Status of MODIS, VIIRS, and OLI Sensors

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Acknowledgements:
NASA MODIS Characterization Support Team (MCST)
NASA VIIRS Characterization Support Team (VCST)
USGS/NASA Landsat Calibration and Validation Team (CVT)
NOAA VIIRS SDR Team

GSiCS Annual Joint Meeting, JAXA, Tsukuba, Japan (29 Feb – 04 March 2016)
Outline

• Background
  – MODIS, VIIRS, and OLI

• On-orbit Calibration
  – Strategies and Activities

• On-orbit Performance
  – Reflective Solar Bands (RSB)

• Status of Sensor L1B Data Products

• Summary
  – Challenging Issues and Future Effort
MODIS on Terra and Aqua
- Terra: Dec. 18, 1999 – Present
- Aqua: May 04, 2002 – Present

VIIRS on S-NPP and JPSS
- S-NPP: Oct. 28, 2011 – Present
- JPSS-1: Launch in early 2017
- JPSS-2: Currently in I&T phase

OLI on L8 and L9
- Landsat 8: Feb 11, 2013 – Present
- Landsat 9: Transition from phase A to phase B in mid 2016
### MODIS, VIIRS, and OLI Spectral Bands

<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></td>
<td></td>
<td></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>
<td>1000</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>
</tr>
<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>
</tr>
<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>
</tr>
<tr>
<td>M5</td>
<td>0.662 - 0.682</td>
<td>750</td>
<td>13 or 14</td>
<td>0.662 - 0.672</td>
<td>1000</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>
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<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>
<td>1000</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>
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<tr>
<td>M11</td>
<td>2.225 - 2.275</td>
<td>750</td>
<td>7</td>
<td>2.105 - 2.155</td>
<td>500</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>
<td>1000</td>
</tr>
<tr>
<td>M12</td>
<td>3.660 - 3.840</td>
<td>750</td>
<td>20</td>
<td>SAME</td>
<td>1000</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>
<td>1000</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>
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<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>

L8 carries a separate TIR sensor (TIRS)

MODIS bands 33-36 with wavelengths above 12 μm
On-orbit Calibration

- **MODIS (Aqua)**
  - SD/SDSM calibration performed weekly first 2.5 years then bi-weekly to tri-weekly; a screen open/close mode for low/high gain bands; SD door opens only during SD/SDSM calibration
  - Monthly SRCA radiometric mode
  - Monthly lunar observations from SV port with phase angles @ -55°

- **VIIRS (S-NPP)**
  - SD calibration performed every orbit (no SD door but with a fixed screen); SDSM operated on a daily basis for first 3.5 years and 3 times/week starting from May 16, 2014 (also with a short duration time)
  - Monthly lunar observations from the SV port with phase angles @ -51°

- **OLI (Landsat 8)**
  - Working lamps daily; backup lamps every 16 days; pristine lamp every 6 months
  - Working diffuser every ~ 8 days; pristine diffuser every 6 months
  - Monthly lunar observation from EV port with phase angles @ +5° to +9°
Instrument On-board Calibrators
On-orbit Performance

- **MODIS (Aqua)**
  - Wavelength-dependent SD degradation - large at short wavelength
  - Large changes in VIS and NIR; small changes in SWIR
  - Changes in sensor responses versus scan-angle (RVS)

- **VIIRS (S-NPP)**
  - Wavelength-dependent SD degradation - Similar to MODIS
  - Large changes in NIR and SWIR (due to mirror contamination)
  - On-orbit modulated RSR (wavelength dependent optics degradation)

- **OLI (Landsat 8)**
  - Only band with significant trend is 443 nm (Coastal Aerosol) ~1 % degradation over 3 years; other bands stable to within ~0.3% or better
  - All calibration techniques (diffusers (2), lamps (3), and lunar) consistent to within 0.3% or better
  - ± 0.5% scatter in SWIR lunar data (apparently a result of lunar irradiance model)
  - Reflectance calibration consistent to within 5% with field (vicarious) measurements (better than 3% for most bands)
SD degradation: strong wavelength dependence
S-NPP VIIRS: no SD door
Aqua MODIS: SD door opens only during SD/SDM calibration
Aqua MODIS Radiometric Responses

**SD View (AOI=50.2°)**

Aqua MODIS VIS (Band–Averaged, MS 1)

**SV View (AOI=11.2°)**

Aqua MODIS VIS (Band–Averaged, MS 1)

**Wavelength, AOI, and Mirror-side dependence; small changes for SWIR bands**
S-NPP VIIRS Radiometric Responses

wavelength dependent optics degradation (large at NIR/SWIR)

On-orbit modulated RSR
Landsat-8 OLI Radiometric Responses

- Landsat-8 OLI Radiometric Responses

  - **OLI CA Band 1 Trends: Band Average**
  - **OLI NIR Band 5 Trends: Band Average**
  - **OLI SWIR2 Band 7 Trends: Band Average**
  - **OLI Cirrus Band 9 Trends: Band Average**

  - Graphs showing trends over time since launch for different bands.
  - Current Cal and Planned Update indicated.

