Status of MODIS and VIIRS Instruments

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Acknowledgements:
MODIS Characterization Support Team (MCST)
VIIRS Characterization Support Team (VCST)
Outline

• Introduction
  ▪ MODIS and VIIRS Instruments
  ▪ Calibration Approaches

• MODIS and S-NPP VIIRS On-orbit Performance

• MODIS L1B and S-NPP VIIRS SDR (L1B)
  ▪ Calibration Improvements

• Summary
Introduction

• MODIS on Terra and Aqua Missions
  – Terra: Dec. 18, 1999 – Present
  – Aqua: May 04, 2002 – Present

• VIIRS on S-NPP and JPSS Missions
  – JPSS-1 (now NOAA 20): Nov. 18, 2017 – Present
  – JPSS-2: Launch March 2022
  – JPSS-3/4: Launch 2026/2031
Background

**MODIS**
- Key instruments for NASA EOS Terra and Aqua
- Spectral bands: 20 reflective solar bands (RSB) and 16 thermal emissive bands (TEB)
- Spectral wavelengths: 0.4-14.5 μm
- Spatial resolutions: 250 m (2 bands), 500 m (5 bands), and 1 km (29 bands)

**VIIRS**
- Key instruments for SNPP and JPSS
- Spectral bands: 14 reflective solar bands (RSB), 7 thermal emissive bands (TEB), and 1 day night band (DNB)
- Spectral wavelengths: 0.4-12.4 μm
- Spatial resolutions: 375 m for I bands; 750 m for M bands and DNB
Response versus scan-angle (RVS) for MODIS RSB derived using a combination of solar, lunar, and desert response trends.
VIIRS On-orbit Calibration Methodologies

VIIRS on-orbit operation and calibration are based on the experience and lessons from MODIS.

Current SDSM operation frequency: N20 (weekly), SNPP (weekly). Reduced from at-launch operation frequency.
MODIS On-orbit Performance

• **Terra MODIS**
  – Terra MODIS: Stable FPA and Inst. temperatures
  – SD degradation: wavelength-dependent (larger at shorter wavelengths; faster with more solar exposure after the July 2003 SD door anomaly)
  – Terra PV LWIR improvements (electronic crosstalk), restored performance of several noisy detectors
  – Impacts of polarization sensitivity changes for short wavelength bands

• **Aqua MODIS**
  – Aqua MODIS: Stable FPA and Inst. temperatures
  – SD degradation: wavelength-dependent but slower than Terra MODIS
  – Improvement in the long-term stability of bands 1-4 (C6.1) after the EV-based RVS corrections
VIIRS On-orbit Performance

• SNPP VIIRS
  – The FPA (VIS/NIR, LWIR): stable, SMIR CFPA temperature increased by 50 mK since launch, BB: very stable
  – SD degradation: wavelength dependent, faster than Aqua MODIS
  – Early mission detector gain decrease in the NIR/SWIR bands has leveled off; TEB gains remain stable

• NOAA-20 VIIRS
  – VIS/NIR FPA temperature stable; CFPA temperature: stable; BB: very stable
  – SD degradation: slightly smaller than S-NPP
  – SNRs exceed requirements except N20 band I3 detector 29 (noisy since prelaunch)
  – RSB detector gains remain stable, TEB gains recovered and remain stable after the mid-mission outgassing
  – DNB stray light correction for both S-NPP and NOAA-20
Aqua MODIS VIS/NIR Radiometric Responses

**SD View (AOI=50.2°)**

**Space View (AOI=11.2°)**

Similar λ, AOI, and mirror side dependence for Terra MODIS VIS and NIR responses
Terra MODIS Radiometric Responses

Amplified impacts due to electronic crosstalk in PV LWIR bands after Feb, 2016 safe-hold
MODIS and VIIRS show similar wavelength dependent SD degradation

- Terra MODIS: SD door kept at open since 2003 (1999-present)
- Aqua MODIS: SD door opens only during SD/SDM calibration (2002-present)
- S-NPP VIIRS: no SD door (2011 to present)
- NOAA-20 VIIRS: no SD door (2017 to present)
Large changes in SNPP VIIRS NIR/SWIR responses due to telescope mirror degradation ➔ on-orbit modulated RSR
Excellent stability for S-NPP VIIRS TEB responses – similar to Aqua MODIS. MODIS has more TEB bands with wavelengths up to 14.5 μm
Status of MODIS Level 1B Data Products (C6 and C6.1)

