MODIS L1B Algorithm Status: Collection 6

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Contributions:
MODIS Characterization Support Team (MCST)
Outline

- Background
- Overview of MODIS L1B Calibration Algorithm
- Collection 6 (L1B)
  - Development Status
  - Changes for RSB and TEB and Their Impact (examples)
- Future Work
MODIS L1B Algorithm (Code and LUTs)

- Developed, maintained, and updated by MCST
  - Input also provided by MODIS science team representatives and users
  - Algorithm changes and major LUT updates reviewed and approved by the MsWG (MODIS sensor Working Group)
- Two separate sets of code and LUTs
  - One for Terra MODIS and one for Aqua MODIS
- L1B collections and versions
  - Terra MODIS mission: C2 to C6 (18 code versions used in production)
  - Aqua MODIS mission: C3 to C6 (11 code versions used in production)

Additional Support (code and LUTs) for Ocean and Other Science Testing
More details in back-up slides and on MCST Webpage
Timeline of MODIS L1B (code and LUTs) Updates

Links to L1B (code/LUT changes): http://mcst.gsfc.nasa.gov/l1b/l1b-lut-history
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Links to L1B (code/LUT changes): http://mcst.gsfc.nasa.gov/l1b/l1b-lut-history
Key L1B Documents

http://mcst.gsfc.nasa.gov/content/l1b-documents

ATBD
High-Level Code Design
LUTs Information Guide
Product User Guide
Data Dictionary
References

• Key Journal Papers

• Key SPIE Papers
Overview of MODIS L1B Calibration Algorithm

• Reflective Solar Bands (RSB)
  – Linear calibration algorithm
  – Calibration referenced to the on-board solar diffuser and lunar observations
  – Calibration coefficients (gains and RVS) updated regularly via LUTs (offline process)
  – Special considerations
    • SWIR crosstalk correction; band 26 de-striping

• Thermal Emissive Bands (TEB)
  – Quadratic calibration algorithm
  – Calibration referenced to the on-board blackbody
  – Calibration coefficients (gains) updated scan-by-scan (real-time process)
  – Special considerations
    • PC optical leak correction (Terra only); simple linear algorithm for band 21; fixed linear gains (b1) for Aqua bands 33, 35, and 36 when BB temperature is above their saturation temperature
EV Reflectance:  \[ \rho_{EV} \cdot \cos(\theta_{EV}) = m_1 \cdot d_{n_{EV}}^* \cdot d_{Earth-Sun}^2 \]

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

\[ \Delta_{SD} = \frac{d_{c_{SD}}}{d_{c_{Sun}}} \]

\( \Delta_{SD} \): SD degradation factor
\( \Gamma_{SD} \): SD screen vignetting function
\( d \): Earth-Sun distance
\( d_{n^*} \): Corrected digital number (incl. RVS correction)
\( d_{c} \): Digital count of SDSM
Radiometric Calibration for RSB

**EV Radiance:**

\[
L_{EV} = \frac{E_{Sun} \cdot \rho_{EV} \cdot \cos(\theta_{EV})}{\pi \cdot d_{Earth-Sun}^2(\text{EV})}
= \frac{E_{Sun}}{\pi} m_1 \cdot dn_{EV}
\]

\[
dn^*_EV = dn_{EV} \cdot (1 + k_{INST} \cdot (T_{INST_EV} - T_{INST_REF})) / RVS_{EV}
\]

\[
dn^*_SD = dn_{SD} \cdot (1 + k_{INST} \cdot (T_{INST_SD} - T_{INST_REF})) / RVS_{SD}
\]

- \( k_{INST} \) - Inst temperature correction coefficient
- \( T_{INST} \) - Inst temperature
- \( T_{INST\_REF} \) - Reference Inst temperature
- \( RVS \) - Response versus scan-angle

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

Others:
- Thermal leak correction applied for SWIR bands (B5-7 and B26)
- B26 de-striping algorithm added (from C. Moeller of Wisconsin)
EV Radiance:

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

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

RVS: Response Versus Scan-angle
\( \epsilon \): Emissivity
L: Spectral band averaged radiance
dn: Digital count with background corrected

