MODIS TEB Calibration Performance and Collection 6 Improvements

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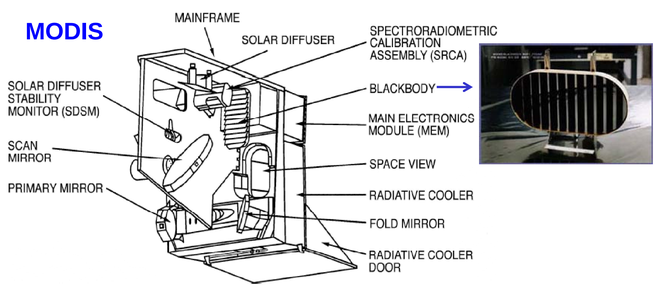
Introduction

- The **MOD**erate Resolution **I**maging **S**pectroradiometer (**MODIS**) is a key instrument for NASA's Earth Observing System (**EOS**). It is onboard both **Terra** and **Aqua** spacecrafts. Terra was launched in December 1999 and Aqua in May 2002.
- MODIS has 36 spectral bands ranging from 0.42 to 14.5 µm, located on four focal plane assemblies (FPA), with spatial resolution (at nadir) of 250 m (bands 1-2), 500 m (bands 3-7) and 1000 m (bands 8-36). There are 16 thermal emissive bands (TEB), B20-25 and B27-36, located on the SMIR and LWIR focal planes controlled at 83K on-orbit. Each band has 10 independently calibrated detectors aligned along-track.
- MODIS 2-sided paddle wheel scan mirror provides a -55 to +55 degree scan of the Earth View (EV) covering 10 km (at nadir) along track by 2330 km along scan swath.
- The TEB bands are calibrated using scan-by-scan observations of the on-board blackbody (BB), controlled at 290 K (Terra) and 285 K (Aqua).



TEB On-orbit Calibration Algorithm

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

Linear calibration coefficient (b_1):

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

- a_0 and a_2 : offset and the non-linear terms
- b_1: the linear calibration coefficient
- *RVS*: response versus scan angle
- *dn*: background subtracted instrument signal
- L_S: source radiance (band integrated)
- ε_S: source emissivity

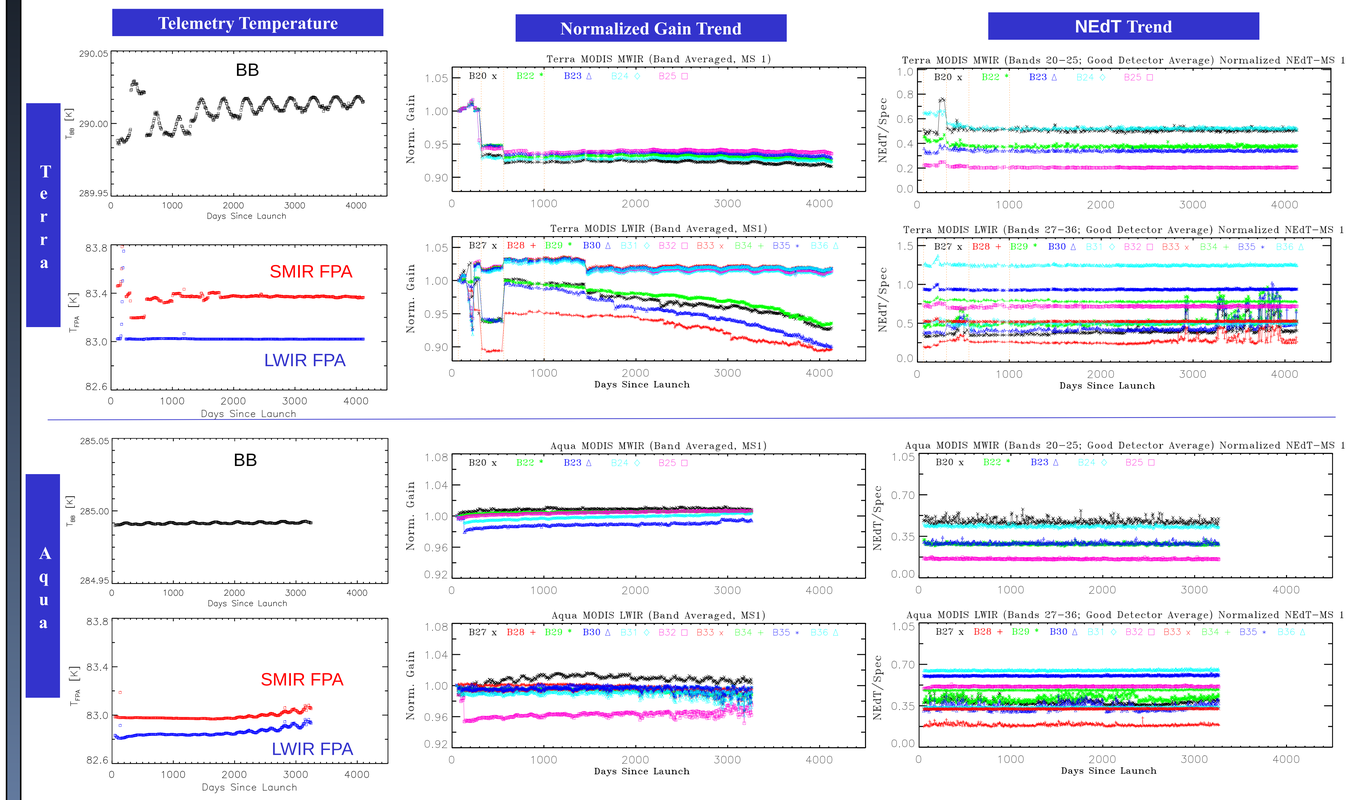
EV: Earth View
SV: Space View
BB: Blackbody
SM: Scan Mirror
Cav: Instrument Cavity