- Collection 6 (C6) L1B products released to public July 2012 for Aqua and Nov 2012 for Terra
- Collection 6.1 (C6.1) L1B products released to public October 15, 2017
- C6 and C6.1 L1B data can be downloaded from:
  http://ladsweb.nascom.nasa.gov/
- New improvements in C6.1 release
  - Terra MODIS PV LWIR crosstalk correction applied for bands 27-30
  - Updated QA flagging for several PV LWIR detectors (crosstalk correction restores the performance of detectors)
  - Improved response versus scan-angle (RVS) characterization for Aqua MODIS bands 1-4
Calibration Improvements since the C6.1 release

• Terra MODIS SWIR band calibration: To mitigate the impact of the electronic crosstalk, a switch in the TEB sending band from 28 to band 25 has been formulated and implemented.
  • *Results show improved quality of the calibration coefficients and EV calibrated imagery. The implementation is planned in forward C6.1 and the entire mission reprocess using this approach will be done in a future reprocess*

• Terra MODIS VIS band polarization impacts
• Improved algorithm for Terra and Aqua SWIR SD degradation
Terra SWIR xtalk improvements

• MODIS SWIR bands (5-7 and 26) have a known issue related to electronic crosstalk and OOB leak identified during prelaunch characterization
  – A correction with its coefficients derived from the night-time-day-mode acquisitions has been applied since early mission. Correction employs band 28 as sending band (Aqua MODIS uses band 25 as sending)

• After the Feb 2016 safe mode, the response of the Terra MODIS PV LWIR bands showed increased impacts due to electronic crosstalk

• Evaluated multiple options to improve mitigation of SWIR xtalk
  – Use band 25 as sending band in Terra MODIS SWIR correction

Terra SWIR xtalk improvements

- Band 7 shows smoother $m_1$ trends and less detector striping for images after 2016 safe mode
- Bands 5 and 6 show similar improvements
Terra Polarization correction

MCST approach for next Collection

Gain ($m_1/RVS$) derived from desert trends

- Derive BRDF corrected reflectance, $\rho_{BRDF}$, for desert using first few years of data and the time-dependent OBPG polarization coefficients $m_{12}$ and $m_{13}$
- Then derive the gain from the measured $dn^*$ and the polarization and BRDF corrected desert reflectance

$$gain = \frac{dn^* d_{ES}^2 / \cos(\theta)}{\rho_{BRDF} + m_{12}Q + m_{13}U}$$
Status of S-NPP VIIRS SDR (NASA SIPS Support)

- **Land SIPS SDR reprocess using IDPS Code with VCST LUTs (C1.0 and C1.1)**
  - IDPS SDR/EDR codes Mx based version with LUTs input from VCST.
  - 71 sets of LUTs for RSB (and DNB) have been delivered to Land SIPS for data reprocessing and SDR/EDR assessments in Collections 1.0 and 1.1.

<table>
<thead>
<tr>
<th>Collection</th>
<th>Code Base</th>
<th># of LUTs</th>
<th>Period (Year.Month)</th>
<th>Improvements</th>
</tr>
</thead>
<tbody>
<tr>
<td>LPEATE Early</td>
<td>Mx6.3</td>
<td>5</td>
<td>2012.10 - 2013.01</td>
<td>Smoothed functions for SD degradation H-factor and calibration coefficients F-factor.</td>
</tr>
<tr>
<td></td>
<td>Mx6.4</td>
<td>5</td>
<td>2013.04 - 2013.11</td>
<td>Updated SD/SDSM screen transmission, SD BRDF, RTA mirrors degradation model, and modulated RSRs.</td>
</tr>
<tr>
<td>LPEATE C1</td>
<td>Mx7.2</td>
<td>25</td>
<td>2013.12 - 2016.02</td>
<td>Improved time-dependent modulated RSR, DNB stray light correction, H &amp; F fitting functions. (LSIPS data AS3110)</td>
</tr>
<tr>
<td>LSIPS C1</td>
<td>Mx8.11</td>
<td>36</td>
<td>2016.03 - 2019.05</td>
<td>Improved Quality Flags, introduced DNB gain ratio and LGS LUTs, fixed solar/lunar vectors, with RSBAutoCal option. (LSIPS data AS5000)</td>
</tr>
</tbody>
</table>

- **Atmosphere SIPS SDR reprocess using IDPS Code with VCST LUTs**
  - Mission data reprocessing VIIRS SDR/EDR using Mx8.4 software in late 2014.
  - 9 sets of LUTs based on Mx8.4 code format have been delivered (Nov 2014 - Feb 2016) – same quality as those sent to Land C1.1.
### Status of S-NPP VIIRS L1B (NASA SIPS Support)

