VIIRS reflective solar bands calibration performance

Jack Xiong[a], Junqiang Sun[b], Ning Lei[b], Kevin Twedt[b], and Amit Angal[b]

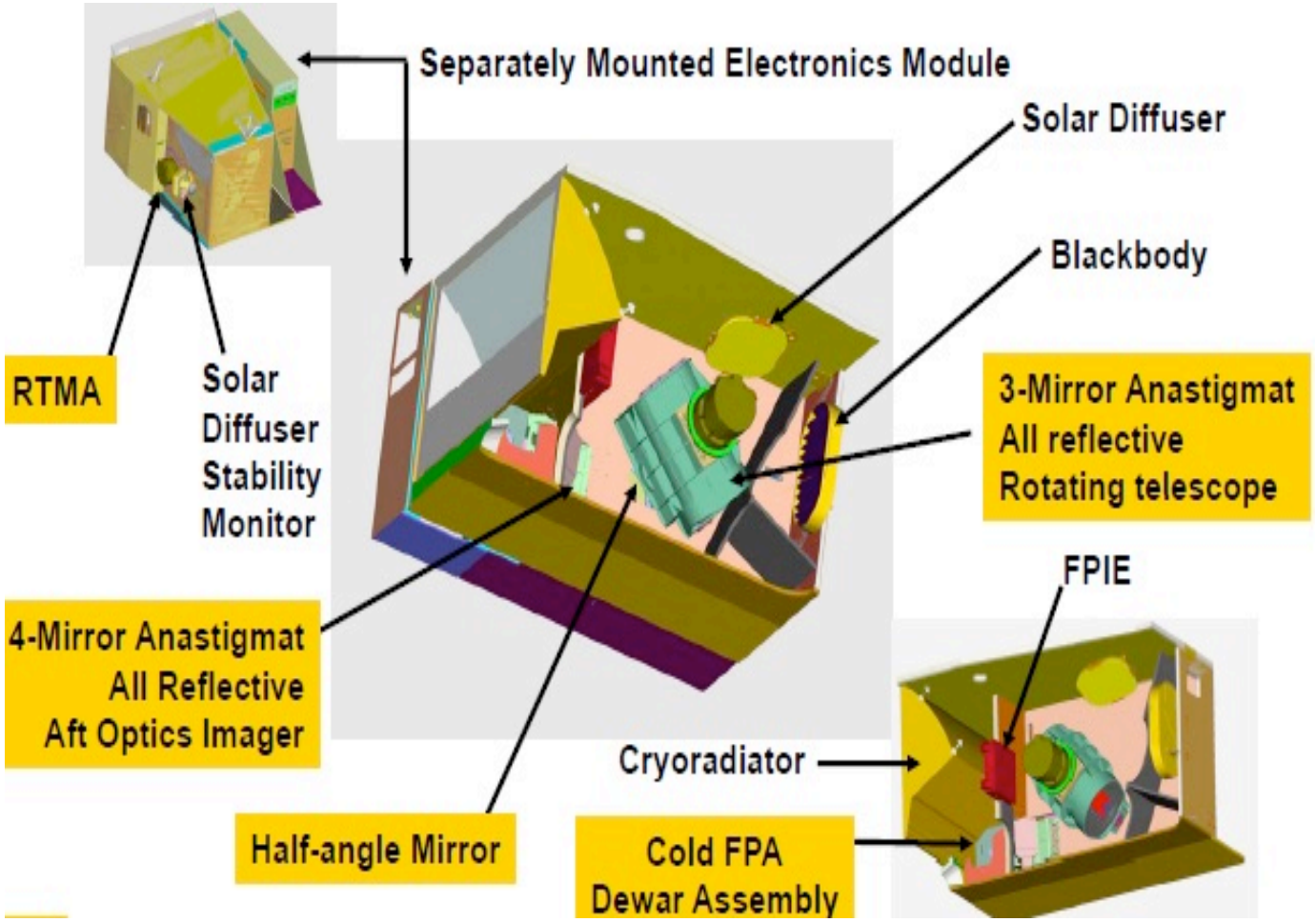
[a]*Code 618.0, NASA Goddard Space Flight Center, Greenbelt, MD 20771*
[b]*Science Systems and Applications Inc*

GSICS Annual Meeting 2023, College Park, MD, USA, February 27 – March 3, 2023

Outline

- Introduction
- VIIRS on-orbit calibration methodology
- SNPP, N20, N21 on-orbit performance
- Summary

Introduction



Three VIIRS instruments on-orbit currently:

- SNPP launched on 28 Oct. 2011
- NOAA 20 / J1 launched on 18 Nov. 2017
- NOAA 21 / J2 launched on 10 Nov. 2022

- *22 spectral bands - 410 nm to 12.013 μm spectral range*
- *14 Reflective Solar Bands (RSB) : 3 image bands, I1-I3, and 11 moderate bands, M1-M11*
- *The VIIRS RSB are calibrated on orbit by SD/SDSM calibration*
- *Monthly lunar observation through its space view (SV) since launch.*
- *For VIIRS, the angle of incidence (AOI) of the SV is exactly the same as that of the SD. Lunar observations should provide identical on-orbit gain change for VIIRS RSB as SD/SDSM calibration.*

VIIRS RSB uncertainty specification is 2%.

