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

Presented by VIIRS SDR Team
Date: 8/3/2023

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 levels.
- 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.

Validated Maturity Review - Entry Criteria (provided by JSTAR)

- Product Requirements
- Pre-launch Performance Matrix/Waivers
- Validated 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
- Summary

Validated Maturity Review - Exit Criteria (provided by JSTAR)

- Validated 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
  - Validated Maturity Performance
  - Risks, Actions, Mitigations
  - Path forward to Validated Maturity

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

Validated 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

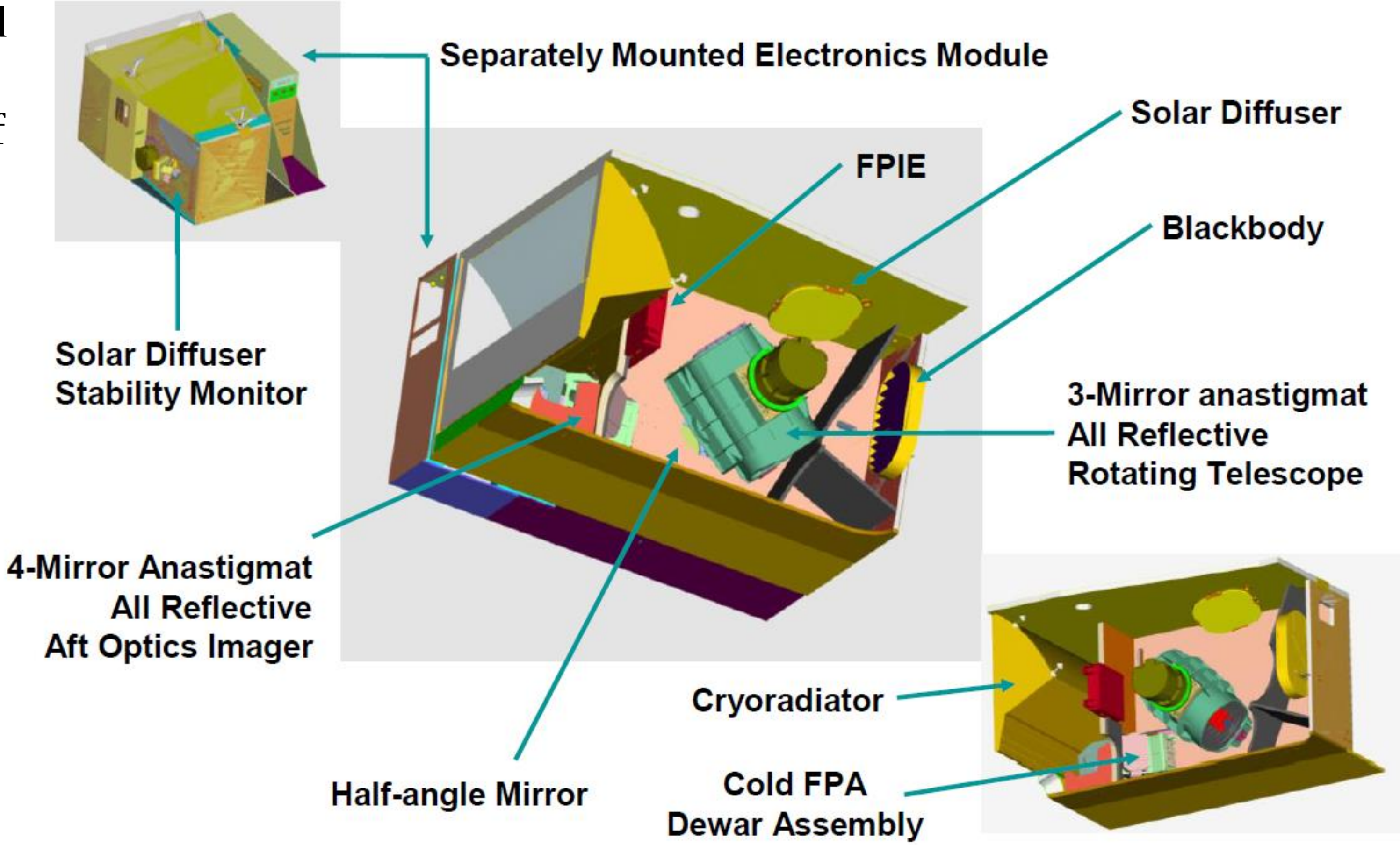
Name	Organization	Major Task
Changyong Cao	NOAA/STAR	NOAA STAR VIIRS Cal/Val Team Lead
Slawomir Blonski	GST, Inc. @ NOAA/STAR	Instrument science; POC for operations; STAR VIIRS Cal/Val Team
Wenhui Wang	UMD/CISESS @ NOAA/STAR	TEB cal/val/CPM; STAR VIIRS Cal/Val Team
Xi (Sean) Shao	UMD/CISESS @ NOAA/STAR	DNB/lunar cal/orbits; STAR VIIRS Cal/Val Team
Taeyoung (Jason) Choi	GST, Inc. @ NOAA/STAR	Solar/lunar cal; STAR VIIRS Cal/Val Team
Feng Zhang	UMD/CISESS @ NOAA/STAR	CRTM Modeling; 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	Post-launch 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;

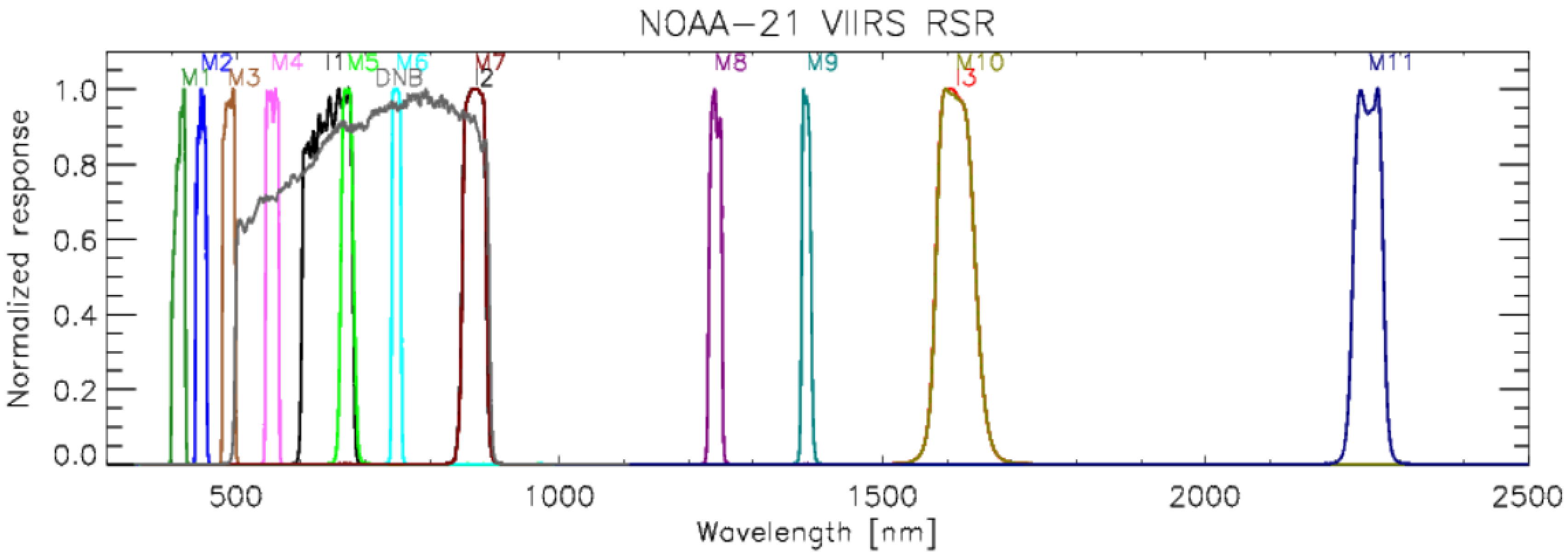
- The operationally produced VIIRS data are widely used globally to monitor hurricanes/typhoons, cloud and aerosol properties, ocean color, sea and land surface temperature, ice motion and temperature, active fires, and Earth's albedo.

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



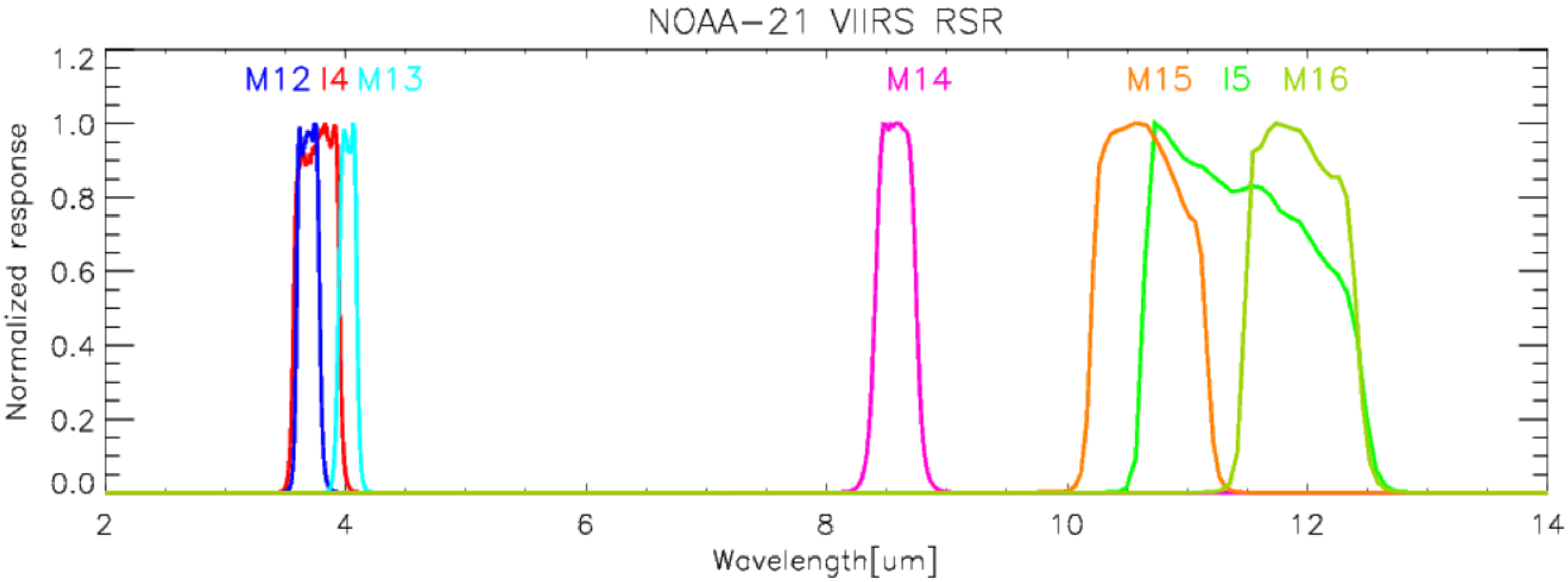
VIIRS Spectral Bands: Reflective Solar Bands (RSB)/ Day/Night Band (DNB)

- 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 bands (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	$3x10^{-9}$ (w/cm^2-sr)) (HG)	6	5%, 10%,30% (LG,MG,HG)

NOAA-21 VIIRS SDR Validated Review Highlights

Since Provisional review on Mar. 30, 2023

Thermal Emissive Bands (TEB)

- RVS LUT update on 6/7/2023 to reduce scene-temperature and scan angle dependent biases
- TEB Nominal performance since 3/19/2023
- Comparisons with CrIS show 0.1 K agreement (M13: ~0.13 K)
- MWIR gains continue degrading; Impacts on NEdTs and SDRs of MWIR are negligible so far.
- No other major issues found

Day/Night Band (DNB)

- Monthly DN0 offset, gain ratio calibration coefficients based on new moon day data and straylight correction are developed and delivered to operations since March 30, 2023.
- DNB gain ratios are stable; Imagery and radiance are consistent with NOAA-20 DNB, and SNRs (>11) are stable.
- DNB trailing scan response tail issue: Impact is small; No user concerns; No mitigation is needed

Reflective Solar Bands (RSB)

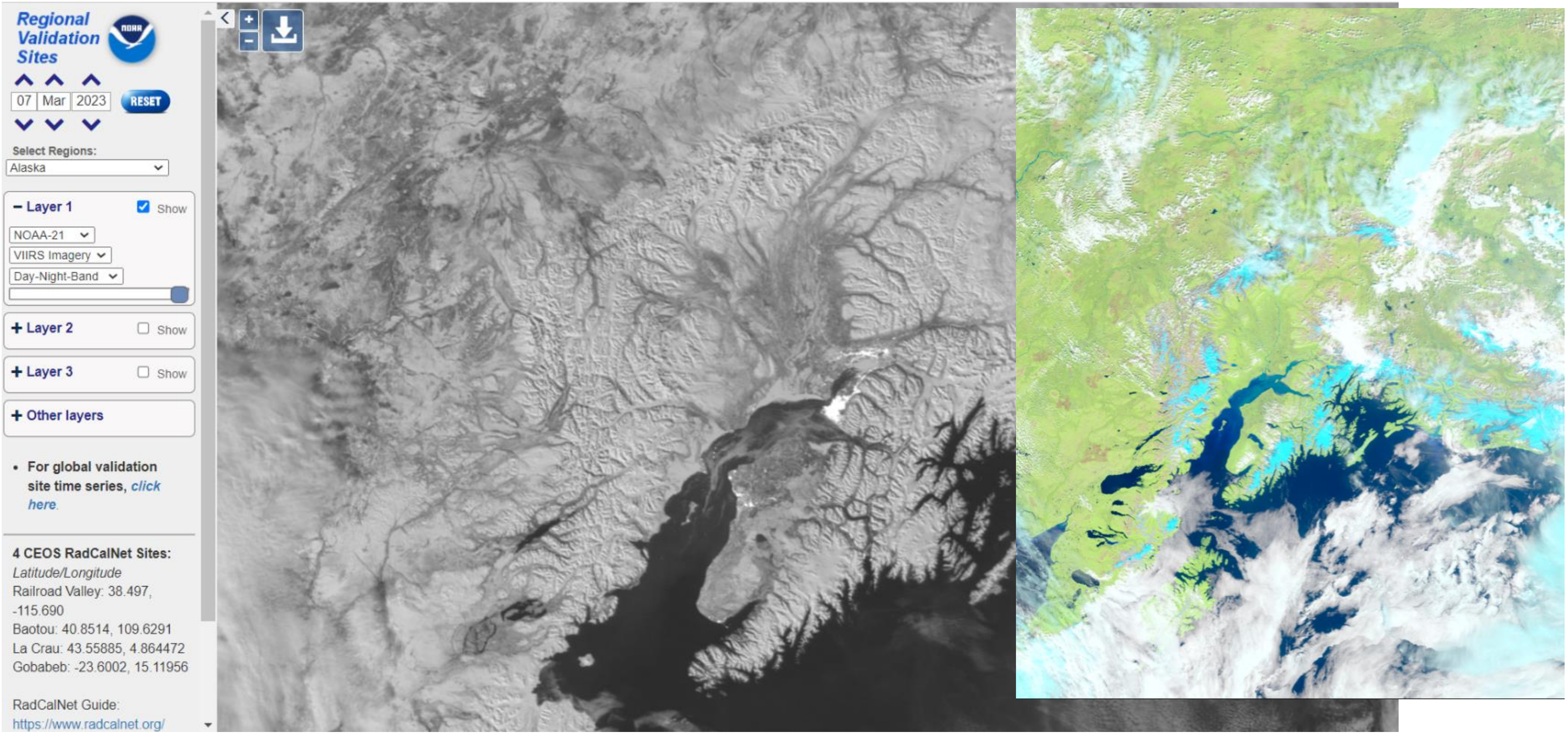
- SWIR band gain degradation continues, requires monthly calibration updates until automated, causes striping in KPP if not corrected
- Radiometric biases relative to NOAA-20 reduced to within 2% for all channels, including SWIR bands
- Lunar calibration conducted on 4/1, 5/1, 5/31, 6/28 (summer break until November)

Geolocation

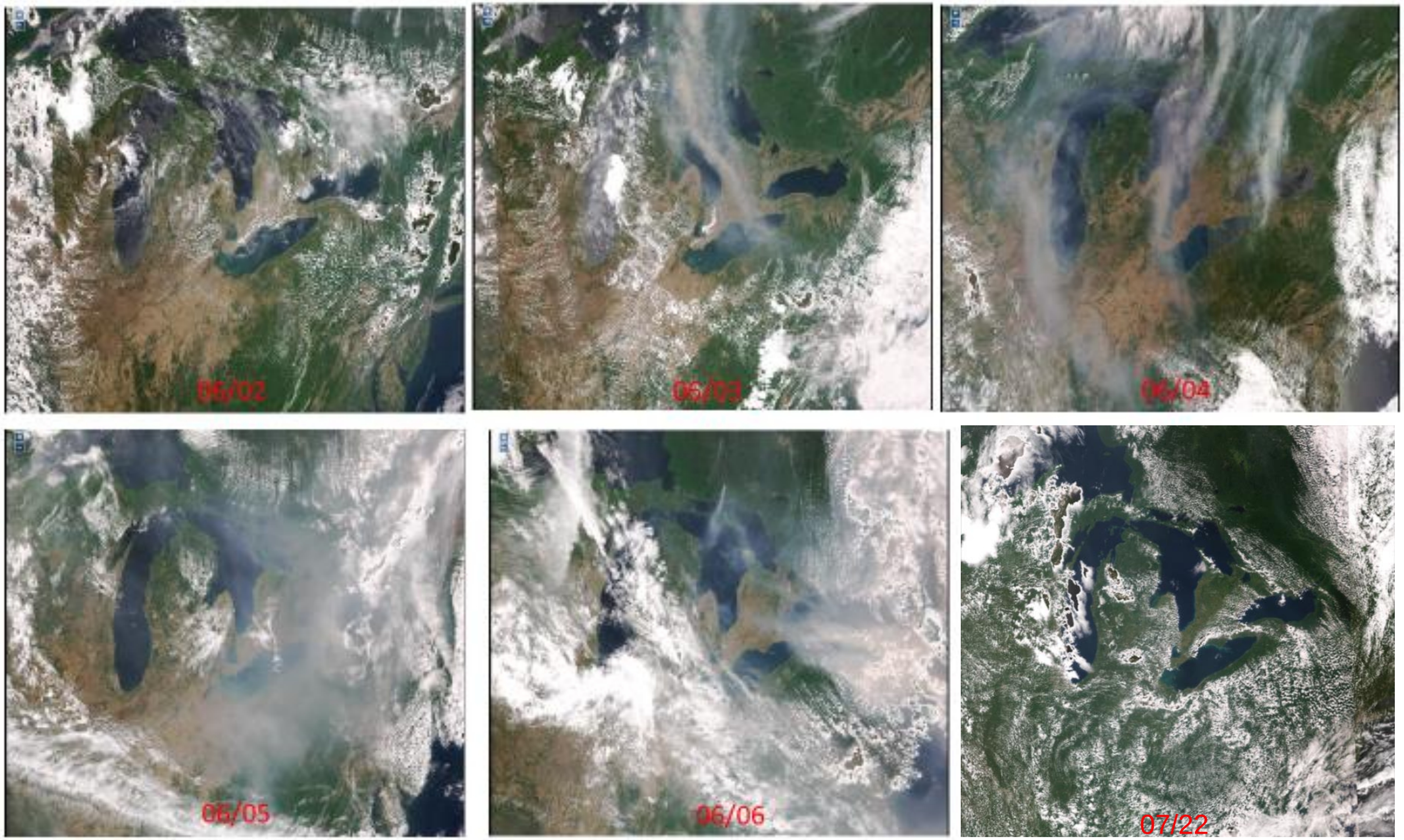
- Uncertainty <400 m at nadir as required, stable since the mounting matrix update on January 12, 2023

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

Alaska from our Regional Validation Sites



Smoke from Canadian Fire monitored by NOAA-21 VIIRS at Regional Validation Sites



Processing Environment and Algorithms

- Description of processing environment and algorithms used to achieve the maturity stage:
  - Algorithm version: IDPS Block 2.3 Release Mx7 (until 7/13/2023) and Mx8 (thereafter)
  - Version of LUTs used: at-launch LUT versions with the following updates effective on the dates shown below
    - F-PREDICTED LUT on 1/12/2023 (VNIR only), 3/23/2023 (adds SWIR), 4/20/2023 (adds SWIR degradation correction), 5/11/2023 (adds SWIR bias corrections for I3, M8, M10, M11), 6/1/2023, 6/23/2023 (adds SWIR bias correction for M9), 7/27/2023
    - GEO-DNB/IMG/MOD-PARAM LUTs on 1/12/2023 (post-lunch mounting matrix)
    - DNB Onboard Offset Tables (ID 5 & 33-35) on 3/17/2023 (using s/c "backflip" pitch maneuver)
    - DNB DN0 and GAIN-RATIOS LUTs on 3/9/2023, 3/30/2023, 4/27/2023, 6/1/2023, 6/29/2023, 7/27/2023, and continuing monthly after each new moon
    - DNB STRAY-LIGHT-CORRECTION LUTs on 3/30/2023, 4/27/2023, 6/1(2)/2023, 6/29/2023, 7/27/2023, and continuing monthly after each new moon during the first year on orbit
    - RVF (RVS) LUT on 6/7/2023 (TEB LWIR only, using s/c "backflip" pitch maneuver)
    - RSBAUTOCAL-HISTORY file on 6/8/2023 (re-initialized RSBautoCal calculations)
    - 5 RSBAUTOCAL LUTs (using s/c yaw maneuvers for VIIRS and also to prepare for SWIR automated calibration) on 7/31/2023

Post-Launch NOAA-21 VIIRS Cal/Val Timeline

	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 + 266 (8/3/2023)	

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..