**NASA SIPS L1B Software**

- VIIRS L1A and L1B software/LUT and data design are developed under NASA EDOS/SIPS.
- VIIRS L0 data as the input for L1A software => 6-min L1A data.
- L1A and L1B calibration LUTs are the input for L1B software => Geolocation and L1B products including OBC. Calibrated data files are reduced from 22,000 SDRs to 720 L1Bs daily.
- First L1B software V1.1.0 was released in Jan 2016 for SIPS evaluation and testing.
- V2.0.0 was officially released in Oct 2016.
- V3.0.0 was officially released in August 2018 for both S-NPP and NOAA-20 (JPSS-1).
- LUTs generations are based on corrected solar vector (error fix), on-orbit SD/SDSM screen transmission & SD BRDF, modulated RSR, and consistent fitting of mission data.
- Data can be downloaded from: [http://ladsweb.nascom.nasa.gov/](http://ladsweb.nascom.nasa.gov/)

<table>
<thead>
<tr>
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<th>Code Base</th>
<th># of LUTs</th>
<th>Period (Year.Month)</th>
<th>Improvements</th>
</tr>
</thead>
<tbody>
<tr>
<td>LSIPS Testing</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>
</tr>
<tr>
<td>LSIPS C1</td>
<td>L1B V2.0.0</td>
<td>31</td>
<td>2016.08 - 2019.05</td>
<td>Improved L1B software functions and algorithms. (LSIPS data AS5110)</td>
</tr>
<tr>
<td>LSIPS Evaluation</td>
<td>L1B V3.0.0</td>
<td>14</td>
<td>2018.01 - 2019.05</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>
</tr>
</tbody>
</table>
**Status of N20 VIIRS L1B (NASA SIPS Support)**

- **NASA SIPS L1B for NOAA-20 (JPSS1)**
  - L1B software V3.0.0-rc (release candidate versions 1-6) were released between Dec 2017 and July 2018 for SIPS evaluation and testing by using N20 pre-launch LUTs.
  - V3.0.0 was released in August 2018 with full NOAA-20 (JPSS1) and S-NPP support.
  - V3.0.0 LUTs updates have been released by VCST with 2 months forward prediction.
  - Land SIPS plans to reprocess N20 mission using V3.0.0 software in May 2019.
  - The improvements in the N20 LUTs include on-orbit SD/SDSM screen transmission & SD BRDF and consistent fitting of mission data.

<table>
<thead>
<tr>
<th>Collection</th>
<th>Code Base</th>
<th># of LUTs</th>
<th>Period (Year.Month)</th>
<th>Improvements</th>
</tr>
</thead>
<tbody>
<tr>
<td>LSIPS Evaluation</td>
<td>L1B V3.0.0</td>
<td>6</td>
<td>2018.06 - 2019.04</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. (LSIP data AS3194)</td>
</tr>
</tbody>
</table>
S-NPP VIIRS L1B RSB Calibration for Collection 2

- NASA SIPS L1B for NOAA-20 (JPSS1)
  - Use the correct Delta-C table consistent in F-Predicted LUT and in L1B software. Use a fixed c0=0. Impact as up to 0.5%. Largest in bands I1, I2, M4 and M5. No impact on M1, M2, M8-M11.
  - Solar Diffuser (SD) degradation H-factors are adjusted by solar azimuth angular dependence for all Reflective Solar Bands (RSB) with impact up to 0.25%. The SD positional dependence is also applied to H-factor to reduce Earth View striping, with impact by up to 0.8%.
  - Apply 6 years lunar calibration data to adjust H-factor RTA view, with impact as large as 0.5% in band M1.
  - Noisy detector quality flags are included in L1B.
  - Uncertainly index to be applied in L1B.
N20 VIIRS Screen Characterization Improvements

Collection 2 Improvement
SDSM screen BRDF*tau supplementing the yaw measurements with on-orbit measurements to achieve a better characterization
DNB Stray Light Correction

S-NPP: 08:35:00, 07/13/18 (N. America)  N-20: 07:44:45, 07/13/18 (N. America)

S-NPP: 08:35:00, 07/13/18 (N. America)  N-20: 07:44:45, 07/13/18 (N. America)
Summary

