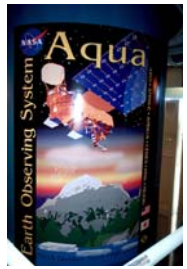


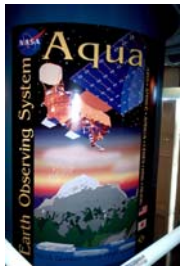
MODIS Calibration Workshop

Jack Xiong
Sciences and Exploration Directorate, NASA/GSFC

and

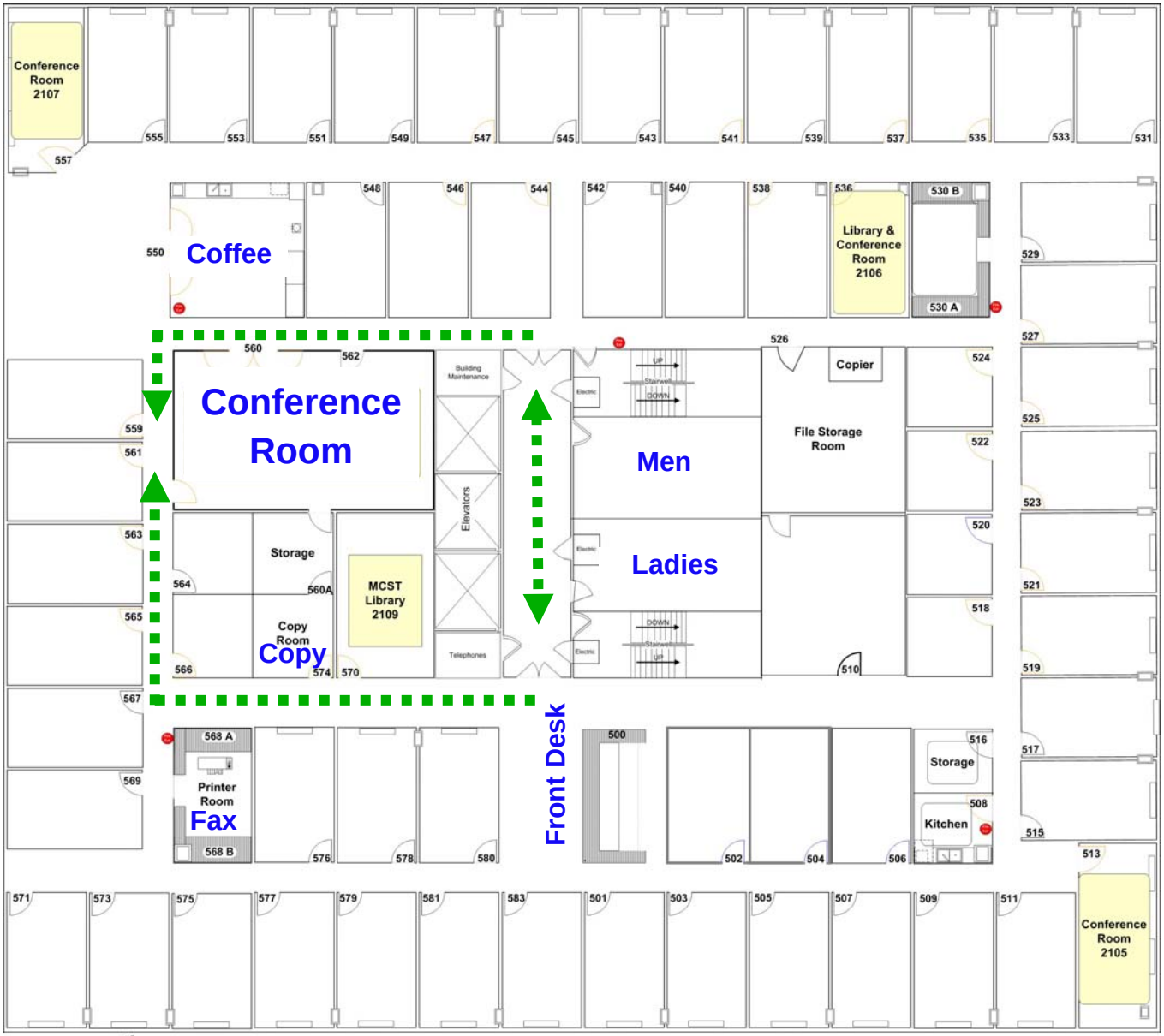
MODIS Characterization Support Team (MCST)

Logistics



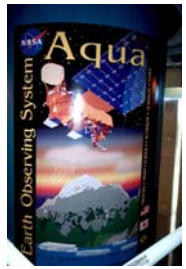
- Badge (sign-in at front desk)
- Restroom (keys available at front desk)
- Breaks (lunch and coffee)
- Copy and Fax (available upon request)
- Wireless Internet
  - Login:
  - Password:

SSAI 5th Floor Layout



SSAI 5th Floor

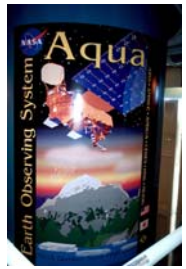
MCST Contact



- Team leader: Jack Xiong (code 614.4, NASA/GSFC)
- MCST technical coordinator: Brian Wenny
- Instrument operation: Roy Yi
- RSB Calibration: Junqiang Sun / Hongda Chen
- TEB Calibration: Brian Wenny / Aisheng Wu
- Spectral and Spatial: Jason Choi
- L1B and LUT: James Kuyper

http://www.mcst.ssai.biz/mcstweb/index.html

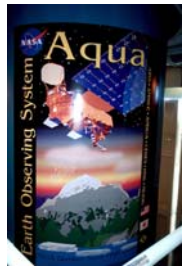
- Information on MODIS Operation, Calibration, L1B Code & LUTs
- L1B ATBD and MCST Publications
- Workshop Presentations (current and previous)



Acknowledgements

- MCST Groups: IOT, L1B/LUT, and Calibration
- MODIS Science Team
  - Science Team Leader (Vince Salomonson)
  - Land (Eric Vermote and Zhengming Wan)
  - Ocean (Gerhard Meister et al.)
  - Atmosphere (Chris Moeller)
  - Cal/Val (Stu Biggar et. al)
- Raytheon / SBRS MODIS Team
  - **Recently transitioned to Raytheon El Segundo**
- Others
  - Bill Barnes, Bruce Guenther, Eugene Waluschka, and Robert Wolfe

- Special Thanks to SSAI
  - Conference support

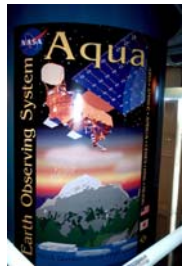


Outline

- Instrument Status (J. Xiong and R. Yi)
- Level 1B and LUT Updates (J. Kuyper)
- On-orbit Calibration and Characterization
  - RSB Calibration Performance (J. Sun)
  - TEB Calibration Performance (B. Wenny)
  - Spatial and Spectral Characterization (J. Choi and J. Xiong)
  - Geolocation (R. Wolfe)
- Challenging Issues (J. Xiong and A. Wu)
- Science Presentations (C. Moeller, E. Kwiatkowska, E. Vermote, and R. Evans / P. Minnett)
- Summary
  - Future Work for Collection 6

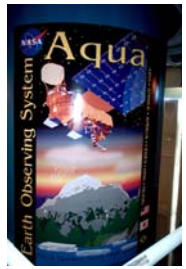
Open Discussions (All)

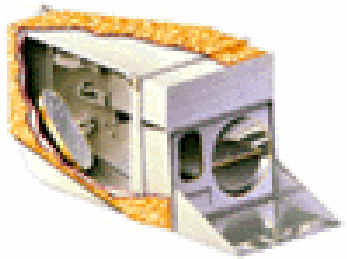
Instrument Status



- Instrument Background (for reference purposes)
- On-orbit Calibration Activities
- Instrument and FPA Temperatures Trending
- Recent Events / Activities (S/C included)
- Summary of Instrument Status (operation/calibration)
- History of Instrument Events/Activities (backup slides)

Instrument Background





PFM

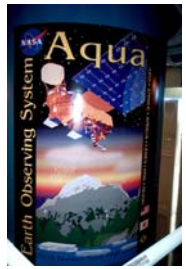
Terra (EOS-AM):
Launched on 12/18/99
First light on 02/24/00

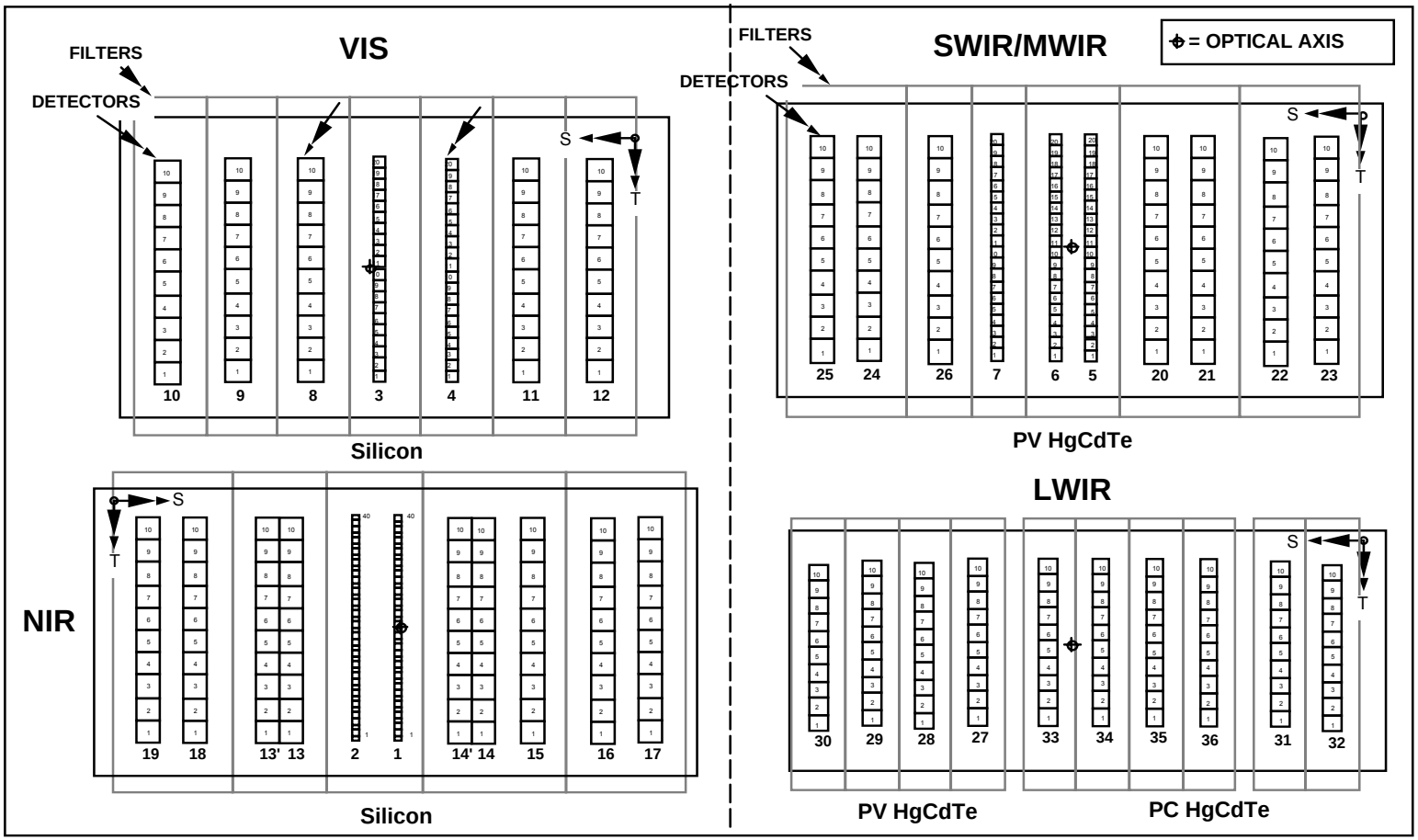
FM1

Aqua (EOS-PM):
Launched on 05/04/02
First light 06/24/02

- 2-sided Paddle Wheel Scan Mirror
- 3 Nadir Spatial Resolutions
  - 250m (1-2), 500m (3-7), and 1km (8-36)
- 4 Focal Plane Assemblies (FPAs)
  - VIS, NIR, SMIR, and LWIR
- 36 Spectral Bands (490 detectors)
  - Reflective solar bands (1-19, and 26), thermal emissive bands (20-25, 27-36)
- On-Board Calibrators (OBCs):
  - Solar diffuser (SD)
  - SD stability monitor (SDSM)
  - Blackbody (BB)
  - Spectro-radiometric calibration assembly (SRCA)
  - Space view (SV)
- Science Applications
  - Land, oceans, and atmosphere
  - Nearly 40 science products generated and distributed

MODIS Focal Plane Assemblies (FPA)





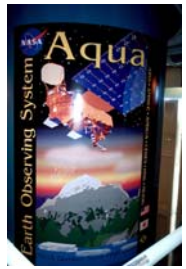
Instrument FPA Main Frame Temperature

Cold FPAs: (80. 83, 85k)

S: scan direction; T: track direction

B13 and B14 have 2 columns of detectors for TDI high and low gain output

MODIS Key Specifications



Primary Use	Band	Bandwidth[1]	Spectral Radiance[2]	Required SNR[3]
Land/Cloud/Aerosols Boundaries	1	620 - 670	21.8	128
	2	841 - 876	24.7	201
Land/Cloud/Aerosols Properties	3	459 - 479	35.3	243
	4	545 - 565	29	228
	5	1230 - 1250	5.4	74
	6	1628 - 1652	7.3	275
	7	2105 - 2155	1	110
Ocean Color/ Phytoplankton/ Biogeochemistry	8	405 - 420	44.9	880
	9	438 - 448	41.9	838
	10	483 - 493	32.1	802
	11	526 - 536	27.9	754
	12	546 - 556	21	750
	13	662 - 672	9.5	910
	14	673 - 683	8.7	1087
	15	743 - 753	10.2	586
	16	862 - 877	6.2	516
Atmospheric Water Vapor	17	890 - 920	10	167
	18	931 - 941	3.6	57
	19	915 - 965	15	250

[3] SNR = Signal-to-noise ratio

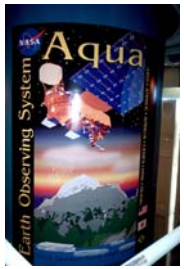
Primary Use	Band	Bandwidth[1]	Spectral Radiance[2]	Required NEΔT(K)[4]
Surface/Cloud Temperature	20	3.660 - 3.840	0.45 (300K)	0.05
	21	3.929 - 3.989	2.38 (335K)	0.2
	22	3.929 - 3.989	0.67 (300K)	0.07
	23	4.020 - 4.080	0.79 (300K)	0.07
Atmospheric Temperature	24	4.433 - 4.498	0.17 (250K)	0.25
	25	4.482 - 4.549	0.59 (275K)	0.25
Cirrus Clouds Water Vapor	26	1.360 - 1.390	6	150 [3]
	27	6.535 - 6.895	1.16 (240K)	0.25
	28	7.175 - 7.475	2.18 (250K)	0.25
Cloud Properties	29	8.400 - 8.700	9.58 (300K)	0.05
Ozone	30	9.580 - 9.880	3.69 (250K)	0.25
Surface/Cloud Temperature	31	10.780 - 11.280	9.55 (300K)	0.05
	32	11.770 - 12.270	8.94 (300K)	0.05
Cloud Top Altitude	33	13.185 - 13.485	4.52 (260K)	0.25
	34	13.485 - 13.785	3.76 (250K)	0.25
	35	13.785 - 14.085	3.11 (240K)	0.25
	36	14.085 - 14.385	2.08 (220K)	0.35

[1] Bands 1 to 19 are in nm; Bands 20 to 36 are in μm

[2] Spectral Radiance values are (W/m^2-μm-sr)

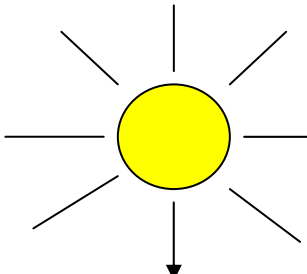
[4] NEΔT = Noise-equivalent temperature difference

MODIS Calibration Activities

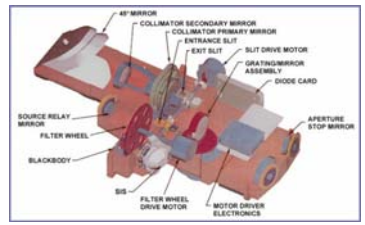


BB (quarterly)
SD/SDSM (weekly first year to bi-weekly)
SRCA (monthly radiometric, bi-monthly spatial, quarterly spectral)
Maneuvers (roll: monthly **Moon**; yaw: 2 for Terra and 1 for Aqua; pitch: 2 for Terra)

SDSM



Solar Diffuser



SDSM

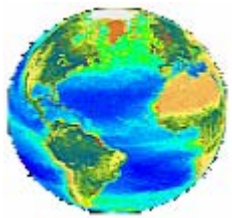
SRCA

Blackbody

Scan Mirror

Space View

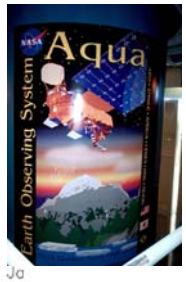
Moon

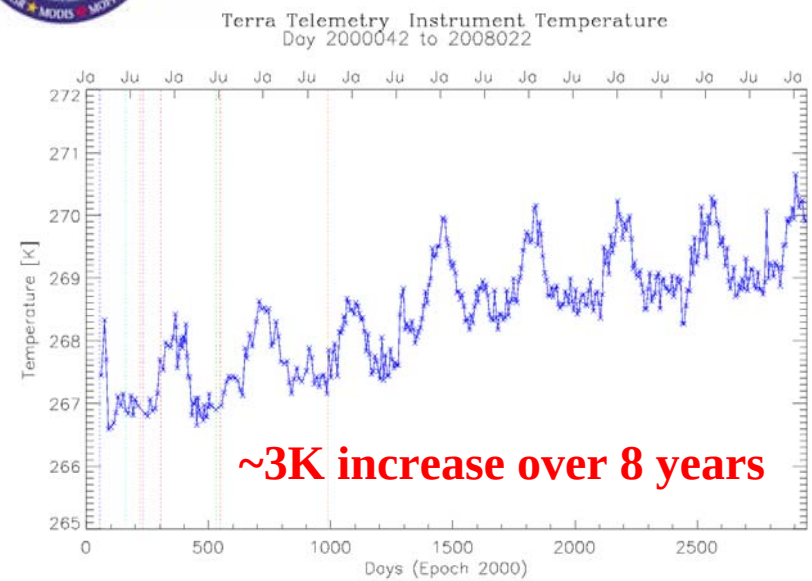


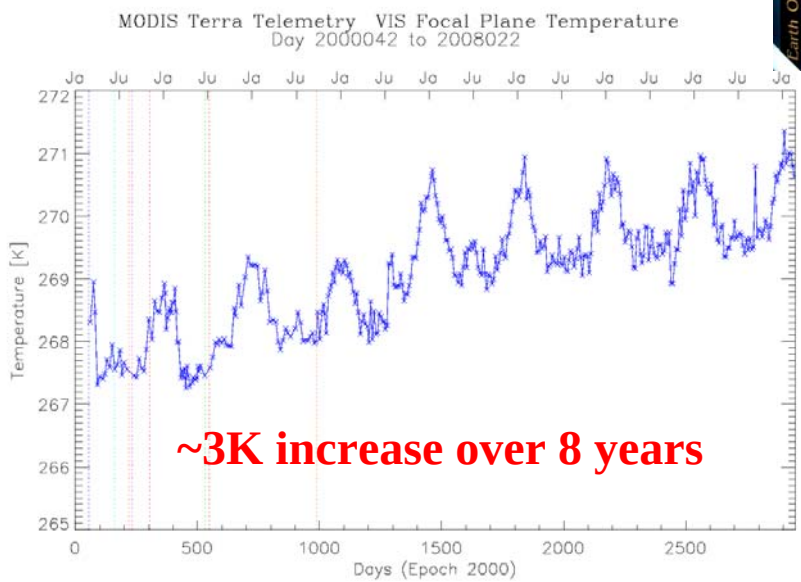
SRCA is currently operated at reduced frequencies (30W configuration removed). This has no impact on radiometric calibration.

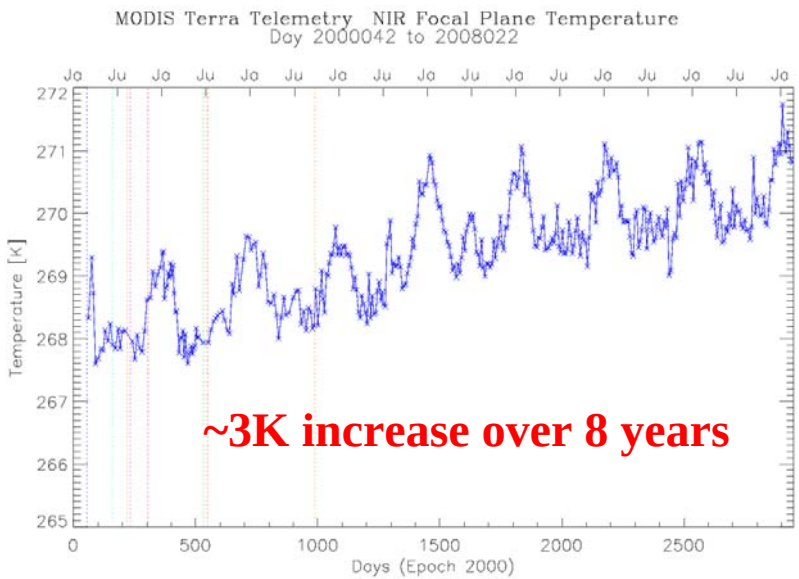
Starting from July 2, 2003, Terra SD door fixed at open with SD screen down; more efforts for SD calibration data analysis

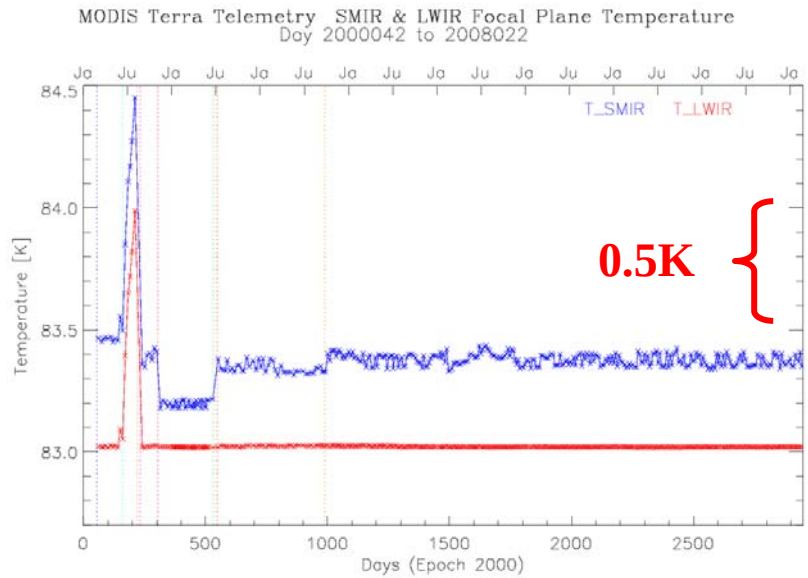
Terra Instrument and FPA Temperatures



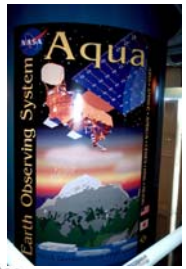


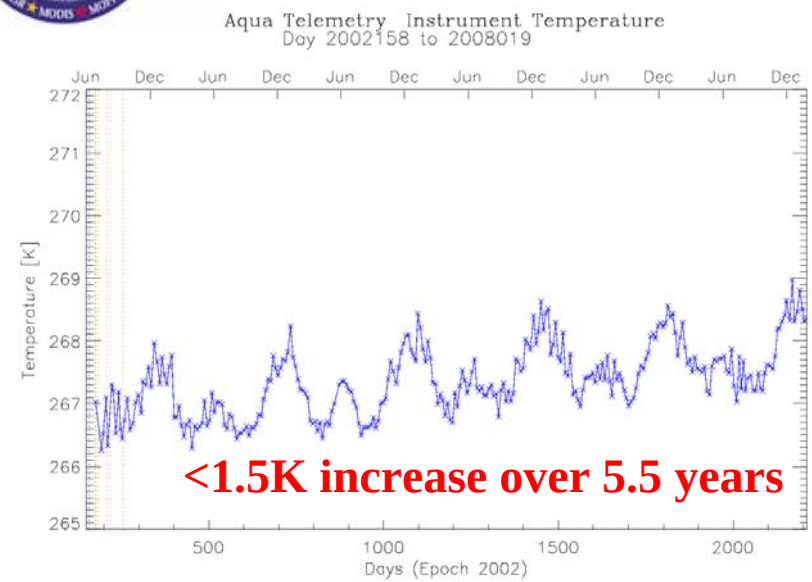


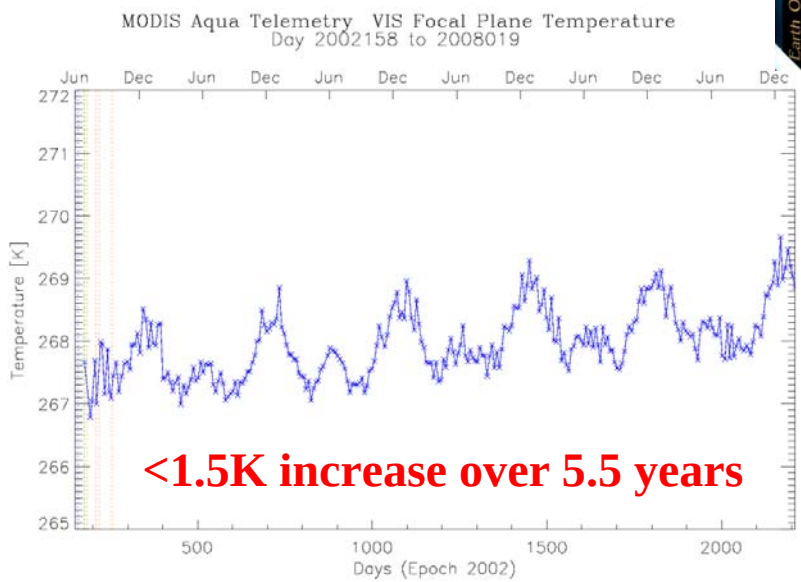


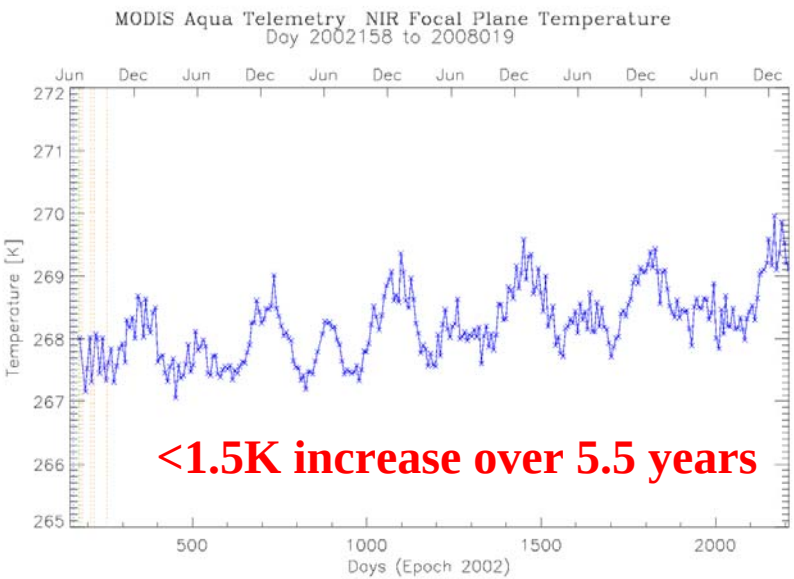


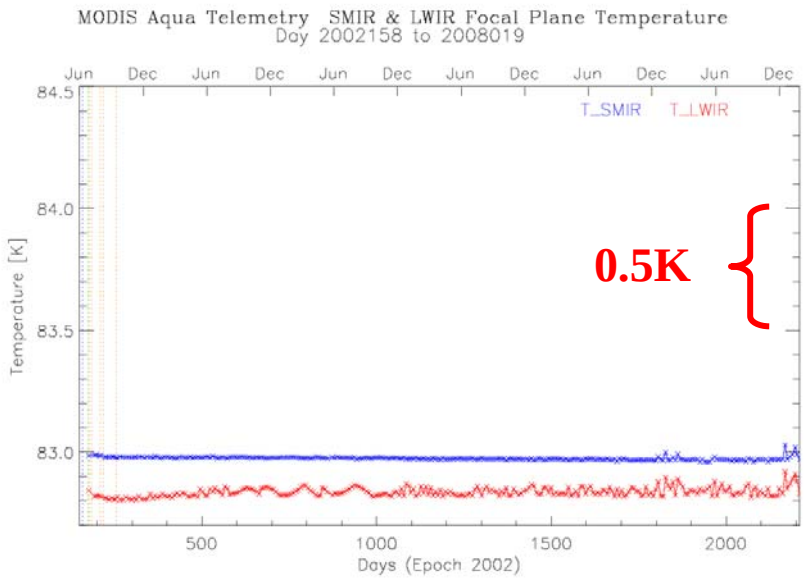
Aqua Instrument and FPA Temperatures



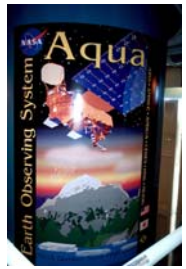






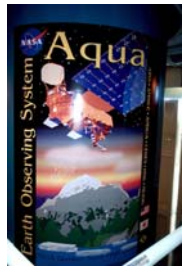


Recent Events (Terra/MODIS)

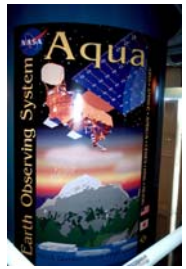


- Spacecraft Events
  - June 7, 2007 SSR DMU swap which allowed for more data storage for MODIS (data loss occurred during swap operation)
  - No change in SSR configuration (current SSR configuration considered “limit” of no loss operations with current TDRSS scheduling)
  - Two instances of SFE anomalies: one in Nov. and one in Dec. 2007 (data loss occurred).
- MODIS Events
  - No new events

Recent Events (Aqua/MODIS)



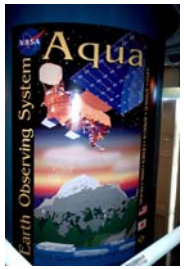
- Spacecraft Events
  - December 2, 2007 SSR anomaly (small data loss).
  - SSR is currently not in a nominal configuration, but all data collection has resumed with no impact on data processing
- MODIS Events
  - No new events
  - Several calibration events were cancelled/ postponed due to SSR anomaly



Summary of Instrument Status

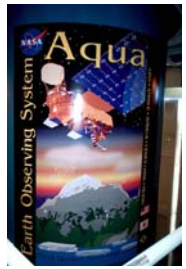
- Both instruments continue to operate normally
- All on-board calibrators continue to perform designed functions
  - Terra SD door fixed at open (July 2, 2003)
  - SRCA 30W configuration removed (2005 for Aqua MODIS, 2006 for Terra MODIS); No impact on radiometric calibration
- Instrument and FPA temperatures remain stable
  - Instrument and warm FPA temperature drift: less than 3K for Terra MODIS (over 8 years); less than 2K for Aqua MODIS (~ 6 year)
  - Cold FPA temperature controlled at 83K (A-side for Terra MODIS via LWIR; B-side for Aqua MODIS via SMIR)
  - Aqua cooler margin is a concern for CFPA short-term stability (unable to completely control the CFPA to the setting temperature)

Level 1B and LUT Updates



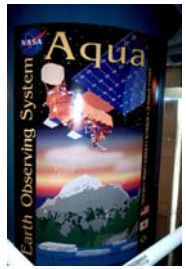
- **Recent Code and LUTs Updates**
  - **Terra and Aqua**
- **Number of MCST L1B Code and LUT Versions**
  - **Terra and Aqua**
- **History of Production Changes to MOD-PR02 (backup slides)**
- **Issues and Future Work for Collection 6**

Recent Code and LUT Updates



- L1B code has been relatively stable
  - 7 minor code changes made since end of 2004 (4 for Terra MODIS and 3 for Aqua MODIS)
- Near-monthly LUT update for each MODIS forward processing
  - 13 for Terra MODIS and 11 for Aqua MODIS in 2007
  - Additional LUTs generated, tested, and delivered to OBPG (Ocean Biology Processing Group) for special investigations
  - Special LUTs produced to support FEWSN (Famine Early Warning Systems Network)
  - Most LUT updates were driven by response changes of VIS bands

Number of MCST L1B Code and LUT Versions (as of 1/22/2008)

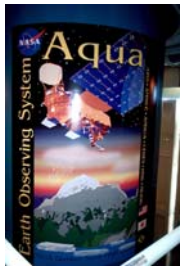


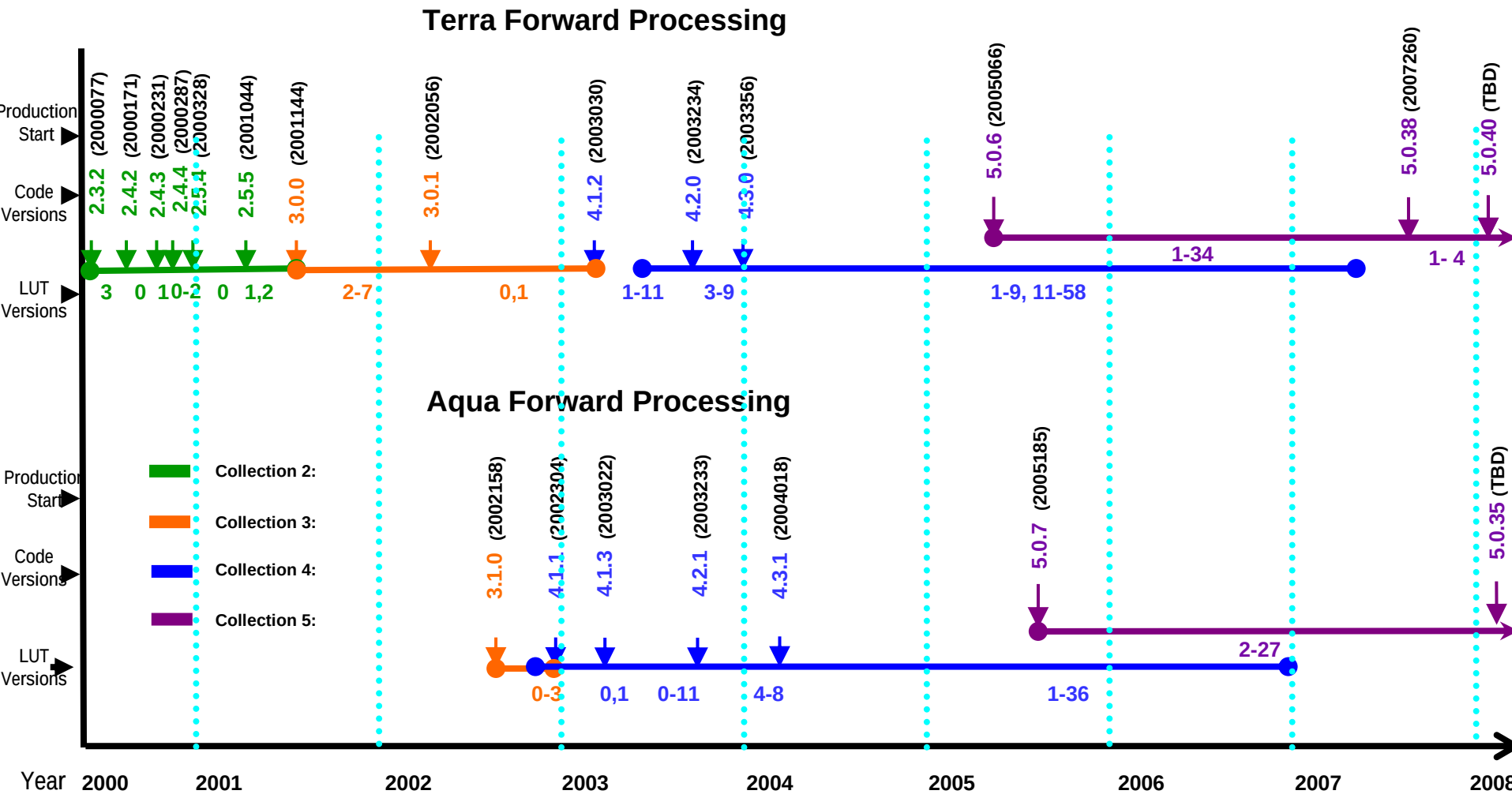
Since 2004, L1B code has been relatively stable:

Year	Terra Code Versions	Terra LUTs C2	Terra LUTs C3	Terra LUTs C4	Terra LUTs C5	Aqua Code Versions	Aqua LUTs C3	Aqua LUTs C4	Aqua LUTs C5	Total
2000	5	2	0	0	0	0	0	0	0	7
2001	2	1	5	0	0	0	0	0	0	8
2002	3	0	1	0	0	2	3	1	0	10
2003	3	0	0	19	0	3	0	17	0	42
2004	1	0	0	17	1	1	0	11	0	31
2005	2	0	0	18	10	2	0	11	7	50
2006	0	0	0	20	14	0	0	12	9	55
2007	1	0	0	1	13	0	0	0	11	26
2008	1	0	0	0	1	1	0	0	0	3
Total	18	3	6	75	39	9	3	52	27	232

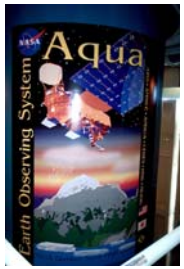
Additional LUTs also produced for OBPG and other special requests

MODIS MOD_PR02 L1B Code/LUTs Major Production Changes Timeline



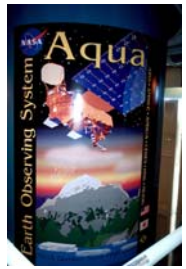


Latest Production Changes to MOD_PR02 TERRA L1B Code



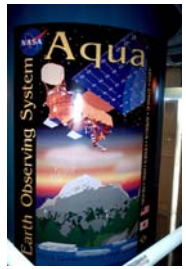
PGE02 Version	Forward Processing Begin	Code Changes
V4.3.0_Terra	12/22/2003 (356 2003) 22:35	• Maneuver flag changed to key on spacecraft attitude
V5.0.6_Terra	03/07/2005 (066 2005) 23:55	• Add a new LUT to enable the SWIR OOB correction detector dependency • Enable Band 21 calibration with mirror side dependency • Improve the code portability • Comply with the ESDIS guideline • Add HDFEOS_FractionalOffset • Minor fix for code version recording • Correct wrong dimension mapping offset setting for 250m band data
V5.0.38_Terra	9/17/2007 (260 2007) 19:35	• Relax the RVS correction limit range from [0.8, 1.2] to [0.4, 2.4].
V5.0.40_Terra	TBD	• Changed to set the PGEVersion ECS inventory metadata based upon the MODAPS PGE Version, rather then the obsolete GDAAC PGE Version. • Removed the ScanType of "Mixed" from the code. • Changed for ANSI-C compliance and comments correction.