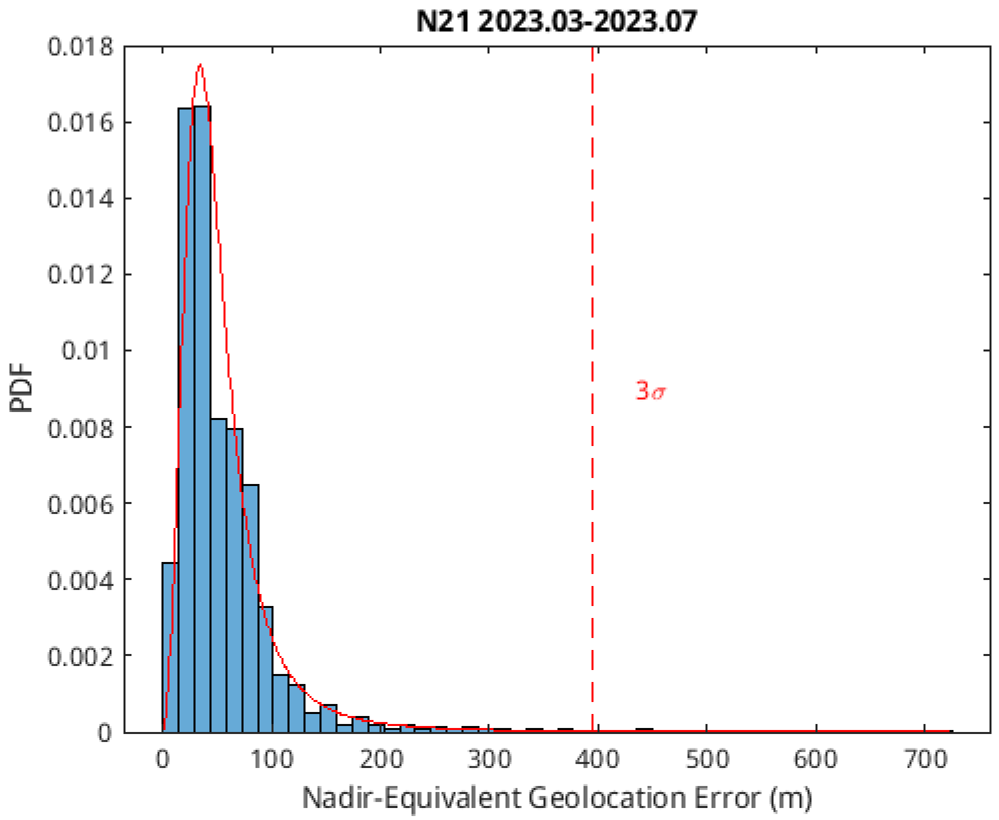
Long-term monitoring required PLTs are highlighted in yellow.

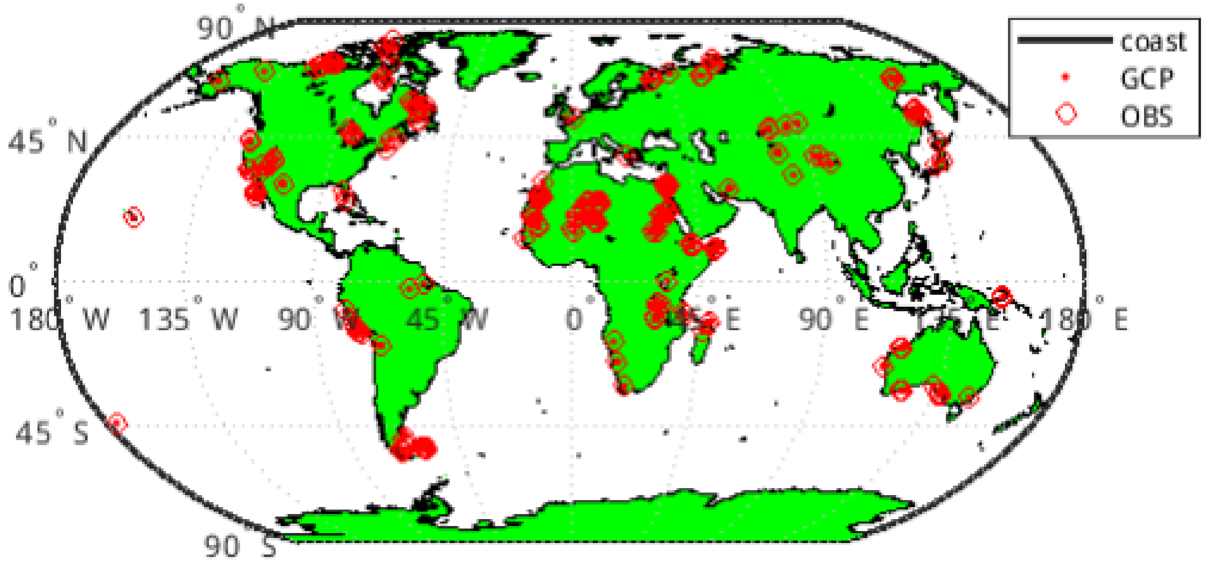
Task ID	Title
	Tasks Started after Instrument Activation
GEO-1	Initial Validation of Spacecraft Ephemeris and Attitude Data
GEO-2	Initial Validation of VIIRS Encoder Data, Scan Time, Scan Period, and Scan Rate Stability
FPF-2	Detector Operability and Noise Verification with Nadir Door Closed: RSB VNIR, 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



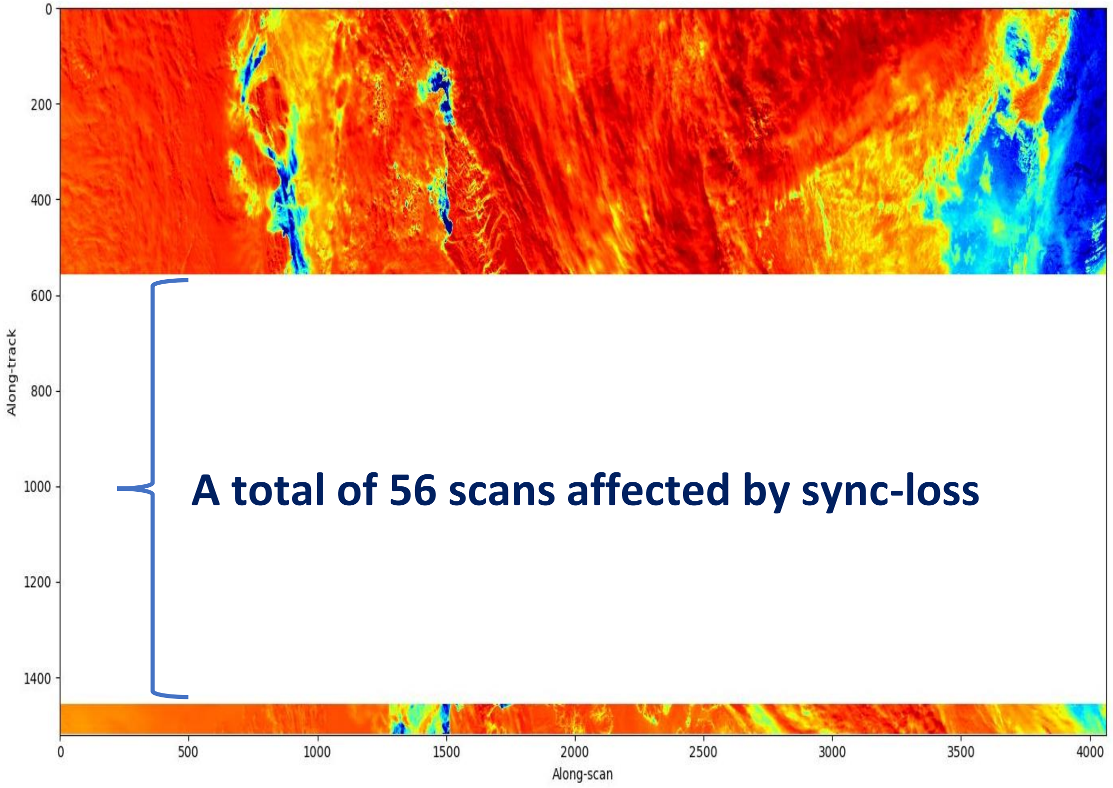


- NOAA-21 VIIRS SDR geolocation uncertainty: 395 m (< 400 m required at the 3-sigma, 99.7%, level) after the post-launch mounting matrix update on Jan. 12, 2023

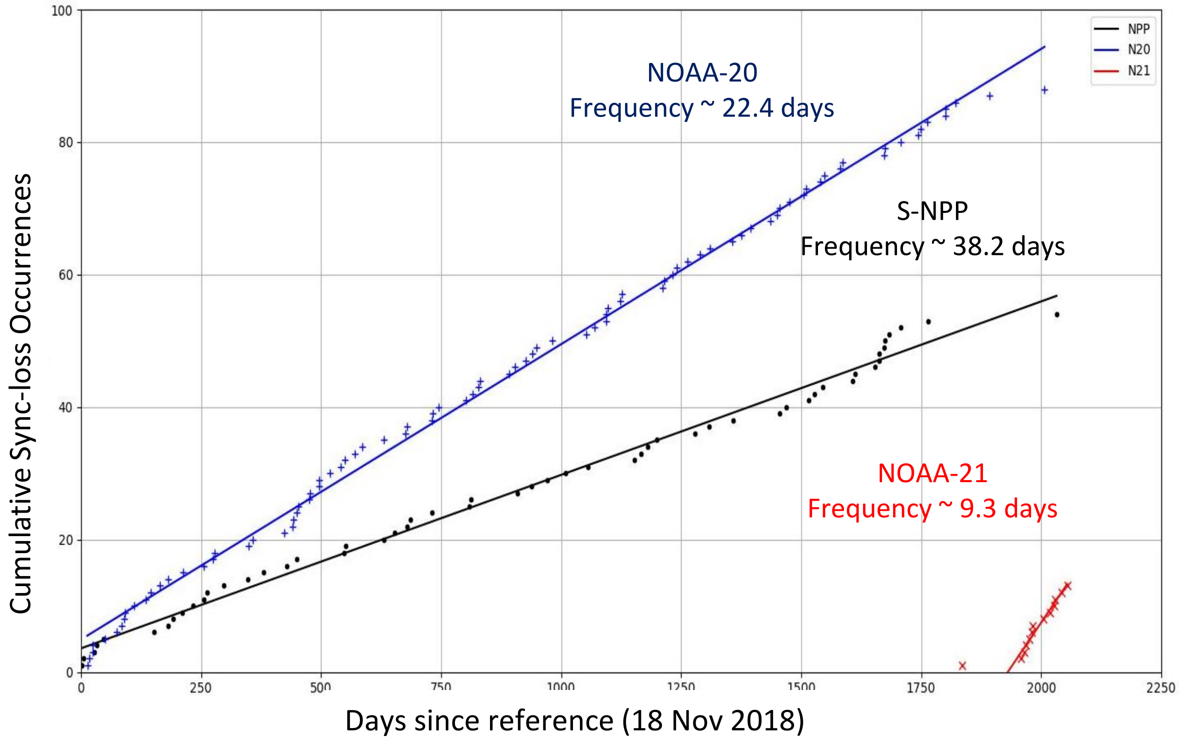
- Based on 2369 GCP (ground control point, i.e., Landsat "chip") matchups (with 0.96 xcal threshold)
- Potential further mounting matrix RPY corrections: only -0.3, 1.4, 0.0 arcsec (<< pixel size)
- Potential DNB detector shift parameter change for alignment with the I- and M-bands at nadir: only from -0.00126 to -0.00132 (i.e., ~5%)

NOAA-21 VIIRS Sync-Loss

- A known issue: occasional loss of synchronization (sync-loss) between rotating Telescope & HAM:
  - A total of 13 events as of 7/30/2023 (~2 min/event) so far
  - Affected scans are flagged in SDR products; erroneous data replaced with fill-values
  - Frequency of occurrence tends to slow down with aging of the instrument



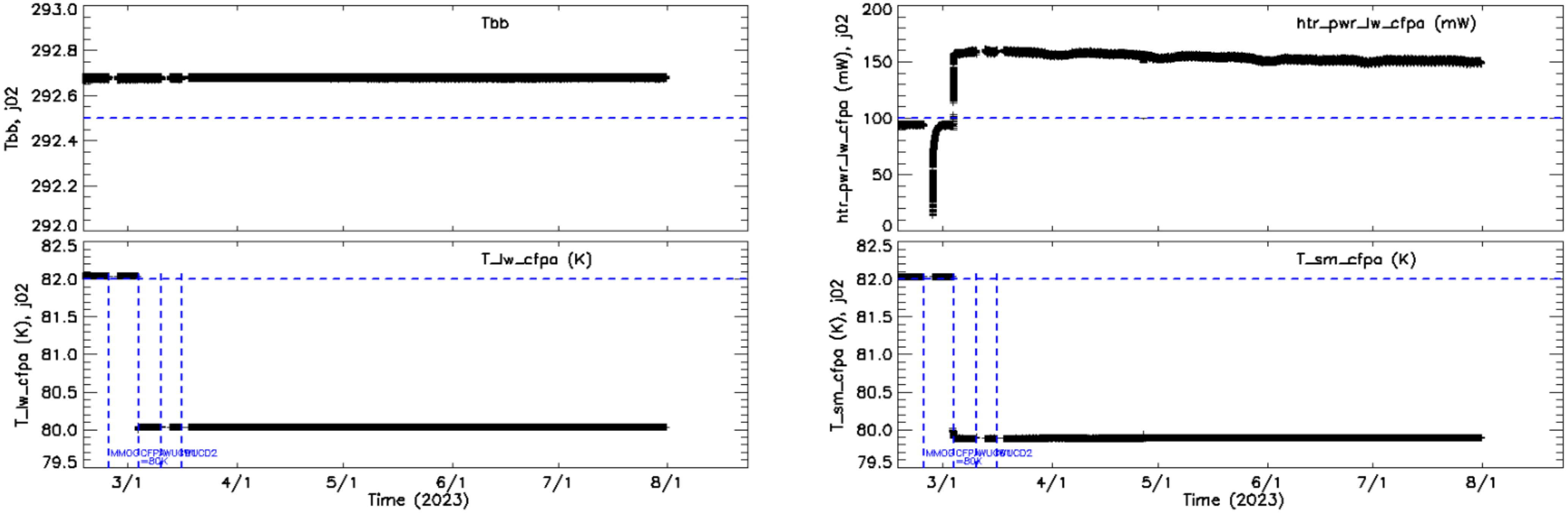
An example of a sync-loss event affecting DNB data over N. Pole from 7 June 2023



Comparison of cumulative sync-loss occurrence for VIIRS sensors onboard three JPSS satellites: NOAA-21, NOAA-20, and S-NPP

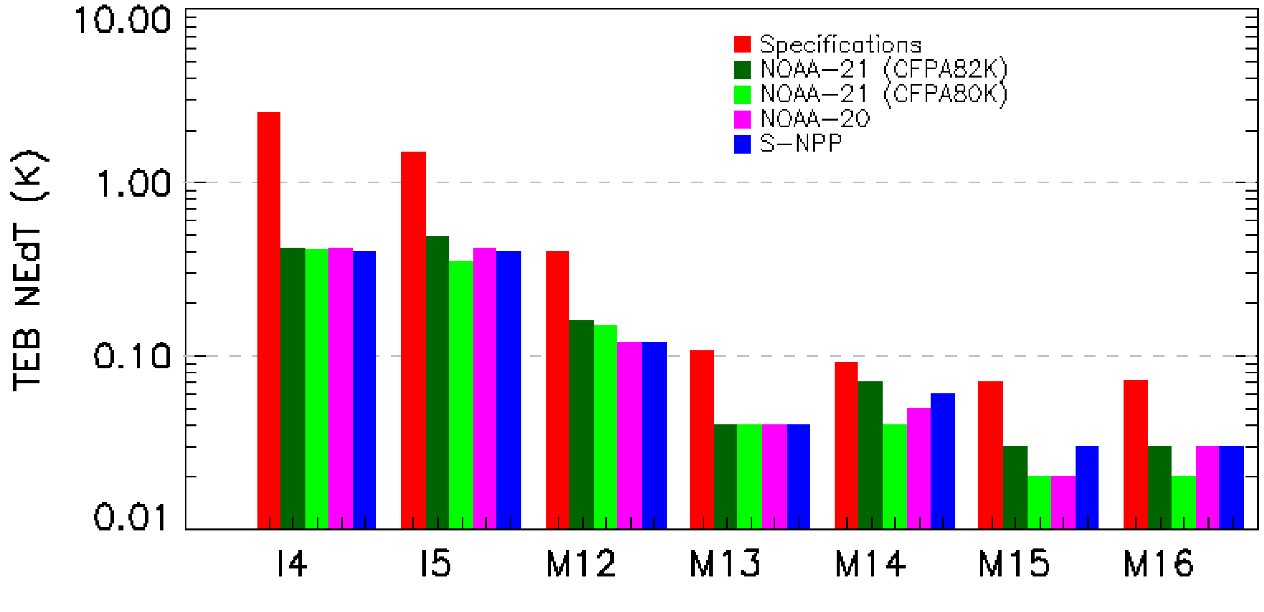
Major TEB Calibration Events and Instrument Temperature Telemetry

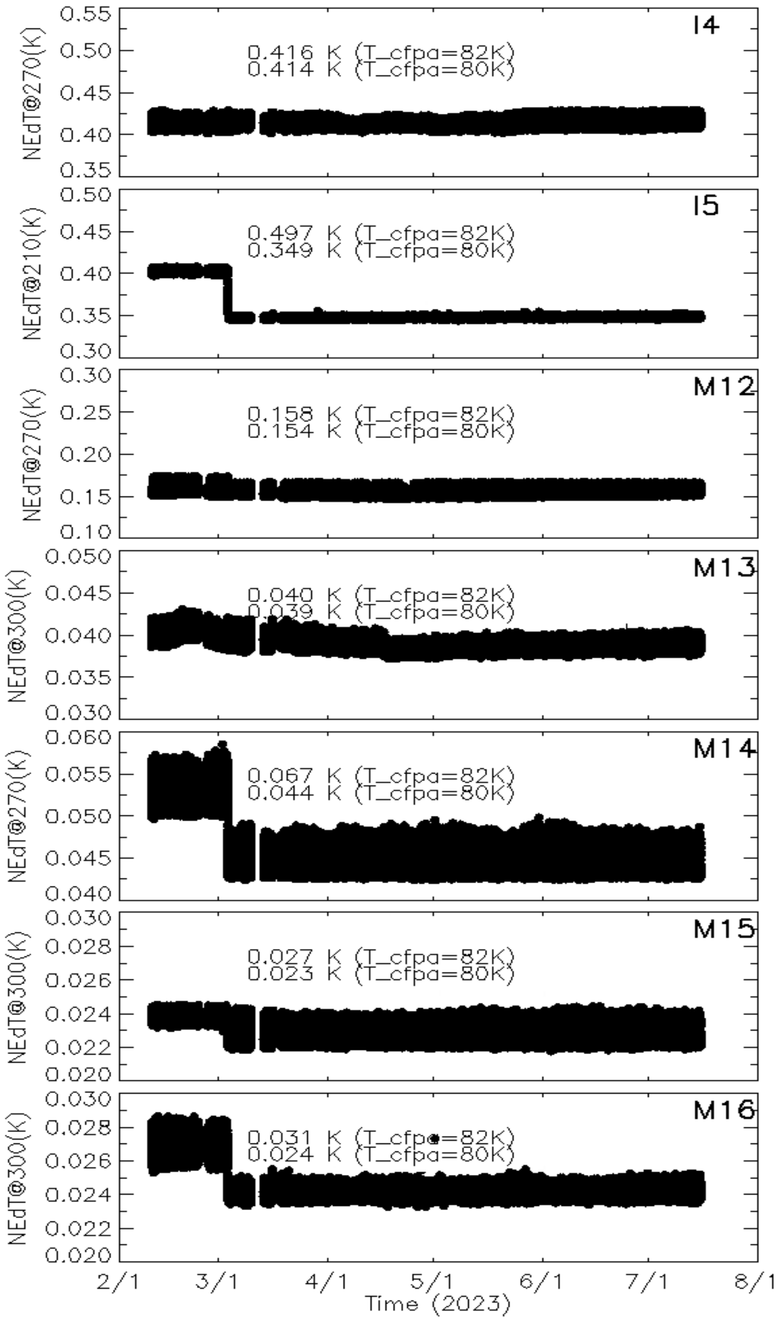
- ➢ Major TEB calibration updates since the provisional maturity review
  - ○ Delta-C LUT for 80 K CFPA temperatures was implemented on March 23, 2023. (CFPA setpoint temperatures was switched to 80 K on Mar. 3)
  - ○ LWIR calibration was improved using pitch maneuver data derived calibration parameters, implemented on June 7, 2023 in the operations.
- ➢ NOAA-21 VIIRS blackbody and other instrument temperatures have been generally stable during nominal operations.



TEB Noise/NEdT

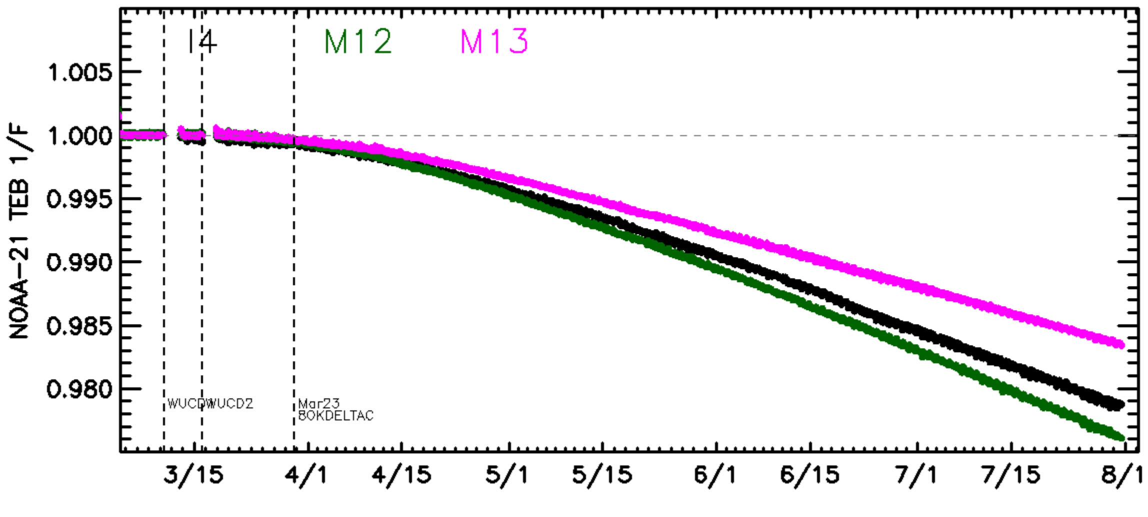
- NOAA-21 VIIRS TEB NEdTs have been comparable to NOAA-20/S-NPP.
  - All well within specifications.
  - LWIR NEdTs were further reduced after the CFPA temperatures switched to 80K.
  - Stable over time.

