MODIS Calibration Workshop

Jack Xiong
Biospheric Sciences Branch 614.4, NASA/GSFC

and

MODIS Characterization Support Team (MCST)

MODIS Calibration Workshop, Lanham, MD 20706 (January 25, 2010)
SSAI 5th Floor Layout

Conference Room

Men

Ladies

Copy Room

Library & Conference Room 2106

Conference Room 2107

Fax

Copy Room

Front Desk

Ladies

Conference Room

Copy Room

Fax

Conference Room 2105

Coffee

Library & Conference Room 2106

Elevator

Building Maintenance

File Storage Room

Copy Room 2109

MCST

Telephones
Logistics

- Badge (sign-in at front desk)
- Restroom (keys available at front desk)
- Breaks (lunch and coffee)
- Copy and Fax (available upon request)
- Dial in # for both MODIS and VIIRS Workshops
  1-866-600-2258; PC: 444018

- Wireless Guest Network
  SSID:
  WPA Key:

Guest Network Login Page:
  User ID:
  Password:
MCST Contacts

- Instrument Operation: Jennifer Dodd / Gavin Westenburger
- L1B and LUT: James Kuyper
- RSB Calibration: Junqiang Sun / Hongda Chen
- TEB Calibration: Tiejun Chang / Aisheng Wu
- Spectral and Spatial: Jason Choi
- General Information: Brian Wenny / Jack Xiong

New Website: http://mcst.gsfc.nasa.gov/ (online but undergoing development)
- Information on MODIS Instrument Status, Calibration, and L1B Code & LUTs
- L1B ATBD, MCST Publications, and Workshop Presentations

Contact Brian Wenny or other MCST members for specific requests
Acknowledgements

• MCST Groups: IOT, L1B/LUT, and Calibration
• MODIS Science Team
  – Science Team Leader (Vince Salomonson and Michael King)
  – Land (Eric Vermote and Zhengming Wan)
  – Ocean (Gerhard Meister et al.)
  – Atmosphere (Chris Moeller et al.)
  – Cal/Val (Stu Biggar et al.)
• Raytheon MODIS Team
  – Raytheon SAS (Space and Airborne Systems) at El Segundo
• Others
  – Bill Barnes, Bruce Guenther, Eugene Waluschka, and Robert Wolfe

Special Thanks to Sigma Space Co (SSC) and Science Systems and Applications, Inc. (SSAI)
**Agenda**

- **Instrument Operation, Calibration, and Performance**
  - Introduction (Jack Xiong) 9:00 am
  - Instrument Operation Status (Jennifer Dodd) 9:15 am
  - Status of L1B Algorithm and LUT Updates (James Kuyper) 9:25 am
  - RSB Calibration and Performance (Junqiang Sun) 9:35 am
  - TEB Calibration and Performance (Tiejun Chang) 10:05 am
  - Spatial and Spectral Performance (Jason Choi) 10:30 am
  - **Coffee Break** 10:40 am
  - Collection 6 Issues (Brian Wenny) 10:55 am
  - Geo-location Characterization and Performance (Robert Wolfe) 11:20 am

- **Science Discipline Presentations**
  - Ocean Presentation (Gerhard Meister/Gene Eplee) 11:35 am
  - Land Presentation (Eric Vermote) 11:55 am
  - Atmosphere Presentation (Chris Moeller/Steve Platnick) 12:10 pm
  - **Adjourn** 12:30 pm
Introduction

• Instrument and Calibration Background
  - On-orbit Calibration Activities
  - Calibration Methodologies

• Key Instrument Telemetry Trending
  - Instrument temperature
  - FPA temperature
  - Blackbody

• Summary of Instrument Performance
MODIS

- MODIS
  - On both Terra and Aqua
  - 36 spectral bands (0.41-14.4 µm)
  - 4 focal plane assemblies (FPA)
  - 3 spatial resolutions (Q/H/1km)

- MODIS On-orbit Calibration
  - Radiometric, spatial, and spectral
  - On-board calibrators and the Moon

- Data and Applications
  - 40 science data products

Launch: 12/18/99
1st Light: 02/24/00

Launch: 05/04/02
1st Light: 06/24/02

International Earth Observing Constellations
Complementary Morning and Afternoon Observations
On-orbit Calibration Activities

SD/SDSM: Weekly to tri-weekly

SRCA:
- Radiometric: monthly
- Spatial: bi-monthly
- Spectral: quarterly

Moon: monthly (nighttime orbits)
0-20° spacecraft roll maneuvers
55° phase angle

Spacecraft maneuvers:
- Yaw (SD BRF, VF)
- Roll (Moon)
- Pitch (only applied to Terra)

Blackbody: quarterly

Scan Mirror

Solar Diffuser
**RSB Radiometric Calibration**

**EV Reflectance**

\[
\rho_{EV} \cdot \cos(\theta_{EV}) = m_1 \cdot dn_{EV}^* \cdot d_{Earth-Sun}^2
\]

\[
m_1 = \frac{BRF_{SD} \cdot \cos(\theta_{SD})}{<dn_{SD}^*> \cdot d_{Earth-Sun}^2} \cdot \Gamma_{SD} \cdot \Delta_{SD}
\]

\[
\Delta_{SD} = \frac{dc_{SD}}{dc_{Sun}}
\]

\[\Delta_{SD}: \text{SD degradation factor;} \]
\[\Gamma_{SD}: \text{SD screen vignetting function} \]
\[d: \text{Earth-Sun distance} \]
\[dn^*: \text{Corrected digital number} \]
\[dc: \text{Digital count of SDSM} \]
TEB Radiometric Calibration

**EV Radiance:**

\[ L_{EV} = \frac{1}{RVS_{EV}} \left( a_0 + b_1 \cdot dn_{EV} + a_2 \cdot dn_{EV}^2 - (RVS_{SV} - RVS_{EV}) \cdot L_{SM} \right) \]

**Calibration Coefficients:**

\[ b_i = \left( RVS_{BB} \cdot \varepsilon_{BB} \cdot L_{BB} + (RVS_{SV} - RVS_{BB}) \cdot L_{SM} + RVS_{BB} \cdot (1 - \varepsilon_{BB}) \cdot \varepsilon_{cav} \cdot L_{cav} - a_0 - a_2 \cdot dn_{BB}^2 \right) / dn_{BB} \]

**RVS:** Response Versus Scan-angle

**\( \varepsilon \):** Emissivity

**L:** Spectral band averaged radiance

**dn:** Digital count with background corrected

**RSR:** Relative Spectral Response

**WUCD:** Warm-up and Cool-down

Aqua TEB WUCD Backbody Temperature (2002242–244)
Spatial and Spectral Characterization

\[
\bar{x}(b,d) = \frac{\sum_{x=0}^{N_x} dn(b,d,x) \cdot x}{\sum_{x=0}^{N_x} dn(b,d,x)}
\]

**Spatial mode**

\[\lambda_C = \frac{2A}{m} \cdot \sin(\theta_C + \theta_{off}) \cdot \cos \beta\]

