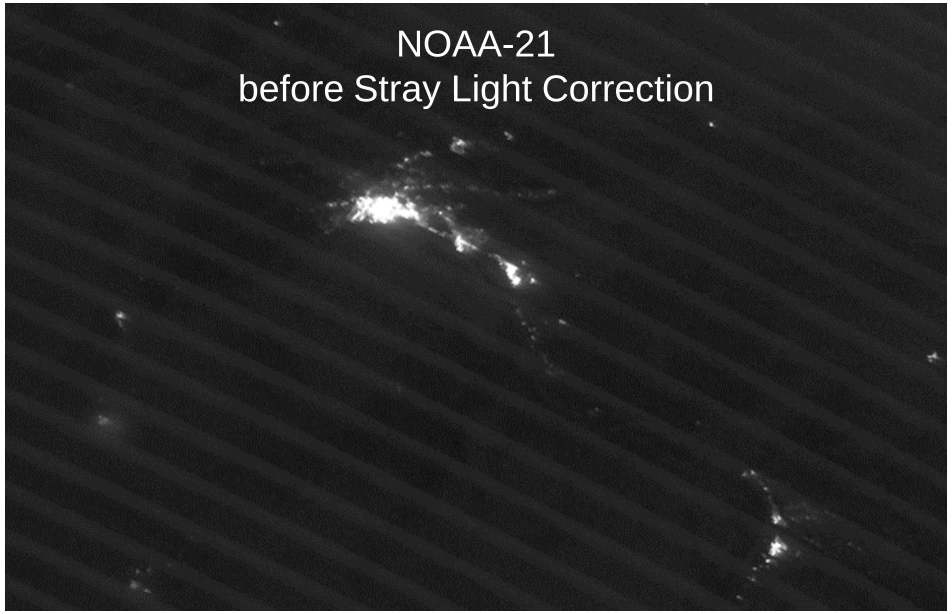
Comparison of NOAA-21/NOAA-20/SNPP DNB Stray Light

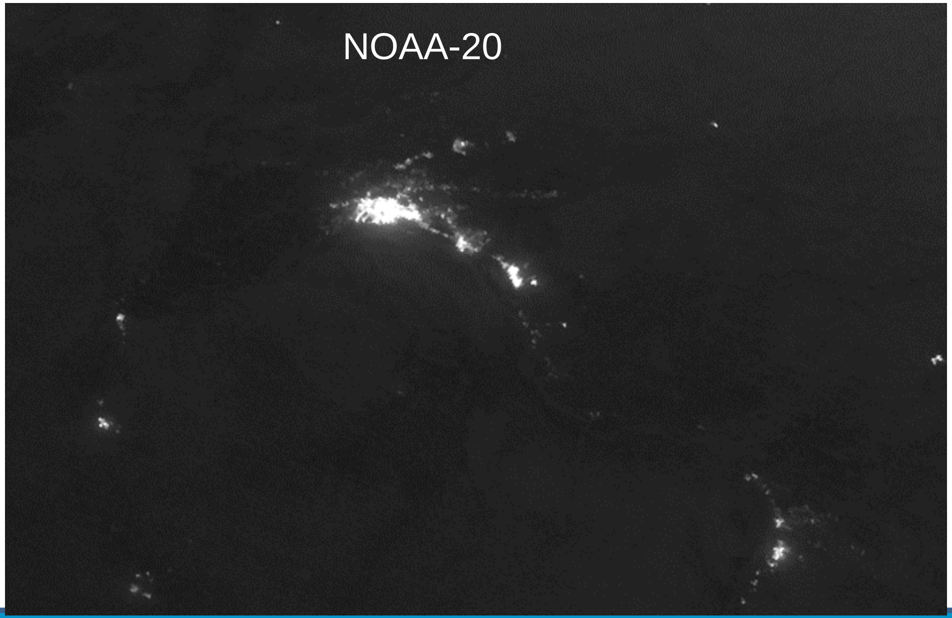


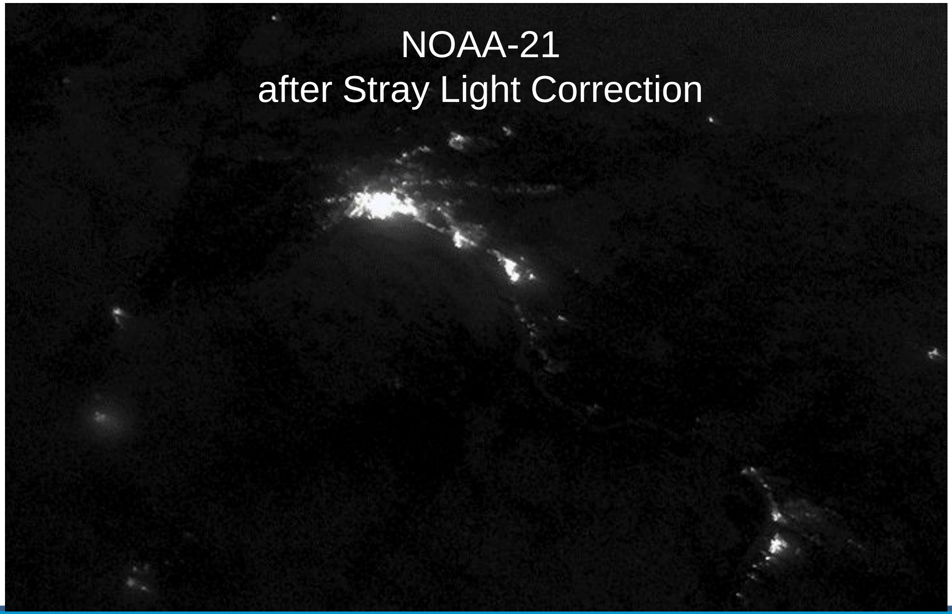
- NOAA-21 DNB stray light is significantly lower than SNPP and NOAA-20 DNB
- After the post launch calibration, we found that NOAA-21 DNB stray light over both hemispheres are reduced by ~40 to 60% (depending on the along scan zone) in comparison with NOAA-20 DNB.

SNPP, NOAA-20 and NOAA-21 DNB Image Comparison









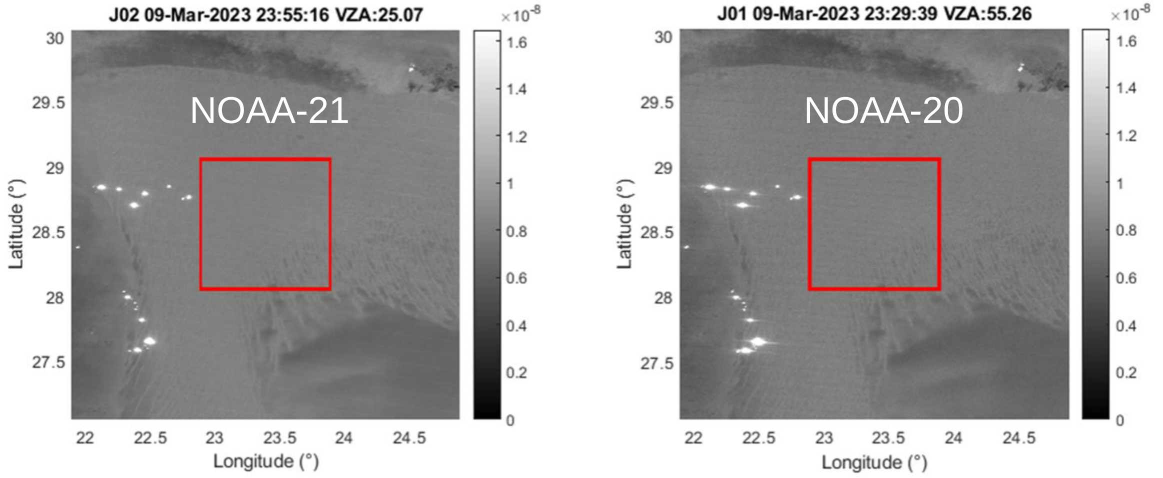
Fairbanks, Alaska

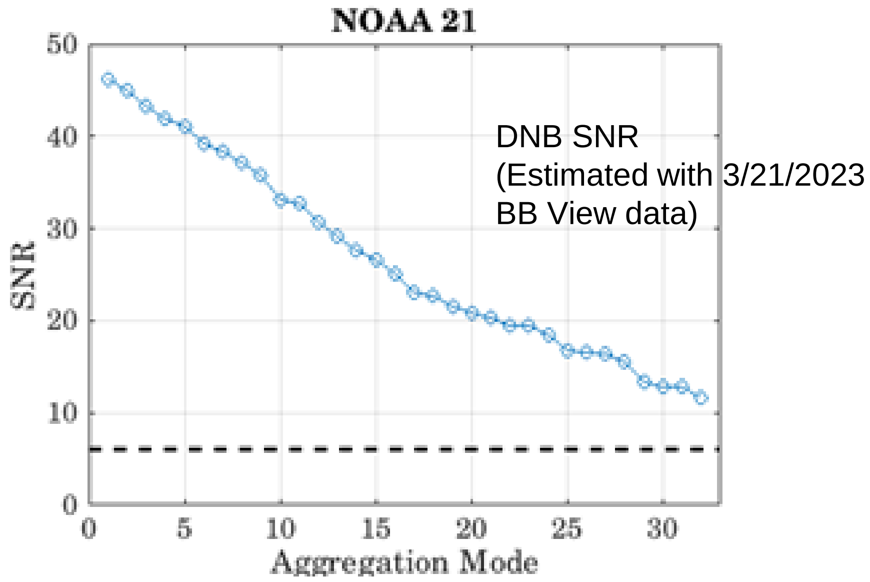
Mar. 21, 2023
(New Moon Day)

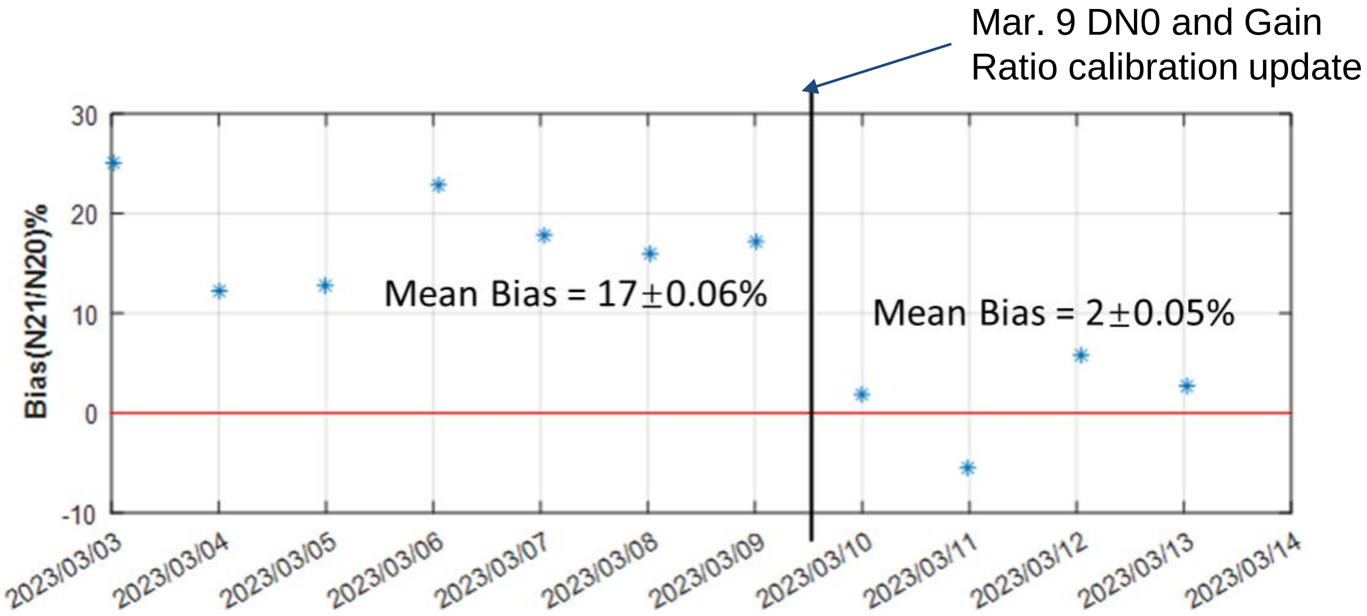
Stray light correction LUT is effective in IDPS after UTC 00:10, Mar. 30, 2023

NOAA-21 and NOAA-20 DNB Radiometric Performance Comparison

DNB Radiometric Bias Assessment
(over Libya-4 Desert under Moon Light)



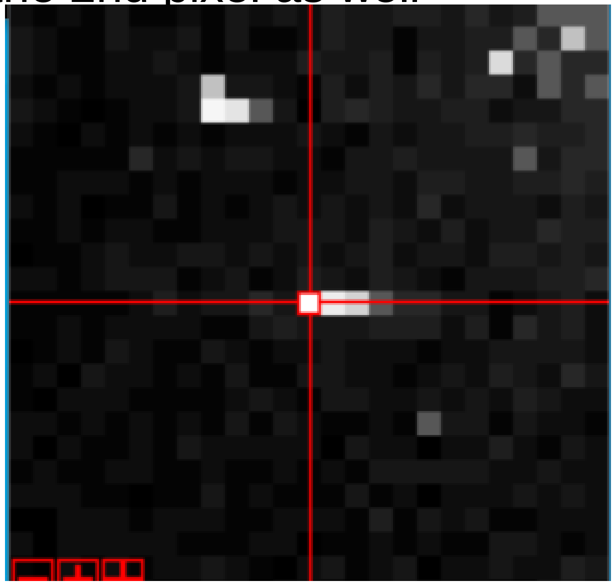


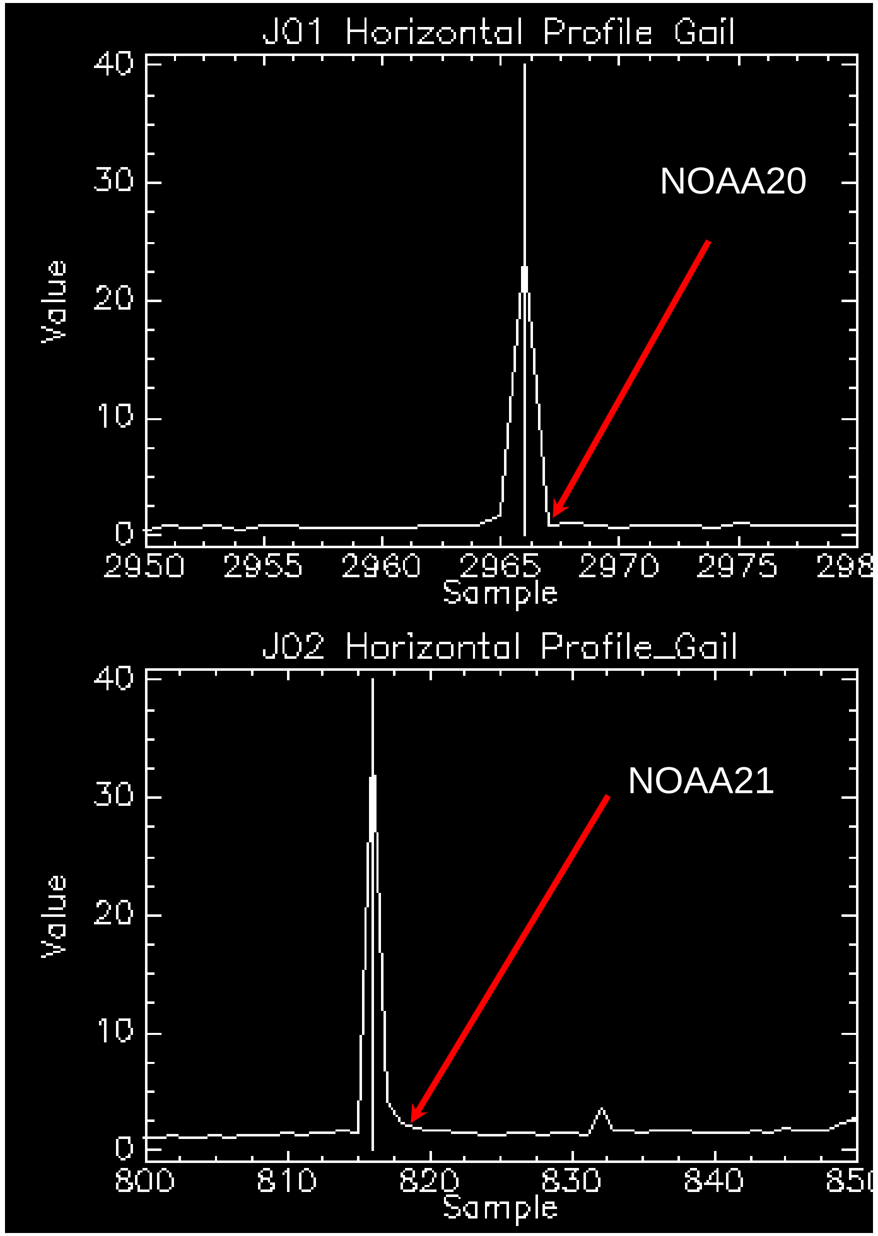


- NOAA-20 leads NOAA-21 by ~25-min
- Account for lunar phase difference with lunar irradiance model, lunar zenith angle and SRF difference
- The Mar. 9 calibration update effectively reduced the bias
- Continue to closely monitor the impact of next calibration update on the radiometric performance

