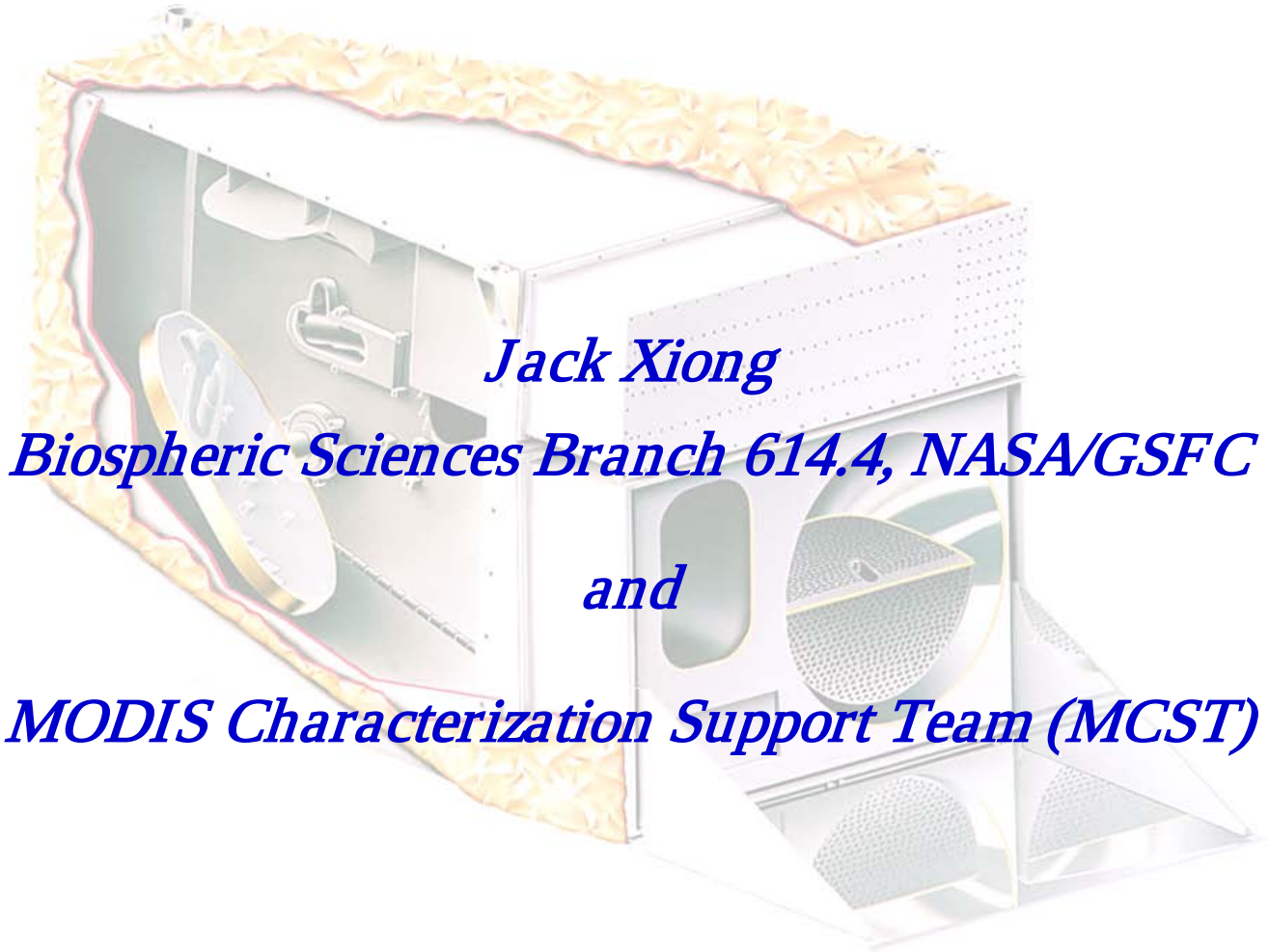
MODIS Calibration Workshop



Jack Xiong

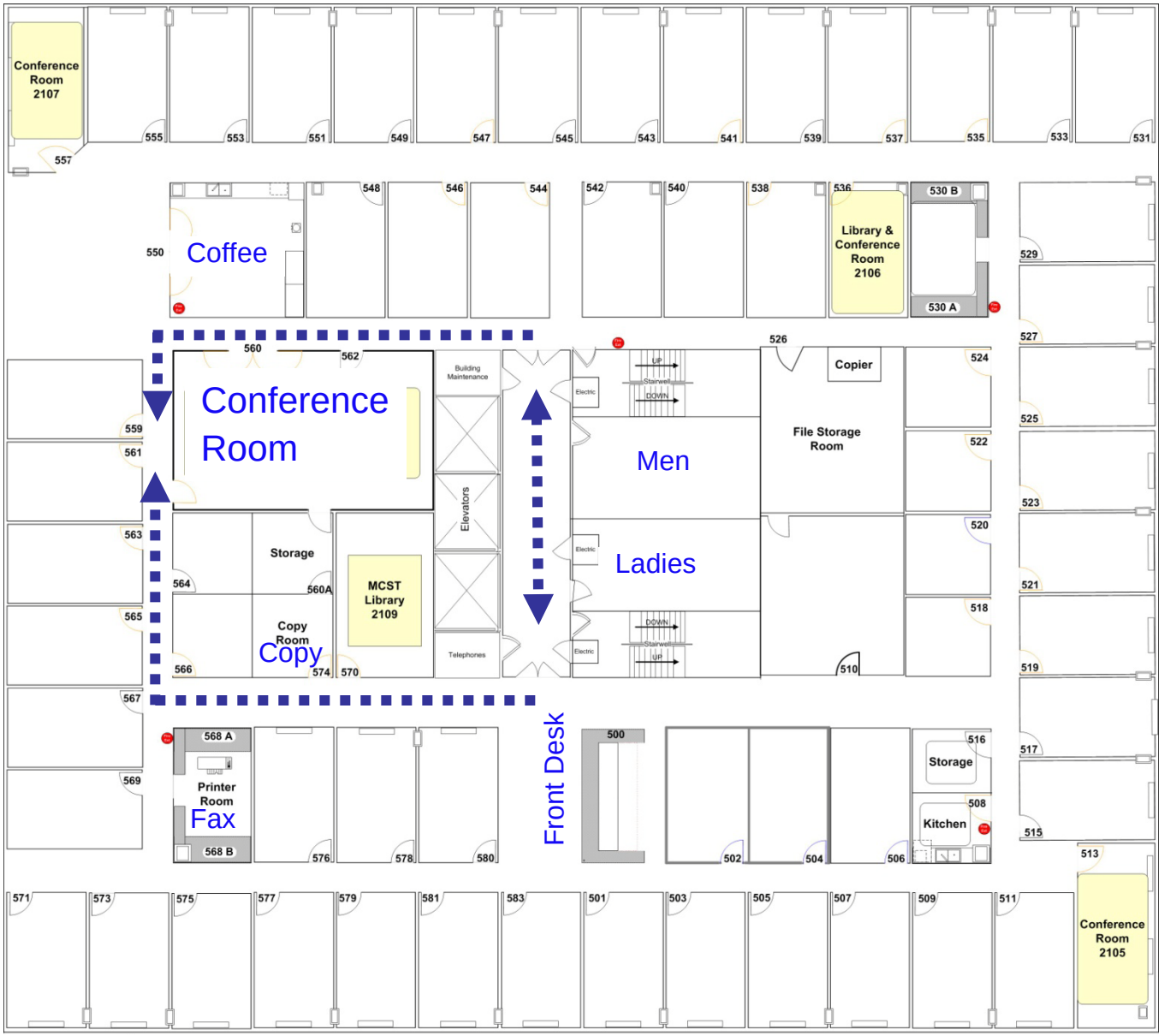
Biospheric Sciences Branch 614.4, NASA/GSFC

and

MODIS Characterization Support Team (MCST)

MODIS Calibration Workshop, Lanham, MD 20706 (January 25, 2010)

SSAI 5th Floor Layout



Logistics

- Badge (sign-in at front desk)
- Restroom (keys available at front desk)
- Breaks (lunch and coffee)
- Copy and Fax (available upon request)
- Dial in # for both MODIS and VIIRS Workshops

  1-866-600-2258; PC: 444018

- Wireless Guest Network

  SSID:

  WPA Key:

  Guest Network Login Page:

  User ID:

  Password:

MCST Contacts

- Instrument Operation: Jennifer Dodd / Gavin Westenburger
- L1B and LUT: James Kuyper
- RSB Calibration: Junqiang Sun / Hongda Chen
- TEB Calibration: Tiejun Chang / Aisheng Wu
- Spectral and Spatial: Jason Choi
- General Information: Brian Wenny / Jack Xiong

New Website: http://mcst.gsfc.nasa.gov/ (online but undergoing development)

- Information on MODIS Instrument Status, Calibration, and L1B Code & LUTs
- L1B ATBD, MCST Publications, and Workshop Presentations

Contact Brian Wenny or other MCST members for specific requests

Acknowledgements

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

Special Thanks to Sigma Space Co (SSC) and Science Systems and Applications, Inc. (SSAI)

Agenda

- **Instrument Operation, Calibration, and Performance**
- Introduction (Jack Xiong) 9:00 am
- Instrument Operation Status (Jennifer Dodd) 9:15 am
- Status of L1B Algorithm and LUT Updates (James Kuyper) 9:25 am
- RSB Calibration and Performance (Junqiang Sun) 9:35 am
- TEB Calibration and Performance (Tiejun Chang) 10:05 am
- Spatial and Spectral Performance (Jason Choi) 10:30 am
- **Coffee Break** 10:40 am
- Collection 6 Issues (Brian Wenny) 10:55 am
- Geo-location Characterization and Performance (Robert Wolfe) 11:20 am

- **Science Discipline Presentations**
- Ocean Presentation (Gerhard Meister/Gene Eplee) 11:35 am
- Land Presentation (Eric Vermote) 11:55 am
- Atmosphere Presentation (Chris Moeller/Steve Platnick) 12:10 pm
- **Adjourn** 12:30 pm

Introduction

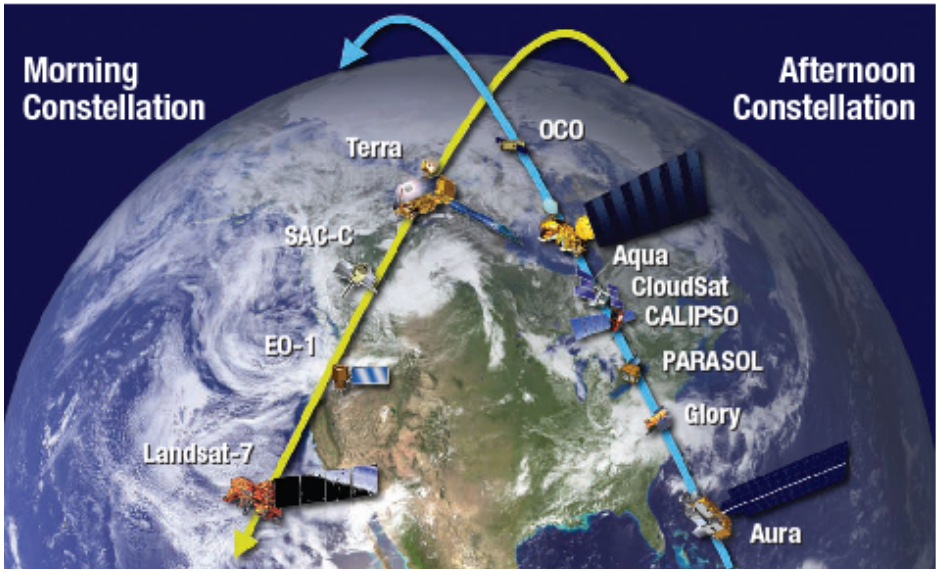
- Instrument and Calibration Background
  - On-orbit Calibration Activities
  - Calibration Methodologies
- Key Instrument Telemetry Trending
  - Instrument temperature
  - FPA temperature
  - Blackbody
- Summary of Instrument Performance

MODIS

- MODIS
  - On both Terra and Aqua
  - 36 spectral bands (0.41-14.4μm)
  - 4 focal plane assemblies (FPA)
  - 3 spatial resolutions (Q/H/1km)

- MODIS On-orbit Calibration
  - Radiometric, spatial, and spectral
  - On-board calibrators and the Moon
- Data and Applications
  - 40 science data products

Launch: 12/18/99
1st Light: 02/24/00



International Earth Observing Constellations
Complementary Morning and Afternoon Observations

Launch: 05/04/02
1st Light: 06/24/02

On-orbit Calibration Activities

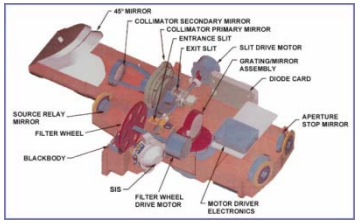
SD/SDSM:
Weekly to tri-weekly

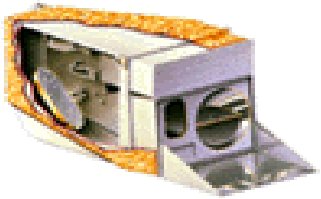
SRCA:
Radiometric: monthly
Spatial: bi-monthly
Spectral: quarterly

Solar Diffuser

SDSM

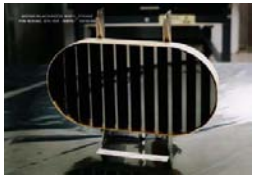
SRCA





Scan Mirror

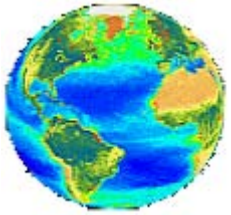
Blackbody



BB: quarterly

Space View

Spacecraft maneuvers:
Yaw (SD BRF, VF)
Roll (Moon)
Pitch (only applied to Terra)



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

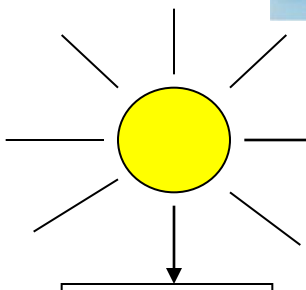
RSB Radiometric Calibration

EV Reflectance

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

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

$$\Delta_{SD} = \frac{\overline{dc_{SD}}}{\overline{dc_{Sun}}}$$



Scan
Mirror

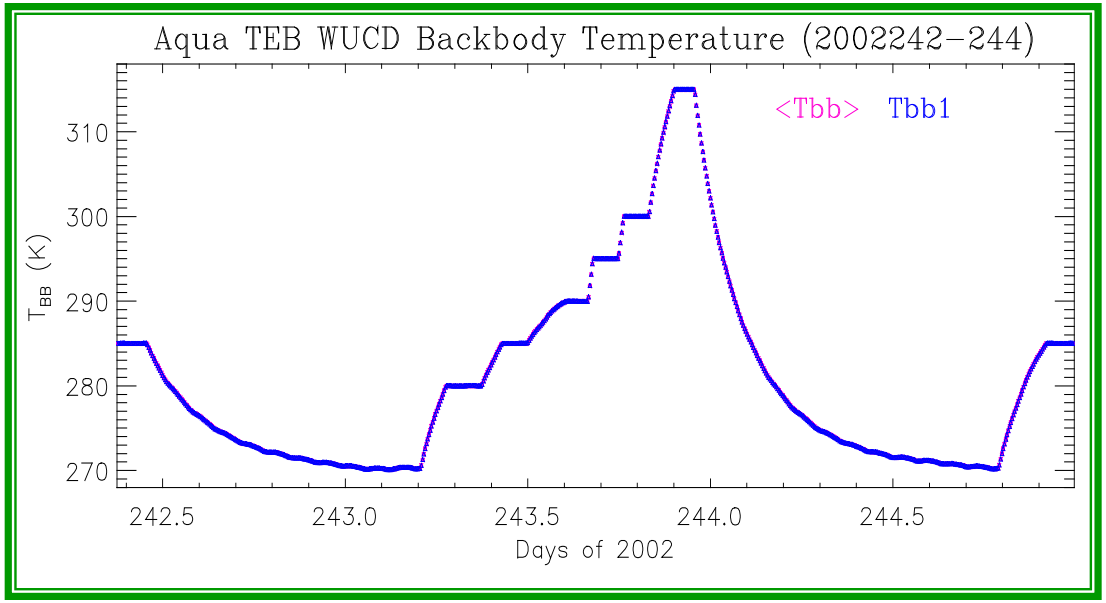
Δ_{SD}: SD degradation factor;
Γ_{SD}: SD screen vignetting function
d: Earth-Sun distance
dn*: Corrected digital number
dc: Digital count of SDSM

TEB Radiometric Calibration

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

Calibration Coefficients:

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



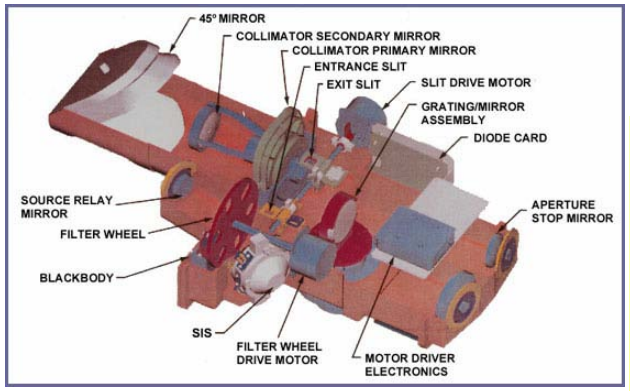
RVS: Response Versus Scan-angle
ε: Emissivity
L: Spectral band averaged radiance
dn: Digital count with background corrected
RSR: Relative Spectral Response

WUCD: Warm-up and Cool-down

Spatial and Spectral Characterization

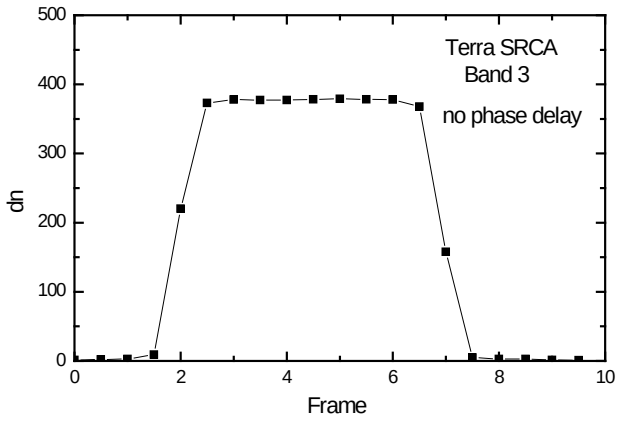
$$\bar{x}(b,d) = \frac{\sum_{x=0}^{N_x} dn(b,d,x) \cdot x}{\sum_{x=0}^{N_x} dn(b,d,x)}$$

