Status of S-NPP VIIRS On-orbit Calibration

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CERES Science Team Meeting, NASA LaRC, Hampton, VA, May 7-9, 2013
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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</thead>
<tbody>
<tr>
<td>DNB</td>
<td>0.500 - 0.900</td>
<td>1000</td>
<td></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>8</td>
<td>0.405 - 0.420</td>
<td>1000</td>
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<tr>
<td>M2</td>
<td>0.436 - 0.454</td>
<td>750</td>
<td>9</td>
<td>0.438 - 0.448</td>
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<tr>
<td>M3</td>
<td>0.478 - 0.498</td>
<td>750</td>
<td>3 or 10</td>
<td>0.459 - 0.479</td>
<td>500</td>
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<tr>
<td>M4</td>
<td>0.545 - 0.565</td>
<td>750</td>
<td>4 or 12</td>
<td>0.545 - 0.565</td>
<td>500</td>
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<tr>
<td>I1</td>
<td>0.600 - 0.680</td>
<td>375</td>
<td>1</td>
<td>0.620 - 0.670</td>
<td>250</td>
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<tr>
<td>M5</td>
<td>0.662 - 0.682</td>
<td>750</td>
<td>13 or 14</td>
<td>0.662 - 0.672</td>
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<tr>
<td>M6</td>
<td>0.739 - 0.754</td>
<td>750</td>
<td>15</td>
<td>0.743 - 0.753</td>
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<tr>
<td>I2</td>
<td>0.846 - 0.885</td>
<td>375</td>
<td>2</td>
<td>0.841 - 0.876</td>
<td>250</td>
</tr>
<tr>
<td>M7</td>
<td>0.846 - 0.885</td>
<td>750</td>
<td>16 or 2</td>
<td>0.862 - 0.877</td>
<td>1000</td>
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<tr>
<td>M8</td>
<td>1.230 - 1.250</td>
<td>750</td>
<td>5</td>
<td>SAME</td>
<td>500</td>
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<tr>
<td>M9</td>
<td>1.371 - 1.386</td>
<td>750</td>
<td>26</td>
<td>1.360 - 1.390</td>
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<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>
<td>750</td>
<td>6</td>
<td>1.628 - 1.652</td>
<td>500</td>
</tr>
<tr>
<td>M11</td>
<td>2.225 - 2.275</td>
<td>750</td>
<td>7</td>
<td>2.105 - 2.155</td>
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<tr>
<td>I4</td>
<td>3.550 - 3.930</td>
<td>375</td>
<td>20</td>
<td>3.660 - 3.840</td>
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</tr>
<tr>
<td>M12</td>
<td>3.660 - 3.840</td>
<td>750</td>
<td>20</td>
<td>SAME</td>
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<tr>
<td>M13</td>
<td>3.973 - 4.128</td>
<td>750</td>
<td>21 or 22</td>
<td>3.929 - 3.989</td>
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<tr>
<td>M14</td>
<td>8.400 - 8.700</td>
<td>750</td>
<td>29</td>
<td>SAME</td>
<td>1000</td>
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<tr>
<td>M15</td>
<td>10.263 - 11.263</td>
<td>750</td>
<td>31</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>31 or 32</td>
<td>10.780 - 11.280</td>
<td>1000</td>
</tr>
<tr>
<td>M16</td>
<td>11.538 - 12.488</td>
<td>750</td>
<td>32</td>
<td>11.770 - 12.270</td>
<td>1000</td>
</tr>
</tbody>
</table>

*Dual gain band*

### Similar MODIS bands

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

<table>
<thead>
<tr>
<th>Name of Product</th>
<th>Group</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imagery *</td>
<td>Imagery</td>
<td>EDR</td>
</tr>
<tr>
<td>Precipitable Water</td>
<td>Atmosphere</td>
<td>EDR</td>
</tr>
<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>
</tr>
<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>
</tr>
<tr>
<td>Cloud Top Temperature</td>
<td>Cloud</td>
<td>EDR</td>
</tr>
<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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<tr>
<td>Soil Moisture</td>
<td>Land</td>
<td>EDR</td>
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<td>Surface Type</td>
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<td>EDR</td>
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<tr>
<td>Vegetation Index</td>
<td>Land</td>
<td>EDR</td>
</tr>
<tr>
<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>
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<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)
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

Similar to MODIS with strong wavelength dependence

Aqua MODIS

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)
Changes in Relative Spectral Response

Mirror Degradation has impact on sensor relative spectral response and radiometric calibration quality

Modulate RSR has recently applied to SDR Calibration and Data Production
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.

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

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.
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)

- MX6.0 (2011-10-28) S-NPP Launch
- MX6.2 (2012-02-07) SDSM Data Format fix
- MX6.3 (2012-05-07) M13 Low Gain Cal fix; Dual Gain bands Cal fix; Aggr in radiance fix for TEB.
- MX6.2 (2012-08-01) F-predict Implement: Moon-In-SV.
- MX6.3.4 (2012-10-18) Dual gain sticking; MG rollover flagged as saturation; OBC-JP added additional telemetry.
- MX6.7 (2013-03-09) Current: DPS version

Pre-Launch LUTs
- (2011-10-28) Pre-Launch LUTs
- (2012-02-06) First on-orbit F-LUT
- (2012-02-21) Correct RSR
- (2012-02-24) Update BB T_in, fix SDR during cool-down
- (2012-03-01) Correct BB Rep value
- (2012-03-01) SDSM trans-screen

SDS LUTs
- (2012-04-01) SDSM trans-screen LUT
- (2012-08-01) New F-predicted LUT with code change
- (2012-11-07) SDSM trans-screen update

New LUTs to go with RSB
- (2013-03-20) Modulated RSR (Feb 1)

New LUTs to go with RSB Auto Cal
- (2013-08) New LUTs to go with RSB Auto Cal

Weekly F-predicted LUT will be reduced after RSB Auto Cal
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