NOAA 21 VIIRS/DNB Line Spread Function (tail effect)

- NOAA21 VIIRS/DNB waiver (RDW-VIIRS-W208) “tail” in the line spread function
- Evaluated this effect using night light point source (Platform Gail)
- Found asymmetry in along scan line response
- The pixel value after the point light source can be as much as 10% of the light source and affect the 2nd pixel as well



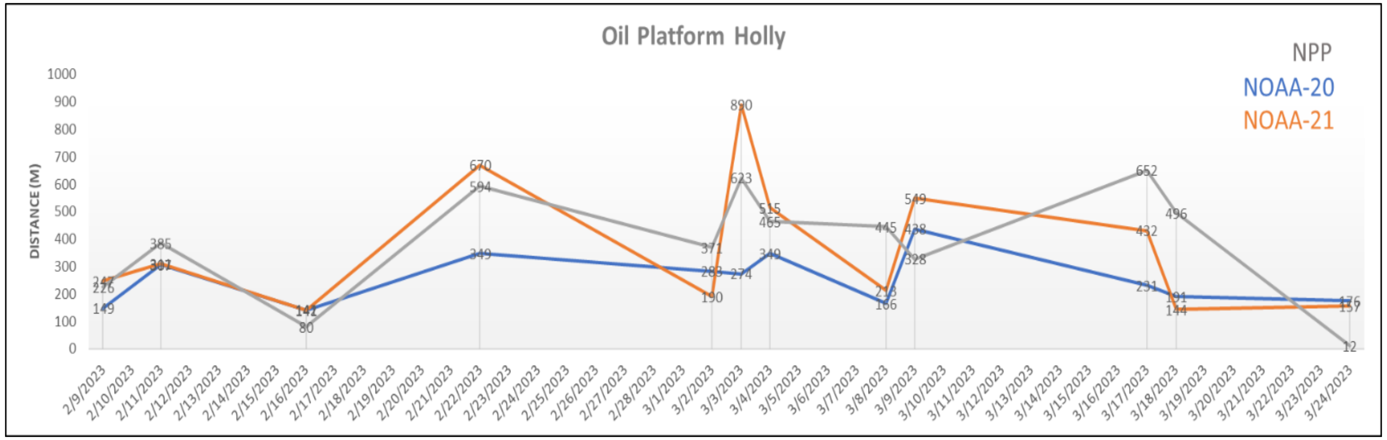


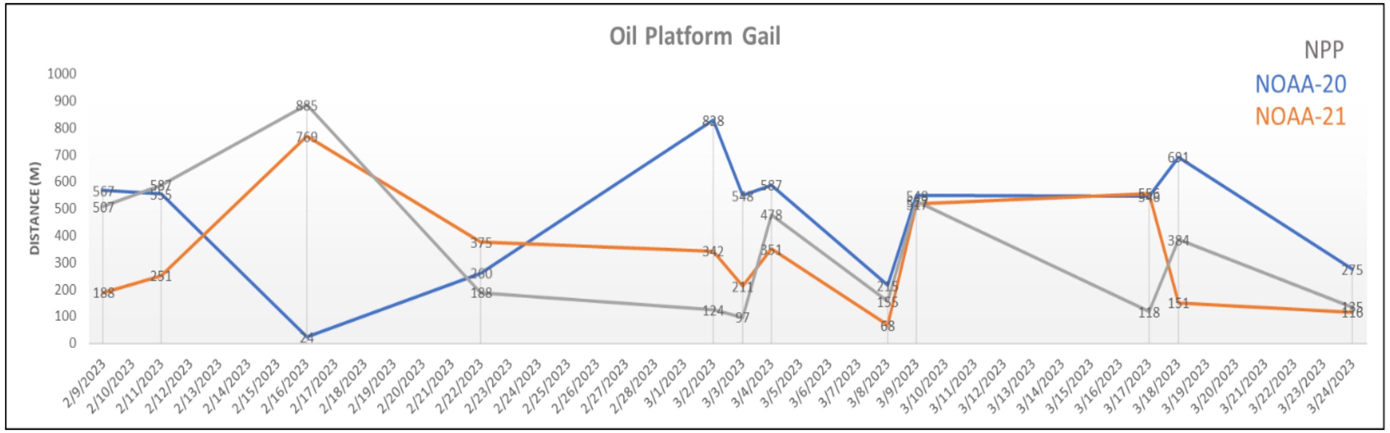
Impact is small:

- Quantitative studies at low light
- Geolocation using point source
- No mitigation needed unless users request

DNB Geolocation Accuracy

Overlay analysis using the GReVS system (https://ncc.nesdis.noaa.gov/Regional/



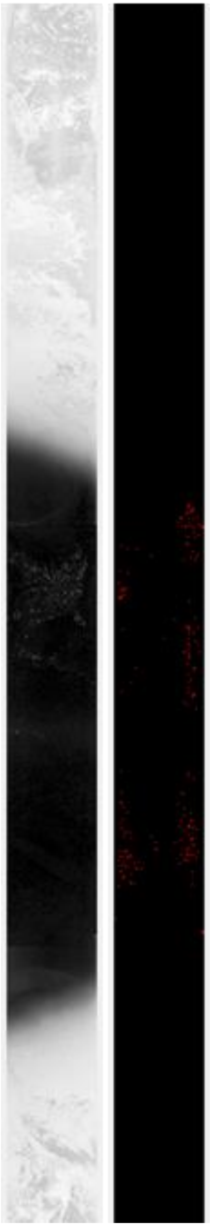


GReVS: https://ncc.nesdis.noaa.gov/Regional/

NOAA-21 and NOAA-20 DNB Co-Registration Verification

Initial assessment of NOAA-21 DNB geolocation accuracy indicates that it is consistent with NOAA-20 and NPP DNB

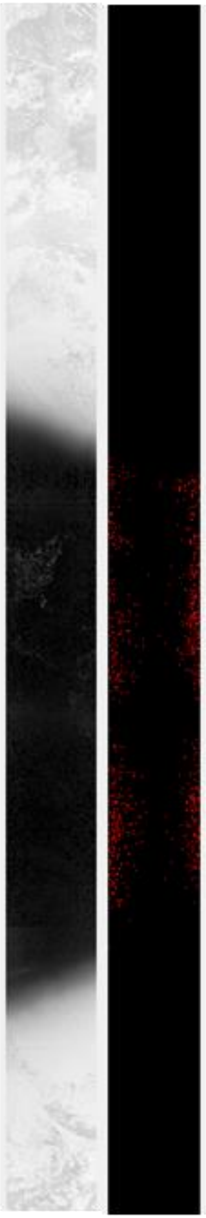
DNB Negative Radiance Issue



NOAA-20 VIIRS

2023-03-21 7:00-8:41 UTC

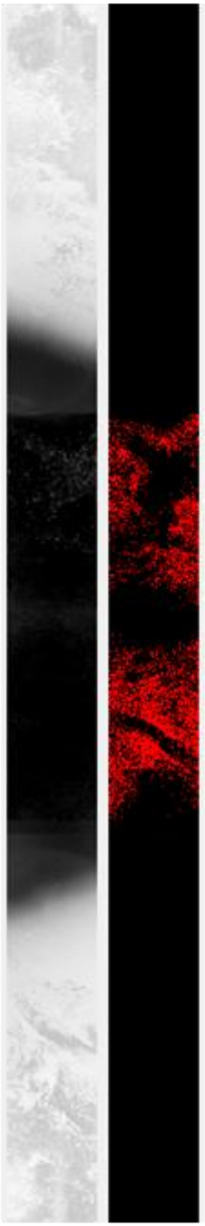
0.2% pixels with negative radiance values



Suomi NPP VIIRS

2023-03-21 6:13-7:52 UTC

1.2% pixels with negative radiance values



NOAA-21 VIIRS

2023-03-21 7:34-9:15 UTC

8.6% pixels with negative radiance values when *initial* DN0 LUT applied

NOAA-21 VIIRS

2023-03-21 7:34-9:15 UTC

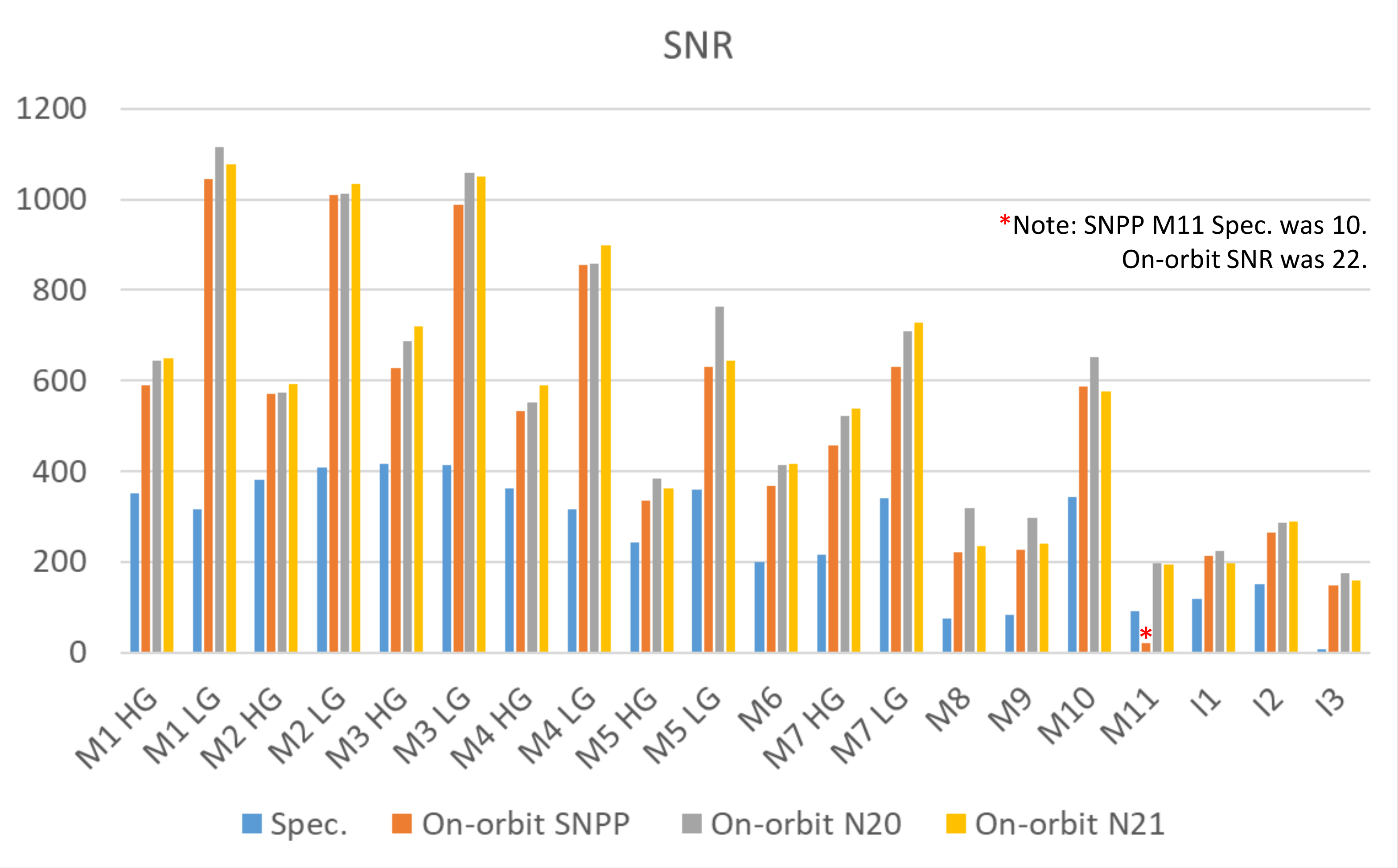
0.02% pixels with negative radiance values when *final* DN0 LUT applied

- Significantly more DNB pixels with negative radiance values for NOAA-21 than for Suomi NPP or NOAA-20 when initial DN0 (offset) LUT used
- Greatly improved after the combined update of the DNB onboard offset tables on Mar. 17, 2023 and the DN0 LUT on Mar. 30, 2023 (Confirmed this morning)

RSB: Signal-to-Noise Ratio (SNR)

Band	L_{typ}	Spec.	SNR on-orbit
M1 HG	44.9	352	648
M1 LG	155	316	1076
M2 HG	40	380	591
M2 LG	146	409	1035
M3 HG	32	416	720
M3 LG	123	414	1049
M4 HG	21	362	589
M4 LG	90	315	898
M5 HG	10	242	362
M5 LG	68	360	645
M6	9.6	199	415
M7 HG	6.4	215	539
M7 LG	33.4	340	728
M8	5.4	74	234
M9	6	83	241
M10	7.3	342	577
M11	1	90	193
I1	22	119	198
I2	25	150	288
I3	7.3	6	158