**Spectral mode**

**Frame \(\rightarrow x\)**

**Grating step \(\rightarrow \theta\)**
Instrument Operations

• Terra MODIS Configurations
  - A-side: July 02, 2001 to Sept 17, 2002
  - A-side electronics and B-side formatter: Sept 17, 2002 to present
  - SD door fixed at open position: July 02, 2003 to present
  - BB temperatures set at 290K
  - Cold FPA controlled at 83K

• Aqua MODIS Configurations
  - Same B-side configuration since launch
  - BB temperatures set at 285K
  - Cold FPA controlled at 83K
Instrument and FPA Temperatures (Terra MODIS)

Instrument $T_{\text{inst}}$ 
$\sim$3.5K increase over 10 years

Warm FPA $T_{\text{vis}}, T_{\text{nir}}$
$\sim$3.5K increase over 10 years

Cold FPA $T_{\text{simr}}, T_{\text{ivir}}$
Extremely stable
Instrument and FPA Temperatures (Aqua MODIS)

- **Instrument Temperature ($T_{\text{inst}}$):** ~1.5K increase over 7.5 years
- **Warm FPA Temperature ($T_{\text{vis}}$, $T_{\text{nir}}$):** ~1.5K increase over 7.5 years
- **Cold FPA Temperature ($T_{\text{em}}$, $T_{\text{em}}$, $T_{\text{nir}}$):** 0.1-0.2K increase in last few years
Excellent BB temperature stability: short- and long-term

Terra MODIS – Lifetime Black Body (BB) Temperature Trend

Day 2000055 – Nadir Door Open
Day 2000160 – CFPA Lost Control
Day 2000218 – Formatter Anomaly
Day 2000232 – Back in Science Mode
Day 2000304, 2001183 – switch to B side, A side

Aqua MODIS – Lifetime Black Body (BB) Temperature Trend

Day 2001166 – PS2 anomaly
Day 2002260 – Formatter switched to B-Side
Day 2003350 – Safe Mode
Day 2003358 – Back in Science Mode
• Both instruments continue to operate normally
  – Over 10 years for Terra MODIS and 7.5 years for Aqua MODIS

• On-board calibrators continue to provide their designed functions
  – Terra MODIS SD door fixed at the “open” position (July 2, 2003) => increased SD degradation rates
  – SRCA 30W configuration replaced by the 20W configuration (2005 for Aqua MODIS, 2006 for Terra MODIS)
  – BB temperatures remain extremely stable

• Instrument and FPA temperatures are stable
  – Instrument and warm FPA temperatures changed less than 3K for Terra MODIS over 10 years; less than 2K for Aqua MODIS over 7.5 years
  – Terra MODIS Cold FPA temperature stably controlled at 83K; Aqua MODIS cooler margin slowly decreased => small orbit-to-orbit and seasonal variations of its CFPA temperatures (up to 0.15K)
• Radiometric (36 spectral bands: 490 individual detectors)
  – 45 noisy detectors (30 from pre-launch; 35 at launch) and no inoperable detectors for Terra MODIS (most on-orbit noisy detectors are in the LWIR PV bands)
  – 6 noisy detectors (2 from pre-launch; 3 at launch) and 15 inoperable detectors (10 from pre-launch and 15 shortly after launch) for Aqua MODIS (mostly in band 6)
  – Large changes in VIS spectral band response (mirror-side dependent)

• Spectral (VIS/NIR bands only)
  – Changes in center wavelengths and bandwidths are less than 0.5nm for most spectral bands (with a few exceptions)

• Spatial (all bands)
  – On-orbit band-to-band registrations (BBR) have been stable; nearly all band pairs meet design requirements for Terra MODIS; large BBR offsets in Aqua MODIS for band pairs with one from cold FPA and another from the warm FPA (a known problem since pre-launch)

• Concerns and Challenges
  – Large optics (mirror and SD) degradation at short wavelengths; changes in RVS and polarization parameters for VIS spectral bands (8, 9, 10)
MODIS Scan Cavity and On-board Calibrators

- Mainframe
- Solar Diffuser
- Spectroradiometric Calibration Assembly (SRCA)
- Blackbody
- Main Electronics Module (MEM)
- Space View
- Radiative Cooler
- Fold Mirror
- Radiative Cooler Door
- Solar Diffuser Stability Monitor (SDSM)
- Scan Mirror
- Primary Mirror
MODIS Focal Plane Assemblies (FPA)

S: scan direction; T: track direction
B13 and B14 have 2 columns of detectors for TDI high and low gain output
MODIS Specifications and Applications

<table>
<thead>
<tr>
<th>Primary Use</th>
<th>Band</th>
<th>Bandwidth (nm)</th>
<th>Spectral Radiance$^1$</th>
<th>Required SNR</th>
<th>Primary Use</th>
<th>Band</th>
<th>Bandwidth (nm)</th>
<th>Spectral Radiance$^1$</th>
<th>Required NEDT(K)</th>
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<tr>
<td>Land/Cloud/Aerosols Boundaries</td>
<td>1</td>
<td>620 - 670</td>
<td>21.8</td>
<td>128</td>
<td>Surface/Cloud Temperature</td>
<td>20</td>
<td>3.660 - 3.840</td>
<td>0.45 (300K)</td>
<td>0.05</td>
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<td>2</td>
<td>841 - 876</td>
<td>24.7</td>
<td>201</td>
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<td>21</td>
<td>3.929 - 3.989</td>
<td>2.38 (335K)</td>
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<td>Land/Cloud/Aerosols Properties</td>
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<td>459 - 479</td>
<td>35.3</td>
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<td>Atmospheric Temperature</td>
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<td>3.929 - 3.989</td>
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<td>4</td>
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<td>4.020 - 4.080</td>
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<td>1230 - 1250</td>
<td>5.4</td>
<td>74</td>
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<td>24</td>
<td>4.433 - 4.498</td>
<td>0.17 (250K)</td>
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<td>6</td>
<td>1628 - 1652</td>
<td>7.3</td>
<td>275</td>
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<td>25</td>
<td>4.482 - 4.549</td>
<td>0.59 (275K)</td>
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<td>7</td>
<td>2105 - 2155</td>
<td>1</td>
<td>110</td>
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<td>26</td>
<td>1.360 - 1.390</td>
<td>6 (150 (SNR))</td>
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<td>Ocean Color/Phytoplankton/Biogeochemistry</td>
<td>8</td>
<td>405 - 420</td>
<td>44.9</td>
<td>880</td>
<td>Cirrus Clouds Water Vapor</td>
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<td>6.535 - 6.895</td>
<td>1.16 (240K)</td>
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<td>9</td>
<td>438 - 448</td>
<td>41.9</td>
<td>838</td>
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<td>7.175 - 7.475</td>
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<td>483 - 493</td>
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<td>Cloud Properties</td>
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<td>11</td>
<td>526 - 536</td>
<td>27.9</td>
<td>754</td>
<td>Ozone</td>
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<td>12</td>
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<td>21</td>
<td>750</td>
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<td>10.780 - 11.280</td>
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<td>0.05</td>
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<td>13</td>
<td>662 - 672</td>
<td>9.5</td>
<td>910</td>
<td>Surface/Cloud Temperature</td>
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<td>14</td>
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<td>8.7</td>
<td>1087</td>
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<td>33</td>
<td>13.185 - 13.485</td>
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<td>15</td>
<td>743 - 753</td>
<td>10.2</td>
<td>586</td>
<td></td>
<td>34</td>
<td>13.485 - 13.785</td>
<td>3.76 (250K)</td>
<td>0.25</td>
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<tr>
<td></td>
<td>16</td>
<td>862 - 877</td>
<td>6.2</td>
<td>516</td>
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<td>35</td>
<td>13.785 - 14.085</td>
<td>3.11 (240K)</td>
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<td>Atmospheric Water Vapor</td>
<td>17</td>
<td>890 - 920</td>
<td>10</td>
<td>167</td>
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<td>36</td>
<td>14.085 - 14.385</td>
<td>2.08 (220K)</td>
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<td>18</td>
<td>931 - 941</td>
<td>3.6</td>
<td>57</td>
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<tr>
<td></td>
<td>19</td>
<td>915 - 965</td>
<td>15</td>
<td>250</td>
<td></td>
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</tr>
</tbody>
</table>