Latest Production Changes to MOD_PR02 AQUA L1B Code



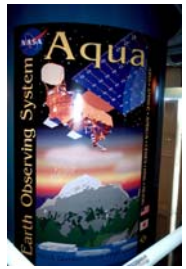
PGE02 Version	Forward Processing Begin	Code Changes
V5.0.7_Aqua	07/03/2005 (185 2005) 00:10	• Add a new LUT to enable the SWIR OOB correction detector dependency • Enable Band 21 calibration with mirror side dependency • Improve the code portability • Comply with the ESDIS guideline • Add HDFEOS_FractionalOffset • Minor fix for code version recording • Correct wrong dimension mapping offset setting for 250m band data
V5.0.35_Aqua	TBD	• Relax the RVS correction limit range from [0.8, 1.2] to [0.4, 2.4] • Changed to set the PGEVersion ECS inventory metadata based upon the MODAPS PGE Version, rather then the obsolete GDAAC PGE Version. • Removed the ScanType "Mixed" from the code because the L1A "Scan Type" is never "Mixed". • Changed for ANSI-C compliance and comments correction.

An entire history provided in the backup slides



Issues and Future Work

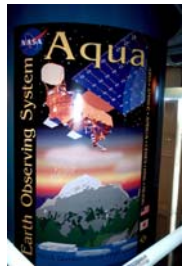
- Issues
  - Minor issues with collection 6 updates (ongoing investigations)
- Future Work for Collection 6
  - Some improvements proposed for collection 6 require code changes and some can be made via LUTs
  - Limited efforts made to implement and test potential changes for collection 6
  - Coordination with calibration analysts on algorithms and science test activities



On-orbit Calibration and Characterization

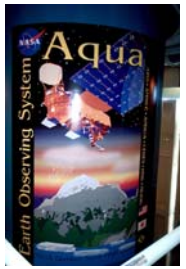
- **RSB Calibration Performance**
- **TEB Calibration Performance**
- **Spatial and Spectral Characterization**
- **Geolocation**

RSB Calibration Performance



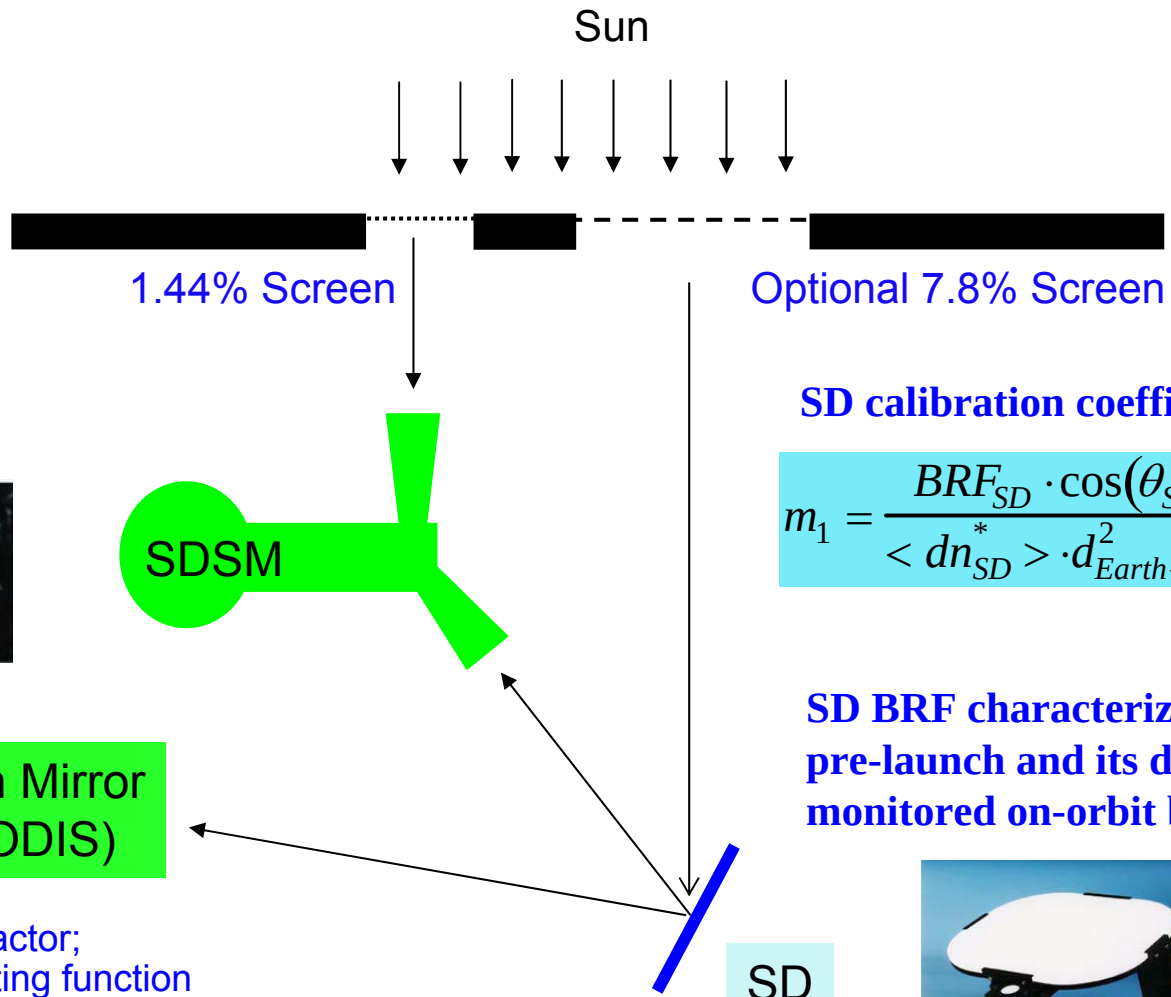
- Overview of RSB calibration
- Noisy & inoperable RSB detectors
  - No new noisy and inoperable detectors since last STM MODIS Calibration Workshop (November 1, 2006)
- RSB response trending
  - Response from SD and lunar observations
  - Mirror side response difference
- Solar Diffuser degradation
  - Terra versus Aqua MODIS
- Summary of RSB overall performance

MODIS RSB Calibration Using SD/SDSM



Reflectance Factor

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



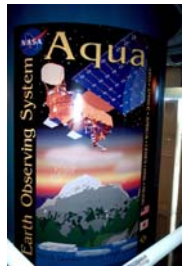
SD calibration coefficients

$$m_1 = \frac{BRF_{SD} \cdot \cos(\theta_{SD})}{< dn^*_{SD} > \cdot d^2_{Earth-Sun}} \cdot \Gamma_{SD} \cdot \Delta_{SD}$$

SD BRF characterization made pre-launch and its degradation monitored on-orbit by SDSM

Δ_{SD}: SD degradation factor;
Γ_{SD}: SD screen vignetting function
d: Earth-Sun distance
dn*: Corrected digital number; **dc**: Digital count of SDSM

MODIS RSB Calibration Using SD/SDSM



EV Radiance:

$$L_{EV} = \frac{E_{Sun} \cdot \rho_{EV} \cdot \cos(\theta_{EV})}{\pi \cdot d^2_{Earth\_Sun(EV)}}$$

$$= \frac{E_{Sun}}{\pi} m_1 \cdot dn_{EV}$$

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

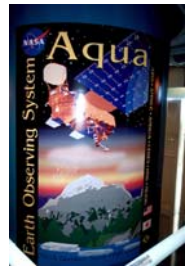
Others:

Thermal leak applied for SWIR bands (B5-7, B26)

Leak coefficients determined from EV night time data

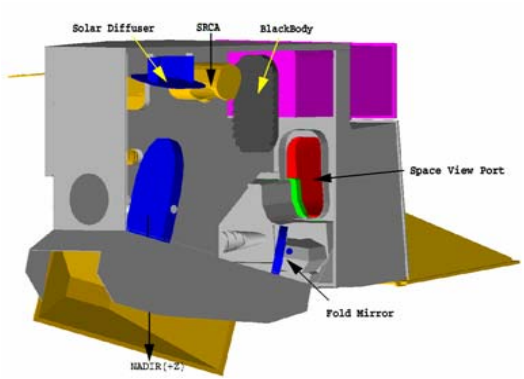
B26 de-striping algorithm added (from C. Moeller of Wisconsin)

RSB Lunar Calibration Using the Moon



$$m_1 = \frac{BRF_{SD} \cdot \cos(\theta_{SD})}{< dn^*_{SD} > \cdot d^2_{Earth-Sun}} \cdot \Gamma_{SD} \cdot \Delta_{SD}$$

SD Calibration



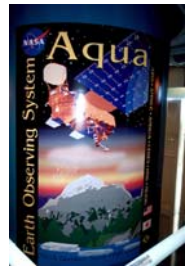
$$m_1 = \frac{f(view\_geometry)}{< dn^*_{Moon} >}$$

Lunar Calibration

$$f = \frac{f_{phase-angle} \cdot f_{libration} \cdot f_{over-sampling}}{d^2_{Sun-Moon} \cdot d^2_{Modis-Moon}}$$

Geometric Factors

RSB Noisy & Inoperable Detectors



Terra

Day/Year	Band	5										6			7		
	SNR Spec	74										275			110		
	Detector	2	4	6	11	13	16	17	18	19	20	3	7	8	1-10	11-13,15-20	14
055/2000	Nadir Dorr Open	0	0	60	80	0	30	0	0	80	0	0	0	100	100	110	0
160/2000	CFPA Lost Control	95	95	60	80	80	30	80	80	80	80	0	0	100	100	110	0
232/2000	Back from FPA recyle	75	95	50	0	80	50	80	0	70	0	0	0	100	100	110	0
304/2000	B Side	85	20	85	80	80	60	80	80	80	80	350	350	275	90	100	100
183/2001	A Side	95	10	90	90	90	90	90	90	90	90	380	380	380	100	110	110
259/2002	A Side B Formatter	100	10	100	100	100	100	100	100	100	100	380	380	380	100	110	110

Detectors in Production order

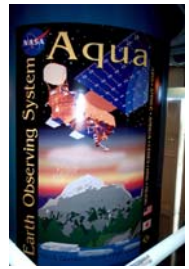
Aqua

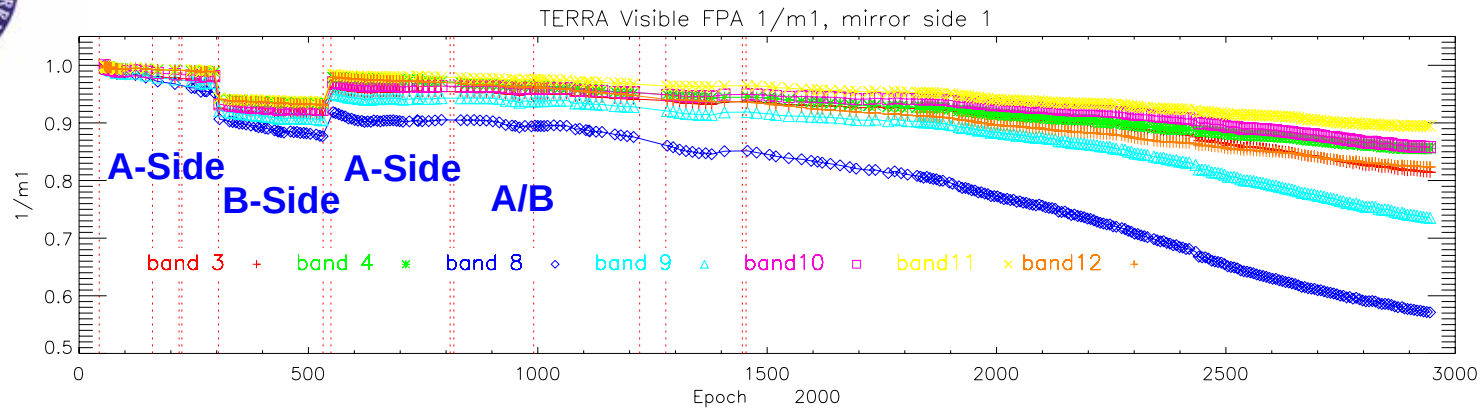
Day/Year	Band	5	6									
	SNR Spec	74	275									
	Detector	20	2	4	5	6	7	9	10	12-16	17	18-20
175/2002	Nadir Dorr Open	0	0	0	0	0	470	470	0	0	100	0
189/2002	Back from Safe Mode	0	0	470	470	0	470	470	0	0	470	0
255/2002	Back from Safe Mode	0	0	0	0	0	470	470	0	0	470	0
266/2002	Back from Safe Mode	0	0	0	0	0	150	400	0	0	470	0
110/2003		0	0	0	0	0	260	470	0	0	320	0
160/2003		0	0	0	0	0	290	400	0	0	470	0
265/2003		0	0	150	0	0	290	400	0	0	275	0
360/2003		0	0	200	0	0	290	275	0	0	270	0
080/2006		0	0	200	0	0	0	350	0	0	270	0
314/2006		0	0	200	0	0	472	350	0	0	270	0

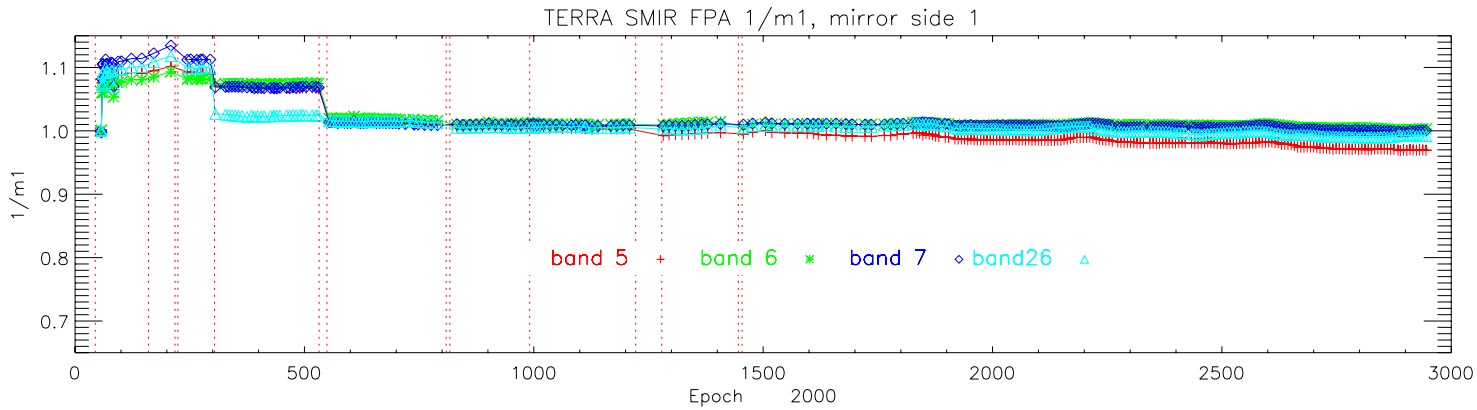
In Spec | Near Spec | Out Spec | Inoperable

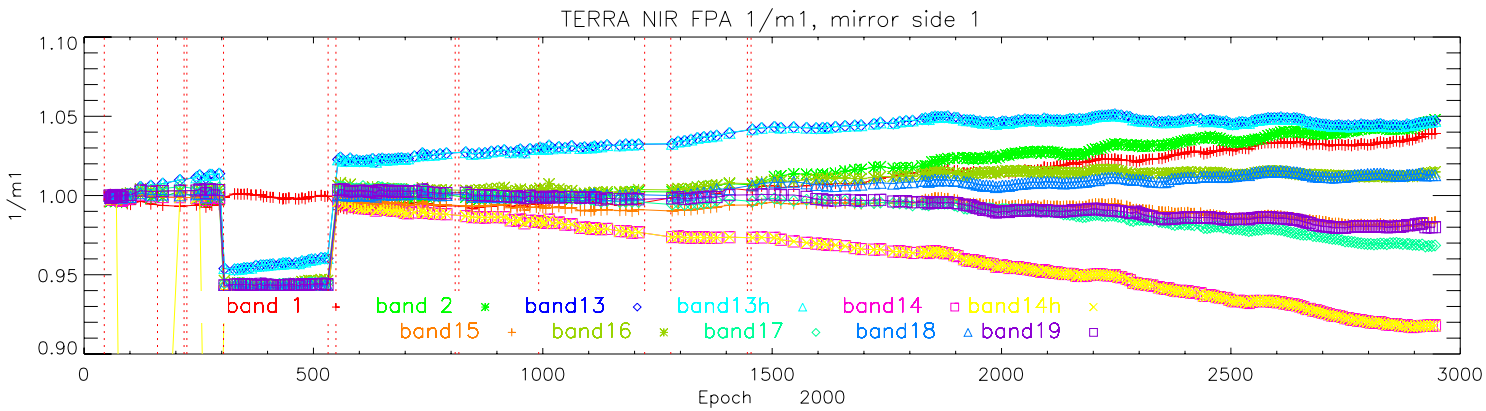
No new noisy and inoperable detectors since Nov. 1, 2006

RSB Response Trending (Terra MODIS)

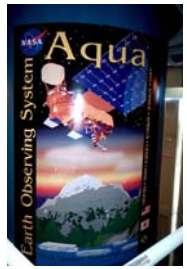


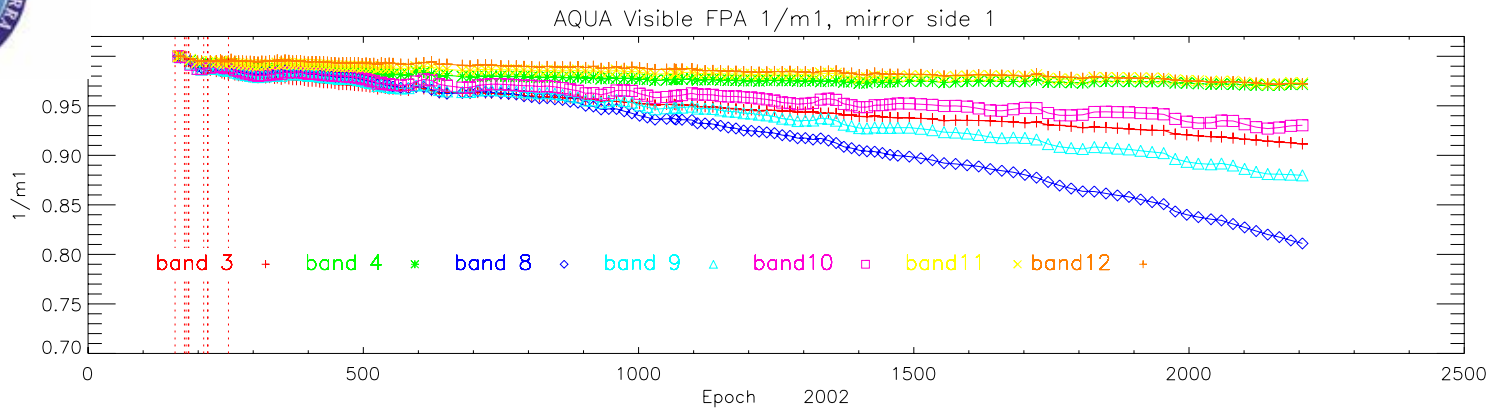


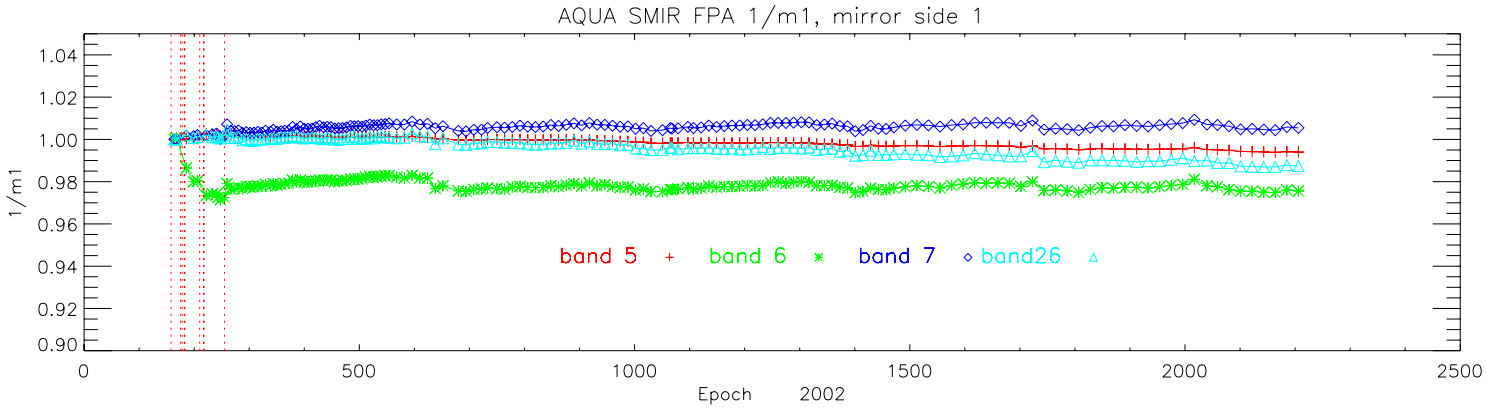


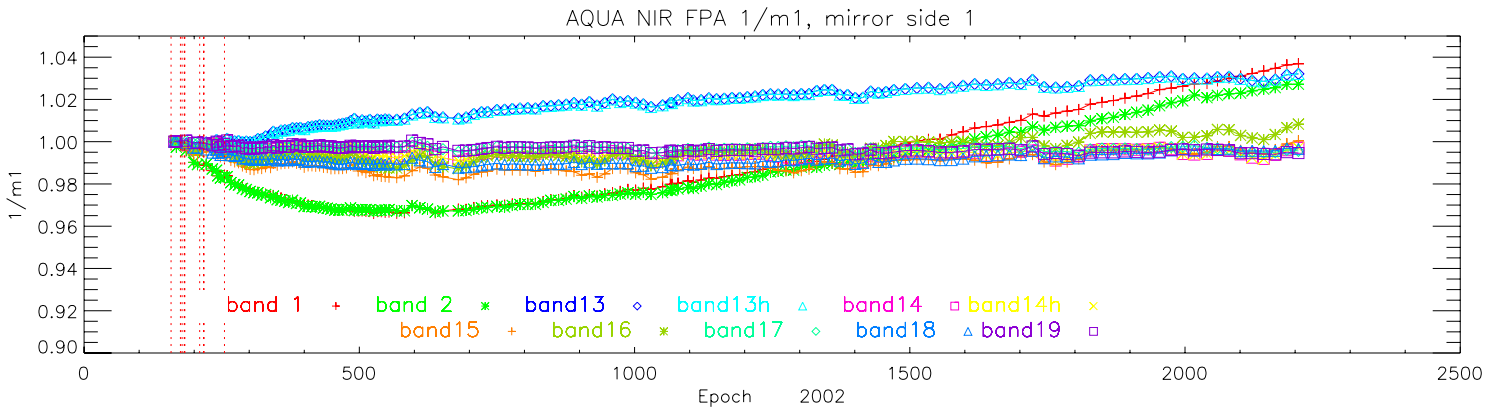


RSB Response Trending (Aqua MODIS)

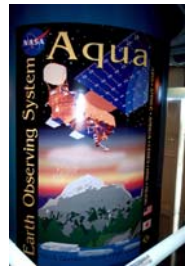


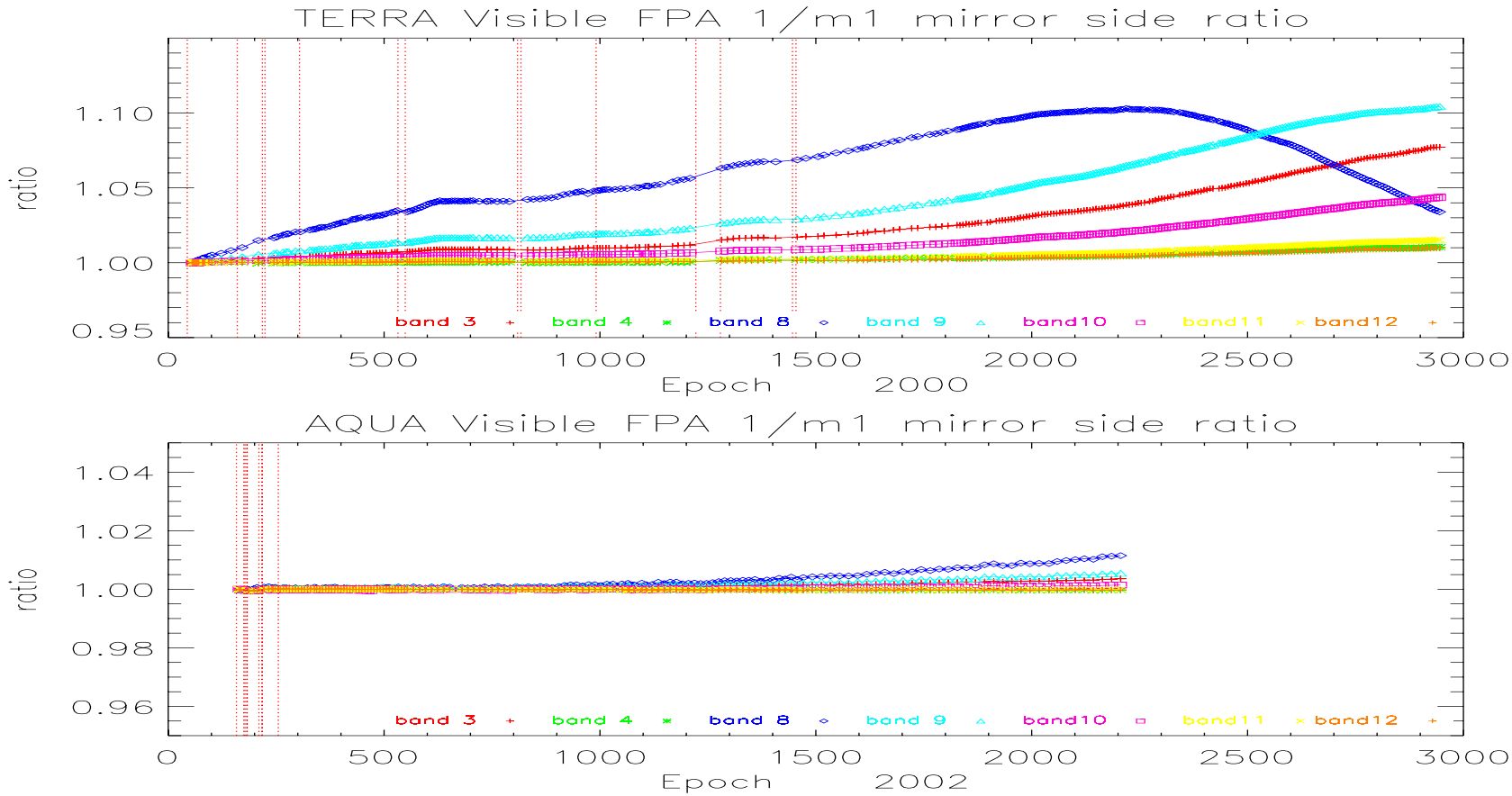






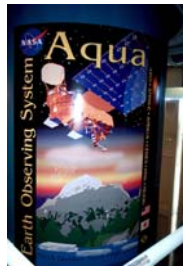
RSB Response Trending (Mirror Side Difference)

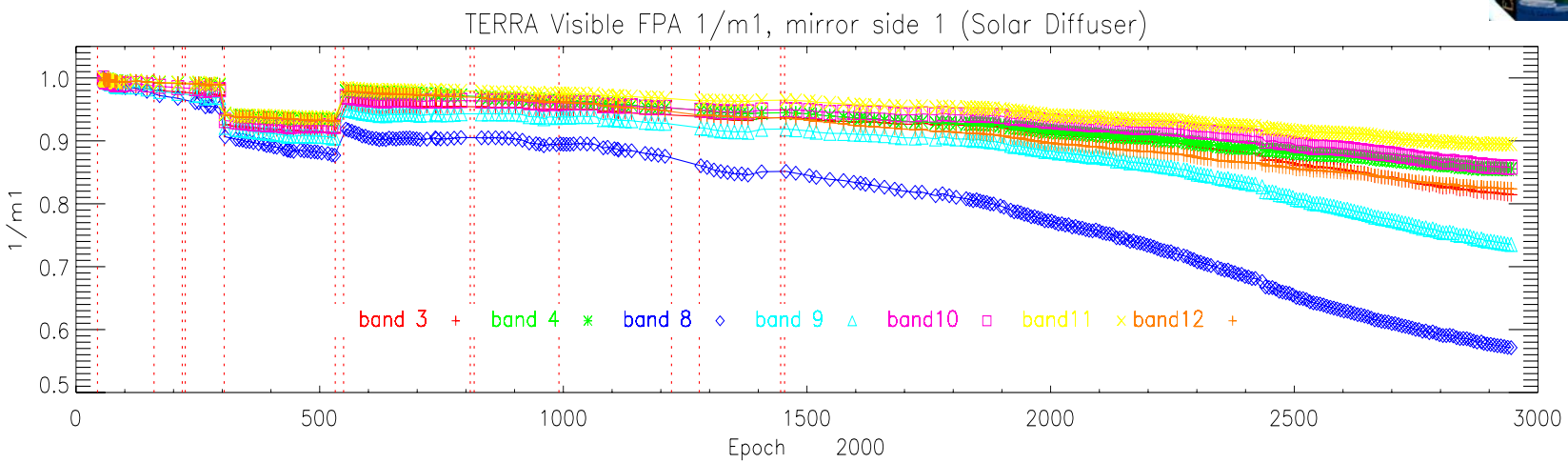


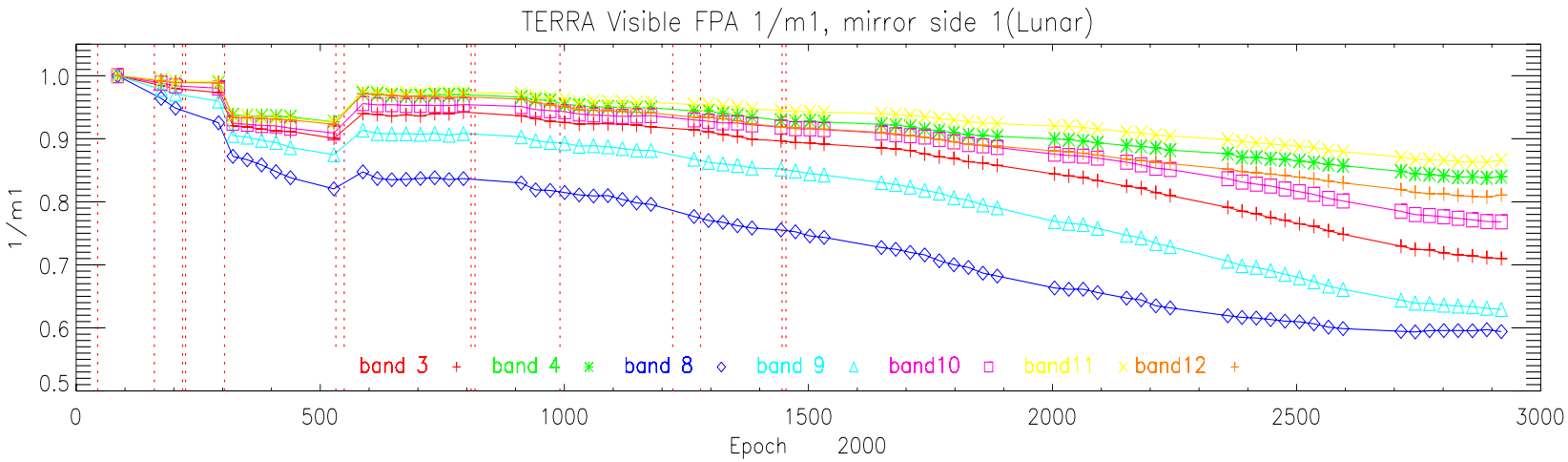


Mirror side difference of Terra MODIS band 8 starts to decrease after 6 years of operation, while other VIS bands still show an increasing trend. In general, Aqua MODIS mirror side differences are less than 1% after 5.5 years of operation. The differences grow faster in recent years.