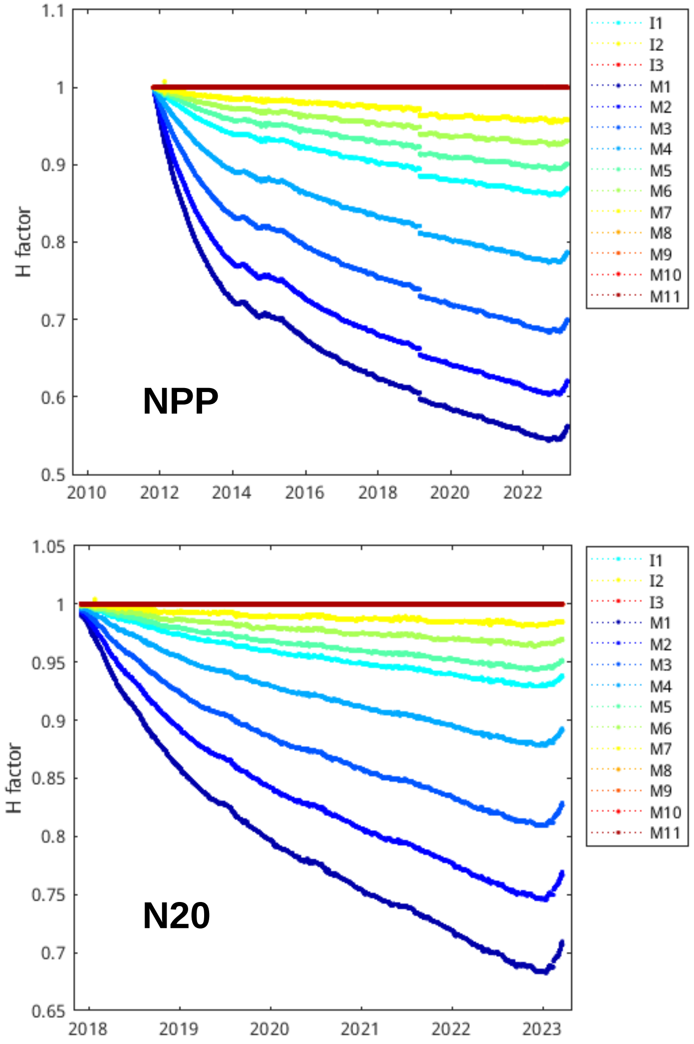
L_{typ} unit: W/m^2-sr-µm



- RSB SNR is calculated from the Solar Diffuser observations on 3/26/2023
- SNR on-orbit of a given band is average over all detectors of the band
- The on-orbit SNR estimation met the requirements (Spec.) for all RSBs

RSB: Calibration Fundamentals

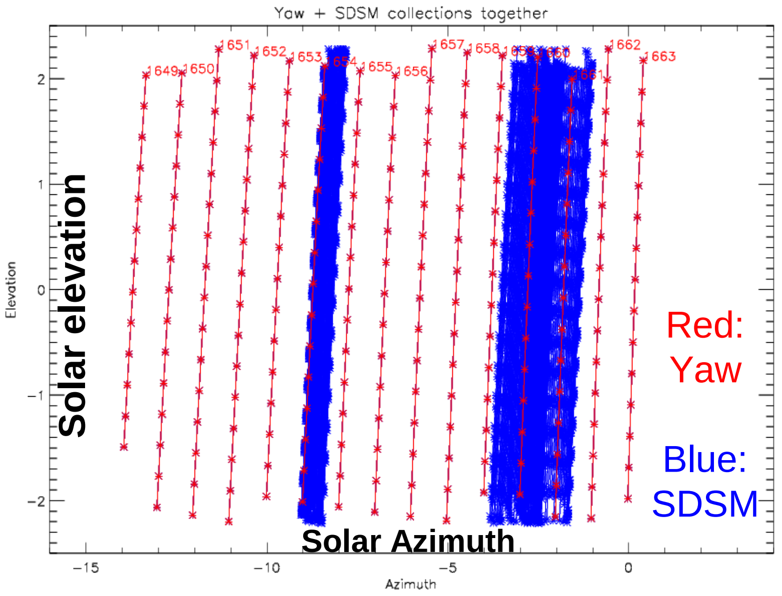
- Post-launch radiometric calibration updated based on solar diffuser (SD) measurements (versus space view or blackbody dark signal) by scaling the pre-launch calibration coefficients obtained from measurements of NIST-traceable light sources
  - Knowledge of the onboard SD reflectance changes critical for the RSB radiometric calibration accuracy
- Calibration coefficients for the visible and near-infrared (VNIR) bands (I1, I2, M1-M7) updated on Jan. 12, 2023, by extrapolation of the SD-derived values to the satellite launch date
  - Radiometric response stability confirmed by Earth target observations and inter-satellite comparisons
- Calibration coefficients for the short-wave infrared (SWIR) bands (I3, M8-M11) updated on Mar. 23, 2023, based on the SD measurements after the detector temperature cool-down to 82 K on Feb. 10, 2023, and the subsequent switch of the temperature setpoint to 80 K on Mar. 3, 2023

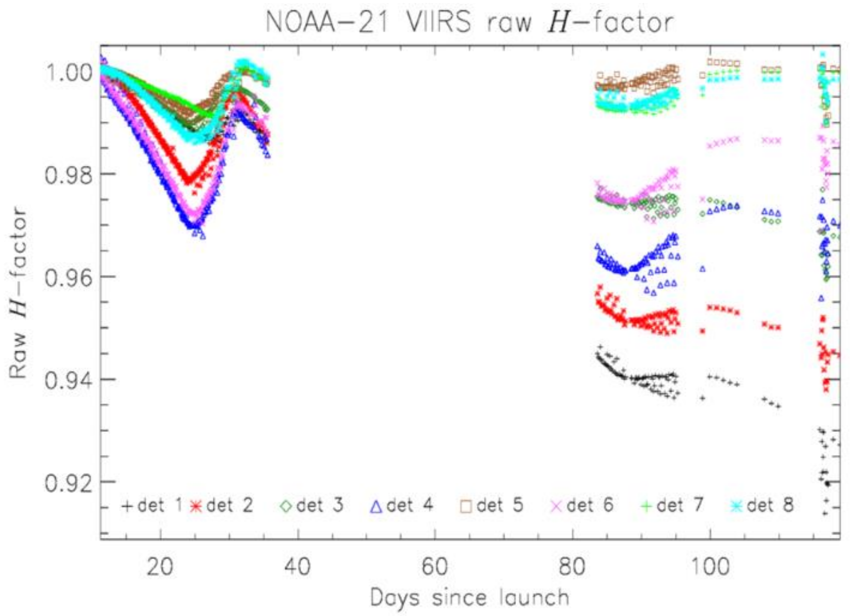


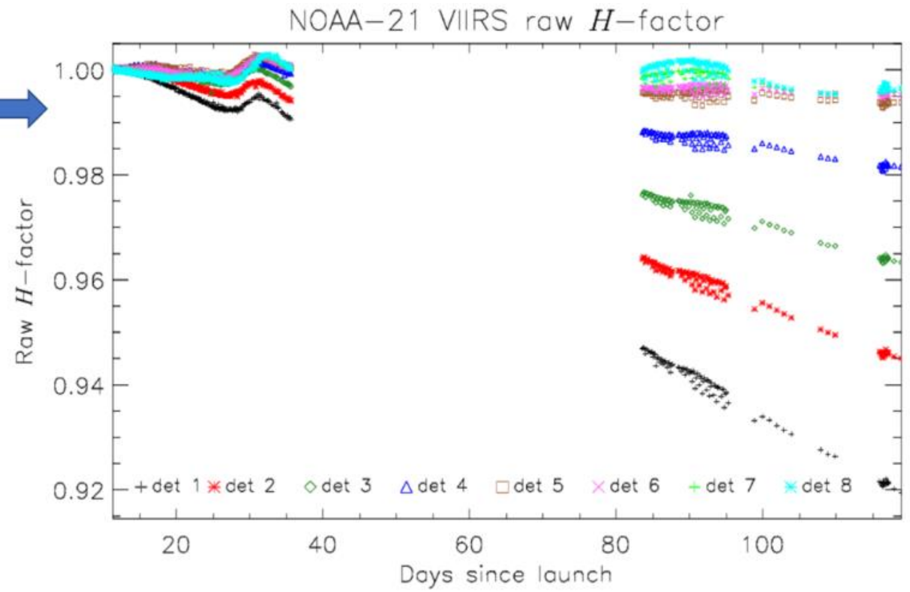
VIIRS SD reflectance changes over the years for Suomi NPP and NOAA-20 (N20)

RSB: Yaw Maneuvers

- NOAA-21 VIIRS yaw maneuvers conducted on Mar. 6-7, 2023
  - Simulated annual changes in the solar azimuth
- Analysis of the collected data improved SD degradation monitoring by reducing oscillations in the SD reflectance time series
- Further improvements expected from addition of SD Stability Monitor (SDSM) measurements throughout the first year on orbit