$^1$ Spectral Radiance values are (W/m$^2$-µm-sr)

20 reflective solar bands (RSB: bands 1-19, and 26) from 0.41 - 2.2µm
16 thermal emissive bands (TEB: bands 20-25, 27-36) from 3.5 - 14.4µm
### MODIS and VIIRS 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>
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<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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<td>M3</td>
<td>0.478 - 0.498</td>
<td>750</td>
<td>3, 10</td>
<td>0.459 - 0.479</td>
<td>500</td>
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<td>M4</td>
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<td>750</td>
<td>4, 12</td>
<td>0.545 - 0.565</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>
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<td>M5</td>
<td>0.662 - 0.682</td>
<td>750</td>
<td>13, 14</td>
<td>0.662 - 0.672</td>
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<td>M6</td>
<td>0.739 - 0.754</td>
<td>750</td>
<td>15</td>
<td>0.743 - 0.753</td>
<td>1000</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>
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<td>750</td>
<td>16, 12</td>
<td>0.862 - 0.877</td>
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<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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<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>
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<tr>
<td>M10</td>
<td>1.580 - 1.640</td>
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<td>6</td>
<td>1.628 - 1.652</td>
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<td>2.225 - 2.275</td>
<td>750</td>
<td>7</td>
<td>2.105 - 2.155</td>
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<td>3.550 - 3.930</td>
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<td>3.660 - 3.840</td>
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<td>21, 22</td>
<td>3.929 - 3.989</td>
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<td>M14</td>
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<td>29</td>
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<td>M15</td>
<td>10.263 - 11.263</td>
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<td>31</td>
<td>10.780 - 11.280</td>
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<td>I5</td>
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<td>375</td>
<td>31, 32</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>
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*Dual gain band*
MODIS Instrument Operations

MODIS IOT

1/25/10
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<th>Activity</th>
<th>Operational Activity</th>
<th>Activity</th>
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<tr>
<td>OA-01</td>
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<td>OA-16</td>
<td>SD/SD SM Screened</td>
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<td>OA-02</td>
<td>Mode Transition</td>
<td>OA-17</td>
<td>SD Sector Shift</td>
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<td>OA-03</td>
<td>Formatter Day Mode</td>
<td>OA-18</td>
<td>SD SM</td>
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<tr>
<td>OA-04</td>
<td>Formatter Night Mode</td>
<td>OA-19</td>
<td>SRCA Full Radiometric</td>
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<tr>
<td>OA-05</td>
<td>Safe/Survival Mode Recovery</td>
<td>OA-20</td>
<td>SRCA 10W Radiometric Continuous</td>
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<td>OA-06</td>
<td>Initial Outgas</td>
<td>OA-21</td>
<td>SRCA 1W Radiometric Continuous</td>
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<td>OA-07</td>
<td>DC Restore On/Off</td>
<td>OA-22</td>
<td>SRCA Full Spectral</td>
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<td>OA-08</td>
<td>S/C Maneuver (Lunar Cal)</td>
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<td>SRCA Full Spatial</td>
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<td>OA-09</td>
<td>S/C Maneuver (SD Scattered Light)</td>
<td>OA-24</td>
<td>SRCA Along-Scan Spatial</td>
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<td>OA-10</td>
<td>S/C Maneuver (RVS)</td>
<td>OA-25</td>
<td>SRCA 1W Along-Scan Spatial</td>
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<td>OA-11</td>
<td>Constraints on Special Operations (Field Campaign)</td>
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<td>Blackbody Cycle</td>
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<td>OA-12</td>
<td>Table Load (GAO)</td>
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<td>PV Electronic Calibration</td>
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<td>OA-28</td>
<td>PC Electronic Calibration</td>
</tr>
<tr>
<td>OA-14</td>
<td>Sector Rotation</td>
<td>OA-29</td>
<td>End Of Mission</td>
</tr>
<tr>
<td>OA-15</td>
<td>SD/SD SM Open</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Recent Events (Terra)

- **Spacecraft Events**
  - Battery Anomaly (2009/286) - possible MMOD (Micro-Meteoroid Orbital Debris)
  - SSR PWA (2010/008) - affecting 2 ASTER supersets, no MODIS impact other than ~10 min data loss during recovery

- **Orbit Adjust Maneuvers**
  - Drag Make-Up #52-54
  - Inclination Adjustment #21-24

- **MODIS Events**
  - A few telemetry points slightly exceeded configuration monitor limits, no impact on MODIS operations or calibration
Recent Events (Aqua)

• Spacecraft Events
  – Partition 6 fix in Jan 2009 to correct offset implemented in Dec 07 as a workaround for the pointer anomaly

• Orbit Adjust Maneuvers
  – Drag Make-Up #33-38
  – Inclination Adjustments #16-24
  – Debris Avoidance Maneuver (2009/329)

• MODIS Events
  – No new events
### Terra MODIS OBC Operations

<table>
<thead>
<tr>
<th>Activity</th>
<th>PL to 05/08</th>
<th>05/08 - present</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>SD/SDSM</td>
<td>562</td>
<td>35</td>
<td>597</td>
</tr>
<tr>
<td>BB WUCD</td>
<td>63</td>
<td>7</td>
<td>70</td>
</tr>
<tr>
<td>SRCA*</td>
<td>265</td>
<td>34</td>
<td>299</td>
</tr>
<tr>
<td>Electronic Cal</td>
<td>55</td>
<td>8</td>
<td>63</td>
</tr>
<tr>
<td>Lunar Roll</td>
<td>78</td>
<td>17</td>
<td>95</td>
</tr>
</tbody>
</table>

* Includes Spatial, Spectral and Radiometric

05/08 = last Science Team Meeting
### Activity PL to 05/08 | 05/08 - present | Total
---|---|---
SD/SDSM | 364 | 44 | 408
BB WUCD | 23 | 8 | 31
SRCA* | 139 | 35 | 174
Electronic Cal | 35 | 8 | 43
Lunar Roll | 53 | 16 | 69