RSB Response Trending (SD versus Moon for Terra MODIS)

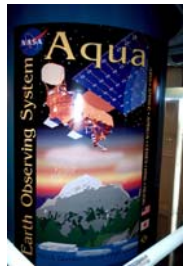


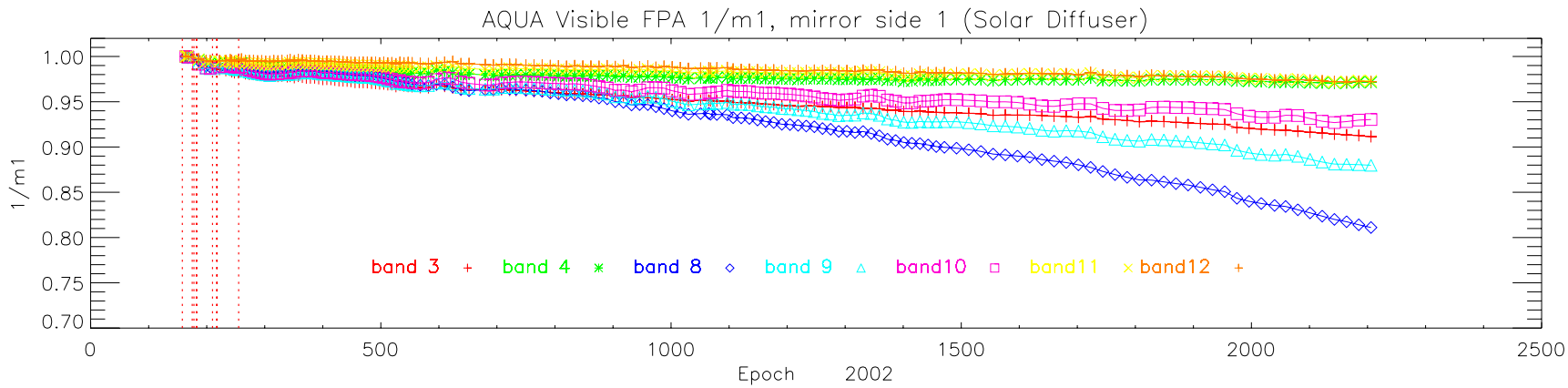


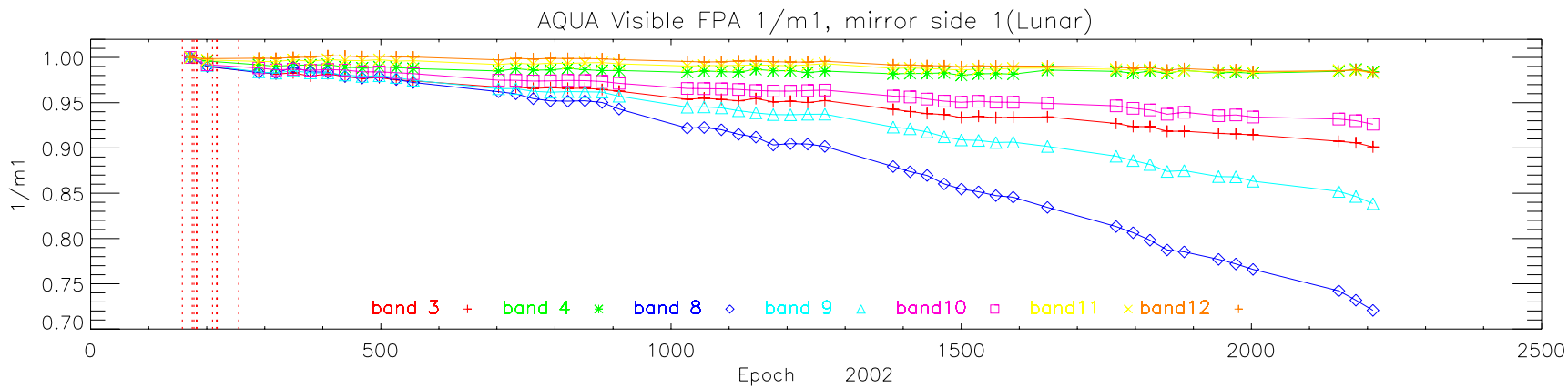


Lunar response trending (through SV port) is used to track MODIS scan mirror RVS (response versus scan angle)

RSB Response Trending (SD versus Moon for Aqua MODIS)

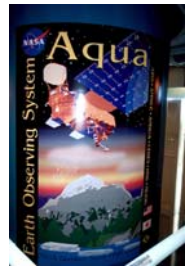


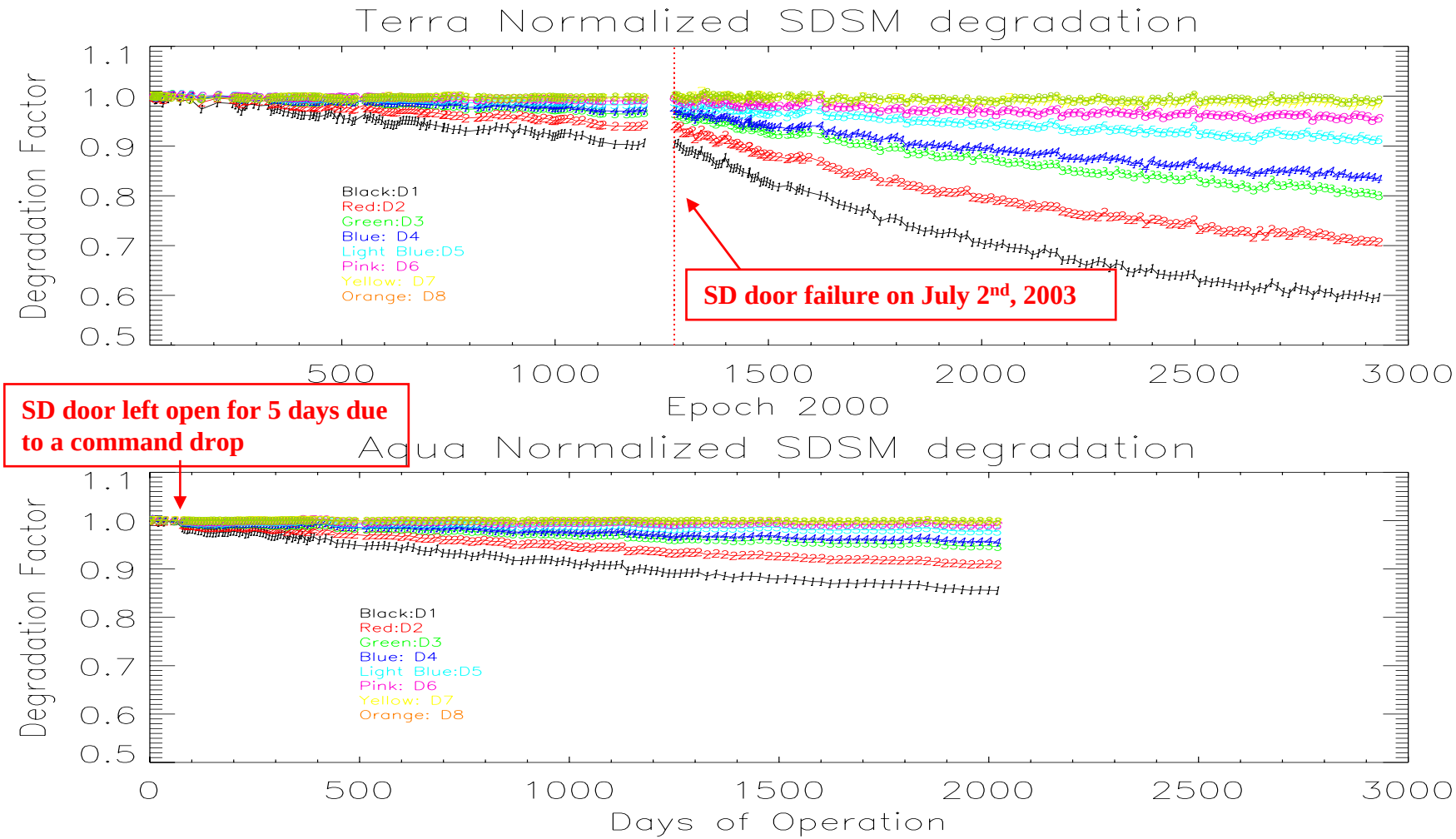




Lunar response trending (through SV port) is used to track MODIS scan mirror RVS (response versus scan angle)

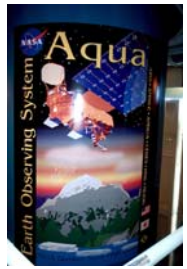
MODIS SD Degradation Trending





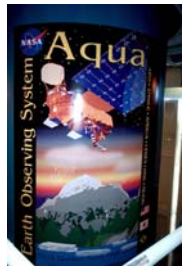
Similar SD degradation in Terra and Aqua MODIS when operated under the same condition

Summary of RSB Overall Performance



- **Terra MODIS (8 years)**
  - Approximately 42% and 47% decrease for band 8 MS 1 and 2 response, respectively
  - Mirror side difference of band 8 starts to decrease after 6 years
  - RSB calibration performed every orbit since SD door was kept open after July 2nd 2003 and this causes more degradation of SD BRF
  - No new noisy and inoperable detectors since last workshop (except for band 8 characterized at low signal levels due to SD and mirror degradation)
- **Aqua MODIS (5.5 years)**
  - Approximately 20% decrease for band 8 response
  - Mirror side differences are less than or about 1% for all RSB bands.
  - No new noisy and inoperable detectors since last workshop

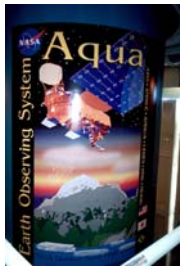
Many challenges to maintain calibration quality for Terra MODIS VIS bands (especially for bands 8 and 9)



TEB Calibration Performance

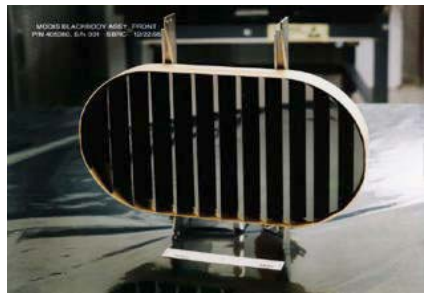
- TEB Calibration Algorithm
- TEB Calibration Special Considerations
- Terra and Aqua TEB On-orbit Performance
  - BB Stability
  - b1 & NEdT Trending
  - Noisy Detector History

TEB Calibration Algorithm



Radiance (TOA), L_{EV}

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



Calibration coefficient, b1, from BB

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

RVS: Response Versus Scan-angle
ε: Emissivity
L: Spectral band averaged radiance
dn: Digital count with background correction

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

Source radiance with RSR integration:

$$\overline{L_S} = \frac{\sum Planck(\lambda, T) \cdot RSR(\lambda)}{\sum RSR(\lambda)}$$

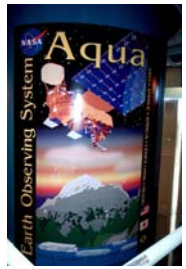
Calibration is performed for each band, detector, mirror side

Calibration is performed on a scan-by-scan basis

OBC BB is normally set at 290K/285K for Terra/Aqua MODIS

a0 & a2 derived from pre-launch or periodic warm-up/cool-down cycles (270-315 K) of the BB

TEB Calibration Special Considerations

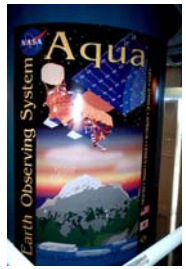


- Band 21: Fixed Gain (b1) derived from BB Warm-up/Cool-down Activity

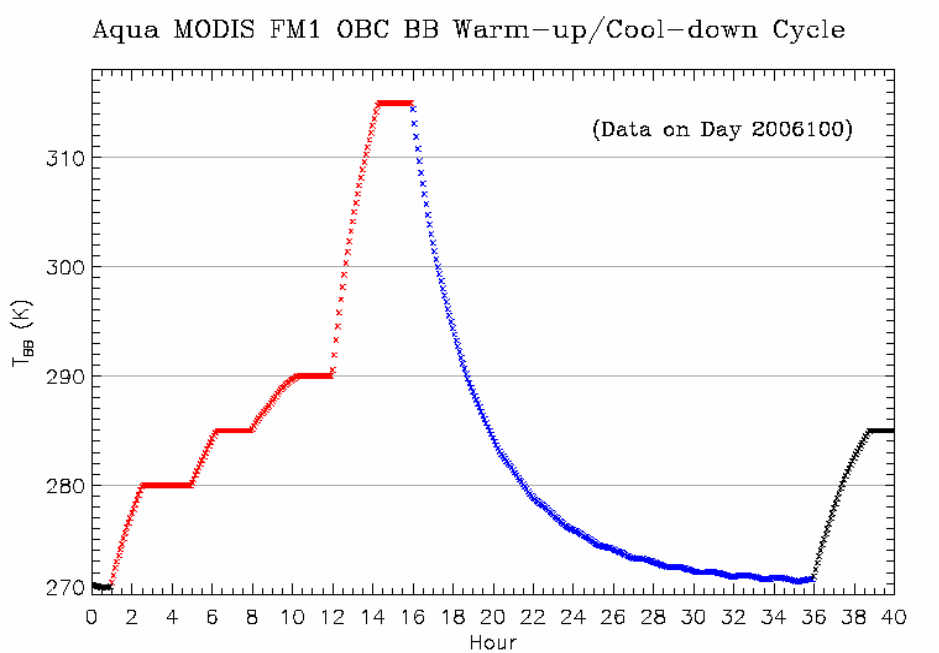
- Terra: PC Crosstalk Correction Coefficients – characterized pre-launch; on-orbit coefficients derived using lunar measurements

- Aqua: Default b1 (fixed gain) for Bands 33,35,36 for periods when BB temperature is > 290K (B33), 295K (B35), and 300K (B36)

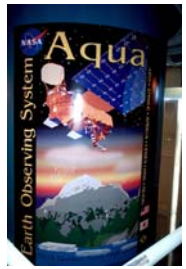
BB Warm-up/Cool-down



- **BB temperatures measured by 12 thermistors, traceable to NIST temperature scale**
- **BB warm-up and cool-down (WUCD) activity executed quarterly or as needed**
- **BB temperature varied from instrument ambient (~ 270K) to 315K during BB WUCD**
- **Nonlinear calibration coefficients derived from detector responses during BB WUCD**
- **Detector noise characterization performed at different BB temperatures**



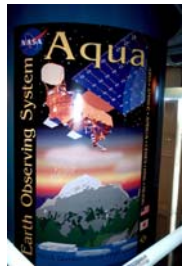
TEB On-orbit Performance

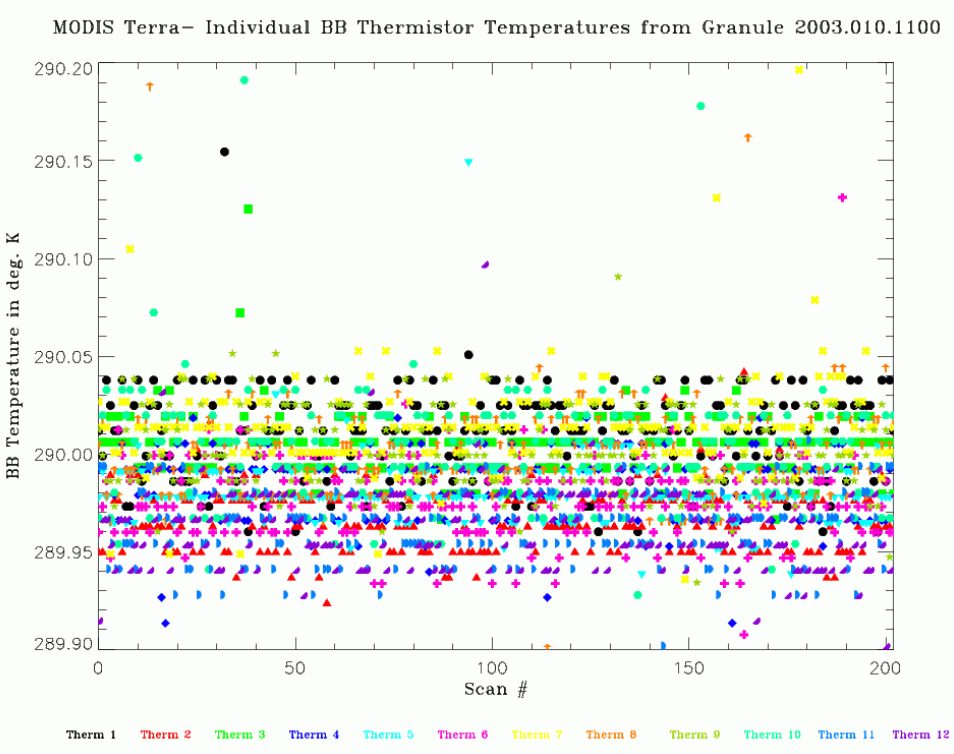


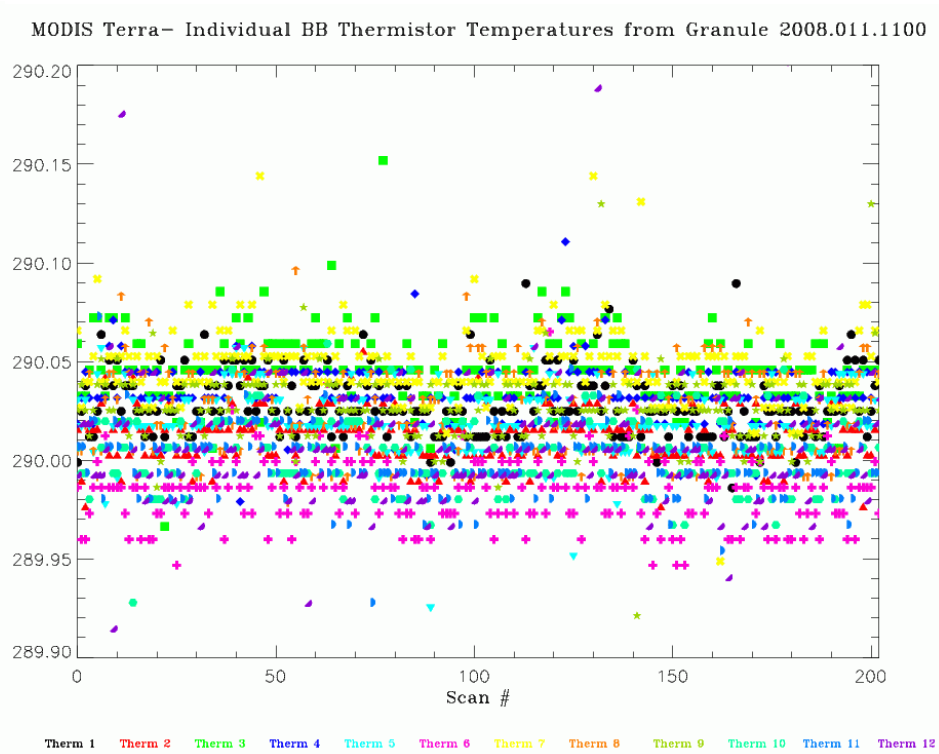
Thermal Emissive Bands (16 bands and 160 detectors)

- **Terra MODIS**
  - **Stable short-term and long-term response trends (excluding sensor configuration changes and instrument reset events)**
  - **25 noisy detectors (1 new since last STM B27 D3) and no inoperable detectors**
  - **B29 D6 extremely noisy (declared "inoperable" in L1B)**
- **Aqua MODIS**
  - **Stable short-term and long-term response trends**
  - **2 noisy detectors (1 new since last STM B29 D8) and 1 inoperable detector (B36 D5)**