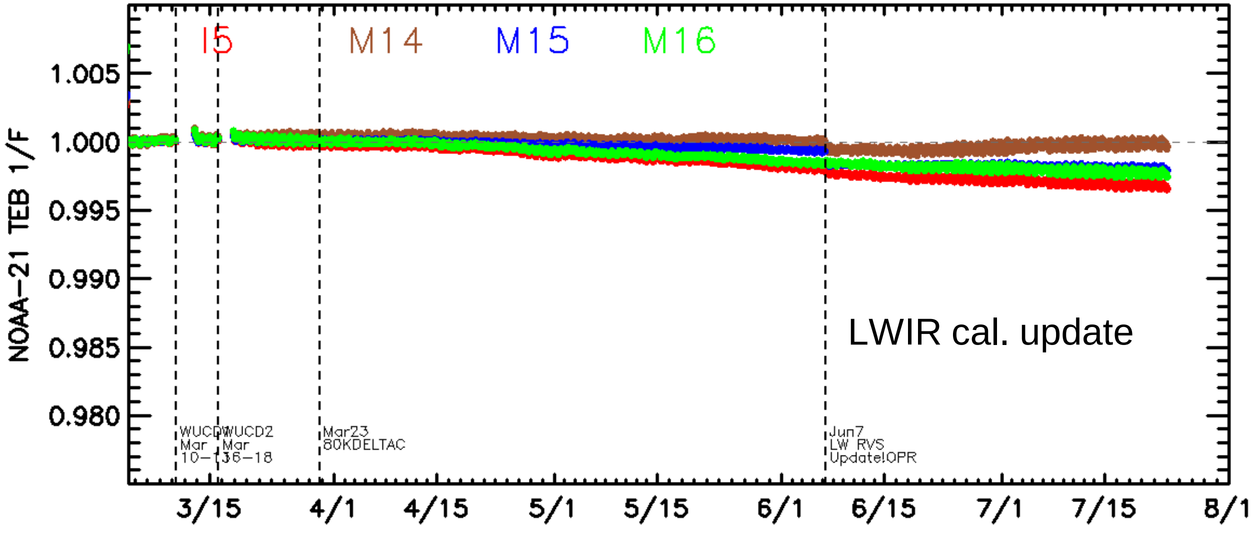




NOAA-21 VIIRS TEB Gains

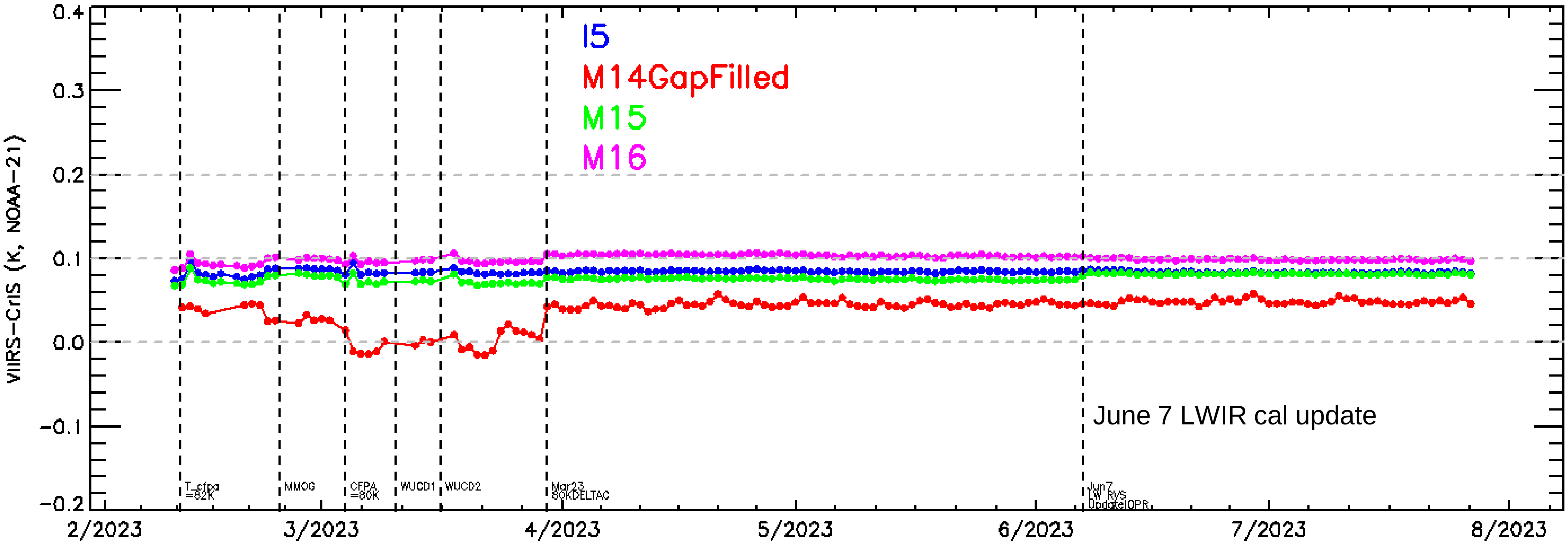
- ➢ NOAA-21 LWIR gains have been generally stable since CFPA switched to 80 K.
  - ○ Degradations are small (<0.4%), comparable to NOAA-20 and S-NPP.
- ➢ NOAA-21 MWIR gains have been continuously degrading since mid-Match.
  - ○ Band averaged degradation: up to ~2.5%
    detector dependent, >4% for some I4/M12 detectors
  - ○ Coincident with the degradations observed in SWIR bands.
  - ○ The impacts on NEdTs and SDRs are negligible so far.





NOAA-21 VIIRS-CrIS Daily Averaged BT Biases (LWIR)

- I5 and M14-M16 agree well with co-located CrIS data during nominal operations.
  - Biases are within ~0.1 K.
  - Comparable to NOAA-20 and S-NPP.
- M14 was evaluated using CrIS gap-filled spectra.
  - Using gap-filling coefficients provided by the GSICS IR subgroup.

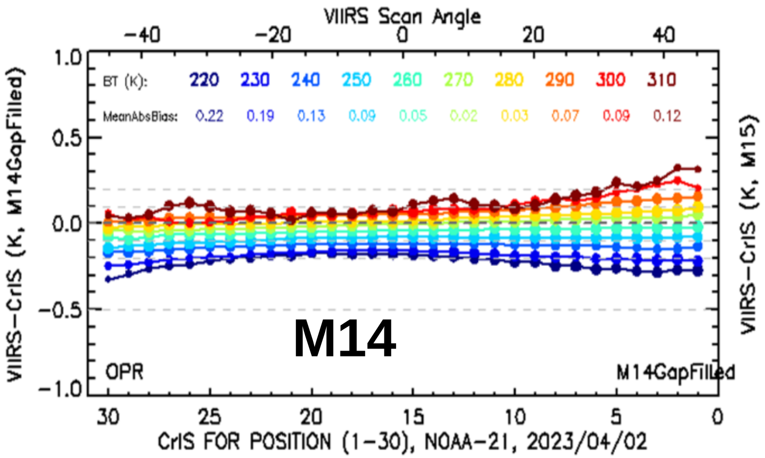


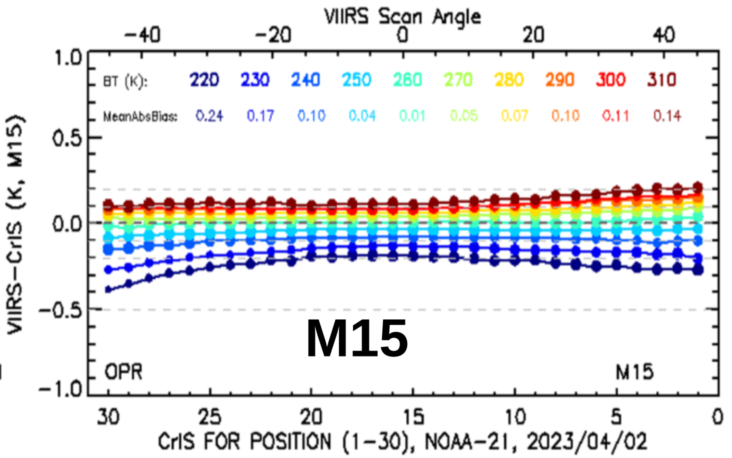
Operational Correction of LWIR Scan Angle and Scene Temperature Dependent Biases

- Persistent larger than expected scan angle/scene temperature dependent biases were observed with pre-launch calibration LUTs.
  - During nominal operations
  - M15: up to ~0.5 K @ 220 K
  - Confirmed by the CrIS team and VIIRS pitch maneuver data analyses.
- Updated LWIR calibration coefficients have been developed and implemented.
  - Using VIIRS pitch maneuver data
  - **Implemented operationally since June 7, 2023.**

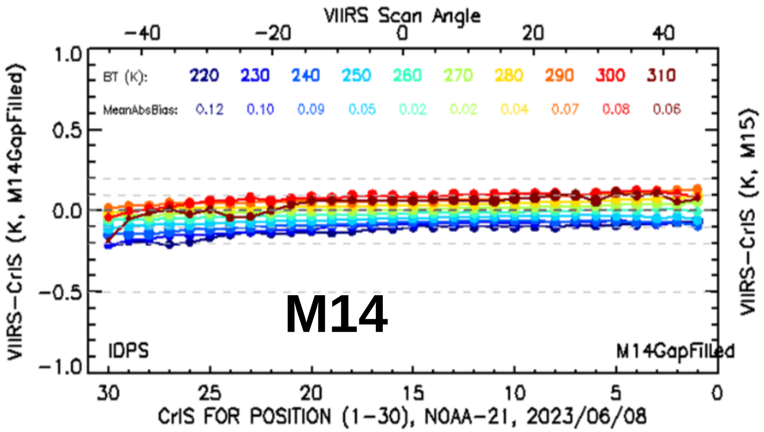
Biases reduced to within ~±0.15K.

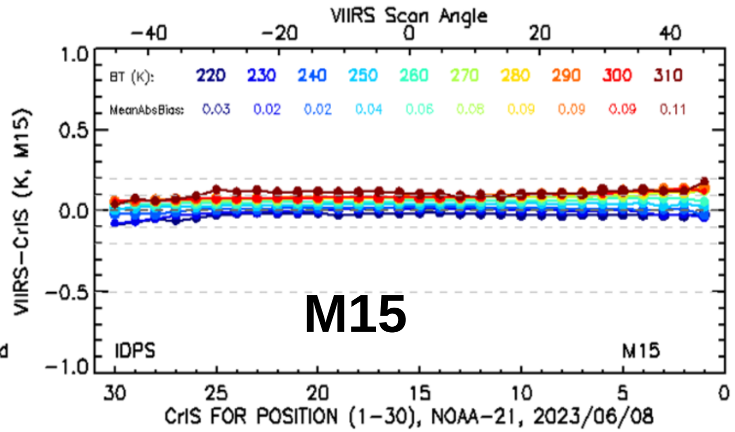
Before (April 2, 2023)





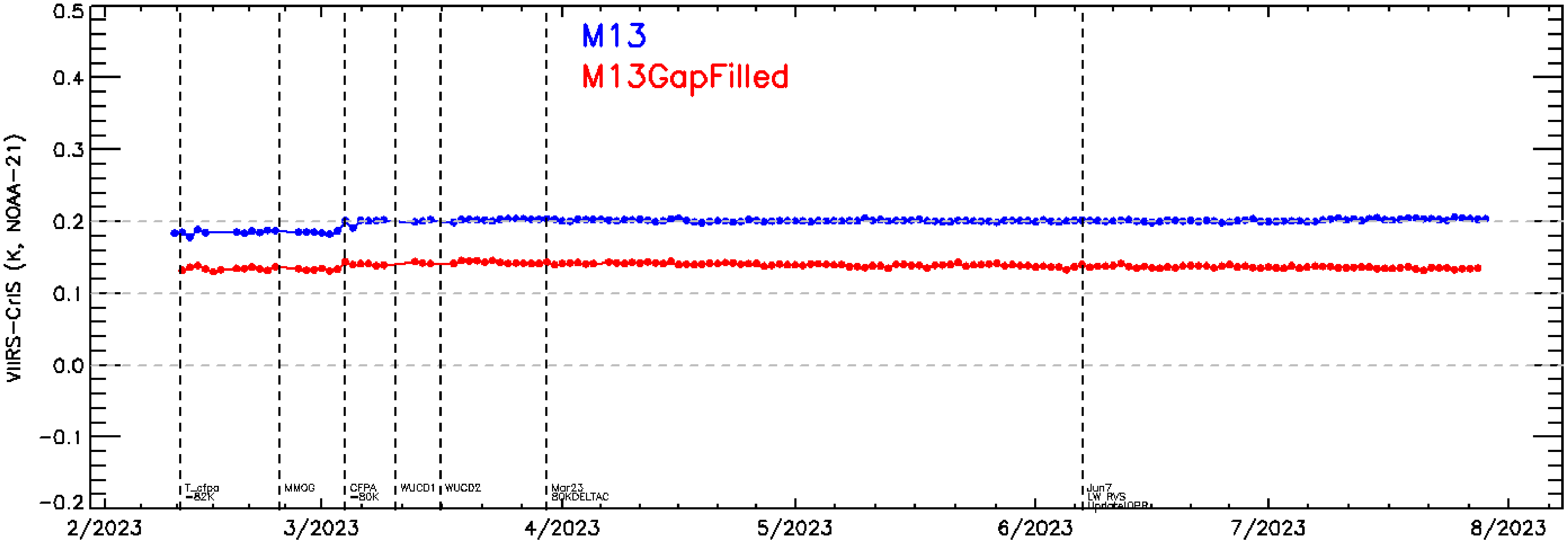
After (June 8, 2023)





NOAA-21 VIIRS-CrIS Daily Averaged BT Biases (MWIR)

- ➢ M13 on-orbit calibration is also stable, relative to co-located CrIS data.
  - ○ Bias: ~0.13 K (based on VIIRS - CrIS gap-filled spectra, nighttime)
  - ○ Meet the requirements.
  - ○ CrIS gap-filled spectra improve RSR coverage: 96.7% (observed) → 99.8%
- ➢ The calibration of I4 and M12 are also stable.

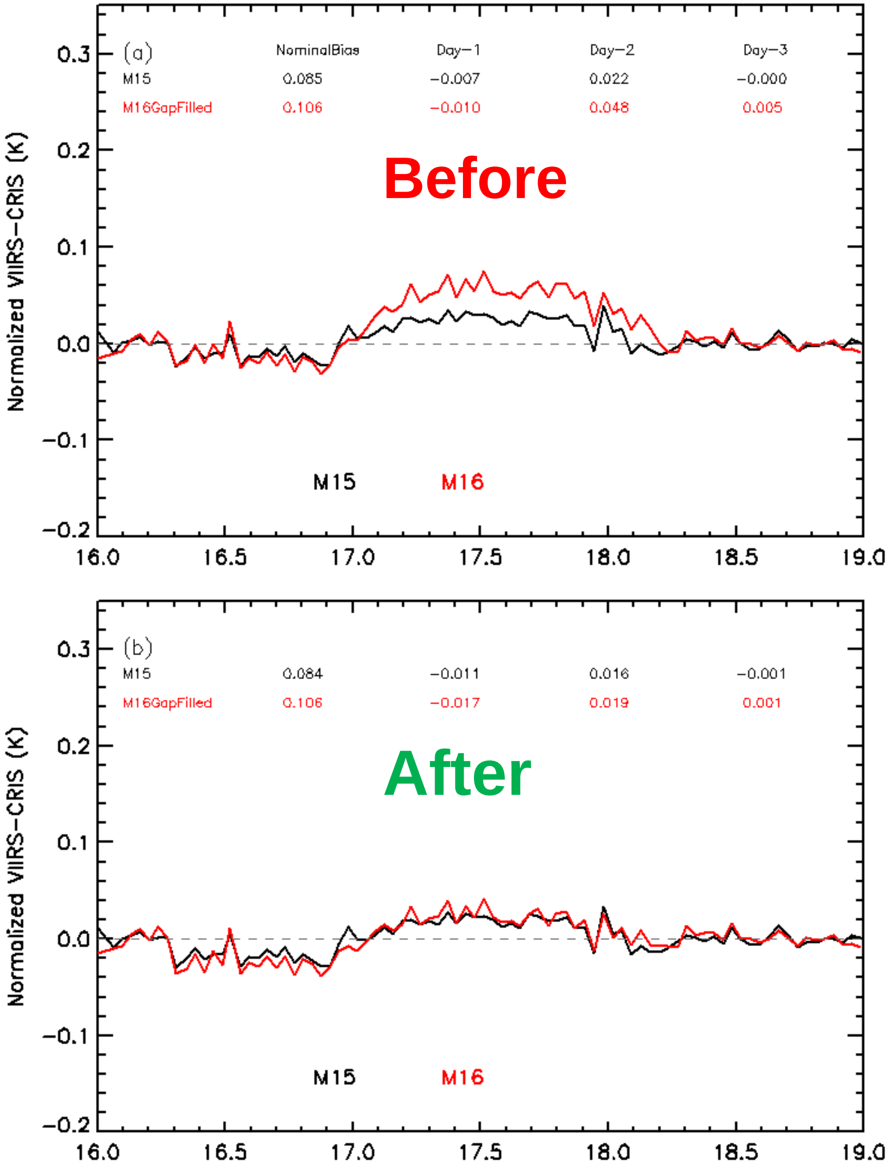


NOAA-21 TEB Calibration Biases during WUCDs

- TEB calibration biases during WUCD were observed.
  - M15-M16: daily averaged biases up to 0.05 K.
  - Similar to NOAA-20/S-NPP.

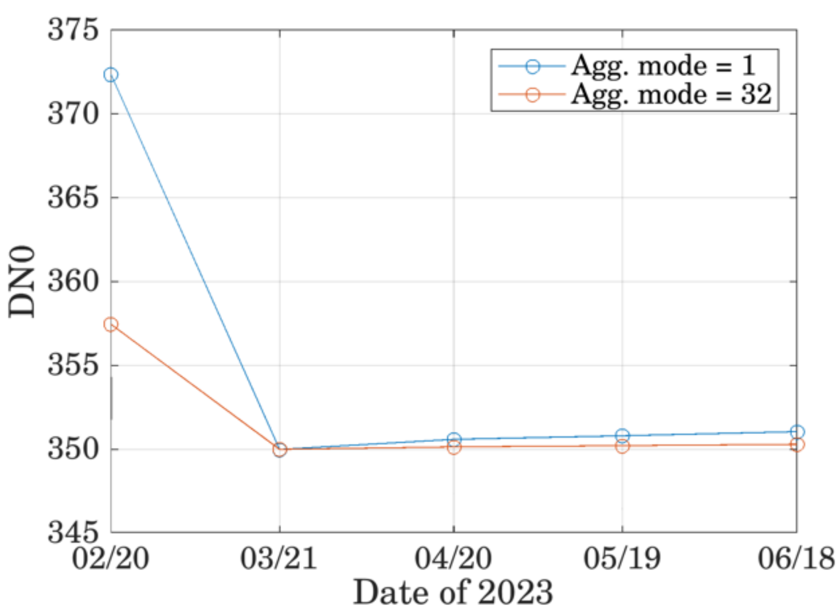
- WUCD bias correction coefficients have been developed.
  - Preliminary results indicate that residual biases are on the order of 0.01 K, similar to NOAA-20 and S-NPP.
  - Will be delivered for operations after further evaluations.

- Next WUCD may occur after the end of the hurricane season.

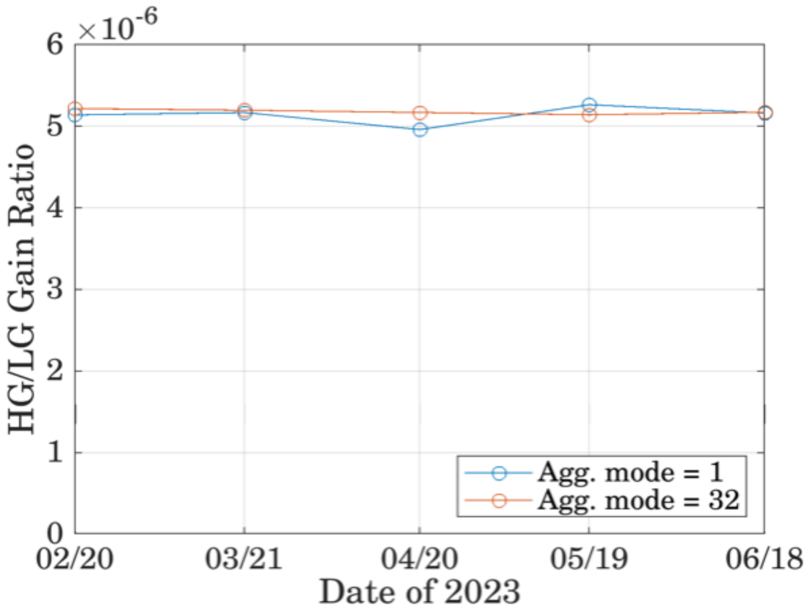


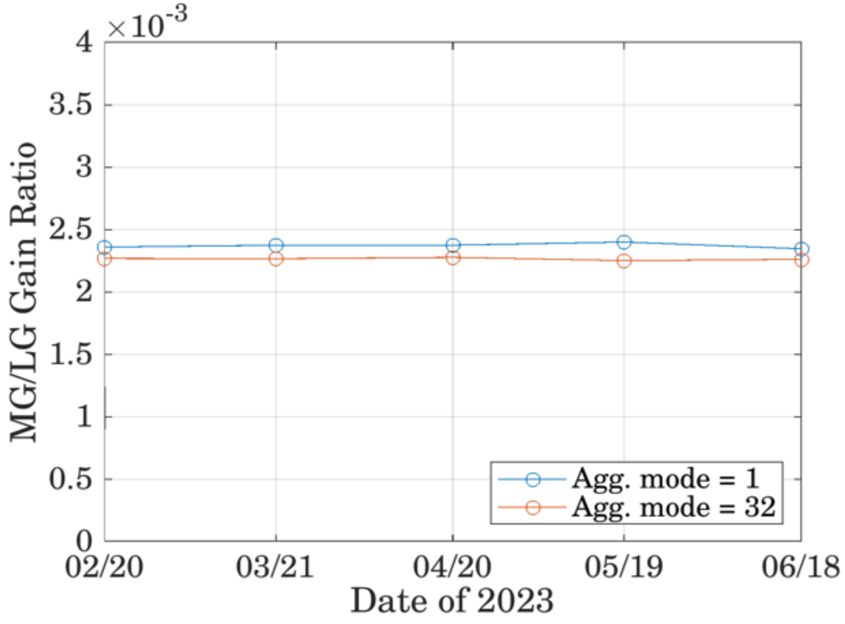
NOAA-21 DNB Calibration Updates

Monthly DN0 LUT Update



Monthly DNB Gain Ratio LUT Update

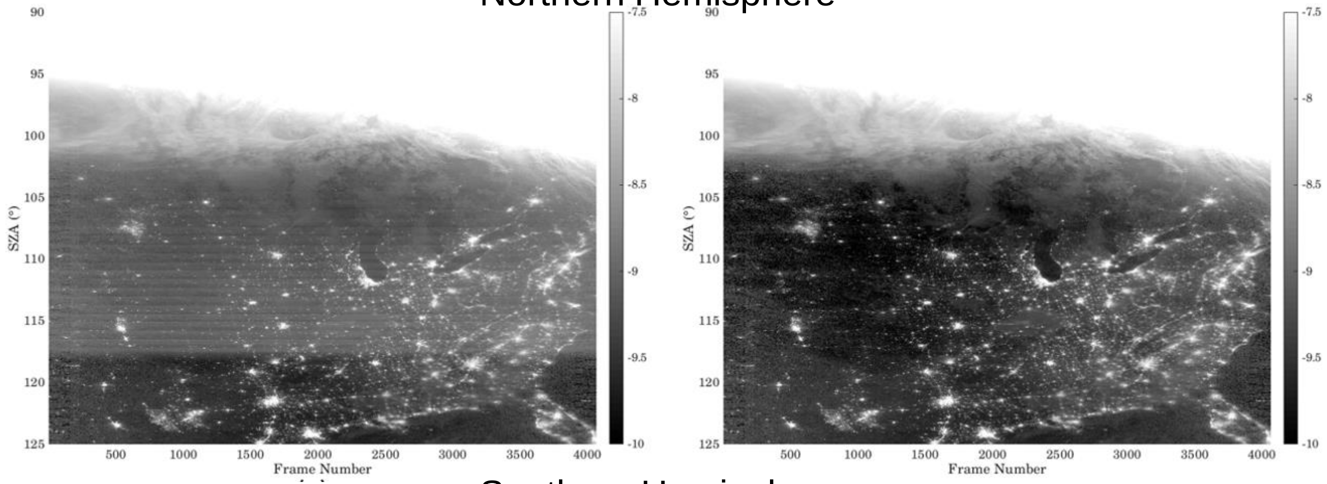




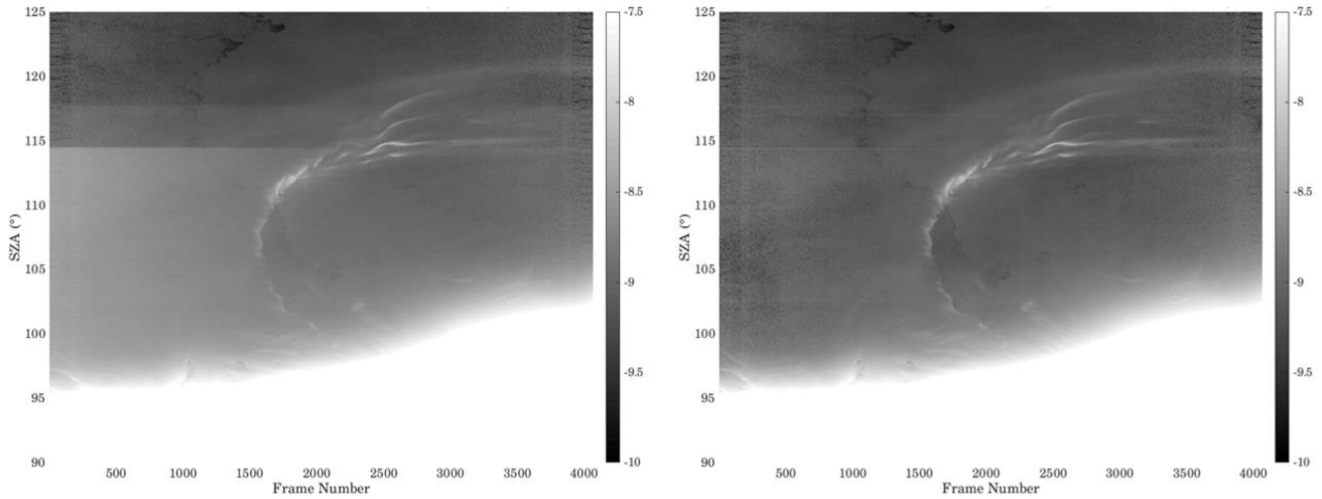
- Pitch maneuver for deriving DNB onboard offset on March 10, 2023; Onboard offset updated on March 17, 2023.
  - Since March 21, 2023, monthly DN0 updates show a small gradual increase of DN0 for near nadir pixels
- The HG/LG and MG/LG gain ratios from the monthly gain ratio updates are stable.

