Inter-comparison of Terra and Aqua MODIS

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Outline

• Introduction
  – Instrument Background
  – MODIS On-orbit Calibration (SD and Moon)
• Inter-comparison of Terra and Aqua MODIS Using Lunar Observations
  – Approach and results for thermal emissive bands
• Inter-comparison of Terra and Aqua MODIS Using AVHRR
  – Approach and results for reflective solar bands
• Summary
Instruction

• MODIS is on both Terra and Aqua spacecraft.
  Terra (EOS-AM) launched on 12/18/99 (first light 02/24/00)
  Aqua (EOS-PM) launched on 05/04/02 (first light 06/24/02)
    – http://terra.nasa.gov/
    – http://eos-pm.gsfc.nasa.gov/
• Improved (over heritage sensors)
  spatial, spectral, temporal resolutions
• Broad range of applications
  – Land, oceans, atmosphere
  – Close to daily global coverage
  – Morning & afternoon observations
• Extensive pre-launch and
  on-orbit calibration activities
**Instrument Background**

- **36 spectral bands (4 FPAs)**
  - Reflective solar bands (1-19, and 26)
  - Thermal emissive bands (20-25, 27-36)
- **3 nadir spatial resolutions**
  - 250m (1-2), 500m (3-7), and 1km (8-36)
- **On-Board Calibrators:**
  - Solar diffuser (SD)
  - SD stability monitor (SDSM)
  - Blackbody (BB)
  - Spectro-radiometric calibration assembly (SRCA)
  - Space View (SV)

**Pre-launch to On-orbit Calibration Transfer**
SD characterized with reference traceable to NISR reflectance standard
BB characterized with a large aperture Blackbody Calibration Source (BCS)
On-orbit Calibration Schematic

Same Approaches apply to both Terra and Aqua MODIS
• Applications of Using the Moon:
  – Radiometric stability (RSB)
  – Inter-comparison (Terra and Aqua MODIS, MODIS and SeaWiFS, MODIS and MISR)
  – Others (*SPIE proceedings V4881, V5234*)
    • Optical leak assessment (LWIR PC bands)
    • Operational configuration evaluation (SMIR)
    • Spatial characterization

• Lunar Observations through Space View Port:
  – Nighttime orbits
  – 0-20° spacecraft roll maneuvers
  – 55° phase angle
MODIS RSB Calibration Using SD

Reflectance

\[ \rho_{EV} \cdot \cos(\theta_{EV}) = m_1 \cdot \text{dn}^*_\text{EV} \cdot d^2_{\text{Earth-Sun}} \]

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

\[ m_1 = \frac{\text{BRF}_{SD} \cdot \cos(\theta_{SD})}{\langle \text{dn}^*_\text{SD} \rangle \cdot d^2_{\text{Earth-Sun}} \cdot \Gamma_{SD} \cdot \Delta_{SD}} \]

\( \Delta_{SD} \): SD degradation factor;
\( \Gamma_{SD} \): SD screen vignetting function
\( d \): Earth-Sun distance
\( \text{dn}^* \): Temperature and RVS corrected digital number;
\( dc \): Digital count of SDSM
MODIS RSB Calibration Using the Moon

**SD Calibration**

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

**Moon Calibration**

\[
m_1 = \frac{f(\text{view \_ geometry})}{<\text{dn}_{Moon}^* >}
\]

\[
f = \frac{f_{\text{phase \_ angle}} \cdot f_{\text{libration}} \cdot f_{\text{over \_ sampling}}}{d_{Sun - Moon}^2 \cdot d_{Modis - Moon}^2}
\]
Using the Moon for Inter-comparison

- Lunar observations
- Lunar irradiance: measured (MODIS) and modeled (Kieffer/Stone)
  - Viewing geometry
  - Over Sampling
- Inter-comparison of Terra and Aqua MODIS
- Inter-comparison of MODIS and SeaWiFS

\[
\frac{I_{\text{Terra\_MODIS}}}{I_{\text{Model}}} / \frac{I_{\text{Aqua\_MODIS}}}{I_{\text{Model}}}
\]
MODIS Lunar Observations

Aqua MODIS B1 (12/03/2003)