Terra BB Short-term Stability

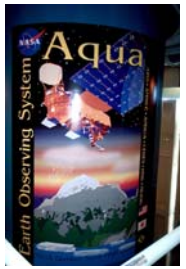


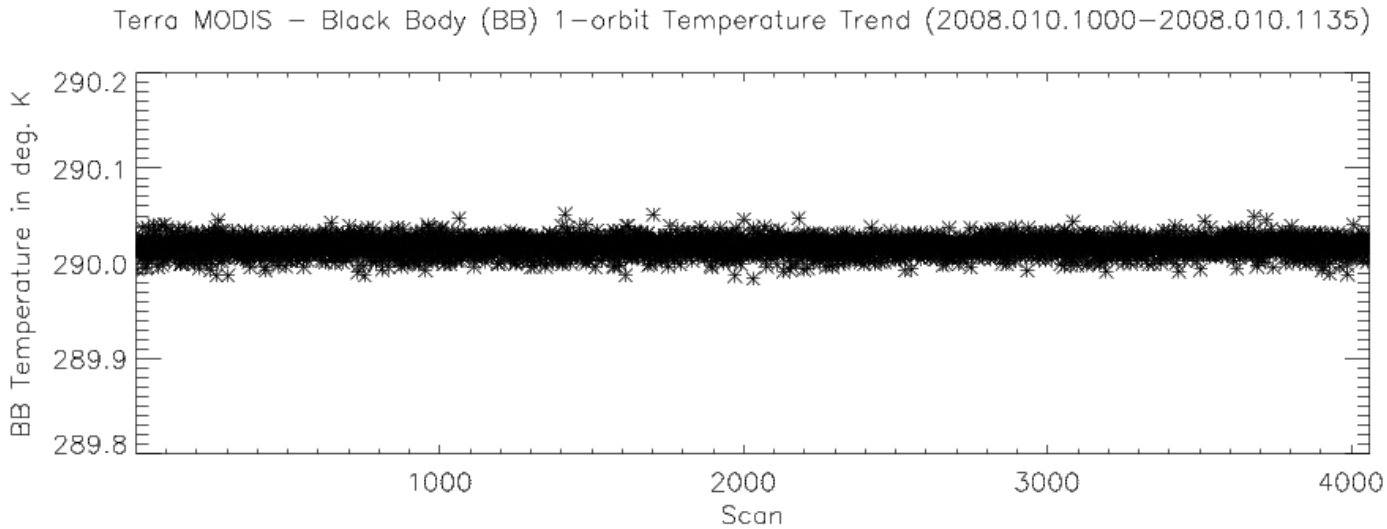


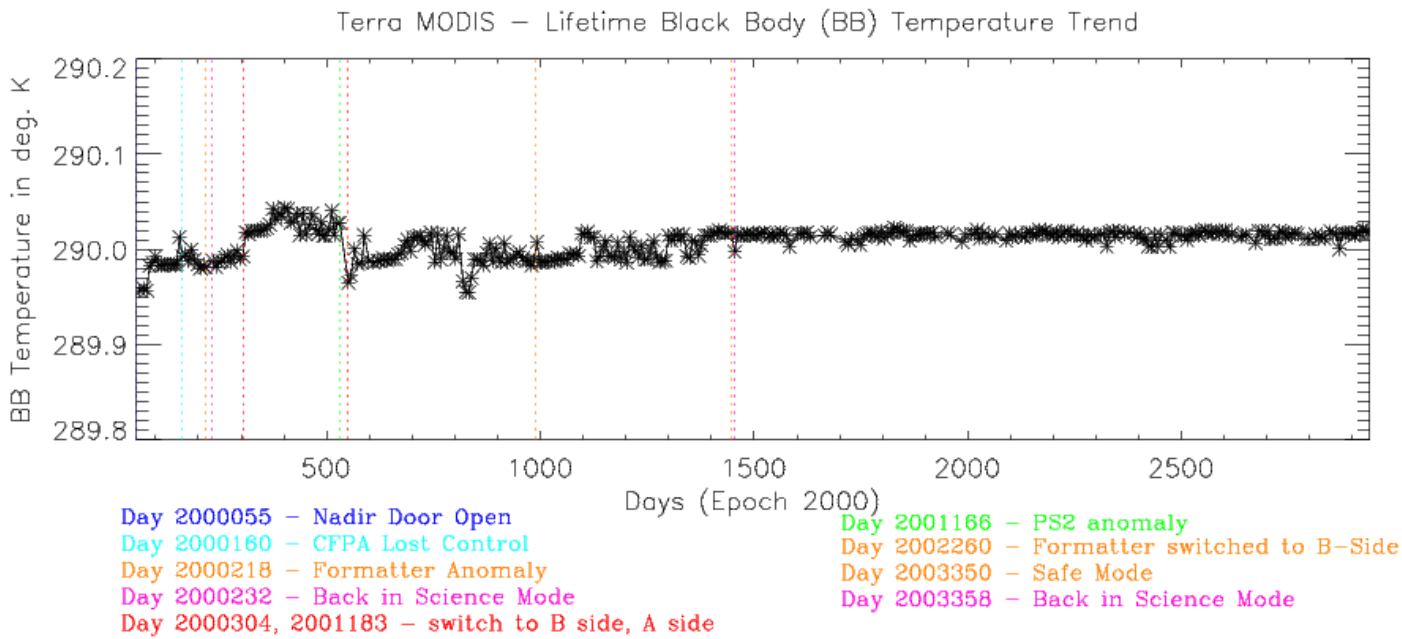


1-granule, scan-by-scan, 12 individual BB thermistors

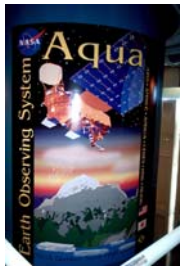
Terra BB On-Orbit Performance

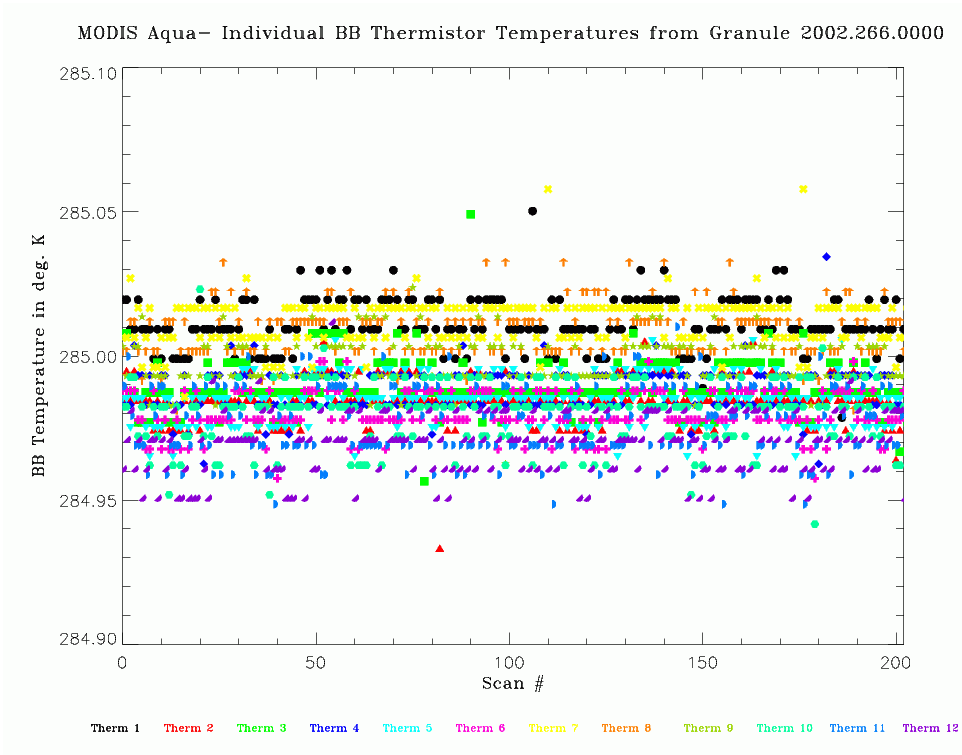


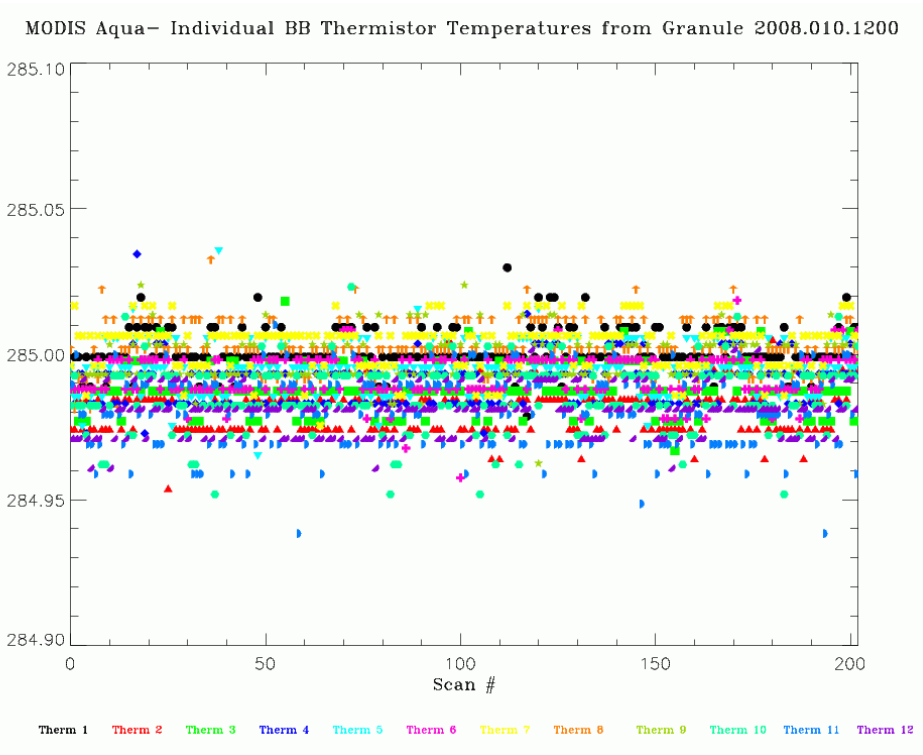




Aqua BB Short-term Stability

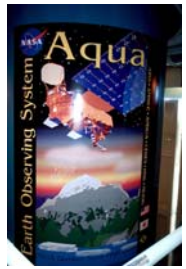


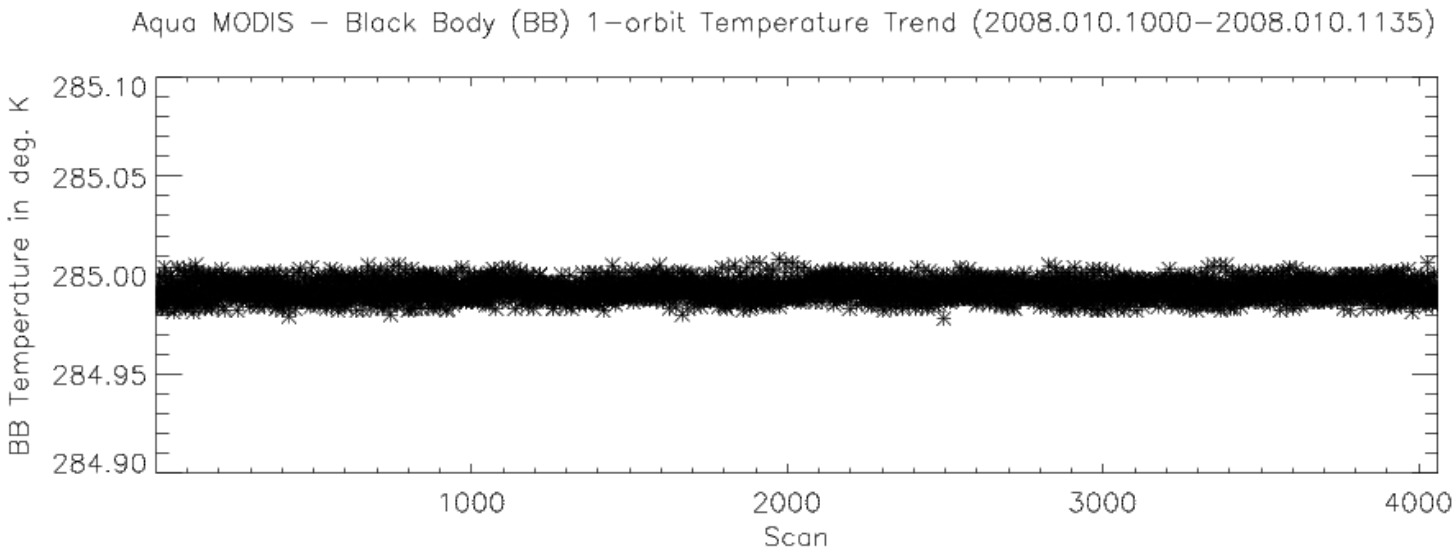


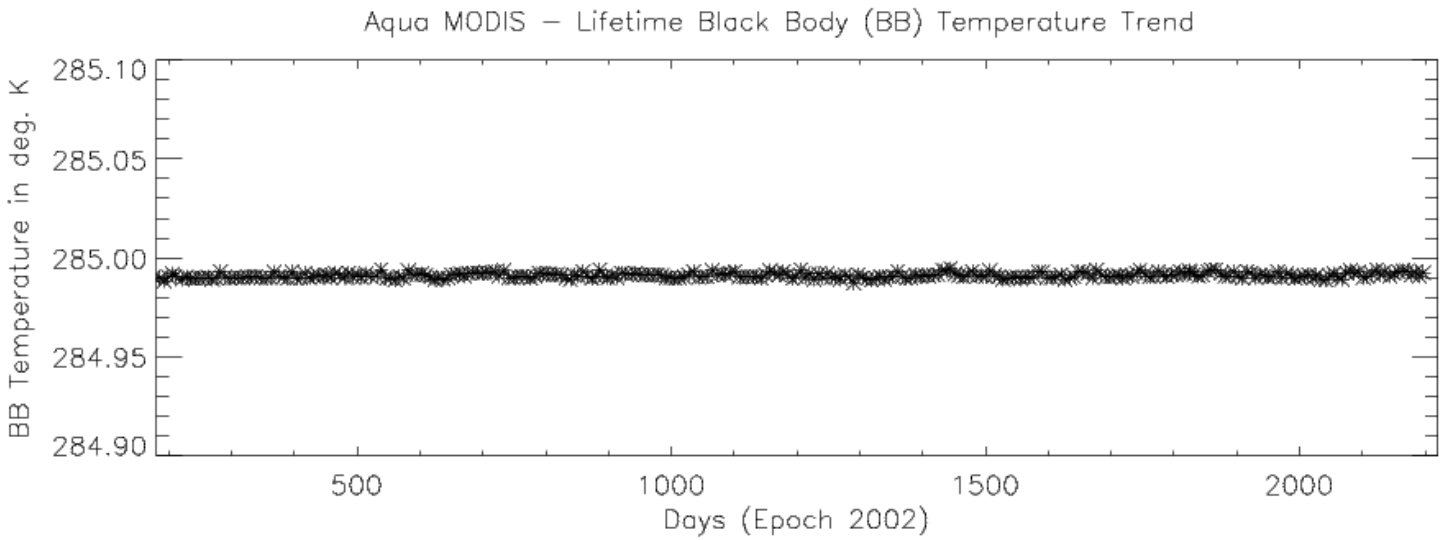


1-granule, scan-by-scan, 12 individual BB thermistors

Aqua BB On-Orbit Performance

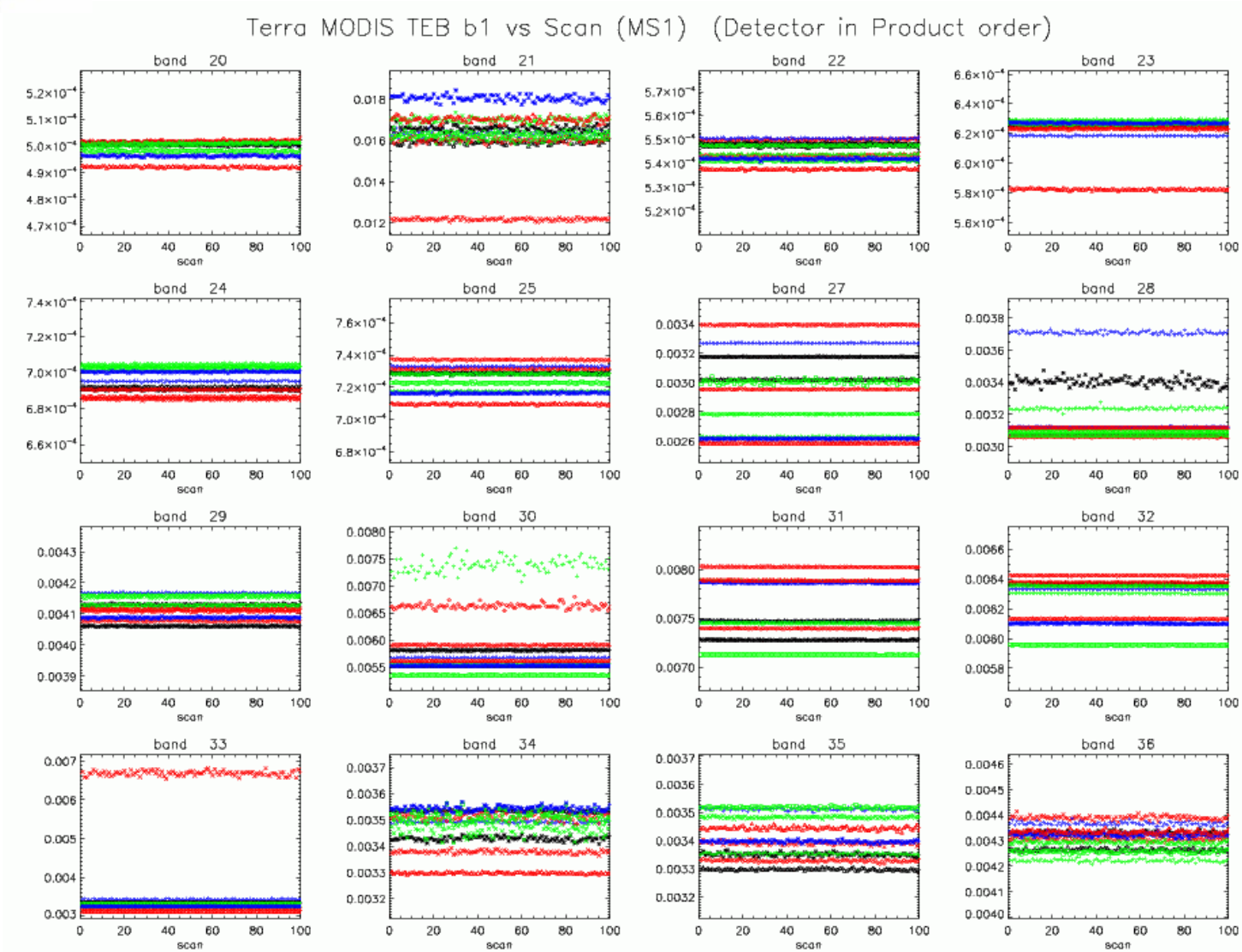






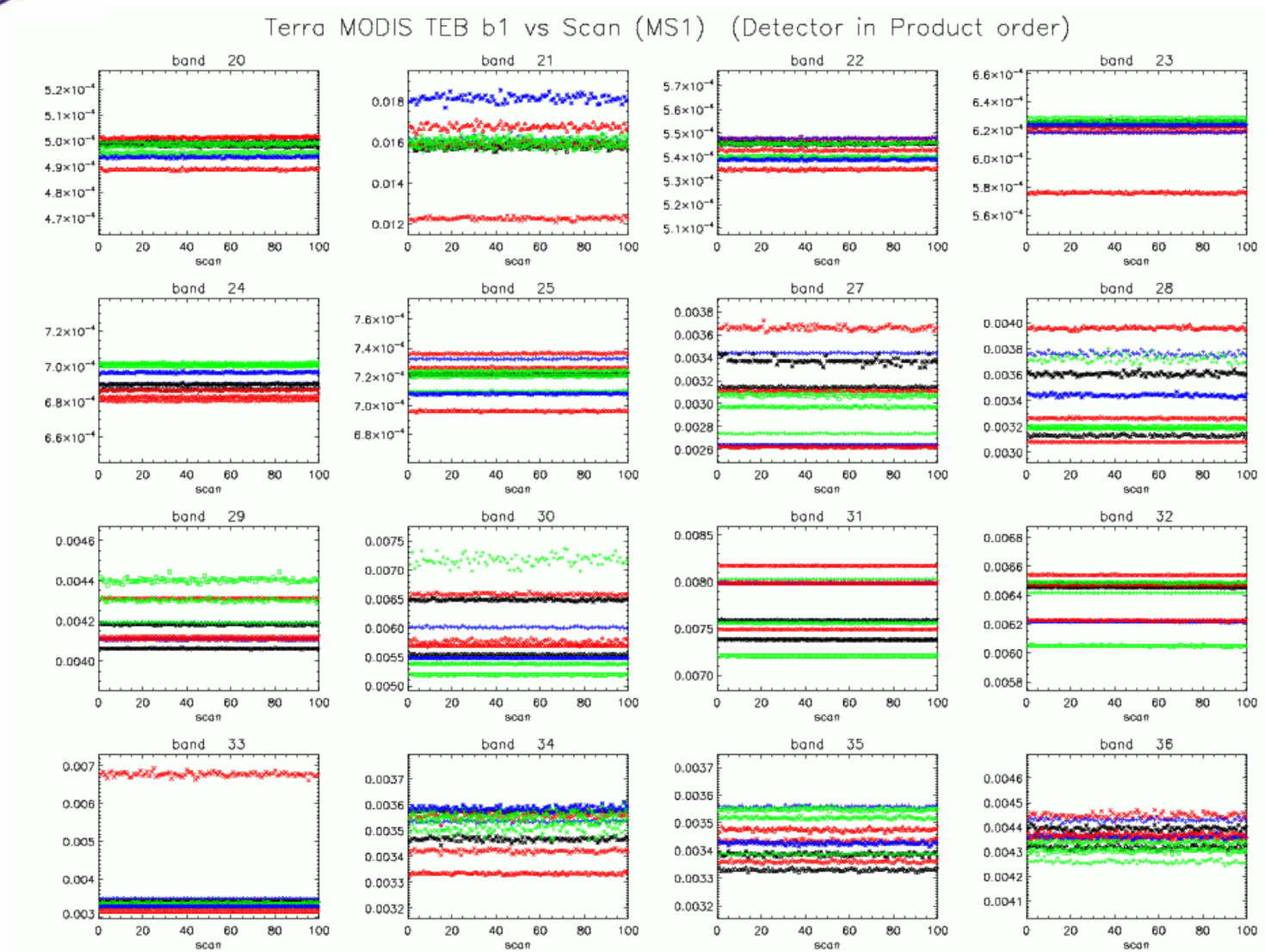
Terra b1 Short-term Stability

2003034.0700



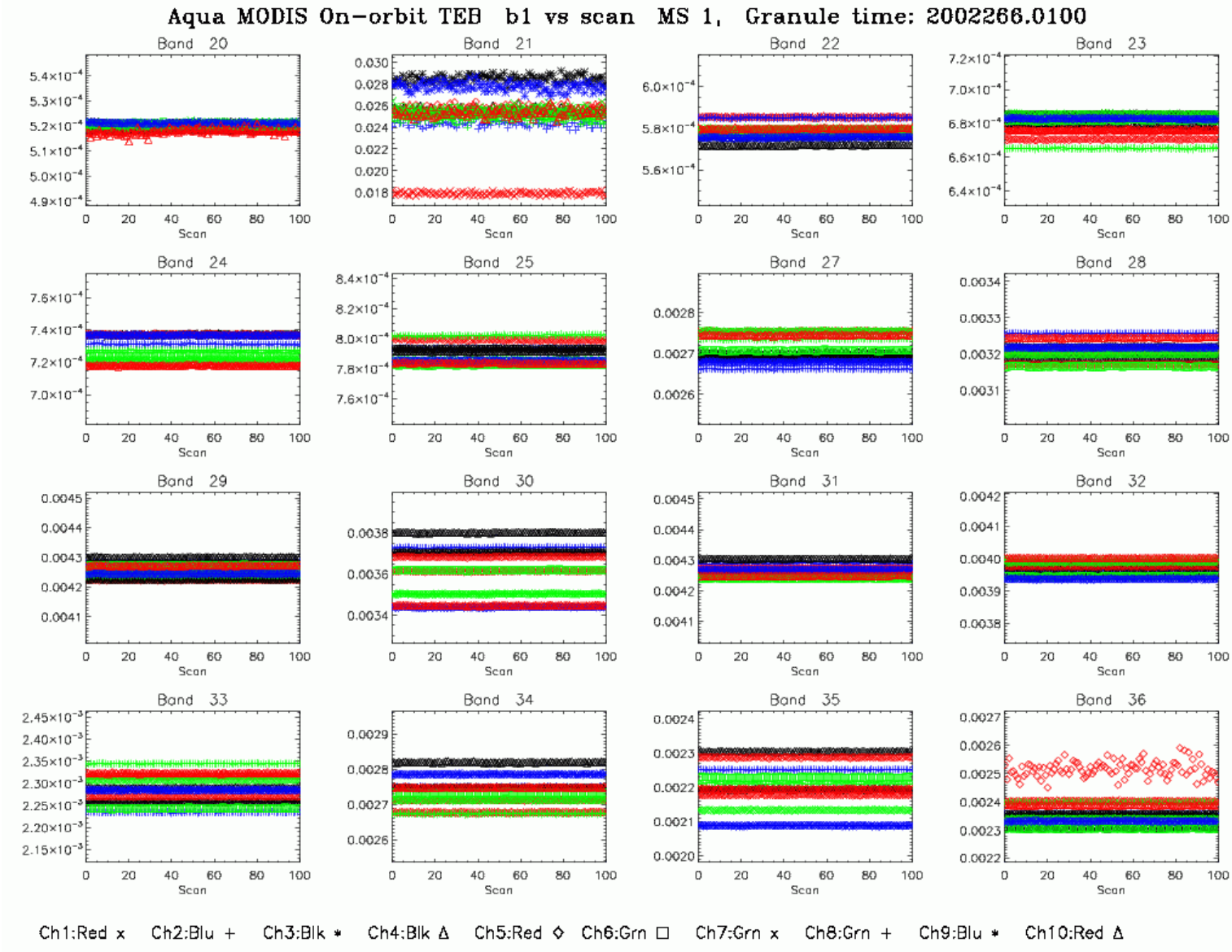
Terra b1 Short-term Stability

2007321.0000



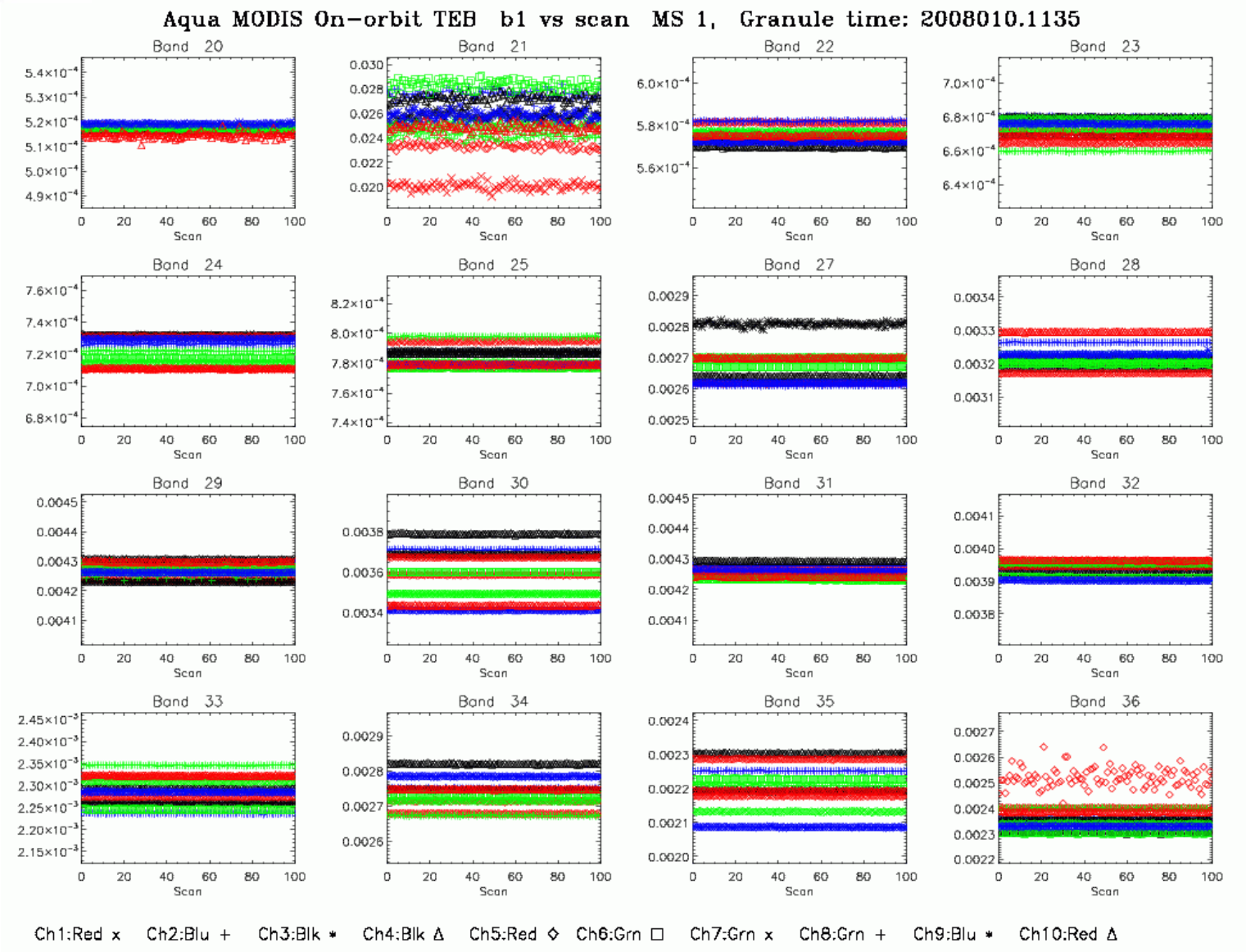
Aqua b1 Short-term Stability

2002266.0100

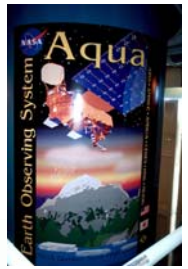


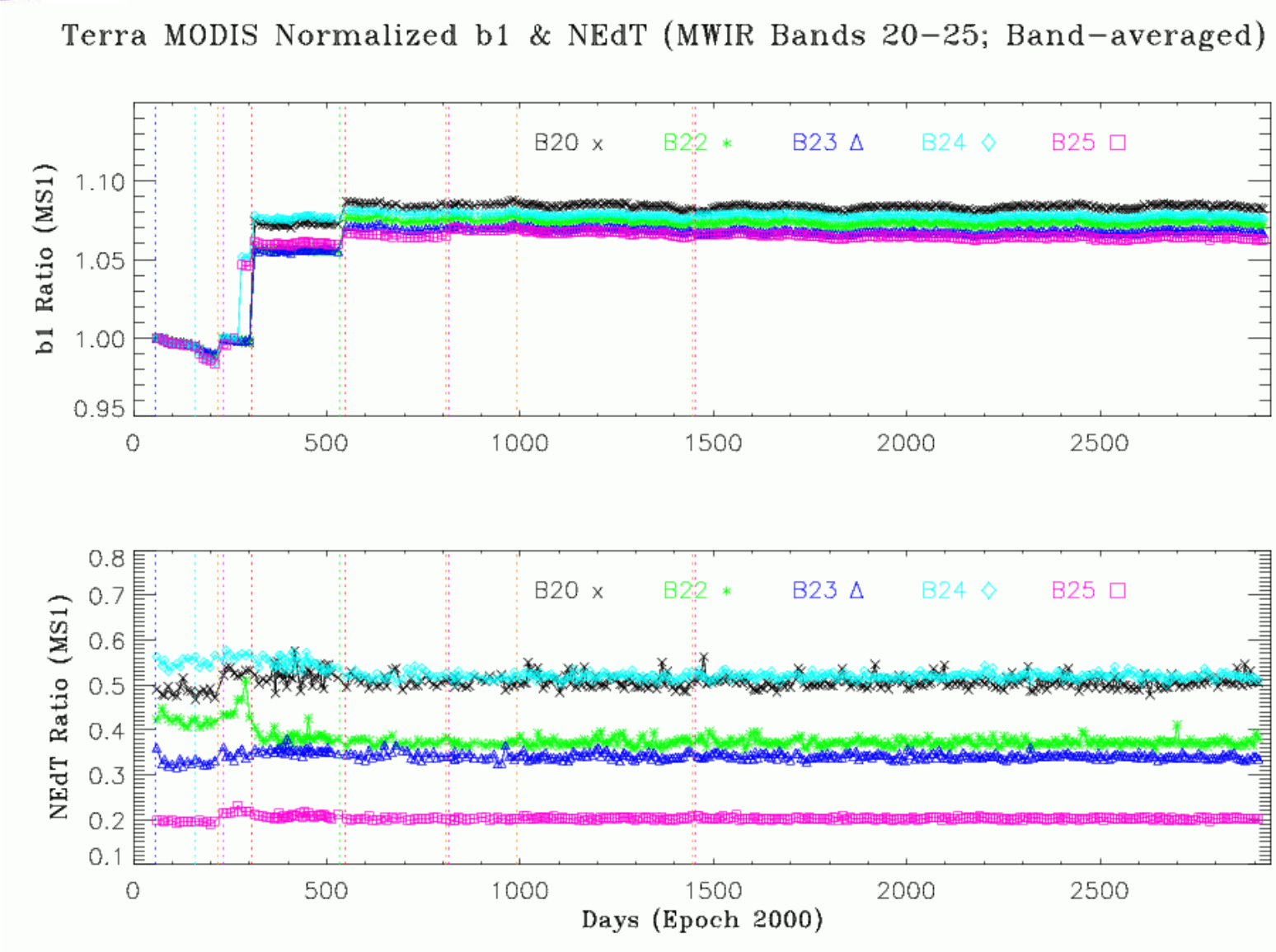
Aqua b1 Short-term Stability

2008010.1135

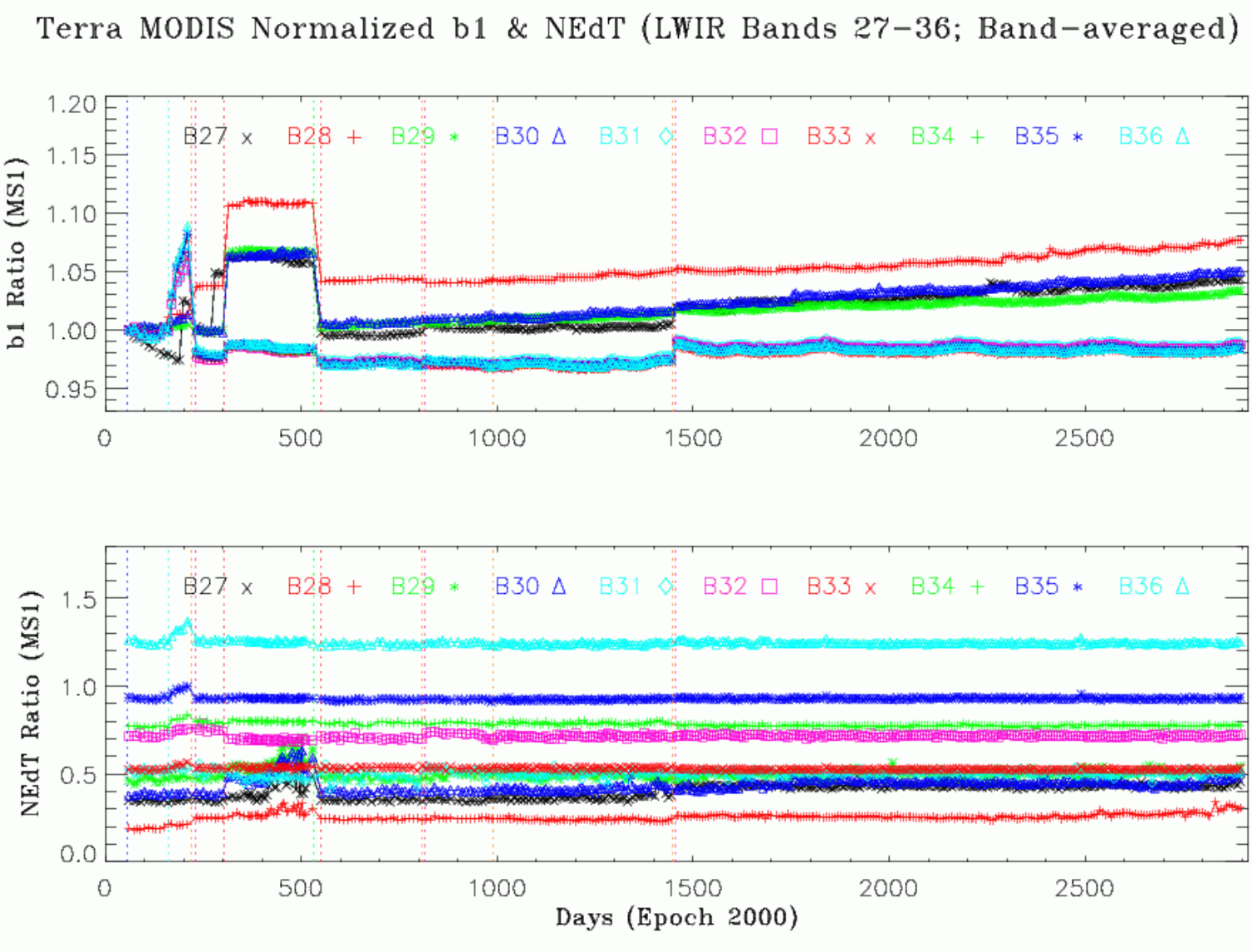


Terra MODIS TEB MWIR Response Trend

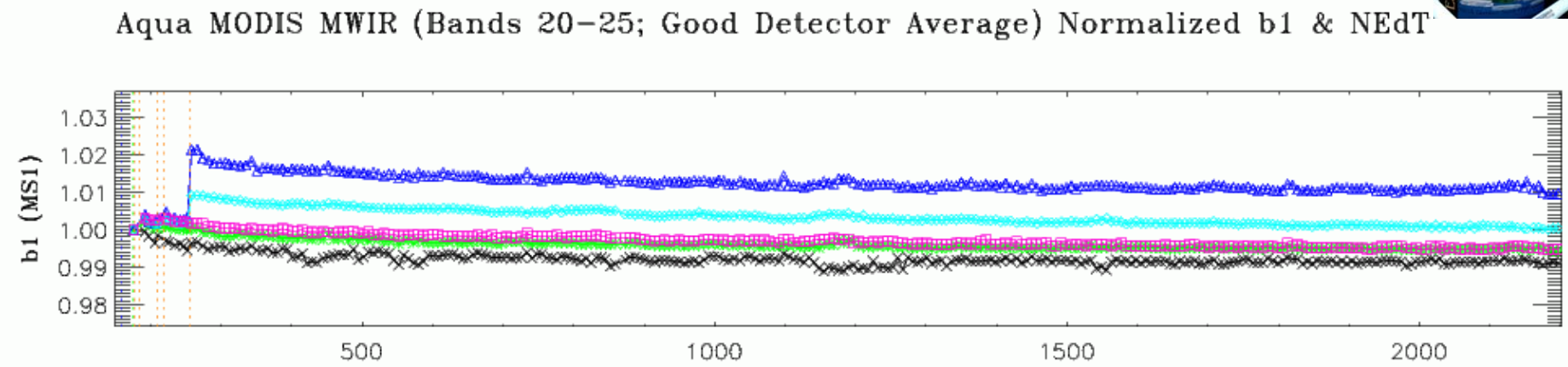




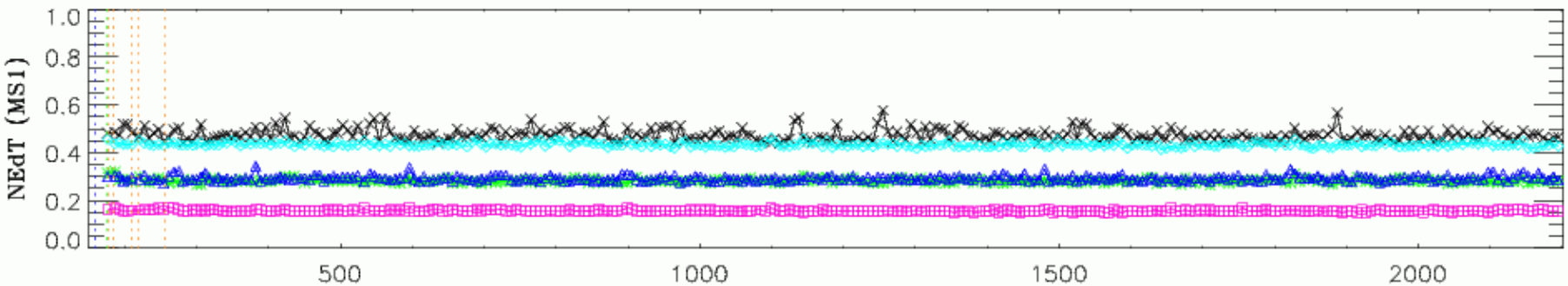
Terra MODIS TEB LWIR Response Trend



Aqua MODIS TEB MWIR Response Trend



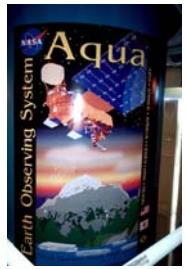
Epoch 2002

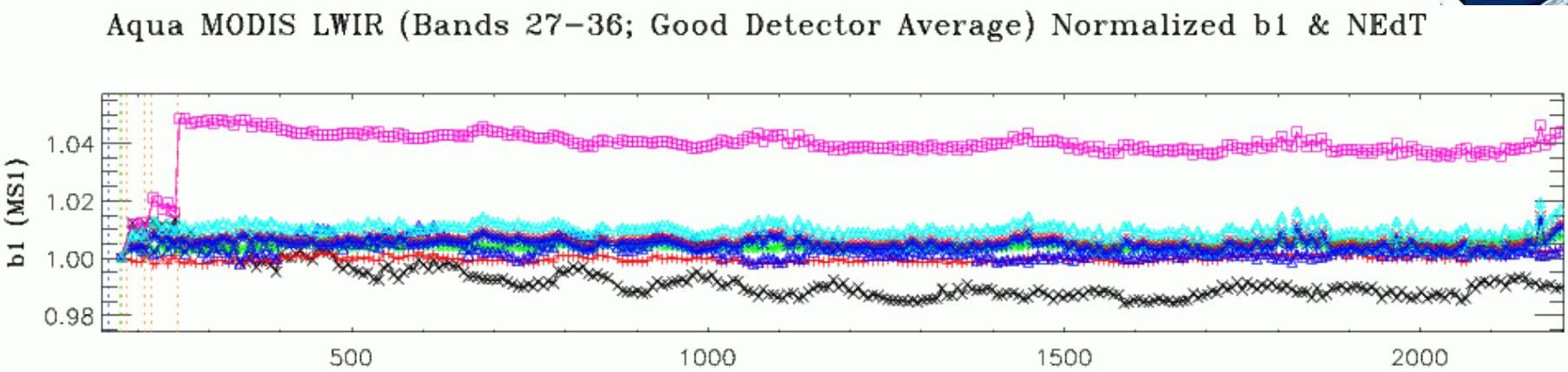


Epoch 2002

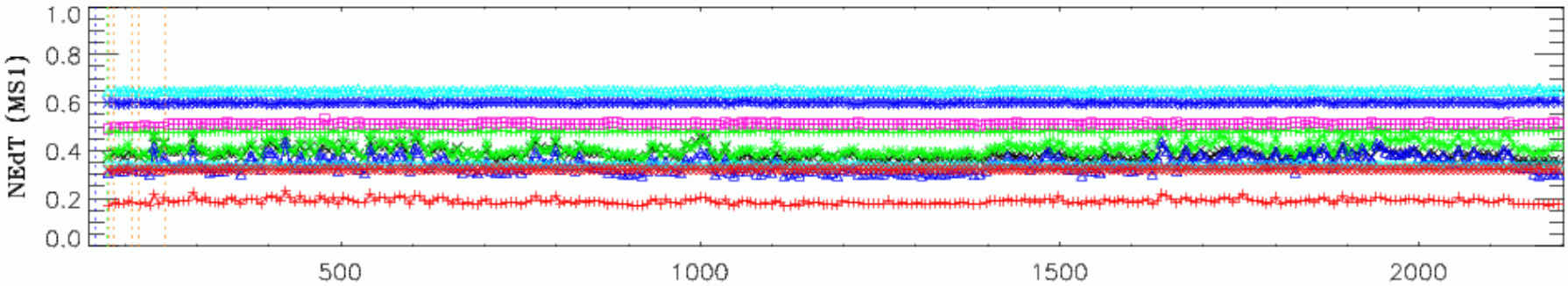
B20 x B22 * B23 Δ B24 ◇ B25 □

Aqua MODIS TEB LWIR Response Trend





Epoch 2002

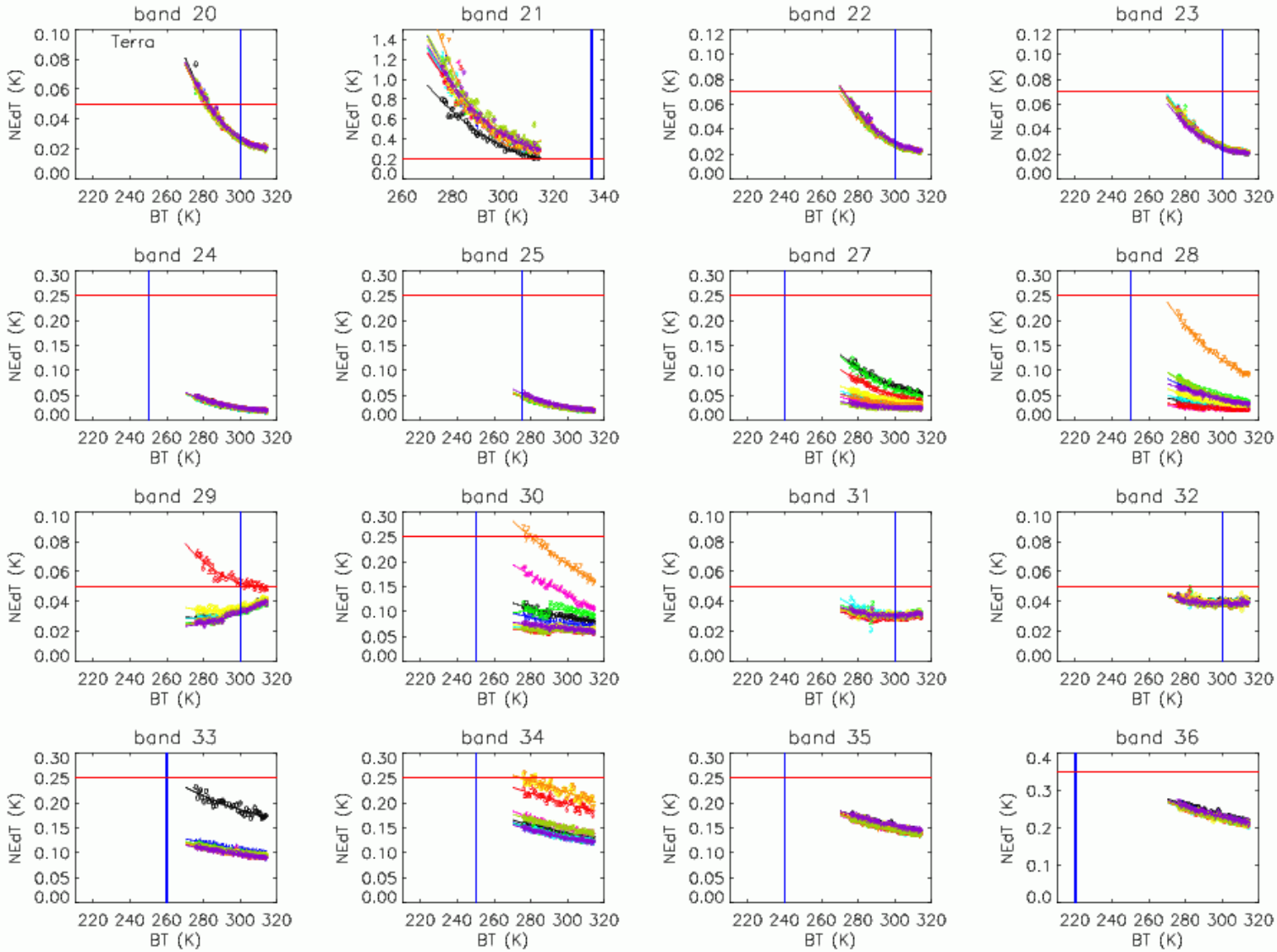


Epoch 2002

B27 x B28 + B29 * B30 Δ B31 ◇ B32 □ B33 x B34 + B35 * B36 Δ

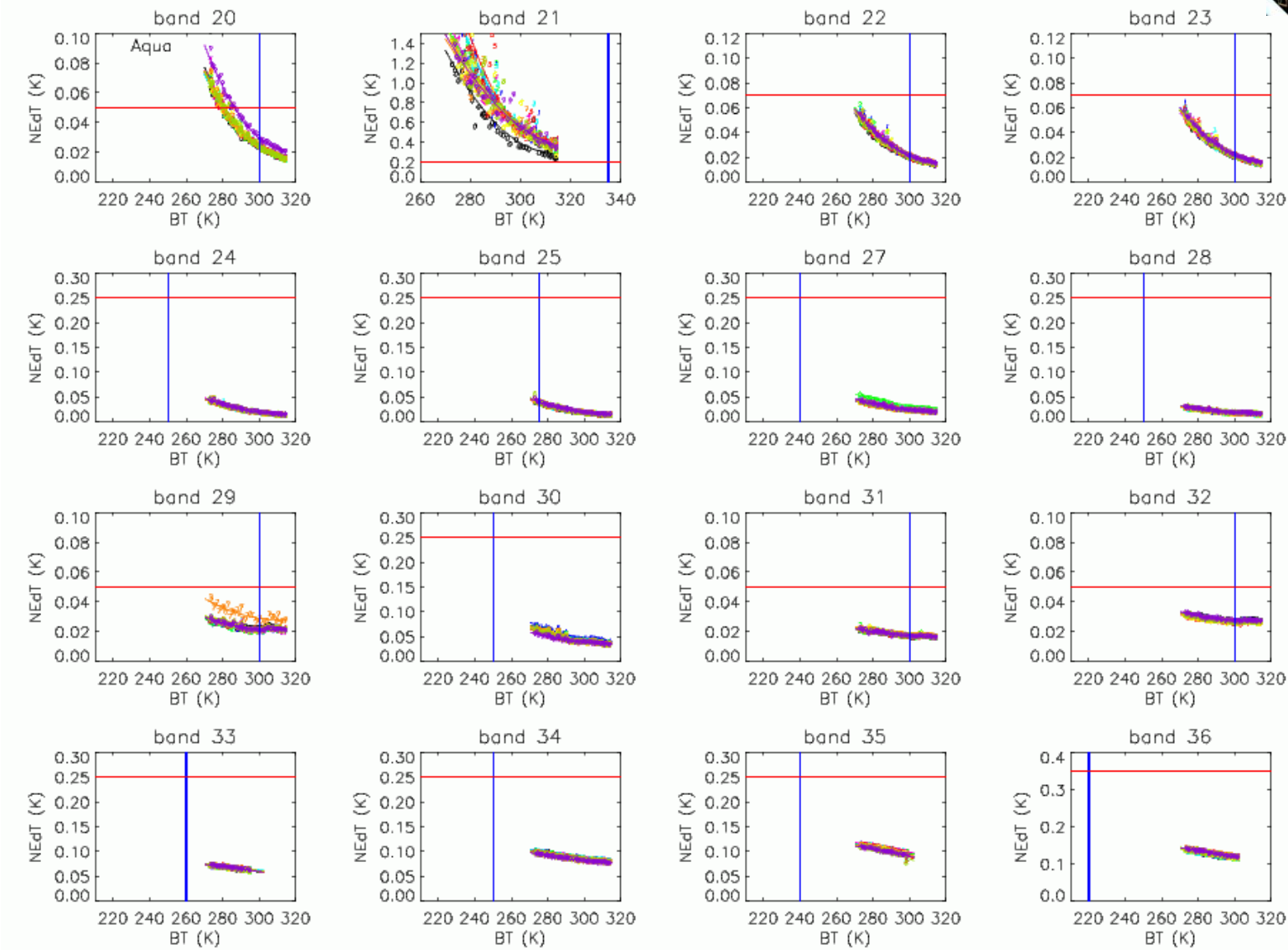
Terra NEdT vs T_{BB}

2007/323

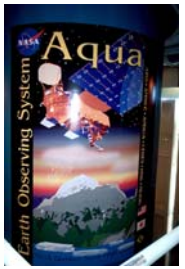


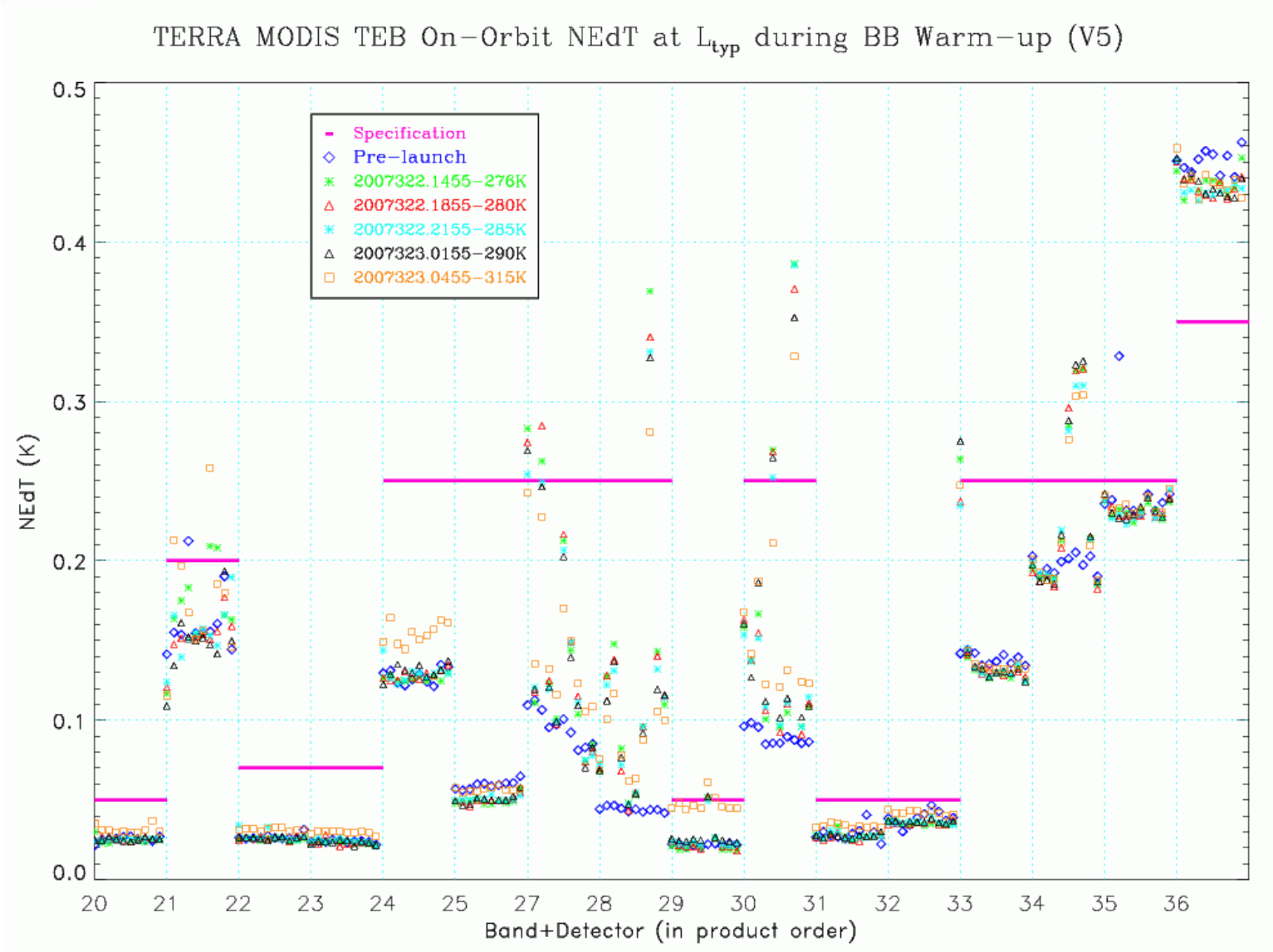
Aqua NEdT vs T_{BB}

2007/350

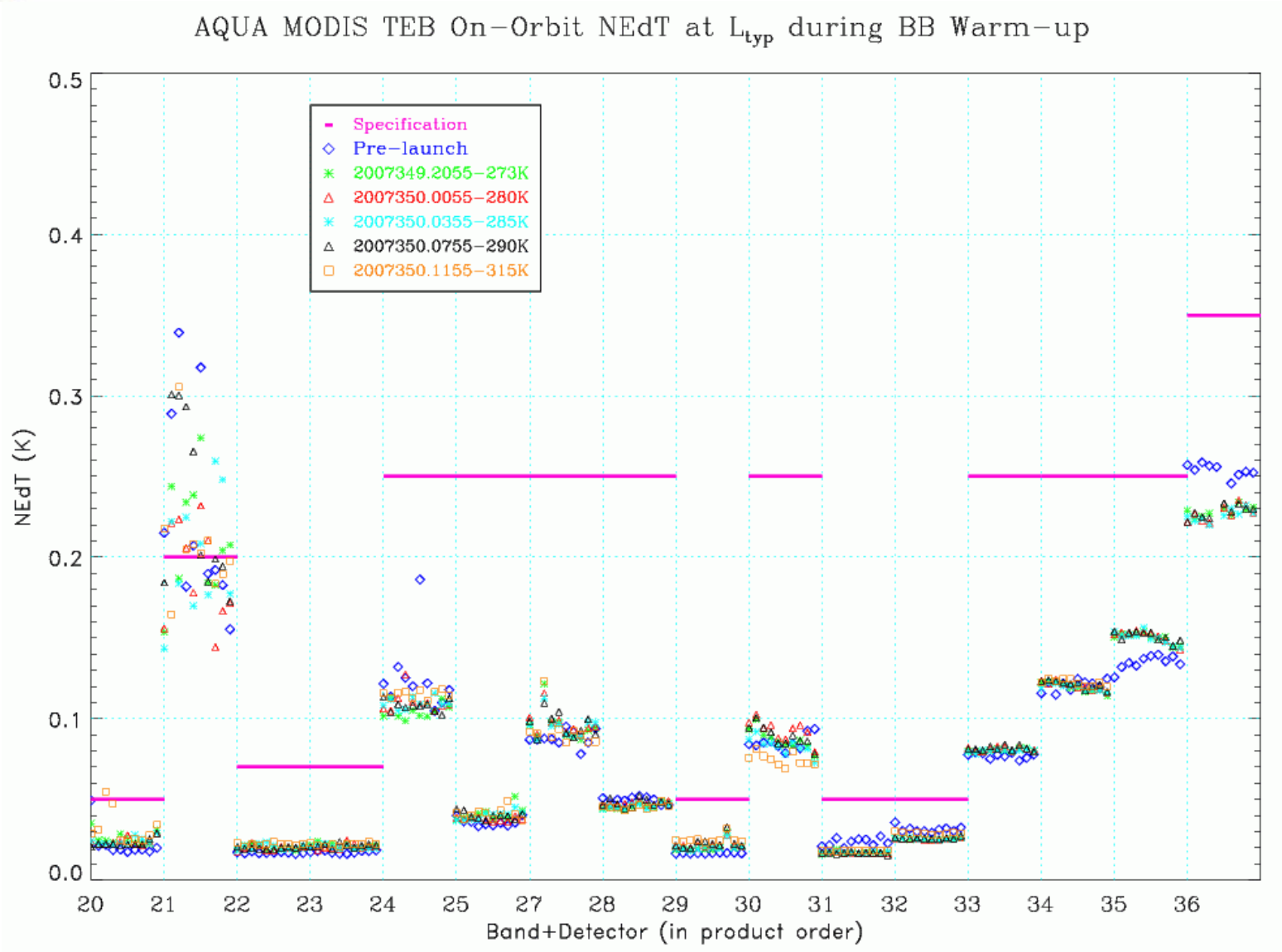


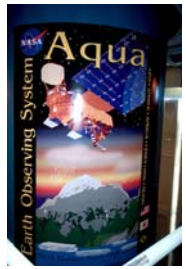
Terra NEdT vs T_{BB}





Aqua NEdT vs T_{BB}





Terra MODIS Noisy Detector History

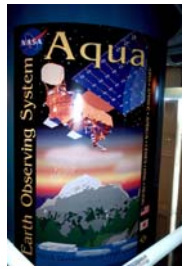
Detectors in Product Order

Day/Year	Band	27				28					29		30				33	34				36
	Spec NEdT[K]	0.25				0.25					0.05		0.25				0.25	0.25				0.35
	Detector #	1	3	6	8	1	3	8	9	10	4	6	2	3	5	8	1	5	6	7	8	1-10
Pre-launch	-	0.10	0.08	0.10	0.03	0.05	0.05	0.04	0.05	0.04	0.02	0.02	0.08	0.10	0.09	0.09	0.14	0.20	0.20	0.21	0.20	0.45
055/2000	Nadir door open	0.09	0.10	0.09	0.03	0.05	0.06	0.06	0.05	0.05	0.02	0.02	0.10	0.06	0.11	0.11	0.28	0.23	0.26	0.27	0.29	0.43
232/2000	Back from FPA recycle	0.10	0.10	0.24	0.03	0.05	0.05	0.05	0.05	0.05	0.02	0.03	0.11	0.07	0.31	0.11	0.27	0.24	0.33	0.37	0.38	0.42
030/2001	-	0.10	0.11	0.27	0.03	0.05	0.06	0.05	0.05	0.05	0.02	0.02	0.12	0.07	0.29	0.30	0.25	0.24	0.33	0.37	0.37	0.43
087/2002	Back from safe mode	0.11	0.10	0.24	0.03	0.06	0.32	0.05	0.05	0.04	0.02	0.02	0.10	0.06	0.26	0.64	0.25	0.24	0.29	0.32	0.33	0.43