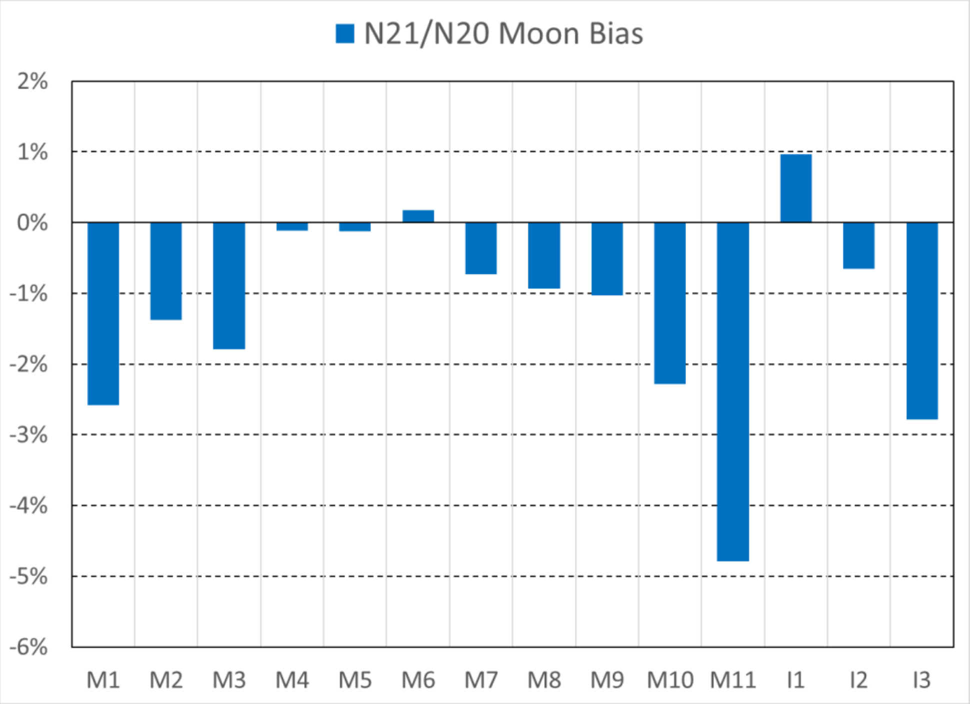


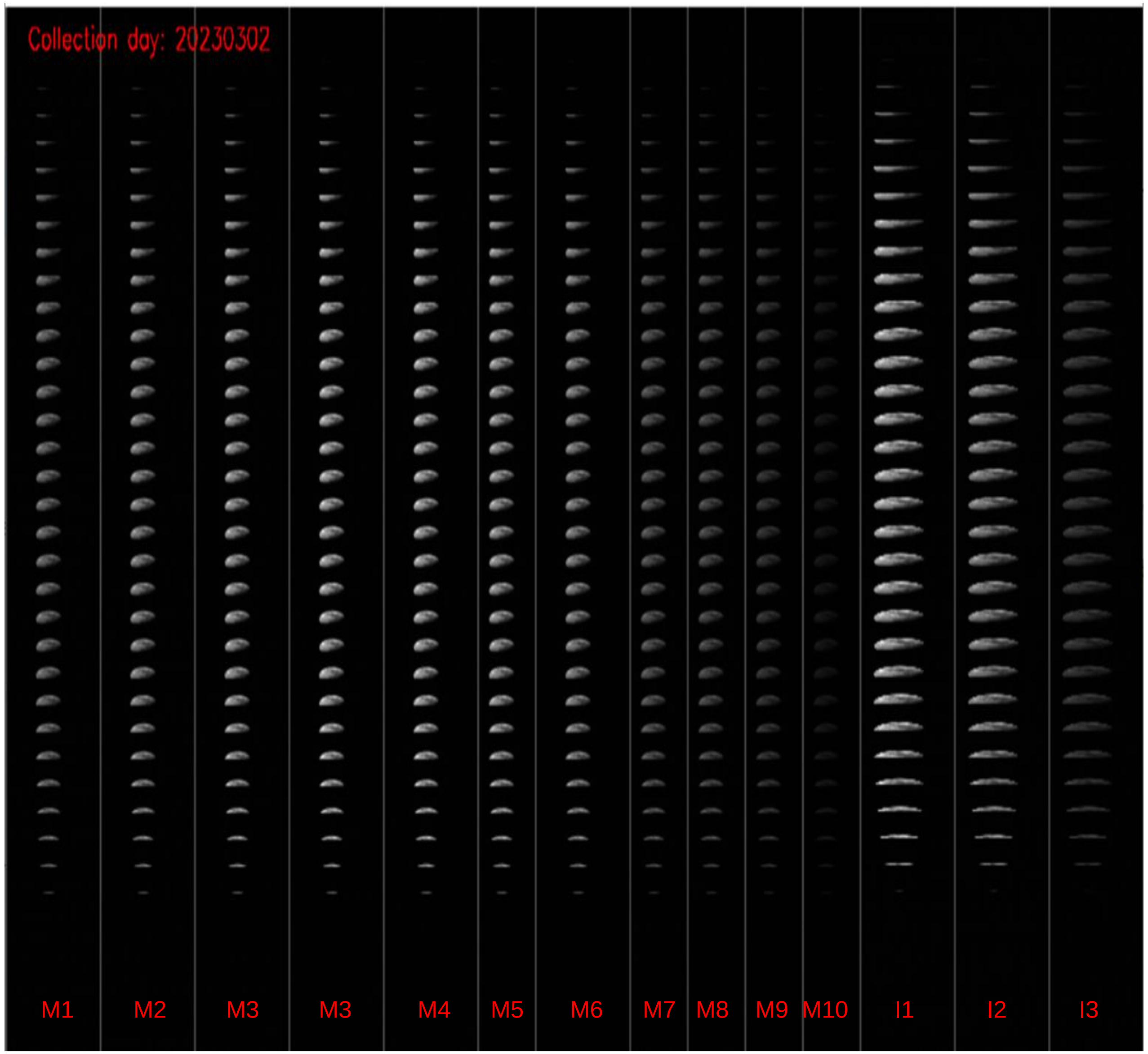




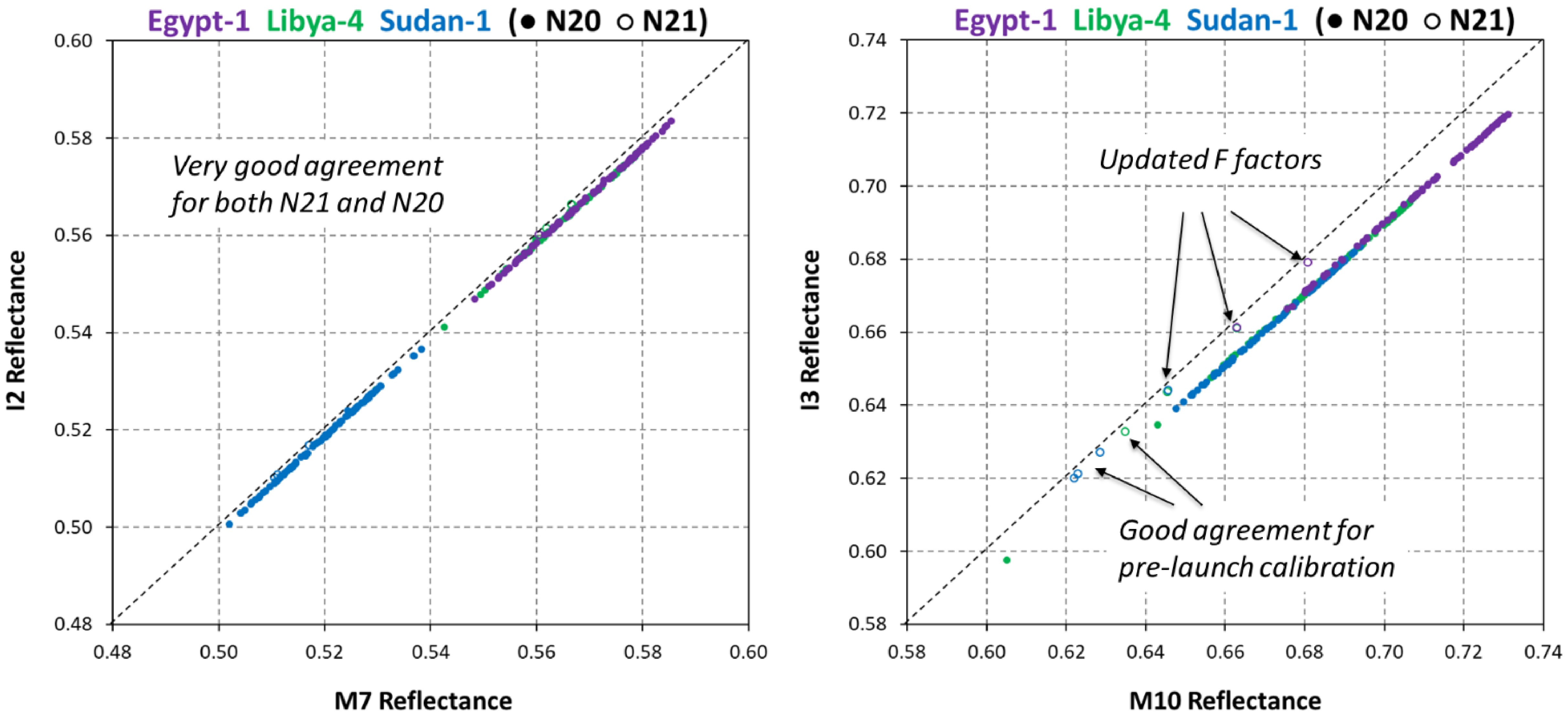
RSB: Lunar Calibration

- VIIRS lunar calibration conducted at least four times each year, often with a spacecraft roll maneuver
  - 1st for N21: Mar. 2, 2023 (1:28:26 UTC, -1.37°)
- Allow for independent verification/correction of the SD reflectance degradation estimates
- Also allows to evaluate spatial resolution, band-to-band registration and calibration biases:



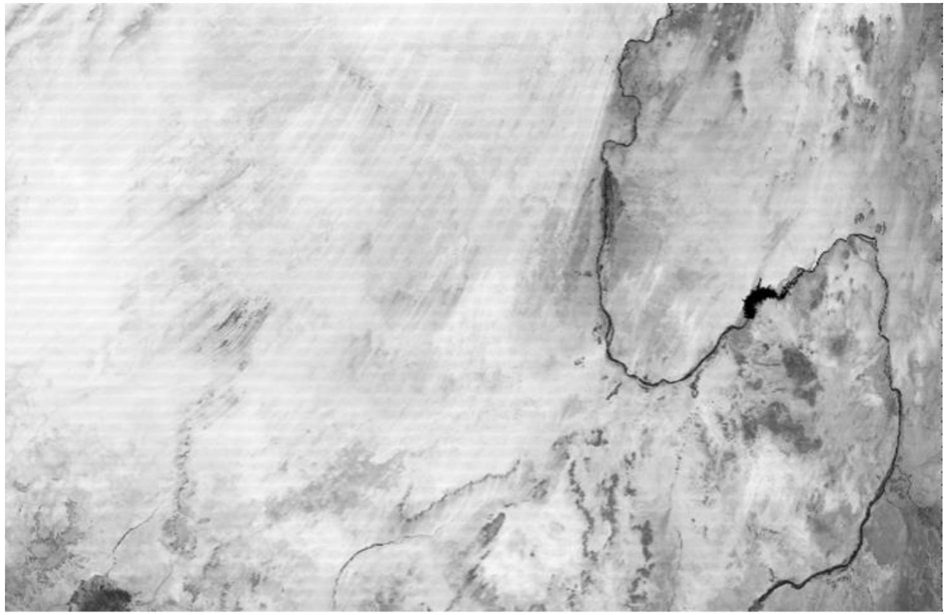


RSB: I-band/M-band Ratios for Saharan PICS

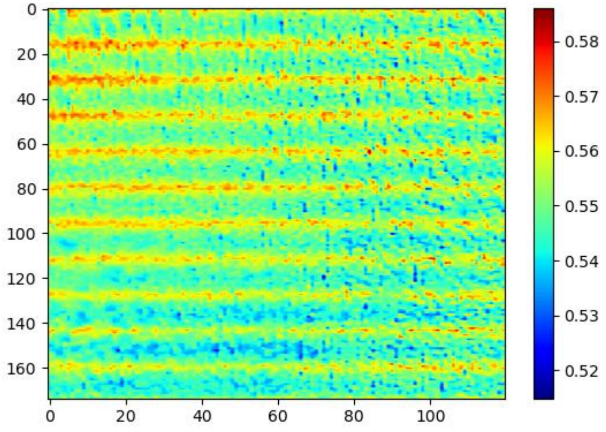


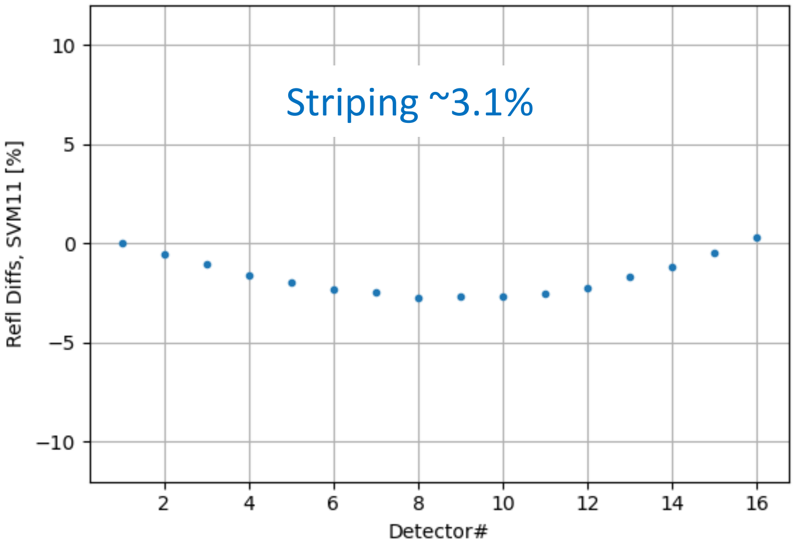
Pairs of Bands with Matching Spectral Responses

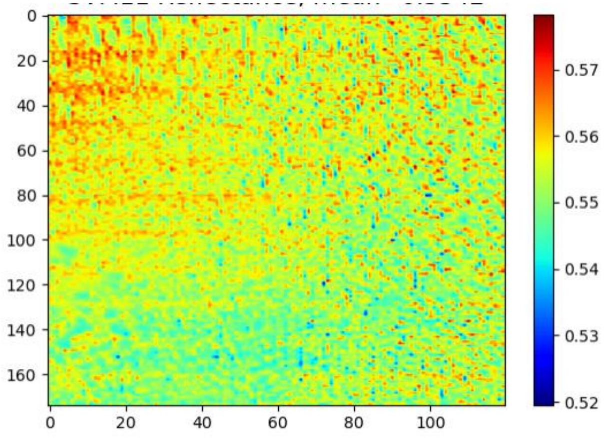
RSB: Band M11 Striping Reduction in Saharan Image

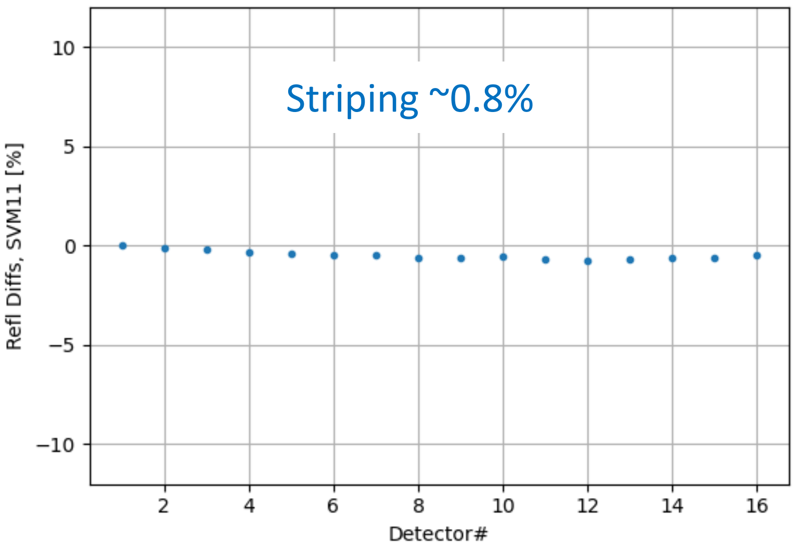


Pre-launch Calibration



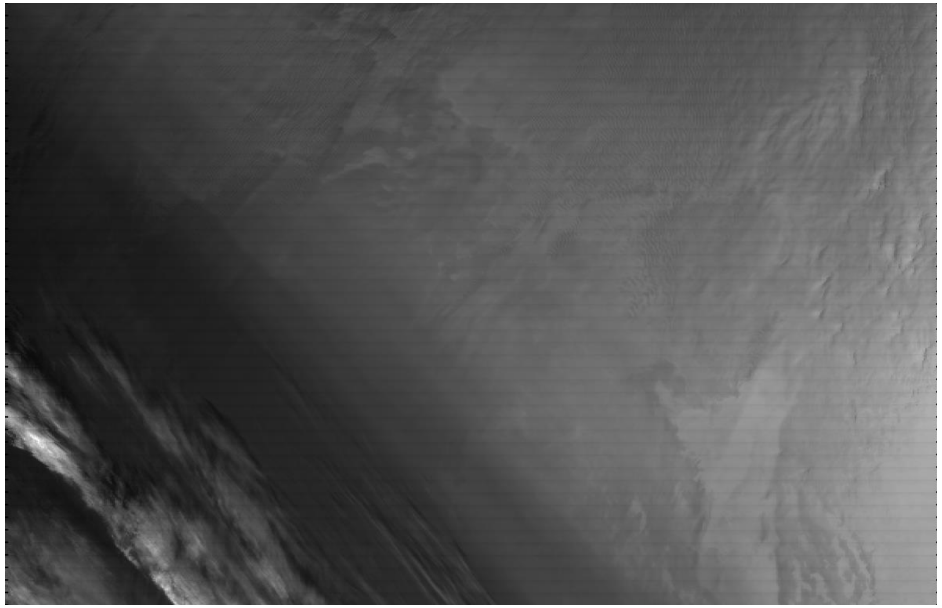


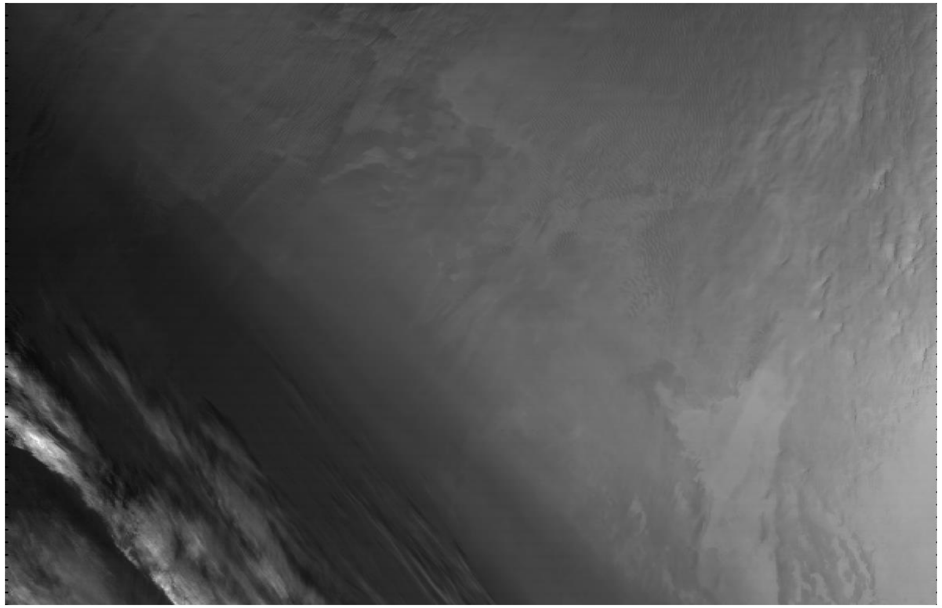




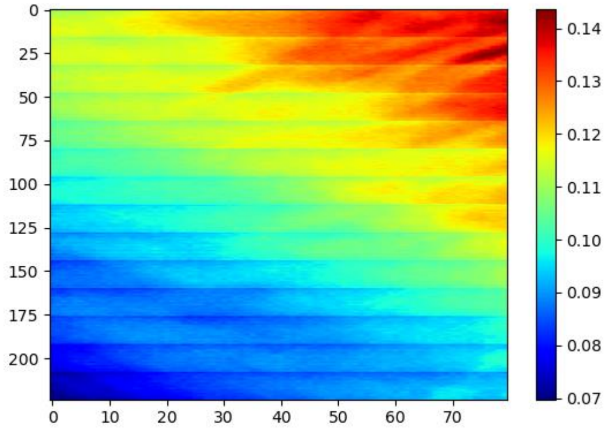
Post-launch Calibration

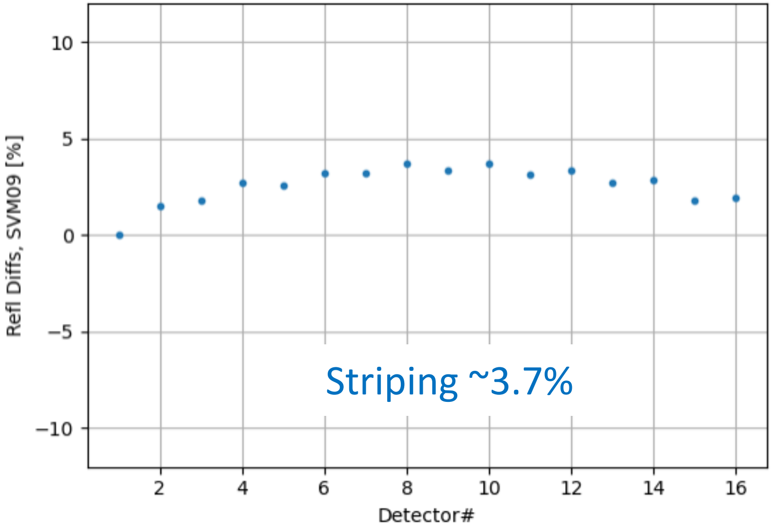
RSB: Band M9 Striping Reduction in Antarctic Image