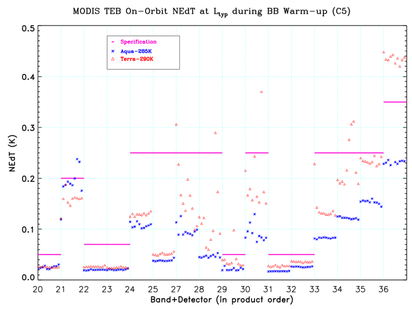
TEB Key Specifications

Band	λ_{ctr} (µm)	L_{typ} Radiance (W/m^2-µm-sr)	Scene Temperature at L_{typ} (K)	Required NEdT (K)	Radiometric Requirement at L_{typ} (%)*	Radiometric Requirement at L_{typ} (K)
20	3.79	0.45	300	0.05	0.75%	0.18
21	3.99	2.38	335	0.20	1%	0.31
22	3.97	0.67	300	0.07	1%	0.25
23	4.06	0.79	300	0.07	1%	0.25
24	4.47	0.17	250	0.25	1%	0.19
25	4.55	0.59	275	0.25	1%	0.24
27	6.77	1.16	240	0.25	1%	0.27
28	7.34	2.18	250	0.25	1%	0.32
29	8.52	9.58	300	0.05	1%	0.53
30	9.73	3.69	250	0.25	1%	0.42
31	11.01	9.55	300	0.05	0.5%	0.34
32	12.03	8.94	300	0.05	0.5%	0.37
33	13.36	4.52	260	0.25	1%	0.62
34	13.68	3.76	250	0.25	1%	0.59
35	13.91	3.11	240	0.25	1%	0.55
36	14.19	2.08	220	0.35	1%	0.47

**defined at L_{typ} and between ±45° off nadir*

TEB On-orbit Performance





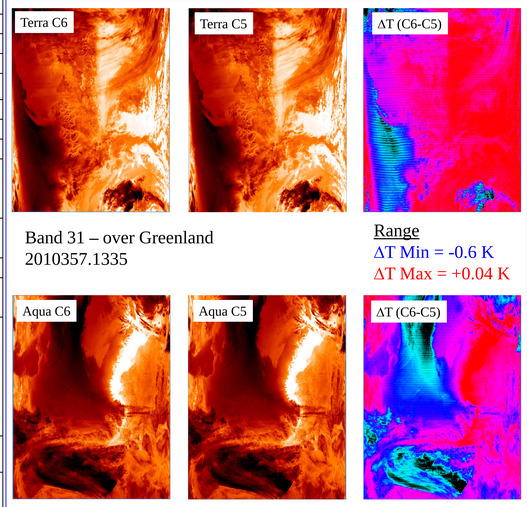
- BB temperatures remain stable over the mission lifetime.
- TEB detector response is stable for both short-term and long-term trends (excluding sensor configuration changes and instrument reset events). The largest changes have been observed for the PV LWIR bands (27-30).
- Terra MODIS has 27 noisy detectors and 1 inoperable detector
- Aqua MODIS has 3 noisy detectors and 1 inoperable detector
- Concerns:
  - Terra PV LWIR detectors (bands 27-30) are becoming increasingly noisy.
  - Aqua cooler margin is a concern for CFPA short-term stability. The impact on L1B product is minor.