022/2003	-	0.10	0.10	0.23	0.03	0.05	0.30	0.27	0.04	0.04	0.02	0.02	0.10	0.06	0.25	0.65	0.27	0.25	0.33	0.37	0.37	0.43
086/2003	After DSM[1]	0.11	0.10	0.23	0.03	0.05	0.29	0.08	0.05	0.05	0.03	0.02	0.10	0.06	0.47	0.65	0.26	0.24	0.33	0.36	0.36	0.44
118/2004	-	0.26	0.10	0.26	0.03	0.05	0.16	0.36	0.05	0.16	0.02	0.03	0.10	0.06	0.33	0.41	0.27	0.21	0.29	0.32	0.32	0.43
158/2004	-	0.28	0.09	0.25	0.03	0.05	0.16	0.37	0.05	0.21	0.03	0.03	0.10	0.07	0.31	0.40	0.27	0.22	0.28	0.31	0.31	0.43
162/2004	-	0.26	0.10	0.27	0.03	0.05	0.16	0.37	0.05	0.20	0.02	0.03	0.14	0.06	0.32	0.42	0.27	0.22	0.30	0.34	0.34	0.43
175/2004	-	0.28	0.10	0.26	0.03	0.12	0.17	0.35	0.05	0.17	0.03	0.02	0.17	0.06	0.30	0.41	0.27	0.21	0.28	0.32	0.32	0.43
034/2005	-	0.28	0.10	0.22	0.03	0.10	0.16	0.45	0.05	0.16	0.04	0.02	0.17	0.06	0.31	0.39	0.26	0.21	0.28	0.31	0.31	0.43
130/2005	-	0.31	0.10	0.22	0.03	0.40	0.15	0.40	0.05	0.14	0.03	0.06	0.17	0.07	0.40	0.40	0.26	0.21	0.31	0.34	0.34	0.43
309/2005	-	0.30	0.10	0.21	0.03	0.09	0.14	0.35	0.30	0.18	0.03	0.04	0.18	0.06	0.31	0.40	0.24	0.21	0.27	0.30	0.30	0.43
053/2006	-	0.30	0.10	0.21	0.27	0.13	0.15	0.40	0.19	0.16	0.03	0.04	0.16	0.11	0.33	0.39	0.28	0.21	0.28	0.31	0.31	0.43
155/2006	-	0.26	0.10	0.21	0.11	0.10	0.14	0.46	0.10	0.15	0.03	0.05	0.14	0.26	0.31	0.41	0.24	0.21	0.28	0.31	0.31	0.44
241/2006	-	0.26	0.10	0.22	0.10	0.10	0.14	0.36	0.10	0.11	0.03	0.11	0.15	0.16	0.29	0.39	0.25	0.22	0.28	0.32	0.32	0.43
193/2007	NEW	0.28	0.19	0.20	0.11	0.07	0.14	0.35	0.10	0.11	0.03	0.10	0.13	0.14	0.27	0.36	0.25	0.21	0.27	0.30	0.30	0.43

[1]Spacecraft Deep Space Maneuver

In Spec | Near the Spec | Out of Spec | inoperable

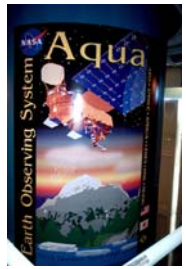
Aqua MODIS Noisy Detector History



Aqua MODIS TEB Noisy Detector History

Day/Year	Band	20	21			27	29	36
	Spec NEdT [K]	0.05	0.20			0.25	0.05	0.35
	Detector #	10	3	9	others	3	8	5
Pre-launch	-	0.05	0.16	0.28		0.10	0.02	1.34
175/2002	Nadir door open	0.03	0.23	0.23	near 0.2	0.09	0.02	1.28
183/2002	Back from safe mode	0.03	0.20	0.25	near 0.2	0.09	0.02	1.31
218/2002	Back from safe mode	0.03	0.19	0.26	near 0.2	0.09	0.02	1.32
255/2002	Back from safe mode	0.03	0.23	0.20	near 0.2	0.09	0.02	1.36
102/2003	-	0.03	0.43	0.19	near 0.2	0.09	0.02	1.31
201/2003	-	0.03	0.18	0.18	near 0.2	0.09	0.02	1.29
010/2005	-	0.03	0.17	0.19	near 0.2	0.23	0.02	1.35
359/2007	-	0.03	0.18	0.21	near 0.2	0.13	0.05	1.34

In Spec	Near Spec	Out of Spec	Inoperable



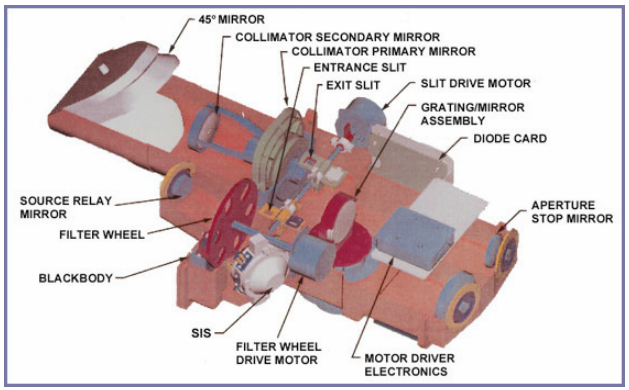
Spatial and Spectral Characterization

- SRCA Spatial and Spectral Modes
  - Design and methodology
- Spatial Characterization Results
  - Band-to-band Registration (BBR): along-scan and along-track
  - Modulation Transfer Function (MTF)
- Spectral Characterization Results (VIS/NIR only)
  - Center wavelengths
  - Bandwidths
- Summary of Spatial and Spectral Performance
  - SRCA lamp issues

SRCA Spatial and Spectral Modes

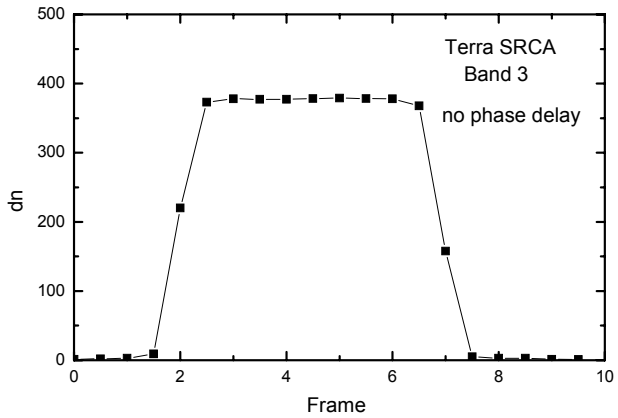
$$\bar{x}(b,d) = \frac{\sum_{x=0}^{N_x} dn(b,d,x) \cdot x}{\sum_{x=0}^{N_x} dn(b,d,x)}$$