VIIRS RSB calibration methodology

16 Moderate (radiometric) bands, 5 Imaging bands, 1 DNB

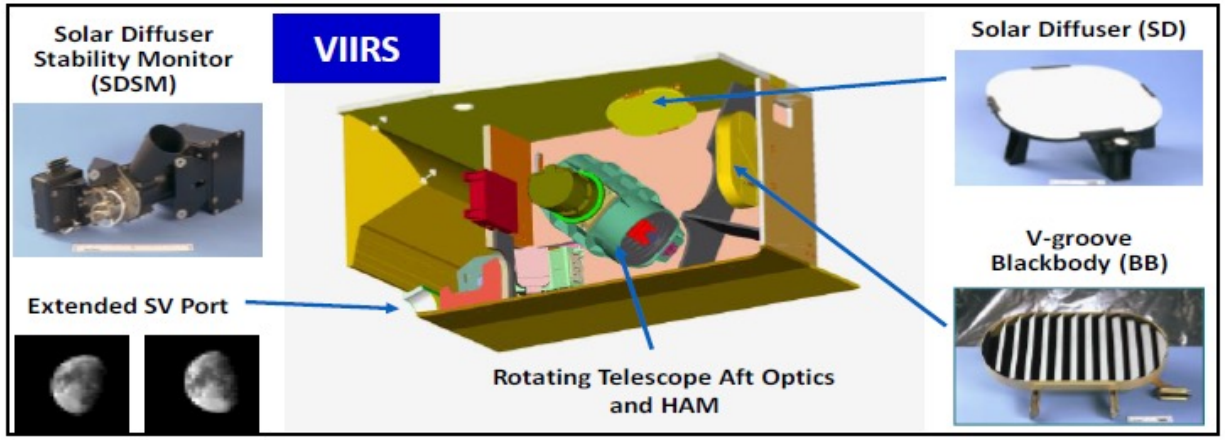
VIIRS		
VIIRS Band	Spectral Range (um)	Nadir HSR (m)
DNB	0.500 - 0.900	
M1	0.402 - 0.422	750
M2	0.436 - 0.454	750
M3	0.478 - 0.498	750
M4	0.545 - 0.565	750
I1	0.600 - 0.680	375
M5	0.662 - 0.682	750
M6	0.739 - 0.754	750
I2	0.846 - 0.885	375
M7	0.846 - 0.885	750
M8	1.230 - 1.250	750
M9	1.371 - 1.386	750
I3	1.580 - 1.640	375
M10	1.580 - 1.640	750
M11	2.225 - 2.275	750
I4	3.550 - 3.930	375
M12	3.660 - 3.840	750
M13	3.973 - 4.128	750
M14	8.400 - 8.700	750
M15	10.263 - 11.263	750
I5	10.500 - 12.400	375
M16	11.538 - 12.488	750

→ **1 DNB**

14 RSB (0.4-2.3 μm)

Dual Gain Bands: M1-M5, M7, M13

7 TEB



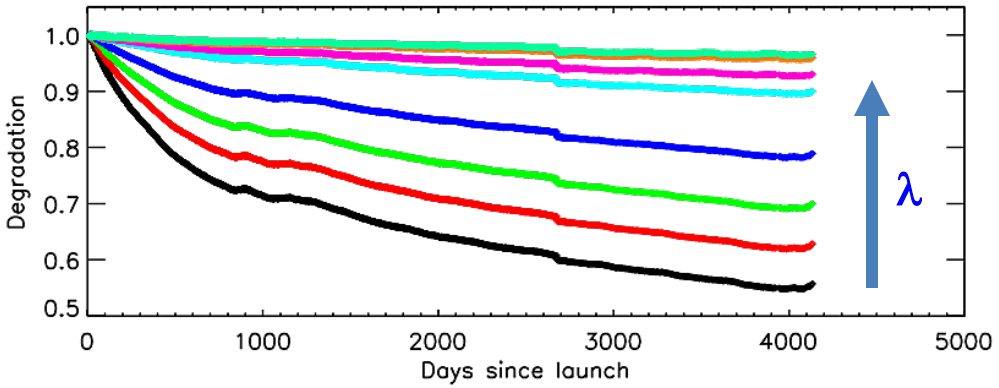
Solar Diffuser (SD): Spectralon® plate provides radiometric ref. measurements for the 14 VIIRS RSB bands.