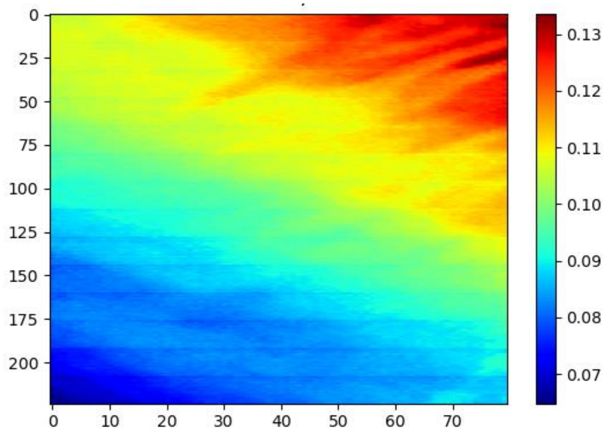


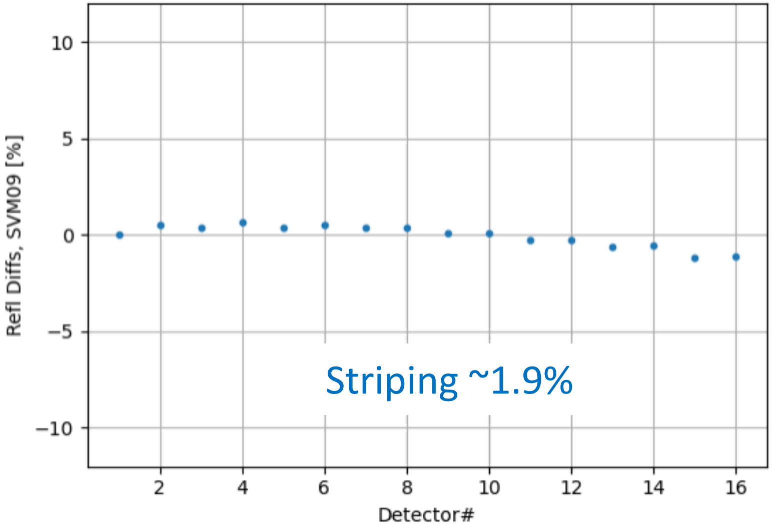


Pre-launch Calibration



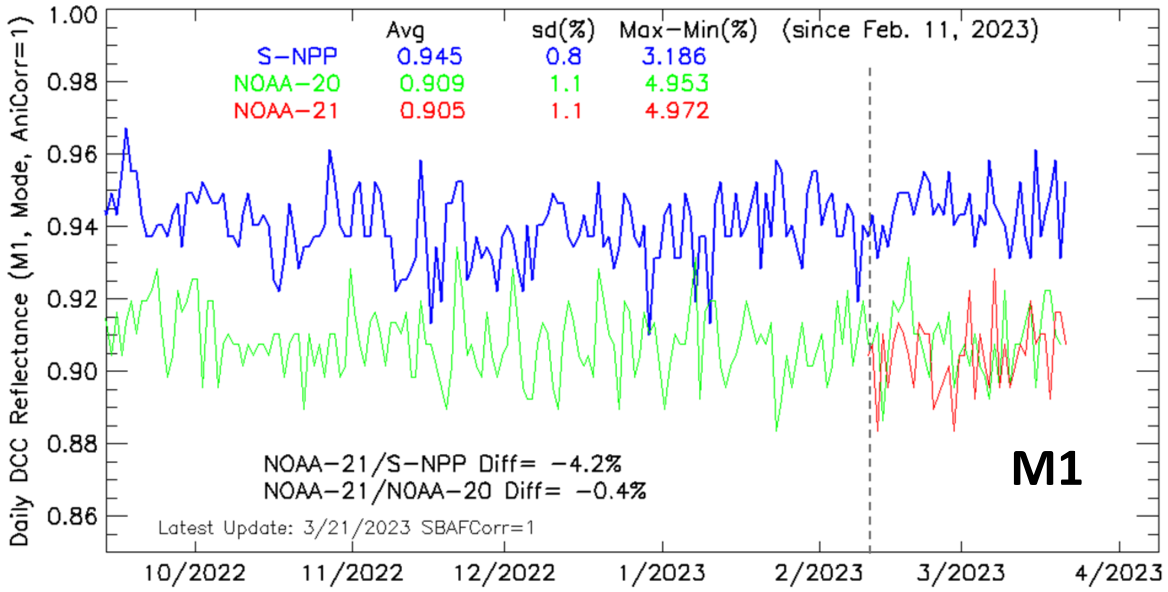


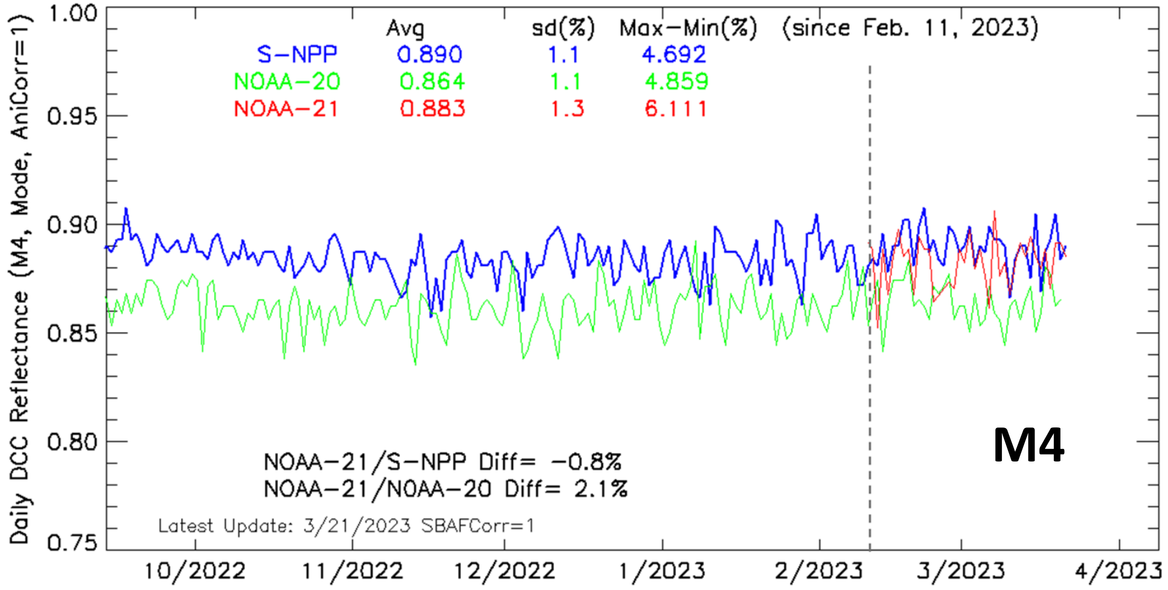




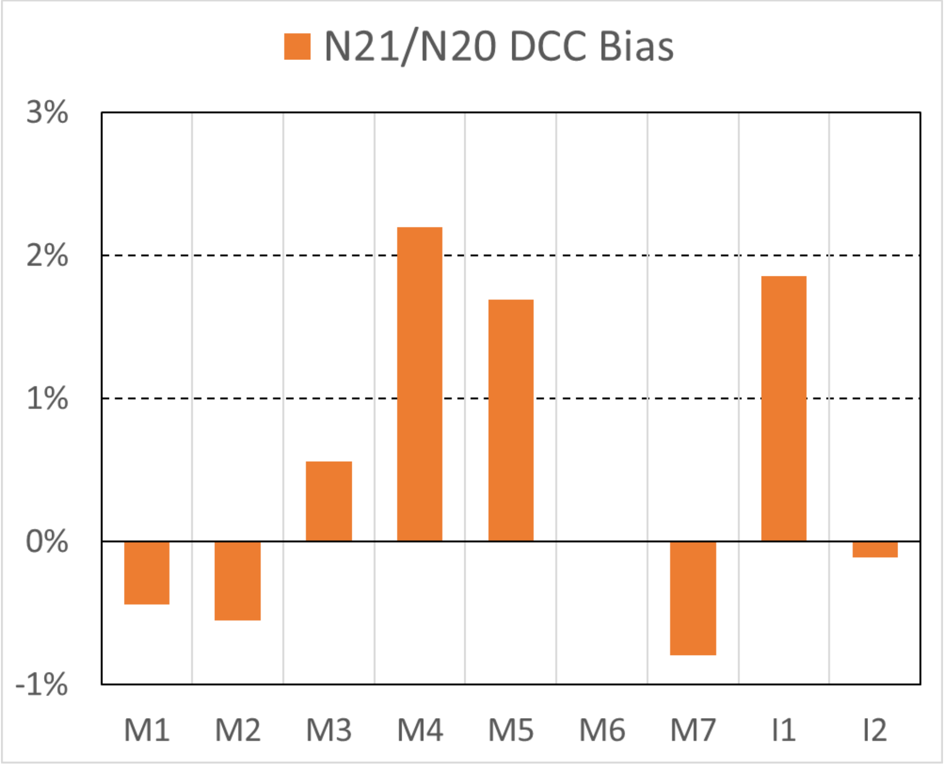
Post-launch Calibration

RSB: Deep Convective Clouds Observations for VNIR Bands

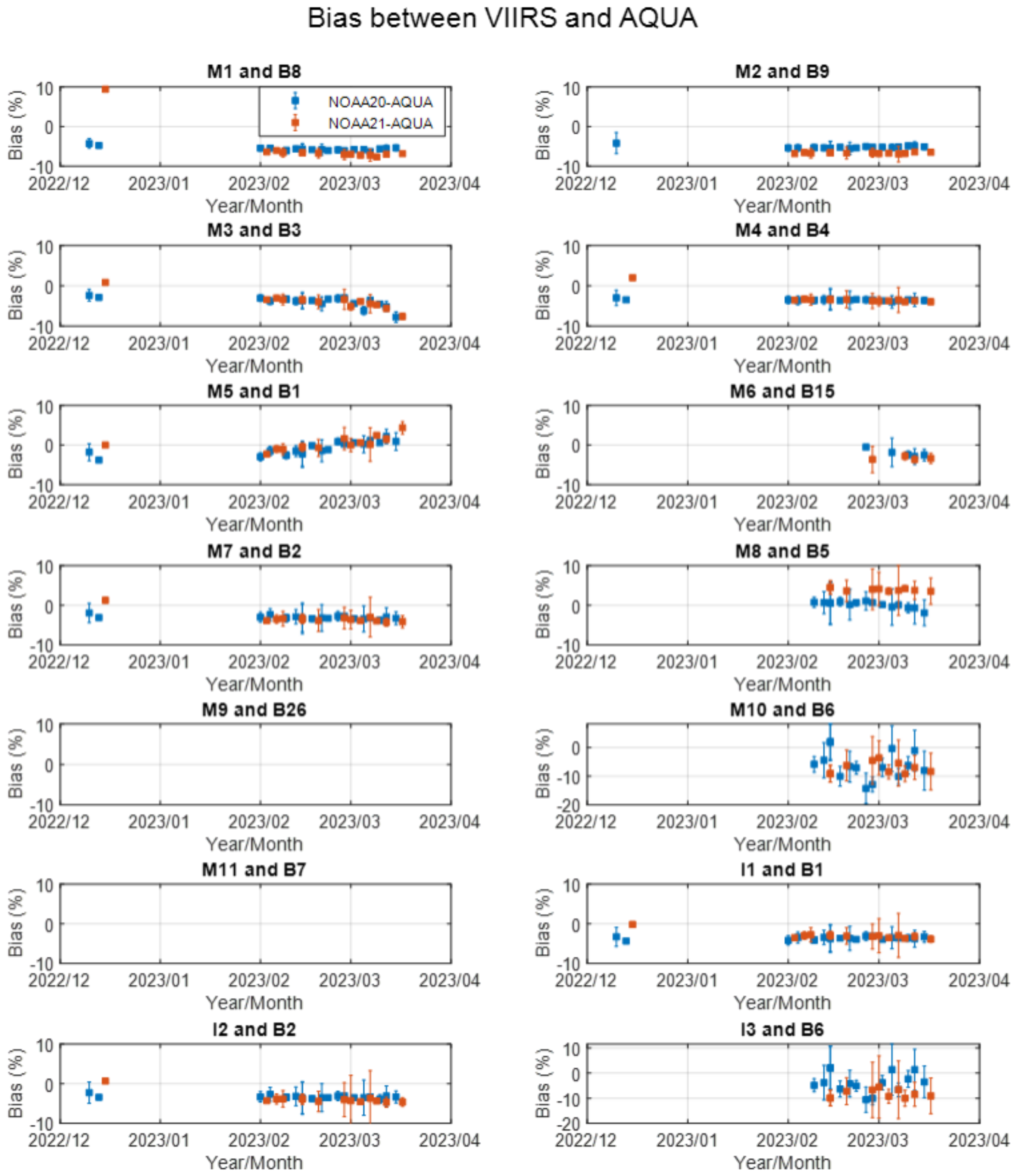


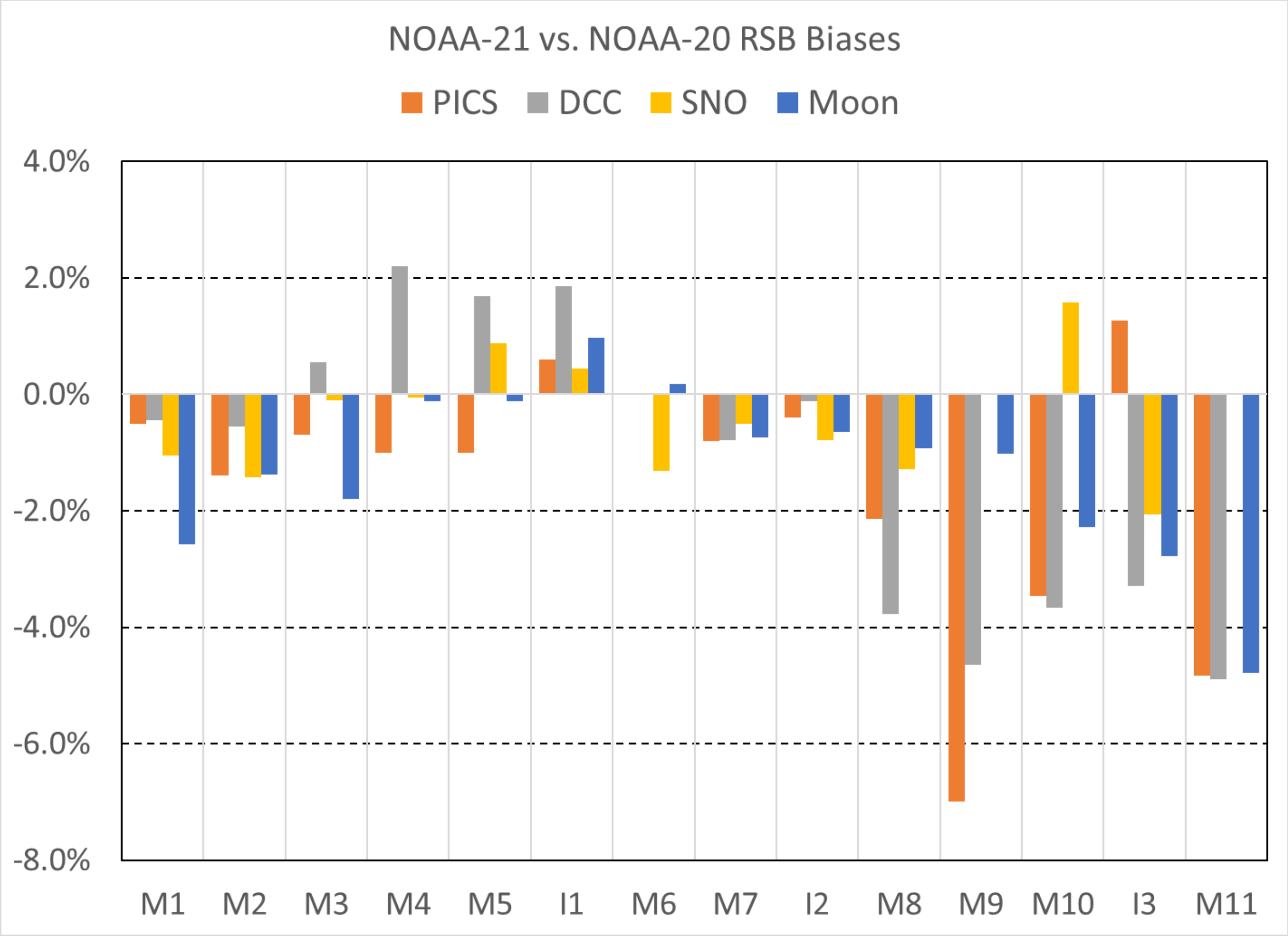


- Daily observations of Deep Convective Clouds (DCC) reflectance demonstrate:
  - Stable radiometric response for NOAA-21 VIIRS
  - Agreement with NOAA-20 VIIRS within the required uncertainty of the absolute radiometric calibration



