Status of S-NPP VIIRS On-orbit Calibration

Jack Xiong\textsuperscript{1}, Changyong Cao\textsuperscript{2}, Vincent Chiang\textsuperscript{3}, Jon Fulbright\textsuperscript{3}, Ning Lei\textsuperscript{3}

1. NASA/GSFC; 2. NOAA/STAR; 3. Sigma Space Corp.

Other Contributors: VIIRS Characterization Support Team (VCST)

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Outline

• Background

• On-orbit Operation and Calibration

• On-orbit Performance
  – On-board Calibrators (SD/SDSM and BB)
  – Changes in Spectral Band Responses (or Gains)
  – Changes in Relative Spectral Response (RSR)
  – Detector SNR/NEdT

• Status of VIIRS SDR Code and LUTs

• Summary
Visible/Infrared Imager Radiometer Suite (VIIRS)

- Key instrument on S-NPP and future JPSS satellites
- Spectral bands: 22 (14 RSB, 7 TEB, and 1 DNB)
- Spectral wavelengths: 0.4-12.4 μm
- Spatial resolution: 375 m for I bands and 750 m for M bands and DNB
- Sensor Data Records (SDR): equivalent of MODIS L1B
- Environmental Data Records (EDR): equivalent of MODIS science data products

Strong MODIS Heritage

- Design and on-board calibrators
- Operation and calibration strategies
## VIIRS Spectral Bands and Data Products

### VIIRS 22 Bands
(16 M-Band, 5 I-Band and 1 DNB)

<table>
<thead>
<tr>
<th>VIIRS Band</th>
<th>Spectral Range (um)</th>
<th>Nadir HSR (m)</th>
<th>MODIS Band(s)</th>
<th>Range</th>
<th>HSR</th>
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<tbody>
<tr>
<td>DNB</td>
<td>0.500 - 0.900</td>
<td>750</td>
<td>8</td>
<td>0.405 - 0.420</td>
<td>1000</td>
</tr>
<tr>
<td>M1</td>
<td>0.402 - 0.422</td>
<td>750</td>
<td>9</td>
<td>0.438 - 0.448</td>
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<tr>
<td>M2</td>
<td>0.436 - 0.454</td>
<td>750</td>
<td>3, 10</td>
<td>0.459 - 0.479</td>
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</tr>
<tr>
<td>M3</td>
<td>0.478 - 0.498</td>
<td>750</td>
<td>4 or 12</td>
<td>0.545 - 0.565</td>
<td>500</td>
</tr>
<tr>
<td>M4</td>
<td>0.545 - 0.565</td>
<td>750</td>
<td>1</td>
<td>0.620 - 0.670</td>
<td>250</td>
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<tr>
<td>I1</td>
<td>0.600 - 0.680</td>
<td>375</td>
<td>13 or 14</td>
<td>0.662 - 0.672</td>
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<tr>
<td>M5</td>
<td>0.662 - 0.682</td>
<td>750</td>
<td>15</td>
<td>0.743 - 0.753</td>
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<tr>
<td>M6</td>
<td>0.739 - 0.754</td>
<td>750</td>
<td>2</td>
<td>0.841 - 0.876</td>
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<tr>
<td>I2</td>
<td>0.846 - 0.885</td>
<td>375</td>
<td>16 or 2</td>
<td>0.862 - 0.877</td>
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<tr>
<td>M7</td>
<td>0.846 - 0.885</td>
<td>750</td>
<td>5</td>
<td>SAME</td>
<td>500</td>
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<tr>
<td>M8</td>
<td>1.230 - 1.250</td>
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<td>26</td>
<td>1.360 - 1.380</td>
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<tr>
<td>M9</td>
<td>1.371 - 1.386</td>
<td>750</td>
<td>6</td>
<td>1.628 - 1.652</td>
<td>500</td>
</tr>
<tr>
<td>I3</td>
<td>1.580 - 1.640</td>
<td>375</td>
<td>6</td>
<td>1.628 - 1.652</td>
<td>500</td>
</tr>
<tr>
<td>M10</td>
<td>1.580 - 1.640</td>
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<td>7</td>
<td>2.105 - 2.155</td>
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<tr>
<td>M11</td>
<td>2.225 - 2.275</td>
<td>750</td>
<td>20</td>
<td>3.660 - 3.840</td>
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<tr>
<td>I4</td>
<td>3.550 - 3.930</td>
<td>375</td>
<td>20</td>
<td>SAME</td>
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<tr>
<td>M12</td>
<td>3.660 - 3.840</td>
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<td>21 or 22</td>
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<tr>
<td>M13</td>
<td>3.973 - 4.128</td>
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<td>29</td>
<td>SAME</td>
<td>1000</td>
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<tr>
<td>M14</td>
<td>8.400 - 8.700</td>
<td>750</td>
<td>31</td>
<td>10.780 - 11.280</td>
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<tr>
<td>M15</td>
<td>10.263 - 11.263</td>
<td>750</td>
<td>31 or 32</td>
<td>10.780 - 11.280</td>
<td>1000</td>
</tr>
<tr>
<td>I5</td>
<td>10.500 - 12.400</td>
<td>375</td>
<td>32</td>
<td>11.770 - 12.270</td>
<td>1000</td>
</tr>
<tr>
<td>M16</td>
<td>11.538 - 12.488</td>
<td>750</td>
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<td></td>
<td></td>
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</table>