NOAA-21 DNB Stray Light Correction

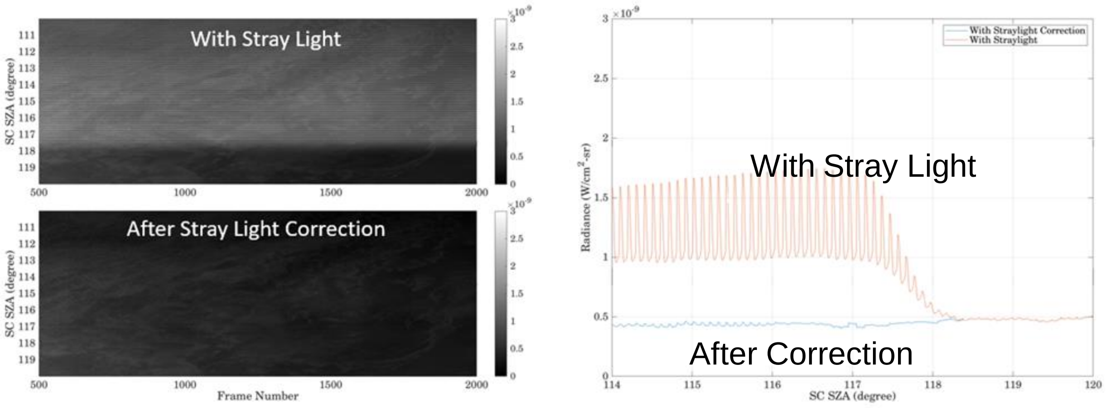
Northern Hemisphere



Southern Hemisphere

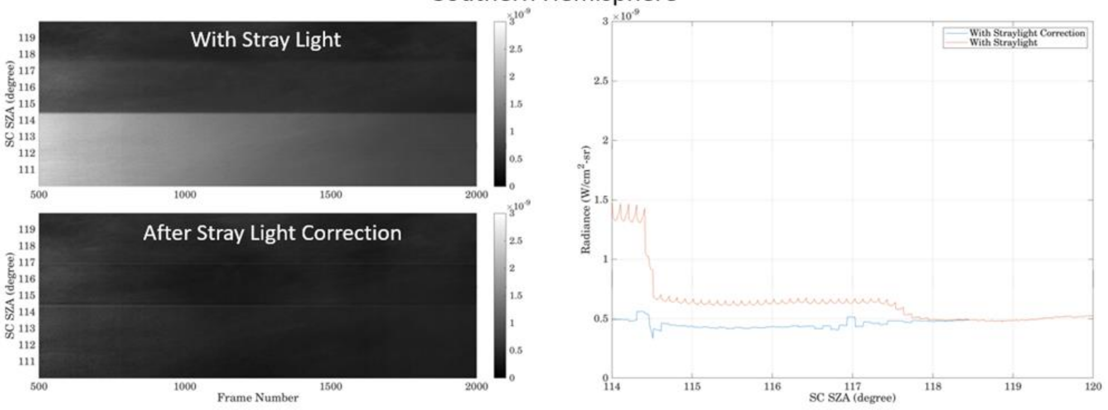


Northern Hemisphere



(a) (b)

Southern Hemisphere

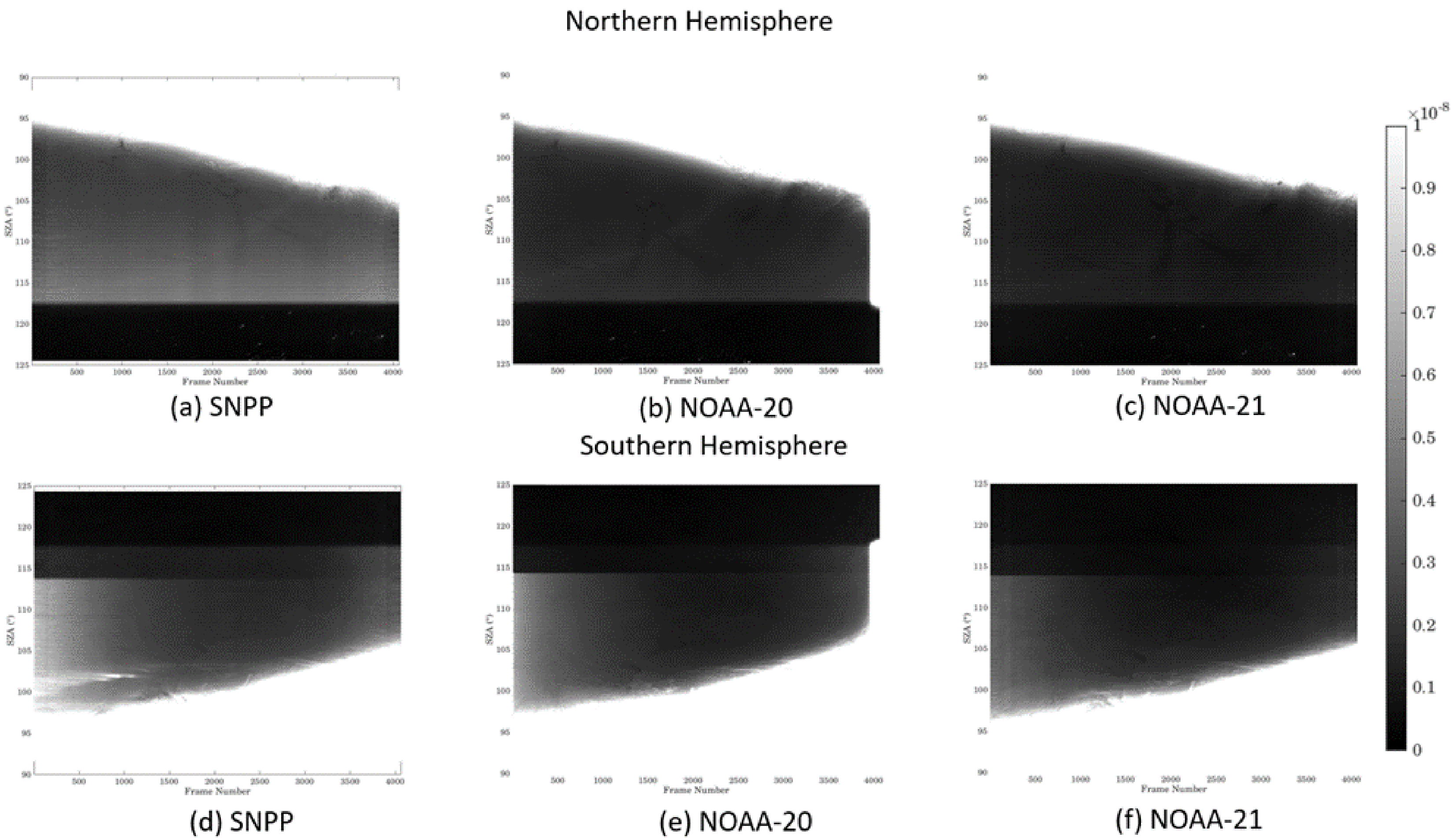


(c) (d)

DNB observation on July 17, 2023

- NOAA-21 DNB stray light stray light correction started on March 30, 2023 (derived with March 21 new moon day data) .
- Monthly DNB stray light correction LUTs are routinely developed (over 12 months) and delivered for operational stray light correction; DNB stray light are effectively removed over both northern and southern hemisphere.

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

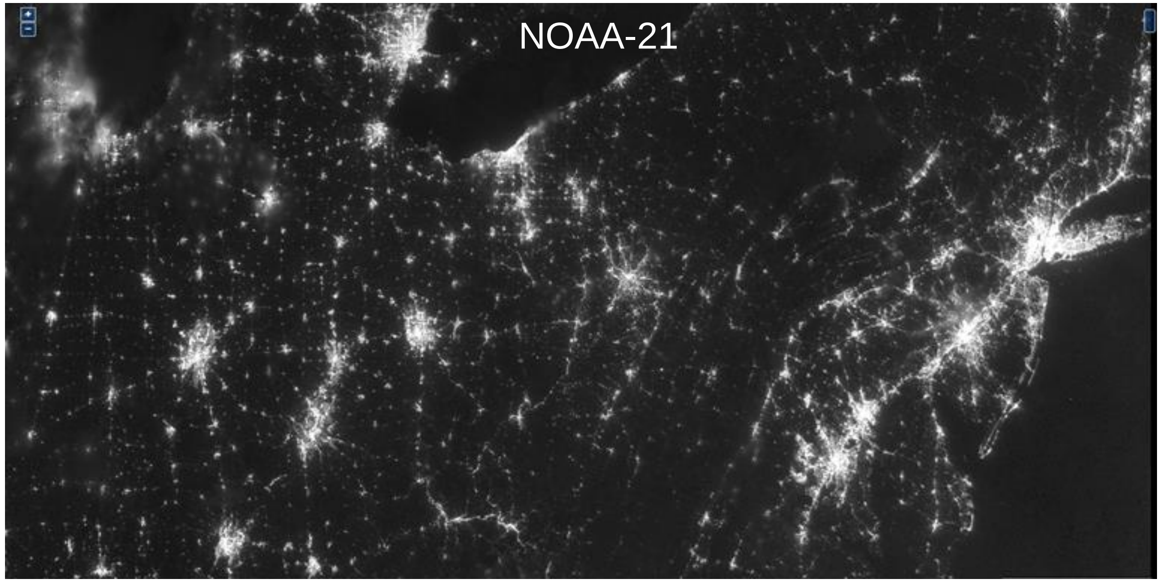


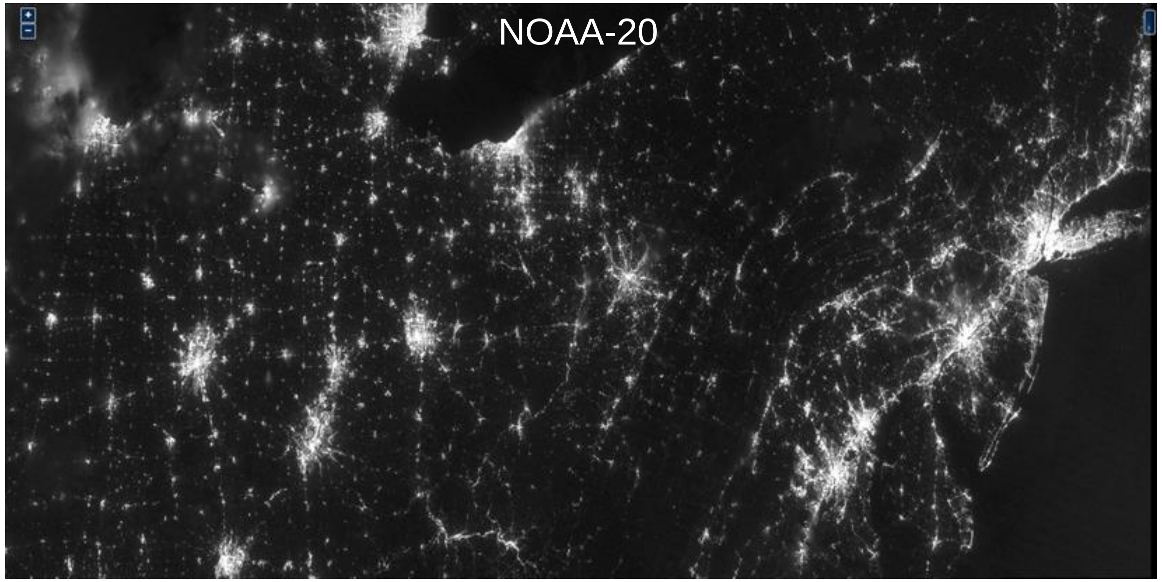
- NOAA-21 DNB stray light is significantly lower than both SNPP and NOAA-20 DNB

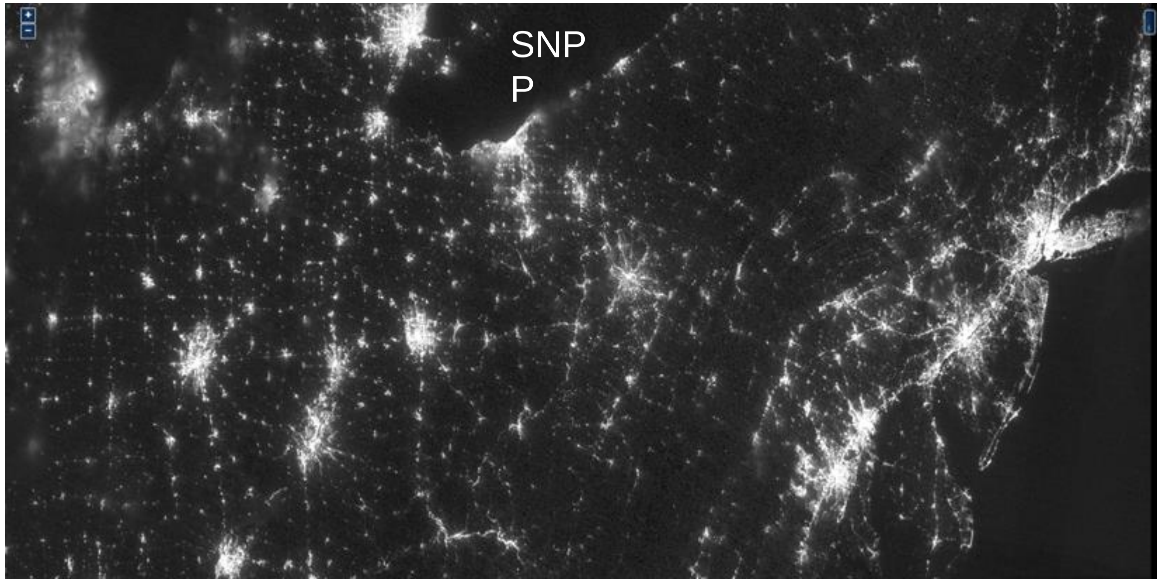
Estimated Stray Light Reduction Magnitude

	Northern Hemisphere	Southern Hemisphere
NOAA-21 vs. SNPP	80.3±2.6%	67.4±7.3%
NOAA-21 vs. NOAA-20	49.1±6.8%	45.3±9.5%

Consistent SNPP, NOAA-20 and NOAA-21 DNB Images



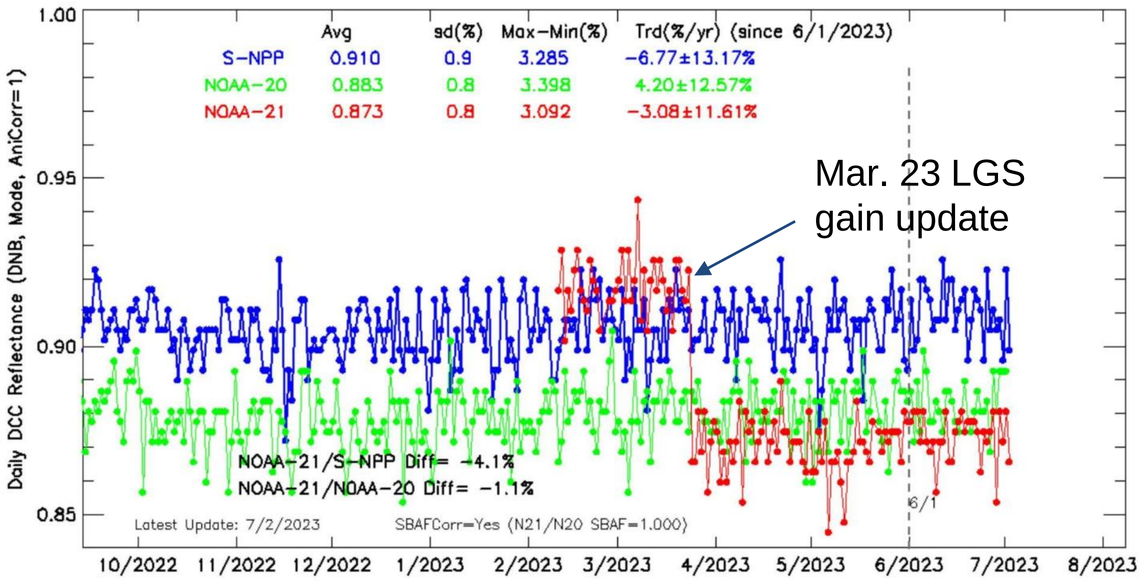




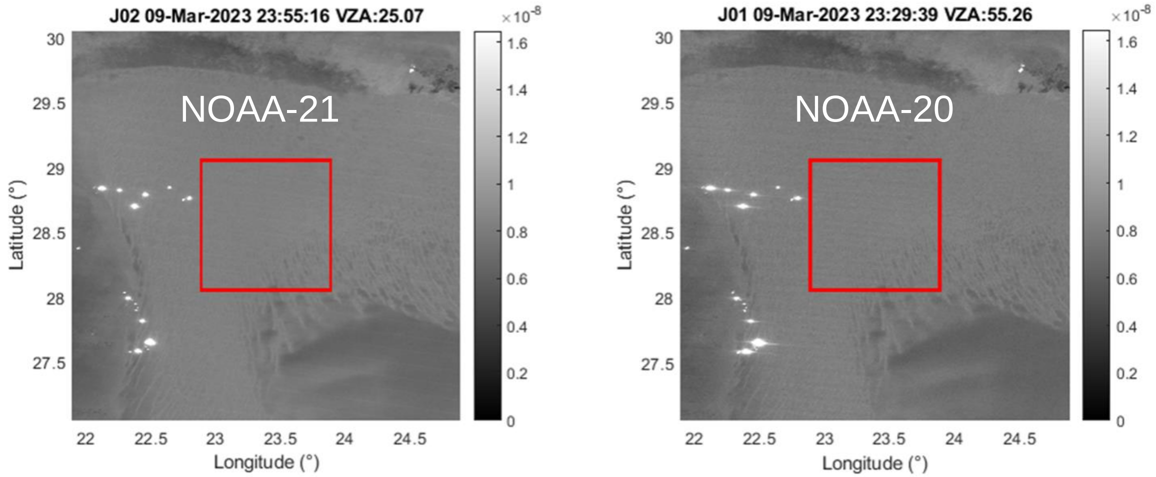
July 23, 2023

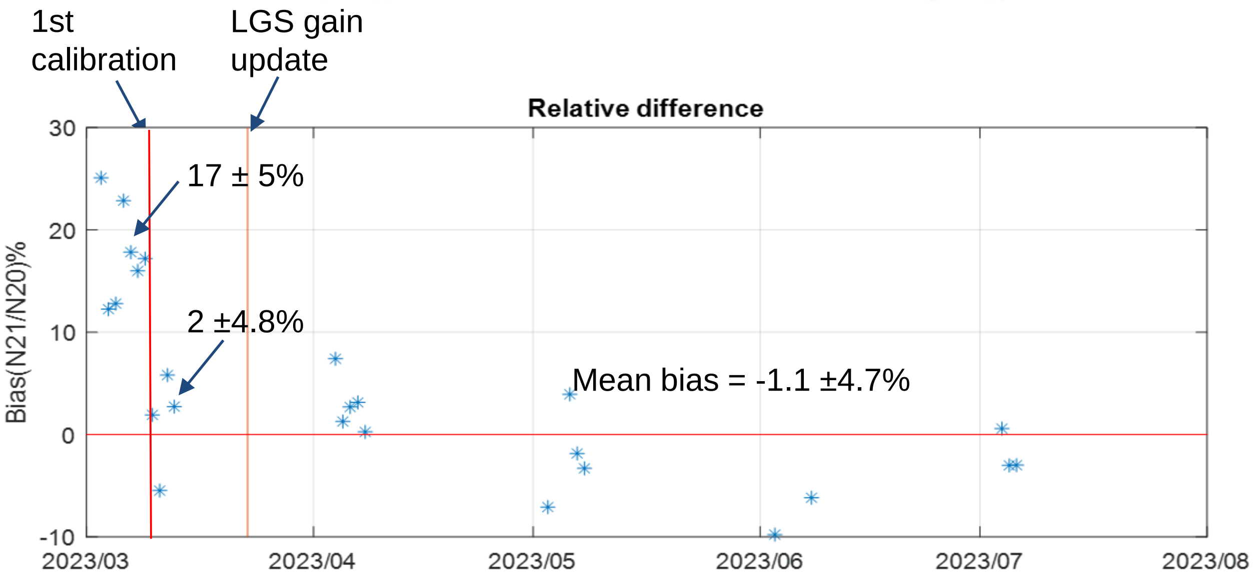
NOAA-21 and NOAA-20 DNB Radiometric Performance Comparison