Single Scan, All detectors

Single detector, All scans
Lunar Irradiance: Measured and Modeled

Aqua MODIS

B1

Solid (Meas.)
Circle (Model)

Terra MODIS

B8

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Inter-comparison of Terra and Aqua MODIS

Terra MODIS B8 Trending

MODIS RSB Uncertainty:
2% in reflectance
5% in radiance

Terra and Aqua MODIS Comparison

Uncertainty Sources:
(1) Model
(2) Measurement
Inter-comparison of MODIS and SeaWIFS

Terra DSM and SeaWiFS Lunar Observations (April 14, 2003)

<table>
<thead>
<tr>
<th>SeaWiFS</th>
<th>MODIS</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Band No.</td>
<td>Wavelength (nm)</td>
<td>Measured I _W/m^2/nm</td>
</tr>
<tr>
<td>1</td>
<td>412</td>
<td>1.790</td>
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<tr>
<td>2</td>
<td>443</td>
<td>2.190</td>
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<tr>
<td>3</td>
<td>490</td>
<td>2.574</td>
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<tr>
<td>4</td>
<td>510</td>
<td>2.589</td>
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<tr>
<td>5</td>
<td>555</td>
<td>2.776</td>
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<tr>
<td>6</td>
<td>670</td>
<td>2.744</td>
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<tr>
<td>7</td>
<td>765</td>
<td>2.480</td>
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<tr>
<td>17</td>
<td>904</td>
<td>1.974</td>
</tr>
<tr>
<td>19</td>
<td>936</td>
<td>1.815</td>
</tr>
</tbody>
</table>
Using AVHRR for Inter-comparison

- Near simultaneous (nadir) observations from orbit intersection
  - Pixel by pixel matching
  - Uniform scene
- MODIS bands 31 and 32 versus AVHRR channels 4 and 5 (11\(\mu\) and 12\(\mu\))

\[
\{BT(\text{Terra \_ MODIS}) - BT(\text{AVHRR})\} \\
\{BT(\text{Aqua \_ MODIS}) - BT(\text{AVHRR})\}
\]
Terra vs. NOAA-17 Orbit Intersection
December 25, 2002, 06:12 GMT, latitude: 77.8N, longitude: 104.1W
Orbital interception at: 00:47 (GMT), July 5, 2001

Terra MODIS, band 31

NOAA16 AVHRR, channel 4

Nadir
Inter-comparison of Terra MODIS and AVHRR (17) in the 11µm band on Nov 25, 2002
Inter-comparison of Terra and Aqua MODIS Using N-17 AVHRR

MODIS Band 31 and 32
Uncertainty: 0.35K; NEdT = 0.05K at 300K

\[ \Delta B_T = 0.08 \pm 0.15K \]

\[ \Delta B_T = 0.14 \pm 0.12K \]
Inter-comparison of Terra and Aqua MODIS Using N-17 AVHRR

MODIS Band 31 and 32
Uncertainty: 0.35K; NEdT = 0.05K at 300K

ΔBT = 0.08 ± 0.15K

ΔBT = 0.14 ± 0.12K
Inter-comparison of Terra and Aqua MODIS Using N-16 AVHRR

MODIS Band 31 and 32
Uncertainty: 0.35K; NEdT = 0.05K at 300K

ΔBT = 0.10 ± 0.10K

ΔBT = 0.19 ± 0.11K
Inter-comparison of Terra and Aqua MODIS Using N-16 AVHRR

MODIS Band 31 and 32
Uncertainty: 0.35K; NEdT = 0.05K at 300K

ΔBT = 0.10 ± 0.10K

ΔBT = 0.19 ± 0.11K
Inter-comparison of NOAA-16 and 17 AVHRR Using Terra MODIS (12µm band)

\[ \Delta BT = 0.28 \pm 0.11 \text{ K} \]
Summary

• Lunar Observations
  – Support on-board calibration
  – Provide long term stability trending
  – Allow inter-comparison among sensors

• Sensors’ Simultaneous Observations (orbital intersection)
  – Inter-comparison

• Consistent Terra and Aqua MODIS Calibration
  – RSB using the Moon
  – TEB using AVHRR
Terra MODIS 500m resolution image on day 2004/051 at 10:35 UTC

**RGB from** Bands 1 (645nm), 4 (555nm), 3 (469nm)