TEB Collection 6 Methodology and LUT Changes

Coeff.	Calibration	Instr.	Band	C5	C6
a0/a2	- One-year sliding window average - Each detector - Each mirror side - Update as needed	**Terra**	20, 22-25, 27, 28, 30	Warm-up a0/a2	Cool-down a0/a2
			21	a0=0 and a2=0	
			29, 31,32	Warm-up a0/a2	a0=0, cool-down a2
			33-36	a0=0, warm-up a2	a0=0, cool-down a2
		Aqua	20, 22-25, 27-30	Pre-launch a0/a2*	
			21	a0=0 and a2=0	
			31,32	Warm-up a0/a2	a0=0, cool-down a2
			33-36	a0=0, Pre-launch a2	
Band 21 b1	- Each detector - Each mirror side - Update as needed	**Terra** **Aqua**	21	Warm-up cool-down	
RVS	- Band averaged - Each mirror side	**Terra**	All	Pre-launch and Update with Deep Space Maneuver (2003/085)	
		Aqua	All	Prelaunch	
PC optical leak	Each detector	**Terra**	32-36	Derived from early mission lunar observation	
RSR	Each band Each detector	**Terra** **Aqua**	All	Pre-launch	
BB emissivity	For each band				
Cavity emissivity	All band averaged				
Default b1	Each detector	Aqua	33, 35, 36	Warm-up	Cool-down#
Inoperable detector QA	Each detector	**Terra** **Aqua**	All	Interpolation	Fill value
UI	Each detector	**Terra** **Aqua**	All	C6 included additional UI terms	

* a2 adjusted to account for long-term drift of PL coefficients
\# methodology modified t compensate for FPA temperature oscillation during WUCD activities

TEB C6-C5 L1B EV Differences



Band 31 – over Greenland
2010357.1335

Range
ΔT Min = -0.6 K
ΔT Max = +0.04 K

Band 31 – over Greenland
2010358.1440

Range
ΔT Min = -0.92 K
ΔT Max = -0.04 K

C6 improves cold scene retrievals by using the modified a0/a2 approach

TEB C6 L1B Impact Estimate

Band	T @ 0.3 L_{typ}	T_{typ}	T @ 0.9L_{max}	ΔT @ 0.3 L_{typ}	ΔT @ L_{typ}	ΔT @ 0.9L_{max}
Terra						
20	274	300	332	-0.10	+0.02	-0.08
21	302	335	493	generally within ±2		
22	273	300	325	-0.07	+0.02	+0.01
23	272	300	362	-0.06	+0.02	+0.01
24	229	250	262	-0.90	-0.30	-0.15
25	249	275	282	-0.40	-0.07	-0.03
27	211	240	267	-0.55	-0.15	-0.03
28	217	250	271	-0.30	-0.06	-0.01
29	247	300	318	-0.35	-0.02	-0.13
30	208	250	270	-1.25	-0.35	-0.17
31	235	300	316	+0.10	-0.03	-0.08
32	231	300	315	+0.15	-0.04	-0.09
33	202	260	277	+0.13	+0.09	+0.04
34	195	250	261	+0.14	+0.11	+0.09
35	188	240	254	+0.11	+0.10	+0.09
36	175	220	232	+0.13	+0.14	+0.13
Aqua						
21	302	300	493	generally within ±2		
31	235	300	316	-0.40	0.00	-0.03
32	231	300	315	-0.40	0.00	-0.05

- Temperature in K
- Actual differences are detector and time dependent (results shown here for 2003 C6 Land Test data)

a) Sigma Space Corp., Lanham, MD b) Science Systems & Applications Inc, Lanham, MD c) Sciences and Exploration Directorate, NASA/GSFC, Greenbelt, MD