• Both Terra (19 years) and Aqua (17 years) MODIS and their OBC continue to operate and function normally
• Both S-NPP (~8 years) and NOAA-20 (~1.5 years) VIIRS and their OBC continue to operate and function normally
• Efforts by MCST and VCST, including support from SDST, SIPS, and science algorithm developers, remain critical to ensure and improve sensor calibration and data quality
• Challenging issues identified for both MODIS and VIIRS will be investigated and addressed for future calibration improvements in support of their data processing/reprocessing
• More efforts are needed to better understand the calibration differences among sensors and to help generate consistent data products of high quality
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- Amit Angal: (amit.angal@ssaihq.com)
- Vincent Chiang: (vincent.chiang@ssaihq.com)
Backup Slides
# Key Design Requirements of MODIS Spectral Bands

<table>
<thead>
<tr>
<th>Primary Use</th>
<th>Band</th>
<th>Bandwidth (nm)</th>
<th>Spectral Radiance</th>
<th>Required SNR</th>
<th>Primary Use</th>
<th>Band</th>
<th>Bandwidth (µm)</th>
<th>Spectral Radiance</th>
<th>Required NE T(K)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Land/Cloud/Aerosols Boundaries</strong></td>
<td>1</td>
<td>620 - 670</td>
<td>21.8</td>
<td>128</td>
<td><strong>Surface/Cloud Temperature</strong></td>
<td>20</td>
<td>3.660 - 3.840</td>
<td>0.45 (300K)</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>841 - 876</td>
<td>24.7</td>
<td>201</td>
<td></td>
<td>21</td>
<td>3.929 - 3.989</td>
<td>2.38 (335K)</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>459 - 479</td>
<td>35.3</td>
<td>243</td>
<td></td>
<td>22</td>
<td>3.929 - 3.989</td>
<td>0.67 (300K)</td>
<td>0.07</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>545 - 565</td>
<td>29</td>
<td>228</td>
<td></td>
<td>23</td>
<td>4.020 - 4.080</td>
<td>0.79 (300K)</td>
<td>0.07</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>1230 - 1250</td>
<td>5.4</td>
<td>74</td>
<td></td>
<td>24</td>
<td>4.433 - 4.498</td>
<td>0.17 (250K)</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>1628 - 1652</td>
<td>7.3</td>
<td>275</td>
<td></td>
<td>25</td>
<td>4.482 - 4.549</td>
<td>0.59 (275K)</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>2105 - 2155</td>
<td>1</td>
<td>110</td>
<td><strong>Cirrus Clouds Water Vapor</strong></td>
<td>26</td>
<td>1.360 - 1.390</td>
<td>6</td>
<td>150 (SNR)</td>
</tr>
<tr>
<td><strong>Land/Cloud/Aerosols Properties</strong></td>
<td>8</td>
<td>405 - 420</td>
<td>44.9</td>
<td>880</td>
<td></td>
<td>27</td>
<td>6.535 - 6.895</td>
<td>1.16 (240K)</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>438 - 448</td>
<td>41.9</td>
<td>838</td>
<td></td>
<td>28</td>
<td>7.175 - 7.475</td>
<td>2.18 (250K)</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>483 - 493</td>
<td>32.1</td>
<td>802</td>
<td><strong>Cloud Properties</strong></td>
<td>29</td>
<td>8.400 - 8.700</td>
<td>9.58 (300K)</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>526 - 536</td>
<td>27.9</td>
<td>754</td>
<td></td>
<td>30</td>
<td>9.580 - 9.880</td>
<td>3.69 (250K)</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>546 - 556</td>
<td>21</td>
<td>750</td>
<td><strong>Surface/Cloud Temperature</strong></td>
<td>31</td>
<td>10.780 - 11.280</td>
<td>9.55 (300K)</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>662 - 672</td>
<td>9.5</td>
<td>910</td>
<td></td>
<td>32</td>
<td>11.770 - 12.270</td>
<td>8.94 (300K)</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>673 - 683</td>
<td>8.7</td>
<td>1087</td>
<td></td>
<td>33</td>
<td>13.185 - 13.485</td>
<td>4.52 (260K)</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>743 - 753</td>
<td>10.2</td>
<td>586</td>
<td><strong>Cloud Top Altitude</strong></td>
<td>34</td>
<td>13.485 - 13.785</td>
<td>3.76 (250K)</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>862 - 877</td>
<td>6.2</td>
<td>516</td>
<td></td>
<td>35</td>
<td>13.785 - 14.085</td>
<td>3.11 (240K)</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>890 - 920</td>
<td>10</td>
<td>167</td>
<td></td>
<td>36</td>
<td>14.085 - 14.385</td>
<td>2.08 (220K)</td>
<td>0.35</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>931 - 941</td>
<td>3.6</td>
<td>57</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>19</td>
<td>915 - 965</td>
<td>15</td>
<td>250</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 Spectral Radiance values are (W/m²-µm-sr)