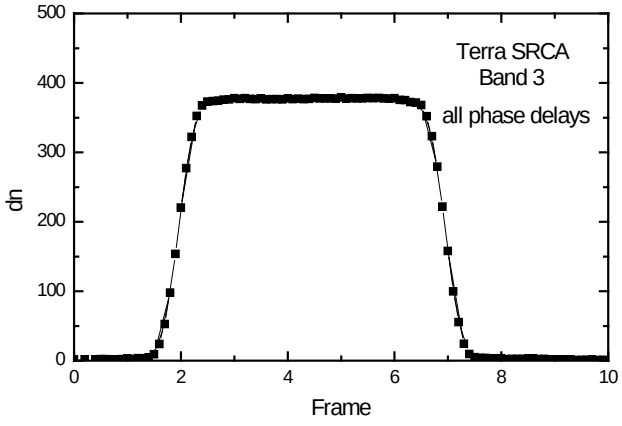
Spatial mode



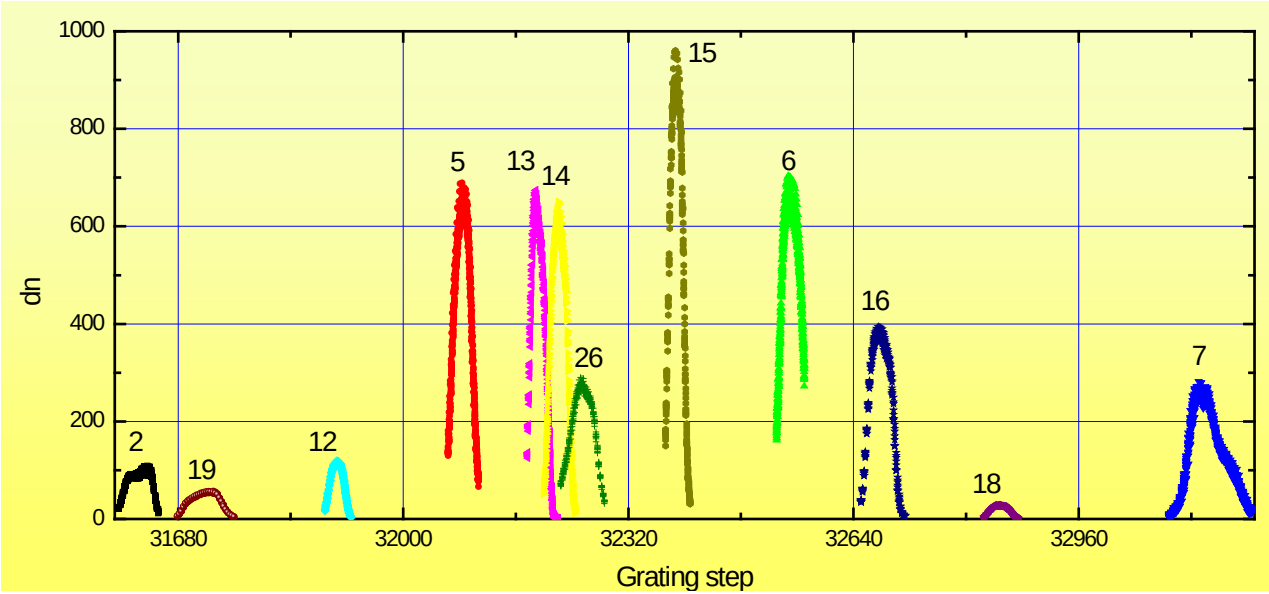
Spectral mode

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





Frame -> x

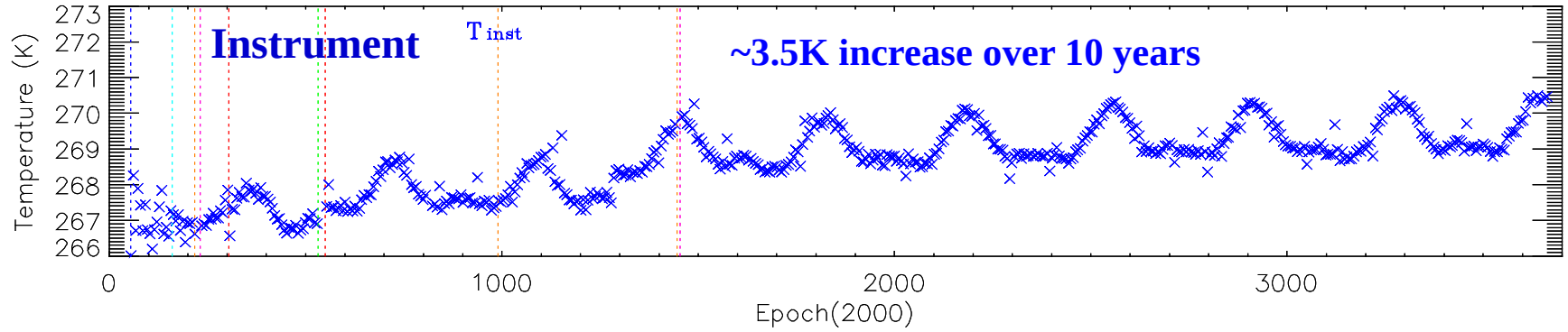


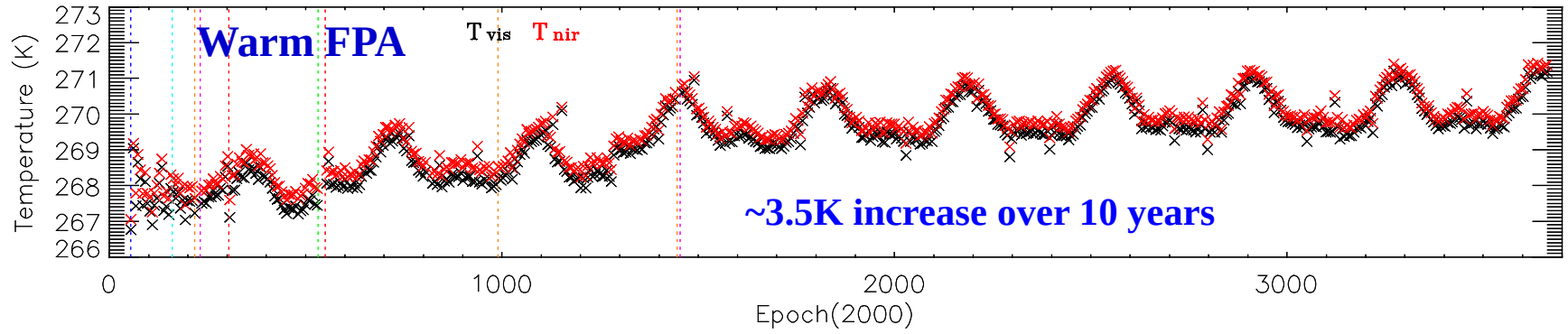
Grating step -> θ

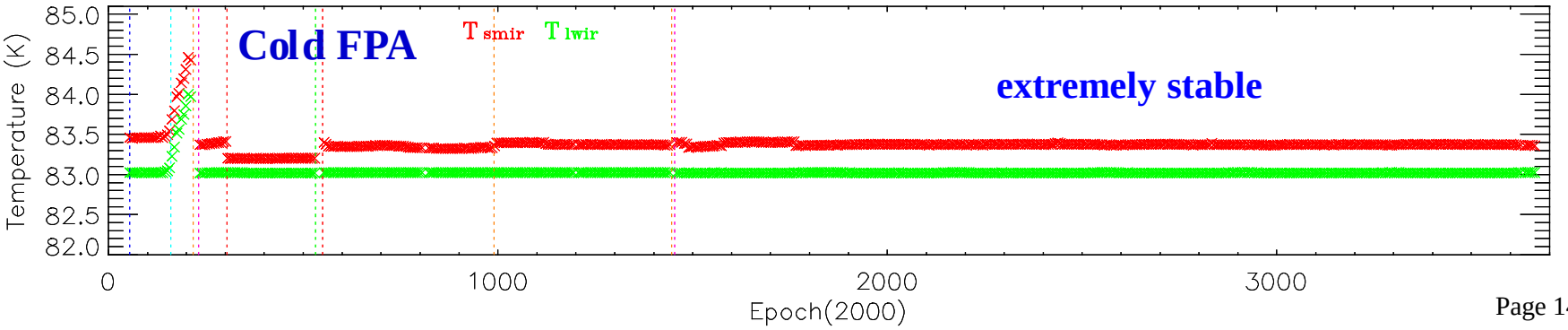
Instrument Operations

- Terra MODIS Configurations
  - A-side: launch to Oct 30, 2000
  - B-side: Oct 30, 2000 to June 15, 2001
  - A-side: July 02, 2001 to Sept 17, 2002
  - A-side electronics and B-side formatter: Sept 17, 2002 to present
  - SD door fixed at open position: July 02, 2003 to present
  - BB temperatures set at 290K
  - Cold FPA controlled at 83K
- Aqua MODIS Configurations
  - Same B-side configuration since launch
  - BB temperatures set at 285K
  - Cold FPA controlled at 83K

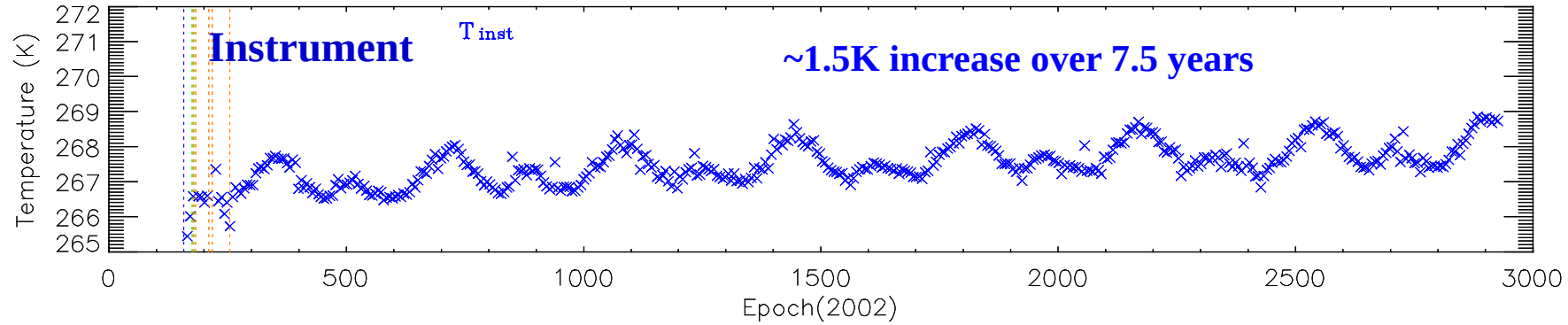
Instrument and FPA Temperatures (Terra MODIS)

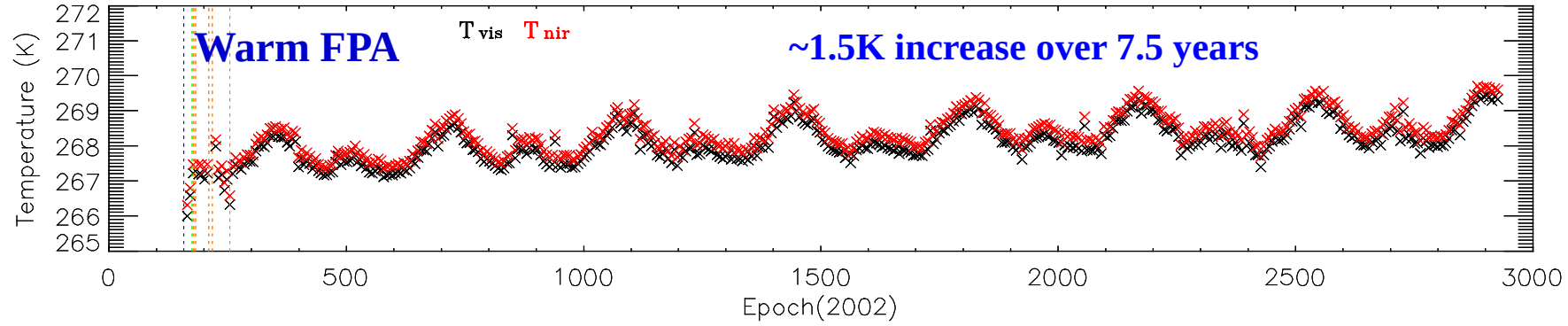


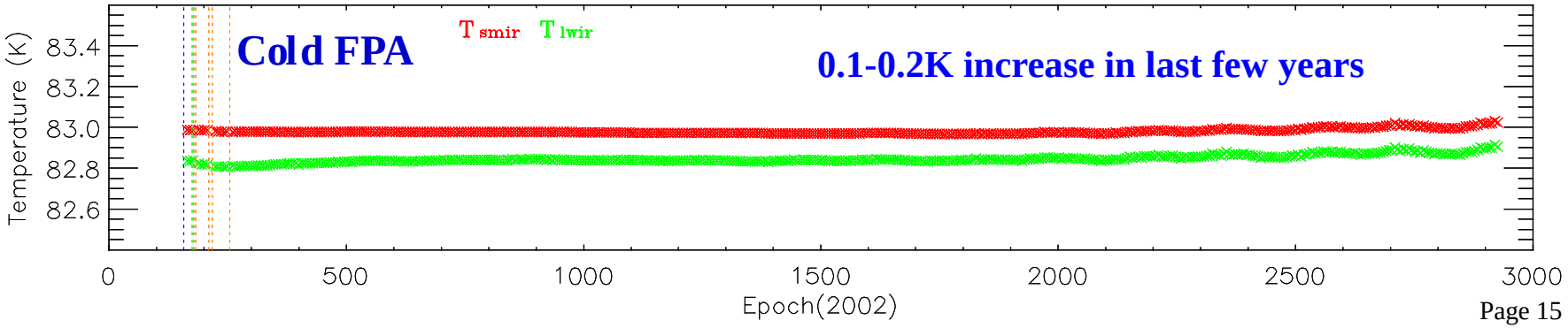




Instrument and FPA Temperatures (Aqua MODIS)

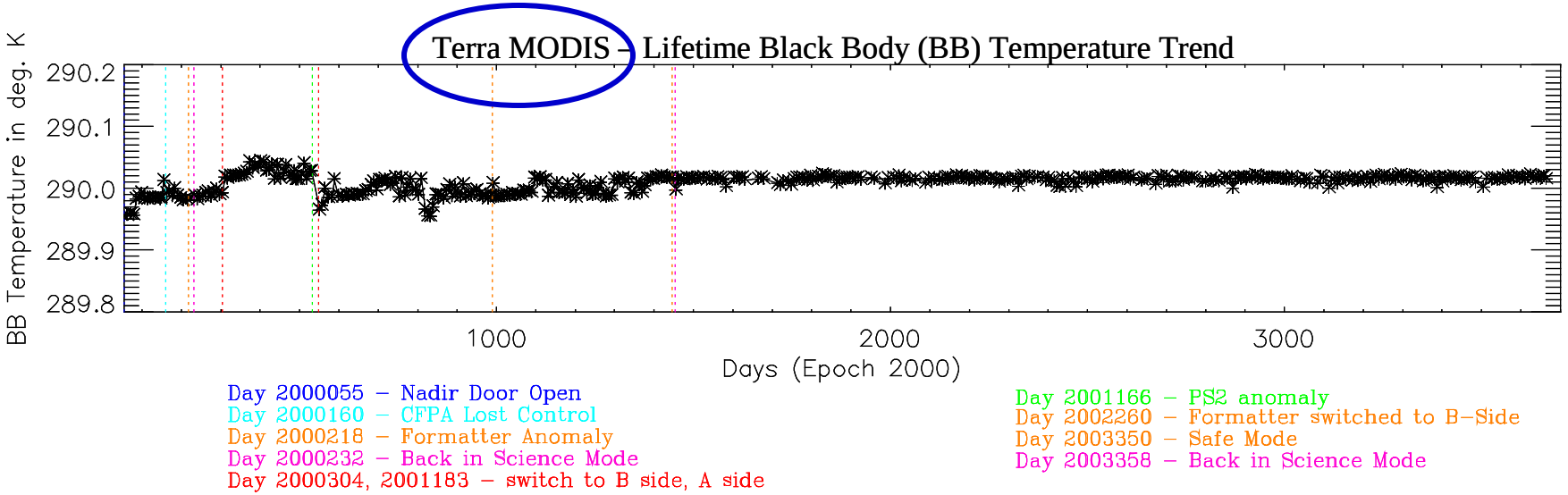


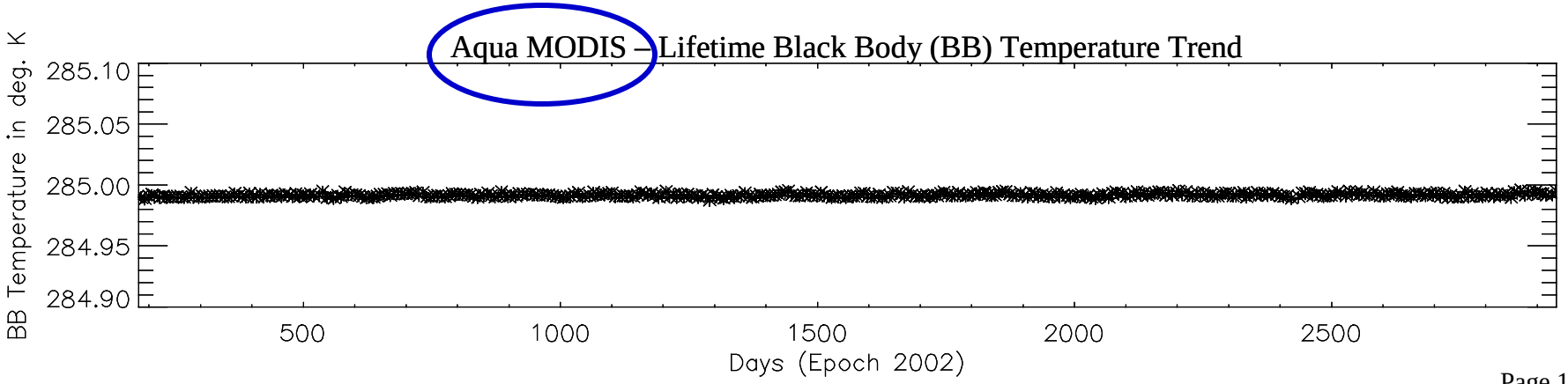




BB Temperatures

Excellent BB temperature stability: short- and long-term





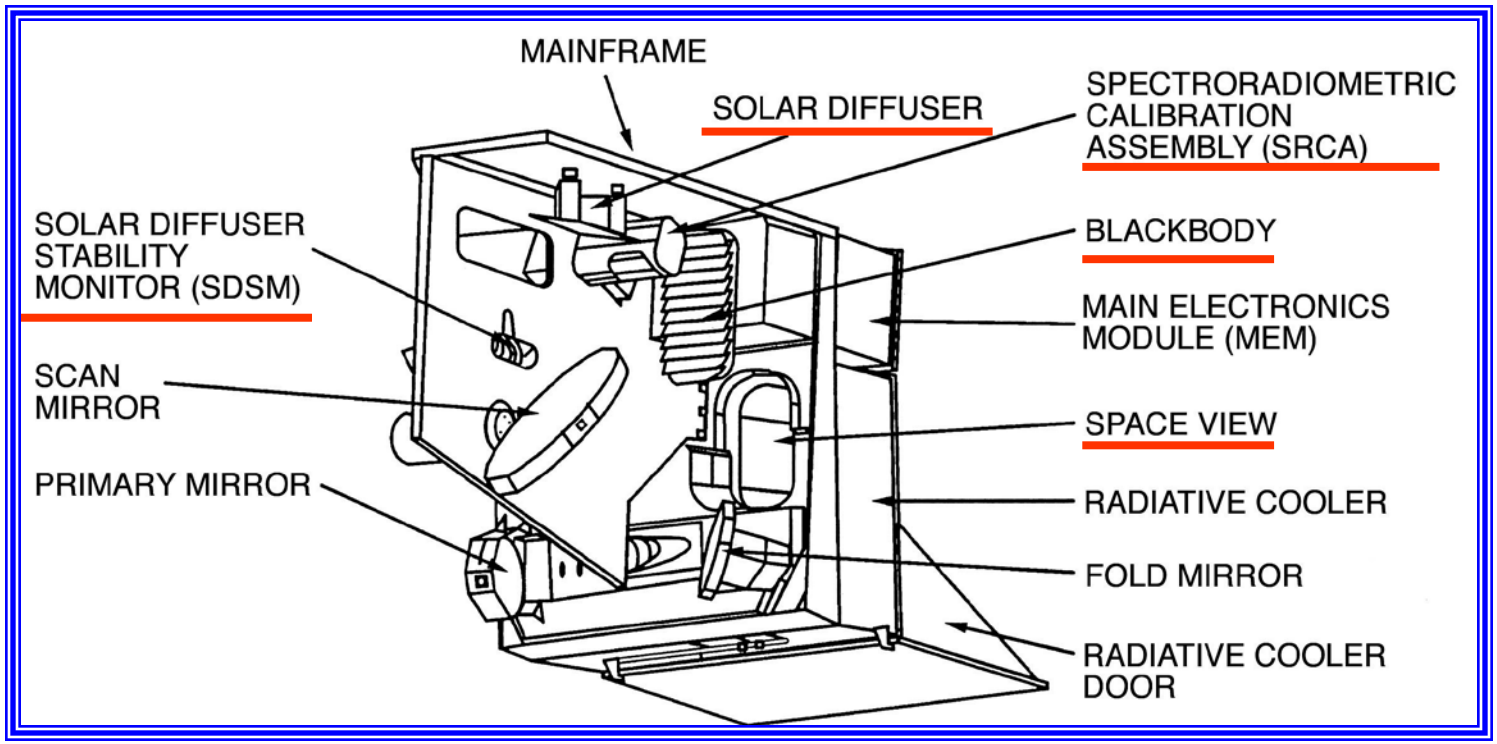
Instrument Performance Summary (I)

- Both instruments continue to operate normally
  - Over 10 years for Terra MODIS and 7.5 years for Aqua MODIS
- On-board calibrators continue to provide their designed functions
  - Terra MODIS SD door fixed at the “open” position (July 2, 2003) => increased SD degradation rates
  - SRCA 30W configuration replaced by the 20W configuration (2005 for Aqua MODIS, 2006 for Terra MODIS)
  - BB temperatures remain extremely stable
- Instrument and FPA temperatures are stable
  - Instrument and warm FPA temperatures changed less than 3K for Terra MODIS over 10 years; less than 2K for Aqua MODIS over 7.5 years
  - Terra MODIS Cold FPA temperature stably controlled at 83K; Aqua MODIS cooler margin slowly decreased => small orbit-to-orbit and seasonal variations of its CFPA temperatures (up to 0.15K)

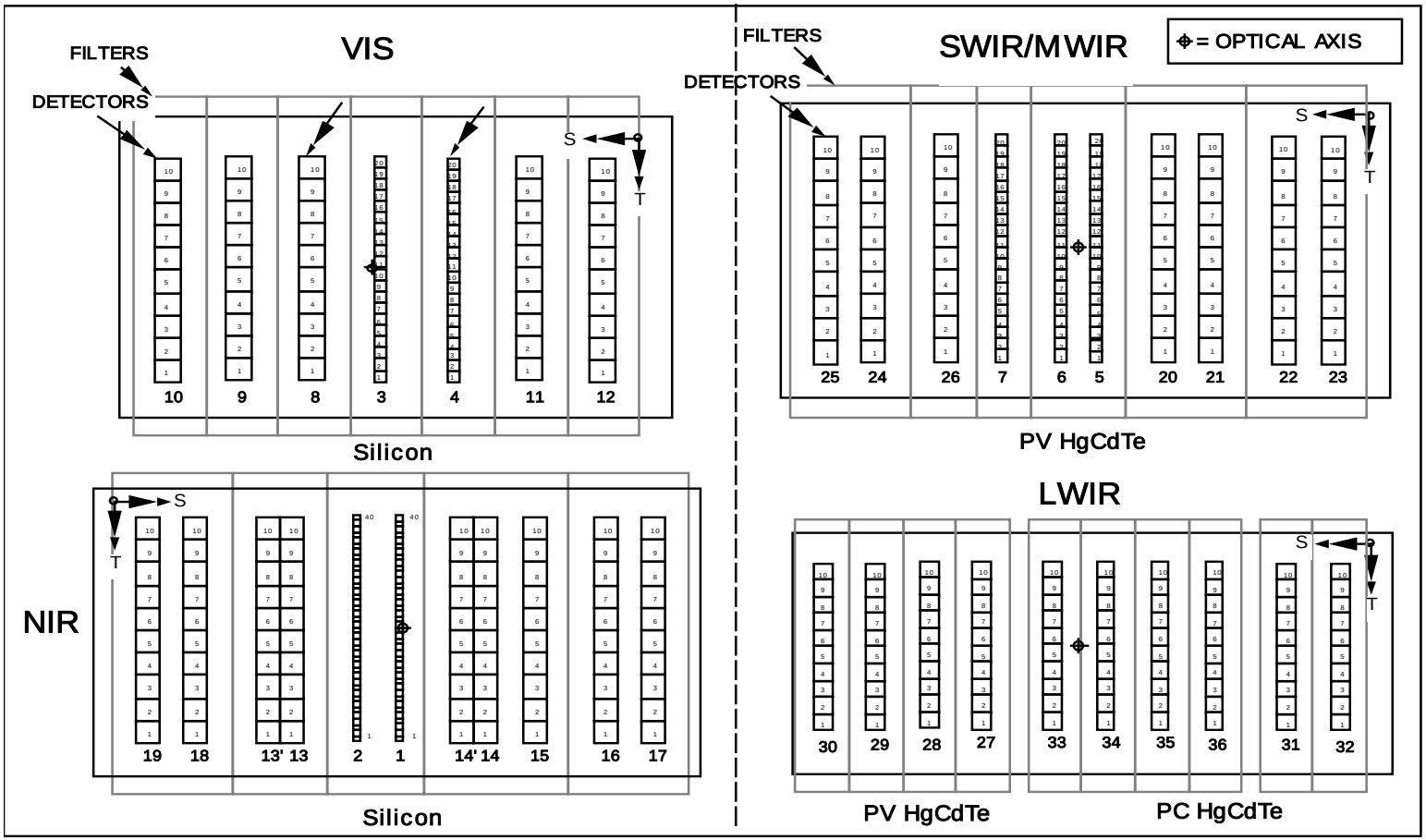
Instrument Performance Summary (II)

- Radiometric (36 spectral bands: 490 individual detectors)
  - 45 noisy detectors (30 from pre-launch; 35 at launch) and no inoperable detectors for Terra MODIS (most on-orbit noisy detectors are in the LWIR PV bands)
  - 6 noisy detectors (2 from pre-launch; 3 at launch) and 15 inoperable detectors (10 from pre-launch and 15 shortly after launch) for Aqua MODIS (mostly in band 6)
  - Large changes in VIS spectral band response (mirror-side dependent)
- Spectral (VIS/NIR bands only)
  - Changes in center wavelengths and bandwidths are less than 0.5nm for most spectral bands (with a few exceptions)
- Spatial (all bands)
  - On-orbit band-to-band registrations (BBR) have been stable; nearly all band pairs meet design requirements for Terra MODIS; large BBR offsets in Aqua MODIS for band pairs with one from cold FPA and another from the warm FPA (a known problem since pre-launch)
- Concerns and Challenges
  - Large optics (mirror and SD) degradation at short wavelengths; changes in RVS and polarization parameters for VIS spectral bands (8, 9, 10)

MODIS Scan Cavity and On-board Calibrators



MODIS Focal Plane Assemblies (FPA)



