Workshop on Aqua MODIS Cold FPA Performance and Operation (I)

Jack Xiong

_Biospheric Sciences Branch 614.4, NASA/GSFC_

_and_

.MODIS Characterization Support Team (MCST)

4801 Forbes Boulevard, Lanham, MD 20706 (May 7, 2010)
Logistics

• Sign-in (at front desk)
• Restrooms (available on the first and second floor)
• Copy and Fax (available upon request)
• Breaks (lunch and coffee)
• Dial-in Number and Passcode
  
  1-888-850-4523; PC: 399530

• Wireless Network
  
  HBS Guest Network; Password: bluемarble
Agenda

• Introduction (15 min)
• Aqua MODIS TEB Calibration and Performance (45 min)
• Aqua MODIS CFPA On-orbit Operation and Performance (40 min)
  Coffee Break (15 min)
• CFPA Impact on TEB Calibration (40 min)
• Options to Maintain CFPA Temperature Stability (30 min)
  Lunch (60 min)
• Discussions (90 min)
  Adjourn
Introduction

• Objectives

• Instrument Background

• On-orbit Calibration Methodologies

• Instrument Performance
  - Operation Configurations
  - Key Telemetry Trending
  - Summary
Objectives

- Review Aqua MODIS CFPA On-orbit Performance
- Present Options to Maintain CFPA Temperature Stability
- Identify Potential Impact on Calibration and Data Products
- Recommend Path Forward
MODIS and On-board Calibrators

- **Terra MODIS**
  - Launch: 12/18/1999; First Light: 02/24/2000

- **Aqua MODIS**
  - Launch: 05/04/2002; First Light: 06/24/2002

- **On-board Calibrators**
  - SD/SDSM, BB, SV, SRCA
On-orbit Calibration Activities

SD/SDSM: Weekly to tri-weekly

Solar Diffuser

SRCA: Radiometric: monthly Spatial: quarterly Spectral: tri-yearly

SDSM

Blackbody

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

Space View

Spacecraft maneuvers:
Yaw (SD BRF, VF) Roll (Moon) Pitch (only applied to Terra)
MODIS Focal Plane Assemblies (FPA)

Instrument FPA Main Frame Temperature

Warm FPA: VIS and NIR; Cold FPA: SMIR and LWIR

Cold FPAs: (80, 83, 85K)
## MODIS Specifications and Applications

<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>
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<th>Bandwidth (nm)</th>
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<td>931 - 941</td>
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<td>19</td>
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<td></td>
<td>19</td>
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<td>250</td>
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1 Spectral Radiance values are (W/m²-µm-sr)
## TEB Calibration Requirements

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<th>CW</th>
<th>Ttyp</th>
<th>NEdT</th>
<th>UC (%)</th>
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<td>220</td>
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</table>

CW: center wavelength in µm;  
Ttyp: typical scene temperature in K;  
NEdT: noise equivalent temperature difference in K;  
UC: uncertainty in percentage and in K
• **Terra MODIS Configurations**
  - **A-side**: launch to Oct 30, 2000
  - **B-side**: Oct 30, 2000 to June 15, 2001
  - **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: $T_{\text{inst}}$ ~3.5K increase over 10 years
- Warm FPA: $T_{\text{vis}}$ $T_{\text{nir}}$ ~3.5K increase over 10 years
- Cold FPA: $T_{\text{smir}}$ $T_{\text{nir}}$ extremely stable

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Instrument and FPA Temperatures
(Aqua MODIS)

Instrument

~1.5K increase over 7.5 years

Warm FPA

~1.5K increase over 7.5 years

Cold FPA

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

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 Warm FPA temperatures are stable
- Instrument and warm FPA temperatures changed less than 4K for Terra MODIS (more than 10 years); less than 2K for Aqua MODIS (nearly 8 years)

Cold FPA temperatures
- Terra MODIS CFPA temperature constantly 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)
Aqua MODIS TEB Calibration and Performance

- Pre-launch Calibration Effort and Results (examples)
- On-orbit Calibration Methodologies and Performance
Pre-launch Calibration Effort (1)

- 3 TV Calibration at SBRS plus S/C TV Calibration at TRW
  - TV1: 07/29/98 - 08/09/98
  - TV2: 09/16/98 - 11/15/98
  - TV3: 06/09/99 - 08/08/99
  - S/C TV: 08/25/01 - 10/09/01

- Calibration Performed at 3 Instrument Temperatures; 3 CFPA Temperatures (nominal plateau); Multiple Configurations

- Successful TEB RVS Characterization

- TEB RSR Characterization Performed in TV

- Post S/C TV Gain Changes for Bands 31 and 32
Pre-launch Calibration Effort (2)

- **Three Instrument Temperature Plateaus**
  - Cold: \( T_{INST} = 257K \)
  - Hot: \( T_{INST} = 274K \)
  - Nominal: \( T_{INST} = 266K \)

- **FM1 TV3 RC02 Data Collects**
  - 11 or 21 BCS Levels; CFPA temperature = 83K

- **Redundant Electronic**
  - Cold, UAID: 3747-3757, \( T_{OBC} = 280K, T_{BCS} = 170-334K \)
  - Hot, UAID: 3812-3824, \( T_{OBC} = 280K, T_{BCS} = 170-334K \)
  - Nom, UAID: 4233-4243, \( T_{OBC} = 292K, T_{BCS} = 170-334K \)

- **Primary Electronic**
  - Cold, UAID: 3733-3743, \( T_{OBC} = 280K, T_{BSC} = 170-334K \)
  - Hot, UAID: 3831-3841, \( T_{OBC} = 280K, T_{BCS} = 170-321K \)
  - Nom, UAID: 3889-3909, \( T_{OBC} = 280K, T_{BCS} = 170-340K \)

Additional data collected at different configurations and CFPA temperatures
MODIS FM1 TEB Pre-launch TV3 Test NEdT at $L_{typ}$ (Redundant)
B33, 35, 36 $T_{\text{sat}} < 310K$!!
Impact on the on-orbit calibration and L1B algorithm.