N21/N20/SNPP DNB Daytime DCC Reflectance Time Series



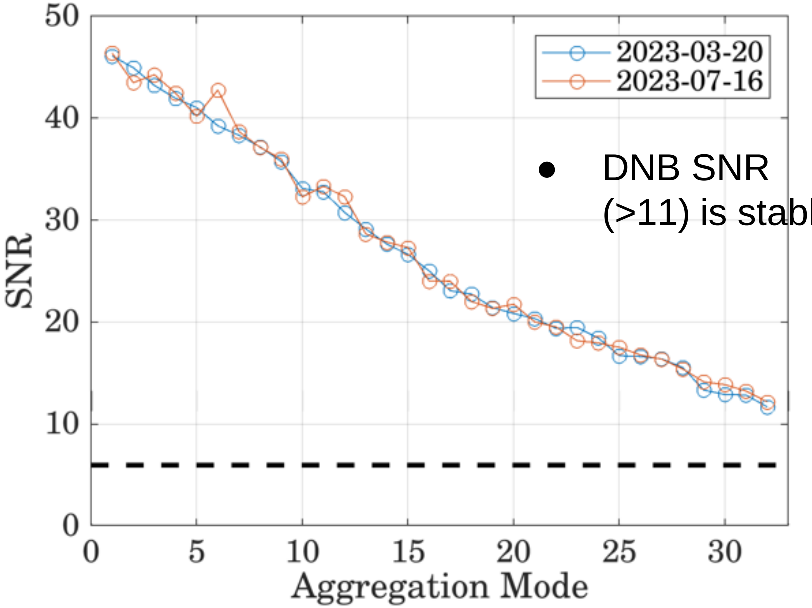
DNB Radiometric Bias Assessment
(over Libya-4 Desert under Moon Light)



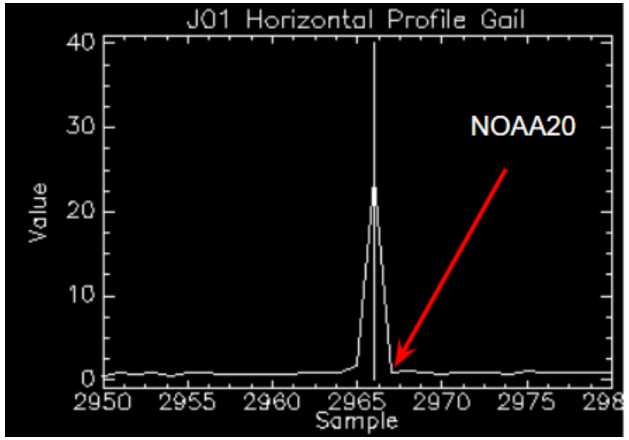


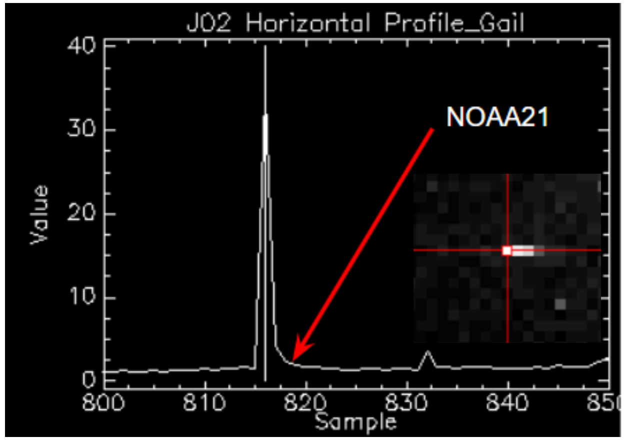
- NOAA-20 leads NOAA-21 by ~25-min
- NOAA-21 DNB agrees with NOAA-20 within ~-1.2% from daytime DCC comparison
- NOAA-21 DNB agrees with NOAA-20 DNB ~-1.1 ±4.7% from night time Libya-4 desert under moon light
  - Account for lunar phase difference with lunar irradiance model, lunar zenith angle and SRF difference
- Continue long term monitoring N21 DNB radiometric performance

NOAA-21 DNB SNR, negative pixels, Line Spread Function (tail effect)



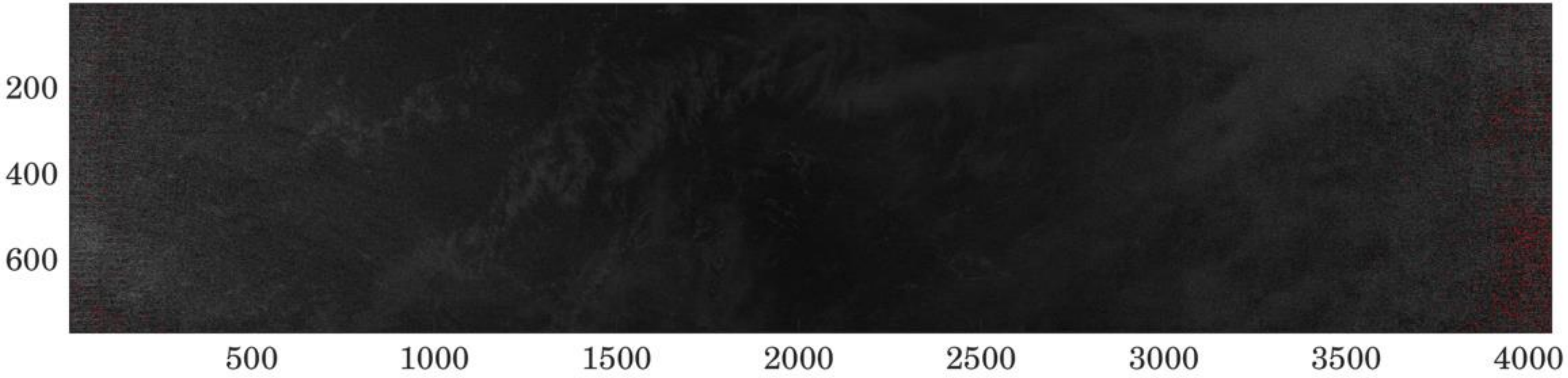
- DNB SNR (>11) is stable





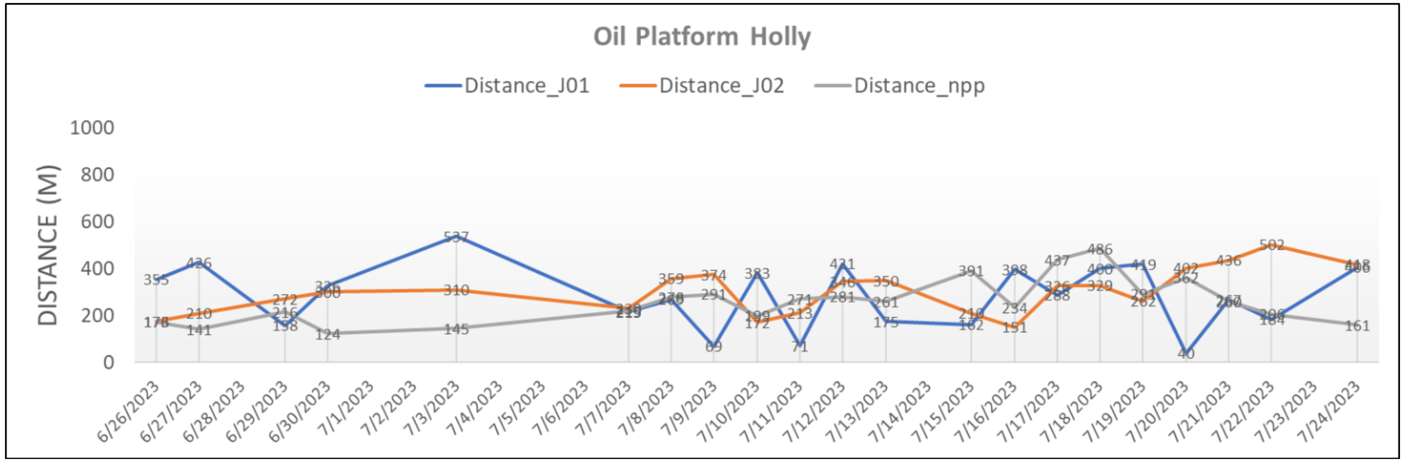
- NOAA21 VIIRS/DNB waiver (RDW-VIIRS-W208) "tail" in the line spread function
- Asymmetry in along scan line response; As much as 10% of the light source and affect the 2nd pixel
- Impact is small; No user complains; No mitigation needed

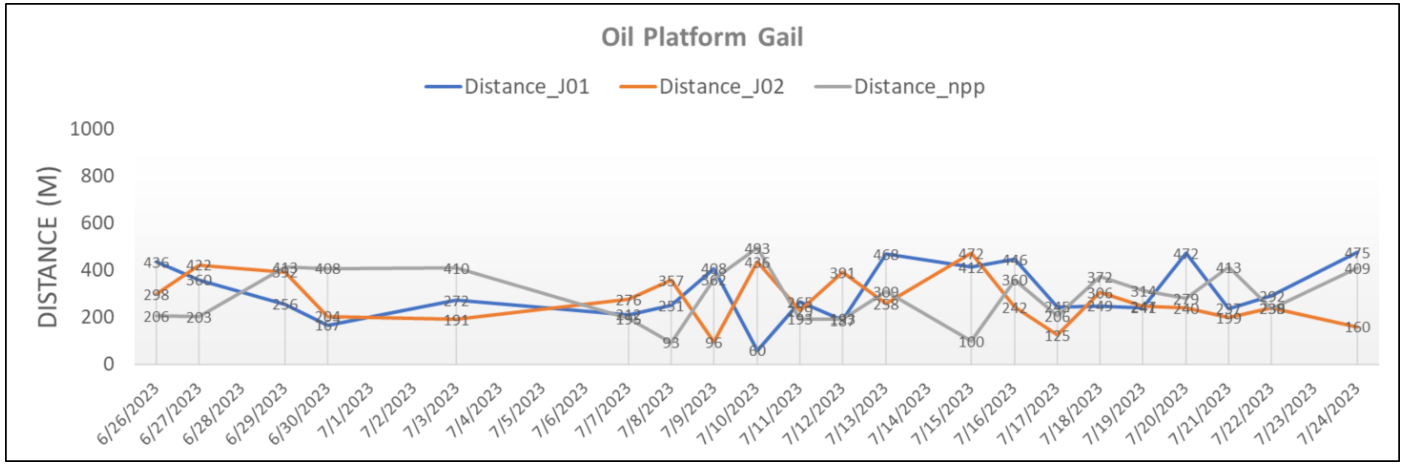
DNB Negative Radiance



- ~0.42% negative radiance data
- Mostly on the EOS

DNB Geolocation Accuracy





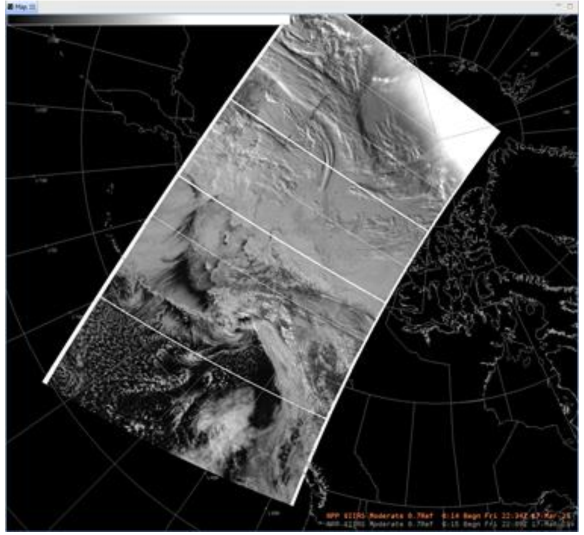
Overlay analysis using the GReVS system

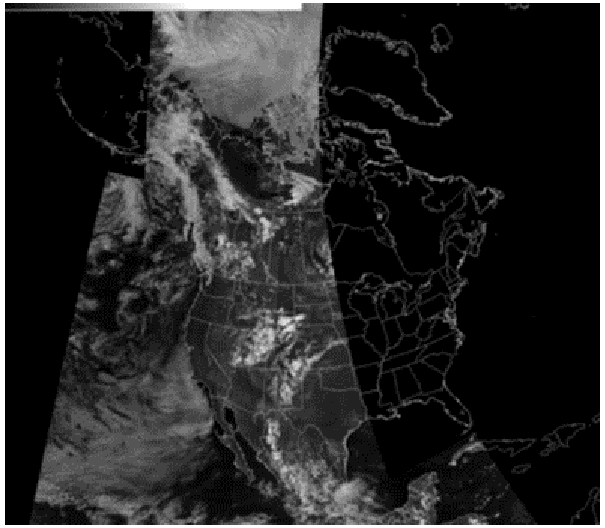
GReVS: https://ncc.nesdis.noaa.gov/Regional/

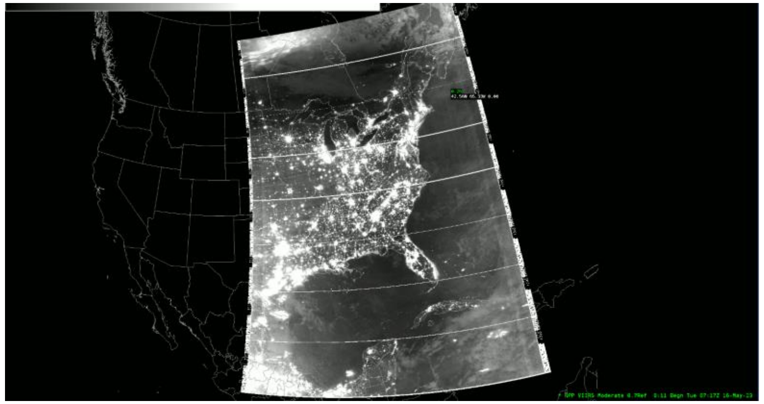
NOAA-21 DNB and I4 Night Co-Registration over Canadian Fire Pixels

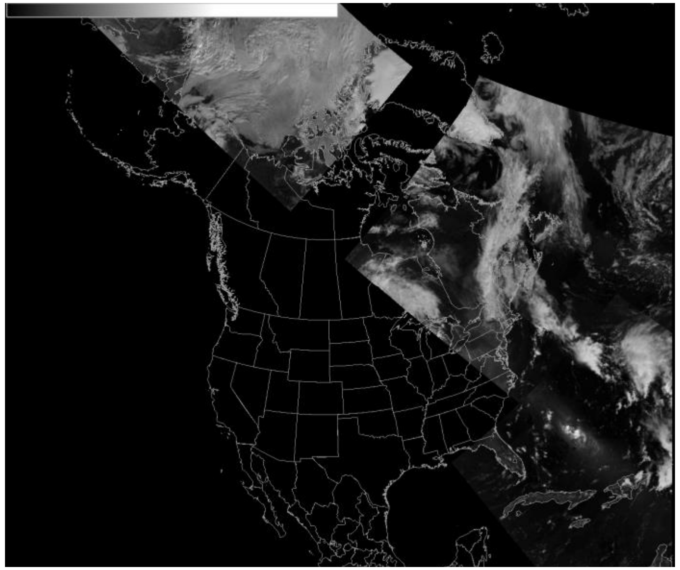
NOAA-21 DNB geolocation accuracy indicates that it is consistent with NOAA-20 and NPP DNB

AWIPS: Resolved white edge issue on NOAA-21 VIIRS DNB NCC imagery





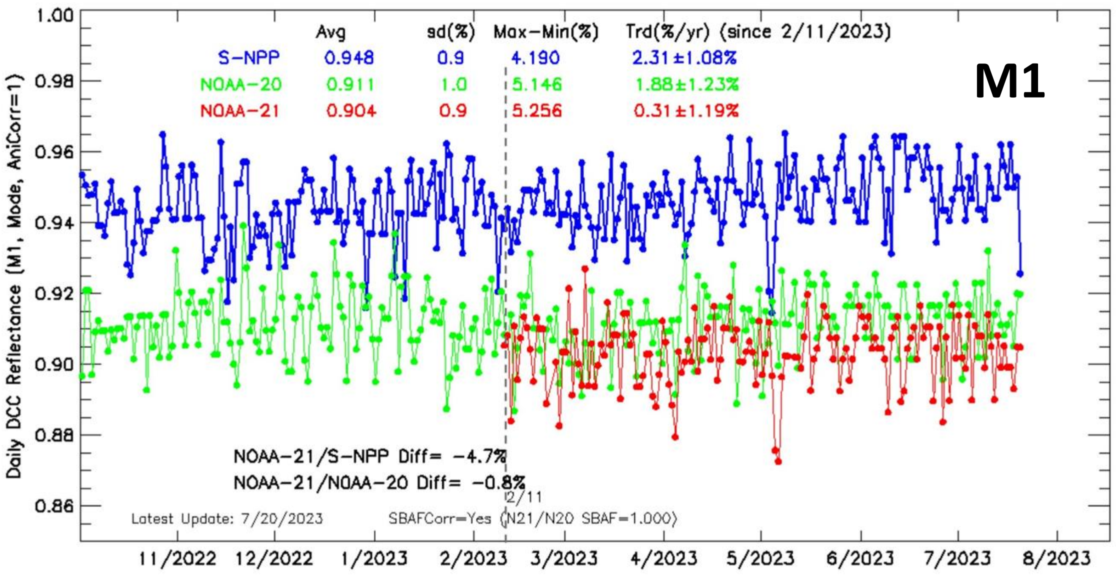


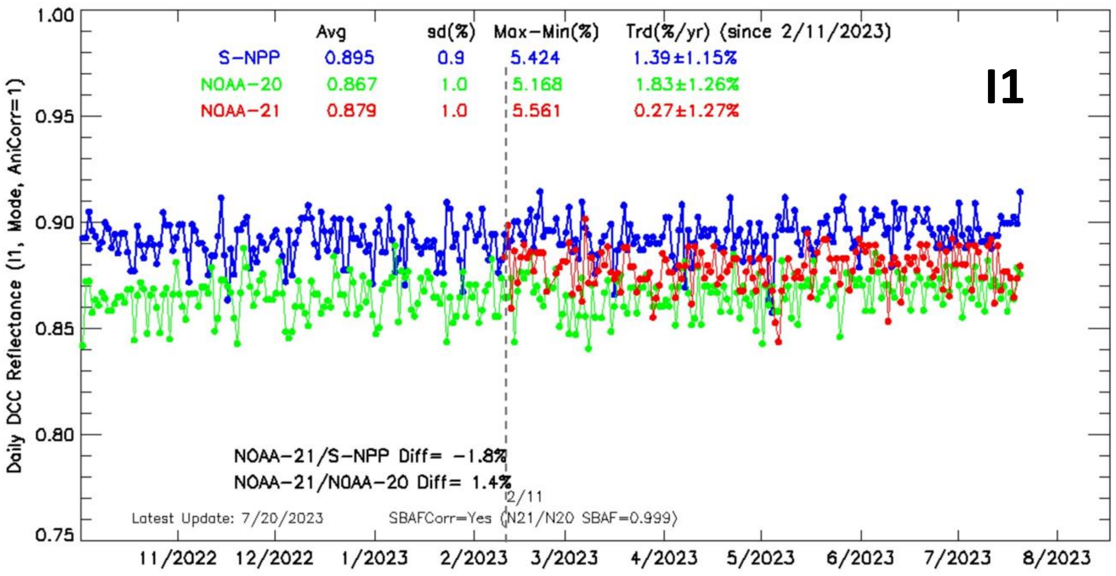


Courtesy of TOWR-S, NWS, John Evans, William Straka, and others

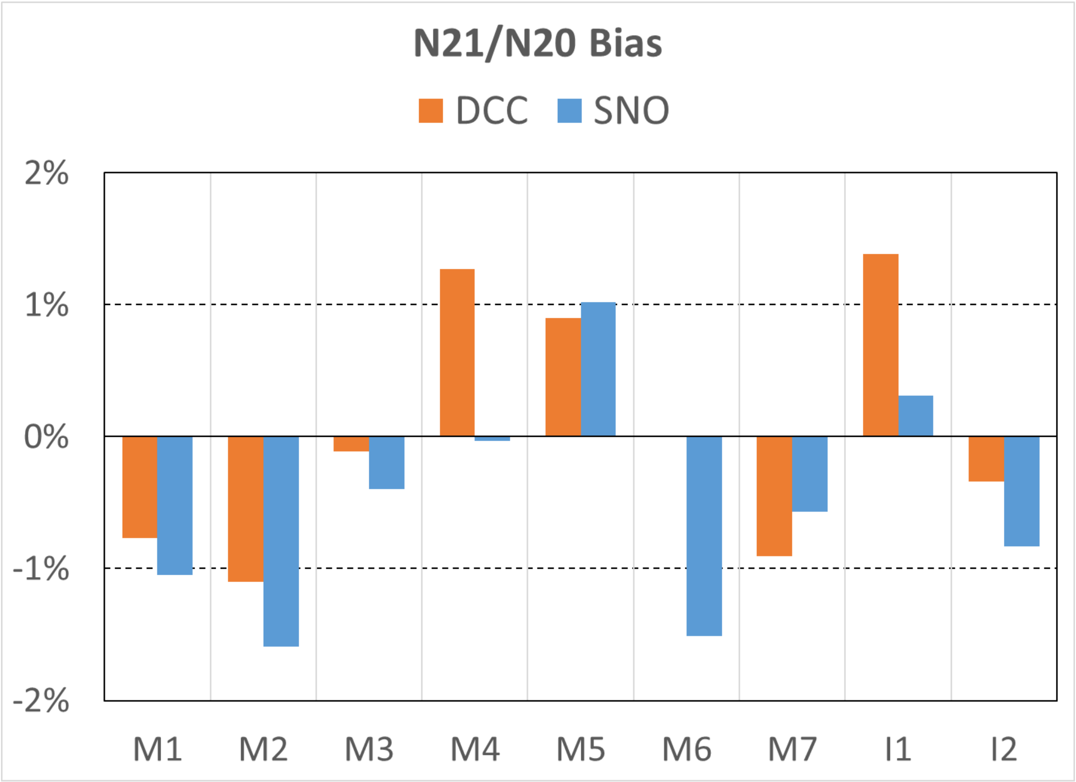
- Multi-team collaboration and deep-dive investigation/analysis
- TOWR-S resolved the issue of visible white edges in AWIPS NCC imagery.
  - Seen in all (SNPP/N20/N21) granules processed (tailored) by NCCF.
- The cause:
  - Products from NDE listed missing values as "65535, 65534, ... , 65528" for the "Albedo" field
  - Products from NCCF listed missing values as "65535US, 65534US, ... , 65528US“
  - AWIPS didn't parse correctly.
- Fix: NCCF reverted to the former missing values list (without "US" suffixes) in all tailored NCC imagery
- Confirmed the fix makes the granule edges disappear in AWIPS: NCC and Alaska KPPs.

