MODIS and VIIRS VIS/NIR Calibration Status

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Contributions:

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NOAA S-NPP and JPSS VIIRS SDR Calibration Team

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Outline

- Calibration Approaches, Activities, Improvements
- On-orbit Performance
- Challenging Issues and Future Efforts
Calibration Approaches and Activities

Calibration Approaches

MODIS
- SD/SDSM calibration: regularly scheduled (except for Terra since 2003)
- Lunar observations: near-monthly
- Regular (less frequent) SRCA operations (Radiometric: quarterly)
- Ground reference targets, such as PICS, and DCC (validation)

VIIRS
- SD calibration: each orbit
- SDSM: scheduled (more frequently than MODIS)
- Lunar observations: near-monthly
- DNB: monthly VROP operation
- Ground targets for validation

N-20 VIIRS SDSM:
- 11/30/17 to 12/14/17: every orbit
- 12/14/17 to 01/04/18: every other orbit
- 01/05/18 to 02/28/19: once per day
- Currently: once per week
Future considerations:

- Pitch lunar views for VIIRS and Aqua MODIS
- Aqua lunar observations at ~ 51° phase angle
- Off nadir lunar observations
Improvements (MODIS)

- Semi-reprocess of the Terra bands 1 and 2 LUT (2012-2017) per Land Group request
- EV-based RVS implemented for Aqua bands 1-4 to mitigate the long-term reflectance drifts observed in C6.
- Changes in sensor DCR operation to minimize digitization error impact on calibration
- Improvements to L1B Uncertainty Index (part of MODIS L1B data products) – update when necessary
- On-orbit changes of Terra VIS polarization sensitivity are being corrected in several L2 products for ocean, land, and atmosphere (an ongoing effort); no noticeable changes are seen in Aqua MODIS
Improvements (VIIRS)

- VIIRS L1A and L1B SW are developed under NASA EDOS/SIPS. The L1A, L1B, and LUTs data are in NetCDF4 format. Raw data feed via NASA (EDOS).
- L1A granule (6-min) and L1B LUTs are required as input to generate 6-min L1B geolocation and radiometric products, including OBC files for calibration and trending. Daily calibrated data files reduced from 22,000 SDRs to 720 L1Bs.
- **V3.0.0 was officially released in August 2018 for both S-NPP and N20 (J1).**

<table>
<thead>
<tr>
<th>Collection</th>
<th>Code Base</th>
<th># of LUTs</th>
<th>Delivery Time</th>
<th>S-NPP</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>V1.1.0</td>
<td>L1B V1.1.0</td>
<td>20</td>
<td>2016.02 - 2017.09</td>
<td>Redesigned L1B software, LUTs, and data format using L1A data input.</td>
<td></td>
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<tr>
<td>V2.0.0</td>
<td>L1B V2.0.0</td>
<td>29</td>
<td>2016.08 - 2019.02</td>
<td>Improved L1B software functions and algorithms.</td>
<td></td>
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<tr>
<td>V3.0.0</td>
<td>L1B V3.0.0</td>
<td>12</td>
<td>2018.01 - 2019.02</td>
<td>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.</td>
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<tr>
<td>V3.0.0</td>
<td>L1B V3.0.0</td>
<td>5</td>
<td>2018.06 - 2019.02</td>
<td>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.</td>
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On-orbit Performance (VIS/NIR)
MODIS and VIIRS SD Degradation

- SD degradation as a function of wavelength: larger at shorter wavelengths (similar for both MODIS and VIIRS)
  - Smaller degradation in Aqua, followed by N-20, S-NPP, and Terra MODIS
  - VIIRS has no SD door; Terra MODIS SD door fixed at “open” at L+2.5 yr.