S: scan direction; T: track direction

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

MODIS Specifications and Applications

Primary Use	Band	Bandwidth (nm)	Spectral Radiance[1]	Required SNR
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

Primary Use	Band	Bandwidth (nm)	Spectral Radiance[1]	Required NEDT(K)
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 (SNR)
	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] Spectral Radiance values are (W/m^2-μm-sr)

- *20 reflective solar bands (RSB: bands 1-19, and 26) from 0.41 - 2.2μm*
- *16 thermal emissive bands (TEB: bands 20-25, 27-36) from 3.5 - 14.4μm*

MODIS and VIIRS Spectral Bands

VIIRS Band	Spectral Range (um)	Nadir HSR (m)	MODIS Band(s)	Range	HSR
DNB	0.500 - 0.900				
○ M1	0.402 - 0.422	750	8	0.405 - 0.420	1000
○ M2	0.436 - 0.454	750	9	0.438 - 0.448	1000
○ M3	0.478 - 0.498	750	3 10	0.459 - 0.479 0.483 - 0.493	500 1000
○ M4	0.545 - 0.565	750	4 or 12	0.545 - 0.565 0.546 - 0.556	500 1000
I1	0.600 - 0.680	375	1	0.620 - 0.670	250
○ M5	0.662 - 0.682	750	13 or 14	0.662 - 0.672 0.673 - 0.683	1000 1000
M6	0.739 - 0.754	750	15	0.743 - 0.753	1000
I2	0.846 - 0.885	375	2	0.841 - 0.876	250
○ M7	0.846 - 0.885	750	16 or 2	0.862 - 0.877 0.841 - 0.876	1000 250
M8	1.230 - 1.250	750	5	SAME	500
M9	1.371 - 1.386	750	26	1.360 - 1.390	1000
I3	1.580 - 1.640	375	6	1.628 - 1.652	500
M10	1.580 - 1.640	750	6	1.628 - 1.652	500
M11	2.225 - 2.275	750	7	2.105 - 2.155	500
I4	3.550 - 3.930	375	20	3.660 - 3.840	1000
M12	3.660 - 3.840	750	20	SAME	1000
○ M13	3.973 - 4.128	750	21 or 22	3.929 - 3.989 3.929 - 3.989	1000 1000
M14	8.400 - 8.700	750	29	SAME	1000
M15	10.263 - 11.263	750	31	10.780 - 11.280	1000
I5	10.500 - 12.400	375	31 or 32	10.780 - 11.280 11.770 - 12.270	1000 1000
M16	11.538 - 12.488	750	32	11.770 - 12.270	1000

○ Dual gain band

MODIS Instrument Operations

MODIS IOT

1/25/10

MODIS Operational Activities

Operational Activity	Activity	Operational Activity	Activity
OA-01	Initial Checkout	OA-16	SD/SDSM Screened
OA-02	Mode Transition	OA-17	SD Sector Shift
OA-03	Formatter Day Mode	OA-18	SDSM
OA-04	Formatter Night Mode	OA-19	SRCA Full Radiometric
OA-05	Safe/Survival Mode Recovery	OA-20	SRCA 10W Radiometric Continuous
OA-06	Initial Outgas	OA-21	SRCA 1W Radiometric Continuous
OA-07	DC Restore On/Off	OA-22	SRCA Full Spectral
OA-08	S/C Maneuver (Lunar Cal)	OA-23	SRCA Full Spatial
OA-09	S/C Maneuver (SD Scattered Light)	OA-24	SRCA Along-Scan Spatial
OA-10	S/C Maneuver (RVS)	OA-25	SRCA 1W Along-Scan Spatial
OA-11	Constraints on Special Operations (Field Campaign)	OA-26	Blackbody Cycle
OA-12	Table Load (GAO)	OA-27	PV Electronic Calibration
OA-13	Deleted	OA-28	PC Electronic Calibration
OA-14	Sector Rotation	OA-29	End Of Mission
OA-15	SD/SDSM Open		

Recent Events (Terra)

- Spacecraft Events
  - SFE-A (2008-252,355-358,2009-116,238,250,252,355)
  - Battery Anomaly (2009/286) - possible MMOD (Micro-Meteoroid Orbital Debris)
  - SSR PWA (2010/008) - affecting 2 ASTER supersets, no MODIS impact other than ~10 min data loss during recovery
- Orbit Adjust Maneuvers
  - Drag Make-Up #52-54
  - Inclination Adjustment #21-24
- MODIS Events
  - A few telemetry points slightly exceeded configuration monitor limits, no impact on MODIS operations or calibration

Recent Events (Aqua)

- Spacecraft Events
  - Partition 6 fix in Jan 2009 to correct offset implemented in Dec 07 as a workaround for the pointer anomaly
- Orbit Adjust Maneuvers
  - Drag Make-Up #33-38
  - Inclination Adjustments #16-24
  - Debris Avoidance Maneuver (2009/329)
- MODIS Events
  - No new events

Terra MODIS OBC Operations

Activity	PL to 05/08	05/08 - present	Total
SD/SDSM	562	35	597
BB WUCD	63	7	70
SRCA*	265	34	299
Electronic Cal	55	8	63
Lunar Roll	78	17	95

* Includes Spatial, Spectral and Radiometric
05/08 = last Science Team Meeting

Aqua MODIS OBC Operations

Activity	PL to 05/08	05/08 - present	Total
SD/SDSM	364	44	408
BB WUCD	23	8	31
SRCA*	139	35	174
Electronic Cal	35	8	43
Lunar Roll	53	16	69

* Includes Spatial, Spectral and Radiometric
05/08 = last Science Team Meeting

SRCA Calibrations

- Terra – 299 SRCA Calibrations
- Aqua – 174 SRCA Calibrations

Lamp Power		10W				1W	
Lamp #		1	2	3	4	1	2
Terra	Usage (hr)	288.6	172.1	190.3	96.7	576.4	282.0
	Life (hr)	500	500	500	500	4000	4000
	percent	57.7 %	Failed on 11-20-2004	Failed on 2-18-2006	19.3%	14.4%	7.1%
Aqua	Usage (hr)	281.3	188.0	205.7	99.6	517.1	274.9
	Life (hr)	500	500	500	500	5000	5000
	percent	56.3%	Failed on 4-14-2003	Failed on 6-28-2005	19.9%	10.3%	5.5%

Future Operational Considerations

- Aqua MODIS CFPA temperature control
  - Currently set at 83K – two options for mitigation
    - Change set point to 85K
    - Perform outgas (given the opportunity)
- Aqua SD/SDSM door movements
  - Adjust calibration frequency to preserve door movements

	PL to 05/08	05/08 to present	Total	Design Lifetime	% Used
Terra*	2146	0	2146	3022	71
Aqua+	2716	130	2849	3022	94

* As of 07/02/2003, SD Door in fixed ‘open’ position with screen in place

+ At current usage rate Aqua will reach designed lifetime of door movement in August 2012

MODIS Level 1B and LUT Status

(Details provided in backup slides)

Recent Code and L1B Updates

- L1B code has been relatively stable
  - 9 minor code changes made in collection 5 since 2005 (5 for Terra MODIS and 4 for Aqua MODIS)
- Near-monthly LUT update for each MODIS forward processing
  - 72 for Terra MODIS and 43 for Aqua MODIS in collection 5 since 2005
  - Additional LUTs generated, tested, and delivered to OBPG (Ocean Biology Processing Group) for special investigations
  - Most LUT updates were driven by response changes of VIS bands

Number of MCST L1B Code and LUT Versions

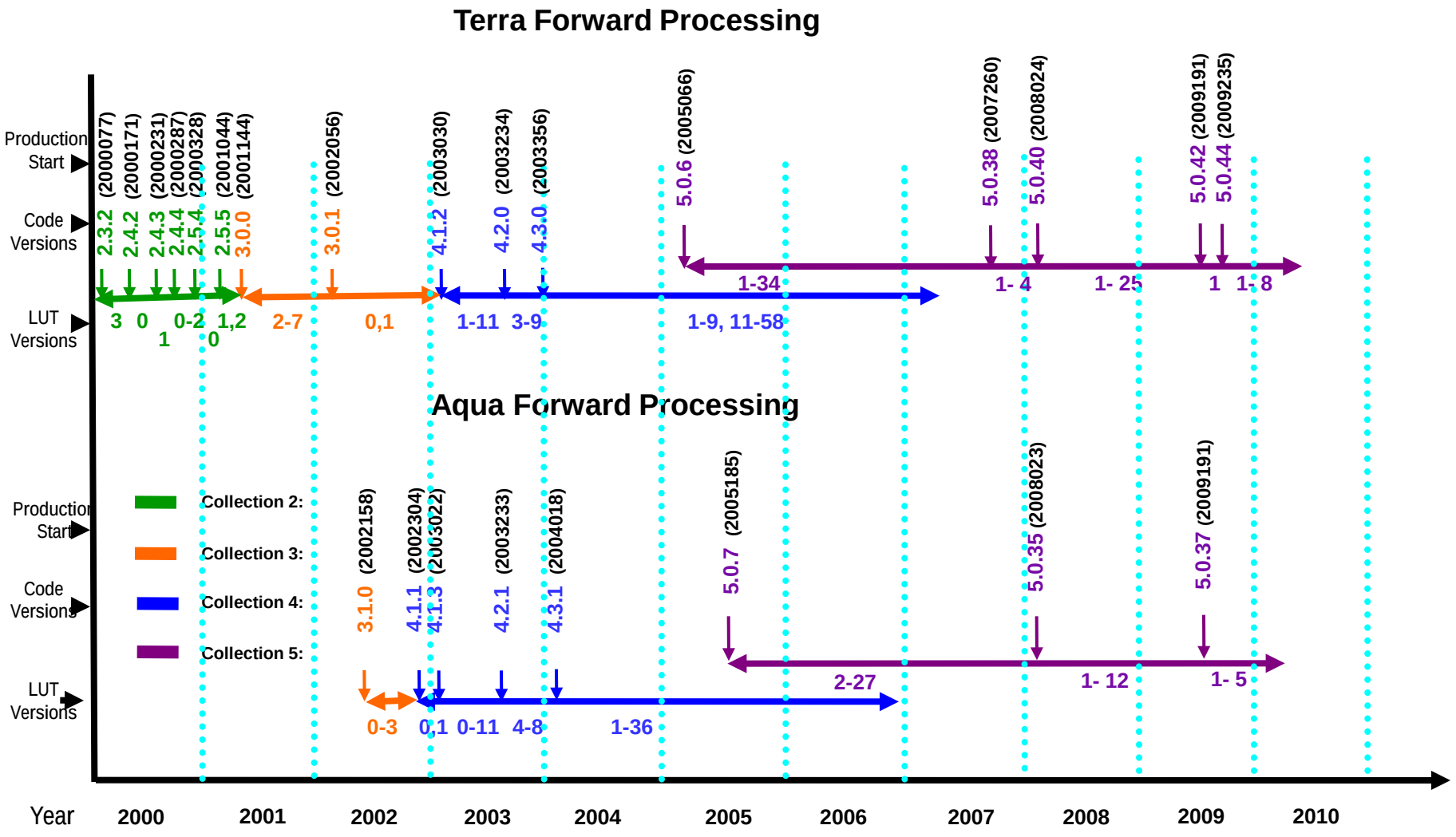
(as of 01/12/2010)

Since 2005, 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	0	1	0	11	0	30
2005	2	0	0	18	10	2	0	11	6	49
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	16	1	0	0	8	26
2009	2	0	0	0	18	1	0	0	8	29
2010	0	0	0	0	1	0	0	0	1	2
Total	20	3	6	75	72	10	3	52	43	284

Does not include internal deliveries(18), nor special deliveries to Ocean Color Group (31) or Miami & Wisconsin (7)

MODIS MOD_PR02 L1B Code/LUTs Major Production Changes Timeline



Production Changes to Collection 5 MOD_PR02 TERRA L1B Code

PGE02 Version	Forward Processing Begin	Code Changes
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	1/24/2008 (024 2008) 00:00	• 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.
V5.0.42_Terra	7/10/2009 (191 2009) 00:00	• Added an extension ".NRT" to the LOCALGRANULEID metadata if the ReprocessingActual from pcf is "Near Real Time" to indentify the NRT production.
V5.0.44_Terra	8/23/2009 (235 2009) 00:00	• Only the PGE02 version is changed for correction to a PGE level error.

Production Changes to Collection 5 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	01/23/2008 (023 2008) 00:00	• 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.
V5.0.37_Aqua	07/10/2009 (191 2009) 00:00	• Added an extension ".NRT" to the LOCALGRANULEID metadata if the ReprocessingActual from pcf is "Near Real Time" to indentify the NRT production.

Collection 6 Code Changes for L1B

- Change to no longer interpolate the values of inoperable detectors from nearby good detectors.
  - The scaled integer value will be set to 65531
- Noisy/inoperable detector (sub-sample) flagging
  - If sub-sample is inoperable, the scaled integer value will be set to 65525
- The sector rotation anomaly fix
  - The anomaly is caused by the mismatch of the timing of the instrument command to perform the sector rotation and the recording of the telemetry point that reports the angle of sector rotation.
  - Will be implemented in C5 PGE02 by end of February, 2010.
- Change in how `ReprocessingActual` ECS metadata is set and used.
  - Previously, value was fixed as "`processed once`"
  - Now the value is controlled by MODAPS operations:
    - "`Near Real Time`" – causes file name to end with "`.NRT.hdf`"
    - "`processed once`"
    - "`reprocessed once`"
  - Also implemented in Collection 5 code.

MODIS Reflective Solar Bands On-Orbit Performance

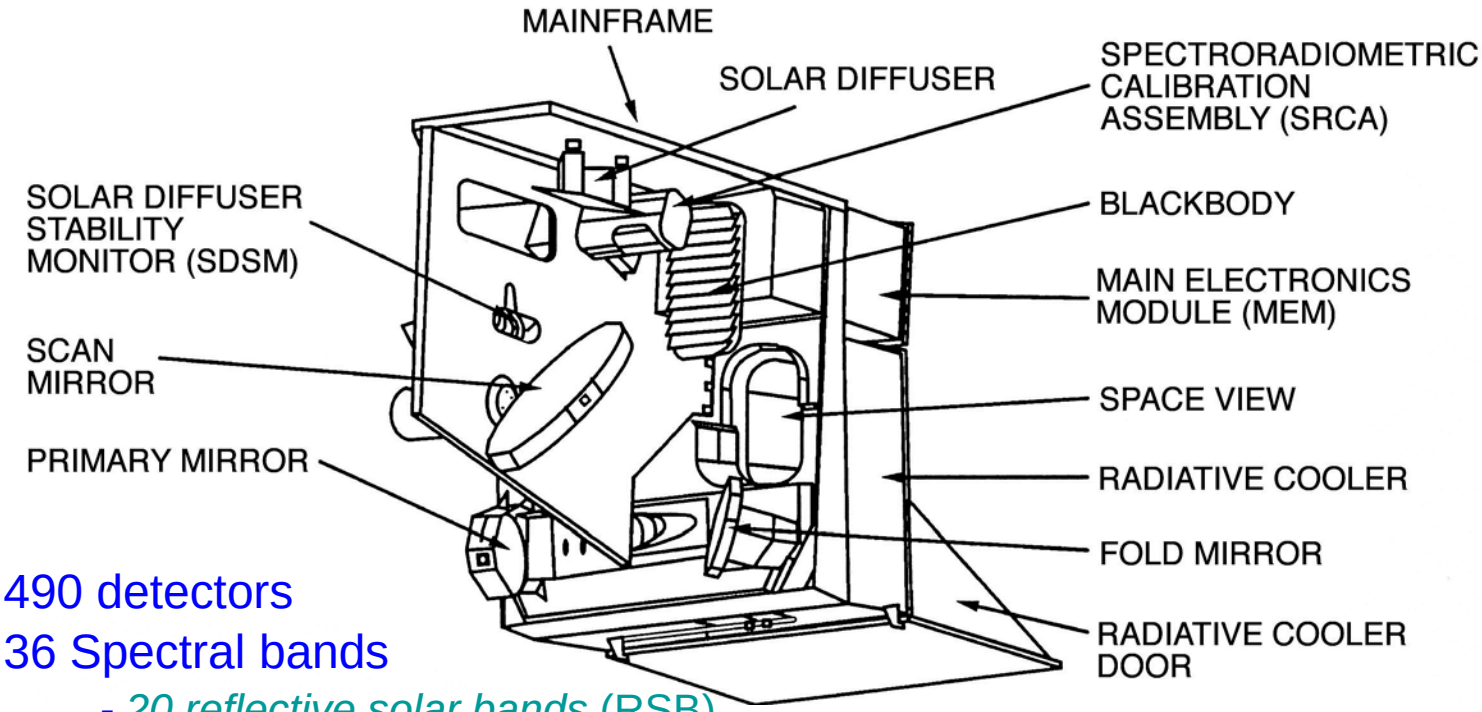
RSB Group
MODIS Characterization Support Team (MCST)

MODIS Science Team Meeting (January 25, 2010)

Outline

- Introduction
- RSB calibration algorithms
- Noisy & inoperable RSB detectors
- Solar Diffuser degradation
- RSB responses trending
- Detector-dependent RVS and EV striping reduction
- Alternative collection 6 LUTs
- Summary of RSB overall performance

Introduction



490 detectors

36 Spectral bands

- *20 reflective solar bands* (RSB)
- *16 thermal emissive bands* (TEB)

Spatial resolution (36 bands) at nadir

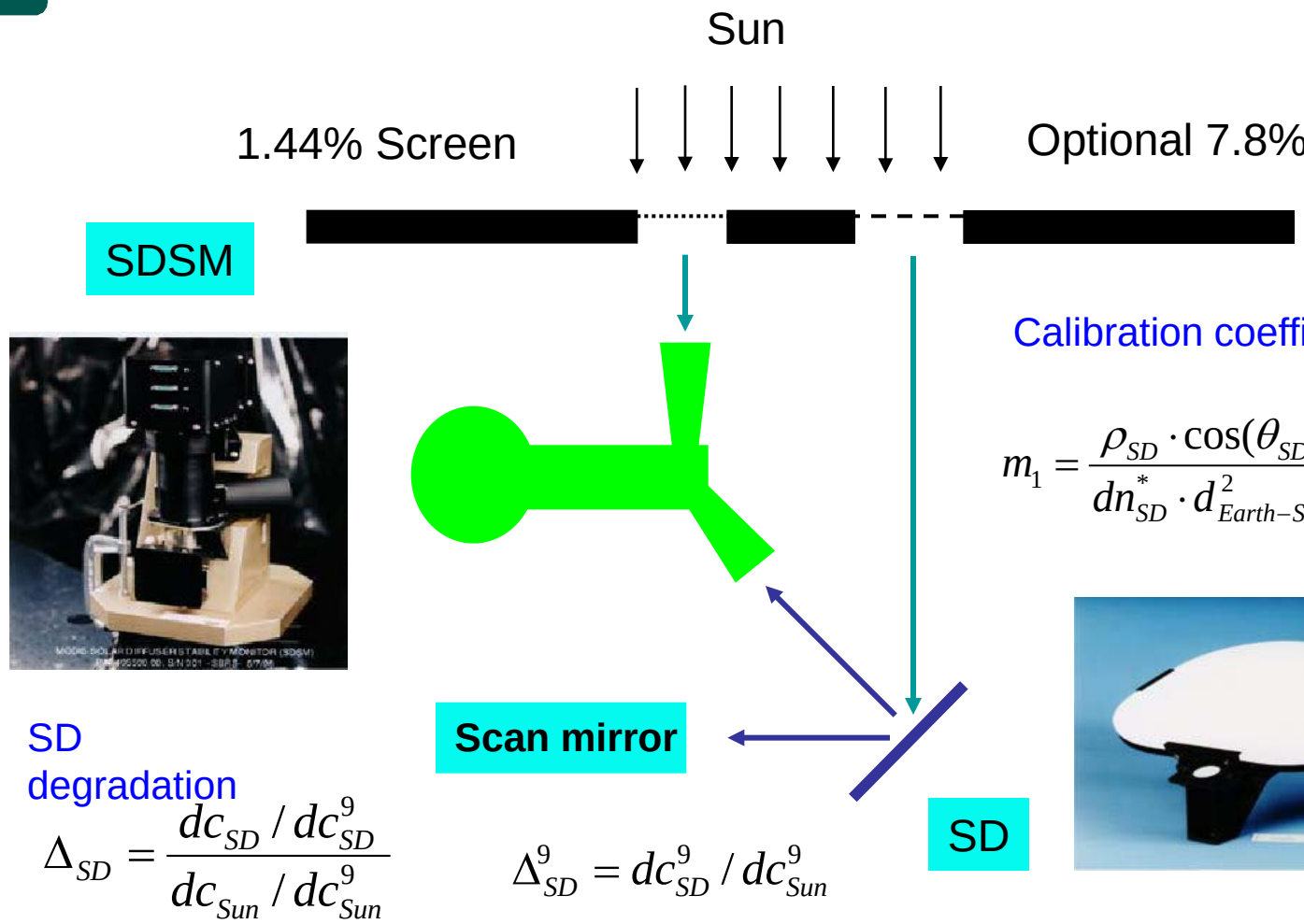
- *250m(2), 500m(5), and 1km (29)*

Wavelength range from 0.4 to 14.5 μm

Two sided paddle wheel scan mirror

- *10 km (nadir) along track by 2330 km cross track swath*
- *1.478 second each scan*

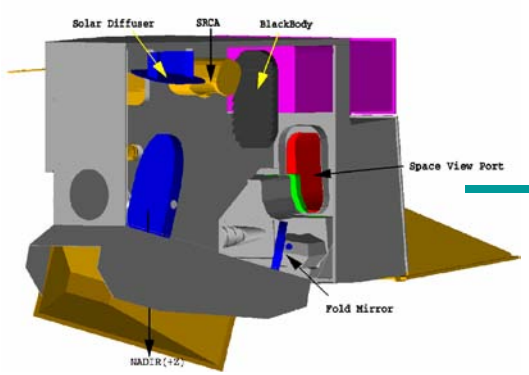
RSB SD Calibration



SD degradation at wavelength 940 nm measured by SDSM D9 is included in Collection 6 through the entire mission and also included in Collection 5 for Terra after Jan. 1, 2009 and Aqua after March 1, 2009.