* Includes Spatial, Spectral and Radiometric

05/08 = last Science Team Meeting
**SRCA Calibrations**

- **Terra** – 299 SRCA Calibrations
- **Aqua** – 174 SRCA Calibrations

<table>
<thead>
<tr>
<th>Lamp Power</th>
<th>10W</th>
<th>1W</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lamp #</td>
<td>1W</td>
<td>1W</td>
</tr>
<tr>
<td>Terra</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Usage (hr)</td>
<td>288.6</td>
<td>172.1</td>
</tr>
<tr>
<td>Life (hr)</td>
<td>500</td>
<td>500</td>
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<tr>
<td>percent</td>
<td>57.7%</td>
<td>Failed on 11-20-2004</td>
</tr>
<tr>
<td>Aqua</td>
<td></td>
<td></td>
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<tr>
<td>Usage (hr)</td>
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<td>188.0</td>
</tr>
<tr>
<td>Life (hr)</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>percent</td>
<td>56.3%</td>
<td>Failed on 4-14-2003</td>
</tr>
</tbody>
</table>
Future Operational Considerations

• **Aqua MODIS CFPA temperature control**
  – Currently set at 83K – two options for mitigation
    • Change set point to 85K
    • Perform outgas (given the opportunity)

• **Aqua SD/SDSM door movements**
  – Adjust calibration frequency to preserve door movements

<table>
<thead>
<tr>
<th></th>
<th>PL to 05/08</th>
<th>05/08 to present</th>
<th>Total</th>
<th>Design Lifetime</th>
<th>% Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terra*</td>
<td>2146</td>
<td>0</td>
<td>2146</td>
<td>3022</td>
<td>71</td>
</tr>
<tr>
<td>Aqua+</td>
<td>2716</td>
<td>130</td>
<td>2849</td>
<td>3022</td>
<td>94</td>
</tr>
</tbody>
</table>

* As of 07/02/2003, SD Door in fixed ‘open’ position with screen in place
+ At current usage rate Aqua will reach designed lifetime of door movement in August 2012
MODIS Level 1B and LUT Status

(Details provided in backup slides)
Recent Code and L1B Updates

• L1B code has been relatively stable
  – 9 minor code changes made in collection 5 since 2005 (5 for Terra MODIS and 4 for Aqua MODIS)

• Near-monthly LUT update for each MODIS forward processing
  – 72 for Terra MODIS and 43 for Aqua MODIS in collection 5 since 2005
  – Additional LUTs generated, tested, and delivered to OBPG (Ocean Biology Processing Group) for special investigations
  – Most LUT updates were driven by response changes of VIS bands
Number of MCST L1B Code and LUT Versions
(as of 01/12/2010)
Since 2005, L1B code has been relatively stable:

<table>
<thead>
<tr>
<th>Year</th>
<th>Terra Code Versions</th>
<th>Terra LUTs C2</th>
<th>Terra LUTs C3</th>
<th>Terra LUTs C4</th>
<th>Terra LUTs C5</th>
<th>Aqua Code Versions</th>
<th>Aqua LUTs C3</th>
<th>Aqua LUTs C4</th>
<th>Aqua LUTs C5</th>
<th>Total</th>
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<tbody>
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<td>2</td>
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<td>0</td>
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<tr>
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<td>0</td>
<td>19</td>
<td>0</td>
<td>3</td>
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<td>17</td>
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<td>17</td>
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<td>11</td>
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<td>2005</td>
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<td>0</td>
<td>18</td>
<td>10</td>
<td>2</td>
<td>0</td>
<td>11</td>
<td>6</td>
<td>49</td>
</tr>
<tr>
<td>2006</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>20</td>
<td>14</td>
<td>0</td>
<td>0</td>
<td>12</td>
<td>9</td>
<td>55</td>
</tr>
<tr>
<td>2007</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>13</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>11</td>
<td>26</td>
</tr>
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<td>2008</td>
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<td>0</td>
<td>16</td>
<td>1</td>
<td>0</td>
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<td>8</td>
<td>26</td>
</tr>
<tr>
<td>2009</td>
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<td>0</td>
<td>0</td>
<td>18</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>8</td>
<td>29</td>
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<tr>
<td>2010</td>
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<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>20</td>
<td>3</td>
<td>6</td>
<td>75</td>
<td>72</td>
<td>10</td>
<td>3</td>
<td>52</td>
<td>43</td>
<td>284</td>
</tr>
</tbody>
</table>

Does not include internal deliveries (18), nor special deliveries to Ocean Color Group (31) or Miami & Wisconsin (7)
MODIS MOD_PR02 L1B Code/LUTs
Major Production Changes Timeline

Terra Forward Processing

Year | Code Versions | LUT Versions
---|---|---
2000 | 2.3.2 (2000077) | 0-3
 | 2.4.2 (2000171) | 1
 | 2.5.6 (2002144) | 2-7
2001 | 3.0.1 (2002056) | 0,1
 | 3.1.2 (2002304) | 1-11
 | 3.2.0 (2003079) | 3-9
2002 | 4.1.2 (2003030) | 1-25
 | 4.1.3 (2003022) | 0-11
 | 4.2.0 (2003234) | 4-8
2003 | 4.2.1 (2003233) | 1-36
 | 4.3.0 (2003356) | 2-27
 | 4.3.1 (2004018) | 1-34
2004 | 5.0.5 (2005066) | 1-9, 11-58
2005 | 5.0.6 (2005066) | 1-9, 11-58
2006 |

Aqua Forward Processing

Year | Code Versions | LUT Versions
---|---|---
2007 | 3.1.0 (2002158) | 0-2
 | 4.1.1 (2002304) | 1-12
 | 4.1.3 (2003022) | 4-8
 | 4.2.1 (2003233) | 1-36
2008 | 4.3.0 (2003356) | 2-27
 | 5.0.6 (2005066) | 1-9, 11-58
2009 | |
 | 5.0.7 (2005185) | 1-9, 11-58
2010 | |

Production Start

Collection 2: 2000
Collection 3: 2002
Collection 4: 2003
Collection 5: 2005

LUT Versions

0-3 0,1 0-11 4-8 1-36 2-27 1-9, 11-58
## Production Changes to Collection 5
**MOD_PR02 TERRA L1B Code**

<table>
<thead>
<tr>
<th>PGE02 Version</th>
<th>Forward Processing Begin</th>
<th>Code Changes</th>
</tr>
</thead>
</table>
| V5.0.6_Terra  | 03/07/2005 (066 2005) 23:55 | • Add a new LUT to enable the SWIR OOB correction detector dependency  
  • Enable Band 21 calibration with mirror side dependency  
  • Improve the code portability  
  • Comply with the ESDIS guideline  
  • Add HDFEOS_FractionalOffset  
  • Minor fix for code version recording  
  • Correct wrong dimension mapping offset setting for 250m band data |
| V5.0.38_Terra | 9/17/2007 (260 2007) 19:35 | • Relax the RVS correction limit range from [0.8, 1.2] to [0.4, 2.4]. |
| V5.0.40_Terra | 1/24/2008 (024 2008) 00:00 | • Changed to set the PGEVersion ECS inventory metadata based upon the MODAPS PGE Version, rather than the obsolete GDAAC PGE Version.  
  • Removed the ScanType of "Mixed" from the code.  
  • Changed for ANSI-C compliance and comments correction. |
| V5.0.42_Terra | 7/10/2009 (191 2009) 00:00 | • Added an extension ".NRT" to the LOCALGRANULEID metadata if the ReprocessedActual from pcf is "Near Real Time" to identify the NRT production. |
| V5.0.44_Terra | 8/23/2009 (235 2009) 00:00 | • Only the PGE02 version is changed for correction to a PGE level error. |
## Production Changes to Collection 5
**MOD_PR02 AQUA L1B Code**