Solar Diffuser Stability Monitor (SDSM): Rationing radiometer with 8 detector bands (0.41 to 0.94 μm). Seven bands have the same wavelength center as bands M1-M7.

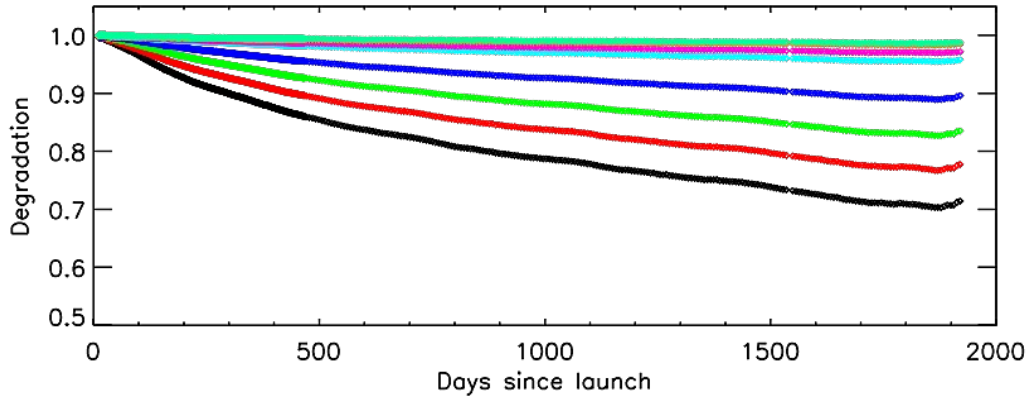
Moon: Near-monthly lunar measurements to track the gain changes for the RSB