RSB lunar calibration

MODIS



Moon

Lunar coefficients

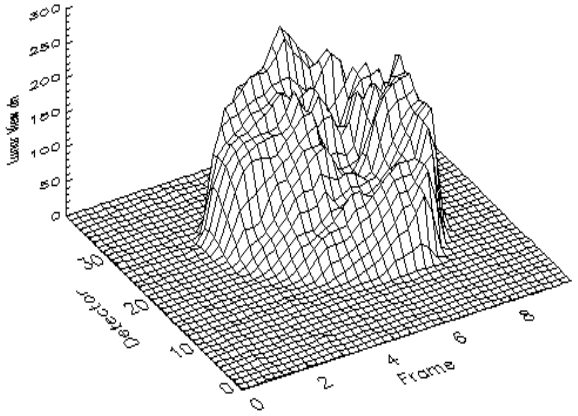
Bands 1-4, 8-12 and 17-19

$$m_1^{moon} = \frac{f_{vg}}{< dn^*_{Moon} >}$$

Bands 13-16 (Saturated)

$$m_1^{moon} = m_{1,B18}^{moon} \cdot \frac{< dn^*_{Moon,B18} >}{< dn^*_{Moon} >}$$

MODIS Response



View geometry correction

$$f_{vg} = \frac{f_{phase-angle} \cdot f_{libration}}{d^2_{Sun-Moon} \cdot d^2_{Moon-MODIS}}$$

MODIS RSB Earth View Radiance

EV Radiance:

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

$$= \frac{E_{Sun}}{\pi} \cdot m_1 \cdot dn^*_{EV}$$

where

$$dn^*_{EV} = dn_{EV} \cdot (1 + k_{Inst} \cdot \Delta T_{Inst}) / RVS_{EV}$$

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

MODIS 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

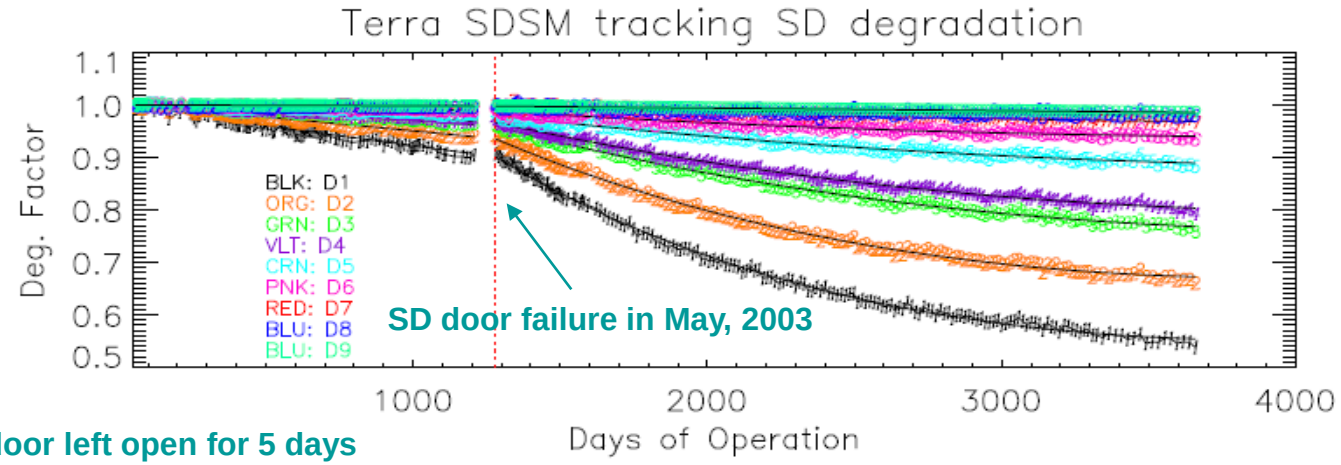
Aqua

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

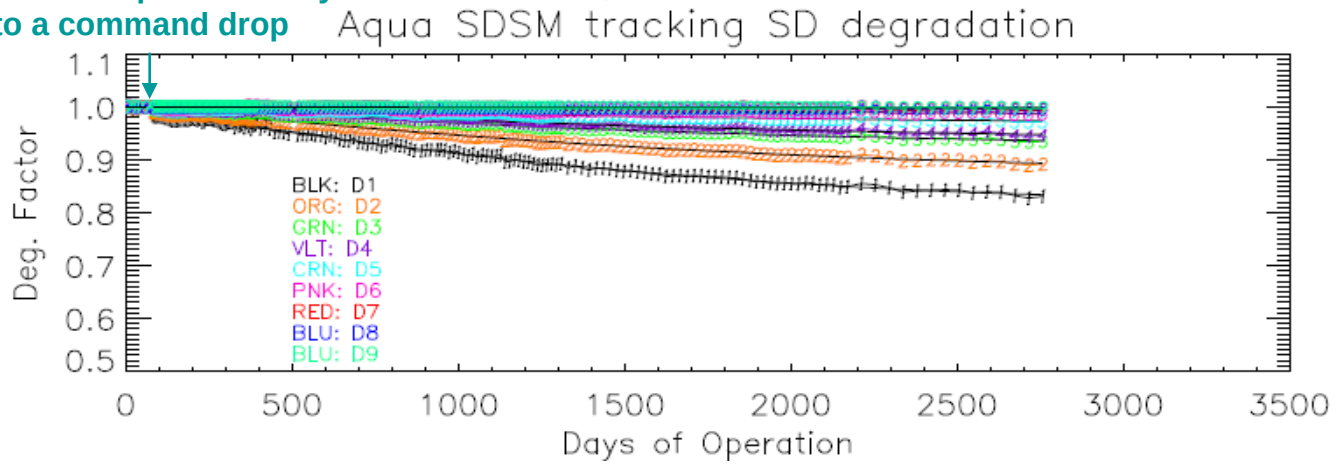
In Spec Near Spec Out Spec Inoperable

Detectors in Production order

MODIS SD Degradation Trending



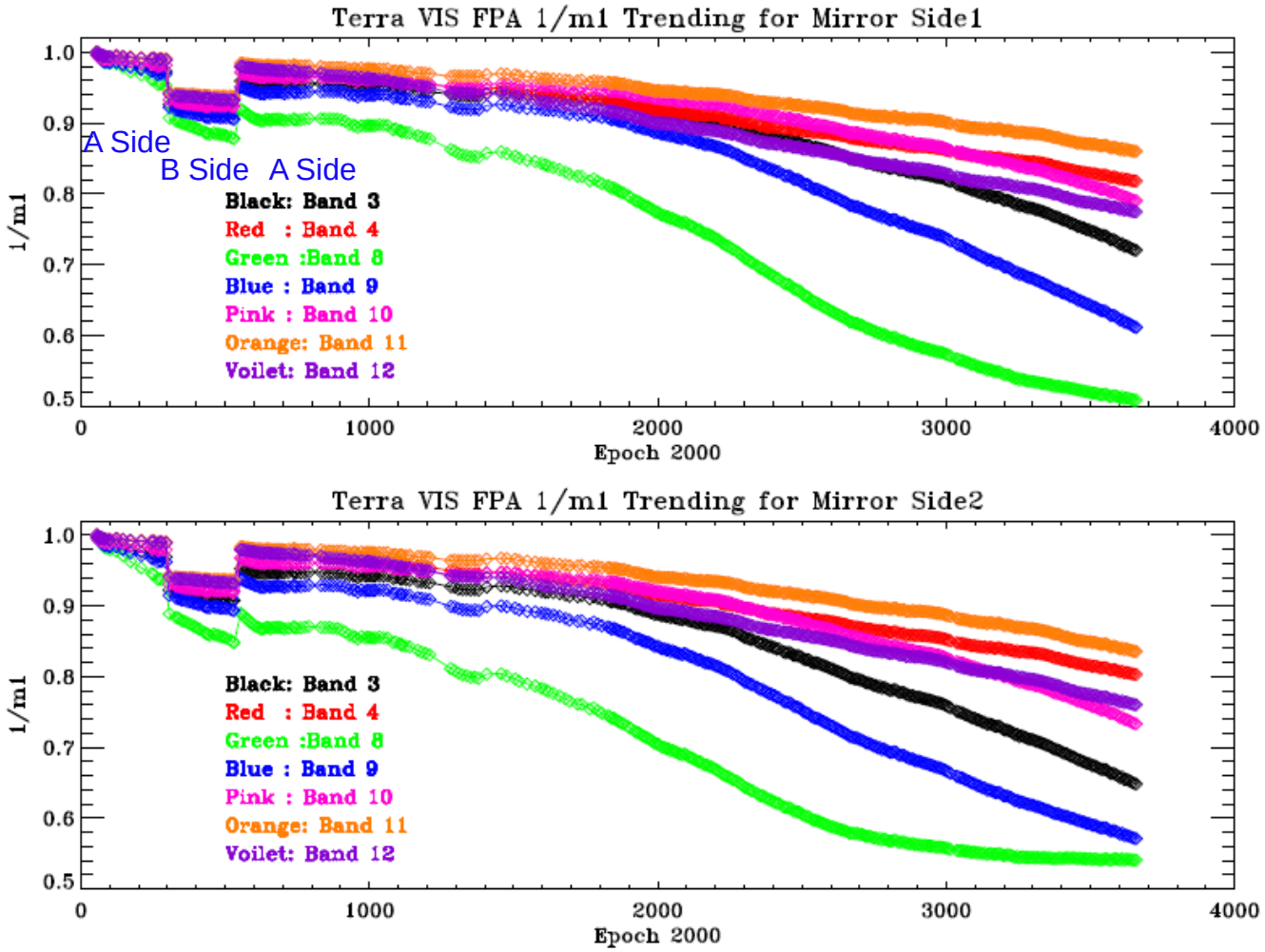
SD door left open for 5 days due to a command drop



Results are derived from normalization approach (to D9). Additional D9 corrections are applied to Collection 6 through the entire mission and to Collection 5 after Jan. 1, 2009 for Terra and after March 1, 2009 for Aqua, respectively.

