NOAA-21 VIIRS Postlaunch On-Orbit Performance and Calibration/Validation Results

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Outline

- Introduction
- NOAA-21 VIIRS geolocation performance
- NOAA-21 VIIRS thermal bands (TEB) performance
- NOAA-21 VIIRS Day-Night/Band (DNB) performance
- NOAA-21 VIIRS solar bands (RSB) performance
- Summary
Introduction

- The Visible Infrared Imaging Radiometer Suite (VIIRS) onboard the NOAA-21 satellite (previously known as JPSS-2) was launched on November 10, 2022.
  - Following the successful operations of the VIIRS on the S-NPP/NOAA-20 satellites.

- There are 22 spectral bands on VIIRS:
  - 14 Reflective Solar Bands (RSB)
    VNIRs: I1-I2 and M1-M7
    SWIRs: I3 and M8-M11
  - 7 Thermal Emissive Bands (TEB)
    MWIRs: I4 and M12-M13
    LWIRs: I5 and M14-M16
  - 1 Day/Night band (DNB, 750m)
    I1-I5 (375m) M1-M16 (750m)

- More than 26 Environmental Data Records (EDRs) are derived from the VIIRS Sensor Data Records (SDR).
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
- **L + 140 (3/30/2023)**: DNB Calibration (new moon)
- **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**
- **1st Delivery of Updated LUTs:** VNIR Cal., GEO
- **VIIRS First Light Images for VNR 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**
Geolocation Performance

- NOAA-21 VIIRS geolocation have been performing well and stable since the post-launch mounting matrix update on January 12, 2023.

Overall uncertainty: 395 m
Meets the 400 m required at the 3-sigma, 99.7%, level.
TEB Gains and MWIR Degradations

- LWIR gains have been generally stable after since March 3, 2023 (CFPA 82 K → 80K).
  - The Feb 23 MMOG was successful.
  - Increases by 4-11% after the switch of CFPA temperatures to 80 K.

- MWIR gains have been continuously degrading since mid-March.
  - Band-averaged degradations up to ~2.8%.
  - Co-incident with the much faster degradations in the SWIR bands (slide #11).

- The impacts on NEdTs/SDRs are negligible so far.

![Graph showing LWIR and MWIR gains and degradations](image-url)
LWIRs agree well with co-located CrIS observed/gap-filled spectra during nominal operations.
- Biases are within ~0.1 K, comparable to NOAA-20 and S-NPP.

The calibration of MWIRs are also stable.
- M13 Bias: ~0.13 K
Operational Corrections of TEB Calibration Biases

- Updated LWIR calibration coefficients have been implemented operationally since June 7, 2023.
  - To mitigate LWIR scan angle and scene temperature dependent biases.

- Warm-Up Cool-Down (WUCD) bias correction coefficients have been developed, will be delivered for operations before the next WUCD.
  - Reduce biases up to 0.05 K ~0.01 K
  - Similar to NOAA-20
DNB Radiometric Calibration Performance

- DNB calibration has been stable after the March 23 LGS gain update.
- NOAA-21 DNB agrees with NOAA-20 within ~1.1%, over DCCs (daytime) and Libya-4 (under moon light).
- Accounted for lunar phase difference with lunar irradiance model, lunar zenith angle and SRF difference.

![Daytime DCC Time Series](image1)

![1st calibration LGS gain update](image2)

![Relative difference](image3)

DNB Radiometric Bias Assessment (Libya-4, under Moon Light)
NOAA-21 DNB stray light is significantly lower than both SNPP/NOAA-20.
- 50% lower in comparison with NOAA-20.

NOAA-21 DNB stray light correction started on March 30, 2023,
- First new moon data: March 21.
- Routinely developed/delivered (over 12 months) for the operational processing.
- Stray lights are effectively removed over both northern and southern hemisphere.
On-Orbit Solar and Scheduled Lunar Derived F-Factors

- VNIR (I1-I2 & M1-M7) gains are stable over time.
- SWIR (I3 and M8-M11) gains are rapidly changing.
  - M8 exhibits the largest degradations.
  - Detector dependent.

M8 Offline SD F-factors

~30% in det #16
8/11/2023
The on-orbit calibration of the VNIR bands have controlled with the F-PREDICTED LUT
- Constant since Jan. 12, 2023.