RSB: Deep Convective Clouds Observations for VNIR Bands



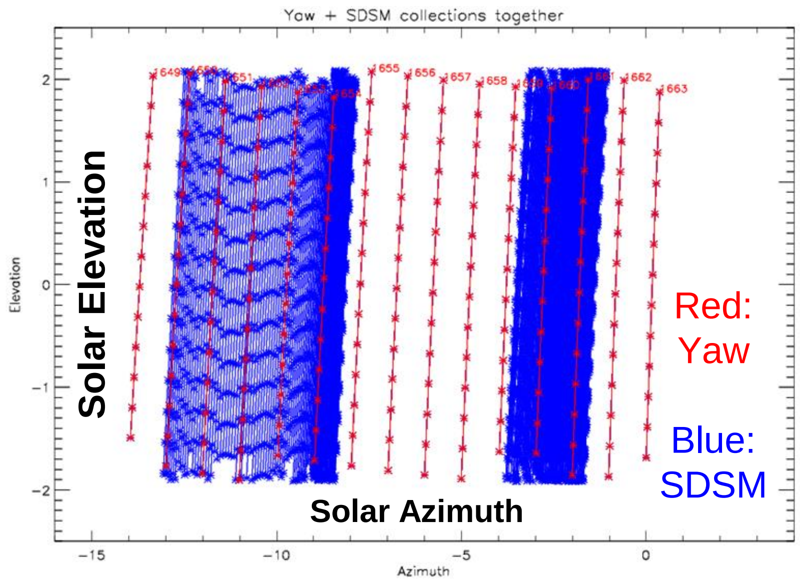


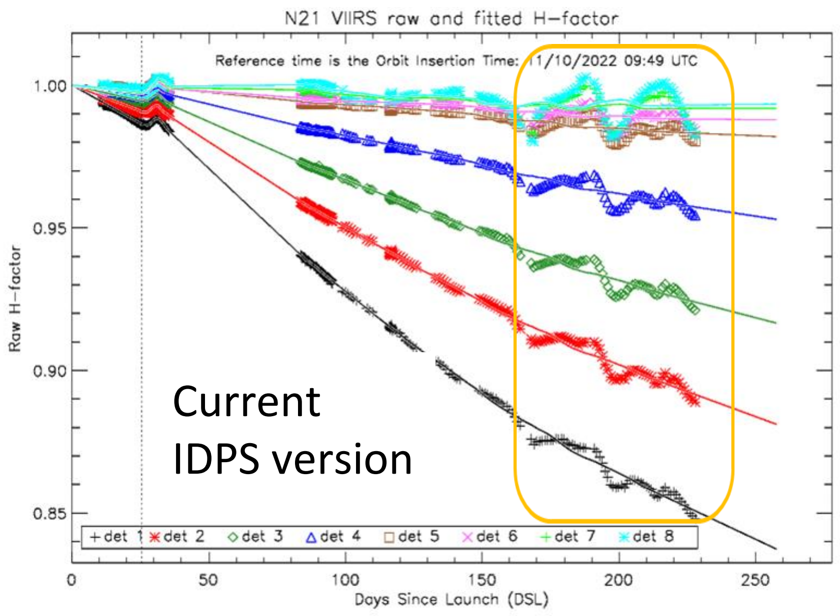
- Daily observations of the DCC (Deep Convective Cloud) reflectance demonstrate:
  - NOAA-21 VIIRS VNIR (visible/near-infrared) band calibration has been stable since the update on Jan. 12, 2023
  - Continues to agree with NOAA-20 VIIRS within the required uncertainty of the absolute radiometric calibration

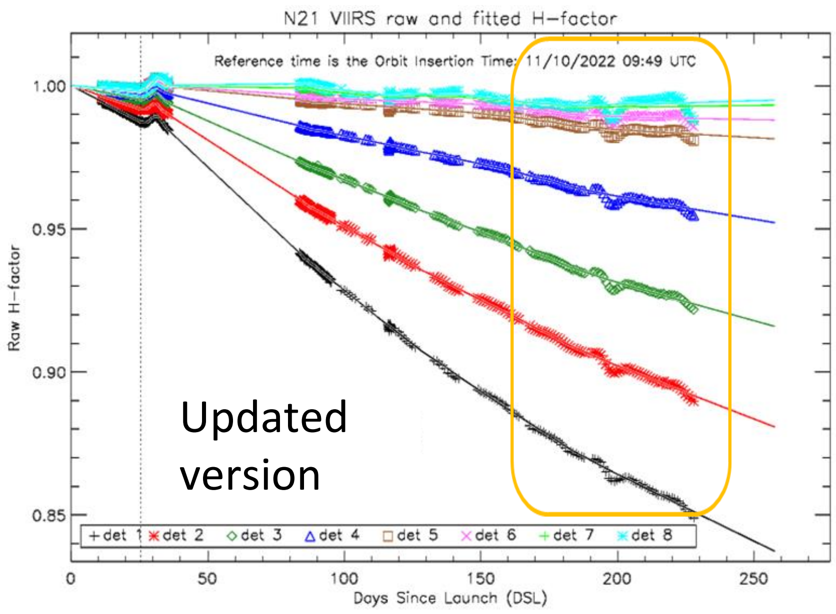


RSB: Solar Diffuser Reflectance Monitoring

- Knowledge of the onboard solar diffuser (SD) reflectance changes is critical for the RSB radiometric calibration accuracy
- SD degradation estimates improved by SD Stability Monitor (SDSM) data from the NOAA-21 yaw maneuvers conducted on Mar. 6-7, 2023, and from the regular SDSM measurements during the initial months on orbit
  - Further improvements expected after the first year on orbit



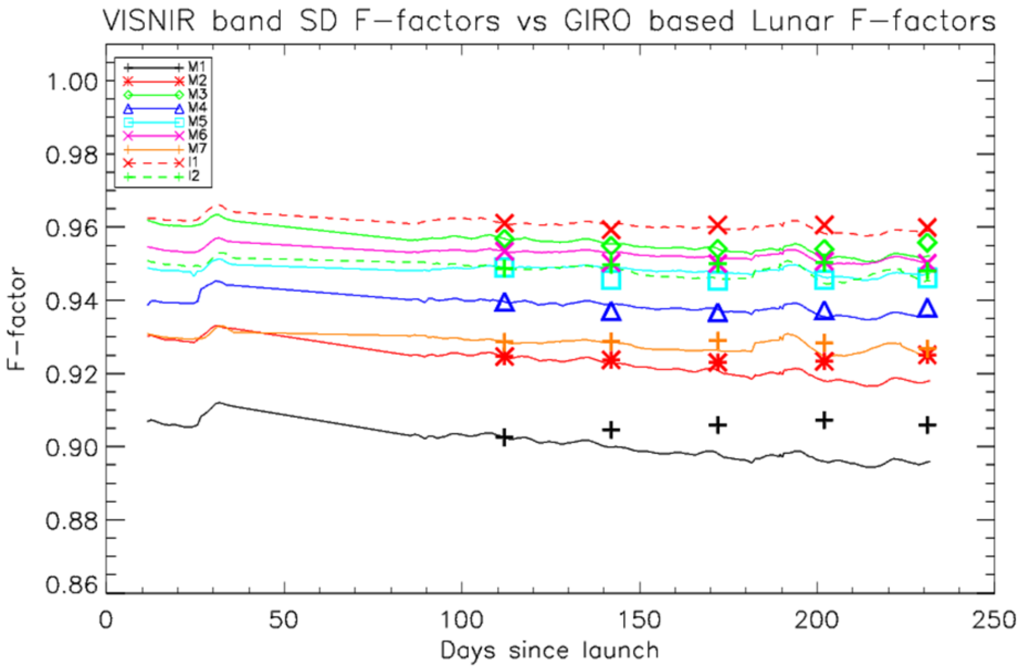


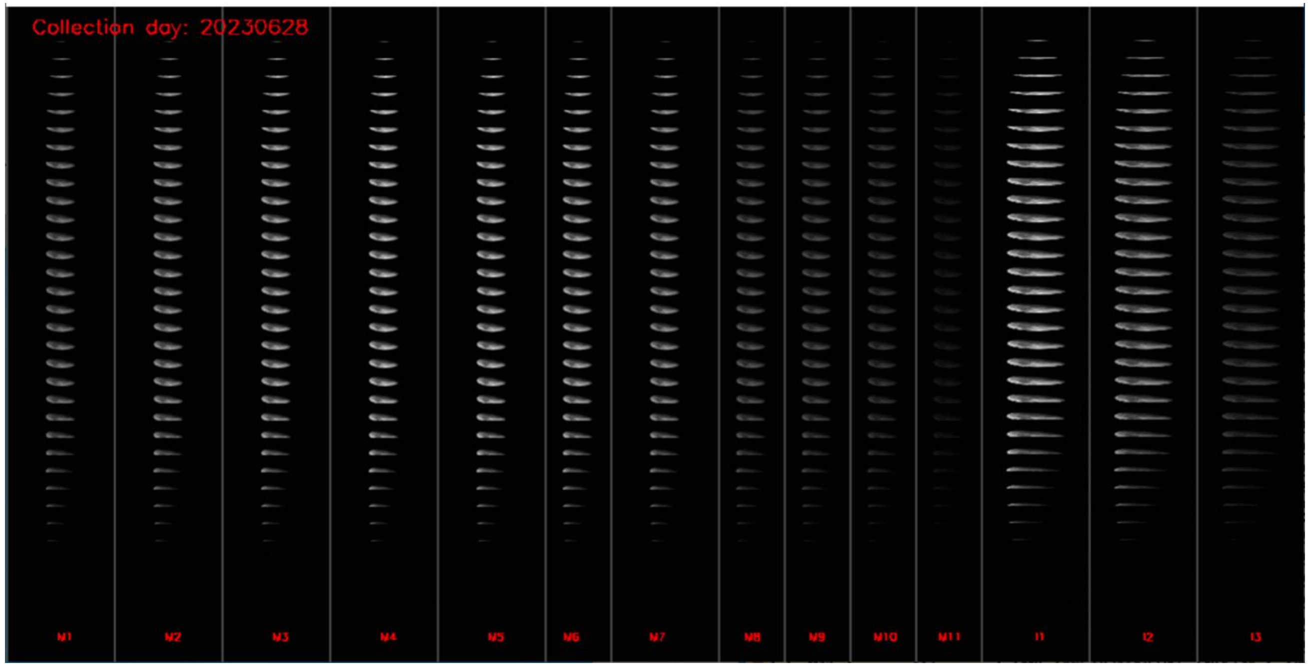


H-factor oscillations are significantly reduced

RSB: Lunar Calibration

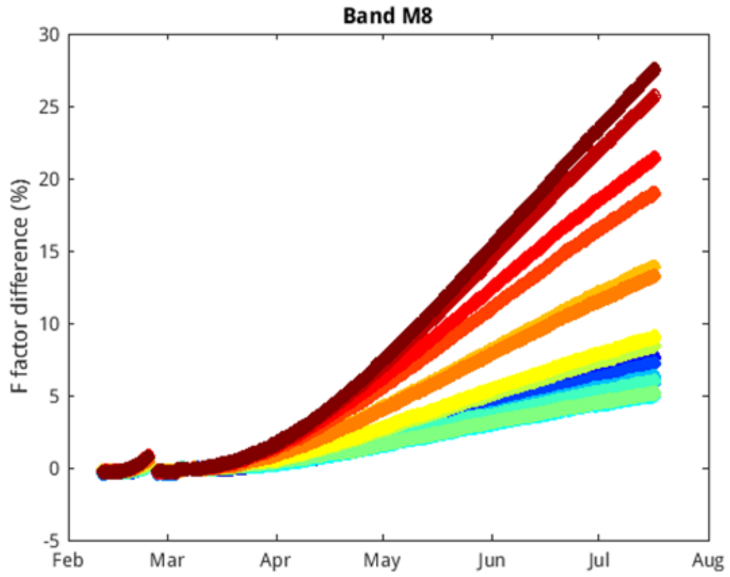
- Allows for independent verification of the SD degradation monitoring
- NOAA-21 VIIRS lunar calibration conducted five times so far:
    - To be repeated at least four times each year
- Shows that the current SD degradation estimates for the VNIR bands need further improvements, potentially with a lunar correction

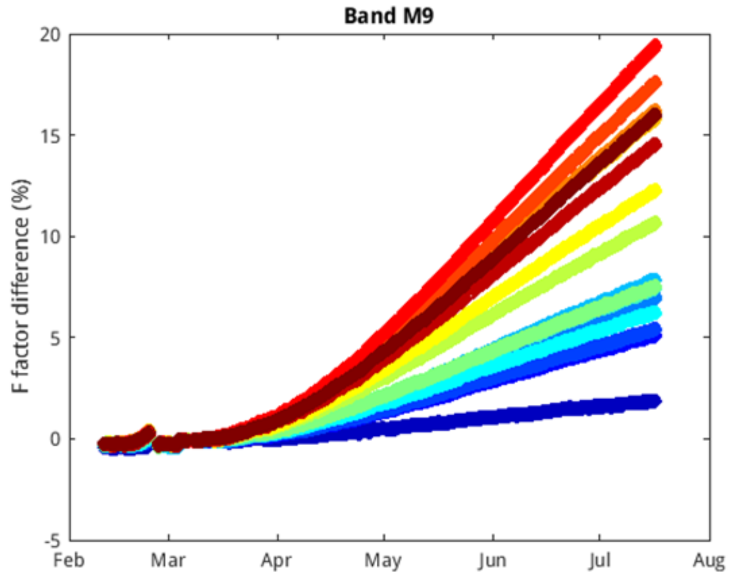




- Demonstrates that the radiometric response for NOAA-21 VIIRS VNIR bands is stable and that the pre-launch calibration coefficients can still be applied, with the proper, constant scaling (as implemented in the IDPS post-launch F factor update)

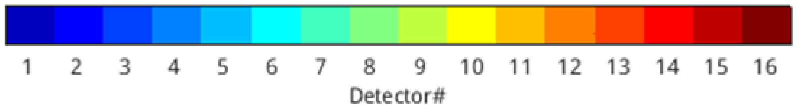
RSB: SWIR Band Radiometric Response Degradation

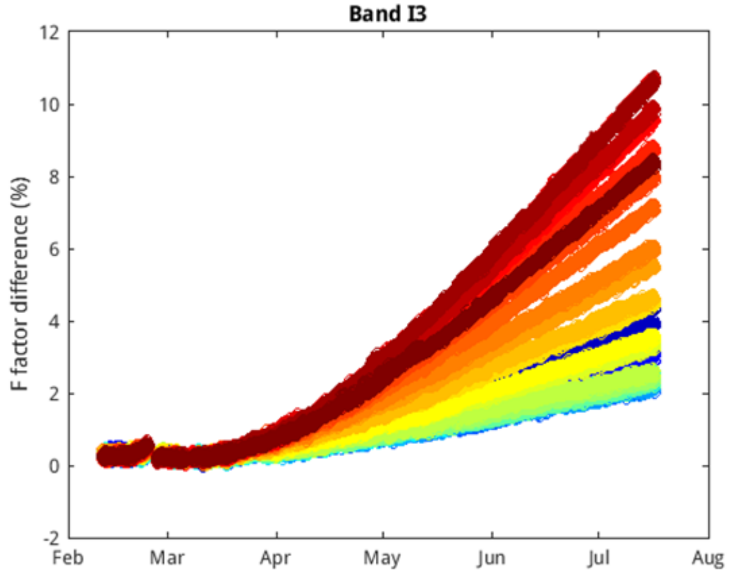


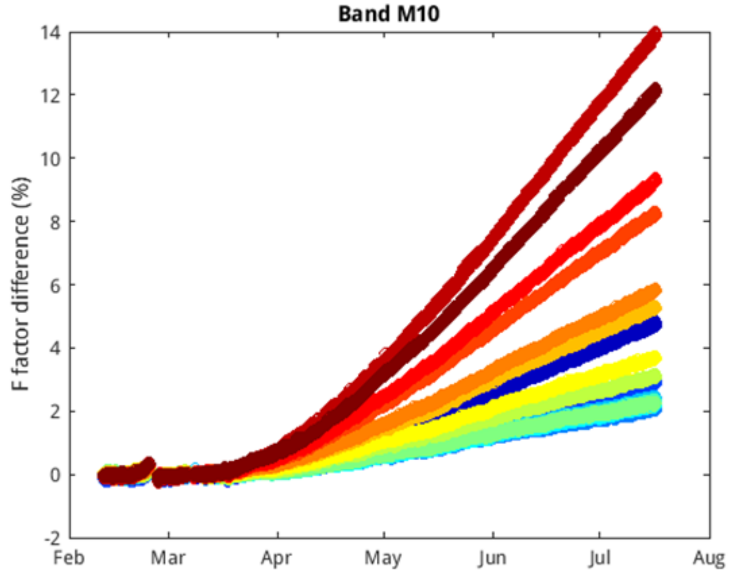


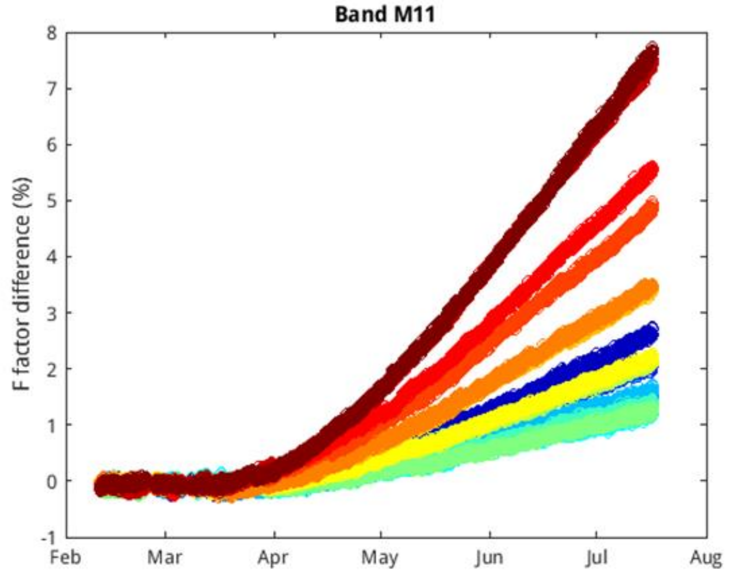
Radiometric response degradation for the NOAA-21 VIIRS SWIR bands continues:

- up to ~28% by 7/16/2023
- band- and detector-dependent
  - the largest for M8 detector #16 (in Product Order)