Aqua TEB WUCD Backbody Temperature (2002242-244)
Radiometric Calibration for TEB

• Special Considerations:
  – PC optical leak correction applied to Terra MODIS bands 32-36 (not in Aqua)
  – Band 21 (fire detection) calibration uses a linear calibration coefficients (b1 - detector, mirror side, and time dependent) derived from an offline process
  – Aqua bands 33, 35, and 36 use a fixed b1 when the on-board BB temperature is above their saturation temperatures (during BB WUCD)
Collection 6 (L1B)

• MODIS L1B Collection 6
  – Plan and development started as early as Jan, 2008
  – Development, including all the changes to algorithms and LUTs, completed (reviewed and approved) Feb, 2012
  – 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
Changes in L1B C6

- Reflective Solar Bands (RSB)
  - SD degradation at 936 nm included (previous degradation normalized at 936 nm)
  - Time dependent RVS for all VIS/NIR bands, including bands 13-16
  - Detector bias corrections (derived from EV data) and detector dependent RVS applied to Terra bands 3, 8-12 and Aqua bands 8-12
  - EV response trending used to correct calibration drifts noticeable in recent years at different AOIs (including SD AOI) for Terra bands 1-4, 8, 9, 10 (proposed) and Aqua 8-9
    - SD to provide radiometric calibration reference
    - Lunar trending to track on-orbit radiometric change
    - EV trending at different AOIs to track on-orbit changes in RVS
Changes in L1B C6

• Thermal Emissive Bands (TEB)
  – Use BB cool-down data to compute TEB nonlinear calibration coefficients
  – Use a0=0 for Terra PV bands mirror side 1 (mirror side 2 a0 is adjusted to minimize the mirror side difference) and a0=0 for Terra/Aqua b31-32
  – Aqua pre-launch a2 (used in L1B) are adjusted to capture on-orbit changes using on-board BB calibration, while keeping the small initial difference
  – Add FPA temperature dependence to the “fixed” b1 for Aqua bands 33, 35, and 36 when the BB is operated above their saturation temperatures

• Others
  – Fill-value for inoperable detectors and QA flag for inoperable or noisy detectors at sub-frame level
  – Improved implementation of calibration uncertainty algorithm (based on actual on-orbit calibration/retrieval with time, AOI, and scene dependence)
  – L1B code fix for sector rotation data anomaly (during lunar roll)
Changes in L1B C6 (examples)

Detector bias correction applied to Terra bands 8-12, 3 and Aqua bands 8-12

Detector dependent RVS applied to Terra bands 8-12, 3 and Aqua bands 8-12

Reduced striping in C6
Changes in L1B C6 (examples)

New approach for m1 and RVS derivation and updates (for selected bands)

Reduced temporal drift in C6 TOA reflectance trending at all AOI
Changes in L1B C6 (examples)

Use of CFPA temperature dependent b1 (band 36, 2011)

**Saturation of detector response (B33, 35&36)**

BB Temp

- $T_{\text{sat}}$ for B36 is 300K

CFPA Temp

- Improved data quality 1.7%

B36 D1 (MS1) b$^1$

- C5 1.7%

B36 D1 (MS1) b$^1$

- C6
Changes in L1B C6 (examples)

Use of CFPA temperature dependent b1 (band 36, 2003, 2013)

When $T_{BB} > T_{sat}$ (300K)
Future Work

• Add FPA temperature dependent a2 (Aqua)
• Investigate and resolve bands 1-2 drift
• Improve RSB RVS
  • Current algorithms: band selections
  • New algorithms: for future applications
• Improve TEB RVS characterization (update if necessary)
• Terra/Aqua data product consistency
• Terra configuration consistency (request of SST group)
• Wisconsin spectral correction to PC bands
# L1B Code Versions

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| Aqua    |                          |      |           |       |                          |      |           |       |
|         |                          |      |           |       |                          |      |           |       |

**Used:** Used in official data production.

**Delivered:** Delivered to SDST by MCST for testing and data production

**Total:** All the code changes (major and minor) developed by MCST