VIIRS SD Degradation

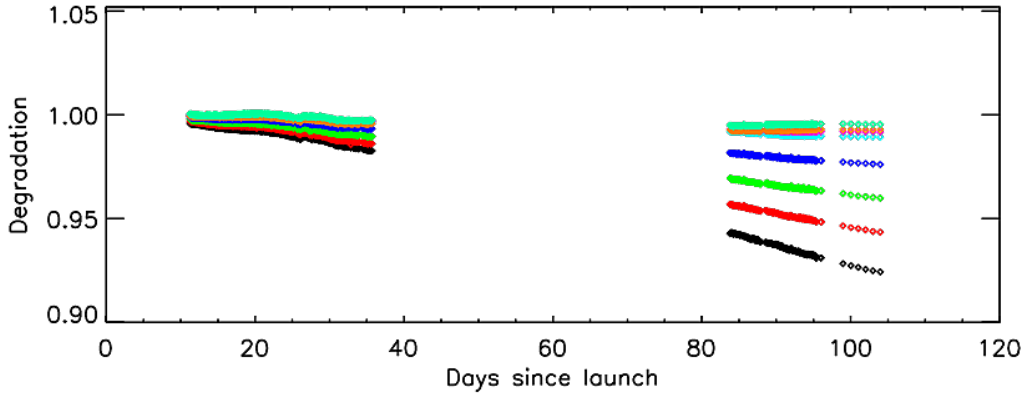
S-NPP VIIRS



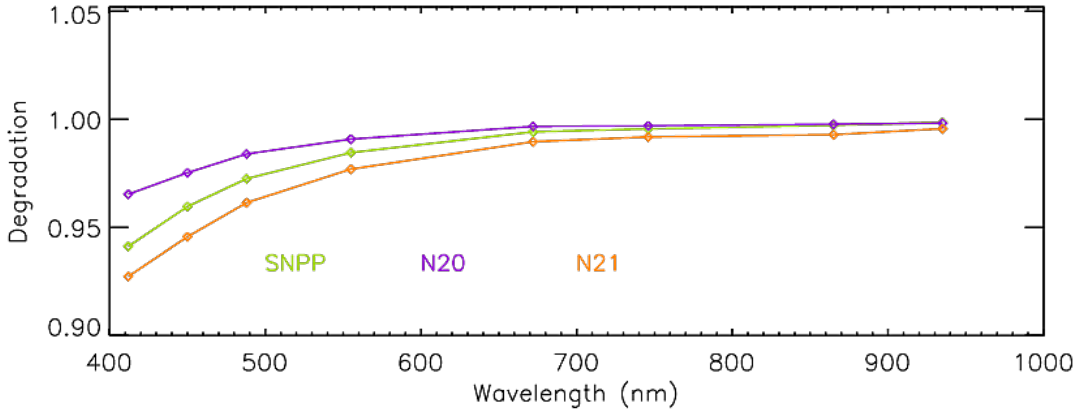
N-20 VIIRS



N-21 VIIRS*



Degradation (day 100) as a function of λ



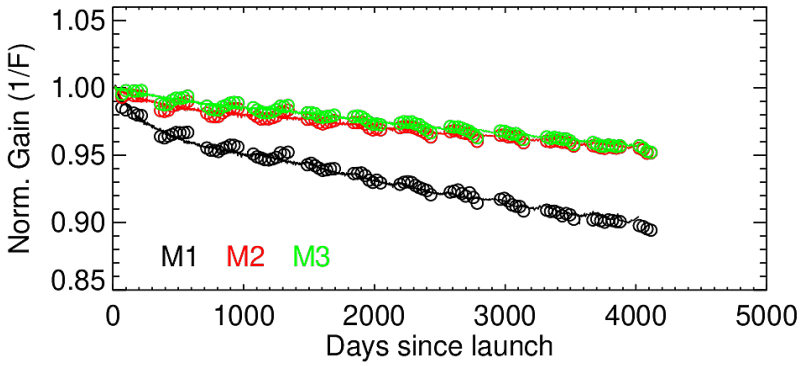
SDSM Detector	D1	D2	D3	D4	D5	D6	D7	D8
VIIRS (μm)	0.412	0.445	0.488	0.555	0.672	0.746	0.865	0.935

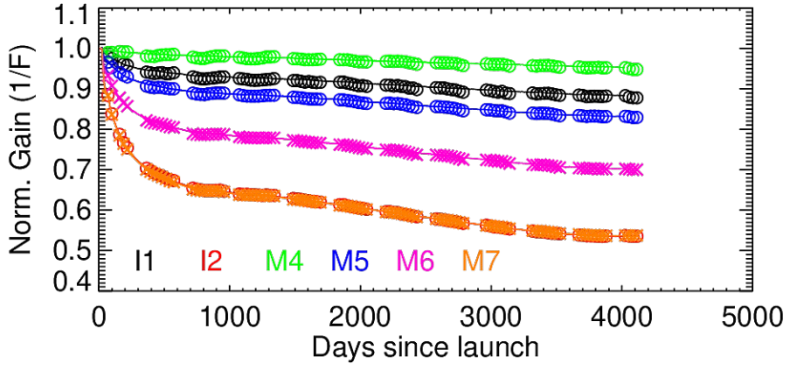
*N21 SD degradation derived using N20 post-yaw screen function. Expected to be refined after the upcoming yaw maneuvers (March, 2023)

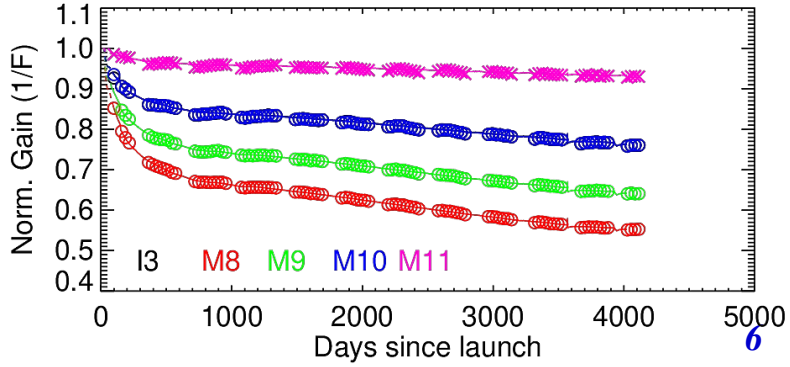
SNPP VIIRS On-orbit Performance

Instrument Operations and RSB Performance – Normal

- VIIRS RSB calibration based on the solar diffuser (SD) with its degradation monitored using the solar diffuser stability monitor (SDSM). Long-term drift in the gain corrected using lunar measurements
- Gain (1/F) decrease at NIR wavelengths due to RTA mirror contamination observed in the early mission and has stabilized in recent years
- SNRs for all RSB detectors continue to meet the specification. SDSM detector gain trends also nominal
- Two recent safe-mode events (Aug 2021 and Aug 2022) resulted in noticeable gain changes (primarily in the SWIR bands). Trends have been stable since those events