MODIS RSB Response Trending

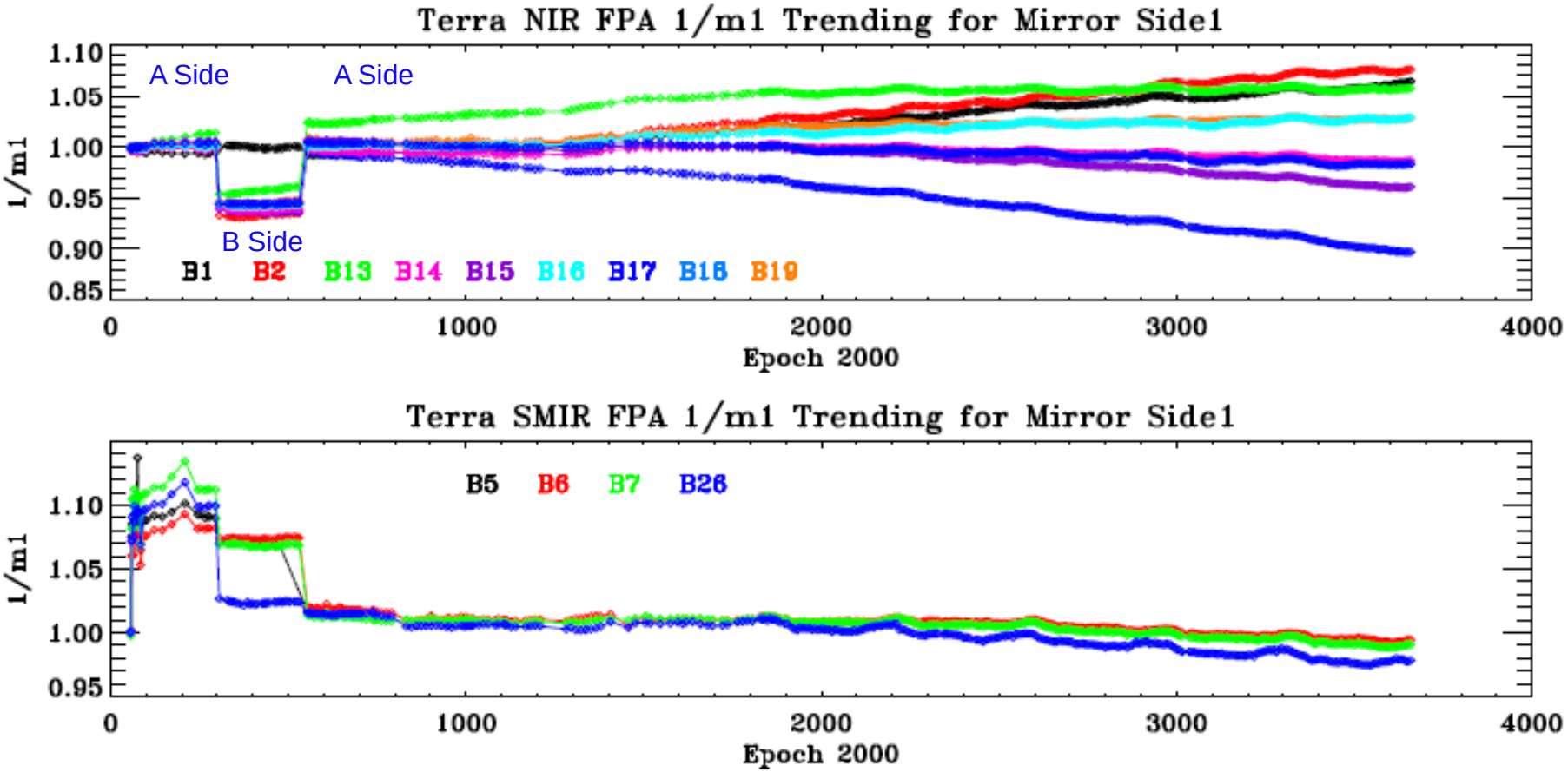
Detector Averaged



Large mirror side differences are observed in short wavelength bands

MODIS RSB Response Trending

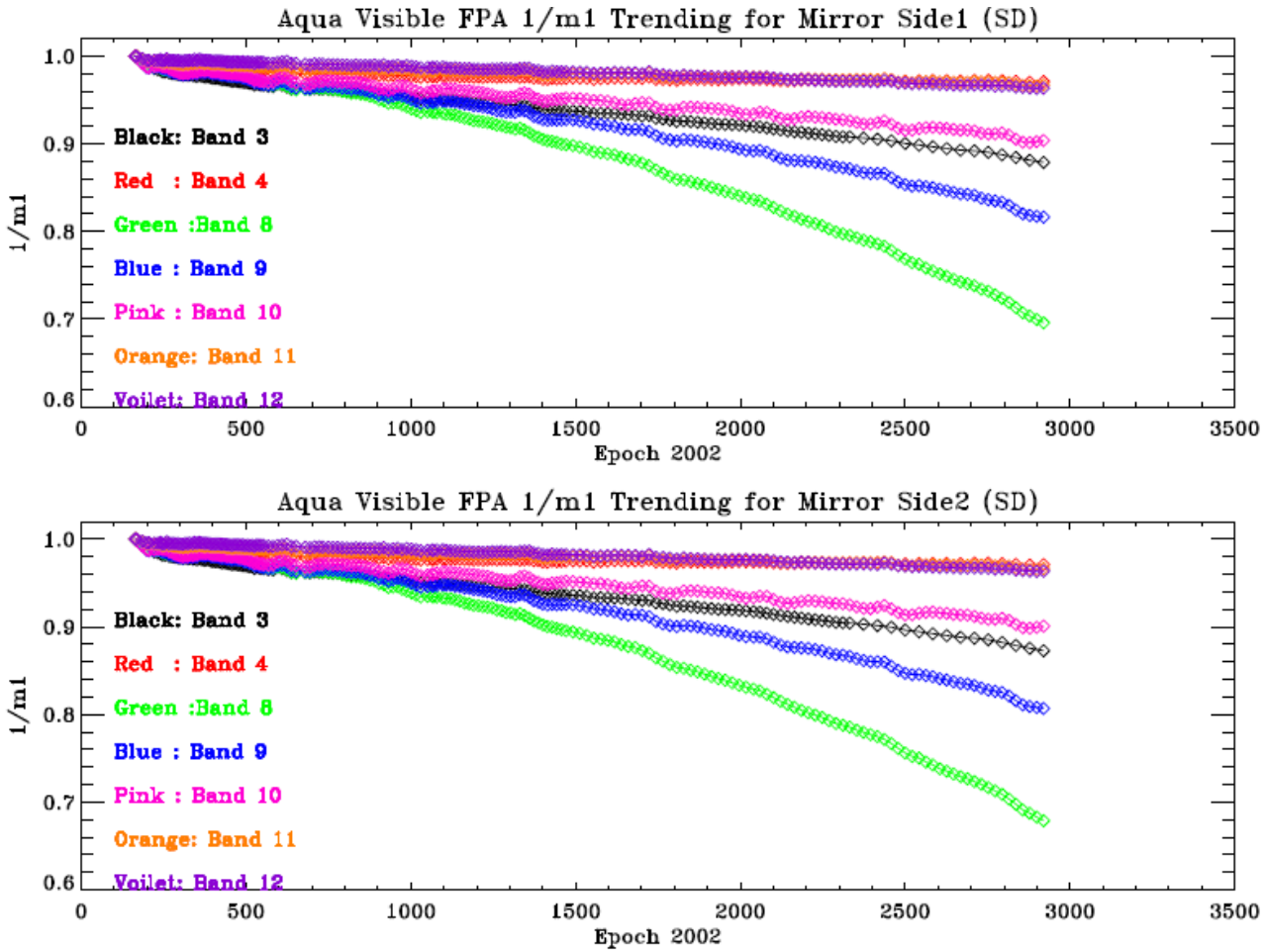
Detector Averaged



Mirror side differences are small in Terra NIR and SWIR bands

MODIS RSB Response Trending

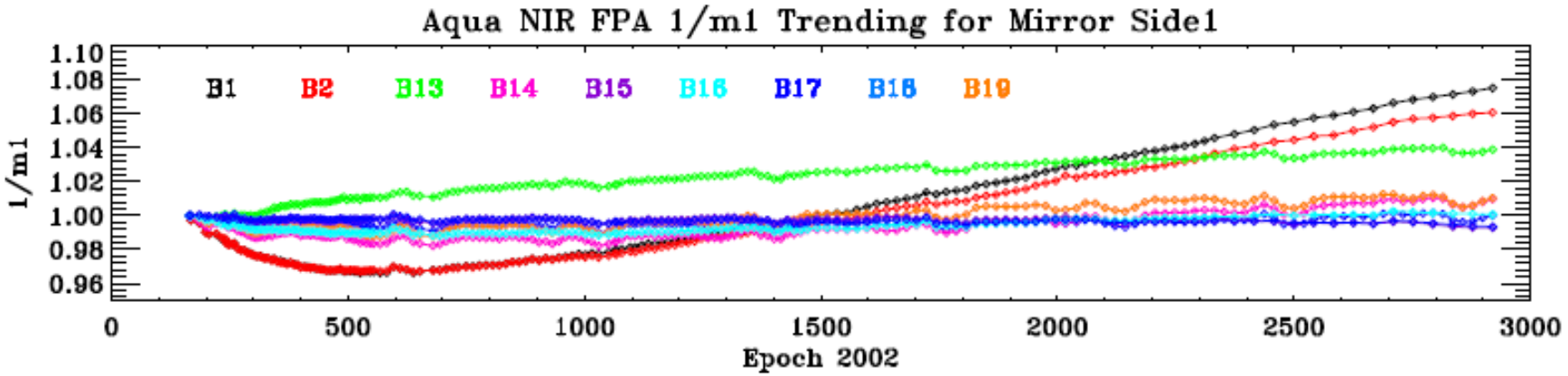
Detector Averaged

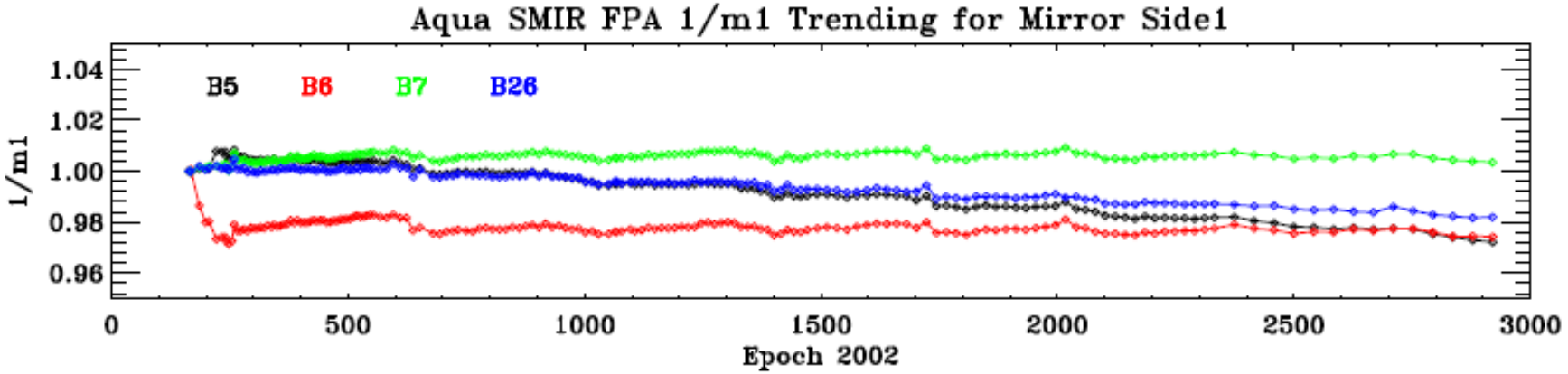


Much smaller mirror side differences in Aqua MODIS

MODIS RSB Response Trending

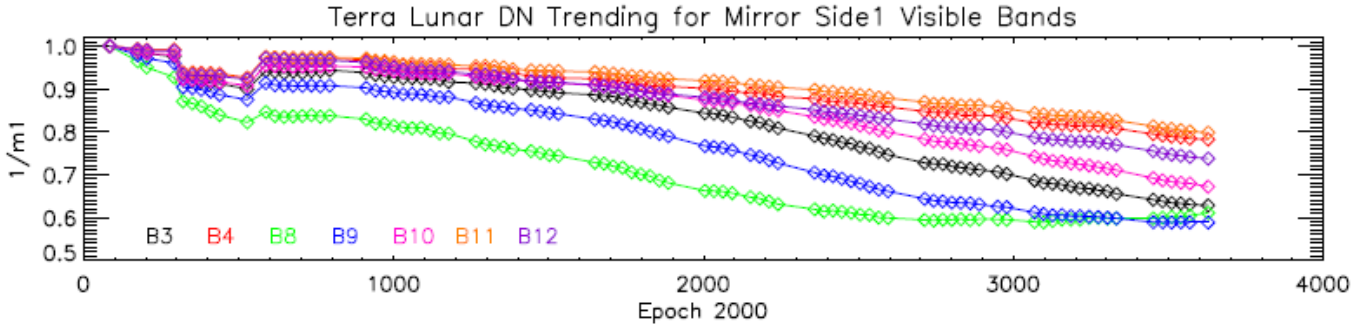
Detector Averaged

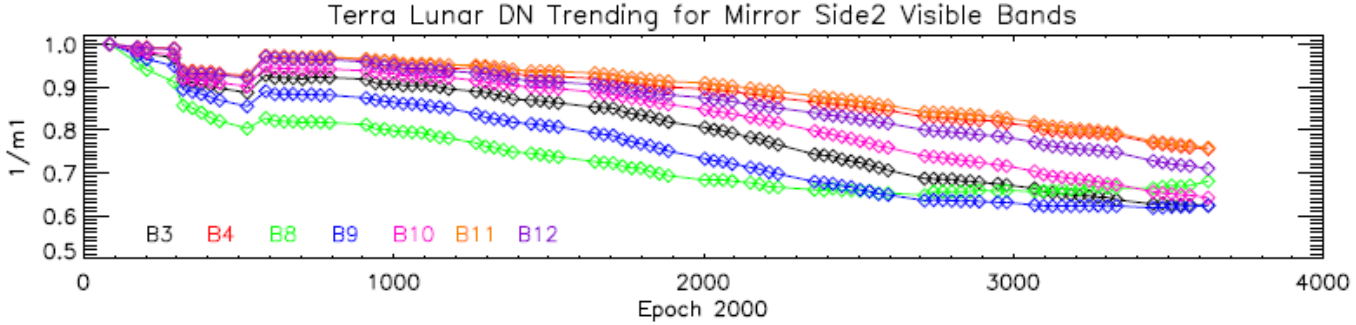


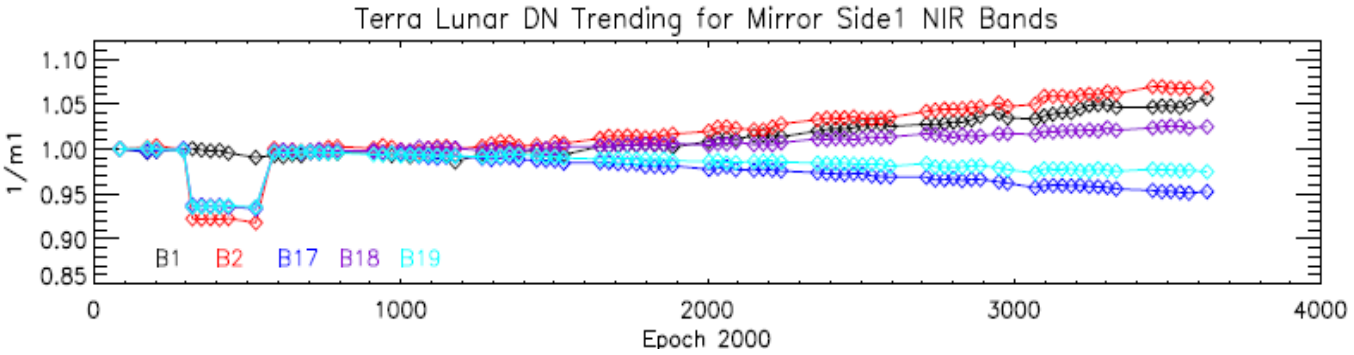


MODIS RSB Response Trending

Detector Averaged

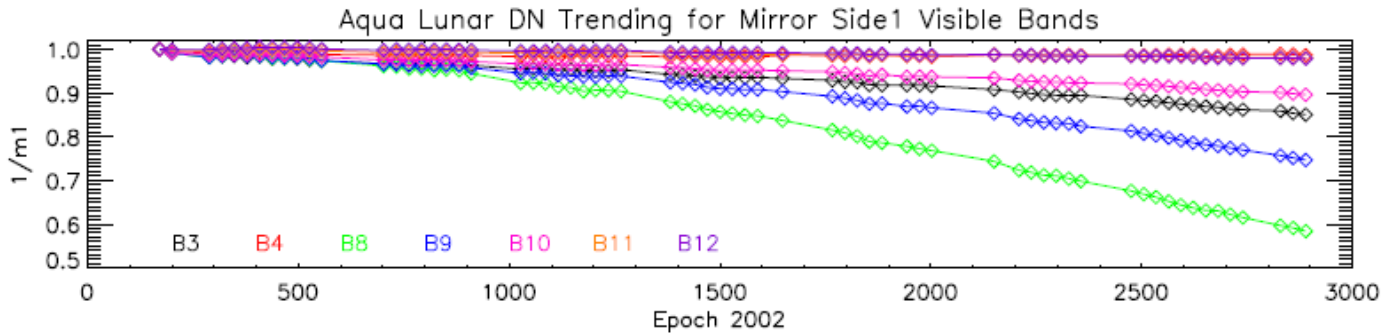


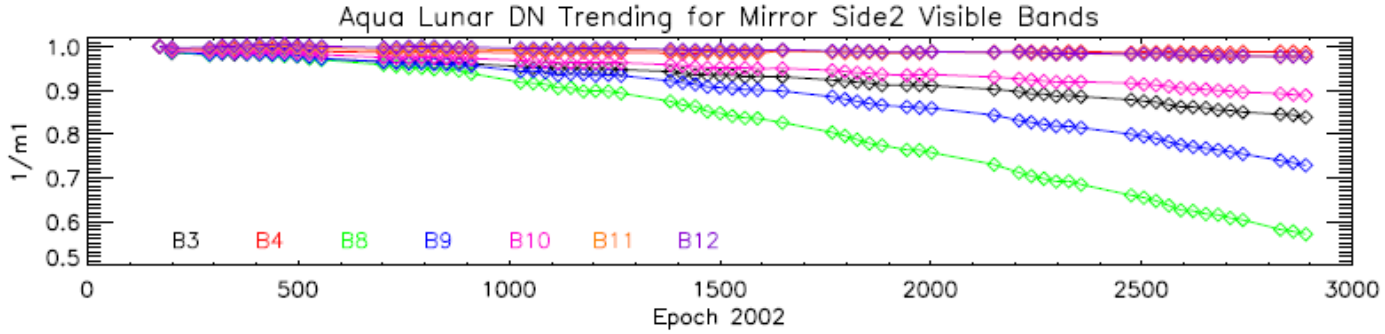


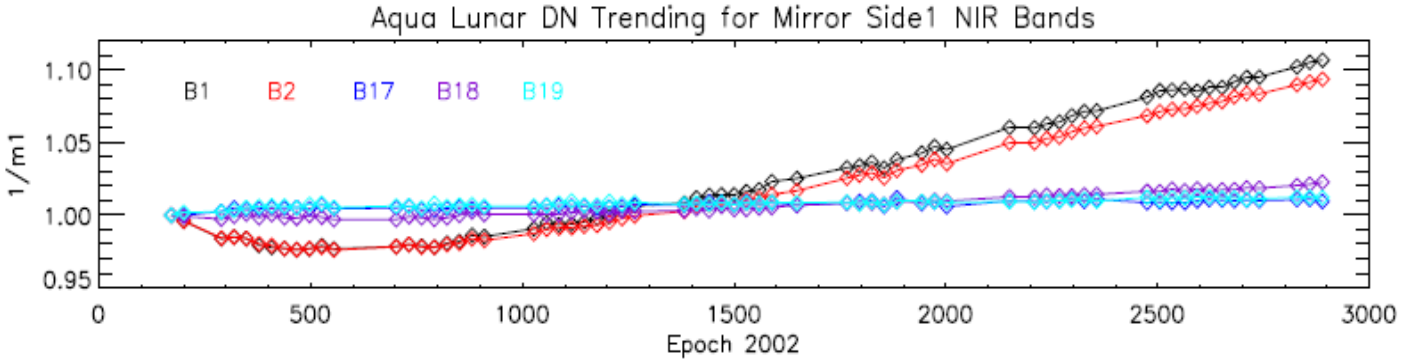


MODIS RSB Response Trending

Detector Averaged

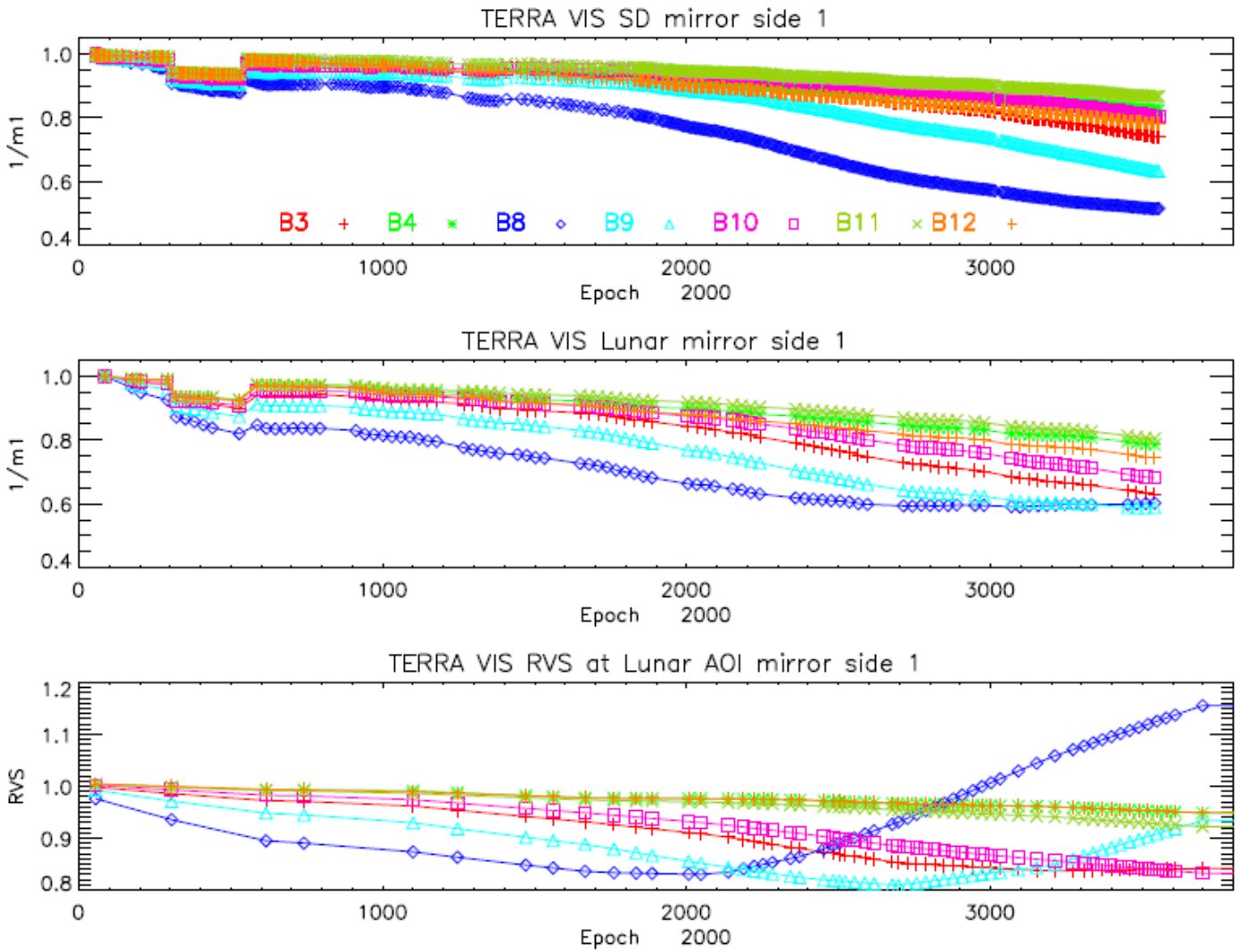






MODIS RSB RVS Trending

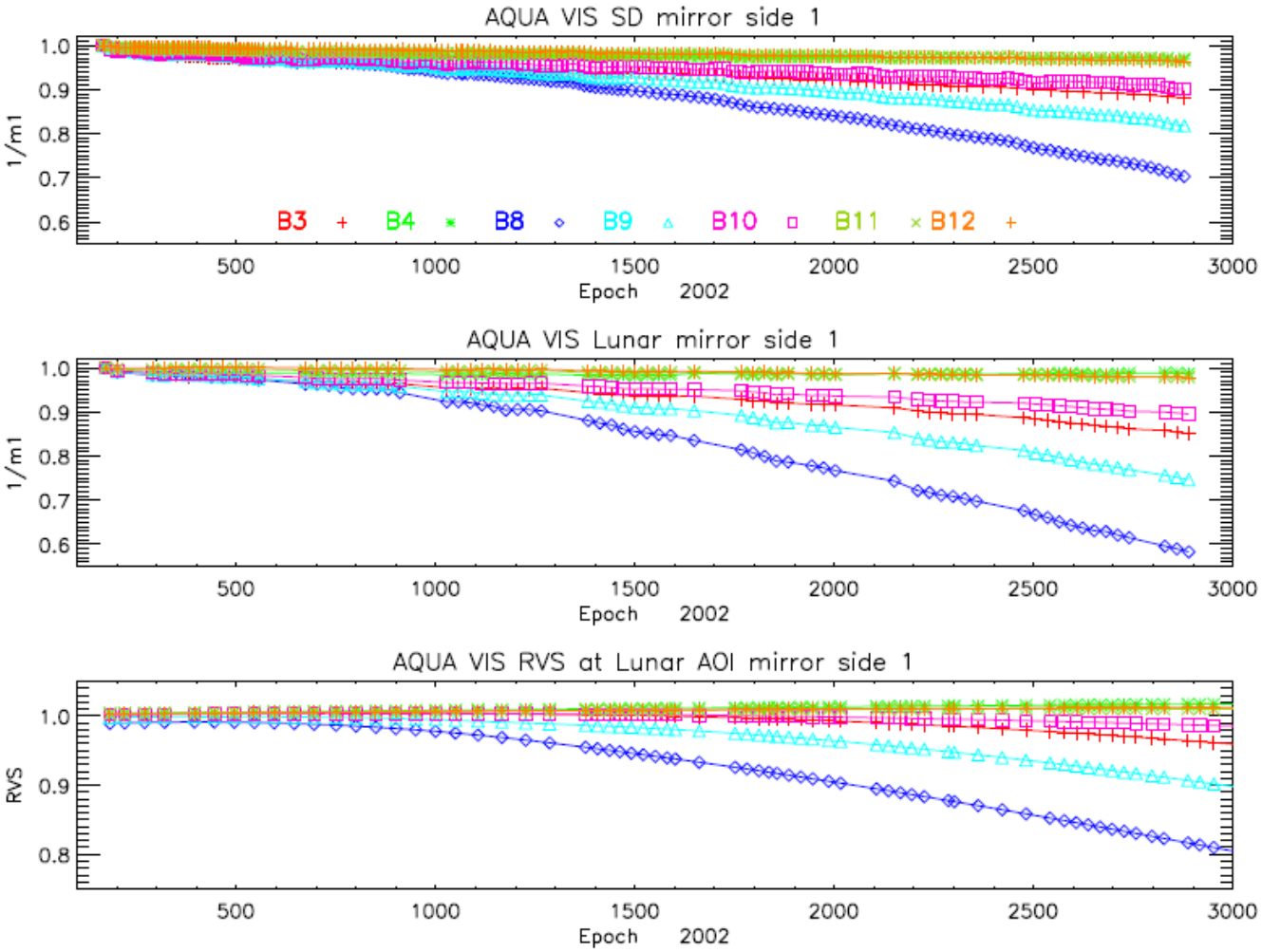
Detector Averaged



Terra band 8 RVS at AOI of the SV has changed about 24% in last few years

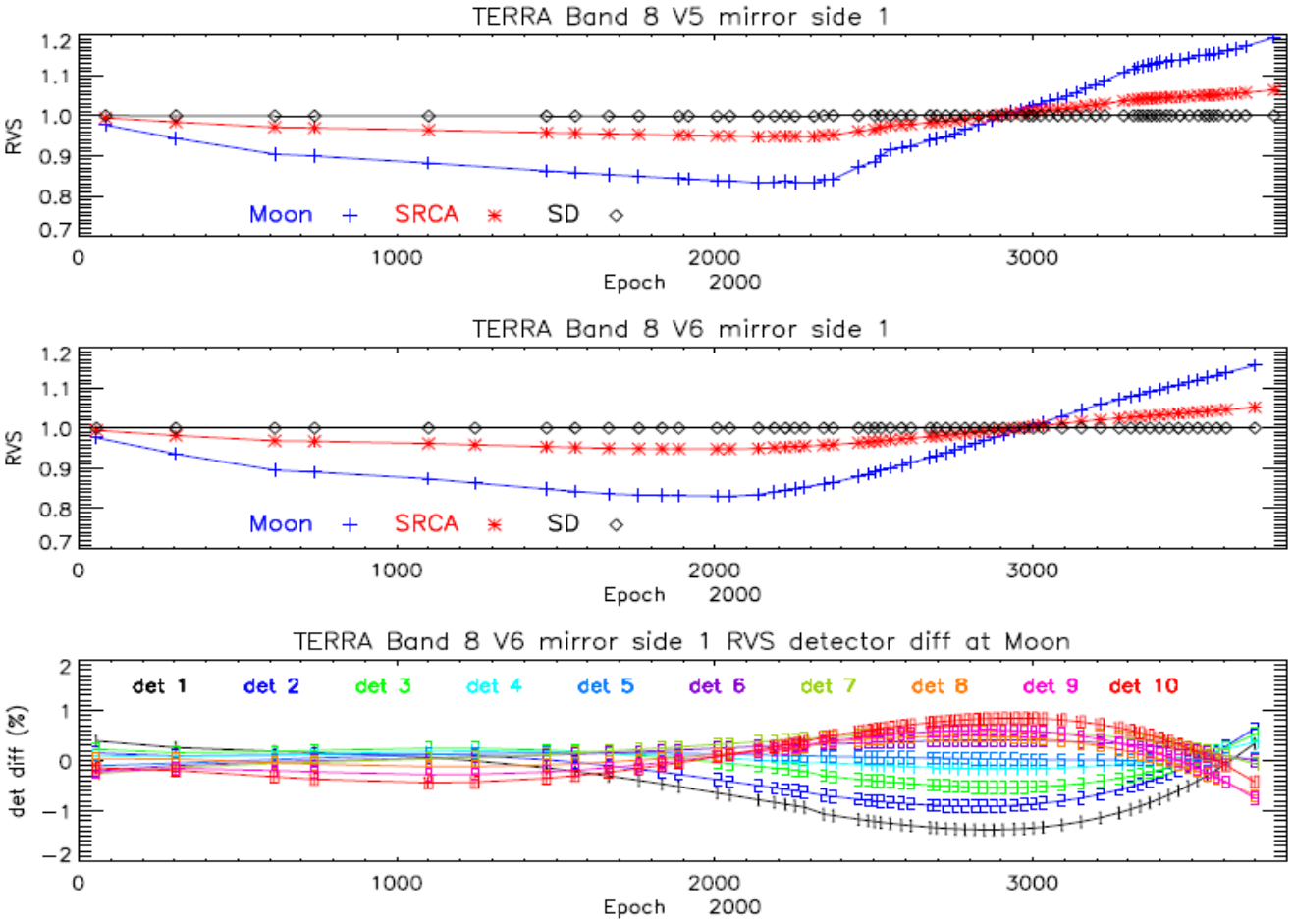
MODIS RSB RVS Trending

Detector Averaged



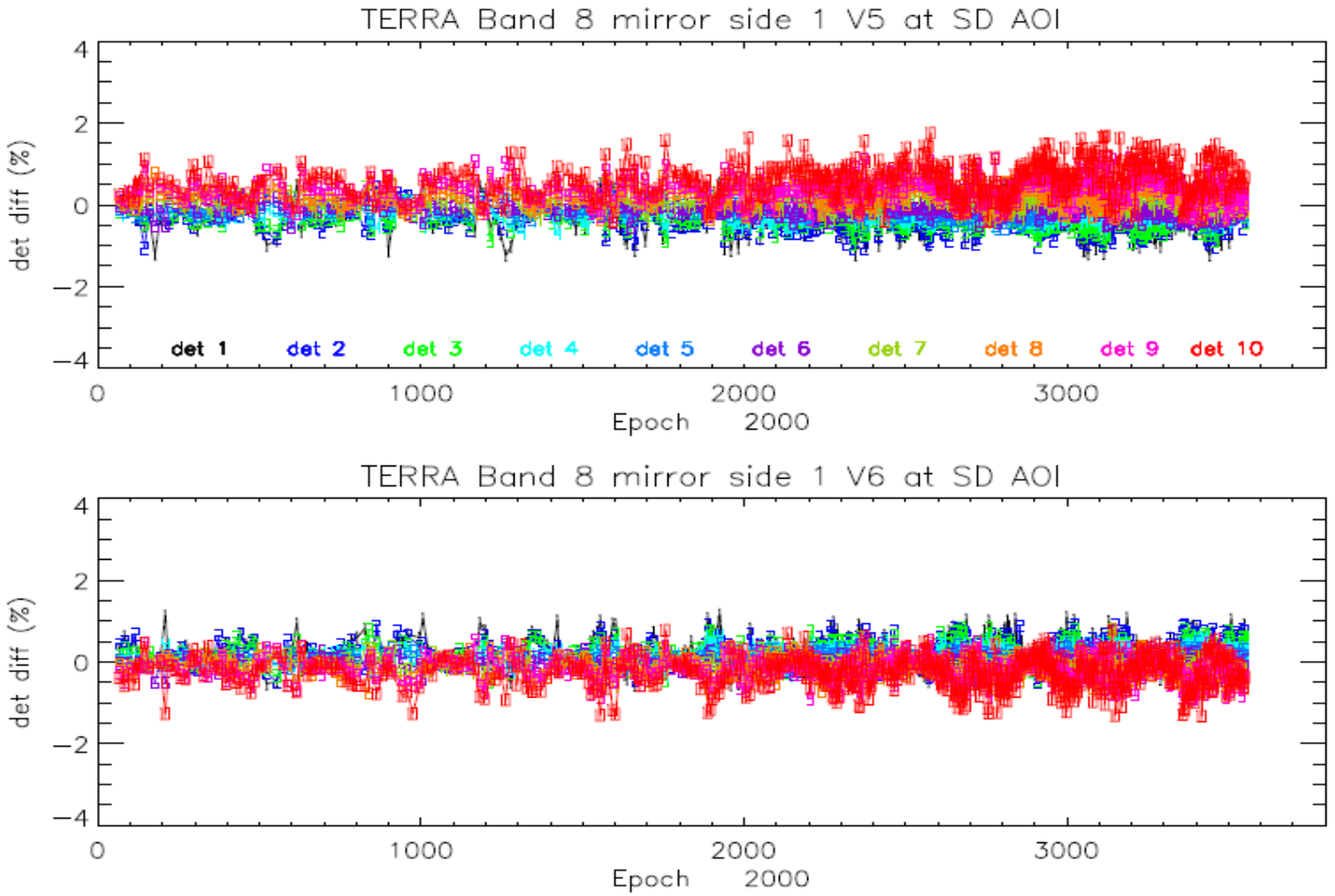
Aqua band 8 RVS at AOI of the SV has decreased about 18% since launch

Terra MODIS Band 8 RVS Trending



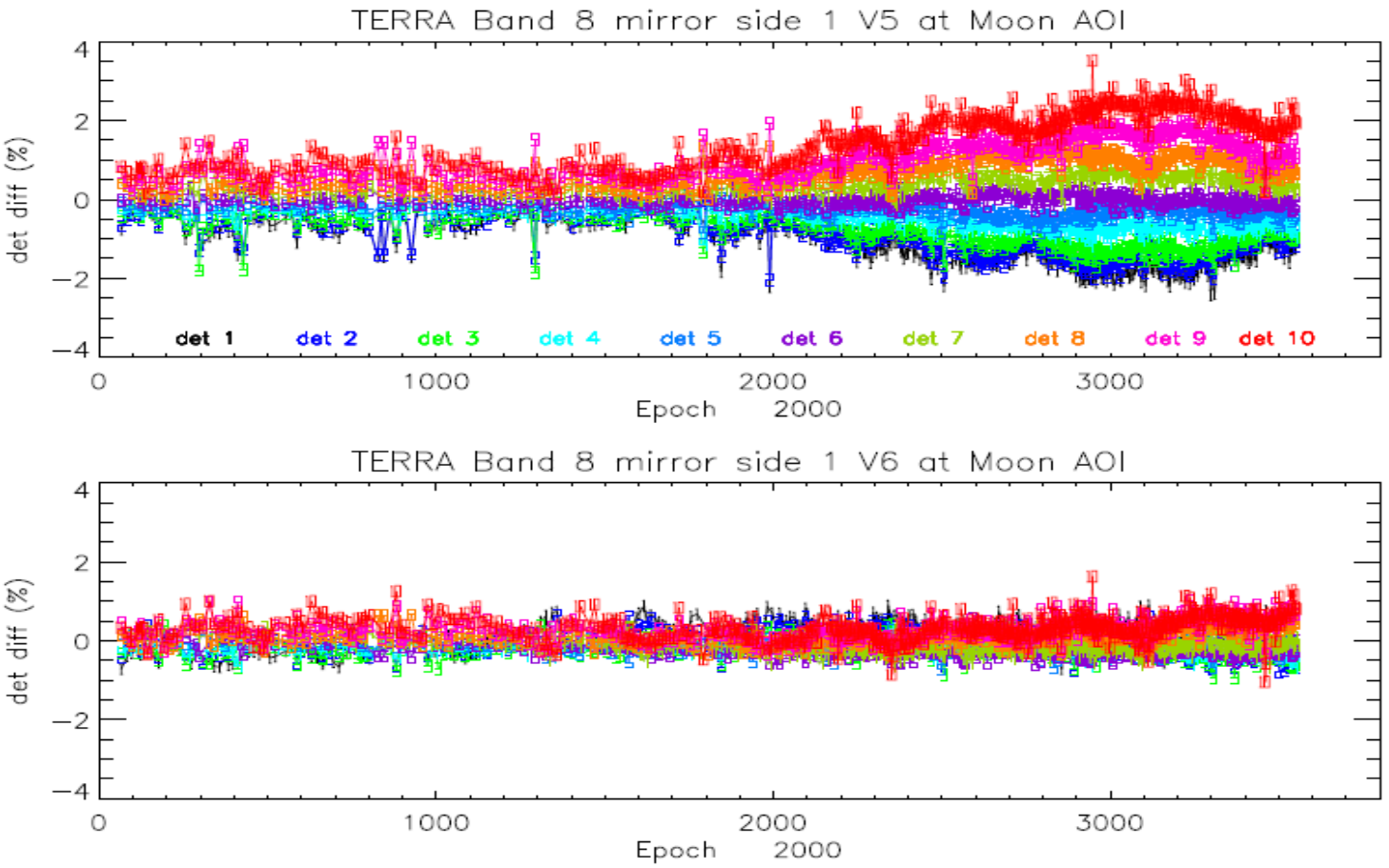
The RVS detector difference can be as large as 2.5% for Terra band 8.