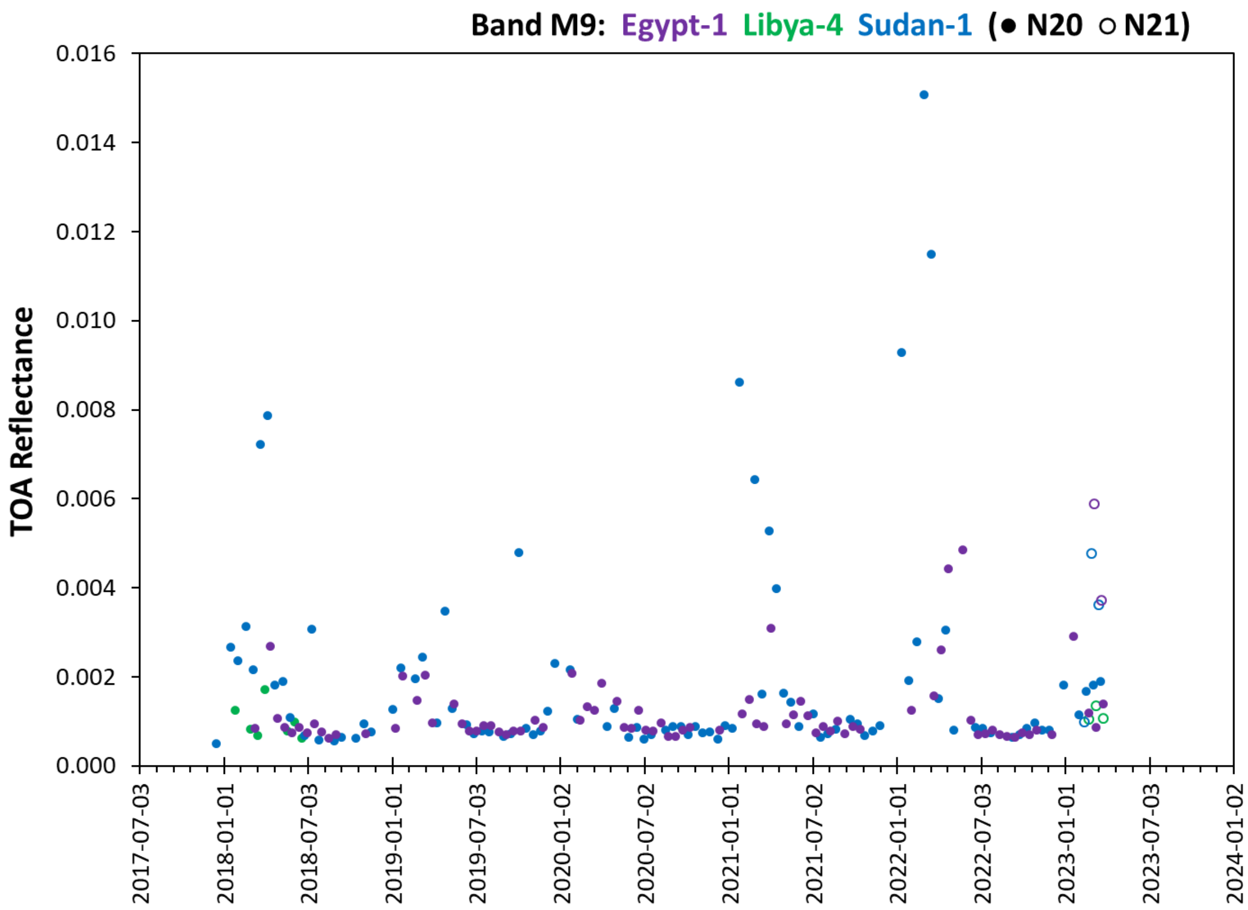
RSB: SNO and Other Inter-Satellite Comparisons

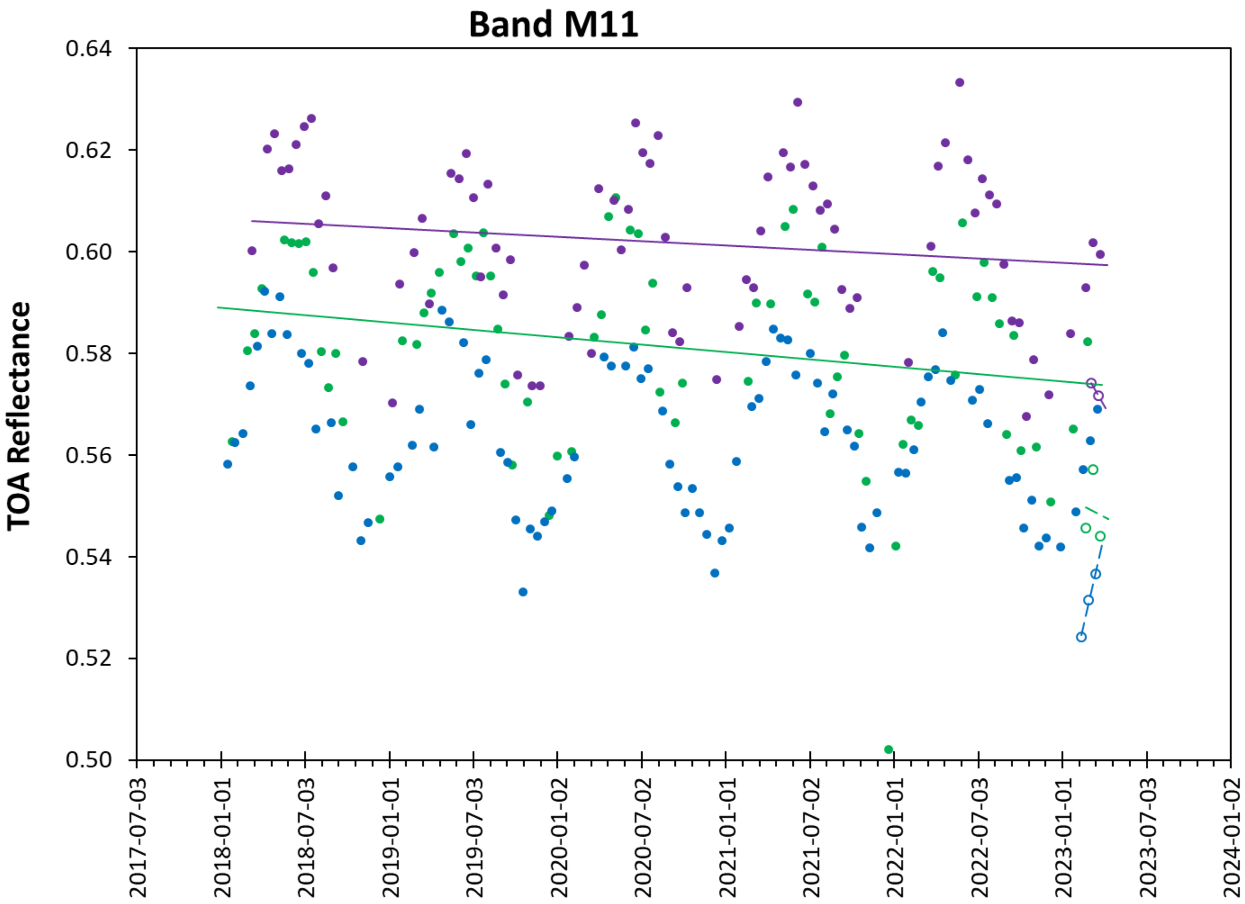




- Good agreement for VNIR bands
- Larger differences and variability for SWIR bands
  - Need further work before Validated Maturity

RSB: Desert Calibration Sites Comparisons for SWIR Bands

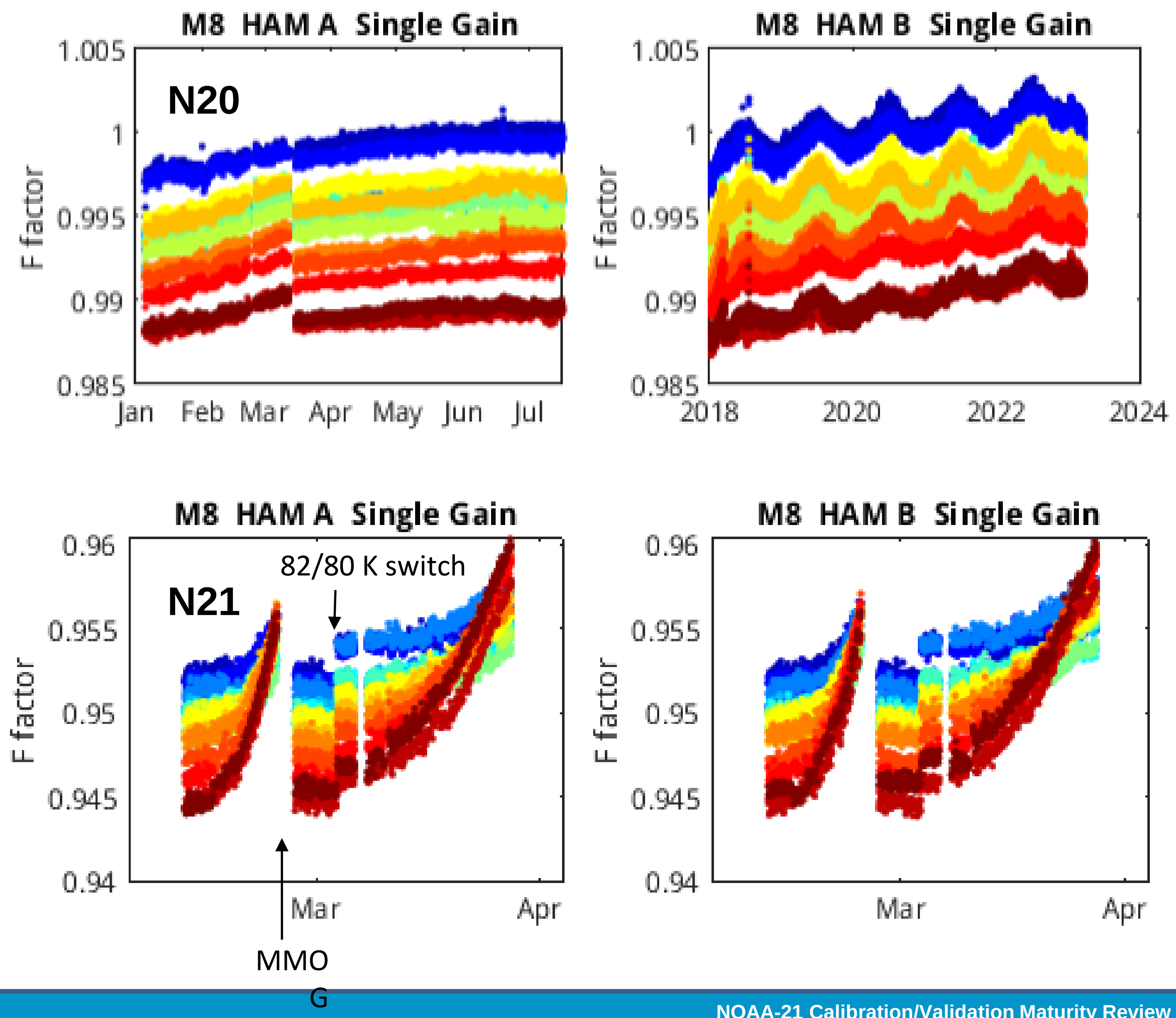




- NOAA-21 VIIRS observations in the cirrus band M9 on cloud-free days (ECM) comparable with those from NOAA-20, despite the significant RSR shift between the two instruments

- NOAA-21 VIIRS observations in band M11 are lower than those from NOAA-20, in line with the other comparisons, but with unknown uncertainty of the RSR-difference correction

RSB: Unexpected SWIR Band “Degradation” Issue



- N20 increase (response degradation) for M8 before MMOG was very small: only about 0.1-0.2%
  - After MMOG, the changes include annual oscillations of about 0.2% and a slow increase over the years due to omitting solar diffuser degradation for the SWIR bands
- The increases for N21 are larger: about 1% by now for some edge detectors
  - Similarities to the trends before MMOG are striking
- Planning to continue monitoring these changes for all SWIR bands
  - The radiometric calibration coefficients can be updated periodically or the automated updates on every orbit can be activated
- N21 VIIRS SWIR bands ready for operational use, but with increased caution and monitoring

Error Budget

Band		Center Wavelength (nm)	Maximum FOV @ Nadir (km)	Maximum FOV @ Edge-of-Scan (km)	Specification SNR (RSB & DNB) NEDT (TEB)	Performance (3/26/2023)	Accuracy Specification	Performance (Initial Assessment)
RSB	M1	412	0.8	1.6	316, 352 (LG,HG)	1076, 648 (LG, HG)	2%	~0.4%
	M2	445	0.8	1.6	409, 380 (LG,HG)	1035, 591 (LG, HG)	2%	~0.5%
	M3	488	0.8	1.6	414, 416 (LG,HG)	1049, 720 (LG, HG)	2%	~0.5%
	M4	555	0.8	1.6	315, 362 (LG,HG)	898, 589 (LG, HG)	2%	~2.1%
	M5	672	0.8	1.6	360, 242 (LG,HG)	645, 362 (LG, HG)	2%	~1.7%
	M6	746	0.8	1.6	199	415	2%	~0.2%
	M7	865	0.8	1.6	340, 215 (LG,HG)	728, 539 (LG, HG)	2%	~0.8%
	M8	1240	0.8	1.6	74	234	2%	~0.9%
	M9	1378	0.8	1.6	83	241	2%	~1.0%
	M10	1610	0.8	1.6	342	577	2%	~2.3%
	M11	2250	0.8	1.6	90	193	2%	~4.7%
	I1	640	0.4	0.8	119	198	2%	~1.9%
	I2	865	0.4	0.8	150	288	2%	~0.2%
	I3	1610	0.4	0.8	6	158	2%	~2.7%
TEB	M12	3700	0.8	1.6	0.396	0.15	0.7% (0.13 K)	
	M13	4050	0.8	1.6	0.107	0.04	0.7% (0.13 K)	~0.2 K
	M14	8550	0.8	1.6	0.091	0.04	0.6% (0.26 K)	
	M15	10763	0.8	1.6	0.07	0.02	0.4% (0.22 K)	~0.1 K
	M16	12013	0.8	1.6	0.072	0.02	0.4% (0.24 K)	~0.1 K
	I4	3740	0.4	0.8	2.5	0.41	5% (0.97 K)	
	I5	11450	0.4	0.8	1.5	0.35	2.5% (1.5 K)	~0.1 K
DNB	DNB	700	0.8	0.8	6	> 11	5%, 10%,30% (LG,MG,HG)	~5% (HG)