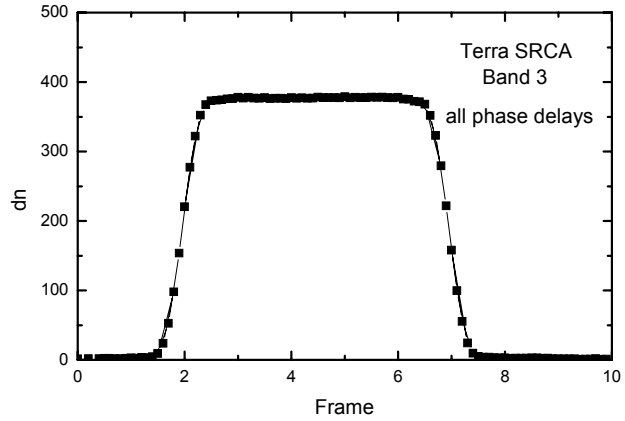
Spatial



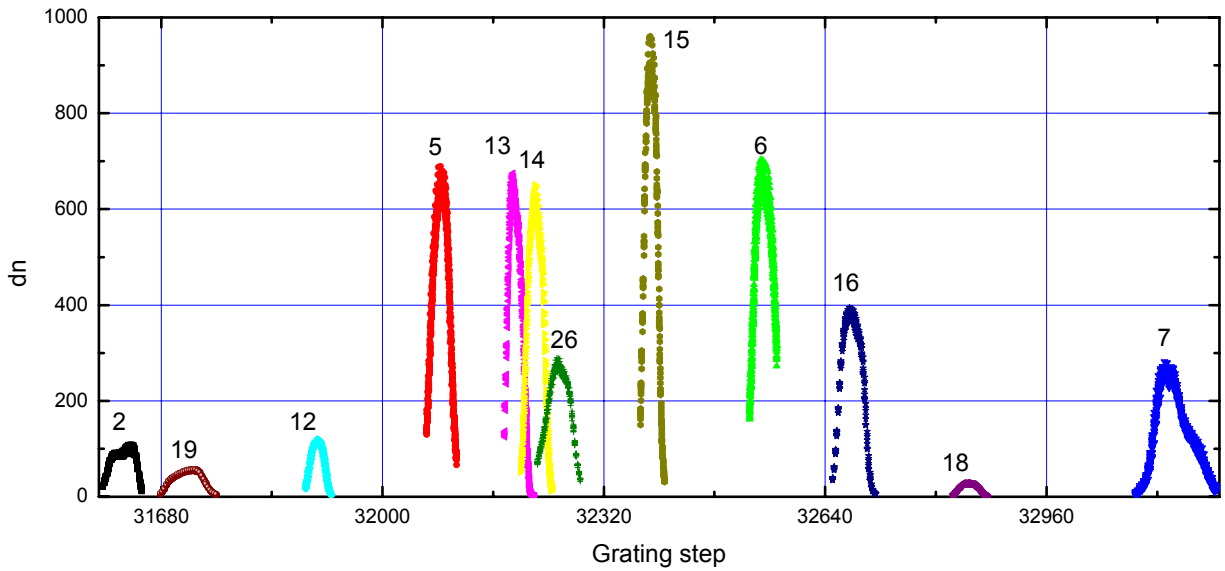
Spectral

$$\lambda_C = \frac{2A}{m} \cdot \sin(\theta_C + \theta_{off}) \cdot \cos\beta$$



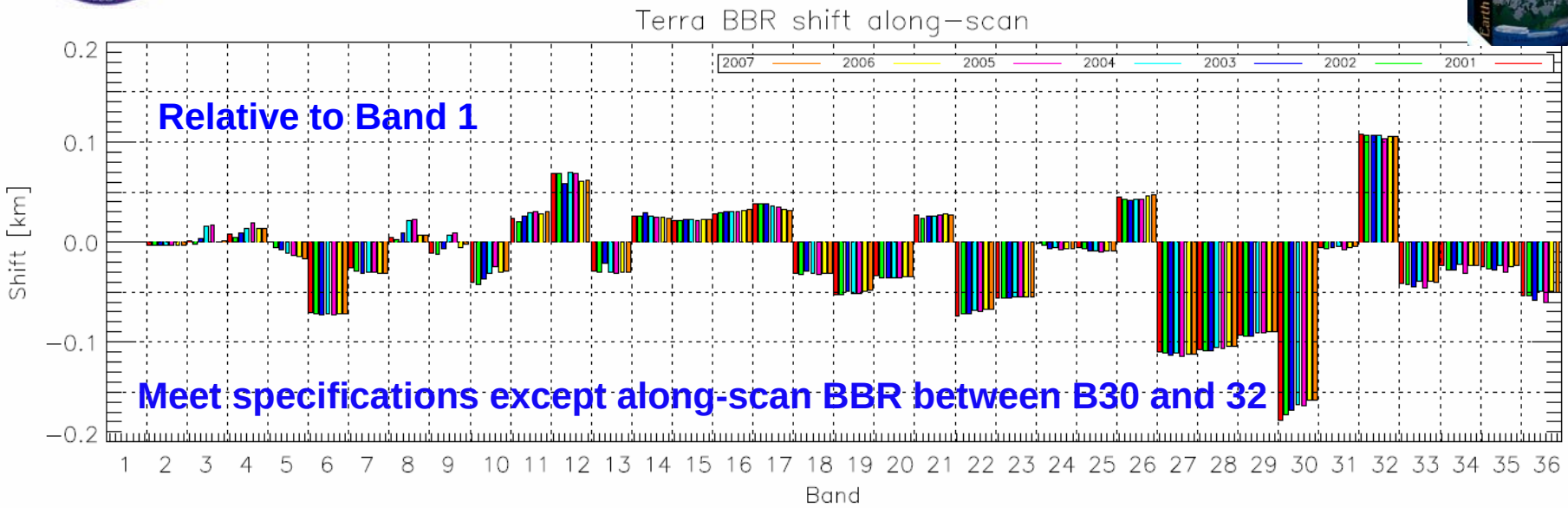


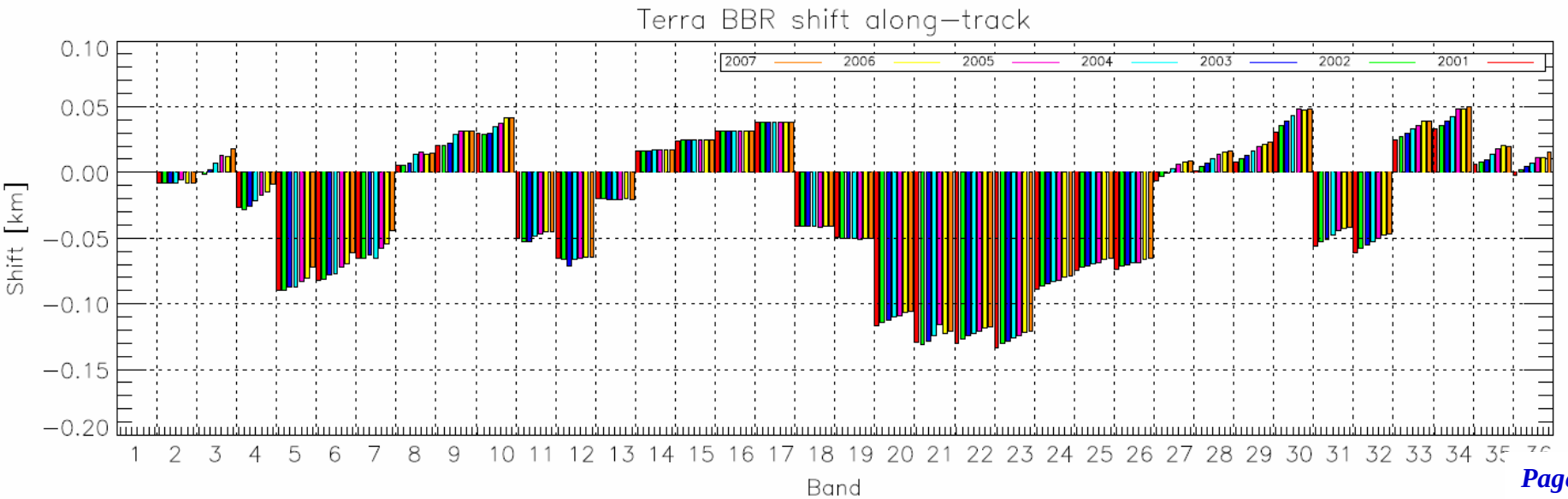
Frame -> x



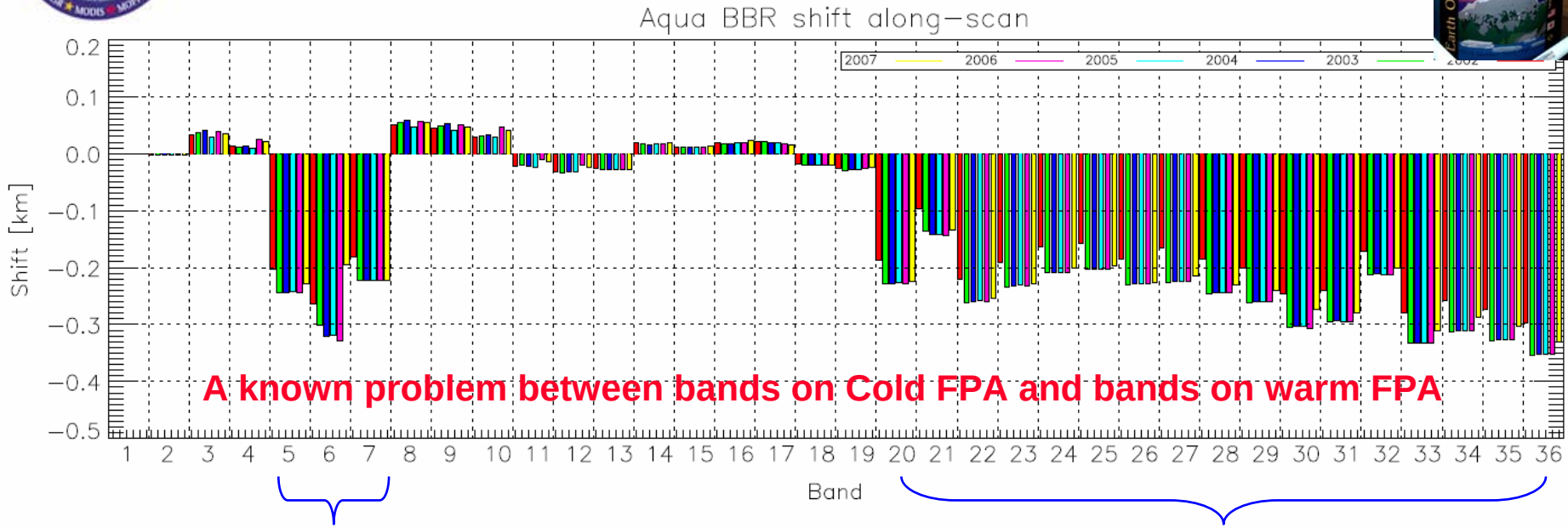
Grating step -> θ

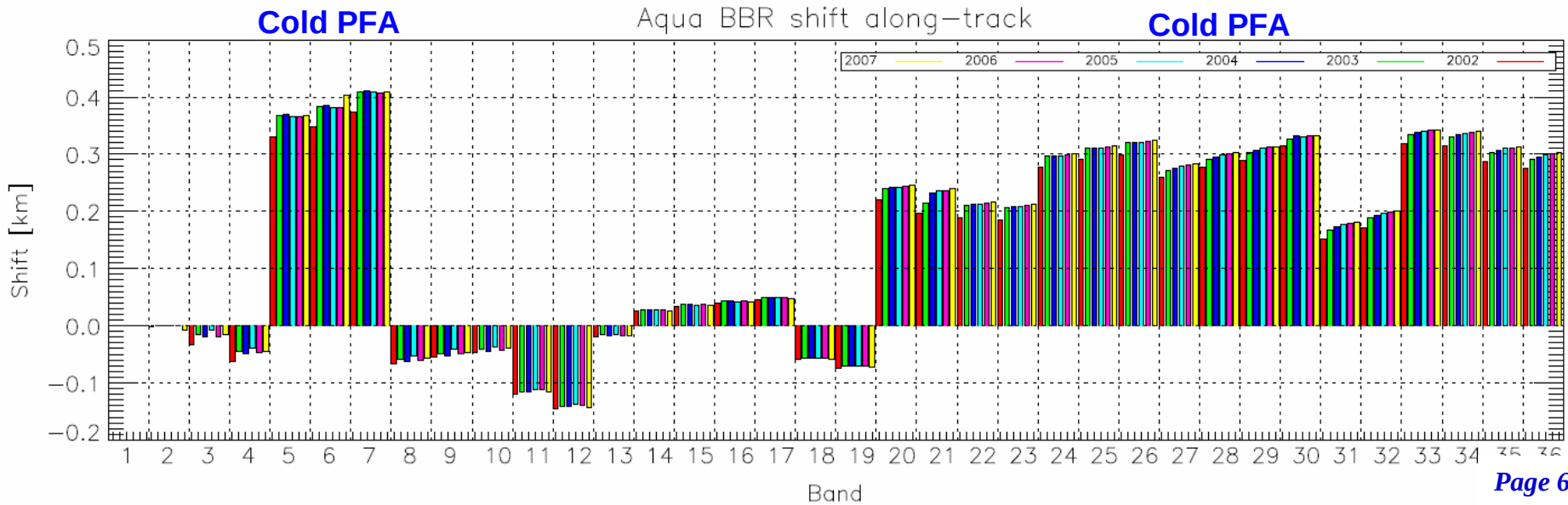
Terra MODIS BBR



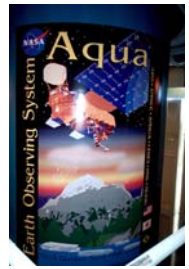


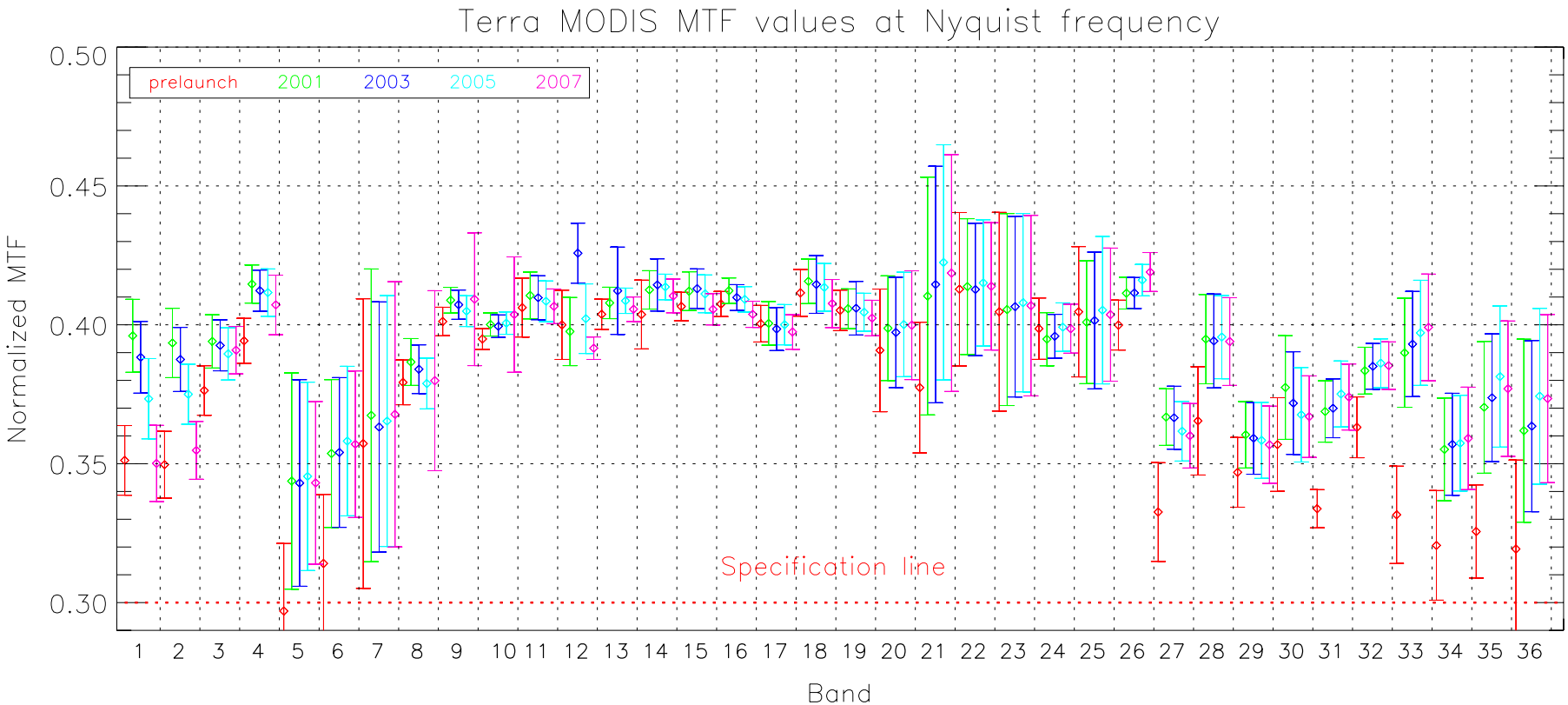
Aqua MODIS BBR





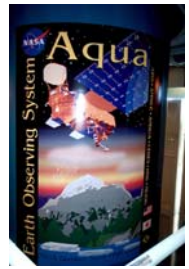
Terra MODIS MTF

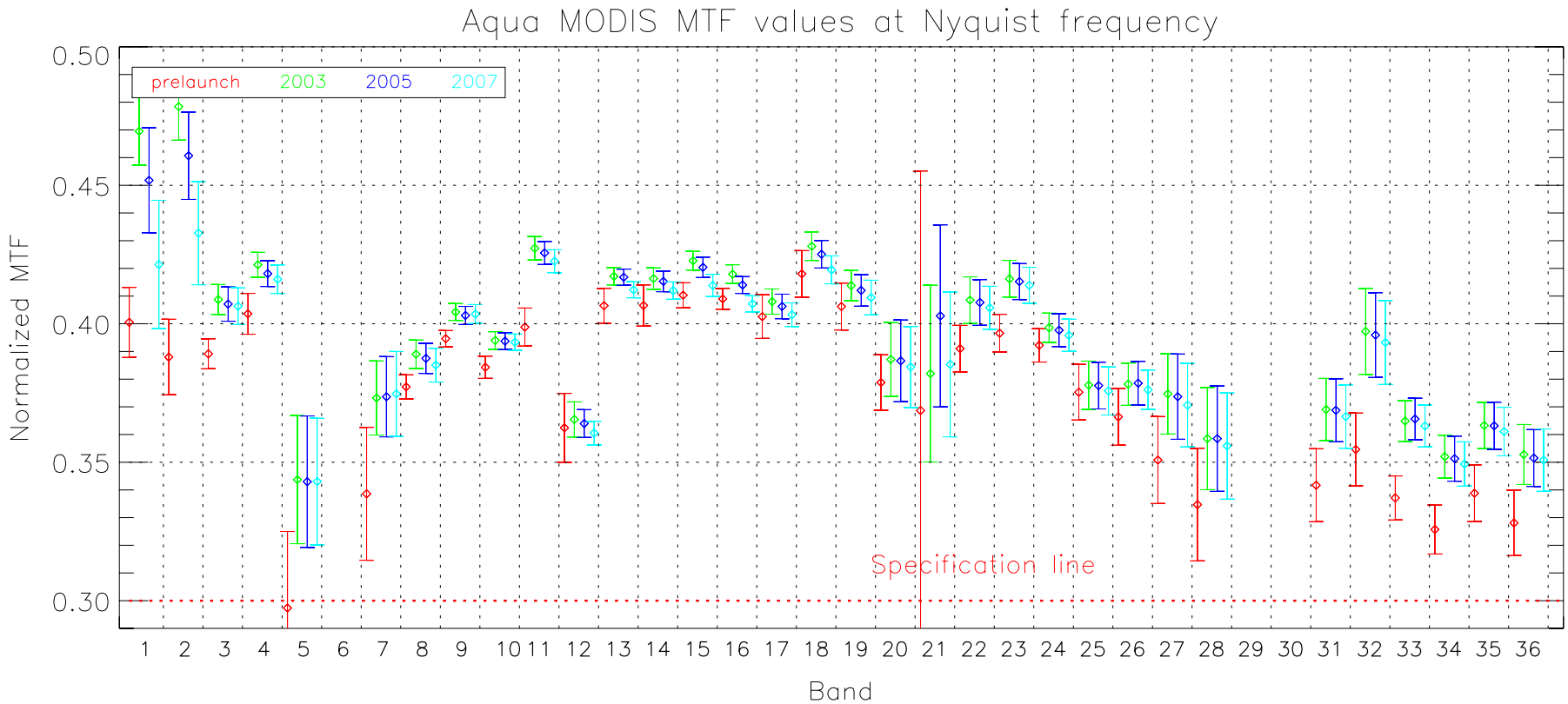




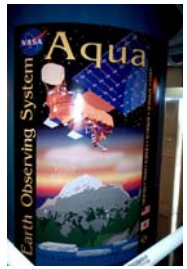
KER => LSF => MTF

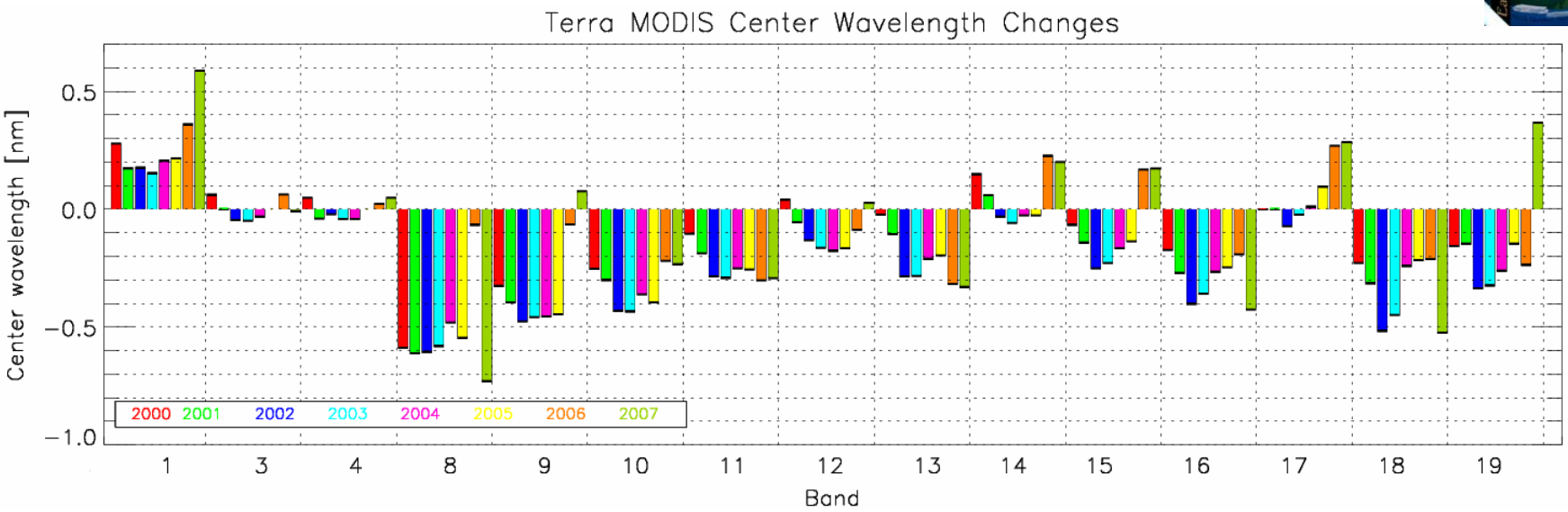
Aqua MODIS MTF

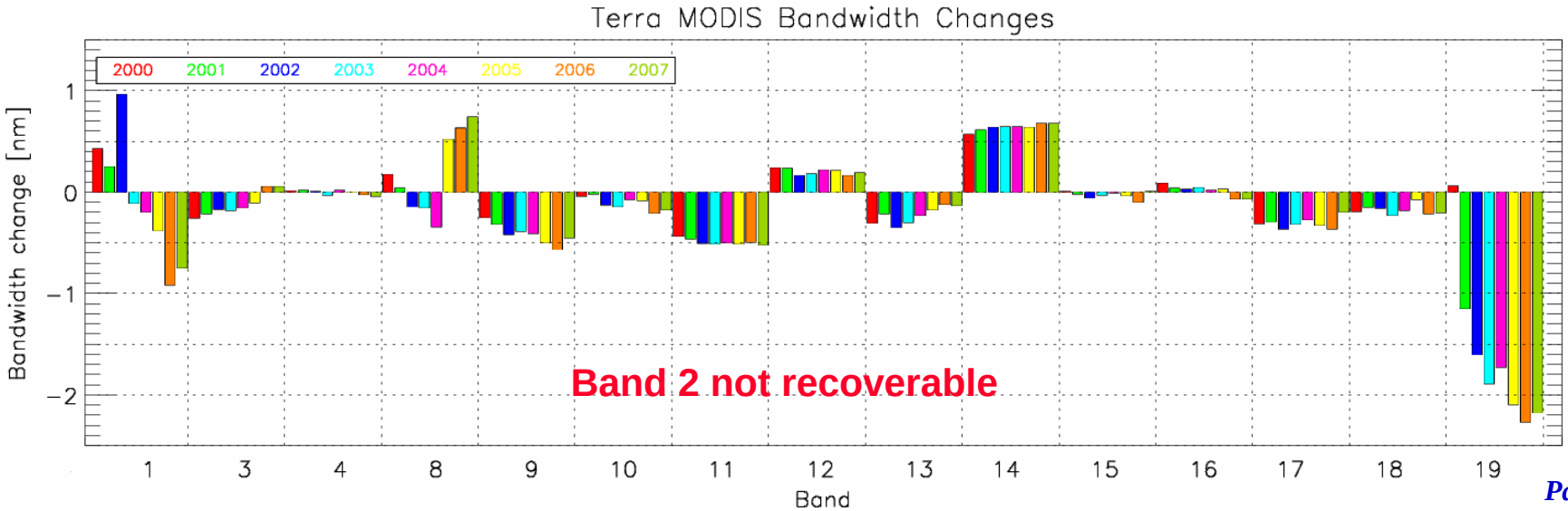




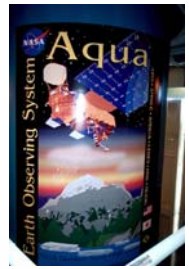
Terra MODIS VIS/NIR CW and BW

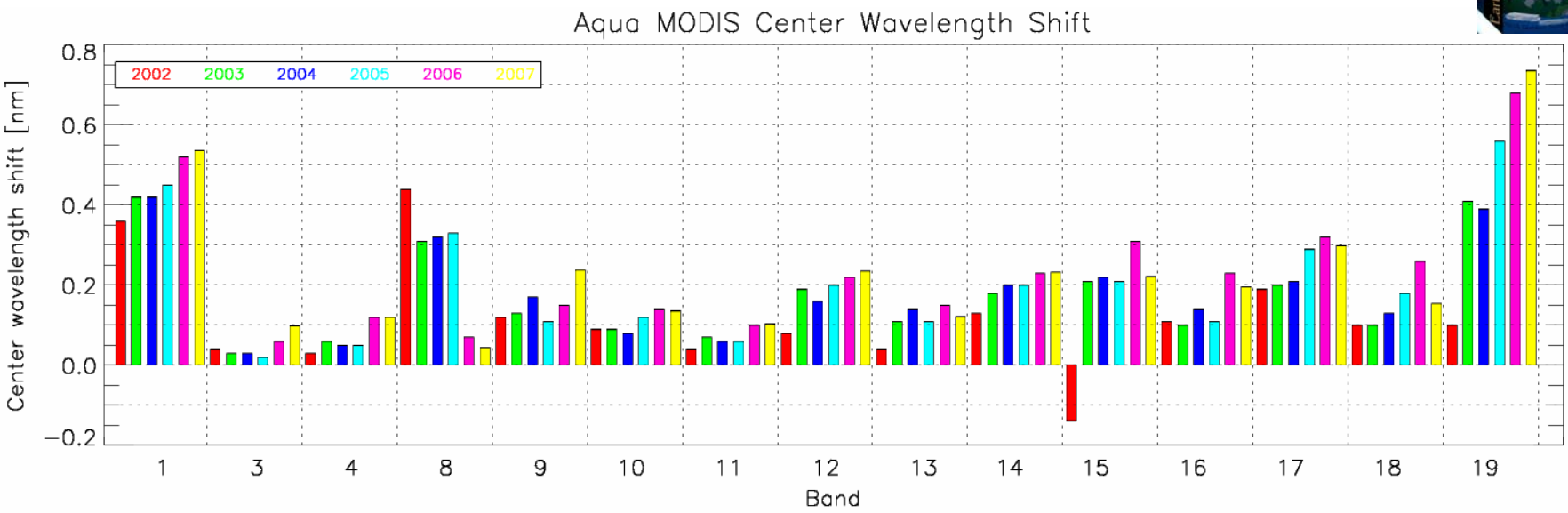


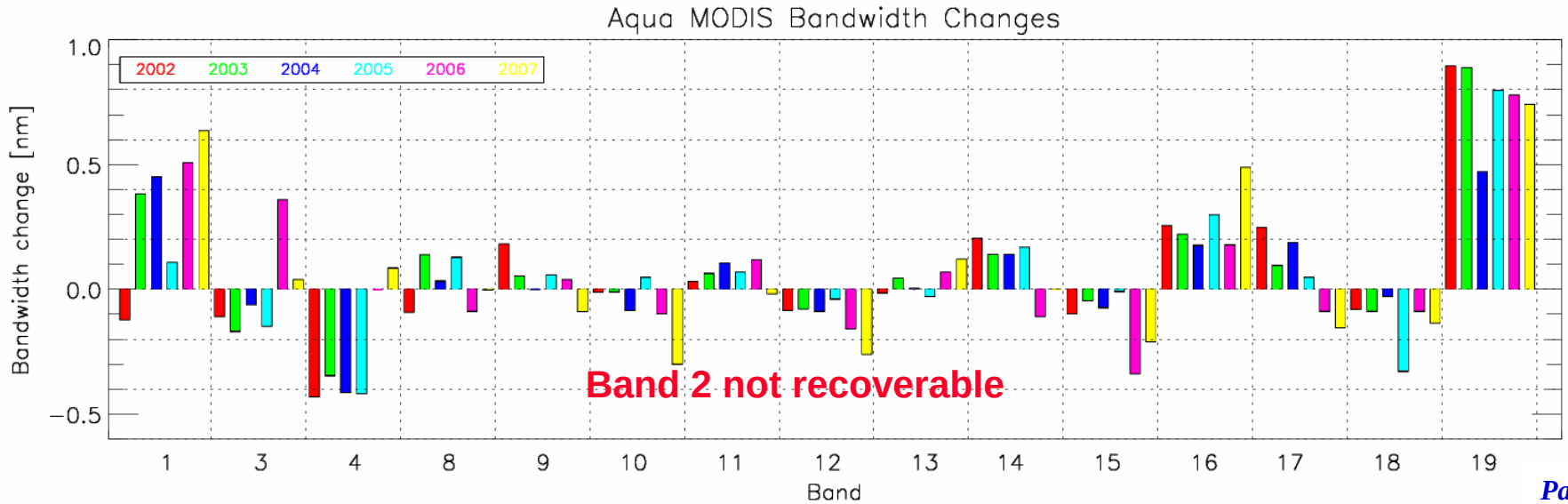




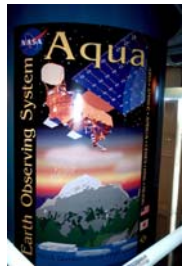
Aqua MODIS VIS/NIR CW and BW





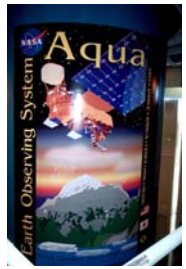


Summary of Spatial and Spectral Performance

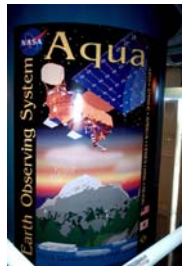


- Spatial Performance Remains Stable
  - Terra MODIS BBR: meet specifications except along-scan BBR between B30 and 32
  - Aqua MODIS BBR: a known problem between Cold FPA band and warm FPA band
  - MTF parameters continue to exceed design requirement
- Spectral Characterization (VIS/NIR only)
  - CW and BW changes are less than 0.5nm, except for bands 1 and 19 which have large bandwidths (50nm), and for band 8 (small SNR and large mirror degradation)
- SRCA lamp issue
  - 30W lamp configuration removed from operation due to lamp degradation (no change since last STM)

Geolocation

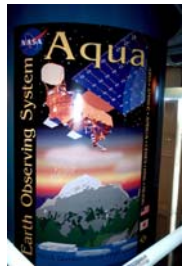


Separate Package from Robert Wolfe (available online after workshop)



Challenging Issues

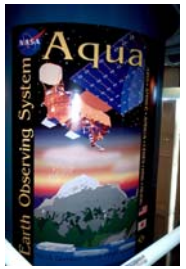
- TEB Calibration Coefficients (a0/a2) Update Strategy
  - Issues identified (impact on low temperature retrieval).
  - Work in progress with Chris Moeller (potential improvements for collection 6)
- Degradation of Scan Mirror Reflectance for VIS Bands
  - Mirror side difference (large increase in Terra MODIS bands 8 and 9)
  - Detector-to-detector difference (large increase in Terra MODIS bands 8 and 9)



TEB a0/a2 Update Strategy

- Background
  - Terra MODIS PV bands (20-25, 27-30) electronics changed before launch; No complete radiometric calibration made after the change
  - Aqua MODIS bands 31 and 32 gain changed before launch (to increase detector resolution)
  - MODIS TEB calibration uses a quadratic approach
- Current a0/a2 update (excluding B21)
  - Terra MODIS: PV bands and bands 31-32 use a0/a2 from on-orbit BB warm-up; bands 33-36 a0=0 and a2 from BB warm-up
  - Aqua MODIS: PV bands use pre-launch a0/a2; bands 31-32 use on-orbit BB warm-up a0/a2; bands 33-36 a0=0 and a2 from pre-launch
  - On-orbit data analyses performed (with input from MsWG) for both Terra and Aqua MODIS to justify above strategy of a0 = 0 for bands 33-36.

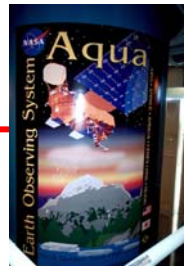
TEB a0/a2 Update Strategy

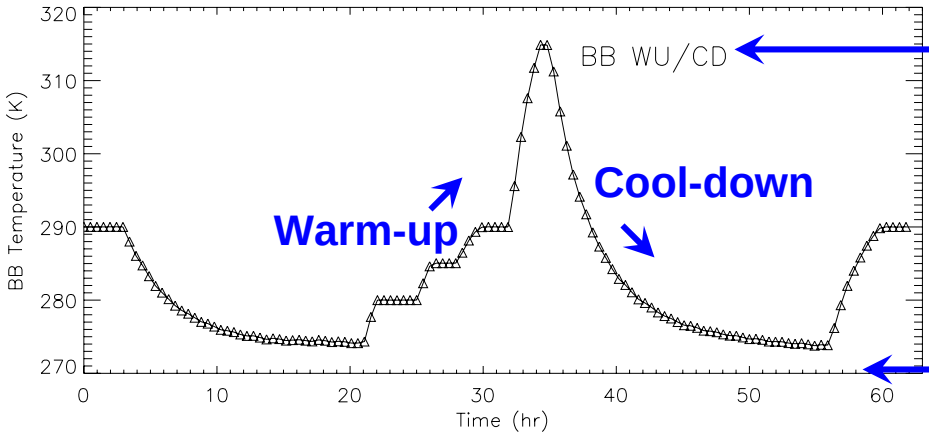


- Pre-launch and on-orbit a0 and a2
  - Pre-launch a0/a2 determined from a blackbody calibration source (BCS) with temperatures varying from 170 to 340K
  - On-orbit a0/a2 determined from the BB warm-up or cool-down (WUCD) with temperatures varying from 270 to 315K
- Small differences (at low temperatures) observed when different a0/a2 approaches are used in L1B
  - Studies made using different combinations of a0 and a2
  - Test granules provided to C. Moeller for validation and science impact assessment

- What is the best approach for a0/a2?
- What is the impact on the current 1B retrieval?

BB Warm-up / Cool-down





340K

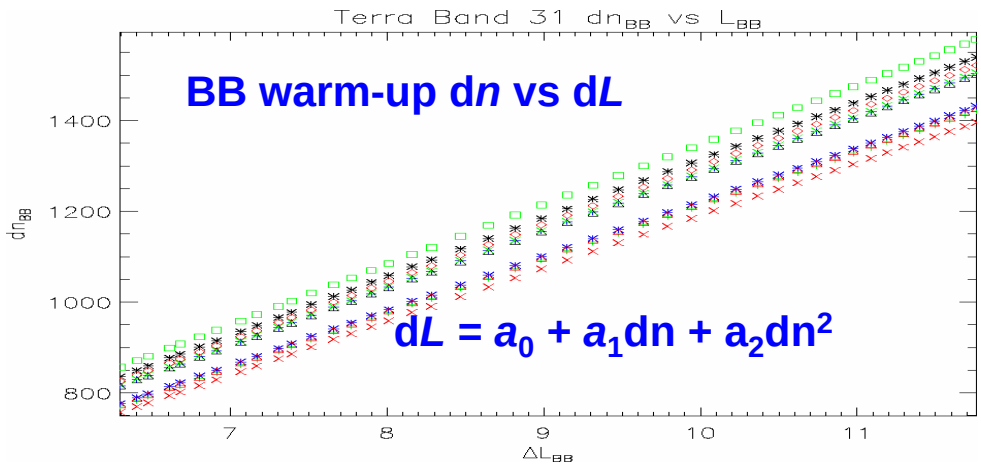
315K

On-orbit

270K

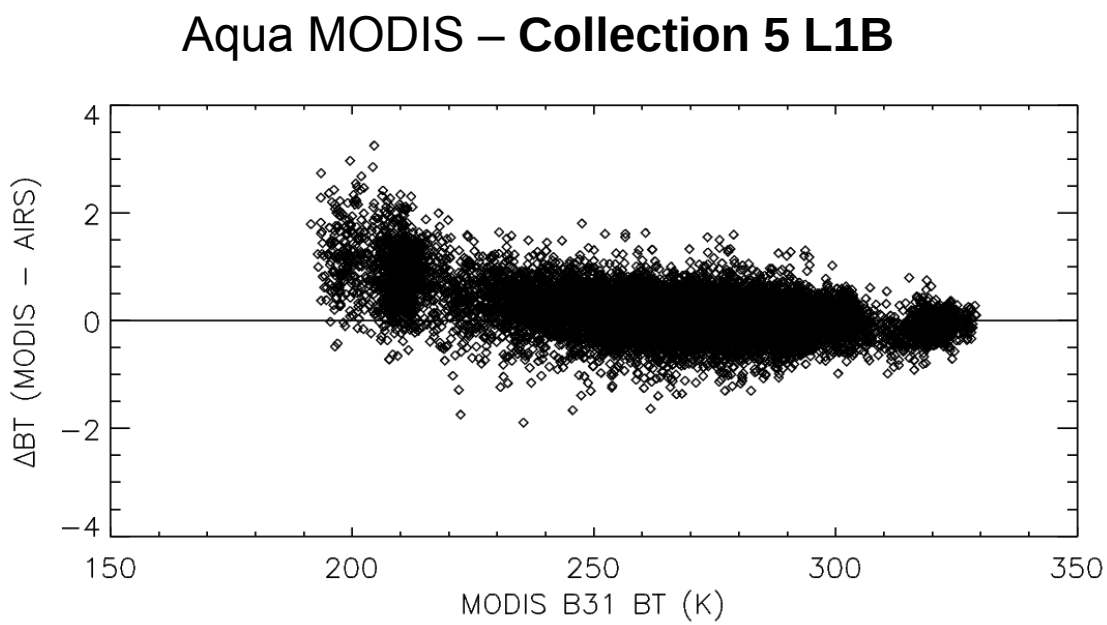
Pre-launch BB range

170K

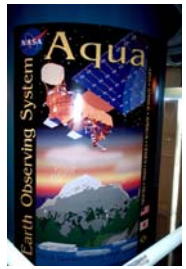


Comparison between MODIS and AIRS

MODIS/AIRS: One orbit of granules – June 20, 2006 – near nadir footprints



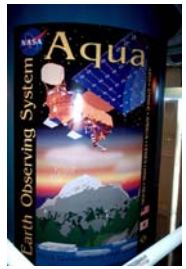
Case Studies Using Different a0/a2



Case	Setting of a_0 and a_2	BB temperature range
1	Prelaunch a_0 and a_2	Prelaunch (170 to 340K)
2	Prelaunch a_0 and a_2	On-orbit (270 to 315K)
3	Prelaunch a_0 and cool-down a_2	On-orbit
4	Prelaunch a_0 and warm-up a_2	On-orbit
5	a_0 = 0 and cool-down a_2	On-orbit
6	a_0 = 0 and warm-up a_2	On-orbit
7	Cool-down a_0 and a_2	On-orbit
8	Warm-up a_0 and a_2	On-orbit (*used in L1B)

Comparison study reference:

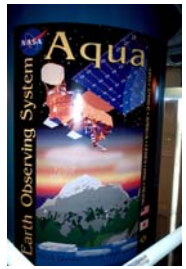
Aqua bands except for bands 31-32; Terra PC bands



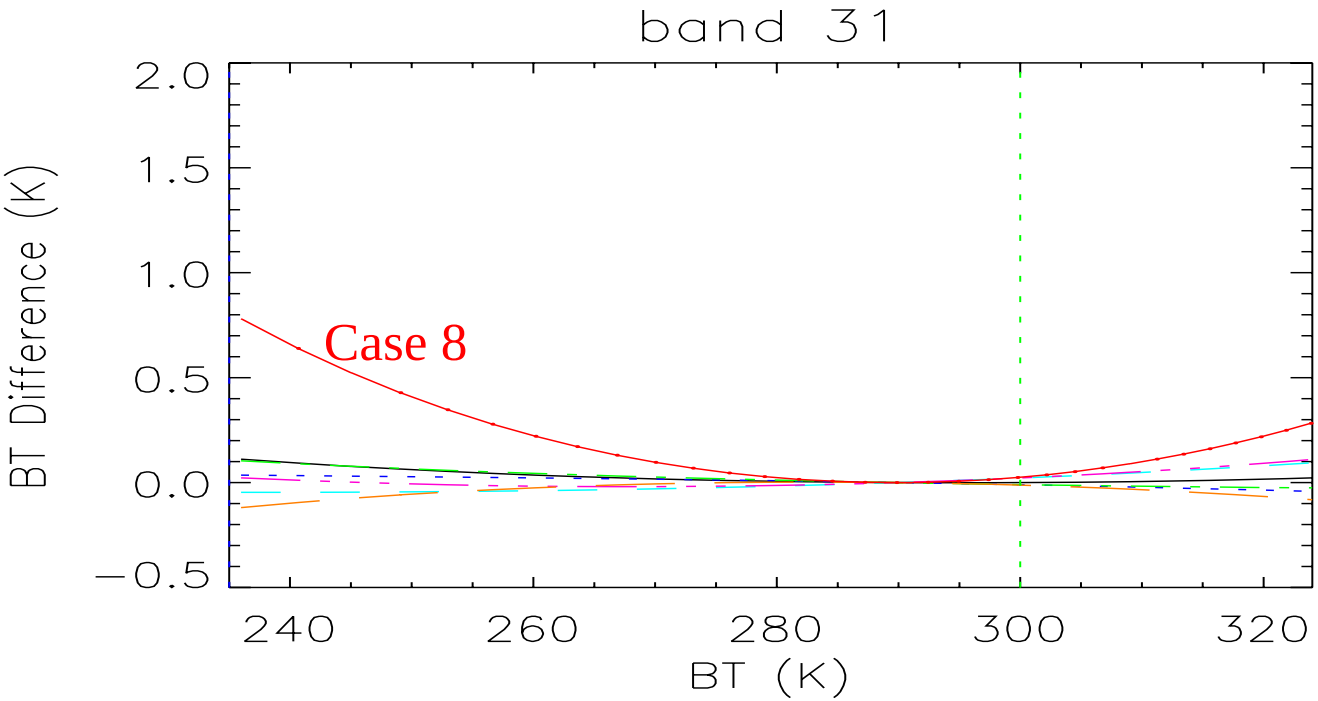
Results from Case Studies

- Relative to the brightness temperature (BT) obtained using pre-launch *a*0 and *a*2, warm-up *a*0 and *a*2 produce the largest positive BT biases among all *a*0/*a*2 settings by ~1.0K (band dependent) at very low temperatures (~200K).
- Using pre-launch *a*0 or setting *a*0 = 0 and *a*2 from either BB warm-up or cool-down produce agreement (within 0.5K) with pre-launch *a*0 and *a*2 over 0.3Ltyp to 0.9Lmax.
- Aqua MODIS/AIRS comparison indicates that MODIS BT (bands 31/32, collection 5) is about 1.0K higher than that from AIRS at low-temperature scenes (~200K).

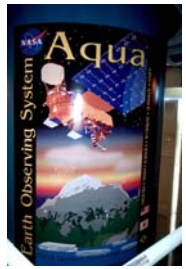
Temperature differences relative to case 1



Terra test granule on 2006326.0605

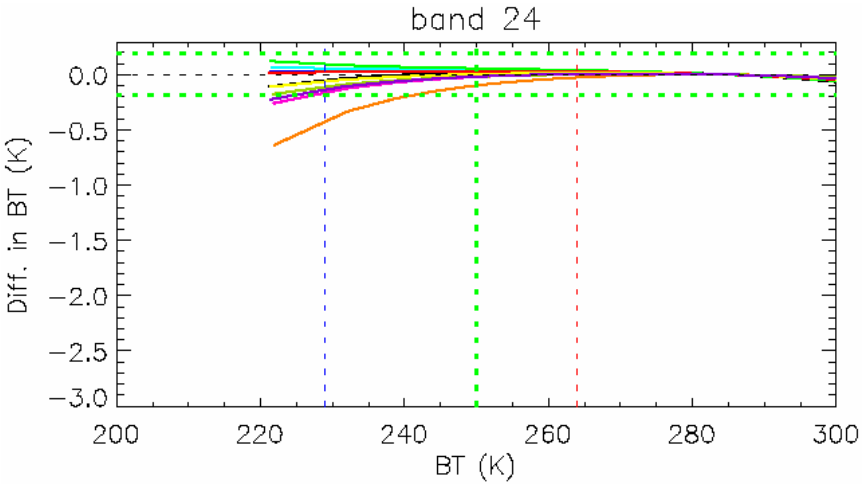


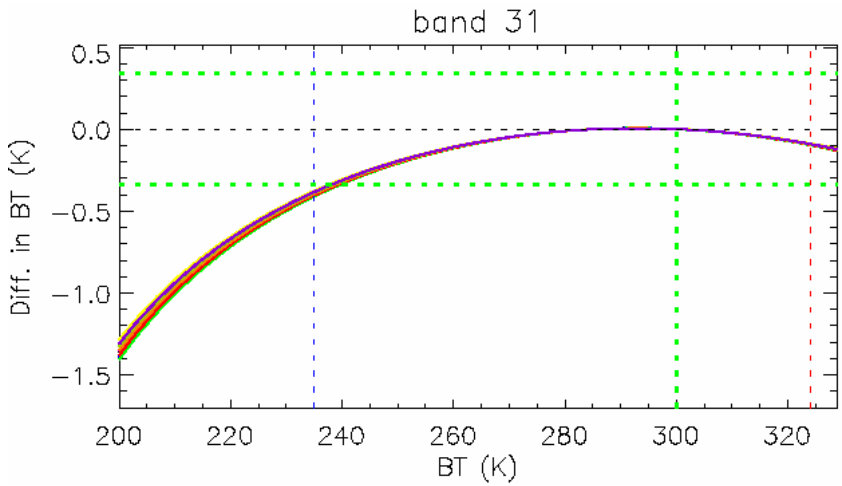
Impact of setting a0 = 0



Aqua 2006354.0050

BT diff = BT(a0=0) – BT(a0≠0)

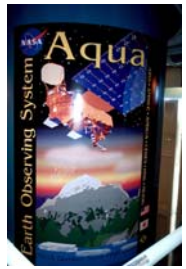




Impact on Aqua band 24 is small, likely due to the fact that the current a0 is from PL

Current Aqua band 31 a0 is from BB warm-up

a0/a2 Update Approaches



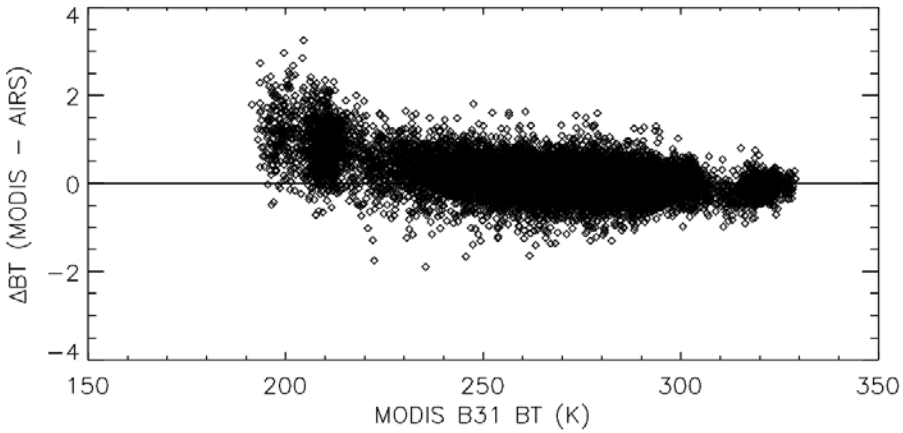
	Collection 5	Collection 6: option-1
Terra		
B20, 22-32	Warm-up a0 and a2	a0 = 0 and warm-up a2
B21	a0 = 0 and a2 = 0	no change
B33-36	a0 = 0 and warm-up a2	no change
Aqua		
B20, 22-30	Pre-launch a0 and a2	no change
B21	a0 = 0 and a2 = 0	no change
B31-32	Warm-up a0 and a2	a0 = 0 and warm-up a2
B33-36	a0 = 0 and pre-launch a2	no change

There are other options that involve more changes to the current approach

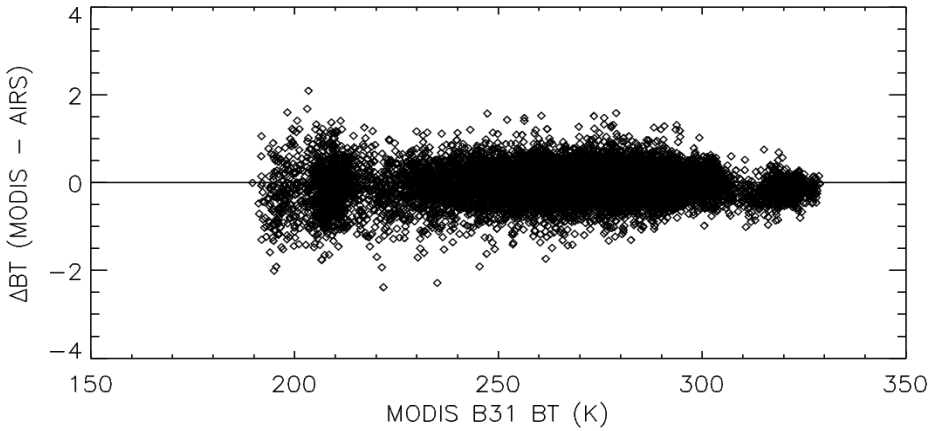
Comparison between MODIS and AIRS

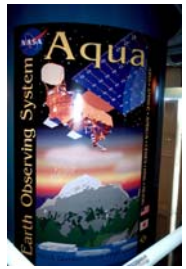
MODIS/AIRS: One orbit of granules – June 20, 2006 – near nadir footprints

Aqua MODIS – **Collection 5 L1B**



'Collection 6' L1B

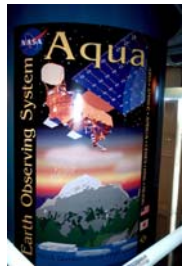




- Aqua MODIS bands (excluding bands 31-32) and Terra PC bands should provide useful reference for a0/a2 update strategy (in L1B)
- Impact assessments on science data products are required (MCST is currently working with C. Moeller on this issue)

- **A decision is needed to prepare for C6**

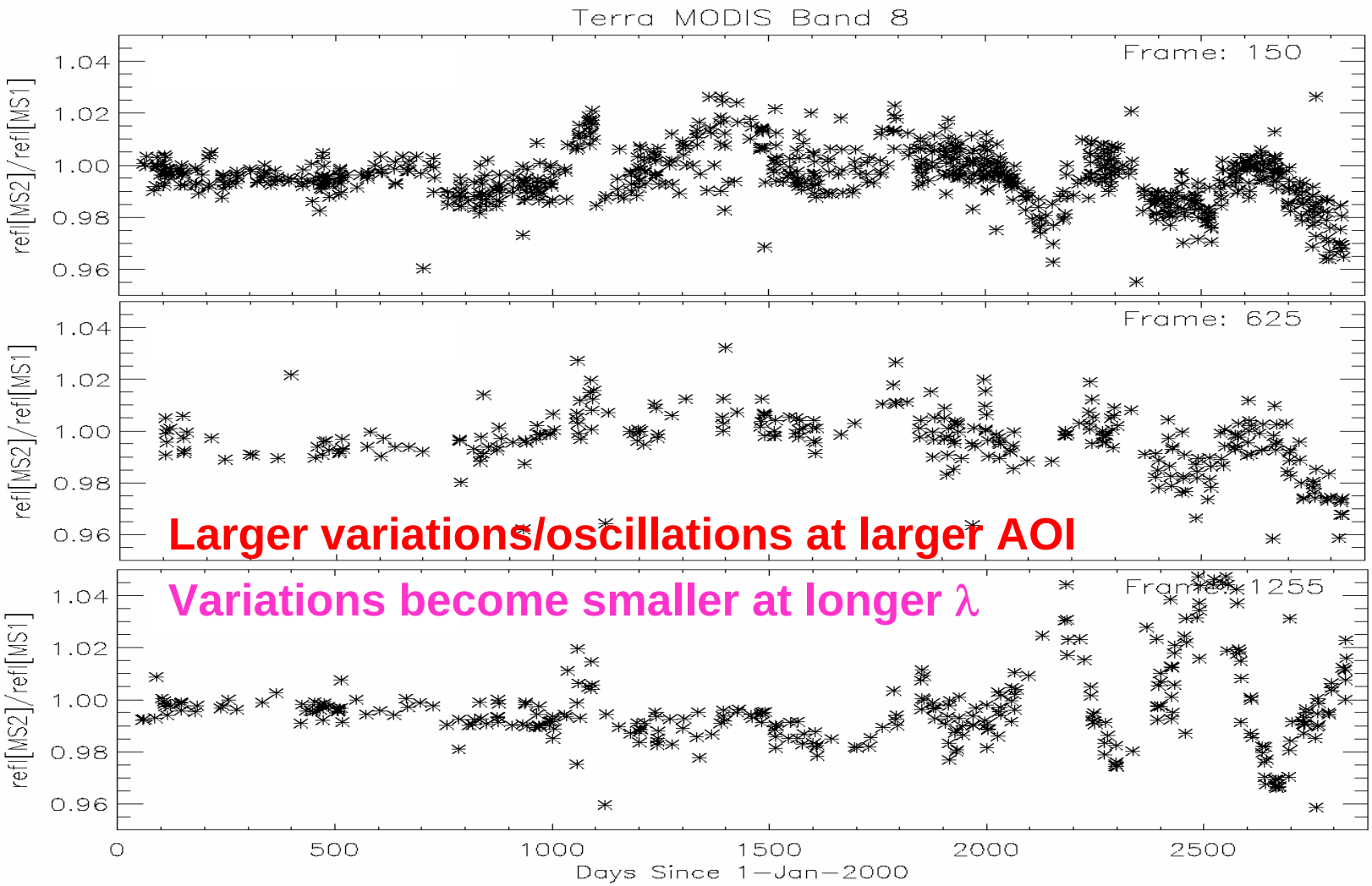
Degradation of Scan Mirror Reflectance for VIS Bands



- Mirror side difference
  - Large impact on Terra MODIS VIS bands (especially bands 8 and 9)
  - Impact on RVS, polarization parameters
  - Corrections for science data products are needed (see other science presentations)
- Detector-to-detector difference
  - Large impact on Terra MODIS VIS bands (especially bands 8 and 9)
  - Detector-dependent RVS is needed
- Impact on radiometric calibration
  - On-board calibration versus EV scene retrieval

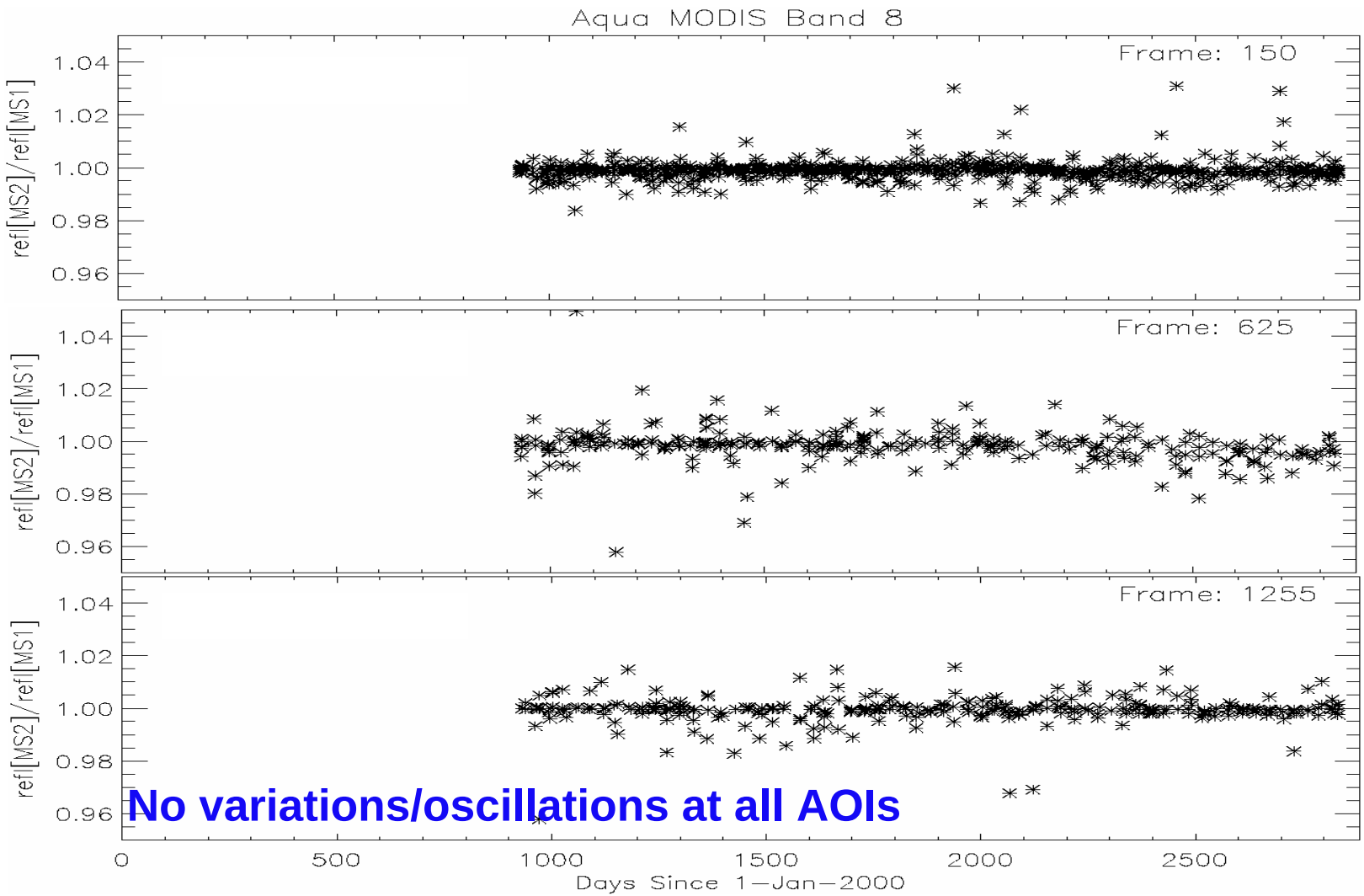
Mirror Side Difference

Terra MODIS band 8 reflectance MS difference at three AOI over Libyan desert



Mirror Side Difference

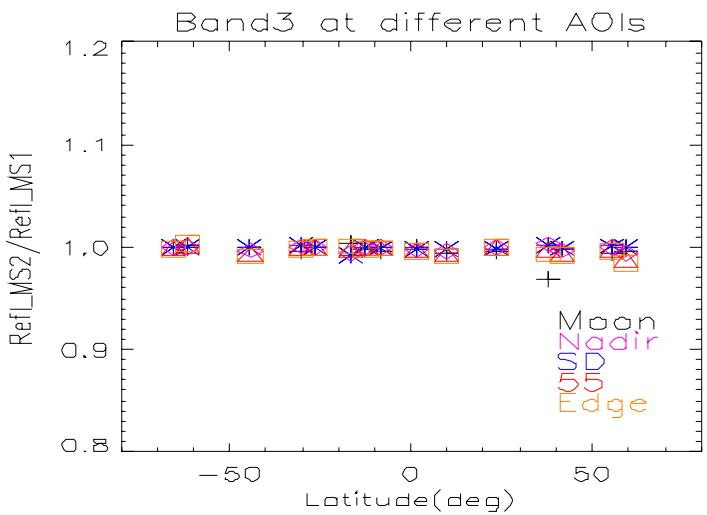
Aqua MODIS band 8 reflectance MS difference at three AOI over Libyan desert