<table>
<thead>
<tr>
<th>PGE02 Version</th>
<th>Forward Processing Begin</th>
<th>Code Changes</th>
</tr>
</thead>
</table>
| V5.0.7_Aqua   | 07/03/2005 (185 2005) 00:10 | - Add a new LUT to enable the SWIR OOB correction detector dependency  
- Enable Band 21 calibration with mirror side dependency  
- Improve the code portability  
- Comply with the ESDIS guideline  
- Add HDFEOS_FractionalOffset  
- Minor fix for code version recording  
- Correct wrong dimension mapping offset setting for 250m band data |
| V5.0.35_Aqua  | 01/23/2008 (023 2008) 00:00 | - Relax the RVS correction limit range from [0.8, 1.2] to [0.4, 2.4]  
- Changed to set the PGEVersion ECS inventory metadata based upon the MODAPS PGE Version, rather then the obsolete GDAAC PGE Version.  
- Removed the ScanType "Mixed" from the code because the L1A "Scan Type" is never "Mixed".  
- Changed for ANSI-C compliance and comments correction. |
| V5.0.37_Aqua  | 07/10/2009 (191 2009) 00:00 | - Added an extension “.NRT” to the LOCALGRANULEID metadata if the ReprocessingActual from pcf is "Near Real Time" to indentify the NRT production. |
Collection 6 Code Changes for L1B

• Change to no longer interpolate the values of inoperable detectors from nearby good detectors.
  • The scaled integer value will be set to 65531

• Noisy/inoperable detector (sub-sample) flagging
  • If sub-sample is inoperable, the scaled integer value will be set to 65525

• The sector rotation anomaly fix
  • The anomaly is caused by the mismatch of the timing of the instrument command to perform the sector rotation and the recording of the telemetry point that reports the angle of sector rotation.
  • Will be implemented in C5 PGE02 by end of February, 2010.

• Change in how ReprocessingActual ECS metadata is set and used.
  – Previously, value was fixed as “processed once”
  – Now the value is controlled by MODAPS operations:
    • “Near Real Time” – causes file name to end with “.NRT.hdf”
    • “processed once”
    • “reprocessed once”
  – Also implemented in Collection 5 code.
MODIS Reflective Solar Bands
On-Orbit Performance

RSB Group
MODIS Characterization Support Team (MCST)
Outline

• Introduction
• RSB calibration algorithms
• Noisy & inoperable RSB detectors
• Solar Diffuser degradation
• RSB responses trending
• Detector-dependent RVS and EV striping reduction
• Alternative collection 6 LUTs
• Summary of RSB overall performance
Introduction

490 detectors
36 Spectral bands
  - 20 reflective solar bands (RSB)
  - 16 thermal emissive bands (TEB)
Spatial resolution (36 bands) at nadir
  - 250m(2), 500m(5), and 1km (29)
Wavelength range from 0.4 to 14.5 µm

Two sided paddle wheel scan mirror
  - 10 km (nadir) along track
  - 2330 km cross track swath
  - 1.478 second each scan
RSB SD Calibration

Sun

1.44% Screen

Optional 7.8% Screen

SDSM

Calibration coefficients

\[ m_1 = \frac{\rho_{SD} \cdot \cos(\theta_{SD})}{d_{n_{SD}} \cdot d_{Earth-Sun}^2} \cdot \Delta_{SD} \cdot \Gamma_{SDS} \]

Scan mirror

SD degradation

\[ \Delta_{SD} = \frac{dc_{SD}^9}{dc_{SD}} / \frac{dc_{Sun}}{dc_{Sun}^9} \]

\[ \Delta_{SD}^9 = \frac{dc_{SD}^9}{dc_{Sun}^9} \]

SD degradation at wavelength 940 nm measured by SDSM D9 is included in Collection 6 through the entire mission and also included in Collection 5 for Terra after Jan. 1, 2009 and Aqua after March 1, 2009.
RSB lunar calibration

**Lunar coefficients**

**Bands 1-4, 8-12 and 17-19**

\[ m_{moon}^1 = \frac{f_{vg}}{<dn_{Moon}^*}> \]

**Bands 13-16 (Saturated)**

\[ m_{moon}^1 = m_{moon}^{1,B18} \cdot \frac{<dn_{Moon,B18}^*>}{<dn_{Moon}^*>} \]

**View geometry correction**

\[ f_{vg} = \frac{f_{phase-angle} \cdot f_{libration}}{d_{Sun-Moon}^2 \cdot d_{Moon-MODIS}^2} \]
MODIS RSB Earth View Radiance

**EV Radiance:**

\[
L_{EV} = \frac{E_{Sun} \cdot \rho_{EV} \cdot \cos(\theta_{EV})}{\pi \cdot d_{Earth\_Sun}^2}
\]

\[
= \frac{E_{Sun}}{m_1} \cdot \frac{d_{n*}}{\pi}
\]

where

\[
d_{n*_{EV}} = d_{n_{EV}} \cdot (1 + k_{Inst} \cdot \Delta T_{Inst}) / RVS_{EV}
\]

**Solar Irradiance \(E_{SUN}:\)**

- 0.4-0.8 µm Thuillier et al., 1998;
- 0.8-1.1 µm Neckel and Labs, 1984;
- Above 1.1 µm Smith and Gottlieb, 1974
MODIS RSB Noisy & Inoperable Detectors

### Terra

<table>
<thead>
<tr>
<th>Day/Year</th>
<th>Detectors in Production order</th>
</tr>
</thead>
<tbody>
<tr>
<td>055/2000</td>
<td>Nadir Dorr Open</td>
</tr>
<tr>
<td>160/2000</td>
<td>CFPA Lost Control</td>
</tr>
<tr>
<td>232/2000</td>
<td>Back from FPA recycle</td>
</tr>
<tr>
<td>304/2000</td>
<td>B Side</td>
</tr>
<tr>
<td>183/2001</td>
<td>A Side</td>
</tr>
<tr>
<td>259/2002</td>
<td>A Side B Formatter</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Day/Year</th>
<th>Band</th>
<th>SNR Spec</th>
<th>5</th>
<th>6</th>
<th>7</th>
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<tr>
<td>055/2000</td>
<td>2</td>
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<td>11</td>
<td>13</td>
</tr>
<tr>
<td>160/2000</td>
<td>95</td>
<td>95</td>
<td>60</td>
<td>80</td>
<td>30</td>
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<td>232/2000</td>
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<td>95</td>
<td>50</td>
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<td>85</td>
<td>80</td>
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<tr>
<td>183/2001</td>
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<td>10</td>
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<td>90</td>
<td>90</td>
</tr>
<tr>
<td>259/2002</td>
<td>100</td>
<td>100</td>
<td>100</td>
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</tbody>
</table>

### Aqua

<table>
<thead>
<tr>
<th>Day/Year</th>
<th>Band</th>
<th>SNR Spec</th>
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<th>6</th>
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</thead>
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<tr>
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<td>4</td>
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<tr>
<td>314/2006</td>
<td>0</td>
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<td>0</td>
<td>472</td>
</tr>
</tbody>
</table>