20 reflective solar bands (RSB) and 16 thermal emissive bands (TEB)
<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>
</tr>
</thead>
<tbody>
<tr>
<td>DNB</td>
<td>0.500 - 0.900</td>
<td></td>
<td></td>
<td>8</td>
<td>0.405 - 0.420</td>
</tr>
<tr>
<td>M1</td>
<td>0.402 - 0.422</td>
<td>750</td>
<td></td>
<td>8</td>
<td>0.405 - 0.420</td>
</tr>
<tr>
<td>M2</td>
<td>0.436 - 0.454</td>
<td>750</td>
<td></td>
<td>9</td>
<td>0.438 - 0.448</td>
</tr>
<tr>
<td>M3</td>
<td>0.478 - 0.498</td>
<td>750</td>
<td></td>
<td>3 or 10</td>
<td>0.459 - 0.479</td>
</tr>
<tr>
<td>M4</td>
<td>0.545 - 0.565</td>
<td>750</td>
<td></td>
<td>4 or 12</td>
<td>0.545 - 0.565</td>
</tr>
<tr>
<td>I1</td>
<td>0.600 - 0.680</td>
<td>375</td>
<td></td>
<td>1</td>
<td>0.620 - 0.670</td>
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<tr>
<td>M5</td>
<td>0.662 - 0.682</td>
<td>750</td>
<td></td>
<td>13 or 14</td>
<td>0.662 - 0.672</td>
</tr>
<tr>
<td>M6</td>
<td>0.739 - 0.754</td>
<td>750</td>
<td></td>
<td>15</td>
<td>0.743 - 0.753</td>
</tr>
<tr>
<td>I2</td>
<td>0.846 - 0.885</td>
<td>375</td>
<td></td>
<td>2</td>
<td>0.841 - 0.876</td>
</tr>
<tr>
<td>M7</td>
<td>0.846 - 0.885</td>
<td>750</td>
<td></td>
<td>16 or 2</td>
<td>0.862 - 0.877</td>
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<tr>
<td>M8</td>
<td>1.230 - 1.250</td>
<td>750</td>
<td></td>
<td>5</td>
<td>SAME</td>
</tr>
<tr>
<td>M9</td>
<td>1.371 - 1.386</td>
<td>750</td>
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<td>26</td>
<td>1.360 - 1.390</td>
</tr>
<tr>
<td>I3</td>
<td>1.580 - 1.640</td>
<td>375</td>
<td></td>
<td>6</td>
<td>1.628 - 1.652</td>
</tr>
<tr>
<td>M10</td>
<td>1.580 - 1.640</td>
<td>750</td>
<td></td>
<td>6</td>
<td>1.628 - 1.652</td>
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<td>M11</td>
<td>2.225 - 2.275</td>
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<td>7</td>
<td>2.105 - 2.155</td>
</tr>
<tr>
<td>I4</td>
<td>3.550 - 3.930</td>
<td>375</td>
<td></td>
<td>20</td>
<td>3.660 - 3.840</td>
</tr>
<tr>
<td>M12</td>
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<td>750</td>
<td></td>
<td>20</td>
<td>SAME</td>
</tr>
<tr>
<td>M13</td>
<td>3.973 - 4.128</td>
<td>750</td>
<td></td>
<td>21 or 22</td>
<td>3.929 - 3.989</td>
</tr>
<tr>
<td>M14</td>
<td>8.400 - 8.700</td>
<td>750</td>
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<td>29</td>
<td>SAME</td>
</tr>
<tr>
<td>M15</td>
<td>10.263 - 11.263</td>
<td>750</td>
<td></td>
<td>31</td>
<td>10.780 - 11.280</td>
</tr>
<tr>
<td>I5</td>
<td>10.500 - 12.400</td>
<td>375</td>
<td></td>
<td>31 or 32</td>
<td>10.780 - 11.280</td>
</tr>
<tr>
<td>M16</td>
<td>11.538 - 12.488</td>
<td>750</td>
<td></td>
<td>32</td>
<td>11.770 - 12.270</td>
</tr>
</tbody>
</table>

1 DNB: L/M/HG
32 Agg. Modes
14 RSB: 0.41-2.3 μm
7 DGB: M1-M5, M7, and M13
7 TEB: 3.7-12.1 μm