  - Graphs include data points and trend lines for various conditions.

  - Legend includes symbols for different conditions and sources.

  - Time axis in years.

  - Response relative to mission day.

  - Graphs show stability and trends in radiometric responses.
Status of MODIS Level 1B Data Products (C6)

• Collection 6 (C6) L1B products released to public July 2012 for Aqua and Nov 2012 for Terra

• C6 L1B data can be downloaded from:
  http://ladsweb.nascom.nasa.gov/

• New improvements since C6 release
  ✓ Correction applied to reduce Terra B5 (and potentially other SWIR bands) long-term drift as MODIS SDSM can only track SD degradation in VIS and NIR spectral region
  ✓ More bands included the earth view trending at different AOIs for RVS characterization
  ✓ Polarization corrected trending for RVS characterization (under performance evaluation)
Status of S-NPP VIIRS Land SIPS SDR (L1B) Products

- **NASA Land SIPS SDR Code/LUTs and data reprocess (C1.0 and C1.1)**
  - Jan 31, 2013: LUTs from launch to Jan 2013 based on Mx6.3 algorithm with smoothed functions to remove outliers for consistent Land SIPS reprocess Collection 1.0 (C1.0).
  - Dec 23, 2013: LUTs from launch to Nov 2013 based on Mx7.2 algorithm for Land SIPS reprocess C1.1, including on-orbit modulated RSR, the DNB Stray Light Correction algorithm, and improved fitting functions; **starting from C1.1, monthly LUT updates**
- Starting from Nov 2014, same C1.1 LUTs, in Mx8.4 format, have been delivered to Atmosphere SIPS

- **NASA SIPS L1B/LUTs for mission reprocess (V1.1.0) – a joint effort for all SPIS**
  - VIIRS L1A data and L1B software/LUT are developed under NASA EDOS/SIPS.
  - SNPP VIIRS L0 data as the input for L1A, which is the input for L1B software.
  - First L1B software V1.1.0 and LUTs V1.1.0.1 were released in Jan 2016 for SIPS evaluation.
  - LUTs generations are based on corrected solar vector (error fix), on-orbit SD/SDSM screen transmission & SD BRDF, modulated RSR, and consistent fitting methods for mission tables.

- **Data can be downloaded from:** [https://ladsweb.nascom.nasa.gov/](https://ladsweb.nascom.nasa.gov/)
Status of L8 OLI Level 1B Data Products  
(Level 1T in Landsat Lingo)

- USGS is adopting a collection processing strategy for Landsat data. Collection 1 processing of Landsat 4 TM – Landsat-8 OLI scheduled to begin late Spring 2016
- L1T data (radiometrically and geometrically corrected) can be downloaded from:
- Radiometric changes for reprocessing – first collection
  - Update OLI relative gain applicable time periods
  - Update OLI band 1 calibration trend to reflect degradation
  - Provide reflectance based calibration coefficients for Landsat-4 TM ➔ Landsat-7 ETM+ consistent with Landsat-8 OLI
  - Implement TIRS stray light correction
  - Update Landsat-5 TM bands 1 and 3 calibration trend
Status of JPSS-1 VIIRS Calibration and Characterization and Characterization

Pre-launch Calibration and Characterization:

• Component (e.g. mirrors, filters) and sub-system (e.g. SDSM, rotating telescope) level testing

• Sensor level testing
  ✓ Ambient: 08/24/2013 - 01/19/2014
  ✓ Pre-TVAC: 05/16/2014 - 07/16/2014
  ✓ TVAC: 07/16/2014 - 10/30/2014
  ✓ Post-TVAC: 11/24/2014 - 12/15/2014

• Observatory level (integrated with other sensors) testing: April, 2016

Preparation for On-orbit Operation and Calibration (led by NOAA SDR team)

• LUTs development for SDR processing
  ✓ Initial version released in July 2015
  ✓ “at launch” quality LUTs delivered in Dec. 2015 (except for a few DNB LUTs to be developed after SC TVAC testing)
Challenging Issues and Future Efforts

• **MODIS (Aqua):**
  - Large changes in VIS/NIR responses: mirror side, wavelength, and AOI dependent => RVS
  - Potential on-orbit changes in sensor polarization sensitivity (VIS and NIR bands)
  - SD degradation correction for SWIR calibration

• **VIIRS (S-NPP):**
  - Large changes in NIR/SWIR responses: wavelength and time dependent => modulated RSR(t)
  - Large SD degradation (no SD door) and correction for SWIR calibration

• **Future Efforts**
  - Improve MODIS RSB RVS characterization: using ground targets; exploring new methodologies, removing/reducing impact due to polarization
  - Examine S-NPP VIIRS and Aqua MODIS calibration consistency via different approaches and methodologies
  - Assess OLI reflectance-based calibration and radiance-based calibration