On-Board Calibration Algorithms

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Pre-Launch On-Board Calibration (OBC)

• Transfer Ground Calibration to OBC
  • MODIS (All Bands)
    - Spectral
    - Spatial
    - Radiometric
  • On-Board Calibration
    SRCA
    - Spectral (Reflective Bands)
    - Radiometric (Reflective Bands)
    - Spatial (All Bands)
    SD/SDSM
    - Radiometric (Reflective Bands)
  Blackbody
    - Radiometric (Emissive Bands)
  Space View
    - Zero Radiance Level (All Bands)
EOS MODIS MISSION ELEMENTS
6 INSTRUMENTS
15 YEAR MISSION
6 CALIBRATION SOURCES

5 years 5 years 5 years

SRCA
Radiometric (VIS/NIR/SWIR)
Spectral (VIS/NIR/SWIR)
Spatial (All Bands)

V-Groove Blackbody
Radiometric (MWIR/LWIR)
DC Restore (All Bands)

Relative Calibration Sites
Non-Instrumented Sites

Instrumented "Vicarious" Sites

Lunar View Radiometric (VIS/NIR/SWIR Spatial)

Space View Radiometric (All Bands)

Sun
Data Sequence for One Scan (Mirror Side 1 or 2)

- PERFORM DC RESTORE
- EXECUTE COMMANDS
- FORMAT SCIENCE ENGINEERING DATA
- SOLAR DIFFUSER (BEGIN SIDE n SCAN)
- SRCA
- BLACK BODY VIEW
- SPACE VIEW
- START EARTH SCAN
- END OF EARTH SCAN
- NADIR
MODIS Spectral Radiometric Calibration Assembly (SRCA)
SRCA Processing

- ~5 Frames per Scan  • ~800 Scans per Orbit
  (Assuming 20% Duty Cycle)

- One Lamp State at a Time

<table>
<thead>
<tr>
<th></th>
<th>TIME (min)</th>
<th>BAND</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiometric Calibration</td>
<td>17</td>
<td>Reflective</td>
</tr>
<tr>
<td>Spectral Characterization</td>
<td>75</td>
<td>Reflective</td>
</tr>
<tr>
<td>(Center Wavelength)</td>
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<td></td>
</tr>
<tr>
<td>Spatial Registration*</td>
<td>37</td>
<td>ALL</td>
</tr>
</tbody>
</table>

*Both Along Scan and Along Track

- Compute Radiometric Calibration, Center Wavelength or Spatial Registration
MODIS Solar Diffuser Stability Monitor

- 11 Detectors & Filters
- Integrating Sphere
- Entrance Port
- Three-Position Rotating Mirror
- 2% Screen Transmitting
- Solar Diffuser
- 8.5% Screen When In Use
- Sun

Solar Diffuser not shown when in use.
Solar Diffuser Processing

(~35 Frames per Scan)
(~30 Scans per Orbit)

• Analyze SDSM Data
• Obtain Degradation Constant for SD
• Correct SD Observations for BRDF and Degradation Effects
• Calculate Average SD Values
Check SD Stability: Analyze SDSM Data

**SDSM Calculations:**

\[ Q_{SD}(\lambda, t) = R'(\lambda) K K(\theta) f(\lambda, \theta, \phi, \phi', t) \cos \theta S(\lambda) \]
\[ Q_S(\lambda, t) = R'(\lambda) K S(\lambda) K(\theta) \]
\[ K(\lambda) = \frac{Q_S(\lambda, t_0) f(\lambda, \theta, \phi, \phi', t_0) K K'(\theta) \cos \theta}{Q_{SD}(\lambda, t_0) K(\theta)} \]
\[ f(\lambda, \theta, \phi, \phi', t) = \frac{K(\lambda) Q_{SD}(\lambda, t_1) K(\theta)}{Q_S(\lambda, t_1) K K'(\theta) \cos \theta} \]
\[ C(\lambda, t_1) = \frac{f(\lambda, \theta_1, \phi_1, \phi'_1, t)}{f(\lambda, \theta_1, \phi_1, \phi'_1, t_0)} \]
\[ <C(\lambda, t_1)> = \frac{1}{N} \sum_{i=1}^{N} C_i(\lambda, t_1) \]

**Solar Diffuser Calculations:**

\[ L(\lambda) = <C(\lambda, t_1)> f(\lambda, \theta, \phi_1, \phi'_2, t_1) \]
\[ <L(\lambda)> = \frac{1}{N} \sum_{i=1}^{N} L_i(\lambda) \]

- \( t_0, t_1 \) = Time Before, After Launch
- \( N \) = Number of Data Points
- \( Q_{SD} \) = Solar Diffuser Counts from SDSM minus offset
- \( Q_S \) = Sun Counts from SDSM minus offset
- \( R'(\lambda) \) = Spectral Responsivity of SDSM
- \( \text{offset} \) = offset from dark position of SDSM
- \( f(\lambda, \theta, \phi, \phi', t) \) = BRDF of Solar Diffuser
- \( S(\lambda) \) = Solar Spectral Irradiance
- \( K(\lambda) \) = Attenuation of SDSM sun-screen
- \( K' \) = 1 for no solar diffuser screen
- \( 0.085 \) for solar diffuser screen
- \( K'(\theta) \) = obliquity factor for solar diffuser screen
- \( K(\theta) \) = obliquity factor for SDSM solar screen
- \( C(\lambda, t_1) \) = Degradation of SD panel
- \(<C(\lambda, t_1)> \) = Average Degradation Value
- \( L(\lambda) \) = Spectral Radiance
- \(<L(\lambda)> \) = Average Spectral Radiance

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Calculate the MODIS SD Data

For all detectors for which the current solar diffuser mode will provide values within those detectors' dynamic ranges.

\[ <Q> = \frac{1}{N} \sum_{i=1}^{N} Q_i \]

\[ <Q> \] = Average Solar Diffuser Value for MODIS

\( N \) = Number of Solar Diffuser Values for MODIS

\( Q_i \) = \( i \)th Solar Diffuser Values for MODIS
Space View Processing

• 15 Frames per Scan
• Occurs Every Scan

• Compute Scan Average Over 15 Frames for Two Consecutive Scans. Interpolate Throughout Scan.

Black Body Processing

• 30 Frames per Scan
• Occurs Every Scan

• Correct each observation for gradient effects. Obtain effective temperature, radiance.

• Compute "Weighted" Average of all Observations for Calibration Every Scan for Two Consecutive Scans. Interpolate throughout Scan.
Emissive Band Calibration

\[ V(L + L_0) = a_1(L + L_0) + \sum_{n=2}^{N} a_n(L + L_0)^n \]

Where:
- \( a_n \) = From Pre-Launch test; \( n = 2, N \)
- \( L_0 \) = Effective Radiance At Aperture during Space Look
- \( V_0 = V(L_0) \) = Space View Signal
- \( a_1 = \frac{V_B - \sum_{n=2}^{N} a_n(L_B + L_0)^n}{(L_B + L_0)} \)
- \( V_B \) = Blackbody Voltage
- \( L_B \) = Blackbody Radiance
Post-Launch On-Board Calibration

- Use OBC to calibrate MODIS.

- OBC will Degrade.
  - Need SD Characteristics (BRDF) With Age
  - Need Lamp Characteristics (Intensity versus Wavelength) With Age
  - Need "Best" Algorithm from Synthesis