### VIIRS 20 EDRs
(Land, Ocean, Cloud, Snow)

<table>
<thead>
<tr>
<th>Name of Product</th>
<th>Group</th>
<th>Type</th>
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<tbody>
<tr>
<td>Imagery *</td>
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<tr>
<td>Precipitable Water</td>
<td>Atmosphere</td>
<td>EDR</td>
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<tr>
<td>Suspended Matter</td>
<td>Atmosphere</td>
<td>EDR</td>
</tr>
<tr>
<td>Aerosol Optical Thickness</td>
<td>Aerosol</td>
<td>EDR</td>
</tr>
<tr>
<td>Aerosol Particle Size</td>
<td>Aerosol</td>
<td>EDR</td>
</tr>
<tr>
<td>Cloud Base Height</td>
<td>Cloud</td>
<td>EDR</td>
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<tr>
<td>Cloud Cover/Layers</td>
<td>Cloud</td>
<td>EDR</td>
</tr>
<tr>
<td>Cloud Effective Particle Size</td>
<td>Cloud</td>
<td>EDR</td>
</tr>
<tr>
<td>Cloud Optical Thickness/Transmittance</td>
<td>Cloud</td>
<td>EDR</td>
</tr>
<tr>
<td>Cloud Top Height</td>
<td>Cloud</td>
<td>EDR</td>
</tr>
<tr>
<td>Cloud Top Pressure</td>
<td>Cloud</td>
<td>EDR</td>
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<tr>
<td>Cloud Top Temperature</td>
<td>Cloud</td>
<td>EDR</td>
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<tr>
<td>Active Fires</td>
<td>Land</td>
<td>Application</td>
</tr>
<tr>
<td>Albedo (Surface)</td>
<td>Land</td>
<td>EDR</td>
</tr>
<tr>
<td>Land Surface Temperature</td>
<td>Land</td>
<td>EDR</td>
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<td>Soil Moisture</td>
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<td>Surface Type</td>
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<td>EDR</td>
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<td>Vegetation Index</td>
<td>Land</td>
<td>EDR</td>
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<td>Sea Surface Temperature *</td>
<td>Ocean</td>
<td>EDR</td>
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<tr>
<td>Ocean Color and Chlorophyll</td>
<td>Ocean</td>
<td>EDR</td>
</tr>
<tr>
<td>Net Heat Flux</td>
<td>Ocean</td>
<td>EDR</td>
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<tr>
<td>Sea Ice Characterization</td>
<td>Snow and Ice</td>
<td>EDR</td>
</tr>
<tr>
<td>Ice Surface Temperature</td>
<td>Snow and Ice</td>
<td>EDR</td>
</tr>
<tr>
<td>Snow Cover and Depth</td>
<td>Snow and Ice</td>
<td>EDR</td>
</tr>
</tbody>
</table>

* Product is a Key Performance Parameter (KPP)

Dual gain band

Similar MODIS bands
VIIRS On-board Calibrators (MODIS Heritage)

- Solar Diffuser with Fixed Screen
- Extended SV Port
- Rotating Telescope Aft Optics and HAM
- Blackbody
- Solar Diffuser Stability Monitor
- S-NPP VIIRS I1 Lunar Images
On-orbit Operation and Calibration

Operation and Calibration Activities (Key Events)

- Launch: 10/28/11
- Instrument turn-on: 11/8/11
- Nadir door open: 11/21/11 (first image from VIS/NIR)
- RTA stow (4 times): 12/9/11 – 1/2/12
- Cryo-cooler door open: 1/18/12 (observations from all bands)

- Roll maneuvers: started from 1/4/12 (Lunar calibration)
- Yaw maneuvers: 2/15/12 – 2/16/12 (SD/SDSM screen transmission)
- Pitch maneuvers: 2/20/12 (TEB response versus scan angle)
- OBC calibration activities: SD, SDSM, and BB
Calibration Methodologies

• **Solar Calibration (RSB)**
  - Quadratic calibration algorithm
  - Linear calibration coefficients derived from SD observations
  - SD degradation tracked by SDSM
  - Lunar observation to track RSB calibration stability
    - Regularly scheduled at nearly the same phase angle, implemented via S/C roll maneuvers, observed through SV port with a data sector rotation, referenced to ROLO lunar model