Detectors in Production order

- In Spec
- Near Spec
- Out Spec
- Inoperable
MODIS SD Degradation Trending

Results are derived from normalization approach (to D9). Additional D9 corrections are applied to Collection 6 through the entire mission and to Collection 5 after Jan. 1, 2009 for Terra and after March 1, 2009 for Aqua, respectively.
Large mirror side differences are observed in short wavelength bands.
Mirror side differences are small in Terra NIR and SWIR bands
MODIS RSB Response Trending
Detector Averaged

Aqua Visible FPA 1/m1 Trending for Mirror Side 1 (SD)

Aqua Visible FPA 1/m1 Trending for Mirror Side 2 (SD)

Much smaller mirror side differences in Aqua MODIS
MODIS RSB Response Trending
Detector Averaged

Aqua NIR FPA 1/m1 Trending for Mirror Side 1

Aqua SMIR FPA 1/m1 Trending for Mirror Side 1
Terra band 8 RVS at AOI of the SV has changed about 24% in last few years
MODIS RSB RVS Trending
Detector Averaged

Aqua band 8 RVS at AOI of the SV has decreased about 18% since launch.
Terra MODIS Band 8 RVS Trending

The RVS detector difference can be as large as 2.5% for Terra band 8.
In Collection 6, the striping at the AOI of the SD is reduced. This reduction is due to the application of the detector bias correction in SD m1, which is derived from EV radiance.
The striping at the AOI of the SV is significantly reduced in Collection 6. This reduction is due to the application of the detector dependent RVS.
Current Versions of RSB LUTs

- **Collection 5 (V5)**
  - SD BRF degradation at wavelength 940 nm is assumed to be very small and is not included in RSB calibration before 2009 for Terra and April 1, 2009 for Aqua. The degradation at the wavelength is included after the aforementioned times for both instruments.
  - RSB calibration coefficients, $m_1$, are derived from SD/SDSM calibration for both instruments.
  - Detector-averaged time-dependent RVS is applied to bands 1-4, 8-12, and 17-19 for both instruments.
  - V5 LUTs are currently in operation for both instruments.

- **Collection 6 (V6)**
  - SD BRF degradation at wavelength 940 nm is included for the entire mission for both instruments, which results in an accumulated 1.3% and 0.3% correction for Terra and Aqua Vis/Nir bands, respectively.
  - Delta $m_1$ derived from EV radiance is applied to bands 8-12 to correct the detector bias in the $m_1$ derived from SD/SDSM calibration for both instruments.
  - Time-dependent RVS is applied to all RSB (including bands 13-16) except SWIR bands for both instruments.
  - V6 LUTs are currently being tested by science teams.
Current Versions of RSB LUTs

- **Alternative V6 LUTs**
  - Detector differences in both m1 and RVS are identical to the V6 LUTs
  - The lunar m1 is used to track the gain change at the AOI of the SV
  - The EV dn trendings at 8 selected AOIs are used to track the detector averaged m1 and RVS change since on-orbit or a chosen time
  - A quadratic form is used to describe the RVS on-orbit change for MS1 as well as MS2
  - Alternative V6 LUTs are currently being tested by Ocean group

- **Aqua band 8 EV dn trending**
Comparison between V6 and Alternative V6 LUTs

Aqua Band 8 m1

Aqua Band 8 m1/RVS

V6
V6_alt

Mirror Side 1
Mirror Side 2

Epoch of 2002

Frame

(m1/RVS)_V6/(m1/RVS)_V6_alt
Summary of RSB overall Performance

- **Terra MODIS (10 years)**
  - SD/SDSM and the Moon observations track the RSB gain change effectively.
  - More than 50% and 46% changes in mirror side 1 and 2, respectively, are observed for MODIS band 8 responses at the SD AOI.
  - The band 8 RVS at the SV AOI has changed about 24% in the last few years.
  - The delta m1 correction and detector-dependent RVS significantly reduce EV striping.

- **Aqua MODIS (7.5 years)**
  - SD/SDSM and the Moon observations track the RSB gain change effectively.
  - Maximum response change for band 8 is around 30%, and less than 8% for NIR & SWIR bands.
  - Mirror side differences are small and less than 3% for all RSB bands.
  - The band 8 RVS at SV AOI has decreased 18% since launch.
MODIS Thermal Emissive Bands
On-Orbit Performance

TEB Group
MODIS Characterization Support Team (MCST)
MODIS TEB Calibration Performance

- MODIS TEB Calibration Algorithm
- Terra and Aqua MODIS TEB On-orbit Performance
  - Black Body Stability
  - Detector Response & Noise Performance
  - Noisy Detector History
  - Aqua CFPA Temperature Concern
MODIS TEB

Thermal Emissive Bands
- 16 spectral bands
- 160 detectors, 10 per band
- 2 CFPAs (SMIR, LWIR; 83K)

<table>
<thead>
<tr>
<th>Band</th>
<th>$\lambda_{\text{center}}$ ($\mu$m)</th>
<th>$L_{\text{typ}}$ Radiance (W/m²$\cdot$μm·sr)</th>
<th>Scene Temperature at $L_{\text{typ}}$ (K)</th>
<th>Required NEIT (K)</th>
<th>Radiometric Requirement at $L_{\text{typ}}$ (%)</th>
<th>Radiometric Requirement at $L_{\text{typ}}$ (K)</th>
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</table>
TEB Calibration Algorithm

EV Radiance (top-of-atmosphere), $L_{EV}$

$$L_{EV} = \frac{1}{RVS_{EV}} \left( a_0 + b_1 \cdot dn_{EV} + a_2 \cdot dn_{EV}^2 - (RVS_{SV} - RVS_{EV}) \cdot L_{SM} \right)$$

- $b_1$ is calibrated from On-board calibration radiance

$$L_{CAL} = RVS_{BB} \varepsilon_{BB} L_{BB} + (RVS_{SV} - RVS_{BB}) L_{SM} + RVS_{BB} (1 - \varepsilon_{BB}) \varepsilon_{cav} L_{cav}$$

$$b_1 = \left( L_{CAL} - a_0 - a_2 dn_{BB}^2 \right) / dn_{BB}$$

- using quadratic algorithm
- for each band, detector, and mirror side
- performed on scan-by-scan basis

- Warm-up and cool-down (WUCD)
  - $BB$ temperature varies $\sim$270 to 315K
  - performed quarterly
  - $a_0/a_2$ characterization and Band 21 $b_1$ calibration
  - $NEdT$ @ typical temperature

**Glossary**

- EV: Earth View
- SV: Space View
- BB: Blackbody
- SM: Scan Mirror
- Cav: Instrument Cavity
- RVS: Response Versus Scan-angle
- $\varepsilon$: Emissivity
- $L$: Spectral band averaged radiance (in $W/m^2\cdot\mu m\cdot sr$)
- $dn$: Digital count with background correction
- $a_0$: Detector response offset
- $b_1$: Detector response linear coefficient
- $a_2$: Detector response nonlinear coefficient
MODIS TEB Calibration Performance