Terra MODIS Band 8 EV Radiance Detector Difference Trending



In Collection 6, the striping at the AOI of the SD is reduced. This reduction is due to the application of the detector bias correction in SD m1, which is derived from EV radiance.

Terra MODIS Band 8 EV Radiance Detector Difference Trending



The striping at the AOI of the SV is significantly reduced in Collection 6. This reduction is due to the application of the detector dependent RVS.

Current Versions of RSB LUTs

❑ Collection 5 (V5)

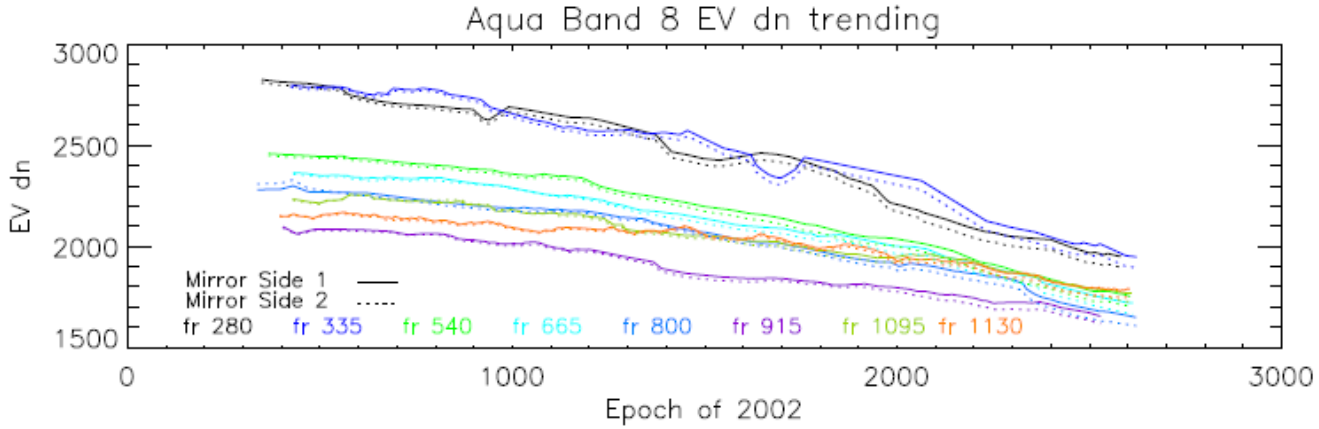
- SD BRF degradation at wavelength 940 nm is assumed to be very small and is not included in RSB calibration before 2009 for Terra and April 1, 2009 for Aqua. The degradation at the wavelength is included after the aforementioned times for both instruments.
- RSB calibration coefficients, m1, are derived from SD/SDSM calibration for both instruments
- Detector-averaged time-dependent RVS is applied to bands 1-4, 8-12, and 17-19 for both instruments
- V5 LUTs are currently in operation for both instruments

❑ Collection 6 (V6)

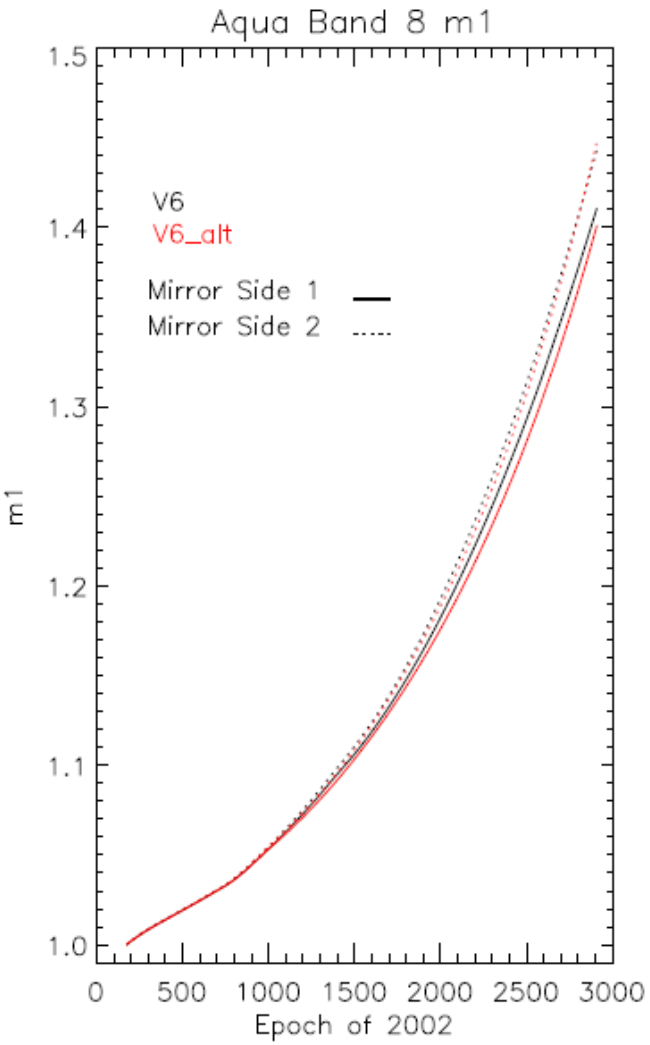
- SD BRF degradation at wavelength 940 nm is included for the entire mission for both instruments, which results in an accumulated 1.3% and 0.3% correction for Terra and Aqua Vis/Nir bands, respectively.
- Delta m1 derived from EV radiance is applied to bands 8-12 to correct the detector bias in the m1 derived from SD/SDSM calibration for both instruments
- Time-dependent RVS is applied to all RSB (including bands 13-16) except SWIR bands for both instruments
- V6 LUTs are currently being tested by science teams.

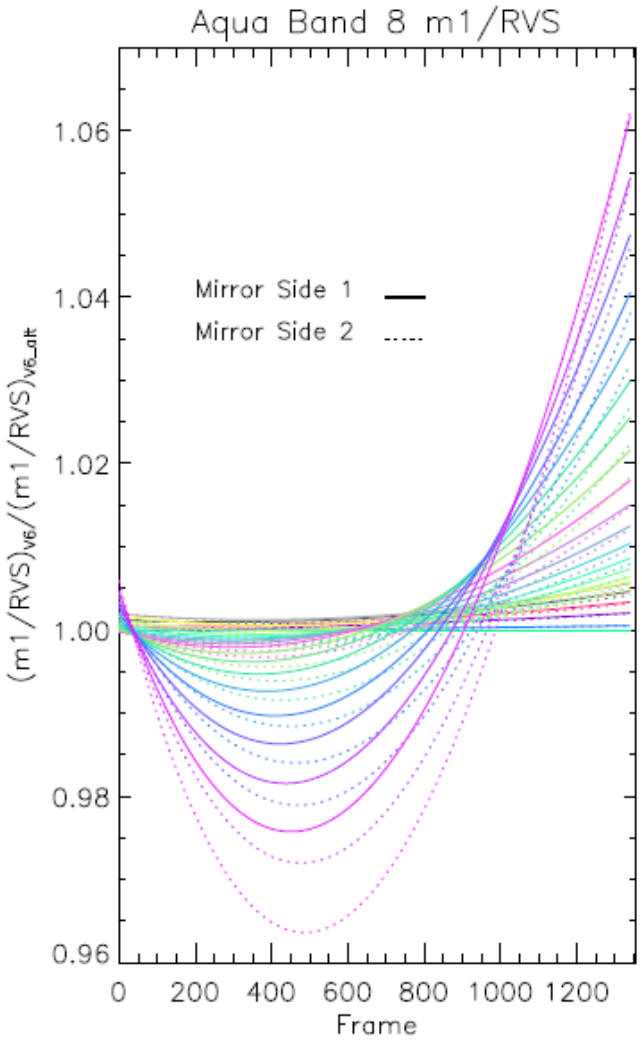
Current Versions of RSB LUTs

- **Alternative V6 LUTs**
  - Detector differences in both m1 and RVS are identical to the V6 LUTs
  - The lunar m1 is used to track the gain change at the AOI of the SV
  - The EV dn trendings at 8 selected AOIs are used to track the detector averaged m1 and RVS change since on-orbit or a chosen time
  - A quadratic form is used to describe the RVS on-orbit change for MS1 as well as MS2
  - Alternative V6 LUTs are currently being tested by Ocean group
- Aqua band 8 EV dn trending



Comparison between V6 and Alternative V6 LUTs





Summary of RSB overall Performance

❑ Terra MODIS (10 years)

- SD/SDSM and the Moon observations track the RSB gain change effectively.
- More than 50% and 46% changes in mirror side 1 and 2, respectively, are observed for MODIS band 8 responses at the SD AOI.
- The band 8 RVS at the SV AOI has changed about 24% in the last few years.
- The delta m1 correction and detector-dependent RVS significantly reduce EV striping.

❑ Aqua MODIS (7.5 years)

- SD/SDSM and the Moon observations track the RSB gain change effectively.
- Maximum response change for band 8 is around 30%, and less than 8% for NIR & SWIR bands.
- Mirror side differences are small and less than 3% for all RSB bands.
- The band 8 RVS at SV AOI has decreased 18% since launch.

MODIS Thermal Emissive Bands On-Orbit Performance

TEB Group
MODIS Characterization Support Team (MCST)

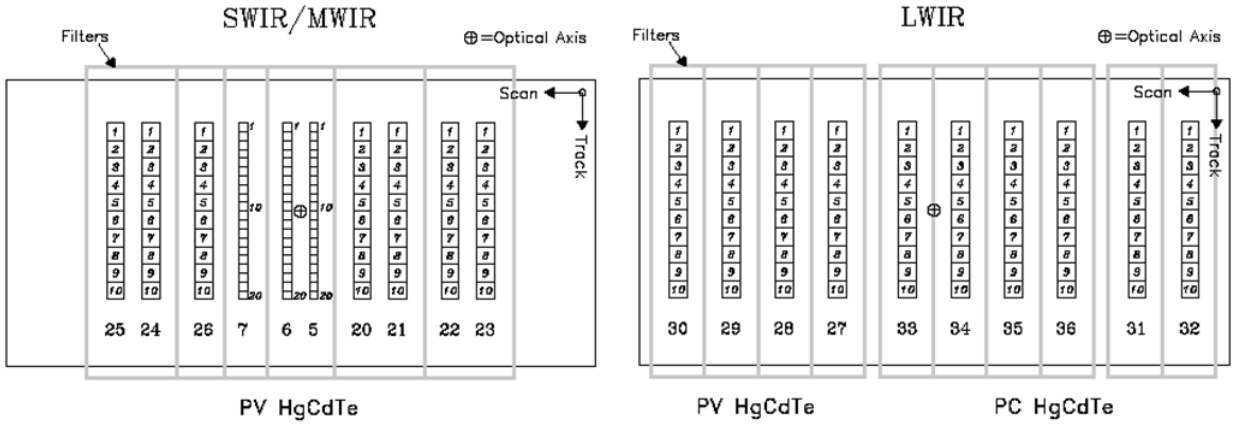
MODIS TEB Calibration Performance

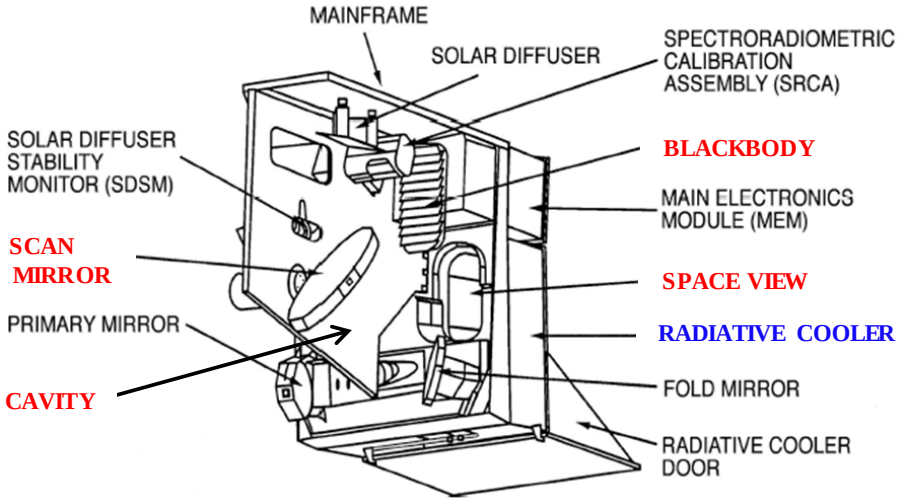
- MODIS TEB Calibration Algorithm
- Terra and Aqua MODIS TEB On-orbit Performance
  - Black Body Stability
  - Detector Response & Noise Performance
  - Noisy Detector History
  - Aqua CFPA Temperature Concern

MODIS TEB

Thermal Emissive Bands

- 16 spectral bands
- 160 detectors, 10 per band
- 2 CFPAs (SMIR, LWIR; 83K)





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

TEB Calibration Algorithm

EV Radiance (top-of-atmosphere), L_{EV}

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

- b1 is calibrated from On-board calibration radiance

$$L_{CAL} = RVS_{BB}\varepsilon_{BB}L_{BB} + (RVS_{SV} - RVS_{BB})L_{SM} + RVS_{BB}(1-\varepsilon_{BB})\varepsilon_{cav}L_{cav}$$

$$b_1 = (L_{CAL} - a_0 - a_2 dn_{BB}^2) / dn_{BB}$$

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

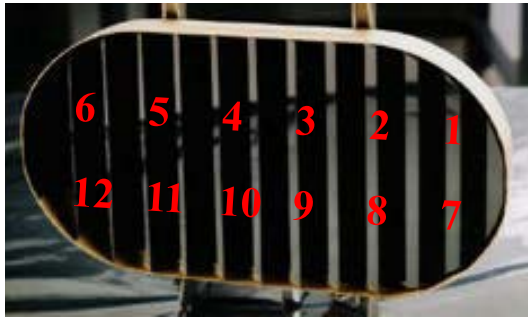
- *using quadratic algorithm*
- *for each band, detector, and mirror side*
- *performed on scan-by-scan basis*

RVS: Response Versus Scan-angle
ε: Emissivity
L: Spectral band averaged radiance (in $W/m^2 - \mu m - sr$)
dn: Digital count with background correction
a_0: Detector response offset
b_1: Detector response linear coefficient
a_2: Detector response nonlinear coefficient

- Warm-up and cool-down (WUCD)
  - *BB temperature varies ~270 to 315K*
  - *performed quarterly*
  - *a_0/a_2 characterization and Band 21 b1 calibration*
  - *NEdT @ typical temperature*

MODIS TEB Calibration Performance

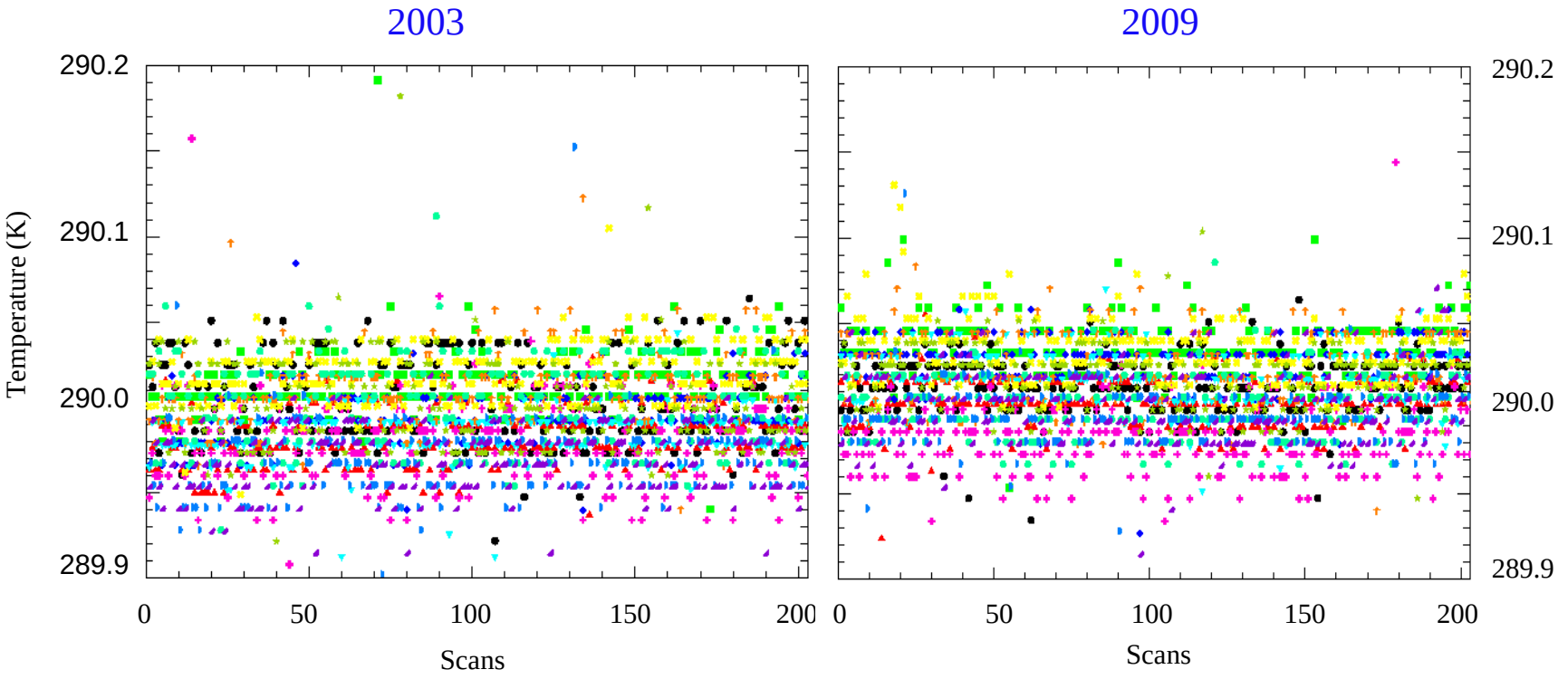
- MODIS TEB Calibration Algorithm
- Terra and Aqua MODIS TEB On-orbit Performance
  - Black Body Stability
  - Detector Response & Noise Performance
  - Noisy Detector History
  - Aqua CFPA Temperature Concern



12 thermistors are evenly embedded in BB panel and the temperature is measured scan-by-scan

Terra BB Short-term Stability

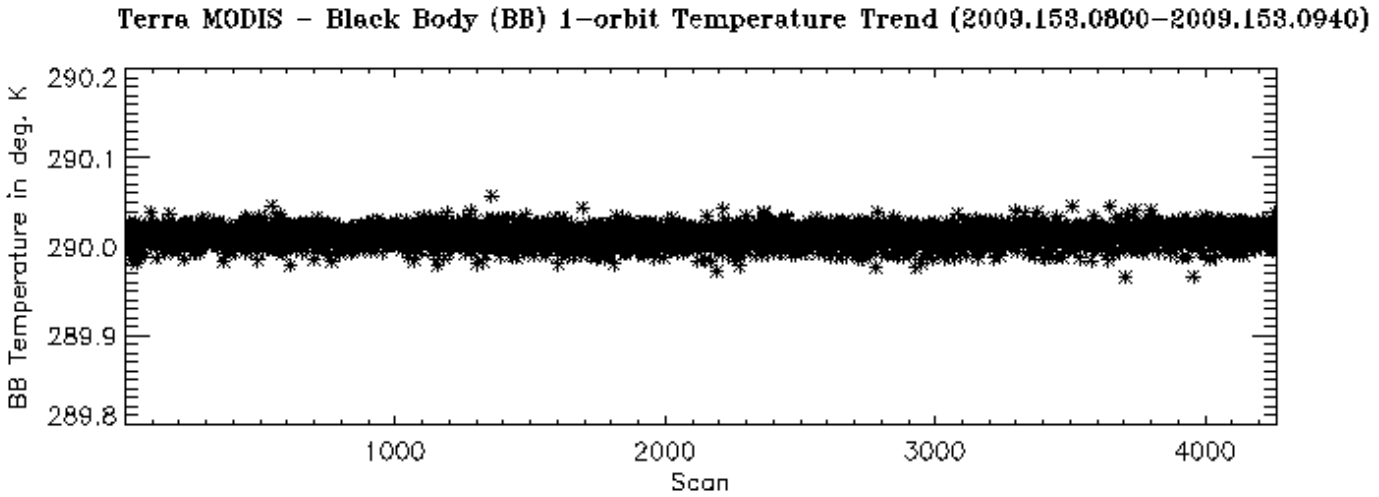
Temperatures from 12 individual BB thermistors (1 granule, scan-by-scan)