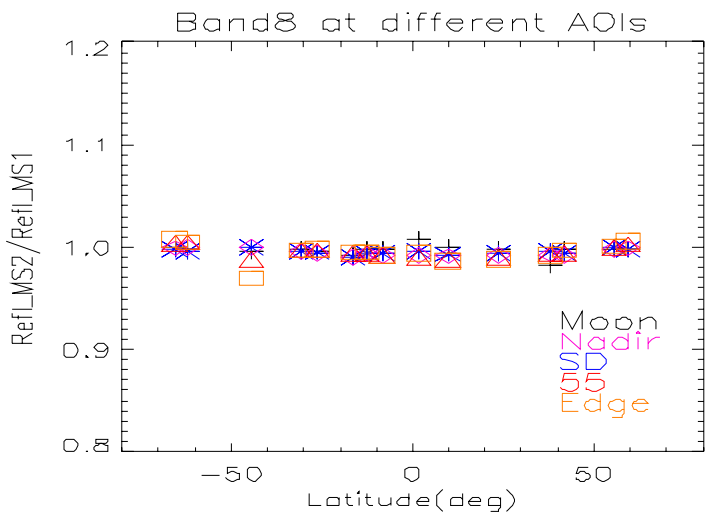


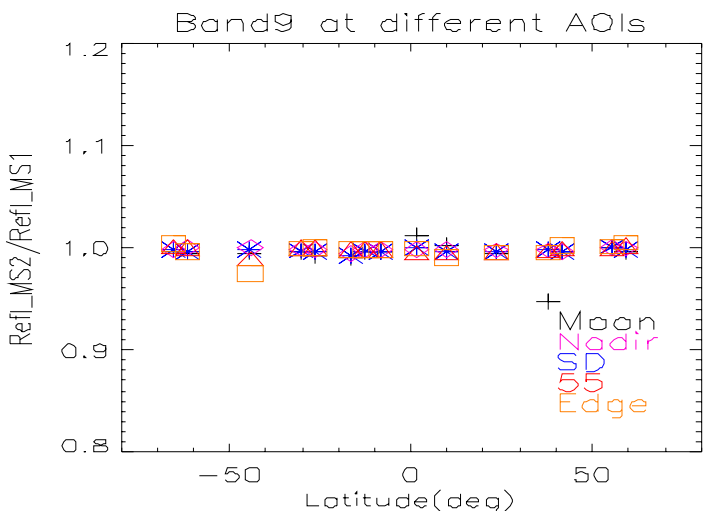
No variations/oscillations at all AOIs

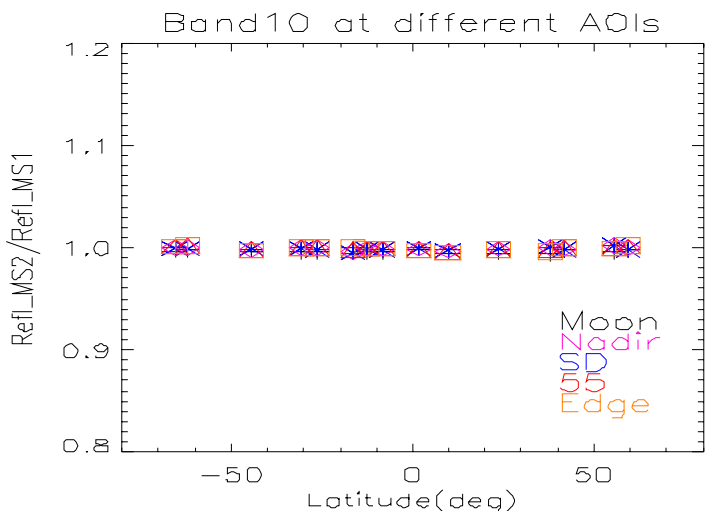
Mirror Side Difference

Terra MODIS VIS bands 3, 8, 9, 10 reflectance MS differences at different AOIs as a function of latitude (2-orbit data on 2001244)









Mirror Side Difference

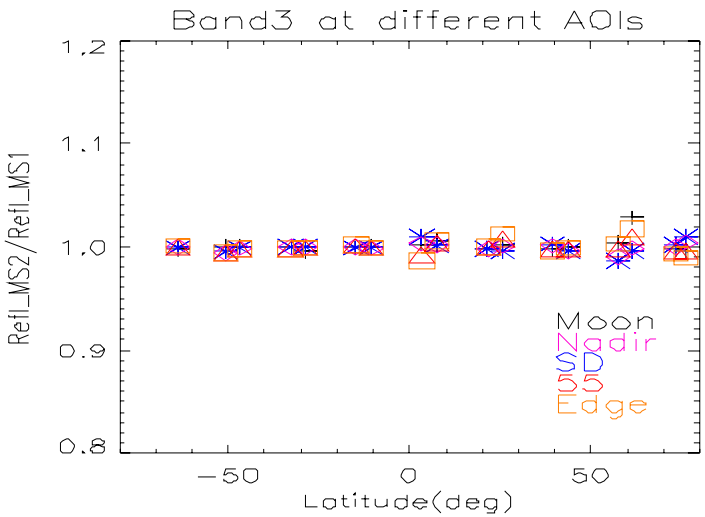
Terra MODIS VIS bands 3, 8, 9, 10 reflectance MS differences at different AOIs as a function of latitude (2-orbit data on 2003244)

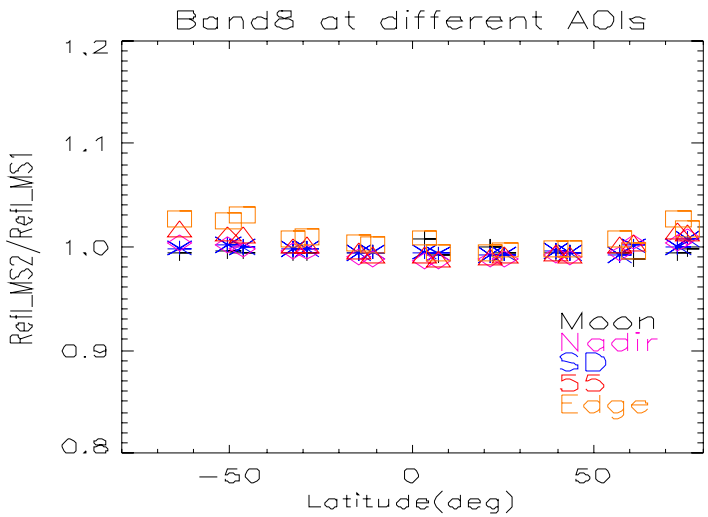
Band 8 412nm

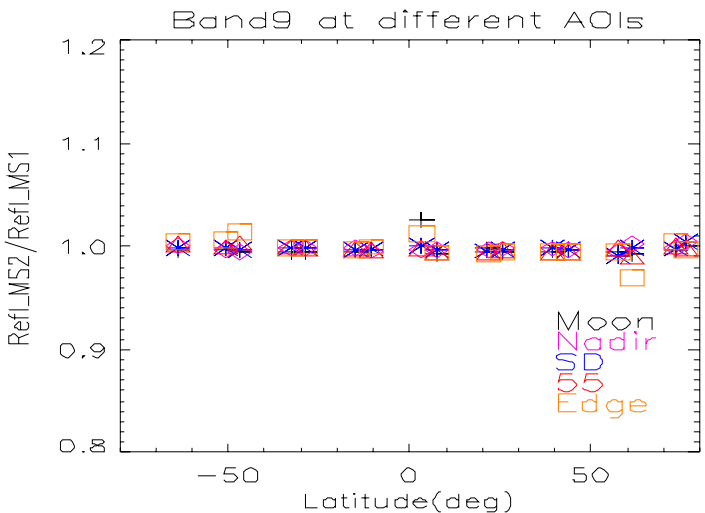
Band 9 443nm

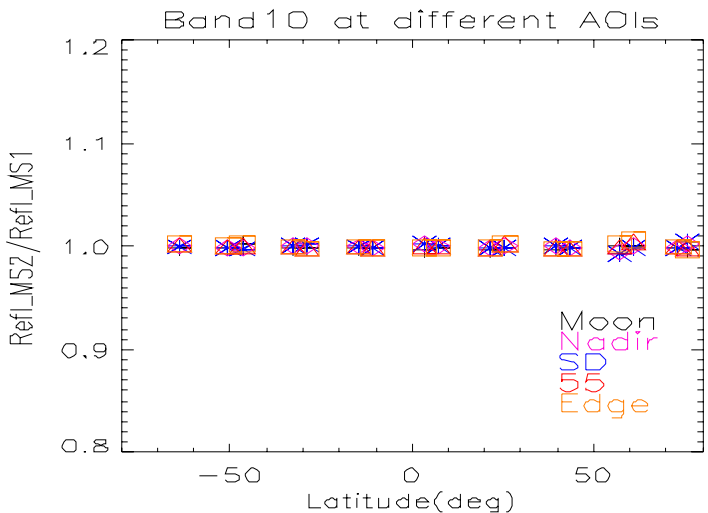
Band 3 469nm

Band 10 488nm



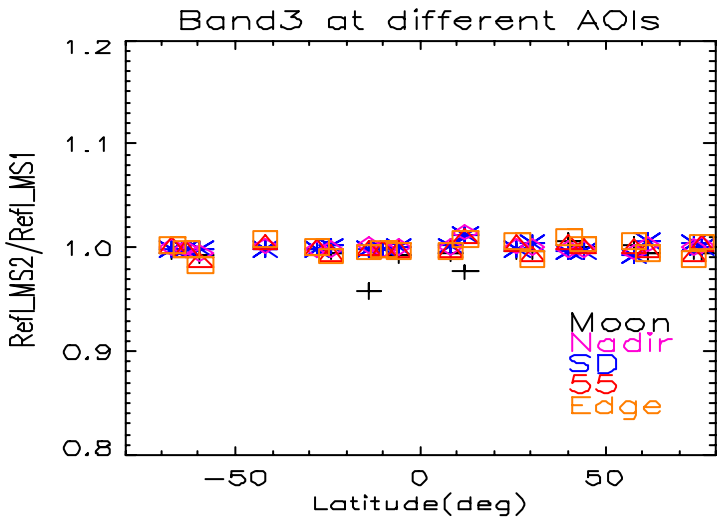


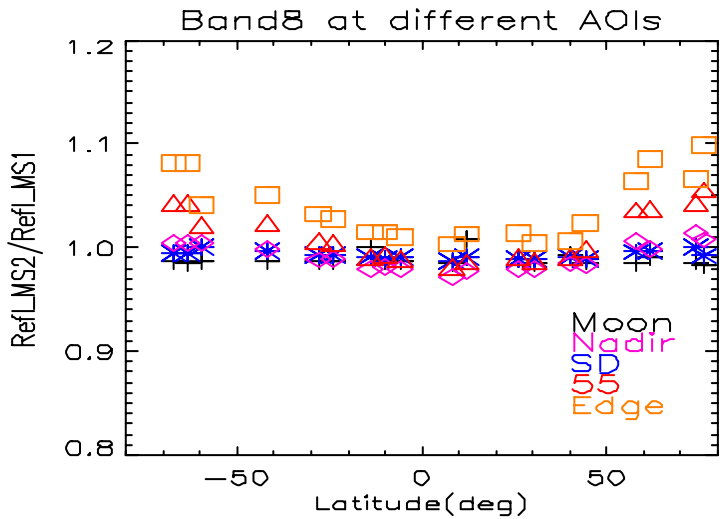


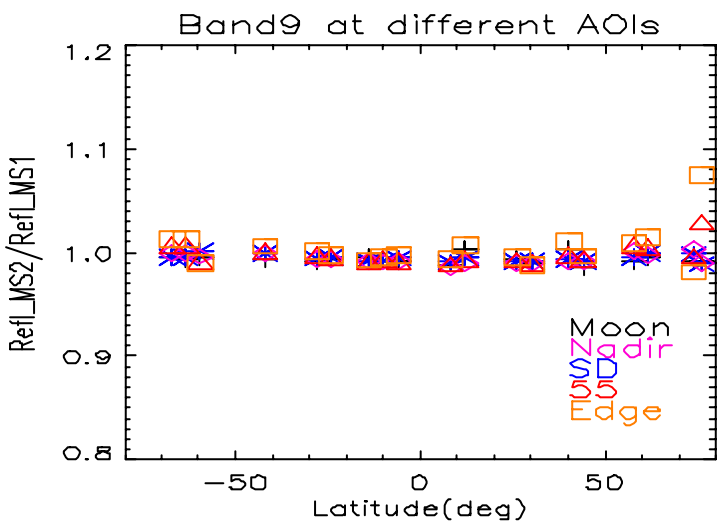


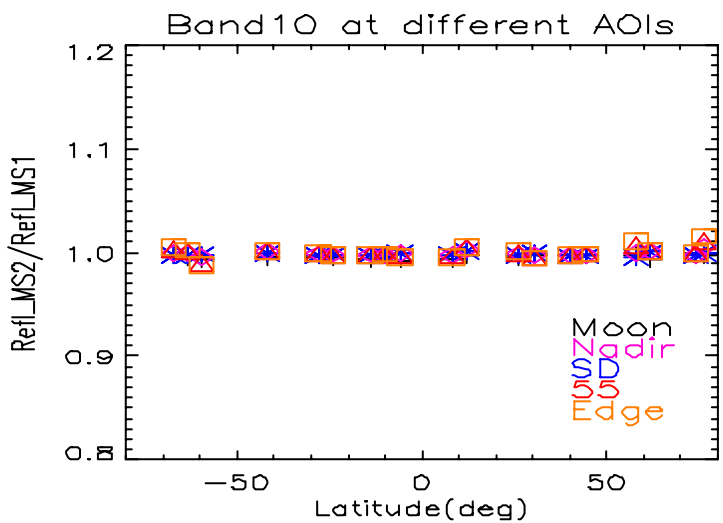
Mirror Side Difference

Terra MODIS VIS bands 3, 8, 9, 10 reflectance MS differences at different AOIs as a function of latitude (2-orbit data on 2005244)



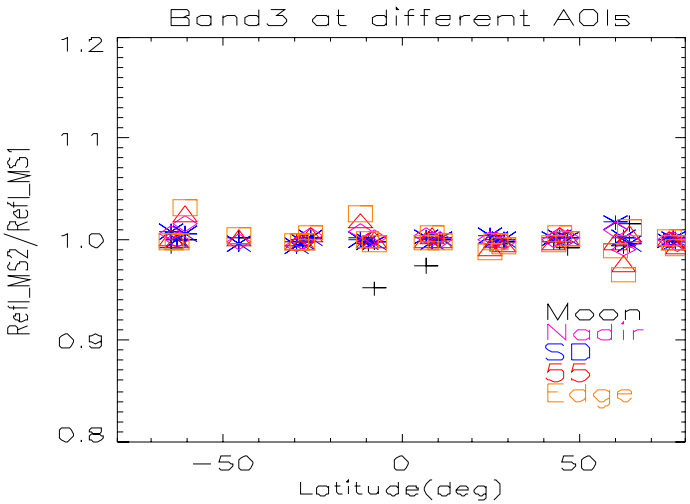


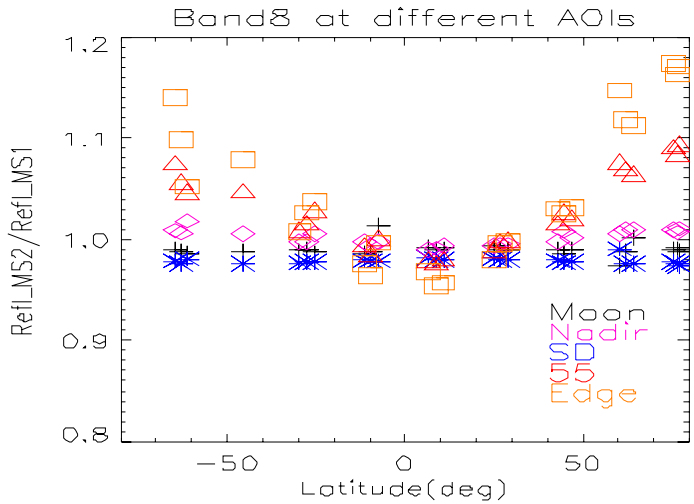


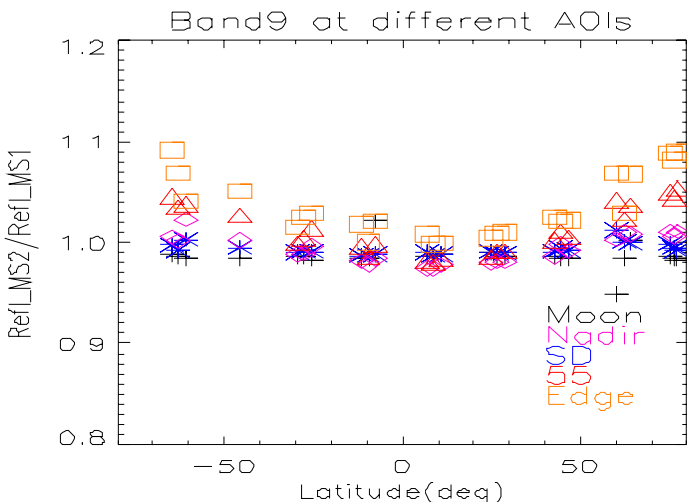


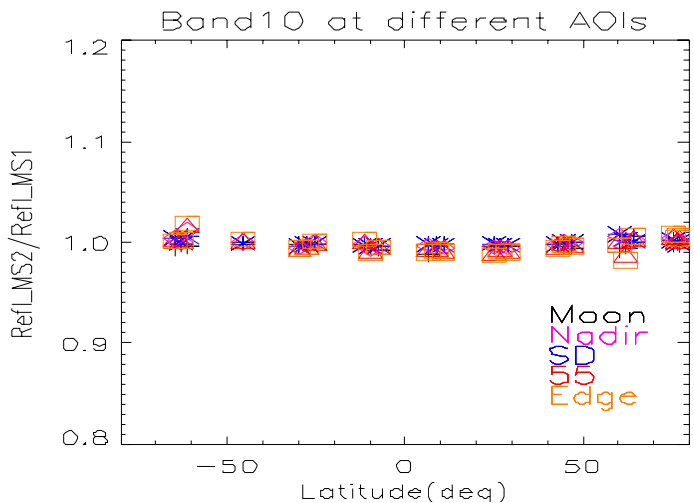
Mirror Side Difference

Terra MODIS VIS bands 3, 8, 9, 10 reflectance MS differences at different AOIs as a function of latitude (2-orbit data on 2007244)



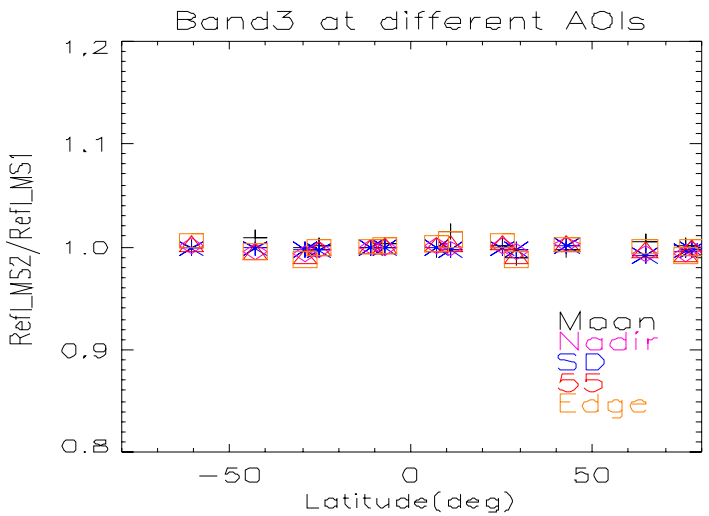


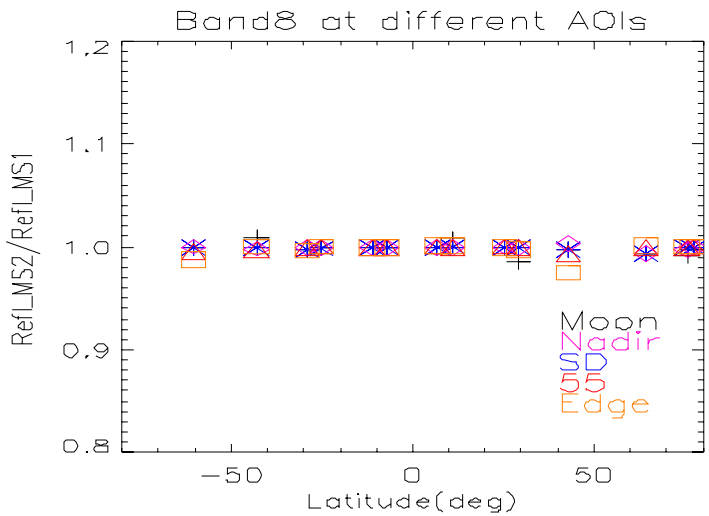


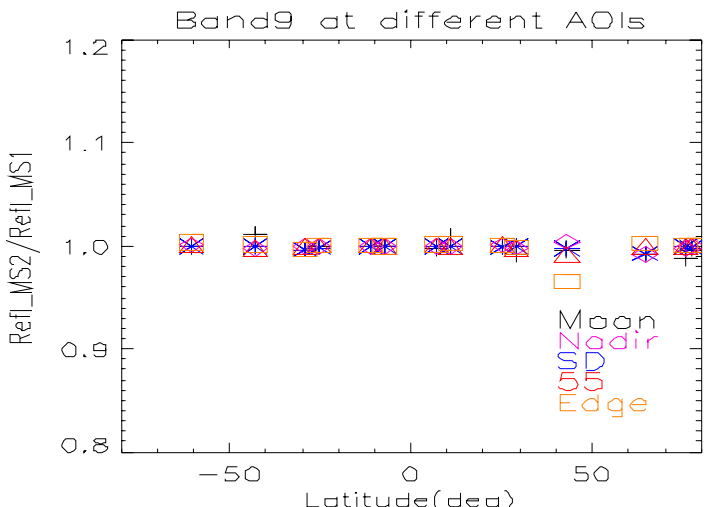


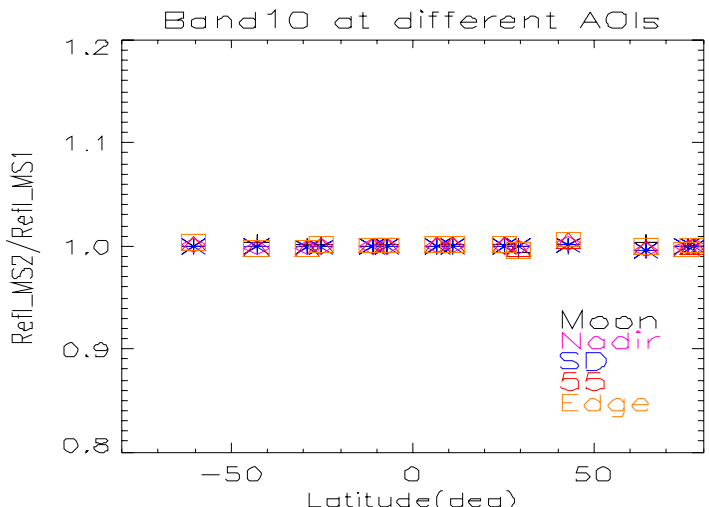
Mirror Side Difference

Aqua MODIS VIS bands 3, 8, 9, 10 reflectance MS differences at different AOIs as a function of latitude (2-orbit data on 2003244)



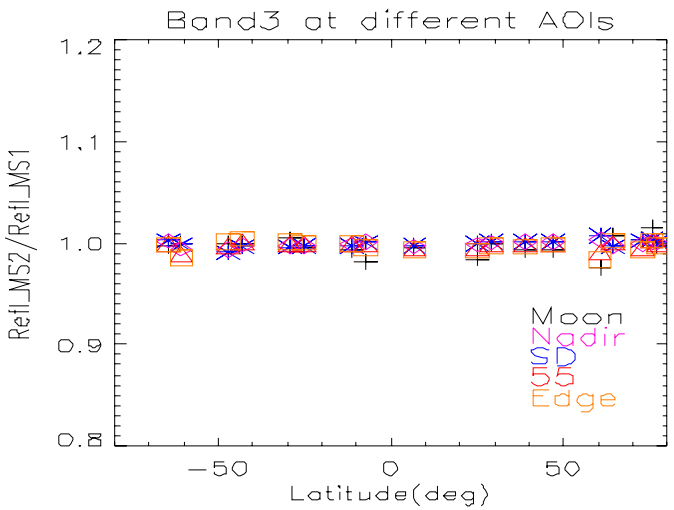


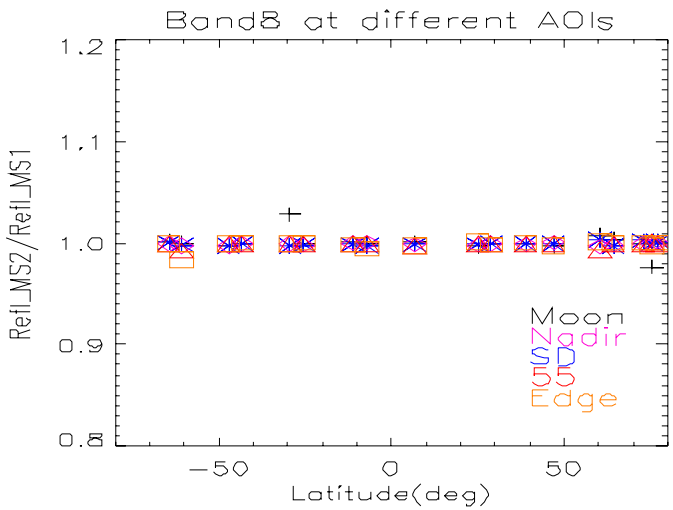


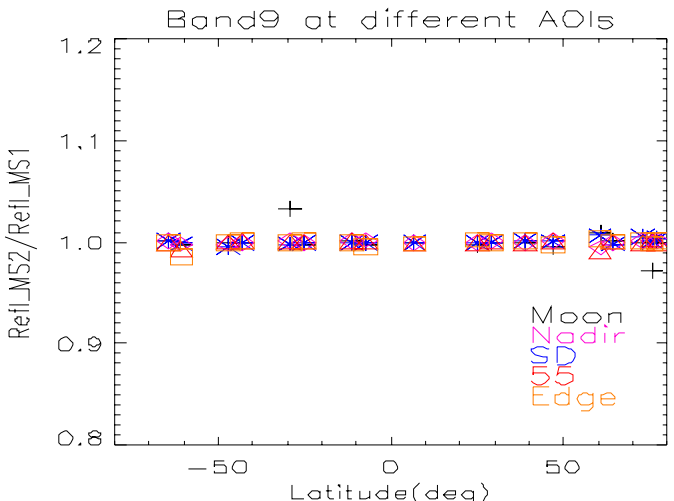


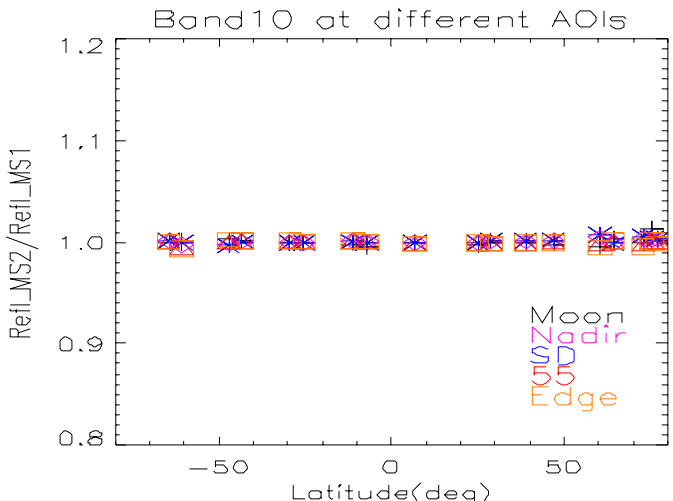
Mirror Side Difference

Aqua MODIS VIS bands 3, 8, 9, 10 reflectance MS differences at different AOIs as a function of latitude (2-orbit data on 2005244)



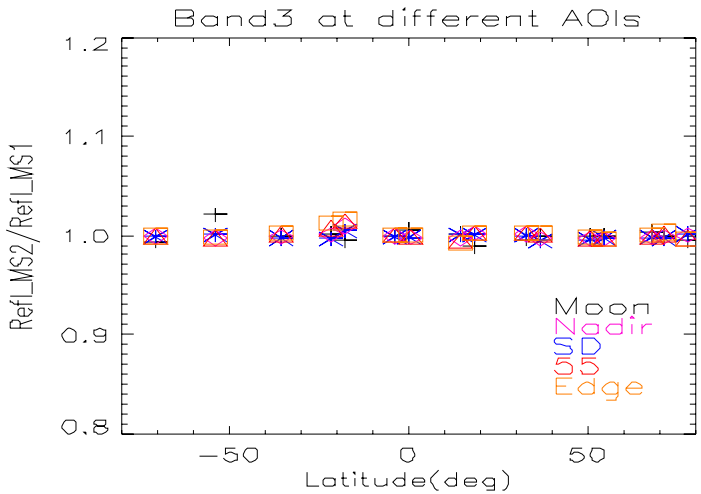


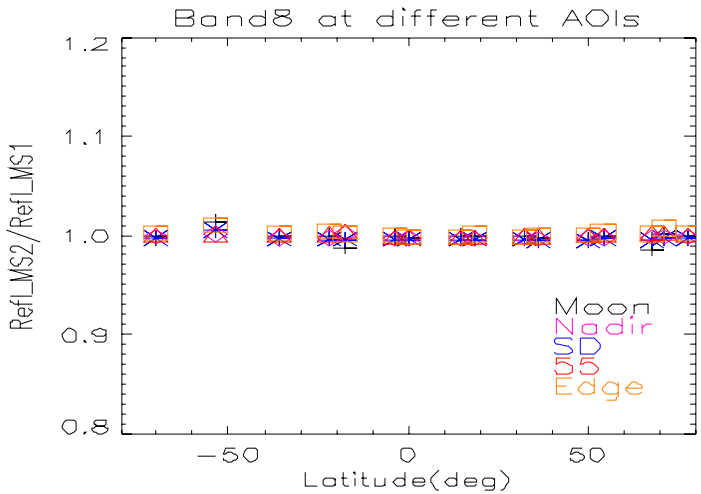


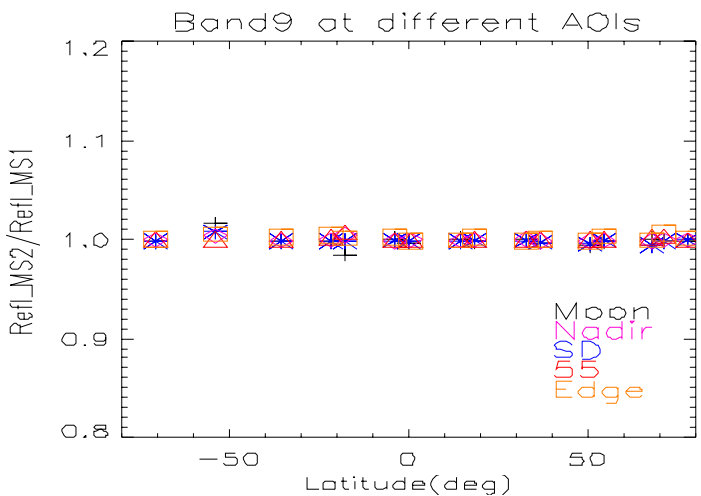


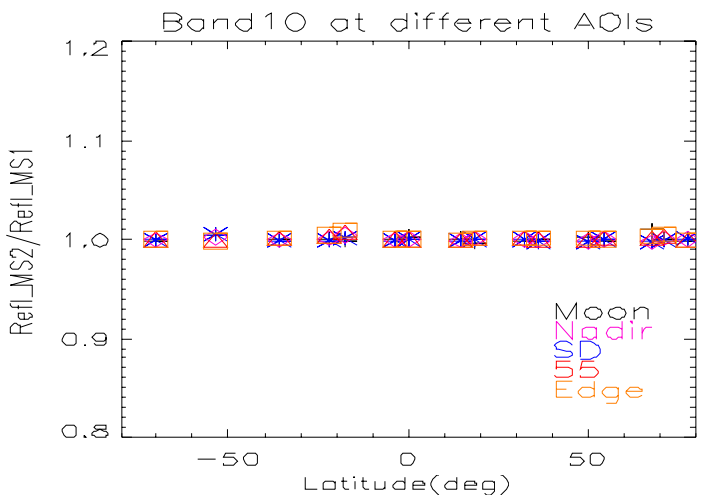
Mirror Side Difference

Aqua MODIS VIS bands 3, 8, 9, 10 reflectance MS differences at different AOIs as a function of latitude (2-orbit data on 2007244)

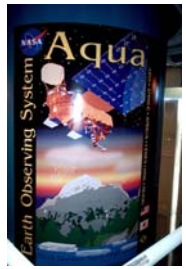








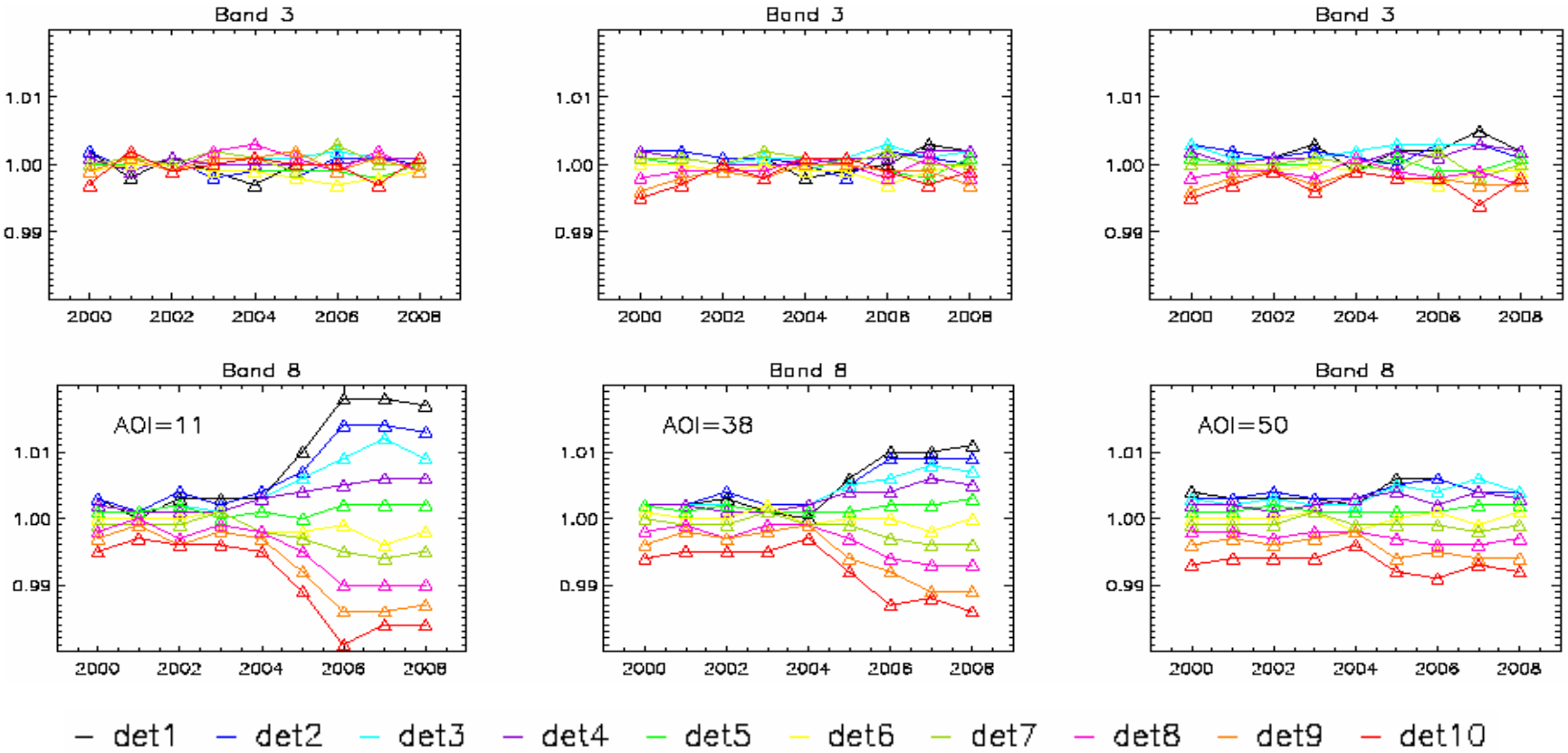
Mirror Side Difference



- An increase of MS difference seen in Terra MODIS bands 8 and 9 (started from 2003) – Noticeable in L1B reflectance / radiance products (images)
  - MS difference increases with time (with a seasonal oscillation)
  - MS difference varies with angle of incidence (AOI) – worse at large AOI
  - MS difference varies with latitude (solar zenith angles) – worse at polar regions (challenge on how relative RVS should be derived)
  - Impact on polarization parameters
    - Corrections for science data products are needed
- **No mirror side difference thus far in Aqua MODIS**

Detector-to-detector Difference

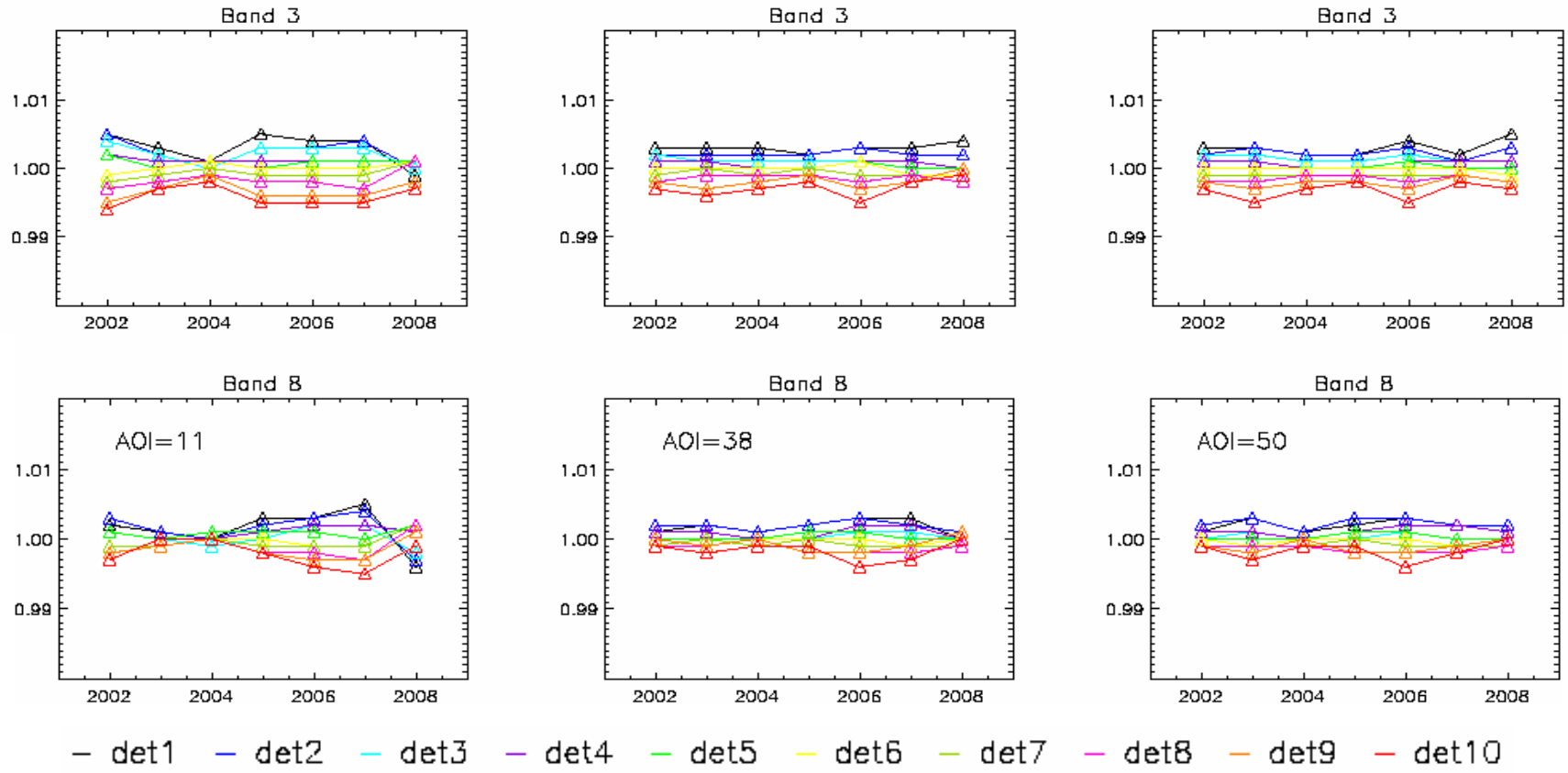
Terra MODIS VIS bands 3 and 8 D2D differences at different AOIs as a function of time (uniform desert site; cloud pixels removed)