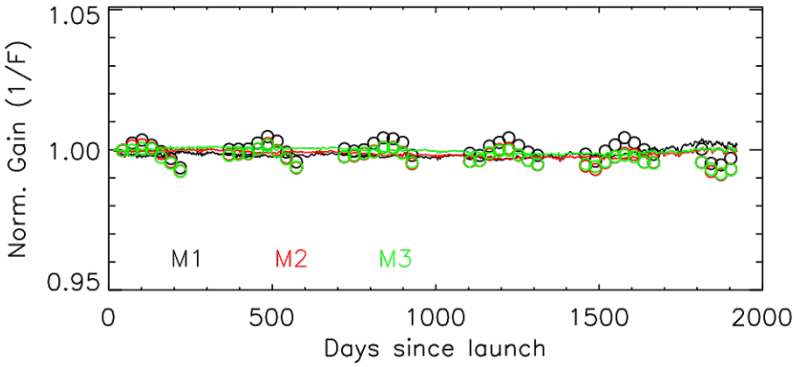


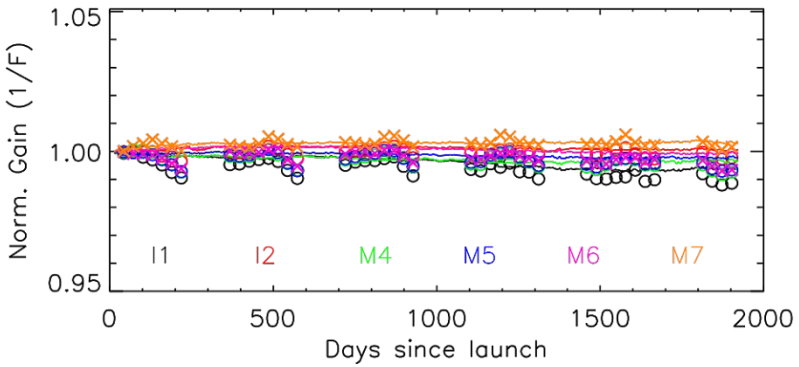


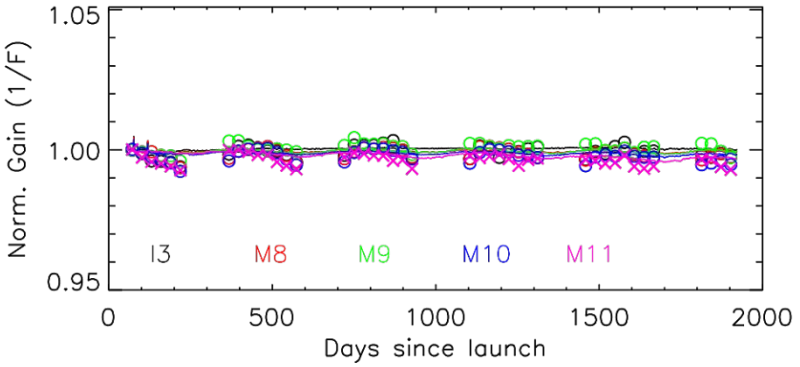
N20 VIIRS On-orbit Performance

Instrument Operations and RSB Performance – Normal

- VIIRS RSB calibration based on the solar diffuser (SD) with its degradation monitored using the solar diffuser stability monitor (SDSM). Long-term drift in the gain corrected using lunar measurements.
- Gain (1/F) has been very stable, with all RSB showing less than 1% change since launch.
- SNRs for all RSB detectors continue to meet the specification.
- N20 SD degradation trends show slightly less degradation compared to the same time period for SNPP. SDSM detector gain trends also nominal.