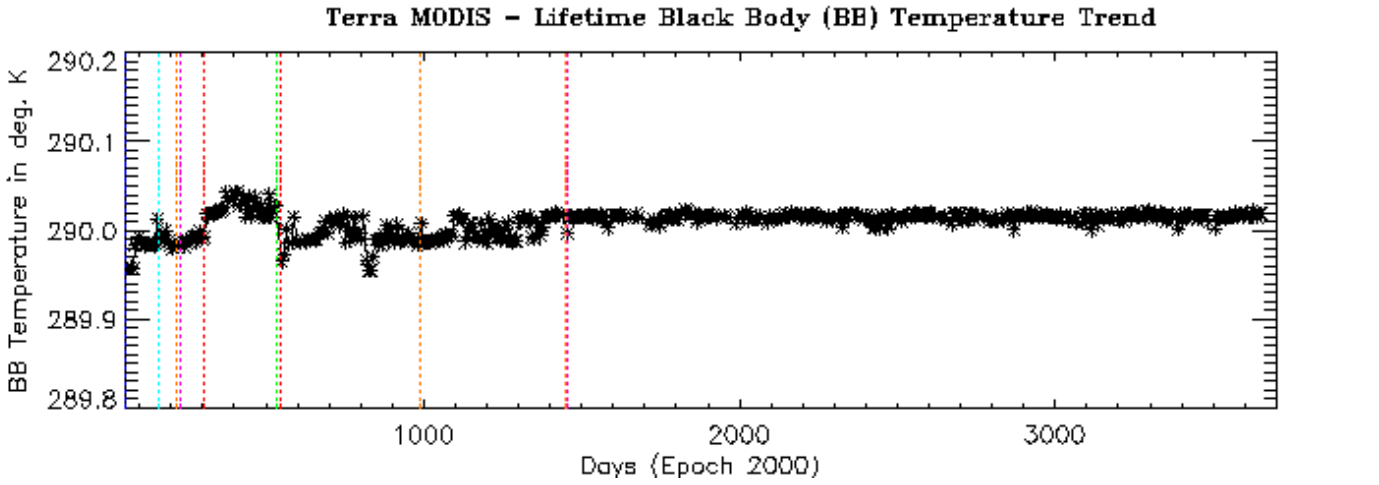


Standard deviation of temperature measured using individual thermistor
(203 scans in one granule, in K)

Thermistor #	1	2	3	4	5	6	7	8	9	10	11	12
2003	0.029	0.031	0.025	0.024	0.034	0.024	0.029	0.031	0.027	0.037	0.022	0.030
2009	0.015	0.032	0.029	0.024	0.020	0.022	0.023	0.045	0.018	0.017	0.016	0.027

Terra BB On-Orbit & Lifetime Performance

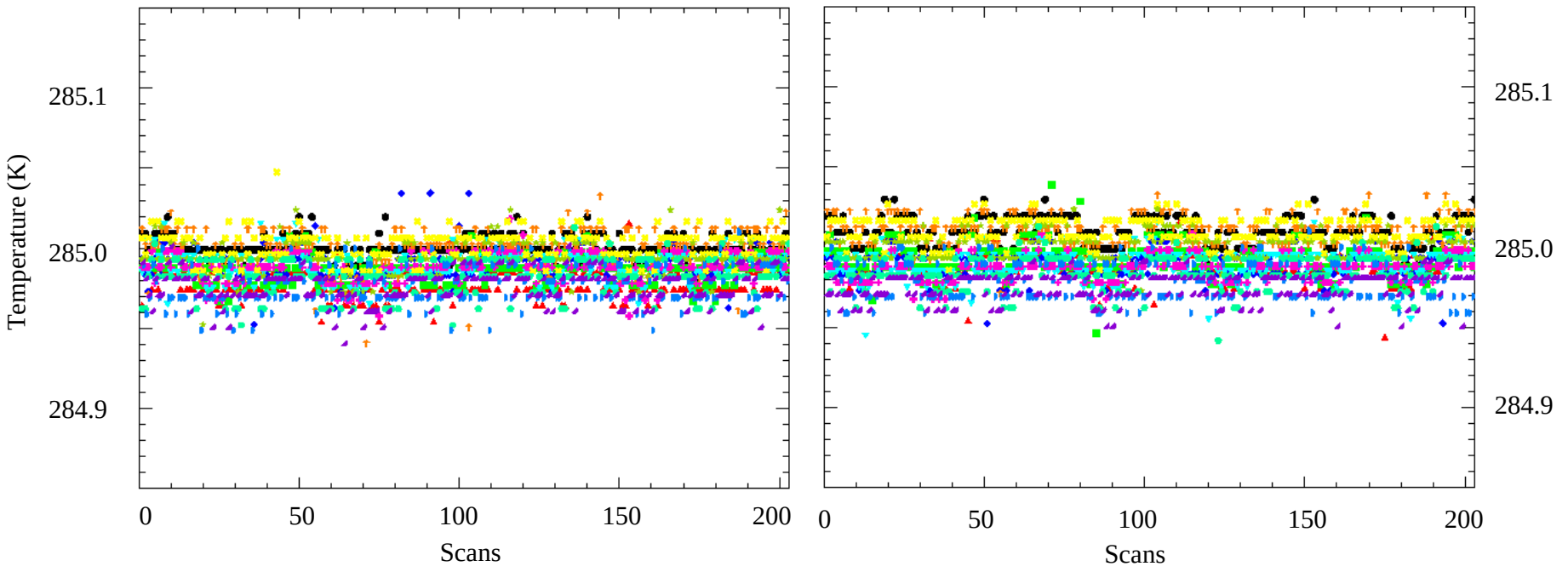




Day 2000055 – Nadir Door Open
Day 2000160 – CFPA Lost Control
Day 2000218 – Formatter Anomaly
Day 2000232 – Back in Science Mode
Day 2000304, 2001183 – switch to B side, A side
Day 2001166 – PS2 anomaly
Day 2002260 – Formatter switched to B-Side
Day 2003350 – Safe Mode
Day 2003358 – Back in Science Mode

Aqua BB Short-term Stability

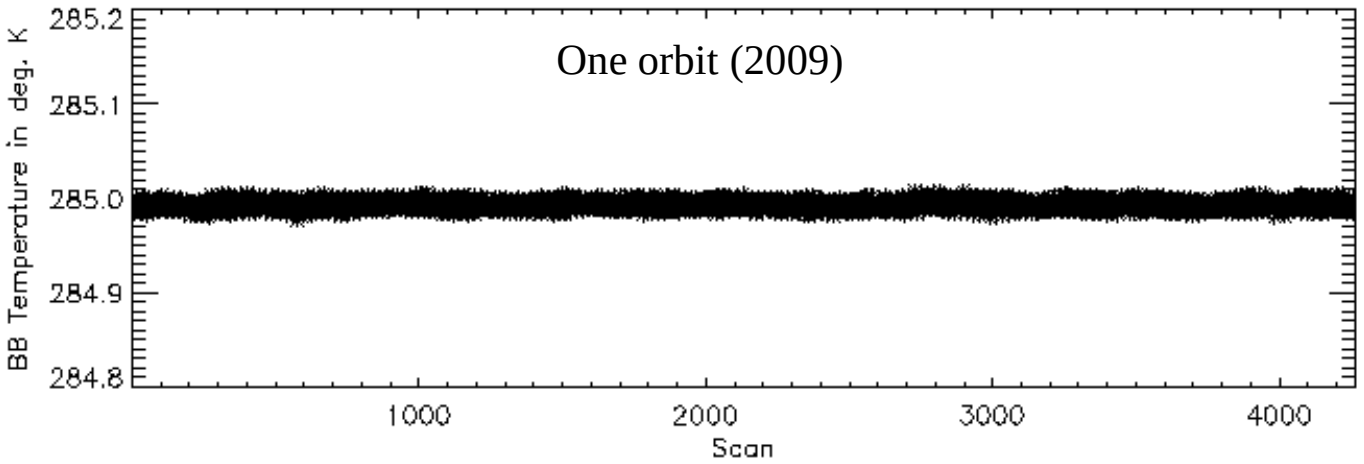
Temperatures from 12 individual BB thermistors (1 granule, scan-by-scan)

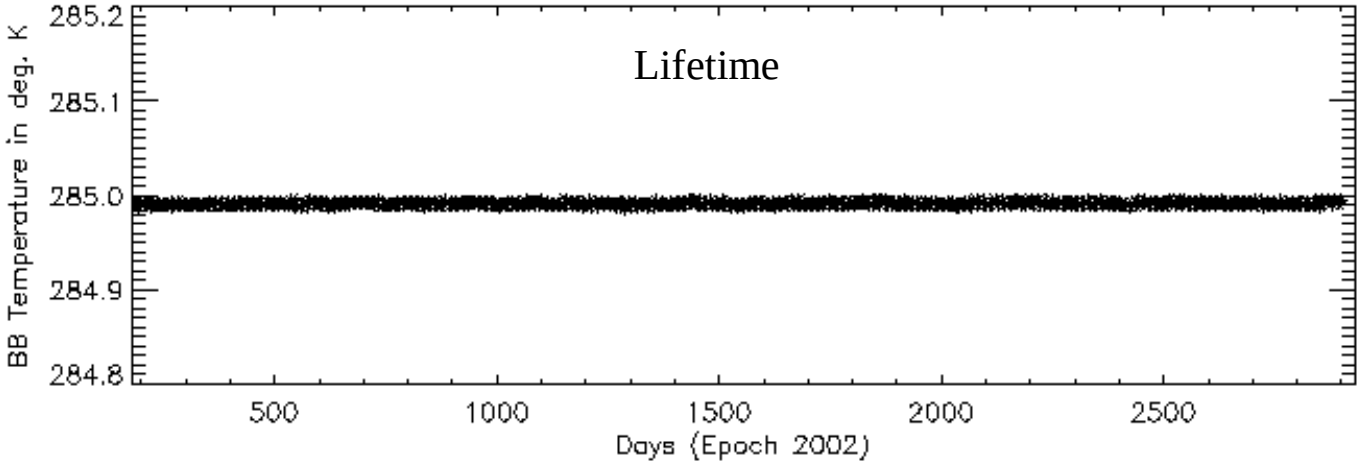


Standard deviation of temperature measured using individual thermistor
(203 scans in one granule, in K)

Thermistor #	1	2	3	4	5	6	7	8	9	10	11	12
2002	0.007	0.008	0.008	0.010	0.009	0.009	0.009	0.012	0.010	0.011	0.012	0.010
2009	0.009	0.010	0.010	0.009	0.010	0.008	0.008	0.010	0.009	0.010	0.012	0.009

Aqua BB On-Orbit and Lifetime Performance



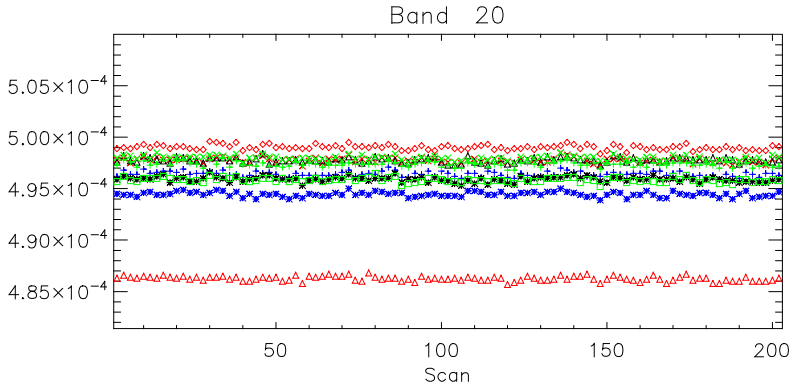


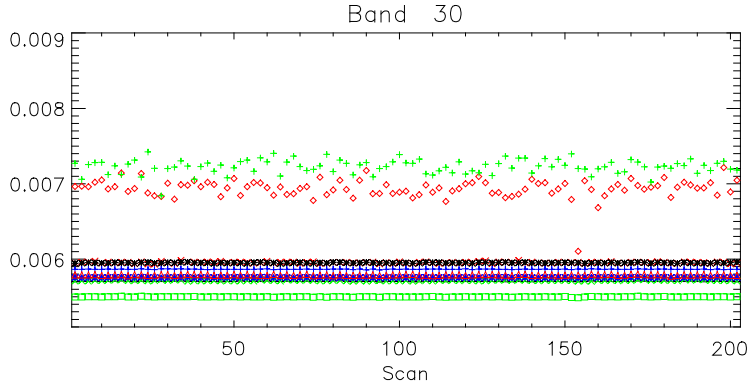
MODIS TEB Calibration Performance

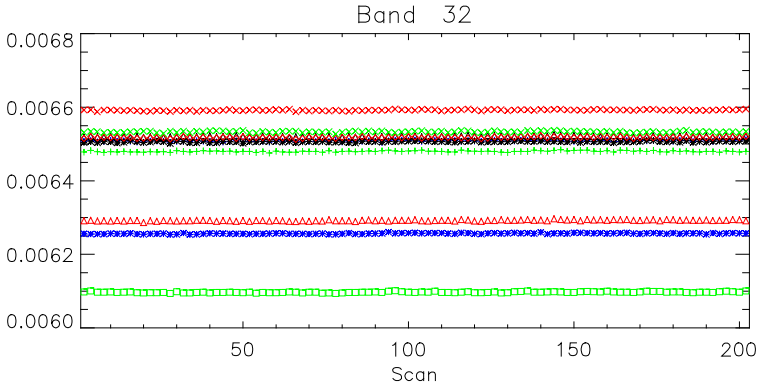
- MODIS TEB Calibration Algorithm
- Terra and Aqua MODIS TEB On-orbit Performance
  - Black Body Stability
  - Detector Response & Noise Performance
  - Noisy Detector History
  - Aqua CFPA Temperature Concern