MODIS FM1 TEB Specified and Measured Saturation Temperature

$T_{\text{sat}}$ from Pre-launch
Detector Nonlinearity

B31 and B32 have higher NL, same behavior as PFM
Gains at Different CFPA Temperatures

MODIS FM1 TEB Pre-launch Linear Coefficient $a_1$ Comparison between FPA Temperature 83K and 85K (Redundant)

Band + Channel Number (SBRS Order)
Pre-launch $a_1$ versus FPA Temperature

Band 20

Band 21

Band 22

Band 23

Band 24

Band 25

Band 26

Band 27

Band 28

Band 29

Band 30

Band 31

Band 32

Band 33

Band 34

Band 35

Band 36
Pre-launch $a_2$ versus FPA Temperature
On-orbit Calibration Methodologies and Performance

- Quadratic Algorithm
  - Linear calibration coefficients computed on a scan-by-scan basis; 40-scan running average used in the L1B
  - Fixed coefficients used for B21 (a simple linear algorithm)
  - Fixed coefficients also used for B33, 35, and 36 when $T_{bb}$ are above $T_{sat}$
- Period BB Warm-up and Cool-down (WUCD) Activities
  - Derive fixed linear coefficients
  - Compute nonlinear coefficients (update if necessary)
- Performance
  - Dedicated short- and long-term monitoring effort (offline)
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:**

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

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

**WUCD \( T_{BB} \):** 270 to 315K
## TEB V6 LUT – A0/A2 Strategy

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<th>V6</th>
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<table>
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Coefficients derived from quarterly BB Warm-up & Cool-down Activities

V6 Approach improves TEB performance for low temperature scenes
BB, Instrument, and CPFA Temperatures

$T_{BB}$

$T_{INST}$

$T_{SMIR}$

$T_{LWIR}$
# Aqua MODIS Noisy Detector History

## Detectors in Product Order

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<td>0.02</td>
<td>1.32</td>
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<tr>
<td>255/2002</td>
<td></td>
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<td>0.43</td>
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<td>0.09</td>
<td>0.02</td>
<td>0.02</td>
<td>1.36</td>
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<tr>
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<td>0.18</td>
<td>0.19</td>
<td>near 0.2</td>
<td>0.09</td>
<td>0.02</td>
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<td>1.31</td>
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<tr>
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<td>0.19</td>
<td>near 0.2</td>
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<td>0.02</td>
<td>0.02</td>
<td>1.29</td>
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<td>0.18</td>
<td>0.19</td>
<td>near 0.2</td>
<td>0.23</td>
<td>0.02</td>
<td>0.02</td>
<td>1.35</td>
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<td>0.18</td>
<td>0.21</td>
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<td>0.13</td>
<td>0.02</td>
<td>0.05</td>
<td>1.34</td>
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<tr>
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<td>0.03</td>
<td>0.19</td>
<td>0.19</td>
<td>near 0.2</td>
<td>0.14</td>
<td>0.05</td>
<td>0.05</td>
<td>1.34</td>
<td></td>
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</tbody>
</table>

**Notes:**

- **Day/Year** refers to the date and year of the event.
- **Band** indicates the band number.
- **Spec NEdT [K]** represents the specific noise equivalent temperature in Kelvin.
- **Detector #** indicates the detector number.
- The colors (yellow and blue) indicate different states or conditions of the detectors.
- The values represent specific measurements or states associated with each event.
Aqua MODIS TEB b1 & NEdT Trending (Product Order; T_{bb}@285K)

Day 158 - Science Mode begin
Day 175 - Nadir Door Open
Day 178, 183 - Safe Mode, Science Mode
Day 210, 218 - Safe Mode, Science Mode
Day 255, 255 - Safe Mode, Science Mode
Aqua MODIS TEB b1 & NEdT Trending (Product Order: T_{BB}@285K)

Day 158 - Science Mode began
Day 175 - Nadir Door Open
Day 178, 183 - Safe Mode, Science Mode
Day 210, 218 - Safe Mode, Science Mode
Day 255, 255 - Safe Mode, Science Mode
Aqua MODIS TEB b1 & NEdT Trending (Product Order: T_{bb}@285K)

Day 158 = Science Mode begin
Day 175 = Nadir Door Open
Day 178, 183 = Safe Mode, Science Mode
Day 210, 215 = Safe Mode, Science Mode
Day 255, 255 = Safe Mode, Science Mode
Aqua MODIS TEB b1 & NEdT Trending (Product Order; T_{bb}@285K)

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Aqua MODIS TEB b1 & NEdT Trending (Product Order; \( T_{BB}@285K \))

**Ch1** - **Ch2** - **Ch3** - **Ch4** - **Ch5** - **Ch6** - **Ch7** - **Ch8** - **Ch9** - **Ch10**

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Ch1:  -  Ch2:  -  Ch3:  -  Ch4:  -  Ch5:  -  Ch6:  -  Ch7:  -  Ch8:  -  Ch9:  -  Ch10:  -

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