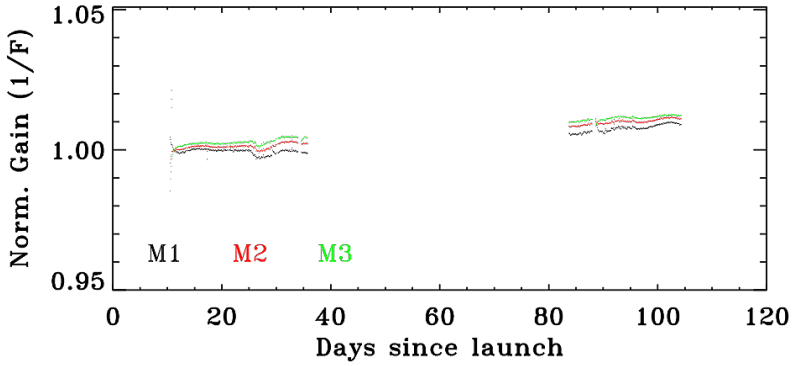


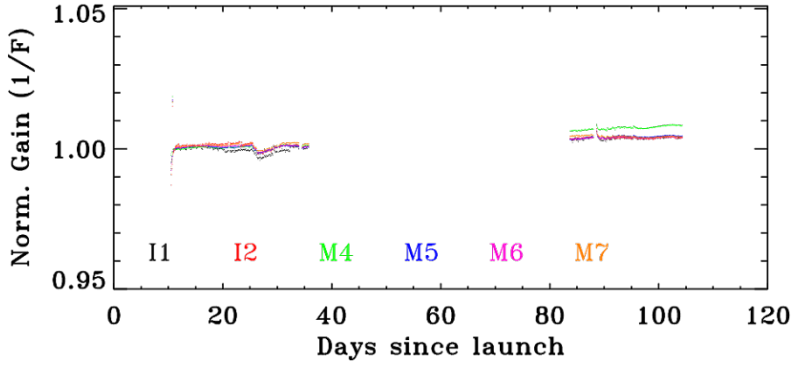


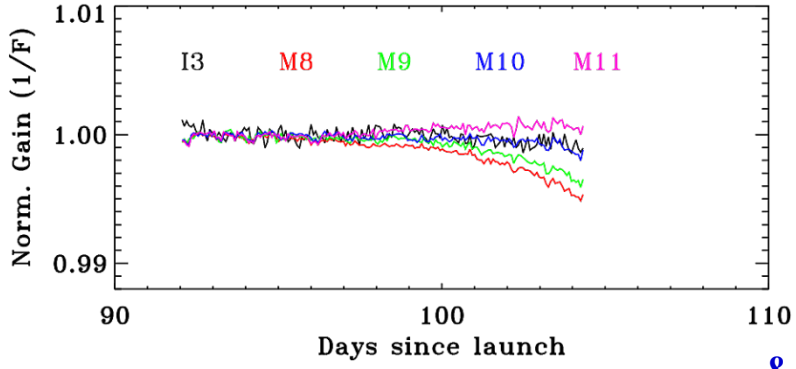
N21 VIIRS On-orbit Performance

Instrument Operations and RSB Performance – Post-launch test phase

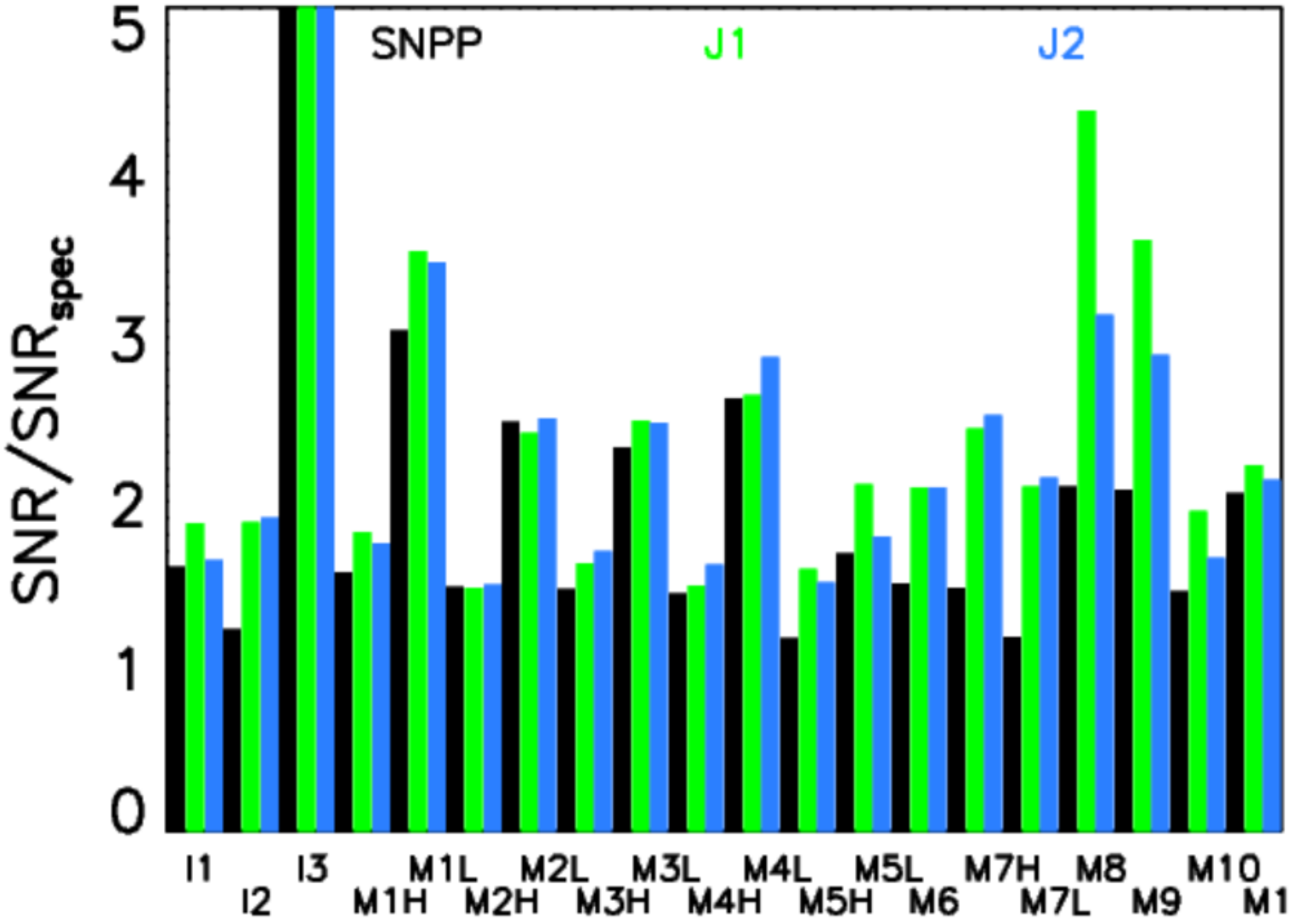
- Initial results indicate comparable performance to SNPP and N20 VIIRS. Initial assessment shows that SNRs for all RSB detectors continue to meet the specification as well as no major gain degradation.
- An anomaly related to the spacecraft Ka-band transmitter led to a hiatus in the data collected as a well as a delay in the opening of the cyro door (SWIR bands operability)
- Calibration data collected during the yaw maneuvers will be used to improve the SD/SDSM screen vignetting functions. After the initial cal/val phase is completed, vicarious calibrations will be performed using various Earth scenes to determine the absolute calibration differences between N21 VIIRS with SNPP and N20.
- Degradation at SWIR wavelengths (also detector dependent) attributed to the possible icing. An MMOG was performed to mitigate the gain drifts