SWIR calibrations have been updated automatically for every orbit using the RSBAutoCal since Aug. 17, 2023.

To improve radiometric agreements with NOAA-20 VIIRS, bias corrections applied.

SWIR Bias corrections applied
- +1.5% for band I3
- +2.0% for bands M8 and M9
- +2.5% for M10
- +4.0% for M11
RSB SDR Calibration Stability and Biases

- VNIR SDRs have been stable since Jan. 12, 2023
- SWIR SDRs become stable since June 1, 2023.
- NOAA-21 RSBs agree with NOAA-20 VIIRS within the required uncertainty of the absolute radiometric calibration (±2%).

![Daily Deep Convective Cloud (DCC) Time Series](image)

**VNIR**

<table>
<thead>
<tr>
<th></th>
<th>Avg</th>
<th>Std (%)</th>
<th>Trend (±5DCS/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>0.903</td>
<td>0.9</td>
<td>0.07±0.81%</td>
</tr>
<tr>
<td>M2</td>
<td>0.900</td>
<td>0.9</td>
<td>0.13±0.82%</td>
</tr>
<tr>
<td>M3</td>
<td>0.903</td>
<td>0.9</td>
<td>0.07±0.81%</td>
</tr>
<tr>
<td>M4</td>
<td>0.880</td>
<td>1.1</td>
<td>1.3±0.81%</td>
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<tr>
<td>M5</td>
<td>0.900</td>
<td>0.9</td>
<td>0.52±0.82%</td>
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<tr>
<td>M7</td>
<td>0.897</td>
<td>0.7</td>
<td>0.72±0.82%</td>
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<tr>
<td>N1</td>
<td>0.878</td>
<td>1.0</td>
<td>0.27±0.81%</td>
</tr>
<tr>
<td>N2</td>
<td>0.879</td>
<td>0.7</td>
<td>1.00±0.81%</td>
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</table>

**SWIR**

<table>
<thead>
<tr>
<th></th>
<th>Avg</th>
<th>Std (%)</th>
<th>Trend (±5DCS/yr)</th>
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</thead>
<tbody>
<tr>
<td>M1</td>
<td>0.686</td>
<td>2.4</td>
<td>-2.36±2.12%</td>
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<tr>
<td>M2</td>
<td>0.580</td>
<td>1.6</td>
<td>-8.22±1.23%</td>
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<tr>
<td>M3</td>
<td>0.230</td>
<td>2.6</td>
<td>9.74±2.20%</td>
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<tr>
<td>M4</td>
<td>0.351</td>
<td>2.2</td>
<td>10.87±1.97%</td>
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<tr>
<td>M5</td>
<td>0.250</td>
<td>2.4</td>
<td>9.74±2.20%</td>
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</tbody>
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NOAA-21 VIIRS SNR/NEDT

- NOAA-21 VIIRS SNRs/NEdTs have been comparable to NOAA-20/S-NPP.
  - TEB NEdTs well within specifications. LWIR NEdTs further improved after CFPA=80 K.
  - RSB/DNB SNRs meet the requirements.
  - The impacts of on-going S/MWIR degradations are small so far.
Summary

- **NOAA-21 VIIRS instrument have been performing well overall.**
  - Feb 23 MMOG successfully removed potential ice contamination.
  - CFPA temperatures were switched from 82 K to 80 K to further improve the performance.
  - SNRs/NEDTs are well within specifications.
  - LWIR and VNIR gains are generally stable.
  - S/MWIR degradations are closely monitored.

- **NOAA operational NOAA-21 VIIRS SDRs have been generally stable.**
  - Achieved Validated Maturity Status on June 23, 2023 ([https://www.star.nesdis.noaa.gov/jpss/AlgorithmMaturity.php](https://www.star.nesdis.noaa.gov/jpss/AlgorithmMaturity.php)).
  - TEB SDRs agree well with co-located CrIS data; LWIR biases were further reduced; WUCD biases will be mitigated before the next event.
  - DNB stray light has been corrected since March 30, 2023.
  - VNIR SDRs have been stable based on DCC and SNO trending results.
  - SWIR degradations have been timely mitigated by frequent calibration updates; RSBAutoCal was turned on since Aug. 17, 2023.
  - The impacts of S/MWIR degradations are small so far.
DISCLAIMER

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