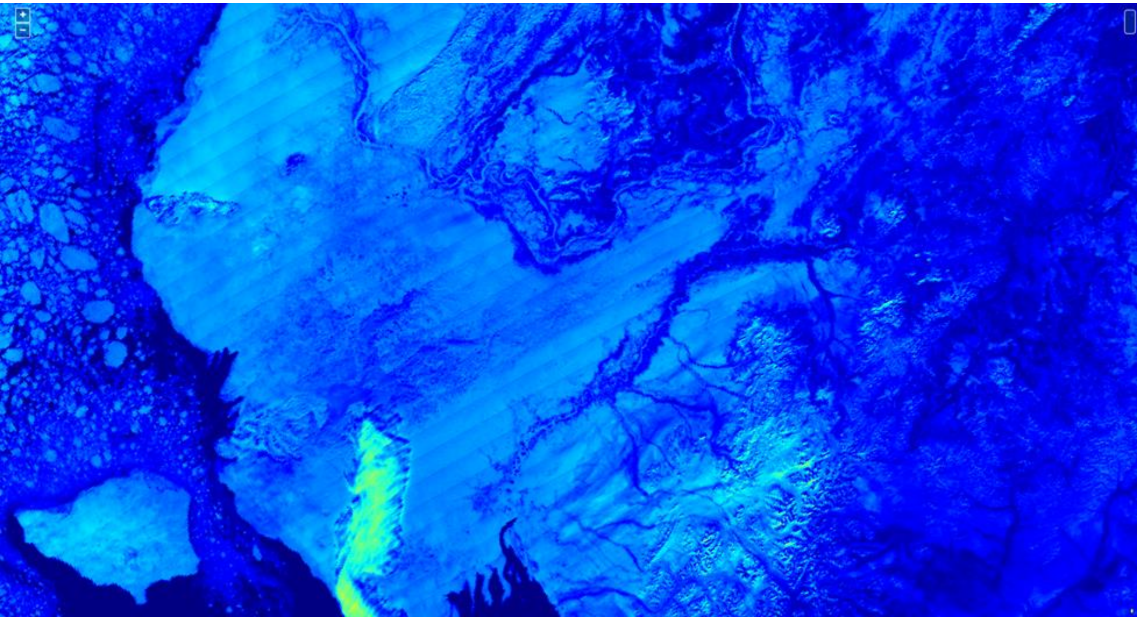




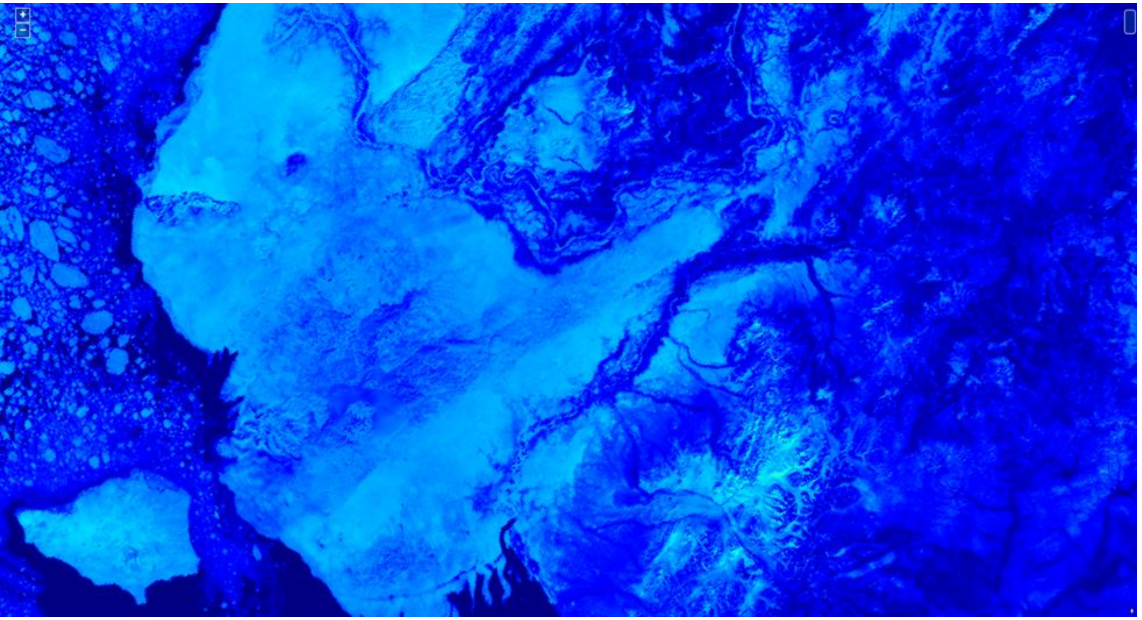


RSB: Calibration Updates to Mitigate SWIR Band Gain Degradation

NOAA-21 VIIRS band M8 images over Alaska



2023-04-19: LUT #3 applied

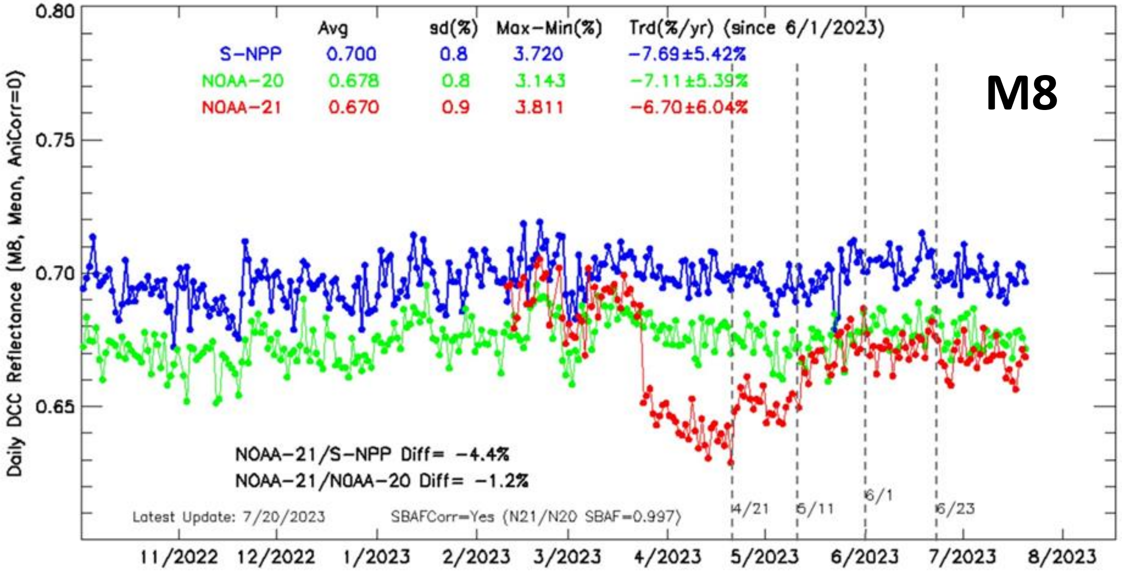


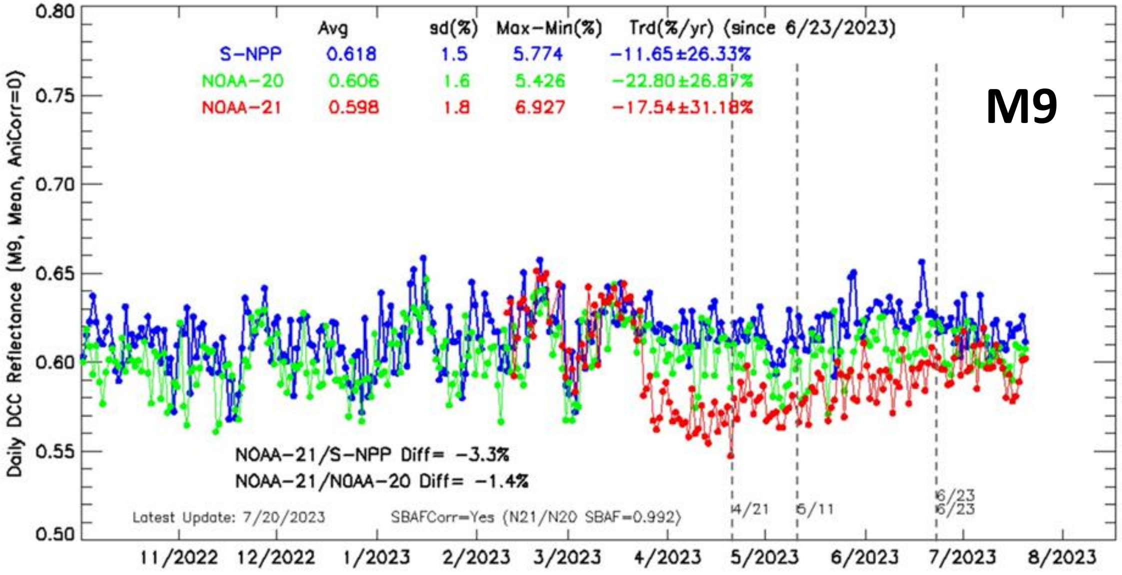
2023-04-20: LUT #4 applied

Continue to work with JPSS Flight Project on possible mitigation

- Degradation of the SWIR band gains mitigated with approx. monthly F-PREDICTED LUT updates:
  - If not corrected, the degradation would create striping in VIIRS imagery (see examples on the left)
- F factor predictions are applied to extrapolate calibration between the LUT updates (using a quadratic function)
- F-factor prediction errors exist and increase with time requiring the LUT updates every few weeks until the SWIR band calibration is automated using the IDPS RSBautoCal software
- RSBautoCal LUTs recently updated to match the processing parameter values used in derivations of the F-PREDICTED LUT updates

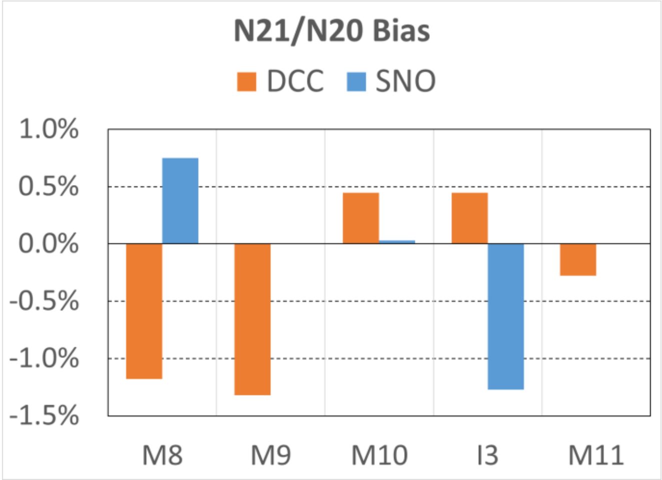
RSB: Deep Convective Clouds Observations for SWIR Bands





NOAA-21 VIIRS SDR time series of DCC observations in the SWIR bands are, in comparison to NOAA-20 and Suomi NPP:

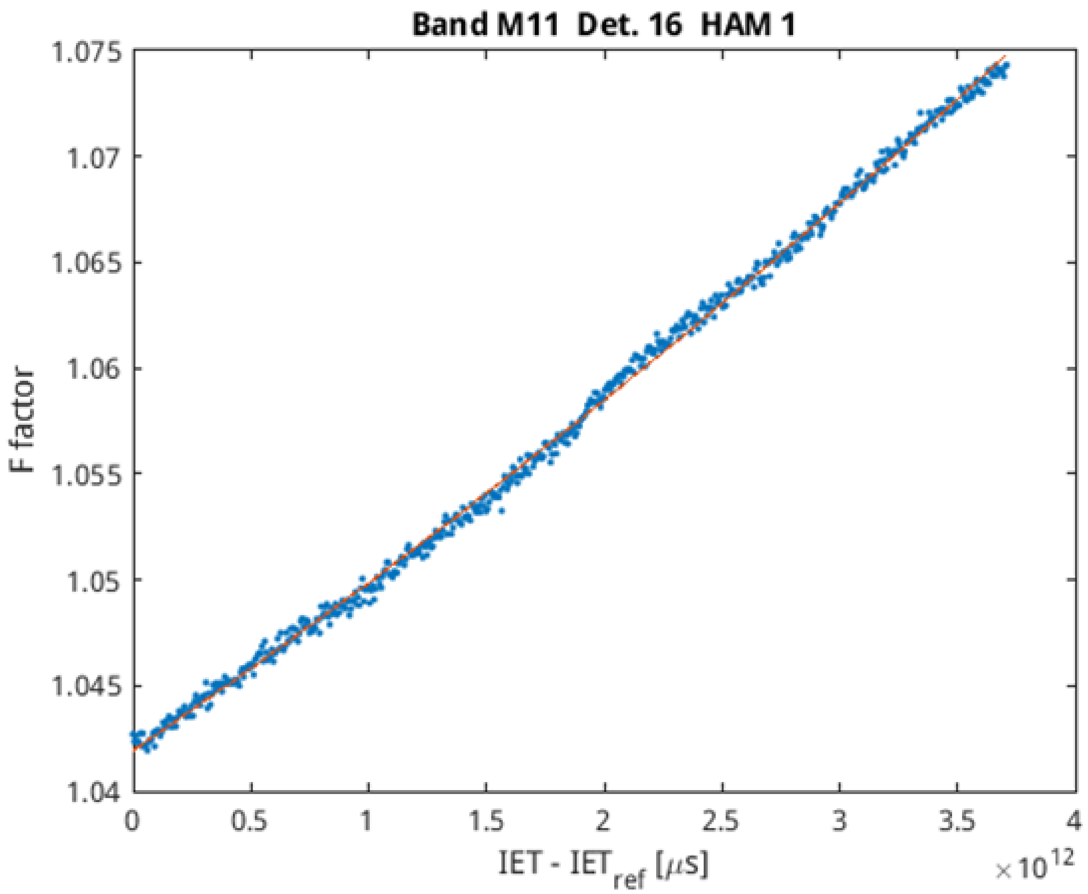
- Holding steady since the LUT update on May 11, including after the recent one on June 23
- With larger differences visible before the degradation corrections applied on April 20 and the bias corrections applied on May 11 (June 23 for M9):
  - +1.5% for band I3, +2.0% for bands M8 and M9, +2.5% for M10, and +4.0% for M11
- With the bias corrections, NOAA-21 and NOAA-20 SWIR products agree within the required uncertainty of the absolute radiometric calibration:



Despite the SWIR band degradation, the impacts on products are small thanks to the calibration updates

no SBAF corr. for M11 (est. ~2%)

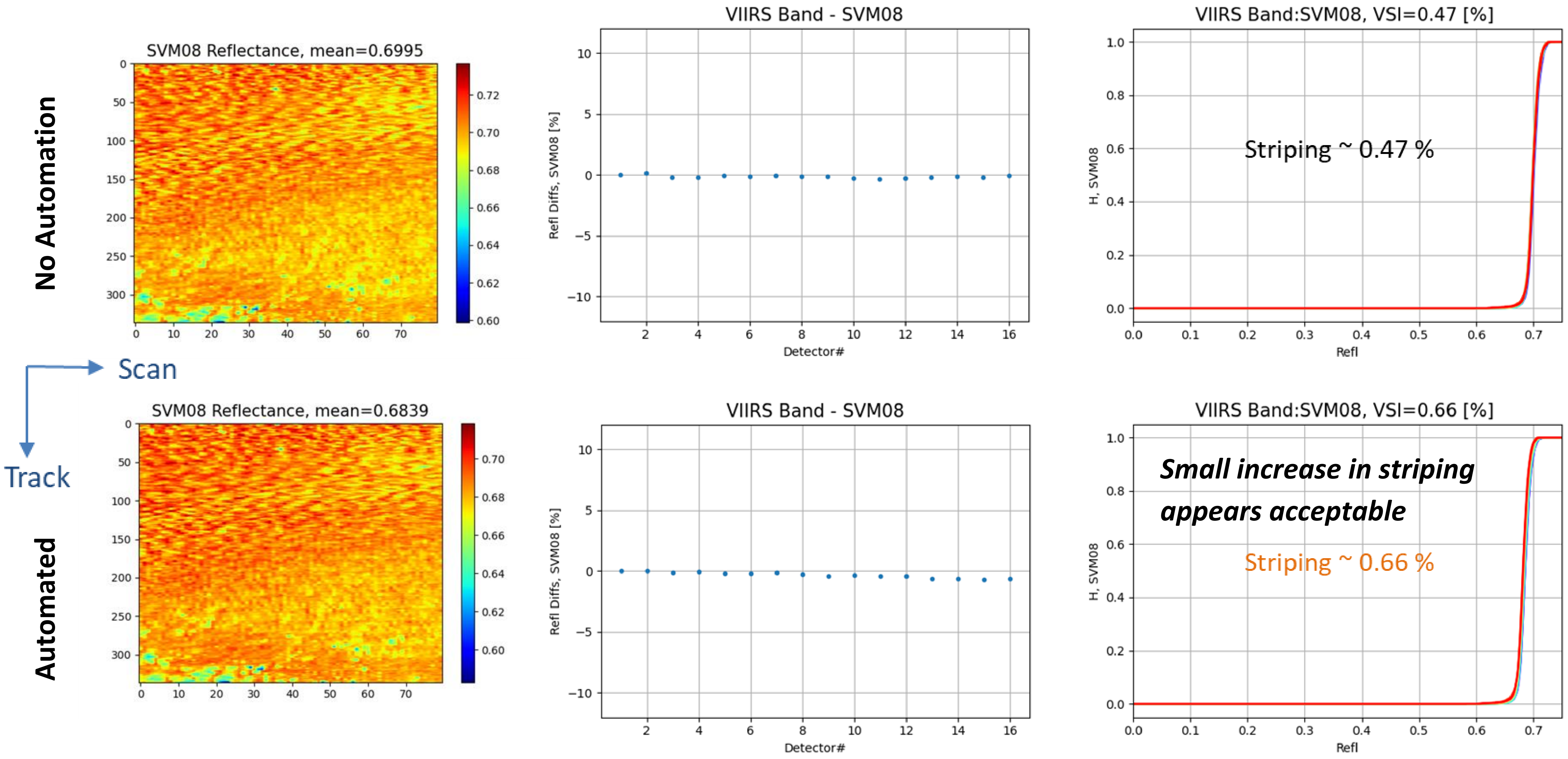
RSB: Automated Solar Calibration for NOAA-21 SWIR Bands



An example of the NOAA-21 VIIRS band M11 F factor values calculated with RSBautoCal (blue dots - one for each orbit) and those from the F-PREDICTED LUT, smoothed by fitting a quadratic polynomial (red line)

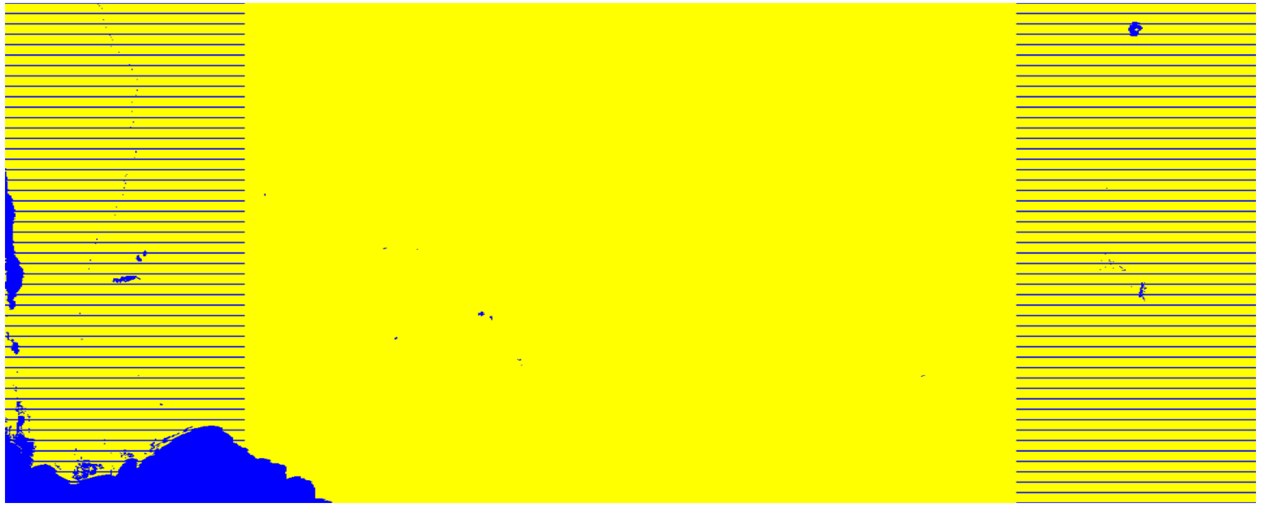
- Calibration of the VNIR bands will remain controlled with the F-PREDICTED LUT
  - VNIR F factors currently constant
- Calibration of the SWIR bands will be automatically updated for every orbit using the RSBautoCal software deployed in IDPS
- Based on the NPP experience, the main challenge is smoothing the calculated F factors by applying the implemented Robust Holt-Winters filter
  - may amplify variability (oscillations)
  - may slow down response to gain changes
- Current plan is to minimize the filtering, but further testing of this approach is still needed:
  - Potentially may introduce sudden changes in calibration from orbit to orbit (not seen in preliminary testing)
  - May increase striping because calibration of each detector is calculated separately and noise is not “averaged out” by filtering (very small effect: see the next chart)

RSB: Band M8 Striping Comparison for Automated Calibration



RSB: Saturated Pixels Code Change in IDPS B2.3 Mx8 - Band M6

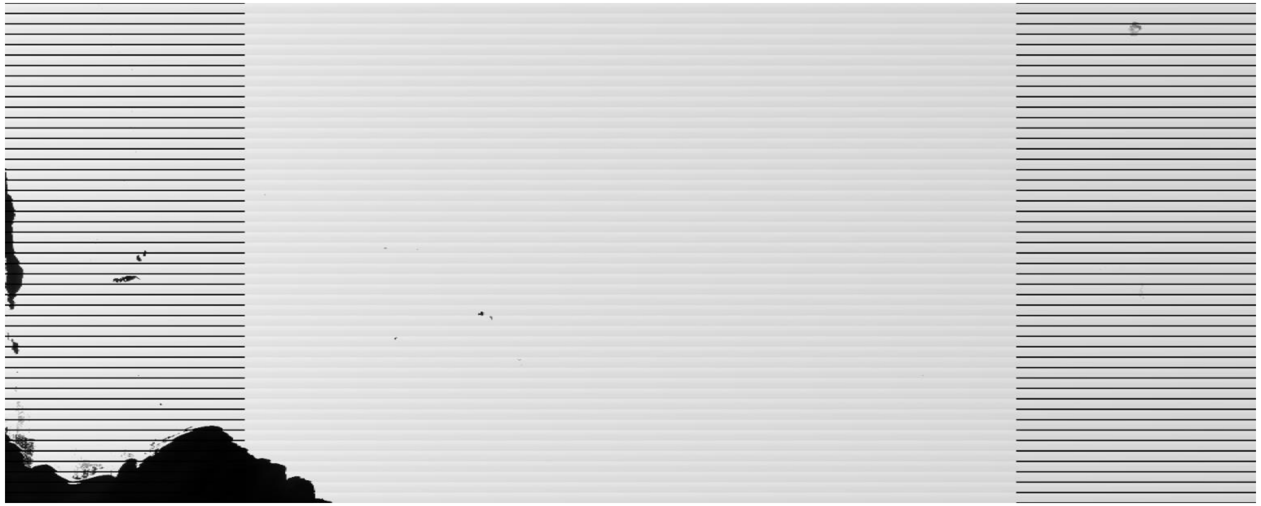
Granule 2023-07-15 11:28 UTC, M6 Quality Flag QF1: *Saturated* (yellow)



- IDPS B2.3 Mx8 transitioned to operations on July 13, 2023 at 15:25 UTC
- Mx8 includes a code change that modifies how radiance and reflectance values are set for saturated pixels from the reflective solar bands:
  - Mx7: assign constant arbitrary values
  - Mx8: estimate values consistent with adjacent, non-saturated pixels
- Each M6 detector saturates at a different radiance level: creates striping in the saturated image areas

M6 Radiance

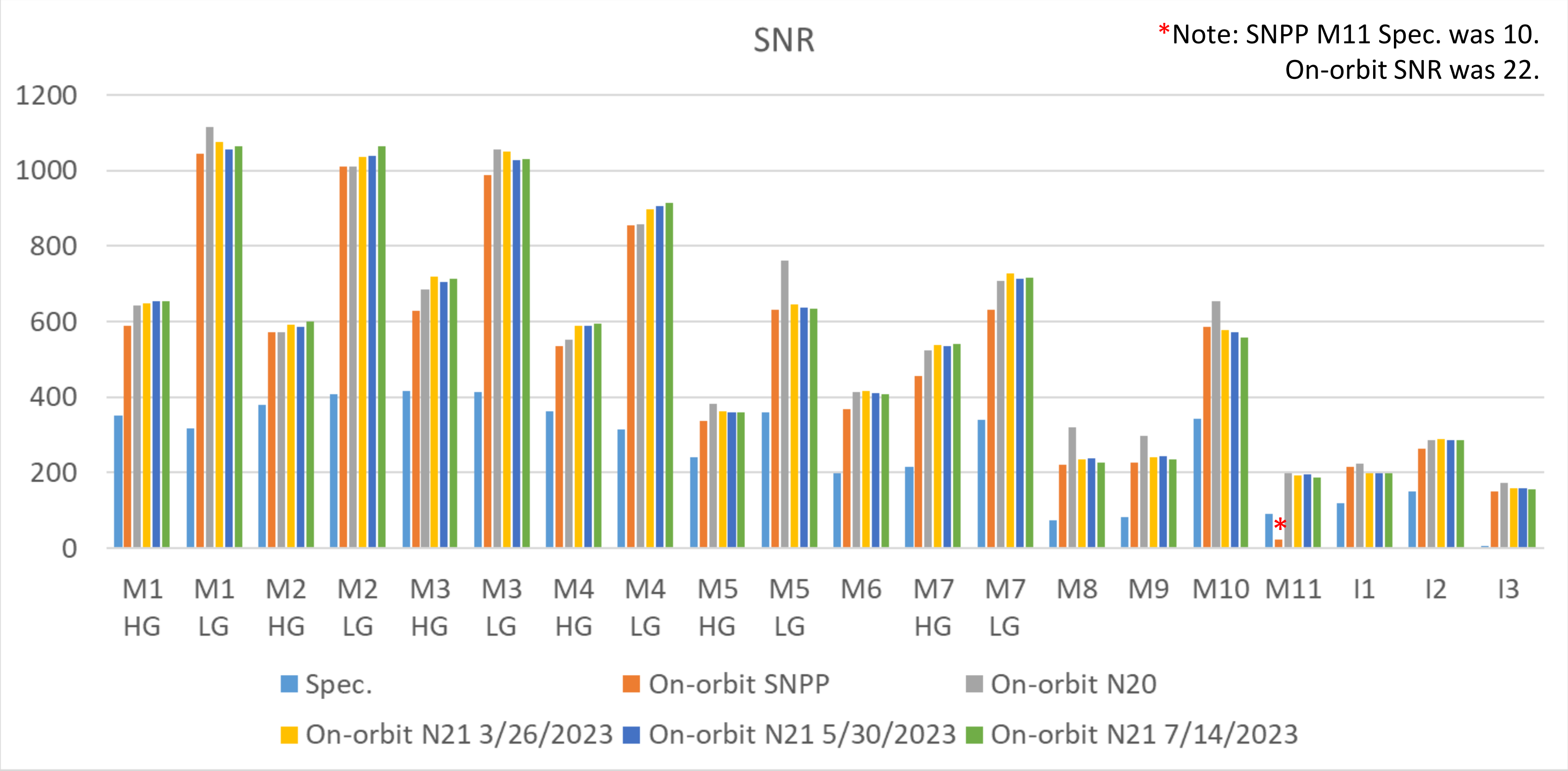
M6 Reflectance



RSB: Signal-to-Noise Ratio (SNR)

Band	L_{typ}	Spec.	SNR on-orbit 7/14/2023
M1 HG	44.9	352	653
M1 LG	155	316	1063
M2 HG	40	380	599
M2 LG	146	409	1065
M3 HG	32	416	714
M3 LG	123	414	1030
M4 HG	21	362	595
M4 LG	90	315	913
M5 HG	10	242	360
M5 LG	68	360	635
M6	9.6	199	408
M7 HG	6.4	215	540
M7 LG	33.4	340	717
M8	5.4	74	226
M9	6	83	234
M10	7.3	342	557
M11	1	90	186
I1	22	119	198
I2	25	150	286
I3	7.3	6	156

L_{typ} unit: W/m^2-sr-µm



- RSB SNR is calculated from the Solar Diffuser observations on 7/14/2023
- 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
  - SWIR bands (M8~M11, I3) showed minor reduction of SNR values (7/14) due to the rapid SWIR band gain degradations.