SNR Performance



SNR computed using SD measurements and SNR continues to meet/exceed the specification for all three VIIRS instruments. SNR results plotted above are for Feb, 2023

Performance assessments using vicarious approaches

- Sensor performance assessment inter-comparison is based on vicarious approaches that include SNO and observations over PICS (desert, Dome C) and deep-convective clouds (DCC). SBAF applied using the SCIAMACHY observations
- Long-term stability monitoring indicates that the SNPP and NOAA20 VIIRS reflectances are stable to within 1% over mission for all bands, except for a few short wavelengths from SNPP VIIRS that show more upward drifts in high-radiance conditions.
- Known biases between SNPP and N20 VIIRS RSB (table below). Preliminary results indicate that N21 VIIRS agrees well with N20 VIIRS to within 3% (average of all approaches) for each RSB

Performance assessments using vicarious approaches

SNPP and N20 VIIRS RSB comparison after correction for band spectral differences. Results are provided in ratio (NOAA20/SNPP). Highlighted are from N21* and N20 comparison (N21/N20)

Band	M1	M2	M3	M4	M5	M7	M8	M9	M10	M11	I1	I2	I3
Libya4	0.925 0.996	0.937 0.986	0.956 1.004	0.967 0.974	0.955 1.012	0.973 0.997	0.976 0.990		0.982 0.964	0.983 0.971	0.971 1.007	0.974 1.003	0.970 0.990
DCC	0.933	0.947	0.944	0.932	0.950	0.952	0.982	0.994	0.997	0.981	0.956	0.946	0.975
Dome C	0.917 0.975	0.933 0.972	0.950 0.985	0.953 0.995	0.949 0.986	0.976 0.985					0.967 0.986	0.974 0.986	
Aqua SNO	0.934 0.967	0.941 0.977	0.957 0.990	0.948 0.998	0.951 0.993	0.968 0.982	0.971 1.003		0.970 0.977		0.968 0.997	0.970 0.985	0.961 0.973

Methodology and other details:
Wu et.al, 2022 Remote Sensing

**Results from N21 VIIRS are preliminary based on Libya 4, Dome C and SNO approaches*

VIIRS intercomparison using the Moon

- For a calibration inter-comparison, the measured lunar irradiance from SNPP VIIRS is first divided by the predicted value from the ROLO and then compared to that from N20 VIIRS. Additional corrections for different solar irradiance models required.

- Detailed Talk by Jack Xiong scheduled for March 2 (14:40) in the VIS/NIR Breakout session

Band	M1	M2	M3	M4	I1	M5	M6
WL (μ)	0.41	0.45	0.49	0.56	0.64	0.67	0.75
DIF	3.78	3.41	3.09	3.14	2.41	2.64	2.89
STD	0.50	0.37	0.34	0.33	0.33	0.29	0.28
UC	2.04	2.02	1.95	1.94	1.91	1.95	2.05
Band	I2	M7	M8	M9	I3	M10	M11
WL (μ)	0.87	0.87	1.24	1.38	1.61	1.61	2.25
DIF	2.93	2.95	3.70	2.98	3.30	2.56	2.56
STD	0.17	0.20	0.29	0.33	0.31	0.32	0.45
UC	1.95	1.92	2.02	2.07	2.68	2.01	2.70

Lunar calibration inter-comparison results for SNPP and N20 VIIRS (WL: wavelength; DIF: difference (SNPP—N20); STD: standard deviation; UC: uncertainty). The values are listed as a percentage and the uncertainties were propagated from the values for each instrument/band.

Summary

- Both S-NPP (~12 years) and NOAA-20 (~6 years) VIIRS and their OBC continue to operate and function normally. Initial assessments on NOAA-21 VIIRS show comparable performance with previous VIIRS instruments. Comprehensive evaluation continues through the post-launch test phase.