• **BB Calibration (TEB)**
  - Quadratic calibration algorithm
  - Linear calibration coefficients derived from BB observations
On-orbit Performance

• On-board Calibrators
  – SD, SDSM, and BB

• Changes in Spectral Band Response
  – Reflective Solar Bands (RSB) and Thermal Emissive Bands (TEB)

• Changes in Relative Spectral Response (RSR)
  – Modulated RSR for VIS/NIR Bands

• Detector SNR and NedT
SD Degradation

S-NPP VIIRS

Aqua MODIS

Similar to MODIS with strong wavelength dependence

VIIRS has no SD door:
Large degradation in SD BRF at short wavelengths
Changes in Spectral Band Response (RSB)

Little change for HAM side and AOI dependence

Large changes in NIR/SWIR response

Noticeable SD and Lunar calibration difference in VIS (M1-M3)
Mirror Degradation has impact on sensor relative spectral response and radiometric calibration quality
Small orbital variations with similar amplitude for thermistor pairs located at the same scan angle. Thermistors 3 and 6, located at the top of the BB (furthest from the EV), have the largest variation.

\[ \Delta \bar{T}(T_3, T_6) = 0.037 \text{ K} \]
\[ \Delta \bar{T}(T_2, T_5) = 0.011 \text{ K} \]
\[ \Delta \bar{T}(T_1, T_4) = 0.014 \text{ K} \]
\[ \Delta \bar{T}(T_1, T_2, T_3, T_4, T_5, T_6) = 0.014 \text{ K} \]

F-factors at nominal temperature show periodic variations of 0.2%, which are correlated with the BB temperature variations.

Long-term drift is small (< 0.5%)

* For clarity the F-factors are shifted.
Detector SNR (RSB) and NEdT (TEB)

SNR* and NEdT*: normalized to specified values

For RSB: SNR* > 1 means performance better than specified requirements
For TEB: NEdT* < 1 means performance better than specified requirements
Status of VIIRS SDR Code/LUTs

- **IDPS VIIRS SDR Code/LUTs (radiometric)**
  - 6 code versions
  - 9 major LUT updates (weekly updates not included)
  - Improved LUT update strategy (on demand -> weekly -> auto cal)

- **VCST Effort**
  - Independent validation and improvements for SDR code/LUTs
  - Two sets of F-LUTs for VISNIR/SWIR and DNB delivered to Land PEATE for SDR/EDR assessment and reprocess.
    - Jan 31, 2013: LUTs from Jan 2012 to Jan 2013 generated using existing IDPS algorithm but with smoothed functions to remove outliers.
    - Apr 19, 2013: LUTs from Jan 2012 to Mar 2013 generated with “best” sensor characterization improvements, including SD/SDSM screen transmission, SD BRDF, RTA mirrors degradation model, modulated RSRs, and smoothed fitting functions.
Major IDPS SDR Code/LUTs Update Timeline (Radiometric)
The VIIRS SDR team developed the Calibration Knowledge base at https://cs.star.nesdis.noaa.gov/NCC/VIIRS with a wealth of information including user’s guide, relative spectral response, SNO predictions, image gallery, VIIRS Events, publication database, conference presentations, etc.


Reference:

Summary

- VIIRS continues to operate and calibrate satisfactorily (as planned and expected)
  - SD/SDSM, BB (warm-up and cool-down), and lunar calibration activities are regularly performed
  - Changes in sensor response are accurately tracked by the on-board calibrators
  - Calibration LUTs are frequently updated
- Overall on-orbit performance meets the design requirements (such as SNR/NEdT)
- Continuous and dedicated calibration efforts are critical for maintaining SDR data and calibration quality
- The modulated RSRs, as a result of mirror degradation, have been developed and applied to sensor SDR calibration and data production.
MODIS L1B Collection 6 Status

- MODIS L1B Collection 6
  - C6 data processing started Feb, 2012 for Aqua and Aug, 2012 for Terra
  - Products released to public July, 2012 for Aqua and Nov, 2012 for Terra
  - C6 L1B processed data can be downloaded: 
    http://ladsweb.nascom.nasa.gov/
C6 Aqua L1+CloudMask/Atmos Profile data reprocessing started in Feb 2012
C6 Aqua L1+CloudMask/Atmos Profile data forward production started Dataday = June 27, 2012
C6 Aqua L1+CloudMask/Atmos Profile data release date: July 18, 2012

C6 Terra L1+CloudMask/Atmos Profile data reprocessing started in Aug 2012
C6 Terra L1+CloudMask/Atmos Profile forward production started from Dataday = Sept 30, 2012
C6 Terra L1+CloudMask/Atmos Profile data release date: Nov 05, 2012

C6 Atmos reprocessing starting date: early May 2013
C6 Land reprocessing starting date: early July 2013