Error Budget

Band		Center Wavelength (nm)	Maximum FOV @ Nadir (km)	Maximum FOV @ Edge-of-Scan (km)	Specification SNR (RSB & DNB) NEdT (TEB)	Performance (7/14/2023)	Accuracy Specification	Performance
RSB	M1	412	0.8	1.6	316, 352 (LG,HG)	1063, 653 (LG, HG)	2%	<2%
	M2	445	0.8	1.6	409, 380 (LG,HG)	1065, 599 (LG, HG)	2%	<2%
	M3	488	0.8	1.6	414, 416 (LG,HG)	1030, 714 (LG, HG)	2%	<2%
	M4	555	0.8	1.6	315, 362 (LG,HG)	913, 595 (LG, HG)	2%	<2%
	M5	672	0.8	1.6	360, 242 (LG,HG)	635, 360 (LG, HG)	2%	<2%
	M6	746	0.8	1.6	199	408	2%	<2%
	M7	865	0.8	1.6	340, 215 (LG,HG)	717, 540 (LG, HG)	2%	<2%
	M8	1240	0.8	1.6	74	226	2%	<2%
	M9	1378	0.8	1.6	83	234	2%	<2%
	M10	1610	0.8	1.6	342	557	2%	<2%
	M11	2250	0.8	1.6	90	186	2%	<2%
	I1	640	0.4	0.8	119	198	2%	<2%
	I2	865	0.4	0.8	150	286	2%	<2%
	I3	1610	0.4	0.8	6	156	2%	<2%
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)	0.13 K
	M14	8550	0.8	1.6	0.091	0.04	0.6% (0.26 K)	0.05 K
	M15	10763	0.8	1.6	0.07	0.02	0.4% (0.22 K)	0.08 K
	M16	12013	0.8	1.6	0.072	0.02	0.4% (0.24 K)	0.10 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)	0.08 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, Clouds, Flooding	1. Good quality except darker than NOAA20 DNB, and striping in the stray light region (Issue fixed with LUT update) 2. VIIRS flood product similar to SNPP and NOAA-20 3. VIIRS cloud products looking very similar to SNPP and NOAA-20. Important to note that the ECM and DCOMP utilize the DNB for nighttime observations of clouds and cloud properties. Will be monitoring for any impacts from SWIR bands.
Bill Line	STAR/CIRA	Imagery	See the Imagery EDR Validated Maturity presentation
Menghua Wang	STAR	Ocean Color	NOAA-21 SDR at visible and NIR bands are quite reasonable. Further evaluations on SWIR bands are needed.
John Evans	NWS	NWS	White edge in AWIPS DNB Imagery (Issue fixed at NCCF)

Risks, Actions, and Mitigations

Identified Risk	Description	Impact	Action/Mitigation and Schedule
1	TEB: Cold Focal Plane Assembly (CFPA) setpoint temperature change from 82 to 80 K	TEB SDR quality	Delta-C LUT updated
2	DNB 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 bias uncertainties	SWIR band calibration accuracy	Applied SWIR band bias correction; Further monitoring and inter-satellite comparisons to valid the corrections.
5	DNB signal leakage line spread function in line with the waiver	DNB spatial resolution	Closely monitored; No user concerns
6	SWIR band degradation	SWIR band calibration	~Monthly F factor updates Preparing to automate SWIR band calibration Potential mitigation by JPSS Flight Project
7	MWIR band degradation (potential risk depending on degradation rate going forward)	MWIR band calibration	Negligible impact on products but closely monitoring calibration accuracy. Potential mitigation by JPSS Flight Project

Mitigated (risks 1–5)

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; NOAA-21 (ongoing)
Regular Validation Reports (at least annually) (Demonstrates long-term performance of the algorithm)	Annual VIIRS SDR performance report

Check List - Validated Maturity

Validated Maturity End State	Assessment
Product performance has been demonstrated over a large and wide range of representative conditions (i.e., global, seasonal).	NOAA-21 VIIRS instrument performance and science data (SDR/GEO) have been verified through a large and wide range of representative conditions (global and limited seasonal) dataset analysis. No significant anomalies have been found affecting data quality.
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.	NOAA-21 VIIRS validated maturity science data quality README file has been created for user reference. All known product anomalies, impacts, and their recommended remediation strategies are also documented (in reports, presentations and papers) to support general data users.
Product analyses are sufficient for full qualitative and quantitative determination of product fitness-for-purpose.	NOAA-21 VIIRS science data have met the validated maturity requirements and can be used for full qualitative and quantitative assessment for downstream products.
Product is ready for operational use based on documented validation findings and user feedback.	NOAA-21 VIIRS SDR data is ready for operational use based on documented validation findings (PLT reports, maturity review and conference presentations, papers) and user participation and feedback.
Product validation, quality assurance, and algorithm stewardship continue through the lifetime of the instrument	Infrastructure and platform for long term monitoring and calibration of NOAA-21 VIIRS SDR data are ready and in use for data quality assurance, and algorithm stewardship.

Check List - Validated Maturity

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NOAA-21 VIIRS Validated Maturity Status

- VIIRS SDR for all four major categories (RSB, TEB, DNB and GEO) are checked;
- On-orbit instrument noise (NEΔT and SNR) are characterized; On-orbit SDR bias was characterized based on comparisons with NOAA-20 VIIRS, lunar, DCC, and validation at selected sites;
- 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 (not all are necessarily implemented);
- All data products can be used for operational use based on documented validation findings and user feedback.
- Feedback from NOAA VIIRS EDR teams including Fire, Imagery, Ocean Color and other teams, and NWS are positive about the data quality based on their assessments.

VIIRS SDR Cal/Val Findings: NOAA-21 VIIRS SDR achieved validated maturity (validated review on 2023/08/03, good since 6/23/2023, 13:42* UTC)

* F-PREDICTED LUT update with the M9 bias correction

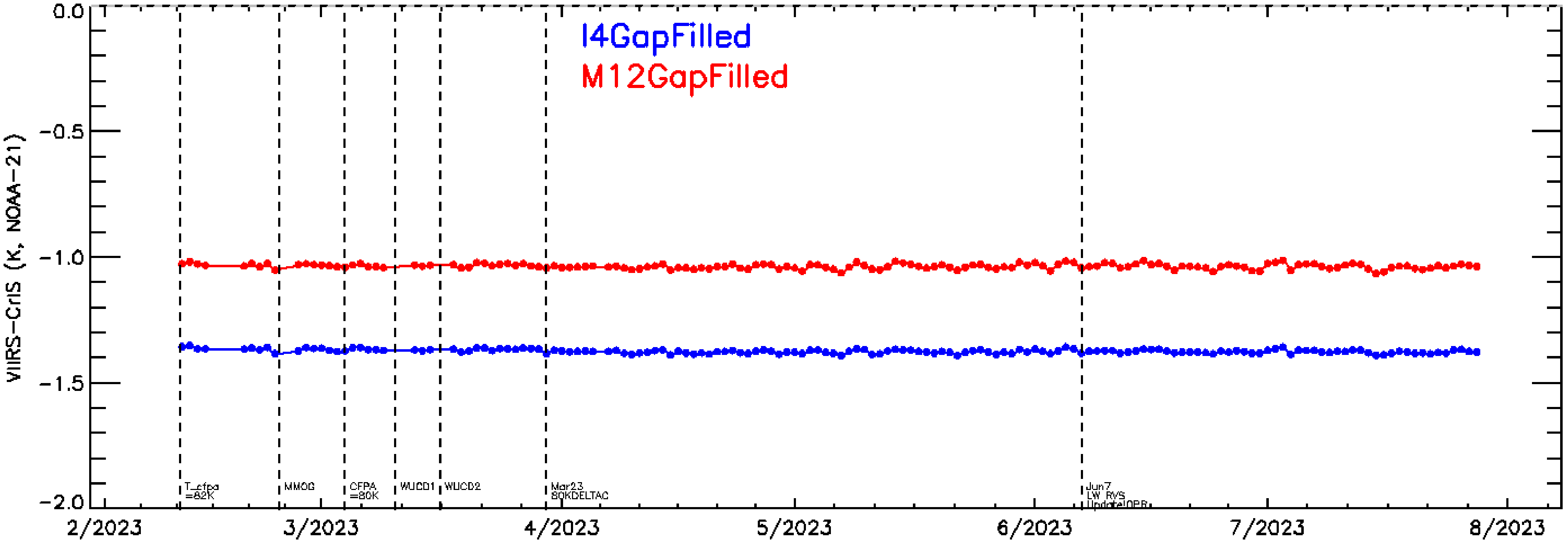
Path Forward

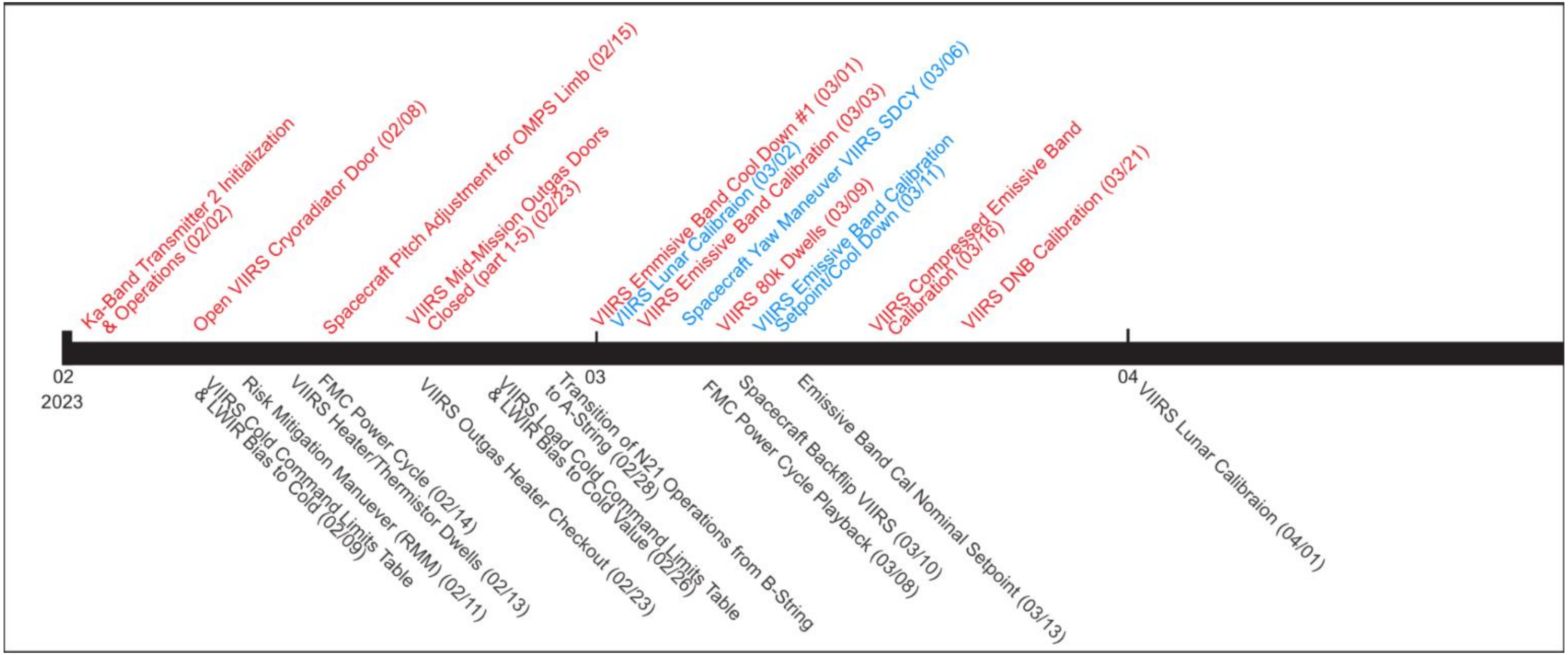
1. Develop and deliver 12 monthly DNB stray light correction tables in a year
2. Continue to closely monitor and mitigate SWIR/MWIR band degradation
   - Automate SWIR band calibration
   - Support potential Outgassing working with flight.
3. Analyze lunar calibration data to independently characterize solar diffuser degradation
4. Further evaluate NOAA-21 pre-launch waiver related issues and address them as appropriate
5. Continue monitoring VIIRS instrument stability and performance, as well as SDR data quality
   - 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
6. Explore the generation of images with alternative spatial resolutions to meet user needs

Backup

NOAA-21 VIIRS-CrIS Daily Averaged BT Biases (MWIR, I4 and M12)

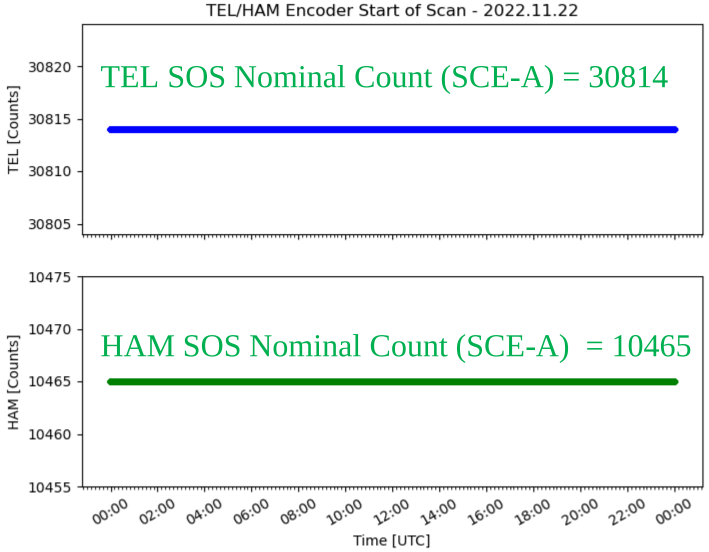
- I4 and M12 calibrations are also generally stable, relative to CrIS gap-filled spectra at nighttime.
- Nearly constant biases exist:
  - Mainly due to incomplete spectral coverages.
  - I4/M12 RSRs are only ~80% covered by the CrIS gap-filled spectra.




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)

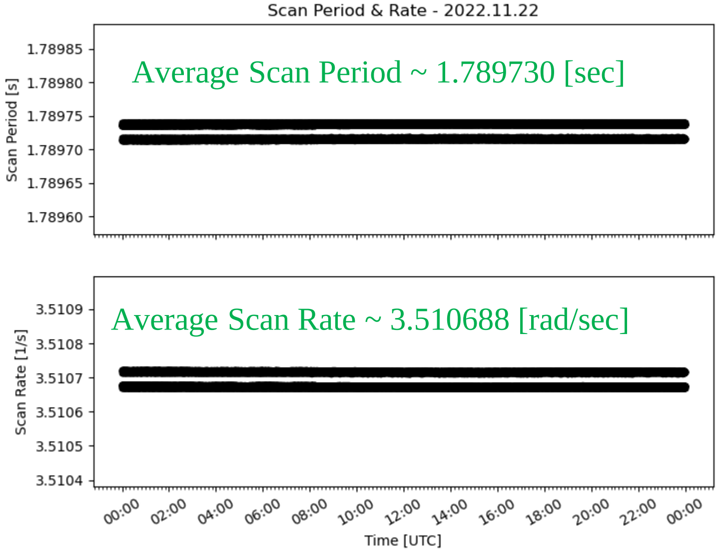
Earth Scan Stability (Optional)

TEL/HAM Encoder Start Values



The TEL and HAM encoder start-of-scan (SOS) values are stable and in agreement with Scan Control Electronics Side-A (SCE-A) pre-launch nominal values

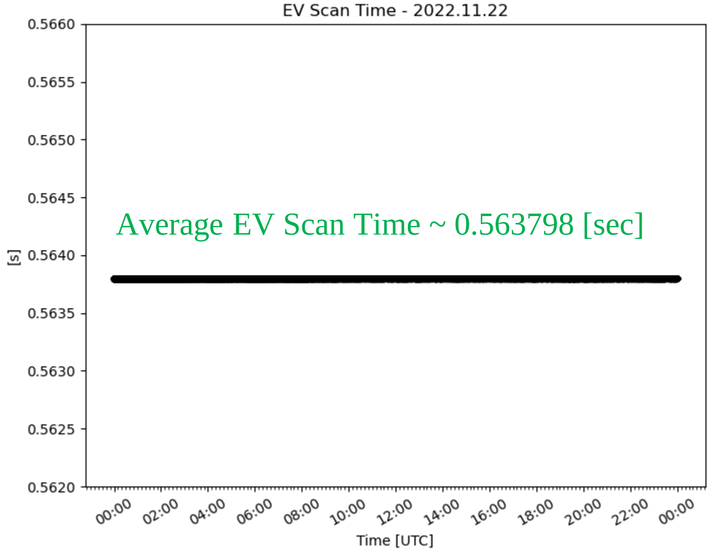
Scan Period / Scan Rate



Scan Period = time difference between two consecutive SOS timestamps

Scan Rate = 2π / Scan Period

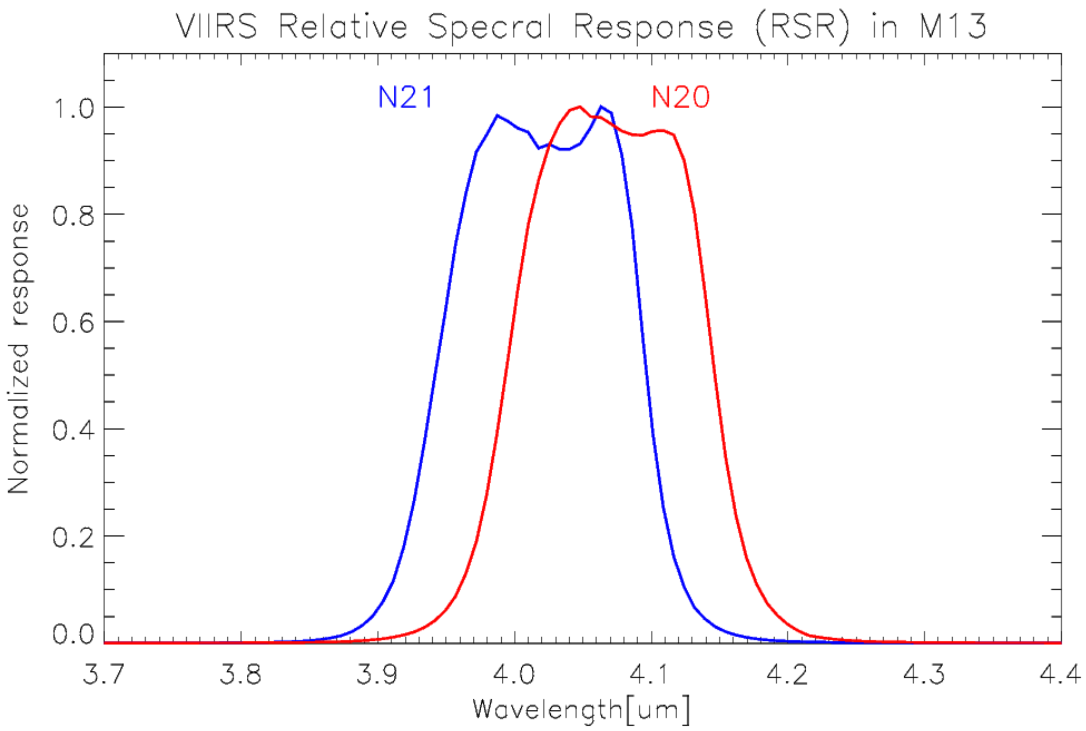
Earth View (EV) Scan Time

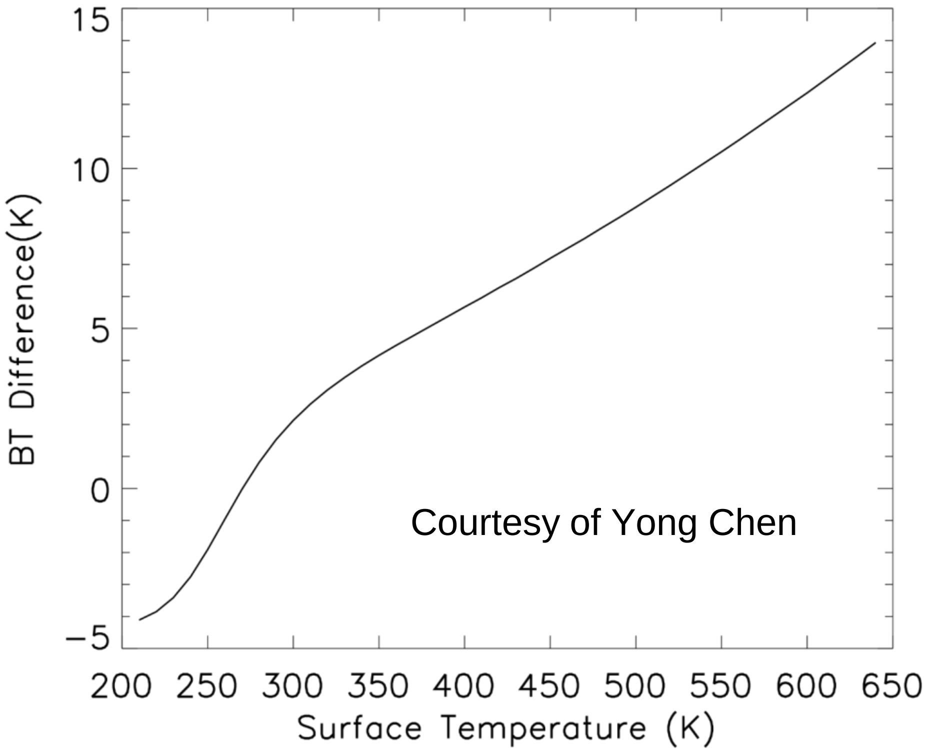


EV Scan Time = Time difference between EV end-of-scan (EOS) and start-of-scan (SOS) timestamps

VIIRS scan parameters are stable and consistent with pre-launch values

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