- RSB accuracy based on comparison with NOAA-20; M1 and M11: Calibration accuracy waivers
- TEB accuracy based on comparison with CrIS

User Feedback

Name	Organization	Application	User Feedback - User readiness dates for ingest of data and bringing data to operations
Ivan Csiszar	STAR	Fire	1. NOAA-21 product very similar to SNPP and NOAA-20 2. I4 Saturation and folding appear to be as usual 3. M13 radiances shift a bit due to shift of SRF (consistent with CRTM predictions)
William Straka	U. of Wisconsin	Imagery	Good quality except darker than NOAA20 DNB, and striping in the stray light region
Bill Line	STAR/CIRA	Imagery	See next presentation
Menghua Wang	STAR	Ocean Color	NOAA-21 SDR at visible and NIR bands are quite reasonable. However, SWIR band radiances appear to be low. Further evaluation after the LUT updates
John Evans	NWS	NWS	DNB sharp transition; Need LUT update

Risks, Actions, and Mitigations

Identified Risk	Description	Impact	Action/Mitigation and Schedule
1	TEB: Proposed changing the Cold Focal Plane Array (CFPA) set point temperature from 82 to 80 K; May introduce uncertainties in using the current set of calibration coefficients for TEBs.	TEB SDR quality	Delta-C table update and mitigated
2	DNB traces of stray light over both the northern and southern hemispheres	DNB SDR	Development of 12 monthly Stray Light Correction LUT
3	RSB: Uncertainties in the solar diffuser degradation monitoring can introduce additional biases in RSB calibration.	RSB Calibration	Yaw maneuvers performed. The updated SD degradation will be applied to the RSB calibration.
4	SWIR band degradation	SWIR band calibration	Close monitoring to determine if more frequent F factor update or activation of RSBAutoCal is needed
5	SWIR band bias uncertainties	SWIR band calibration accuracy	Further calibration/validation with longer time series
6	DNB signal leakage line spread function in line with the waiver	DNB spatial resolution	Closely monitored

Mitigated

Documentations (Check List, 1 slide)

Science Maturity Check List	Yes ?
ReadMe for Data Product Users	Yes
Algorithm Theoretical Basis Document (ATBD)	Yes
Algorithm Calibration/Validation Plan	Yes
(External/Internal) Users Manual	Yes
System Maintenance Manual (for ESPC products)	N.A.
Peer Reviewed Publications (Demonstrates algorithm is independently reviewed)	Many for SNPP/NOAA-20; Coming for NOAA-21
Regular Validation Reports (at least annually) (Demonstrates long-term performance of the algorithm)	Annual VIIRS SDR performance report

Check List - Provisional Maturity

Provisional Maturity End State	Assessment
Product performance has been demonstrated through analysis of a large, but still limited (i.e., not necessarily globally or seasonally representative) number of independent measurements obtained from select locations, periods, and associated ground truth or field campaign efforts.	NOAA-21 VIIRS instrument performance and science data (SDR/GEO) have been verified through a large, but still limited measurement dataset analysis. No significant anomalies have been found affecting data quality.
Product analysis is sufficient to communicate product performance to users relative to expectations (Performance Baseline).	NOAA-21 VIIRS science data have met the provisional maturity requirements and can be used for qualitative and limited quantitative assessment for downstream products.
Documentation of product performance exists that includes recommended remediation strategies for all anomalies and weaknesses. Any algorithm changes associated with severe anomalies have been documented, implemented, tested, and shared with the user community.	NOAA-21 VIIRS provisional maturity science data quality README file has been created for user reference. Calibration related documents are also released to support general data users.
Product is ready for operational use and for use in comprehensive cal/val activities and product optimization.	NOAA-21 VIIRS provisional maturity science data is ready for operational use and for use in comprehensive cal/val activities and product optimization.

NOAA-21 VIIRS Provisional Maturity Status

- VIIRS SDR for all four major categories (RSB, TEB, DNB and GEO) were checked;
- On-orbit NEΔT and SNR are characterized; On-orbit SDR bias was characterized based on preliminary comparisons with NOAA-20 VIIRS;
- All calibration related parameters, and major SDR/GEO quality flags were checked;
- Errors and artifacts in the data products were documented. Solutions have been proposed and evaluated, but not necessarily implemented;
- All data products can be used for making qualitative and limited quantitative assessments.
- Feedbacks from NOAA VIIRS EDR teams including Fire, Imagery, Ocean Color and other teams, and NWS are generally positive about the data quality based on initial assessments.

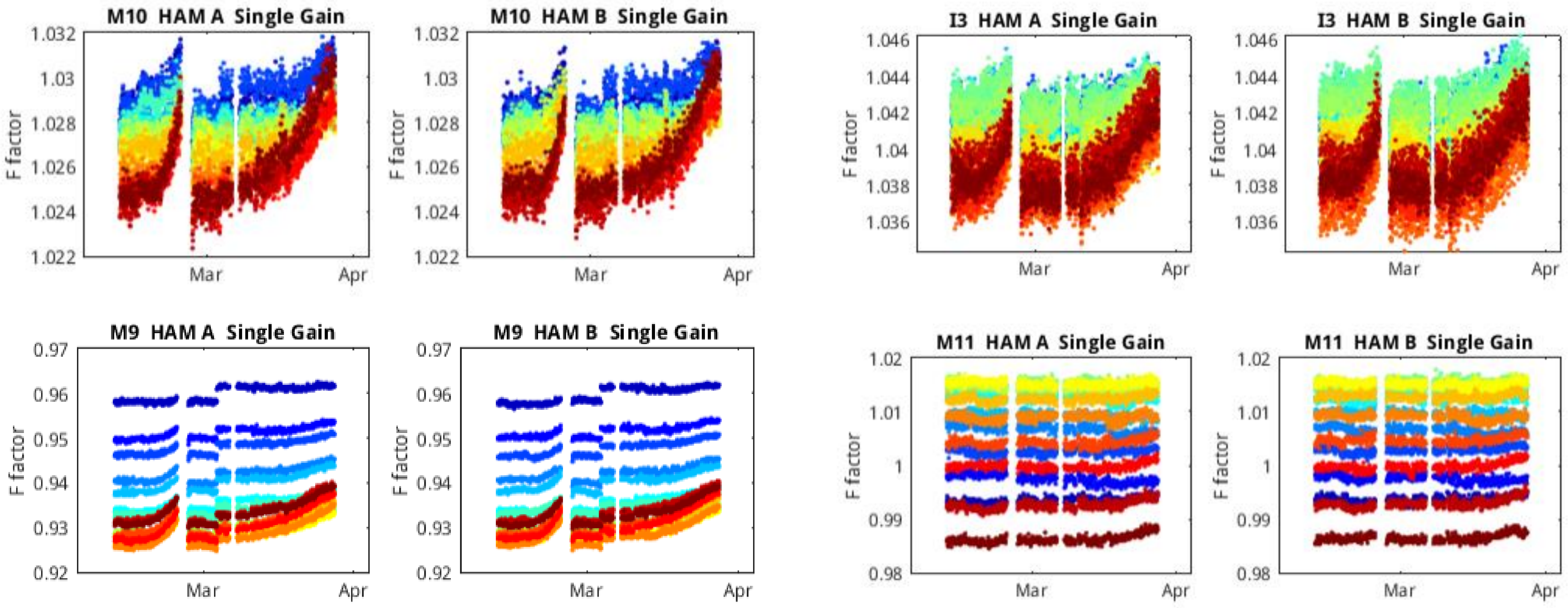
VIIRS SDR Cal/Val Findings: NOAA-21 VIIRS SDR achieved provisional maturity on March 30, 2023, with caveats on SWIR bands

Path Forward

1. Develop and deliver 12 monthly DNB stray light correction tables in a year
2. Closely monitor SWIR band degradation, and further quantify radiometric biases.
3. Evaluate impacts of DNB Line Spread Function (LSF) anomaly and get user feedback
4. Analyze lunar calibration data to independently characterize solar diffuser degradation
5. Further evaluate NOAA-21 pre-launch waiver related issues and address them as appropriate
6. Characterize the instrument performance following the NOAA-21 VIIRS Calibration/Validation Plan
7. Continue monitoring VIIRS instrument stability and performance, as well as SDR data quality
   - Further analyze yaw and pitch maneuver data to improve onboard calibration and ground processing
   - Further quantify geolocation accuracy
   - Update LUT to address TEB bias during warm up cool down
   - Continue to prepare and submit LUT updates to implement improved calibration and error correction coefficients in the operational ground processing system

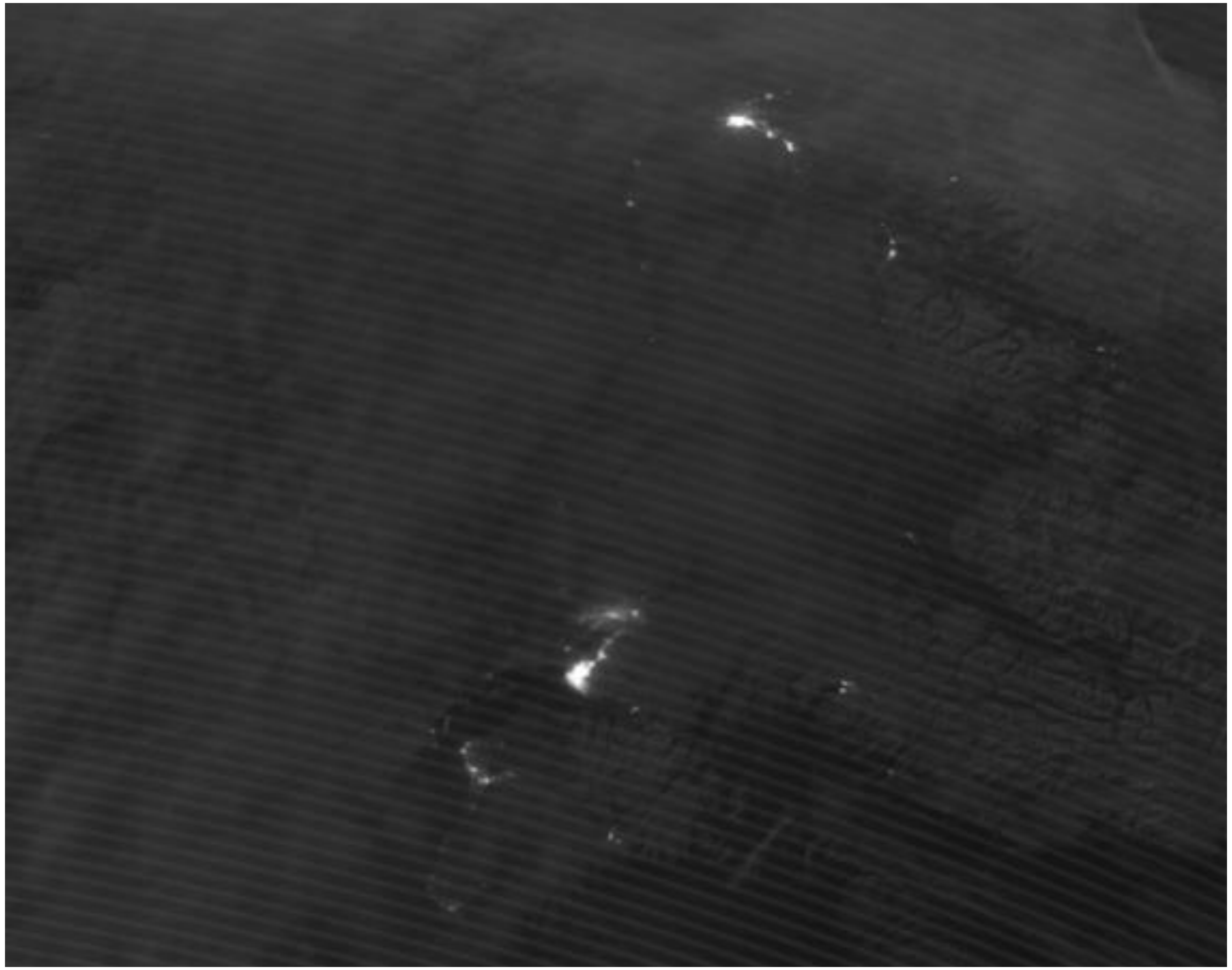
Backup

RSB: Unexpected SWIR Band “Degradation” Issue (cont.)