Current MODIS calibration is performed at SD for each detector with a band averaged RVS applied

Detector-to-detector Difference

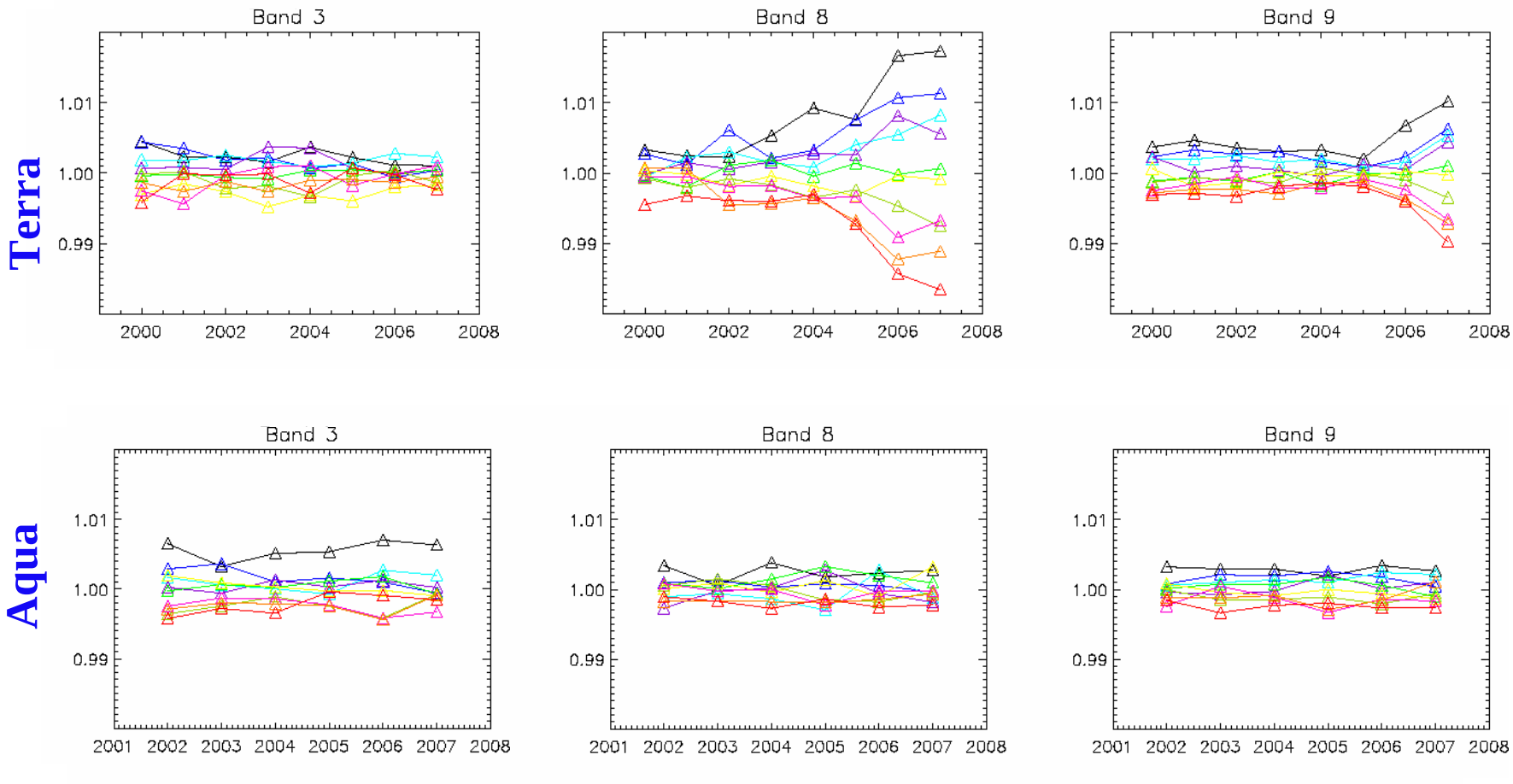
Aqua MODIS VIS bands 3 and 8 D2D differences at different AOIs as a function of time (uniform desert site; cloud pixels removed)



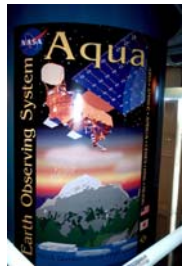
No changes for Aqua MODIS

Detector-to-detector Difference

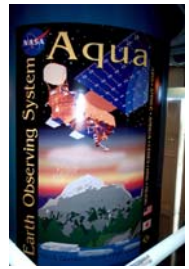
Terra and Aqua MODIS VIS bands 3, 8, and 9 D2D differences at SV (lunar view) AOI as a function of time (derived from lunar observations)



Detector-to-detector Difference



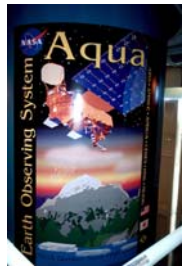
- Changes of D2D difference started from 2004-2005 for Terra MODIS bands 8-9 (related to mirror degradation)
  - D2D difference varies with time (more severe for MS 2 due to its large degradation)
  - D2D difference varies with angle of incidence (AOI)
  - **Impact on RVS correction strategy; need detector-dependent RVS (a collection 6 topic)**
- **No obvious changes of D2D difference in Aqua MODIS**



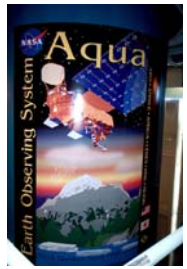
Other Challenging Issues

- SD degradation
  - VIS band signals have dropped significantly in SD observations (SD degradation plus mirror degradation)
  - Detector non-linearity may also impact calibration quality
  - SD degradation uniformity (only verified at beginning of Terra mission)
- Noisy Detectors
  - Terra LWIR PV bands
- RSB RVS Determination
  - Extremely challenging for Terra VIS bands (8 and 9 in particular) due to large mirror degradation and changes of mirror polarization
  - For NIR bands 13-16 (saturate during lunar observations)
- Improvement of band 21 calibration
- Calibration consistency (Terra versus Aqua, MODIS versus other sensors)
- MSCN impact on Terra PC bands 33-36
  - No operational configuration changed since 2003 (Terra)
  - Same operational configuration used for Aqua MODIS

Science Presentations



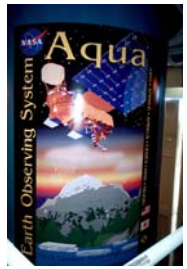
Separate Packages from Presenters (available online after workshop)



Summary

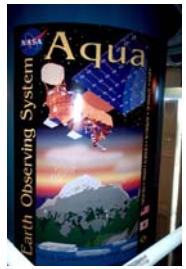
- Terra (8 years) and Aqua (~ 6 years)
  - Both Terra and Aqua MODIS have performed well and are stable
  - On-board calibrators on each sensor function well
- Overall performance of Aqua MODIS is better than Terra MODIS
  - Except for the B6 and BBR problems identified pre-launch
- Large optics (SD and scan mirror) degradation identified and corrections applied
  - Major concerns on Terra scan mirror reflectance change and impact on RVS and polarization
- Continuous effort must be made to maintain instrument calibration and data quality
  - MCST effort is critical
  - Input and support from science groups (representatives), instrument vendor (SBRS), and other expertise are key to success
- Lessons for and support to future missions

Future Work for Collection 6



- Overall RVS improvement
- Detector dependent RSB RVS
- RVS for NIR bands 13-16 (work started with OBPG for quality assessment)
- B21 calibration Improvements
- Noisy detector (sub-sample) QA flag impact on science data products
- a0/a2 update (due to potential change of update strategy)
- Band 2 (Terra) detector's sub-frame Xtalk correction (exist in 2 of 40 detectors)
- SWIR correction coefficients (update)
- Some code changes to improve data QA (e.g. DN=0 check) and to prepare for missing calibration telemetry (e.g. if any of the BB thermistor fails)
- Update on-orbit calibration uncertainty

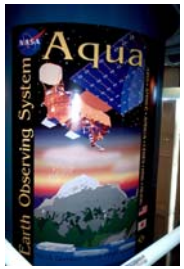
Backup Materials



MODIS Instrument Operations

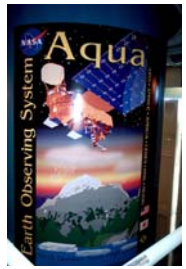
January 2006 – January 2008

Roy.Y.Yi@gsfc.nasa.gov



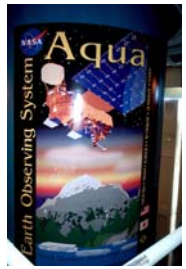
MODIS Operations PFM Highlights

- 4th Spacecraft Solid State Recorder Anomaly
  - August 26, 2005: PWA in the MODIS buffer fails. MODIS loses 2 supersets. Now at 32 supersets.
  - No new events in 2006
    - No change in SSR configuration
    - Current SSR configuration considered “limit” of no loss operations with current TDRSS scheduling
    - Current plan is “wait and see” – FOT ready to perform an SSR recycle if another PWA is lost, NASA HQ has been briefed



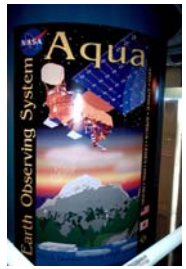
MODIS Operations PFM Highlights

- NAD/SVD door close incident
  - August 22, 2006 (DOY 234) at 16:37, the NAD and SVD were commanded closed by an ATC activity/IOT error.
  - SMIR and LWIR temps increase to 101.2K.
  - August 22, 2006 at 19:13, SVD commanded OPEN.
  - August 22, 2006 at 19:15, NAD commanded OPEN.
  - August 23, 2006 at approx. 19:20, SMIR and LWIR temps back to normal (83K).
  - NAD Open Switch working again
    - Switch stuck on last NAD movement – December 24, 2003



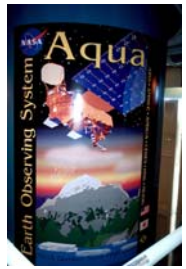
MODIS Operations PFM Highlights

- SRCA Lamp #2 Degradation/Failure
  - Some degrading of SRCA lamp #2 was seen by MCST
  - November 22, 2004: SRCA lamp #2 shuts itself off during an extended SRCA calibration.
- SRCA Lamp #3 Degradation
  - Some degrading of SRCA lamp #3 was seen by MCST
  - February 18, 2006: 10W radiometric tests of 10W lamps #3 and #4 are performed. Lamp #3 is verified to be abnormal. It is taken out of service.
  - Tests since then run in Constant Current mode to lessen load on remaining 10W lamps #1 and #4.



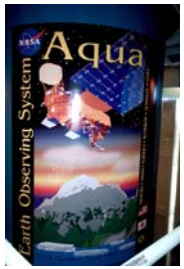
MODIS Operations PFM Highlights

- SRCA Radiometric and Spatial Redesign
  - Small command counts = easy fix
  - CP Macros 15 (Rad.) and 23 (Spat.) replaced by stored commands
  - Both executed multiple times this year
- SRCA Spectral Redesign
  - Reduction to 20W max SRCA lamp configuration required redesign of 30W CP Macros 18 and 19 in ROM
  - Large command counts and precise timing constraints required used of internal MODIS Macro
  - Macros 18 and 19 redesigned and uploaded to Macro 31 in RAM
  - First executed September 28, 2006 (DOY 2006/270)



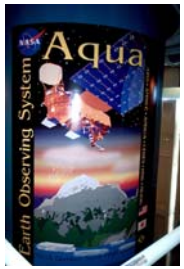
MODIS Operations
PFM SRCA Calibrations

- 258 SRCA Calibrations
  - Including: 36 Full Spectral, 51 Full Spatial, 94 Full Radiometric
  - Including: 1 one watt continuous Radiometric
- Lamp Usage in hours: total (on orbit)
  - 10W Lamps, 500hr life: 1) 268.5 (133.8) 2) 172.1 (53.0) 3) 190.3 (62.0) 4) 87.3 (25.6)
  - 1W Lamps, 4000hr life: 1) 572.9 (29.7) 2) 282.0 (5.6)



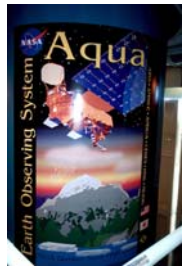
MODIS Operations
PFM SD/SDSM Calibrations

- 556 SD/SDSM Calibrations
  - 183 SD Door Open, 337 SD Door Screened
  - 2146 (1213 on orbit) of 3022 Solar Diffuser Door Movements
  - Note: As of July 2, 2003, the SD Door will remain Open, the SD Screen will remain Screened. No additional door movements are planned.



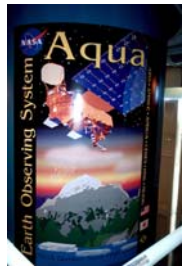
MODIS Operations
PFM Other Doors/Calibrations

- Nadir Door Operations
  - 540 (11 on orbit) of 1316 Nadir Door Movements
- Space View Door Operations
  - 443 (10 on orbit) of 1316 Space View Door Movements
- 62 Blackbody Calibrations (warm/cool cycle)
- 54 Electronics Calibrations
- 78 Lunar Calibrations
- 33 Yaw Maneuver SD/SDSM Calibrations



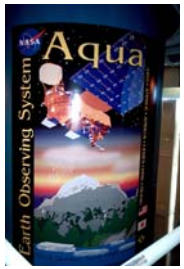
MODIS Operations
FM1 Highlights

- SRCA Lamp #2 Degradation
  - Some degrading of SRCA lamp #2 was seen by MCST
  - As of April 14, 2003: SRCA lamp #2 is no longer being used during SRCA calibrations. Lamp #4 is being used in it's place.
- SRCA Lamp #3 Failure
  - May 17, 2005: During 20W portion of SRCA Full Spatial calibration, SRCA lamps shutdown, SRCA continues to run until normal shutdown.
  - June 28, 2005: Lamps are tested and 10W lamp #3 does not turn on. All other lamps operate nominally.
  - Tests since then run in Constant Current mode to lessen load on remaining 10W lamps #1 and #4.



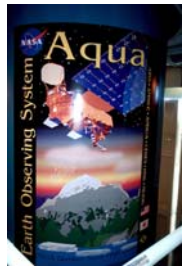
MODIS Operations FM1 Highlights

- SRCA Radiometric and Spatial Redesign
  - Small command counts = easy fix
  - CP Macros 15 (Rad.) and 23 (Spat.) replaced by stored commands
  - Both executed multiple times this year
- SRCA Spectral Redesign
  - Reduction to 20W max SRCA lamp configuration required redesign of 30W CP Macros 18 and 19 in ROM
  - Large command counts and precise timing constraints required used of internal MODIS Macro
  - Macros 18 and 19 redesigned and uploaded to Macro 31 in RAM
  - First executed April 27, 2006 (DOY 2006/117)



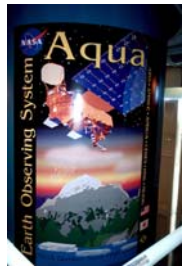
MODIS Operations
FM1 SRCA Calibrations

- 127 SRCA Calibrations
  - Including: 16 Full Spectral, 28 Full Spatial, 50 Full Radiometric
- Lamp Usage in hours: total (on orbit)
  - 10W Lamps, 500hr life: 1) 260.4 (60.2) 2) 188.0 (12.3)
    3) 205.7 (27.2) 4) 89.6 (31.9)
  - 1W Lamps, 5000hr life: 1) 513.5 (14) 2) 274.9 (5.1)



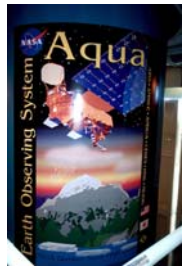
MODIS Operations
FM1 SD/SDSM Calibrations

- 357 SD/SDSM Calibrations
  - 176 SD Door Open, 181 SD Door Screened
  - 2692 (1062 on orbit) of 3022 Solar Diffuser Door Movements



MODIS Operations
FM1 Other Doors / Calibrations

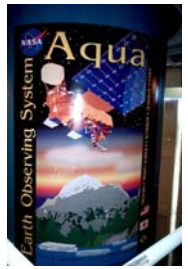
- Nadir Door Operations
  - 1053 (7 on orbit) of 1316 Nadir Door Movements
- Space View Door Operations
  - 632 (8 on orbit) of 1316 Space View Door Movements
- 23 Blackbody Calibrations
- 34 Electronics Calibrations
- 45 Lunar Calibrations
- 29 Yaw Maneuver SD/SDSM Calibrations



Summary of Instrument Status

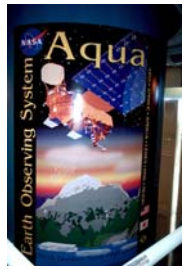
- Both instruments have operated normally since launch in Dec. 1999 and May 2002
- All on-board calibrators function well
  - Terra SD door fixed at open (July 2003)
  - SRCA 30W configuration removed (2005 for Aqua MODIS, 2006 for Terra MODIS); No impact on radiometric calibration
- Instrument and FPA temperatures remain stable
- Aqua MODIS overall performance better than Terra MODIS
  - Aqua MODIS: B6 inoperable detectors and BBR problems - known since pre-launch
  - Terra MODIS: noisy detectors in LWIR PV bands, SD and scan mirror optics degradation for VIS bands (8, 9) has significantly impacted the calibration quality

Production Changes to MOD_PR02 TERRA L1B Code



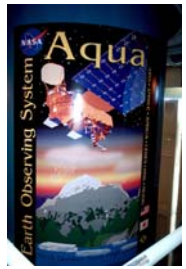
PGE02 Version	Forward Processing Begin	Code Changes
V2.3.2_Terra	3/17/2000 (077 2000) 00:00	• Pre-Launch calibration (SMWIR ltwk/Vdet = 79/190).
V2.4.2_Terra	6/19/2000 (171 2000) 00:00	• Corrected indexing bug affecting emissive bands (this appeared in the product as if something was wrong with RVS). • Corrected bug for determine when the moon is in the SVP (sign error) • Maximum number of scans raised to 208 (consistent with L1A code)
V2.4.3_Terra	8/18/2000 (231 2000) 14:00	• Corrected bug in emissive bands preprocessing for PC bands X-talk. • Interpolation of scaled integers for non-functional (dead) detectors. • Time-dependent LUTs architecture.
V2.4.4_Terra	10/13/2000 (287 2000) 19:55	• New emissive band algorithm to compute <DNsv> with moon in SVP. • Corrected bug in emissive bands preprocessing for the 40 scans preceding or following a sector rotation or Ecal. • Corrected indexing bug in SWIR OOB correction (switch remained OFF). • Several other bug fixes affecting metadata.
V2.5.4_Terra	11/23/2000 (328 2000) 15:55	• Aqua compatible code and metadata • Removed obsolete metadata • New SWIR OOB algorithm & LUTs (for B-side only)
V2.5.5_Terra	02/13/2001 (044 2001) 13:55	• Mis-registration of aggregated images corrected. • Detector average of Esun used for computation of band-dependent radiance_scales.

Production Changes to MOD_PR02 TERRA L1B Code (continued)



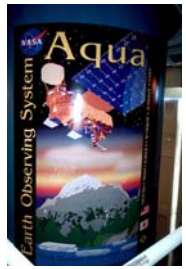
PGE02 Version	Forward Processing Begin	Code Changes
V3.0.0_Terra	05/24/2001 (144 2001) 00:00	• Piecewise linear LUT capability added. • Reflective solar bands (RSBs) now check Space View subtracted values for saturation against lookup table. • For SWIR bands, when the moon is in the Space view port, method of computing average background DN same as that used for emissive bands.
V3.0.1_Terra	2/25/2002 (056 2002) 00:00	• Production of 250m and 500m resolution night data may be turned off. • Various code upgrades/bug fixes.
V4.1.2_Terra*	01/30/2003 (030 2003) 01:55	• Band 26 Correction using aggregated Band 5 radiances inserted; turned ON • RVS correction changed to piecewise linear. • New flag TEB_B1_NOT_CALCULATED added. • Various code upgrades/bug fixes. • Metadata field "ProcessingEnvinronment" is filled in from a call to "uname" from within the L1B code • R* LUT deleted • New OBC MCF files • RSB cal. coefficients reworked in LUTs
V4.2.0_Terra	08/22/2003 (234 2003) 02:00	• SWIR out-of-band correction “sending” band changed to value determined by LUT • Earth-Sun distance calculation corrected • NAD open/closed determination changed • Nominal platform height corrected • Improved ANSI-C compliance

Production Changes to MOD_PR02 TERRA L1B Code (continued)



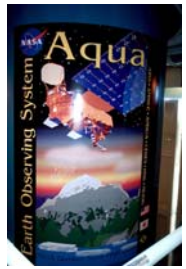
PGE02 Version	Forward Processing Begin	Code Changes
V4.3.0_Terra	12/22/2003 (356 2003) 22:35	• Maneuver flag changed to key on spacecraft attitude
V5.0.6_Terra	03/07/2005 (066 2005) 23:55	• Add a new LUT to enable the SWIR OOB correction detector dependency • Enable Band 21 calibration with mirror side dependency • Improve the code portability • Comply with the ESDIS guideline • Add HDFEOS_FractionalOffset • Minor fix for code version recording • Correct wrong dimension mapping offset setting for 250m band data
V5.0.38_Terra	9/17/2007 (260 2007) 19:35	• Relax the RVS correction limit range from [0.8, 1.2] to [0.4, 2.4].
V5.0.40_Terra	TBD	• Changed to set the PGEVersion ECS inventory metadata based upon the MODAPS PGE Version, rather then the obsolete GDAAC PGE Version. • Removed the ScanType of "Mixed" from the code. • Changed for ANSI-C compliance and comments correction.

Production Changes to MOD_PR02 TERRA L1B LUTs



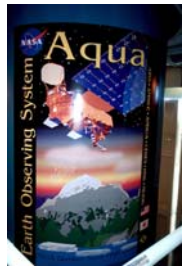
PGE02 Version	LUT Patch Version	LUT Changes
V2.3.2_Terra	3	• Emissive bands calibration and uncertainty LUTs • Reflective bands calibration and uncertainty LUTs • Uncertainty index scaling factors • Detector quality flag • "St. Patrick's Day Update" • LUTs derived from on-orbit data. SMWIR Itwk/Vdet = 110/226.
V2.4.2_Terra	0	• Scientifically same as LUTs v2.3.2.3
V2.4.3_Terra	1	• PC bands X-talk LUTs (from day 084 moon observation) • Emissive bands calibration LUTs (from day 102 BB cool-down observation) • RVS (for mirror side 2 only, from day 118 observation of NAD closed) • L_max for bands 31 and 32 increased • Reflective bands calibration LUTs (from day 171 solar diffuser observation) • SWIR OOB leak correction turned OFF • Detector quality flag – some detectors flagged as dead

Production Changes to MOD_PR02 TERRA L1B LUTs (continued)



PGE02 Version	LUT Patch Version	LUT Changes
V2.4.4_Terra	0, 1, 2	• Switch to B-side. Final values for SMWIR Itwk/Vdet = 79/110 • First implementation of time-dependent LUTs (A-side/B-side) • A-side calibration LUTs remained the same as before. • B-side emissive bands calibration LUTs (from day 305/306 BB observations) • Some B-side emissive bands uncertainty coefficient LUTs • L_max for several bands increased (both A and B side) • B-side reflective bands calibration LUTs (from day 305 solar diffuser observation) • B-side reflective bands uncertainty coefficient LUTs • Detector quality flag – all B-side detectors are functional. • B-side only: SWIR OOB correction switch turned ON and new SWIR LUTs (aimed at improving the first sub-sample of 500m bands)
V2.5.4_Terra	0	• New SWIR OOB LUTs (for B-side only)
V2.5.5_Terra	1, 2	• Added Reflective LUT "E_sun_over_pi"; deleted Emissive LUT "Number of overlap scans for temperatures" (No science content affected). • 2 detectors marked as non-functioning as of day 2001/019. • Time dependent LUT table pieces added to cover day 2000/063.

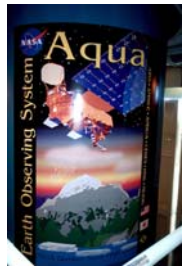
Production Changes to MOD_PR02 TERRA L1B LUTs (continued)



PGE02 Version	LUT Patch Version	LUT Changes
V3.0.0_Terra	1 (Superseded) , 2, 3, 4, 5 (For reprocess only), 6, 7	• RSB LUT update for Band 5 gain change (day 212/2001): • Time stamped table pieces added to RSB calibration tables. • Update for SWIR OOB correction on "A" side (after day 183/2001): • SWIR OOB correction switch turned ON. • New SWIR OOB correction table piece added. • RSB calibration table pieces reworked for SWIR OOB correction. • Update to Detector Quality Flags after return to "A" side electronics: • Detector quality flags QA table: Out-of-family gain flag set for 2 detectors; noisy detector flag set for one detector as of day 183 2001.
V3.0.1_Terra	0, 1	• Slope of fit for Band 3 calibration coefficients adjusted.
V4.1.2_Terra *	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	• New RSB LUT calibration coefficients • Pre-launch SWIR corr. switch “OFF” • R* LUT deleted • RSB cal. coefficients reworked in LUTs • Detector quality flags QA table: noisy detector flag set for one detector as of day 183 2001 and for another detector as of day 086 2003. • Continuous Reflective Calibration Coefficient updates

* For V4.0.7_Terra, LUT V0 delivered but not used and LUT V1 used for reprocessing only;
For V4.0.9_Terra, LUT V0 used for reprocessing only.

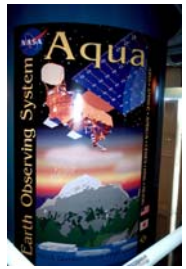
Production Changes to MOD_PR02 TERRA L1B LUTs (continued)



PGE02 Version	LUT Patch Version	LUT Changes
V4.2.0_Terra	3, 4, 5, 6, 7, 8, 9	• SWIR out-of-band correction "sending" band changed to value determined by LUT • Name change for the three LUTs related to the Band 5 to Band 26 correction • Continuous Reflective Calibration Coefficient updates •
V4.3.0_Terra	1,2,3,4,5,6,7,8,9,11*,12, 13,14,15,16,17,18,19, 20,21,22, 23,24,25, 26, 27,28,29,30,31,32,33, 34,35,36,37,38,39,40, 41,42,43,44,45,46,47, 48,49,50,51,52,53,54, 55,56,57	• LUTs updated from V4.2.0.8 • Attitude limit LUTs added for maneuver flagging as of Version 1 • Updates on the coefficients for calculating a0 and a2, and on the value of b1 for each Band 21 detectors, derived using the BB warm-up data set. • Updates on RVS_TEB to reflect the update obtained from the deep space maneuvers on March 26, 2003. • Detector quality flags QA table: "Out-of-family-gain" flag was set for B28/D10 as of 2004118; "Noisy" flags were set for B28/D10 as of 2004118, for B28/D1 as of 2004175, for B29/D6 as of 2005130, for B28/D9 as of 2005309, for B27/D8 as of 2006053, and for B30/D3 as of 2006115; "Dead" flag was set for B29/D6 as of 2006241. • Updated the SWIR bands correction coefficient. • Continuous Reflective Calibration Coefficient updates (m1, Sigma_m1, RVS_RefSB)

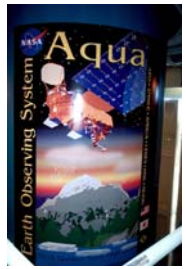
*LUT V4.3.0.10 is a special version for U. of Wisconsin only (not shown here).

Production Changes to MOD_PR02 TERRA L1B LUTs (continued)

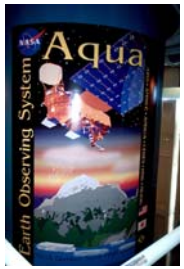


PGE02 Version	LUT Patch Version	LUT Changes
V5.0.6_Terra	1, 2, 3, 4, 5, 6, 7, 8, 9, 10,11,12,13,14,15,16, 17,18,19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34	• Updates of the coefficients for calculating a0 and a2, and of the value of b1 for each Band 21 detectors using the newly developed TEB RVS from Deep Space Maneuver. A new dimension of Mirror Side is added to the band_21_b1 LUT to separate the coefficients of the two mirror sides for Band 21. • Added a new LUT to enable the ability to determine the SWIR out-of-band correction "sending" detectors from the "sending" band. • Detector quality flags QA table: newly revised flags cover the entire time period since the launch. • Updated dn_sat_ev values for presaturating bands. Those which do not exhibit any presaturation are set to 4095 to remove any dn_sat_ev cutoff to make more valid data available. • Updated the SWIR bands correction coefficient. • Detector quality flags QA table: revised flags cover the entire time period since the launch. B22/D2 was flaged as normal as of 2000304. “Noisy” flag were set for B28/D6 as of 2005130, for B28/D1 as of 2004175, for B28/D9 as of 2005309, for B27/D8 as of 2006053, and for B30/D3 as of 2006155. “Dead” flag was set for B29/D6 as of 2006241. • Continuous Reflective Calibration Coefficient updates (m1, Sigma_m1, RVS_EefSB)

Production Changes to MOD_PR02 TERRA L1B LUTs (continued)



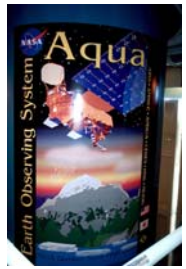
PGE02 Version	LUT Patch Version	LUT Changes
V5.0.38_Terra	1, 2, 3, 4	• Detector quality flags QA table: "Noisy" flag were set for B27/D3 as of 2007193, • Continuous Reflective Calibration Coefficient updates (m1, Sigma_m1, RVS_EefSB)
V5.0.40_Terra	0	• Copied from V5.0.38.4



Production Changes to MOD_PR02 AQUA L1B Code

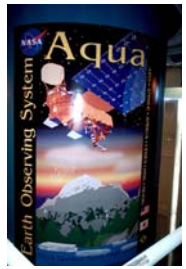
PGE02 Version	Forward Processing Begin	Code Changes
V3.1.0_Aqua	06/07/2002 (158 2002) 18:10	• Blackbody warmup saturation corr. • Aqua temp. conversion coefficients. • New flag TEB_B1_NOT_CALCULATED added.
V4.1.1_Aqua	10/31/2002 (304 2002) 00:15	• RVS corr. changed to piece-wise linear. • Various code upgrades/bug fixes.
V4.1.3_Aqua	01/22/2003 (022 2003) 09:55	No Science Changes to the Code • R* LUT deleted • New OBC MCF files
V4.2.1_Aqua	08/21/2003 (233 2003) 12:00	• SWIR out-of-band correction “sending” band changed to value determined by LUT • Destriping of Band 26 using aggregated Band 5 data added • Earth-Sun distance calc. corrected • NAD open/closed determination changed • Platform height corrected • Improved ANSI-C compliance
V4.3.1_Aqua	01/18/2004 (18 2004) 00:10	• Used for first reprocessing effort, Collection 4 • Maneuver flag changed to key on spacecraft attitude

Production Changes to MOD_PR02 AQUA L1B Code (continued)



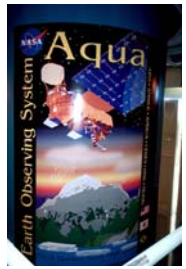
PGE02 Version	Forward Processing Begin	Code Changes
V5.0.7_Aqua	07/03/2005 (185 2005) 00:10	• Add a new LUT to enable the SWIR OOB correction detector dependency • Enable Band 21 calibration with mirror side dependency • Improve the code portability • Comply with the ESDIS guideline • Add HDFEOS_FractionalOffset • Minor fix for code version recording • Correct wrong dimension mapping offset setting for 250m band data
V5.0.35_Aqua	TBD	• Relax the RVS correction limit range from [0.8, 1.2] to [0.4, 2.4] • Changed to set the PGEVersion ECS inventory metadata based upon the MODAPS PGE Version, rather then the obsolete GDAAC PGE Version. • Removed the ScanType "Mixed" from the code because the L1A "Scan Type" is never "Mixed". • Changed for ANSI-C compliance and comments correction.

Production Changes to MOD_PR02 AQUA L1B LUTs



PGE02 Version	LUT Patch Version	LUT Changes
V3.1.0_Aqua	0, 1, 2, 3	• Pre-launch LUTs inserted. • Several LUTs updated after more Pre-launch analysis • New RSB and TEB calibration coefficient LUTs • New BB temp. saturation limits • Detector quality flags changed • SWIR correction switch ON
V4.1.1_Aqua	0,1	• LUTs updated from V3.1.0.3 • New RSB calibration coefficient LUTs using SD degradation • Band 21 b1 table piece added • Detector quality flags changed
V4.1.3_Aqua	0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	• LUTs updated from V4.1.1.1 • R* LUT deleted • Continuous Reflective Calibration Coefficient updates • Band 21, Detector 9 (product order) changed to “noisy” as of Version 3
V4.2.1_Aqua	4, 5, 6, 7, 8	• LUTs updated from V4.2.1.3, which is parallel to V4.1.3.10 • SWIR correction sending band changed to Band 28 before 2003104, Band 25 after as of Version 4 • Continuous Reflective Calibration Coefficient updates • LUTs added for Band 26 destriping using aggregated Band 5 data as of Version 4

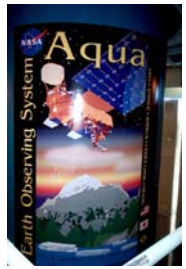
Production Changes to MOD_PR02 AQUA L1B LUTs (continued)



PGE02 Version	LUT Patch Version	LUT Changes

V4.3.1_Aqua	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36	• LUTs updated from V4.2.1.8
		• Reflective Calibration Coefficients reworked for reprocessing as of Version 1
		  • Improved SD sun angles used
		  • BRF and vignetting as a function of SD zenith and azimuth used
		  • Temperature using Kinst used
		  • Non-SWIR bands fitted with smooth function
		  • SWIR bands:
		  • Step functions before 2002255, Linear functions thereafter;
		  • SWIR correction sending band changed to Band 25 for entire mission
		• Attitude limit LUTs added for maneuver flagging as of Version 1
		• Updates on the coefficients for calculating a0 and a2, and on the value of b1 for each Band 21 detectors, derived using the BB warm-up data set.
		• dn_sat_ev has been updated to a step-function time dependent LUT.
		• Updates on coefficient for RVS computation and value of EV pixel dn to treat as saturated
		• Detector quality flags QA table: “Noisy Detector” flags were set for B27/D3 as of 2005010, and for B6/D7 as of 2006314; “Out-of-family-gain” flag was set for B18/D6 as of 2006033.
		• Updated the SWIR bands correction coefficient.
		• Continuous Reflective Calibration Coefficient updates (m1, Sigma_m1, and/or RVS_RefSB)

Production Changes to MOD_PR02 AQUA L1B LUTs (continued)



PGE02 Version	LUT Patch Version	LUT Changes
V5.0.7_Aqua	1(Superseded) , 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27	• Updates of the coefficients for calculating a0 and a2, and of the value of b1 for each Band 21 detectors. A new dimension of Mirror Side is added to the band_21_b1 LUT to separate the coefficients of the two mirror sides for Band 21. • Added a new LUT to enable the ability to determine the SWIR out-of-band correction "sending" detectors from the "sending" band. • Detector quality flags QA table: newly revised flags cover the entire time period since the launch. “Noisy” flags were set for B27/D3 as of 2005010, and for B6/D7 as of 2006314; “Out-of-family-gain” flag was set for B18/D6 as of 2006033 • Updated dn_sat_ev values for presaturating bands. Those which do not exhibit any presaturation are set to 4095 to remove any dn_sat_ev cutoff to make more valid data available. • Continuous Reflective Calibration Coefficient updates (m1, Sigma_m1, and/or RVS_RefSB)
V5.0.35_Aqua	0	• Copied from V5.0.7.27