- Efforts by VCST, including support from SIPS, and science algorithm developers, remain critical to ensure and improve sensor calibration and data quality

- Challenging issues identified for both MODIS and VIIRS will be investigated and addressed for future calibration improvements in support of their data processing/reprocessing

- Continue efforts to understand the calibration differences among sensors (S-NPP and NOAA-20 VIIRS (+ NOAA-21 VIIRS); VIIRS and Aqua MODIS) and to help generate consistent data products of high quality

Backup

VIIRS L1B Data Product Status

- S-NPP L1B C2 is ongoing at Land SIPS – LSIPS Archive Set 5200 using L1B software V3.1 and S-NPP V3 LUT.
- S-NPP L1B C1 is ongoing at Land SIPS for Level-2 downstream process. LSIPS Archive Set 5000 (using SDR Mx software and LUT) and 5110 (using L1B software V2.0 and S-NPP V2 LUT).
- NOAA-20 (JPSS-1) C2.1 is ongoing – LSIPS Archive SET 5201 using L1B software V3.1 and NOAA-20 V3 LUT.
- V3.2 L1B software is available for testing and evaluation (available on the git-server).
- JPSS-2 pre-launch L1B LUT has been delivered to SIPS for testing and it will be updated post-launch.

VIIRS S-NPP L1B Products

- NASA SIPS L1B Products for S-NPP (6-min granule in NetCDF format)
  - VIIRS L1 software/LUT and data design are developed under NASA EDOS/SIPS.
  - Calibrated data files are reduced from 22,000 SDRs to 720 L1Bs daily.
  - First L1B software V1.1.0 was released in Jan 2016 for SIPS evaluation and testing.
  - Software V2.0.0 was officially released in Oct 2016.
  - Software V3.0.0 was officially released in August 2018 for both S-NPP and NOAA-20 (JPSS-1).
  - Software V3.1.0 was officially released in October 2020.

Collection	Code Base	# of LUTs	Delivery Time	Note
C1	L1B V1.1.0	20	2016.02 - 2017.09	Redesigned L1B software, LUTs, and data format using L1A data input.
	L1B V2.0.0	60	2016.08 - 2022.11	* Improved L1B software functions and algorithms. (LSIPS data AS-5110 in NetCDF) * Latest LUT V2.0.0.60 on November 2, 2022.
	L1B V3.0.0-rc	24	2018.01 - 2020.07	Run for both NPP and J1. Add different RTA encoder start value for J1. Modify J1 DNB GEO over extended mode. Introduce M11 process at Ops_Night. Improve M13 radiometric resolution. Add moon phase and illumination for DNB pixel.
C2	L1B V3.0.0	5	2019.11 - 2020.04	* LUT V3.0.0.x: Lunar 6-year data applied to RSB calibration adjustment. * Land SIPS L1B for validation, not officially released.
	L1B V3.0.0	4	2020.05 - 2020.09	* LUT V3.0.1.x: Correct early mission SD Cal on M1/M3 using lunar calibration data. * Land SIPS L1B for validation, not officially released.
C2	L1B V3.1.0	18	2020.10 - 2022.11	* LUT V3.1.0.3 - first LUT using L1B software V3.1.0 officially. LSIPS data AS-5200. * Latest LUT V3.1.0.18 on November 2, 2022.

VIIRS N20 (JPSS1) L1B Products

- NASA SIPS L1B Products for NOAA-20 (JPSS-1)
  - L1B software V3.0.0 was released in August 2018 with full S-NPP and JPSS-1 support.
  - V3.0.0 LUTs updates are being released by VCST with 2 months forward prediction.
  - Land SIPS started JPSS-1 mission reprocessing Collection 2 using V3.0.0 software in June 2019 and completed in September 2019.
  - L1B software V3.1.0 was released in October 2020 for Collection 2.1 reprocessing; forward process ongoing.

Collection	Code Base	# of LUTs	Delivery Time	Note
C1	L1B V3.0.0-rc	8	2018.06 - 2019.05	Run for both NPP and J1. Add diffeerent RTA encoder start value for J1. Modify J1 DNB GEO over extended mode. Introduce M11 process at Ops_Night. Improve M13 radiometric resolution. Add moon phase and illumination for DNB pixel.
C2	L1B V3.0.0	8	2019.06 - 2020.06	* LUT V3.0.0.x Bug fixed in H-factor impacting F-factor for RSB/DNB; mission LUT regenerated. (LSIPS AS-5200)
	L1B V3.0.0	2	2020.07 - 2020.09	* LUT V3.1.0.x Updated pre-launch RVS of all bands (mission LUT). (LSIPS AS-5200)
C2.1	L1B V3.1.0	6	2020.10 - 2022.08	* LUT V3.1.0.3 - first LUT for software V3.1.0. (LSIPS AS-5201). * LUT V3.1.1.1 - first LUT to use N20 Lunar data for RSB calibration. * Latest LUT V3.1.1.3 on August 8, 2022.