- SD degradation as a function of solar exposure time: S-NPP is more closer to T-MODIS and N-20 is more closer to A-MODIS

19 years, 17 years, 7 years, 1 year
Aqua MODIS VIS/NIR Spectral Band Responses (Gains)

SD Calibration (AOI: 50°)

Lunar Calibration (AOI: 11°)

Changes are wavelength, mirror-side, and AOI dependent (RVS)
Large degradation at NIR and SWIR region => modulated RSR
On-orbit Modulated RSR for S-NPP VIIRS

• Large impact for DNB (broad bandwidth)
• Impact for bands with OOB responses

Time dependent Modulated RSR applied to NASA S-NPP L1B (shortly after launch)
• NOAA/STAR will apply this in S-NPP VIIRS mission-long SDR reprocessing
N-20 VIIRS RSB Spectral Band Responses (Gains)

N-20 RSB gains (1/F) from SD (line) and Moon (symbol)

Calibration using both lunar and SD observations needs to be applied for N-20 VIIRS

Much stable than S-NPP for all VIS, NIR, and SWIR spectral bands
On-orbit Performance (RSB)

- **MODIS**
  - Overall Aqua MODIS VIS/NIR performance is better than Terra MODIS
  - SD degradation: large at short wavelengths; Aqua MODIS slower than T-MODIS and VIIRS
  - Spectral band responses: large at VIS and NIR (rate varies), stable for SWIR
  - BBR (tracked using SRCA): stable over the mission
  - Spectral performance: changes are small (0.5-1.0 nm) for most VIS/NIR bands with narrow BW and relatively large for bands with broad BW

- **VIIRS**
  - SD degradation: similar to Terra MODIS; slightly slower in N-20 than S-NPP
  - Spectral band responses: large at NIR and SWIR for S-NPP, very stable for N-20
  - BBR: stable (tracked using lunar observations) for both VIIRS
  - Spectral performance: on-orbit modulated RSR for S-NPP (due to wavelength dependent optical throughput degradation); stable for N-20
Challenging Issues and Future Efforts

- Changes in MODIS VIS/NIR response versus scan-angle (RVS)
- Potential changes in Aqua MODIS (and S-NPP VIIRS) polarization sensitivity (issues identified in Terra MODIS)
- Large SD degradation in VIS bands and no SD degradation monitoring for SWIR bands of both MODIS and VIIRS (modeling effort and vicarious approach)
- **Preparation for C7 and changes of Terra/Aqua SC orbit in 2021/2022**

- Improved use of VIIRS SD and lunar calibration parameters
- Further improvement of N-20 SDSM screen with high quality on-orbit data and H-factor to address its angular dependence (March 2019)
- Updates for S-NPP to address changes occurred on Feb. 24, 2019 (under investigation)
- MODIS and VIIRS calibration consistency and impact on science products, and potentially the differences due to different versions
- **Support NOAA VIIRS SDR reprocessing (strategies and assessments)**

Extensive efforts by NASA MCST/VCST and NOAA SDR team on calibration inter-comparison of Aqua MODIS and S-NPP VIIRS, S-NPP and N-20 VIIRS
Challenging Issues and Future Efforts

N20 and SNPP Reflectance Difference (data from IDPS)

**SNO**
- Pixel-by-pixel match
- 20 x 20 km

**Libya 4 Desert**
- Crossing time (16-D)
  - N20/SNPP: ~11:30
  - A-MODIS: ~11:40

**Dome C**
- Image from NOAA/NCDC
  - Paleoclimatology Program

**DCC**
- Uniform pixel bins
  - $BT(11\mu) < 205K$

**Vicarious Methods**

- M1, M2, M3, M4, M5, M7, I1, I2
- Difference (%)
VIIRS L1B Software V3.0

- Changes in V3.0.0 compared to V2.0.0

V3 software provides full support for VIIRS NOAA-20 (JPSS1)
- Modified scaling and brightness temperature table for M13 to improve radiometric resolution, especially at the low scene level.
- Add moon phase and illumination for each L1B DNB pixel.
- Add lunar calibration option where background data is derived from EV, instead of SV sector, for granules captured during lunar maneuver sector rotation.
- Update DNB geolocation and move RTA and HAM encoder start from hardcoded value to element in GEO LUT.
- Add attitude, position and velocity vectors for the start and end of each scan.
- Update/correct several metadata elements.
- Consolidate files, remove redundant and unused code, reformat code to eliminate duplication and improve maintainability.