• MODIS TEB Calibration Algorithm
• Terra and Aqua MODIS TEB On-orbit Performance
  – Black Body Stability
  – Detector Response & Noise Performance
  – Noisy Detector History
  – Aqua CFPA Temperature Concern

12 thermistors are evenly embedded in BB panel and the temperature is measured scan-by-scan
Terra BB Short-term Stability

Temperatures from 12 individual BB thermistors (1 granule, scan-by-scan)

Standard deviation of temperature measured using individual thermistor
(203 scans in one granule, in K)

<table>
<thead>
<tr>
<th>Thermistor #</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
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<td>0.016</td>
<td>0.027</td>
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</table>
Terra BB On-Orbit & Lifetime Performance


Day 2000055 – Nadir Door Open
Day 2000160 – CFPA Lost Control
Day 2000216 – Formatter Anomaly
Day 2000232 – Back in Science Mode
Day 200304, 2001183 – switch to B side, A side

Day 2001166 – FSZ anomaly
Day 2002260 – Formatter switched to B–Side
Day 2003350 – Safe Mode
Day 2003358 – Back in Science Mode

Terra MODIS – Lifetime Black Body (BB) Temperature Trend
Aqua BB Short-term Stability

Temperatures from 12 individual BB thermistors (1 granule, scan-by-scan)

2002

2009

Standard deviation of temperature measured using individual thermistor
(203 scans in one granule, in K)

<table>
<thead>
<tr>
<th>Thermistor #</th>
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<td>0.012</td>
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</table>
Aqua BB On-Orbit and Lifetime Performance

One orbit (2009)

Lifetime
MODIS TEB Calibration Performance

- MODIS TEB Calibration Algorithm
- Terra and Aqua MODIS TEB On-orbit Performance
  - Black Body Stability
  - Detector Response & Noise Performance
  - Noisy Detector History
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Terra MODIS TEB MWIR Response Trend

Terra MODIS MWIR (Bands 20–25; Good Detector Average) Normalized $1/b_1$ & NEdT

![Graph showing response trend over time](image-url)
Terra MODIS TEB LWIR Response Trend

Terra MODIS LWIR (Bands 27–36; Good Detector Average) Normalized 1/b1 & NEdT

Day (Epoch 2000)
Aqua MODIS TEB MWIR Response Trend

Aqua MODIS MWIR (Bands 20–25; Good Detector Average) Normalized 1/b1 & NEdT
Aqua MODIS TEB LWIR Response Trend

Aqua MODIS LWIR (Bands 27–36; Good Detector Average) Normalized 1/b1 & NEdT

Day (Epoch 2002)

L/b1 (MSI)

NEdT (KSI)

Day (Epoch 2002)

B27 x  B28 +  B29 *  B30 △  B31 ◊  B32 □  B33 x  B34 +  B35 *  B36 △
MODIS Warm-up and Cool-down Process

- performed quarterly
- \( a_0/a_2 \) characterization and band 21 \( b_1 \) calibration
  \[ L_{CAL} = a_0 + b_1 d_{BB} + a_2 d_{BB}^2 \]
- NEdT vs BB temperature
  \( \rightarrow \) NEdT @ typical temperature

Terra band 20

\[ \gamma_{CAL} \quad (W/m^2 - \mu m - sr) \]

Terra band 31

Aqua band 31

\[ \gamma_{CAL} \quad (W/m^2 - \mu m - sr) \]

Terra band 20

\[ \gamma_{CAL} \quad (W/m^2 - \mu m - sr) \]

Terra band 36

Aqua band 22

Aqua band 30

\[ \gamma_{CAL} \quad (W/m^2 - \mu m - sr) \]
TEB detector status (in current LUT)

- Terra PV bands on LWIR CFPA (band 27-30) slowly becoming noisy
- Aqua TEB performs better than Terra TEB
MODIS TEB Calibration Performance

- MODIS TEB Calibration Algorithm
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  - Noisy Detector History
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Terra MODIS Noisy Detector History

Detectors in Product Order

<table>
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<tr>
<th>Day/Year</th>
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<td>0.12</td>
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</table>

¹Spacecraft Deep Space Maneuver

- 2 new noisy detectors since last Science Team Meeting
  (Band 27 detector 2 and band 30 detector 1)
# Aqua MODIS Noisy Detector History

## Detectors in Product Order

<table>
<thead>
<tr>
<th>Day/Year</th>
<th>Band</th>
<th>Spec NEdT [K]</th>
<th>Detectors in Product Order</th>
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### Near Spec, Out of Spec, Inoperable

- No new noisy and inoperable detector since last Science Team Meeting
MODIS TEB Calibration Performance

• MODIS TEB Calibration Algorithm

• Terra and Aqua MODIS TEB On-orbit Performance
  – Black Body Stability
  – Detector Response & Noise performance
  – Noisy Detector History
  – Aqua CFPA Temperature Concern
- The cooler is controlled using SMIR temperature.  \( \rightarrow \) slight oscillation in LWIR temperature (as in 2004) is normal.
- Starting 2005, the fluctuation amplitude increases.  \( \rightarrow \) a concern
- The fluctuation is at orbital frequency (b1 calibration is scan-based).  \( \rightarrow \) no impact on L1B product
– BB temperatures remain stable (Terra 290K and Aqua 285K).
– Stable short-term and long-term detector response
  (excluding sensor configuration changes and instrument reset events)
– Terra PV band detectors on LWIR CFPA (band 27-30) slowly becoming noisy
– Terra MODIS has 23 noisy detectors and 1 inoperable detector
  (2 new noisy detectors since last Science Team Meeting)
– Aqua MODIS has 3 noisy detectors and 1 inoperable detector.
– Aqua cooler margin is a concern for CFPA short-term stability
  (unable to completely control the CFPA to the setting temperature)
– Current Aqua CFPA temperature fluctuation has no impact on L1B product
MODIS Spectral and Spatial Performance

SRCA Group
MODIS Spectral and Spatial Performance

- Spectro-Radiometric Calibration Assembly (SRCA)
  - Spectral mode
  - Spatial mode

- Spectral Characterization Results (VIS/NIR only)
  - Center wavelengths
  - Bandwidths

- Spatial Characterization Results (all bands)
  - Band-to-band Registration (BBR)
    - Along-scan and along-track

- Performance Summary

- SRCA Lamp Status
SRCA in MODIS

- MAINFRAME
- SOLAR DIFFUSER
- CALIBRATION ASSEMBLY (SRCA)
- BLACKBODY
- MAIN ELECTRONICS MODULE (MEM)
- SPACE VIEW
- RADIATIVE COOLER
- FOLD MIRROR
- RADIATIVE COOLER DOOR
- SOLAR DIFFUSER STABILITY MONITOR (SDSM)
- SCAN MIRROR
- PRIMARY MIRROR
Grating is used for spectral mode
Mirror is used for spatial mode
SRCA Spectral Responses

Relative Responses Prior to Corrections

SRCA 30W calibration over two continuous dark orbits

SRCA 10W calibration over two continuous dark orbits

Grating step -> $\theta$

$$\lambda_c = \frac{2A}{m} \cdot \sin(\theta_c + \theta_{off}) \cdot \cos \beta$$
Along-scan & track Positions

\[ x(b, ch) = \frac{\sum_{x=0}^{N_x} dn(b, ch, x) \cdot x}{\sum_{x=0}^{N_x} dn(b, ch, x)} \]