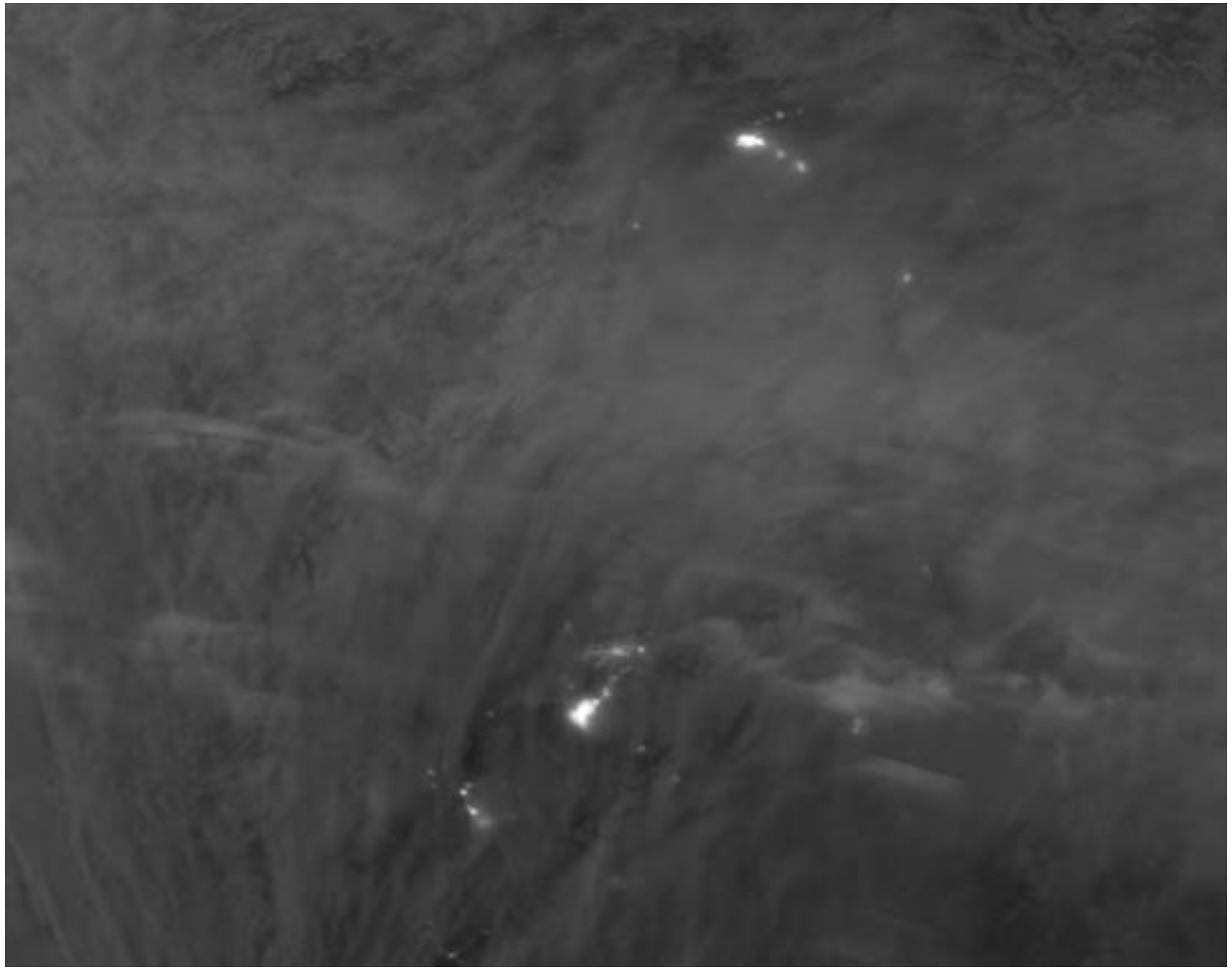


DNB over Alaska

03/29/2023



03/30/2023



Confirm stray light correction LUT applied

Triplet Inter-comparisons

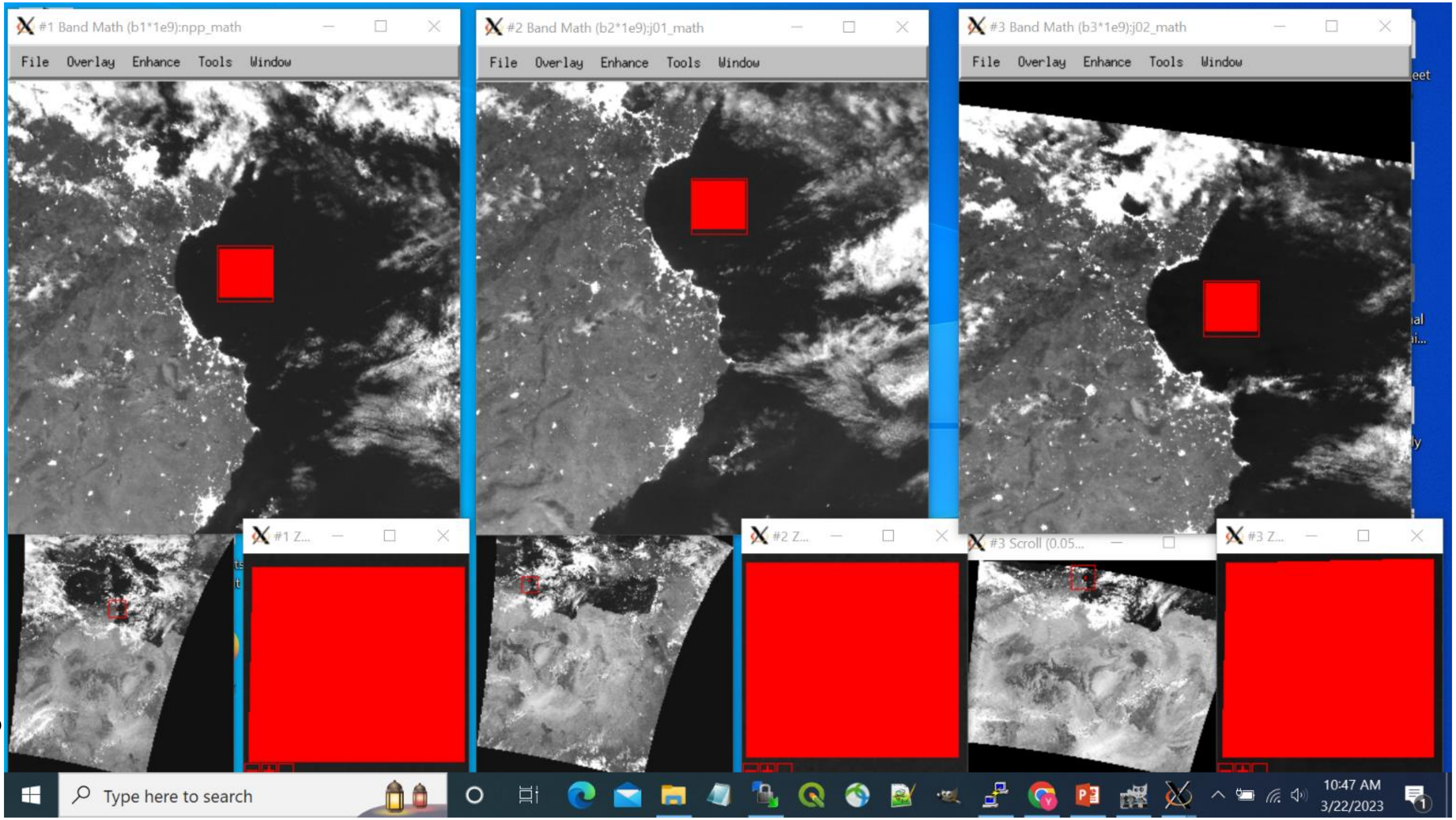
3/17/23 0:34-1:37UTC: Radiances over water: NOAA20 (0.17); NOAA21(-0.02); SNPP(0.32)

The triplet method:

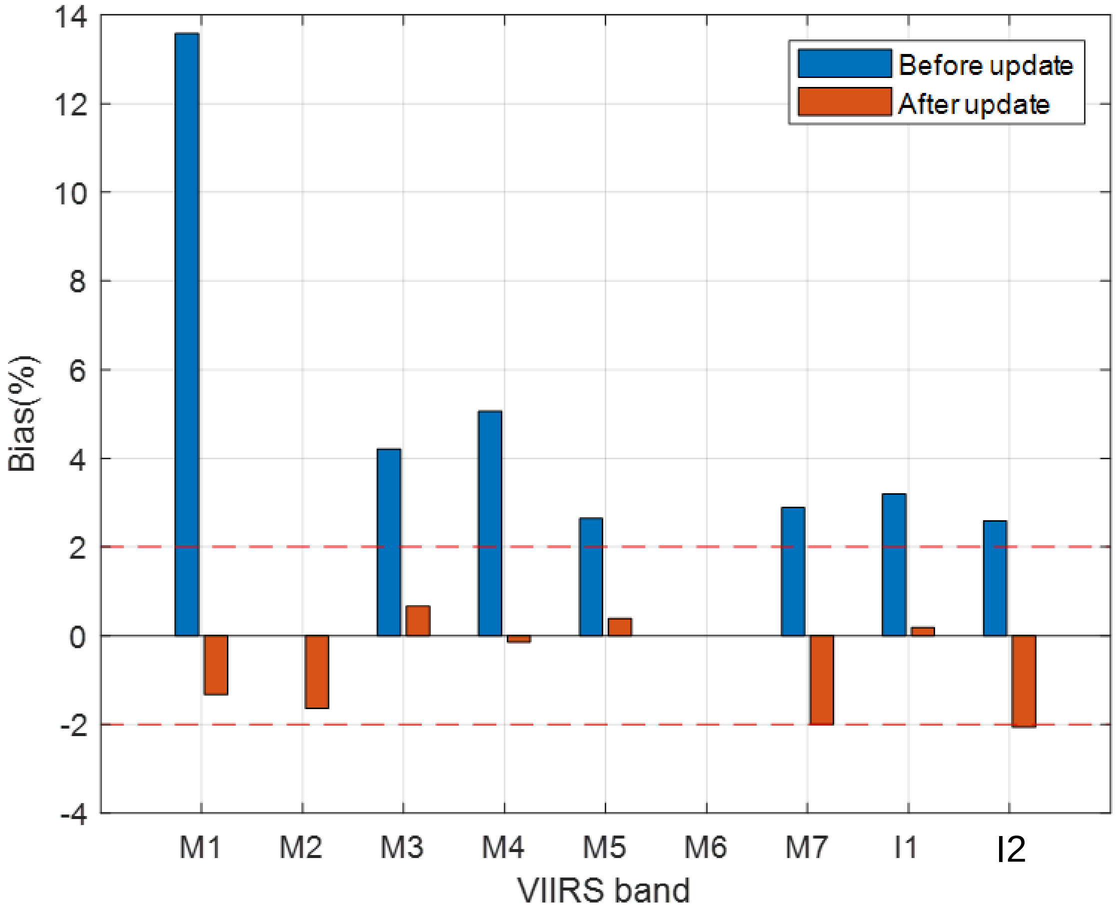
- Three images from NOAA20, NOAA21, and SNPP respectively within 50 minutes over the same calibration target projected
- Geospatially linked to ensure the same region of interest for a selected uniform region
- Compute statistics for each sample dataset

Assumptions:

- Sun or moon zenith angle differences are negligible
- BRDF effects are relatively small and can be estimated
- NOAA21 compares to NOAA20 (leading) and SNPP (trailing) allows to estimate relative biases



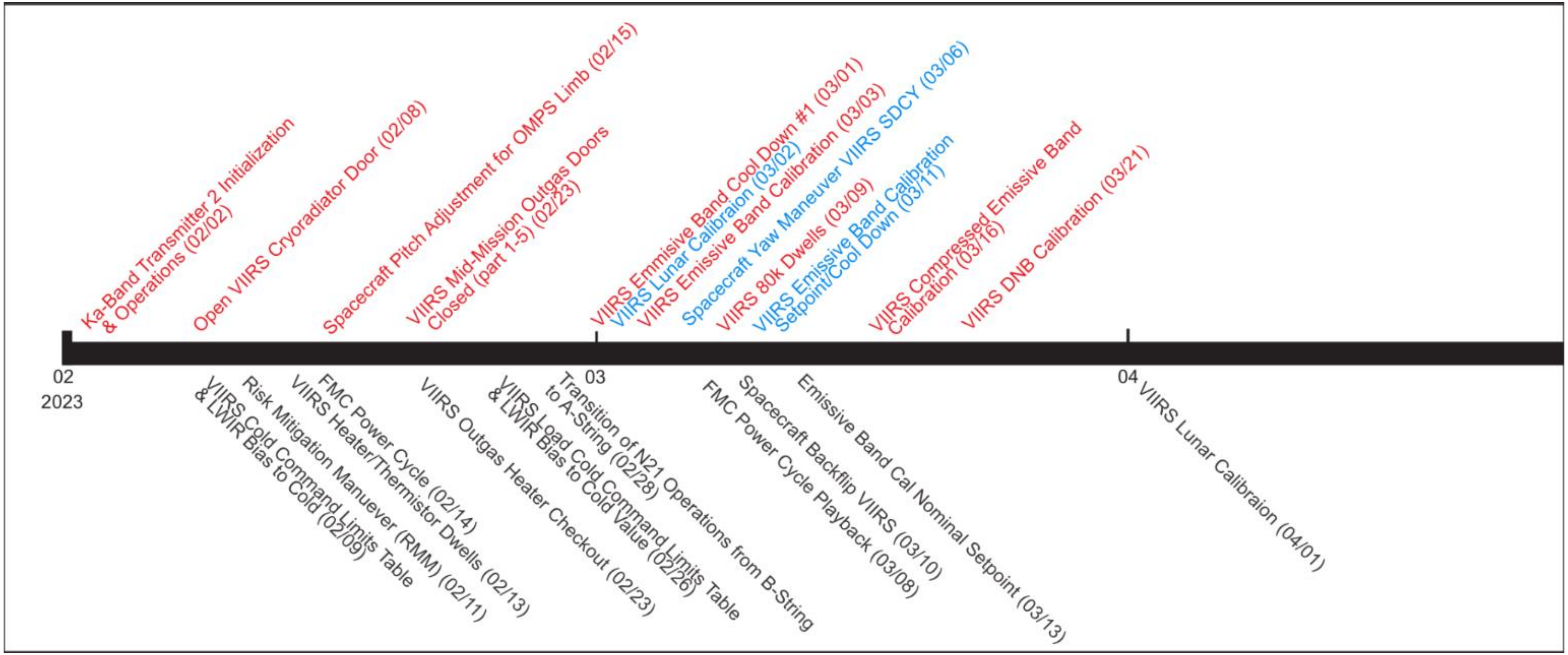
Radiometric Bias Evaluation: NOAA-21 vs. NOAA-20 VIIRS VIS/NIR Comparison at SNO using Aqua MODIS as Reference



NOAA-21 vs. NOAA-20 VNIR Biases Before and after NOAA-21 Calibration Update

	Bias before N21 update (%)			Bias after N21 update		
	N21-AUQA	N20-AQUA	N21-N20	N21-AUQA	N20-AQUA	N21-N20
M1	9.639±0.334	-3.946±0.780	13.585	-6.222±0.304	-4.889±0.672	-1.333
M2	NaN	-6.773±2.678	NaN	-9.593±0.475	-7.949±0.867	-1.644
M3	5.581±0.465	1.370±0.943	4.211	1.197±0.487	0.532±0.919	0.664
M4	2.217±0.491	-2.838±1.083	5.055	-3.313±0.448	-3.169±0.971	-0.144
M5	3.273±0.557	0.628±1.143	2.645	1.582±0.521	1.201±1.137	0.382
M6	NaN	NaN	NaN	NaN	NaN	NaN
M7	3.050±0.626	0.163±1.329	2.887	-2.029±0.641	-0.029±1.337	-2.000
I01	-1.712±0.502	-4.907±1.389	3.194	-4.729±0.595	-4.913±1.275	0.184
I02	2.484±0.603	-0.108±1.455	2.592	-2.347±0.766	-0.285±1.562	-2.062

- Radiometric bias of NOAA-21 VIIRS VIS/NIR (M1-M5, M7) channels are within 2% bias relative to NOAA-20



Ka-Band Transmitter 2 Initialization & Operations (02/02)
Open VIIRS Cryoradiator Door (02/08)
Spacecraft Pitch Adjustment for OMPS Limb (02/15)
VIIRS Mid-Mission Outgas Doors Closed (part 1-5) (02/23)
VIIRS Emmisive Band Cool Down #1 (03/01)
VIIRS Lunar Calibraion (03/02)
VIIRS Emissive Band Calibration (03/03)
Spacecraft Yaw Maneuver VIIRS SDCY (03/06)
VIIRS 80k Dwells (03/09)
VIIRS Emissive Band Calibration Setpoint/Cool Down (03/11)
VIIRS Compressed Emissive Band Calibration (03/16)
VIIRS DNB Calibration (03/21)
02
2023
03
04
VIIRS Cold Command Limits Table & LWIR Bias to Cold (02/09)
Risk Mitigation Manuever (RMM) (02/11)
VIIRS Heater/Thermistor Dwells (02/13)
FMC Power Cycle (02/14)
VIIRS Outgas Heater Checkout (02/23)
VIIRS Load Cold Command Limits Table & LWIR Bias to Cold Value (02/26)
Transition of N21 Operations from B-String to A-String (02/28)
FMC Power Cycle Playback (03/08)
Spacecraft Backflip VIIRS (03/10)
Emissive Band Cal Nominal Setpoint (03/13)
VIIRS Lunar Calibraion (04/01)