Frame (scan direction)

Terra SRCA along-track (two fully opened frames)
Terra MODIS Spectral Performance

Terra MODIS Center Wavelength Changes

Terra MODIS Bandwidth Changes

Band 2 not recoverable
Aqua MODIS Spectral Performance

Aqua MODIS Center Wavelength Shift

Aqua MODIS Bandwidth Changes

Band 2 not recoverable
Less reliable with small SNR in 20W configuration
Terra MODIS Spatial Performance

Terra BBR Shift Along-scan

Terra BBR Shift Along-track

Cold FPA
A known problem between bands on Cold FPA and bands on warm FPA.
Performance Summary

• SRCA Spectral Mode
  – Terra and Aqua MODIS spectral performances are stable on-orbit (VIS/NIR only).
  – CW and BW changes are less than 0.5nm except for bands 1 and 19 (large BW bands > 45nm)
    • Terra and Aqua band 8 results from 20W configuration are not reliable because of low SNR.

• SRCA Spatial Mode
  – The SRCA spatial mode provides stable on-orbit BBR trending for both along-scan and along-track directions (all 36 bands).
    • Terra bands 27, 28 and 30 are out-of-spec (relative to band 32).
    • Aqua MODIS had large BBR offsets (in both directions) between bands on Cold FPA and bands on warm FPA (a known problem since pre-launch).
SRCA Lamp Status

- As of 1-8-2010

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MODIS Collection 6
Calibration and L1B Changes

MODIS Characterization Support Team
1/25/10
Outline

• Introduction

• Collection 6 LUT Changes Summary
  – RSB
  – TEB
  – QA
  – L1B Code

• Science Testing Status

MCST Collection 6 Information will be available on mcst.gsfc.nasa.gov
Introduction

• MODIS Collection History
  – Collection 2: Terra Launch – June 2001
  – Collection 5: Feb 2005 – present
  – Collection 6: **Test L1B datasets available**
MCST Collection 6 History

- Prototype delivery (V6.0.0.0/V6.0.1.0) – Aug. 2008
- 1st official LUT delivery (V6.1.0.0/V6.1.1.0) – Jan. 2009
RSB V6 Changes

• RSB LUT Improvements
  – SD D9 Degradation
  – $\Delta m_1$ correction
  – Time Dependent RVS – B13-16
  – Detector Dependent RVS – B8-12
  – Aqua: MS2 RVS
  – Refit coefficients for entire mission

• RSB LUT Alternative Approach
  – LUTs derived using EV and lunar data
RSB V6 LUT – SDSM D9

- V5: Assumed no SDSM Detector 9 degradation
- V6: SD Degradation analysis now includes correction for D9 on-orbit degradation
• V5: Detector dependent m1
• V6: Detector dependent m1 with correction applied to account for detector differences within a band.
• Improves striping performance.
RSB V6 LUT – RVS

• V5: RVS band averaged

• V6:
  – Time-dependent RVS for bands 13-16
    • Major improvement in lunar algorithm
  – Detector–dependent RVS derived for bands 8-12
  – Aqua RVS mirror side dependence derivation methodology modified to match that of Terra
• Reprocess coefficients for mission lifetime to date
  – Long-term trending has smooth performance
RSB V6 LUT – L1B Impact

V6 Expected Impact on L1B*
Terra: ± 2%
Aqua: ± 1%

*Actual differences are band, detector, mirror side, AOI, & time dependent
MCST developed RSB LUTs (m1 & RVS) derived only from EV and lunar data
- Tied to historical SD measurements with forward LUTs independent of SD calibration.
- Developed and delivered prototype LUTs to Ocean Group (OBPG) for testing.
  - Early results from ongoing testing by OBPG indicate improvement in Ocean products.
TEB V6 Changes

• A0/A2 Derivation strategy
• Reprocess coefficients for entire mission
  – A0, A2, Band 21 b1
• Aqua B33, 35, & 36 Saturation Temp adjusted
# TEB V6 LUT – A0/A2 Strategy

## Aqua
- **V5**
  - B20, 22-30: PL a0/a2
  - B21: a0 = 0 and a2 = 0
  - B31-32: Warm-up a0/a2
  - B33-36: a0 = 0, PL a2

## Terra
- **V5**
  - B20, 22-30: Warm-up a0/a2
  - B21: a0 = 0 and a2 = 0
  - B29, 31-32: Warm-up a0/a2
  - B33-36: a0 = 0, warm-up a2

## V6
- No change
- No change
- **a0 = 0, cool-down a2**
- No change
- **Cool-down a0/a2**
- No change
- **a0 = 0, cool-down a2**
- No change

Coefficients derived from quarterly BB Warm-up & Cool-down Activities

V6 Approach improves TEB performance for low temperature scenes
EV Radiance Levels

$0.3 \, L_{\text{typ}} \quad L_{\text{typ}} \quad 0.9 \, L_{\max}$

At $L_{\text{typ}}$ impact is minimal, at low EV scene temps V6 is generally colder than V5
TEB V6 LUT Impact – Terra B29-36

EV Radiance Levels

\[ 0.3 \, L_{\text{typ}} \quad L_{\text{typ}} \quad 0.9 \, L_{\text{max}} \]

\[ \Delta T = V6 - V5 \]

Epoch 2000
QA V6 Improvements

• Fill Values replace Interpolation in L1B for Inoperable Detectors
  – Code change needed
• Subframe level QA flags
  – Code change needed
  – New QA LUT
QA V6 LUT – Fill vs Interpolation

- V5: Inoperable detectors filled with interpolated value from adjacent detectors
- V6: Science Team request to have no interpolation, explicit fill value for inoperable detectors
QA V6 LUT – Subframe Flags

- V5: QA flags only on detector level
- V6: L1B code change implemented to allow QA flags at subframe level.
  - New QA LUT
  - Terra Band 2 Detectors 29 & 30 Subframe 1 flagged as ‘Noisy’ for V6 (known crosstalk issue)
V6 L1B Code Change

• Sector Rotation Anomaly Fix
  – Anomaly in TEB data during certain sector rotation events (lunar calibrations)

Plots courtesy of S. Devadiga
V6 L1B Code Change

Fire Granule MYD14.A2008343.2235

Plots courtesy of S. Devadiga

MODIS Science Team Meeting – Calibration

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V6 L1B Status

• V6 LUTs latest updates
  – Aqua V6.1.7.9 (12/17/09)
  – Terra V6.1.2.1 (10/06/09)
  – LUT updates delivered ~ every 3 months

• V6 L1B data currently available
  – Terra: Jan 1-16, 2003
  – Aqua: Jan 1-31, 2003
  – https://ladsweb.nascom.nasa.gov
V6 L1B Status

• Science Testing in progress
  – Test V5 Products generated using V6 L1B (Jan. 2003 L1B)
  – Terra & Aqua – Land
  – Aqua only – Atmosphere
  – Ocean (OBPG) generated test products for Aqua using both the official and alternate LUTs.

• All V6 L1B, Geolocation, & Cloud Mask/Profiles products will be generated and archived in LAADS