Terra b1 Short-term Stability

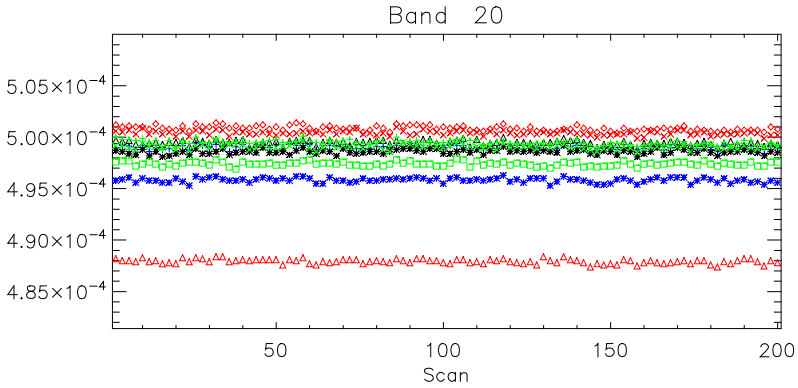
2003/295

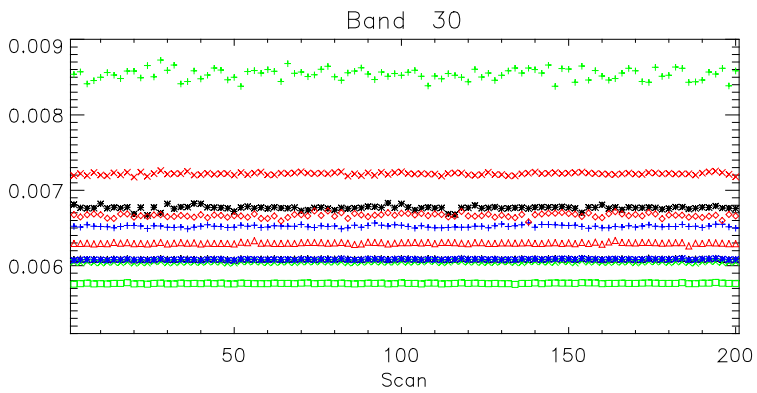


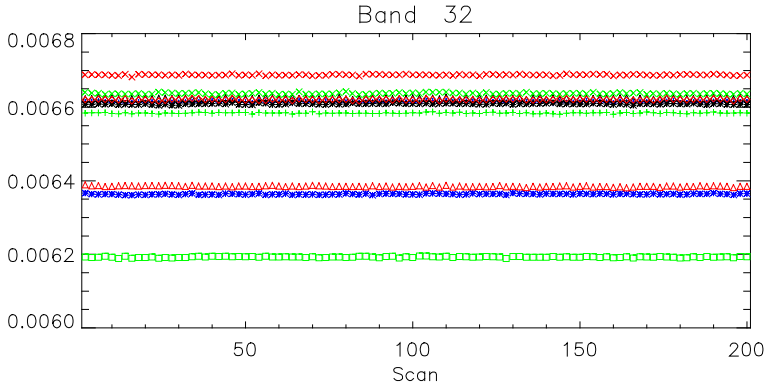




2009/361

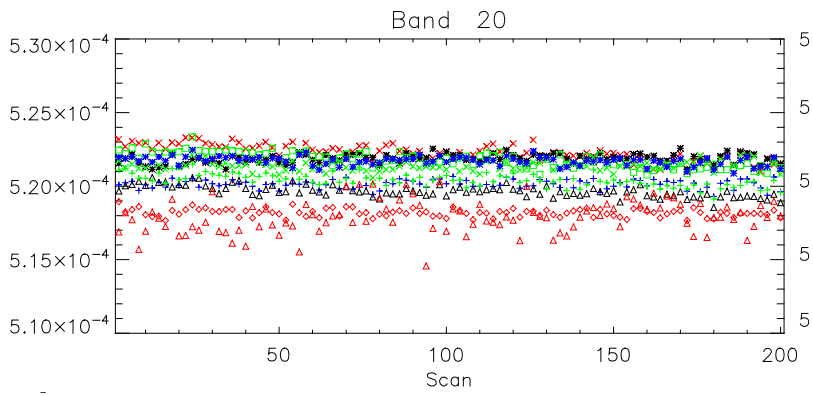


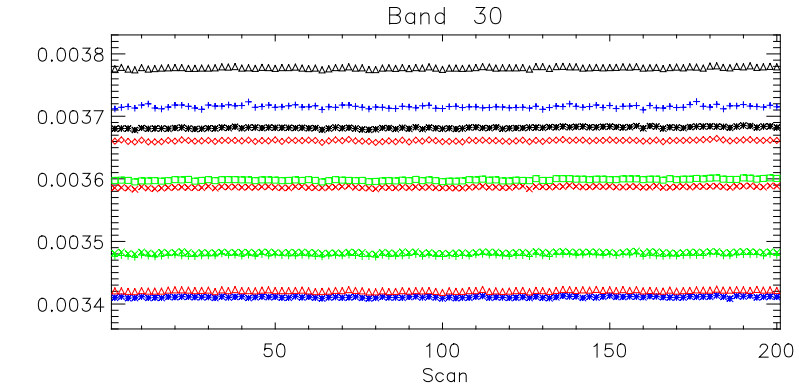


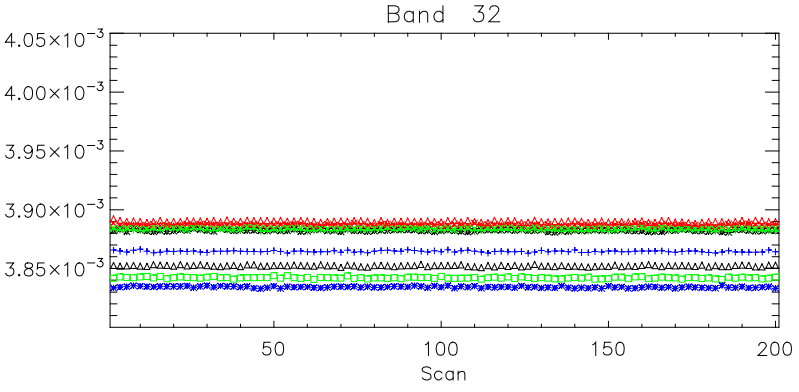


Aqua b1 Short-term Stability

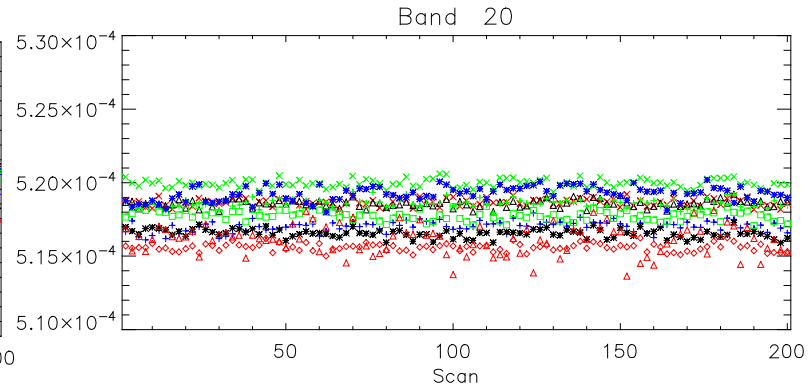
2002/266

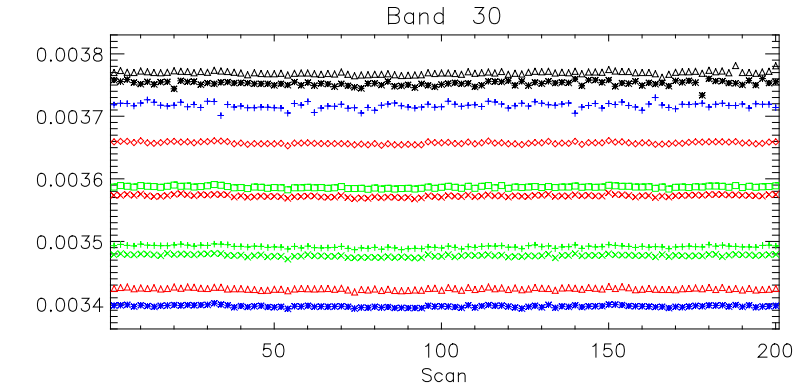


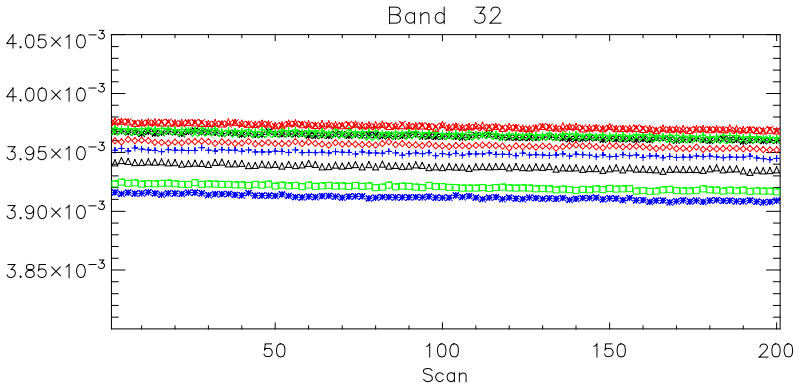




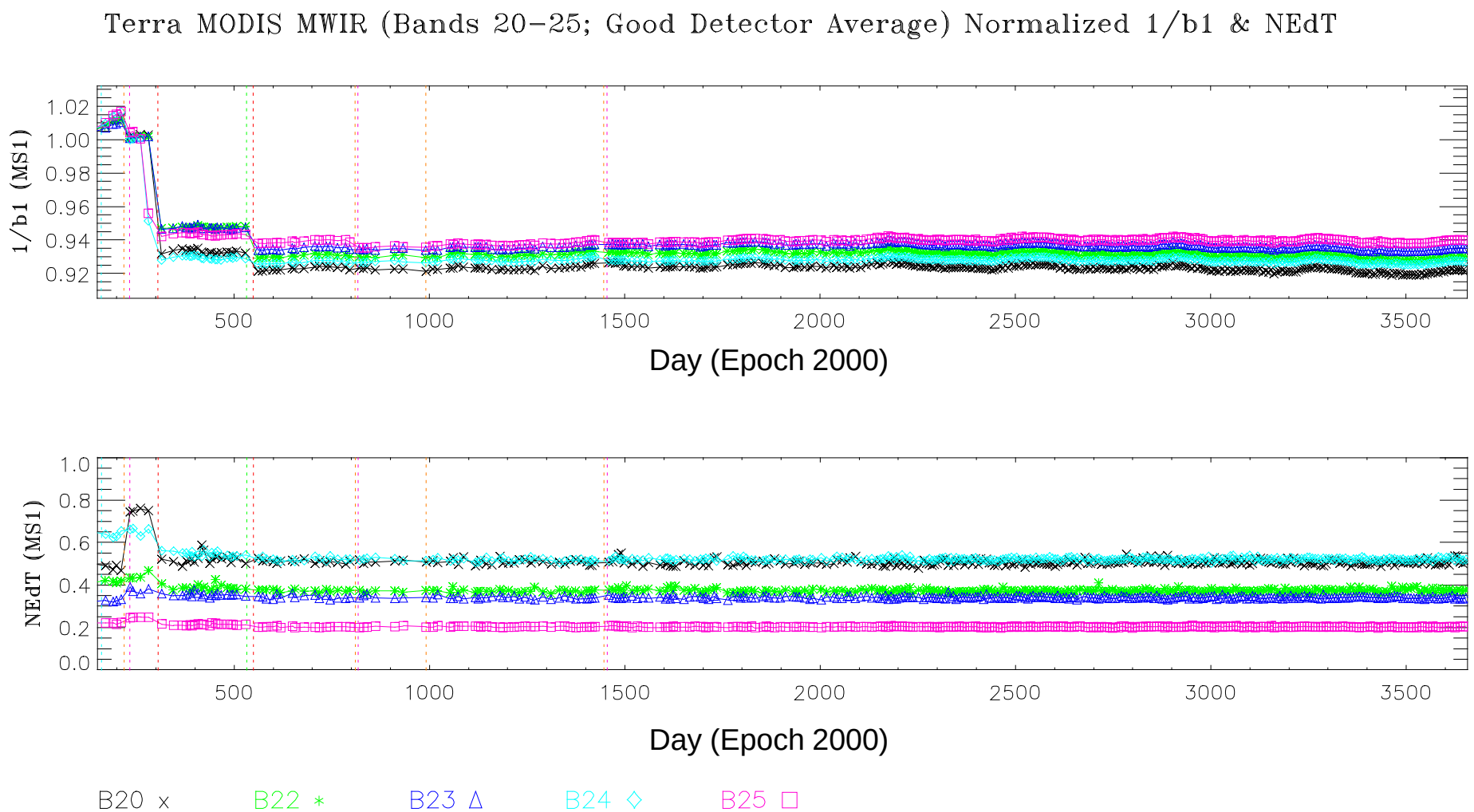
2009/349



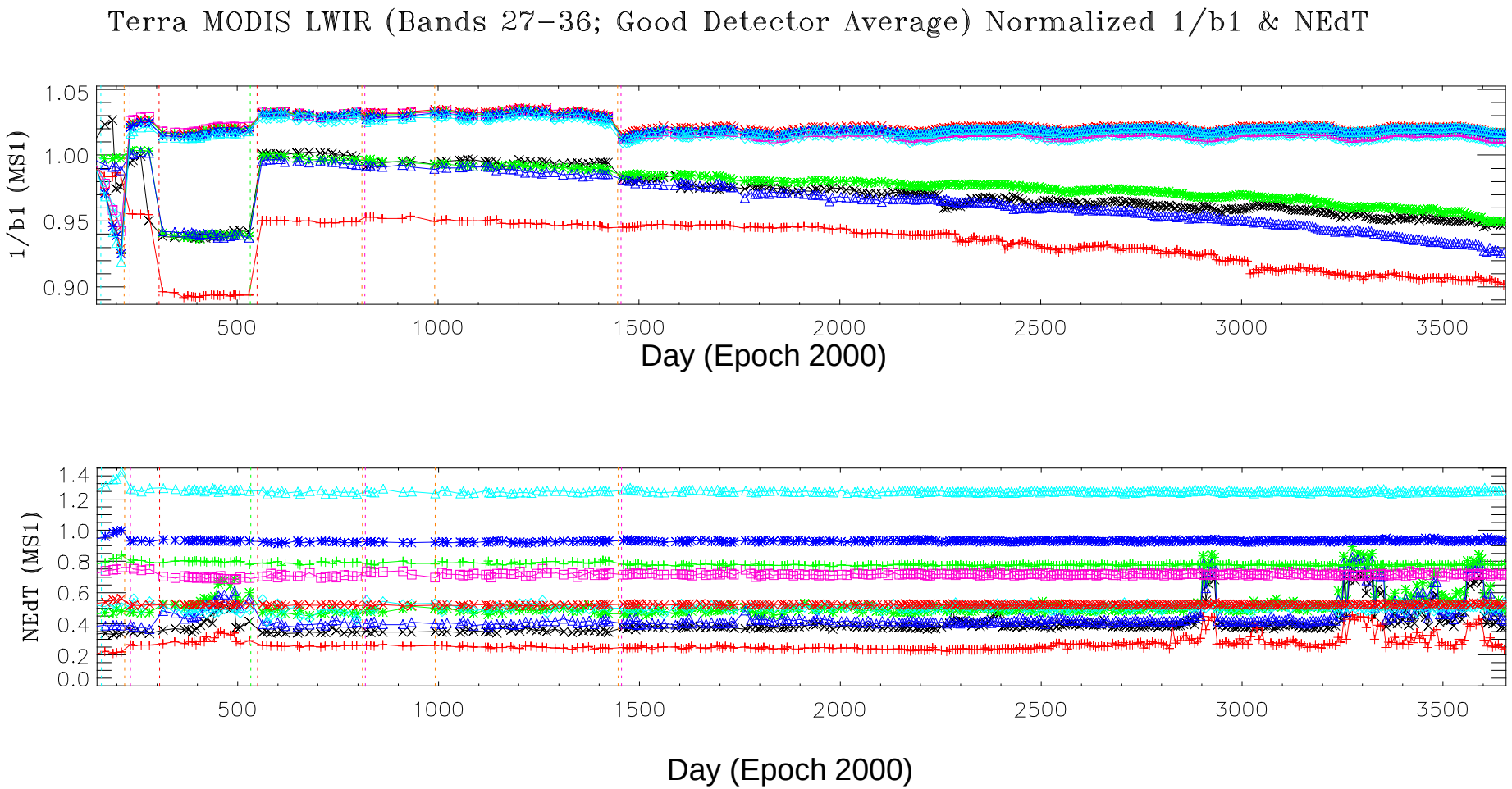




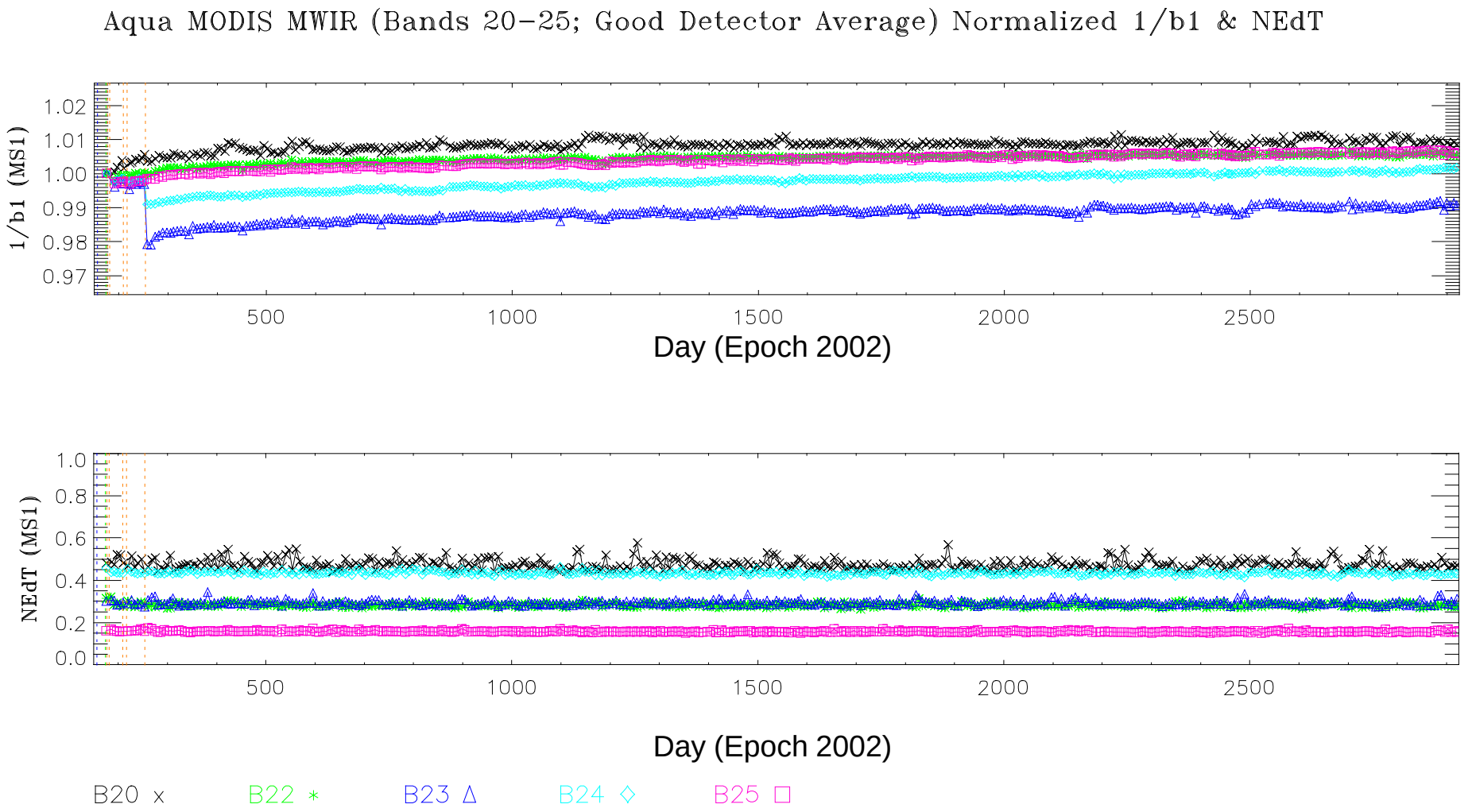
Terra MODIS TEB MWIR Response Trend



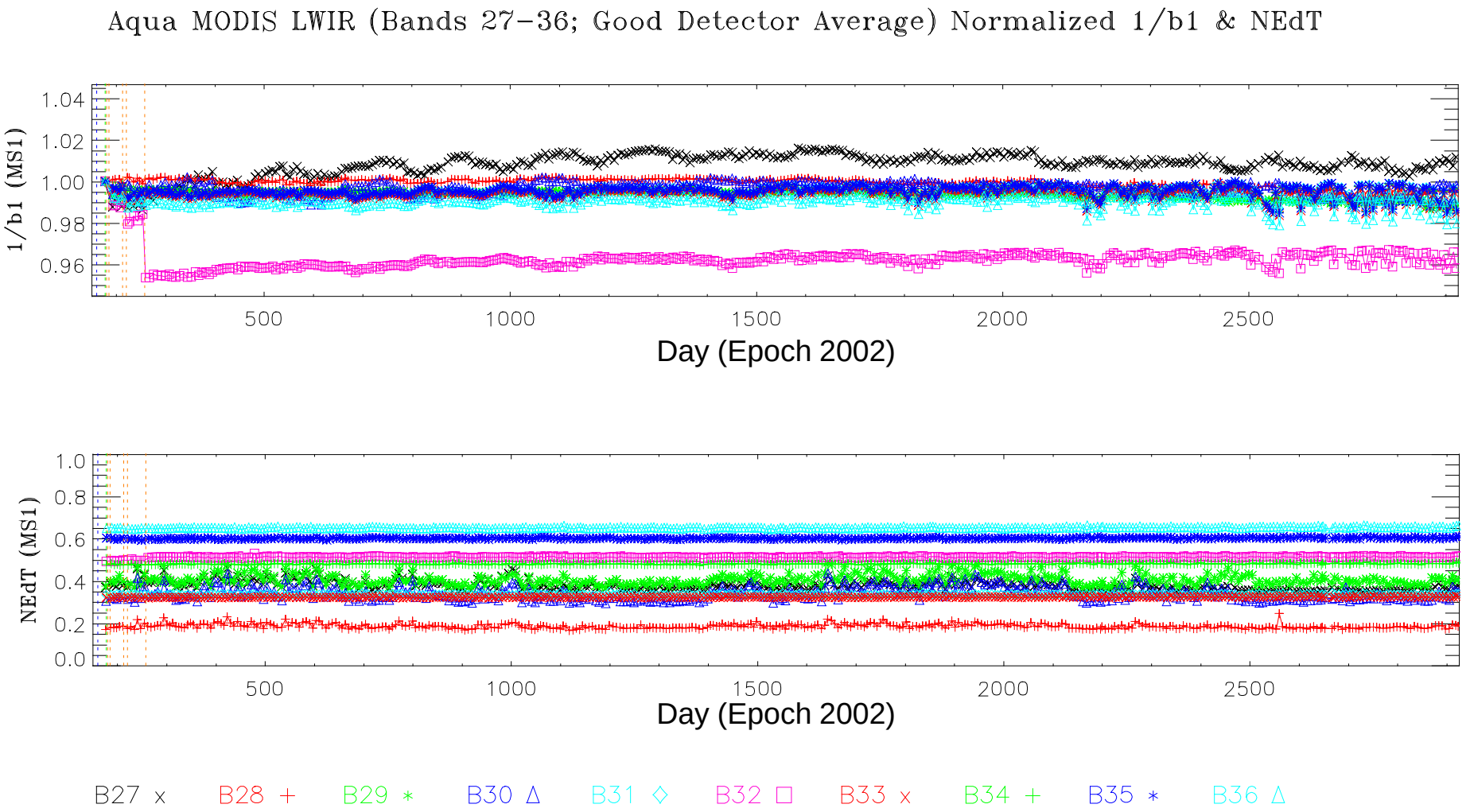
Terra MODIS TEB LWIR Response Trend



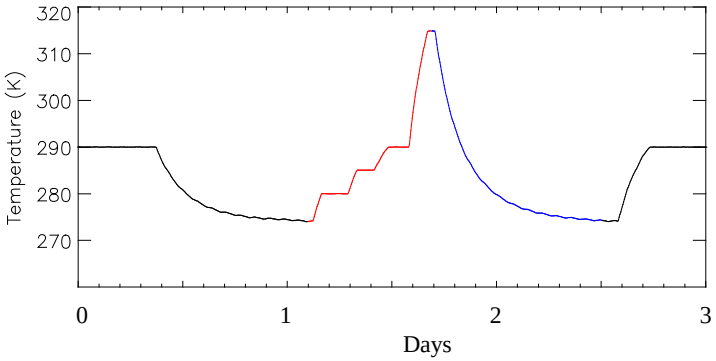
Aqua MODIS TEB MWIR Response Trend



Aqua MODIS TEB LWIR Response Trend



MODIS Warm-up and Cool-down Process



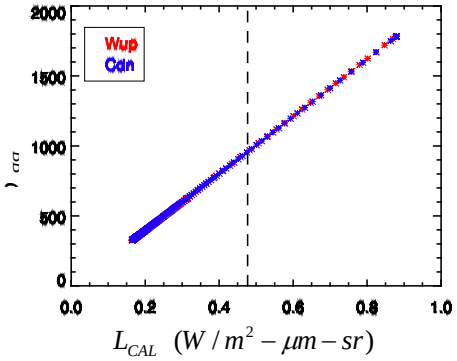
- performed quarterly
- a_0/a_2 characterization and band 21 b_1 calibration

$$L_{CAL} = a_0 + b_1 dn_{BB} + a_2 dn_{BB}^2$$

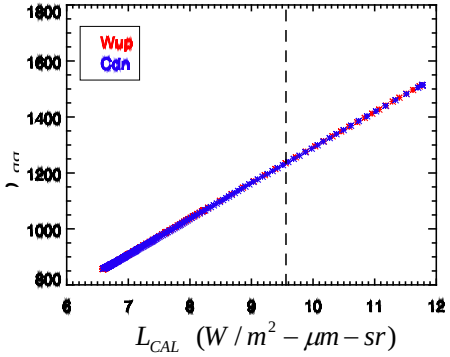
- NEdT vs BB temperature

→ NEdT @ typical temperature

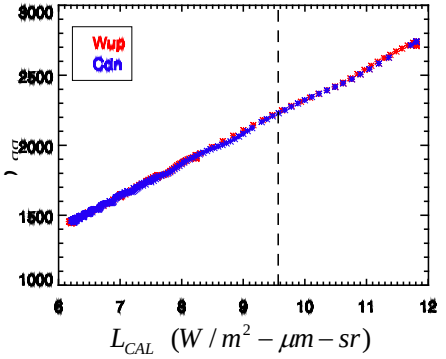
Terra band 20



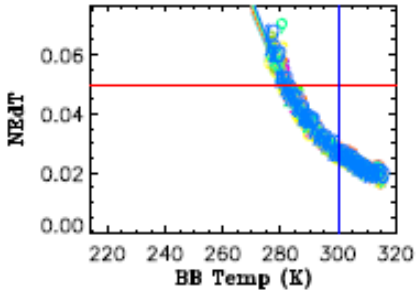
Terra band 31



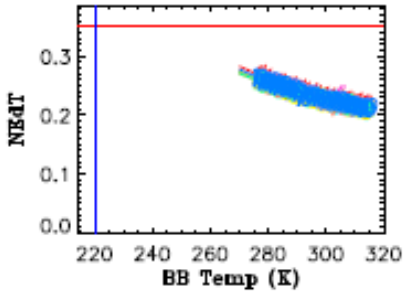
Aqua band 31



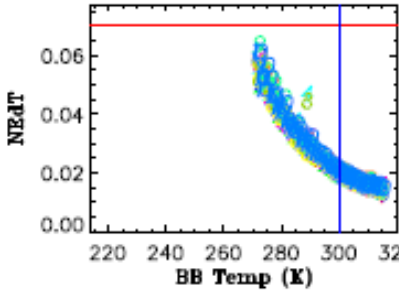
Terra band 20



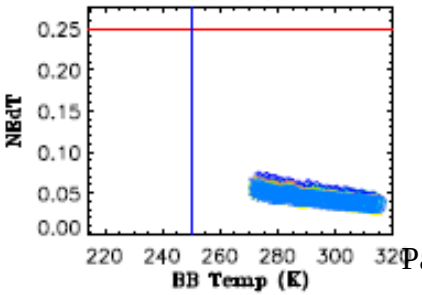
Terra band 36



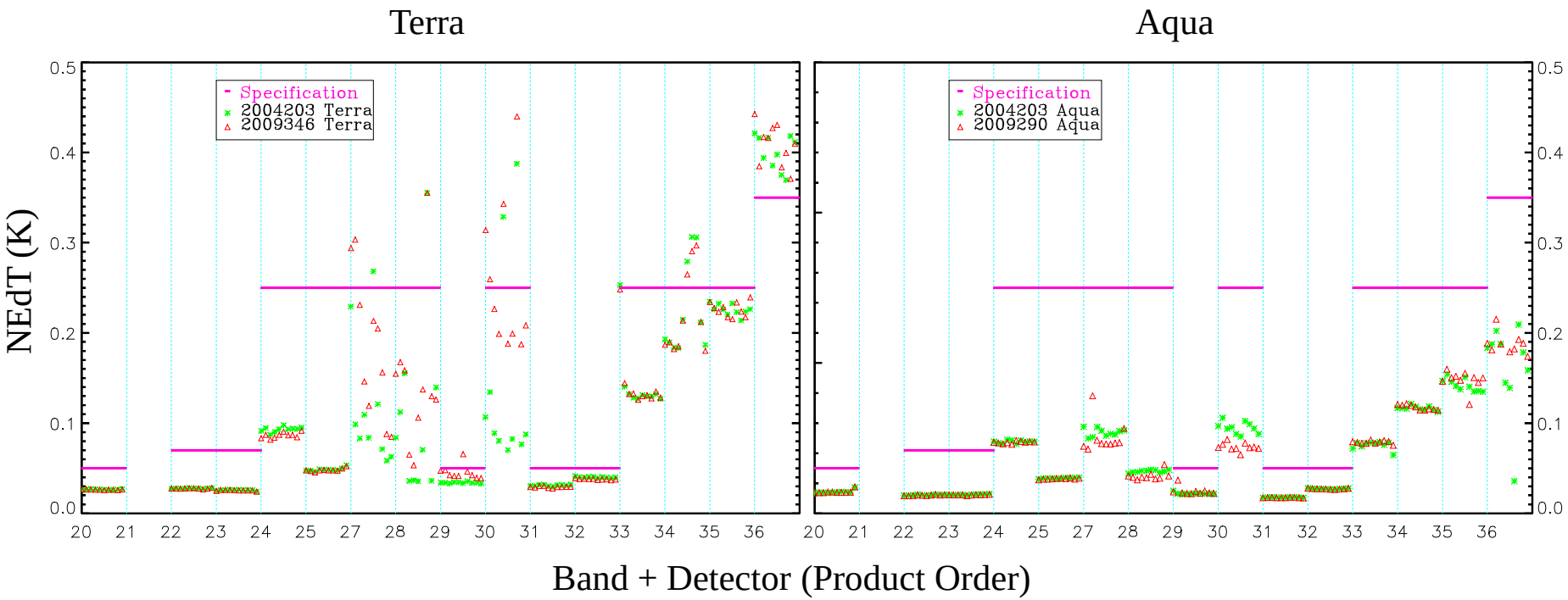
Aqua band 22



Aqua band 30



NEdT @ Typical Temperature



TEB detector status (in current LUT)

Near Spec | Out of Spec | Inoperable

Instr.	Terra																					Aqua			
Band	27					28				29	30					33	34				36	27	29		36
Detector	1	2	3	6	8	1	8	9	10	6	1	2	3	5	8	1	5	6	7	8	all	3	2	8	5

- Terra PV bands on LWIR CFPA (band 27-30) slowly becoming noisy
- Aqua TEB performs better than Terra TEB

MODIS TEB Calibration Performance

- MODIS TEB Calibration Algorithm
- Terra and Aqua MODIS TEB On-orbit Performance
  - Black Body Stability
  - Detector Response & Noise Performance
  - Noisy Detector History
  - Aqua CFPA Temperature Concern

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	2	3	6	8	1	3	8	9	10	4	6	1	2	3	5	8	1	5	6	7	8	1-10
Pre-launch	-	0.10	0.11	0.08	0.10	0.08	0.05	0.05	0.04	0.05	0.04	0.02	0.02	0.09	0.08	0.09	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	0.10	0.09	0.03	0.05	0.06	0.06	0.05	0.05	0.02	0.02	0.09	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	0.10	0.24	0.03	0.05	0.05	0.05	0.05	0.05	0.02	0.03	0.09	0.11	0.07	0.31	0.11	0.27	0.24	0.33	0.37	0.38	0.42
030/2001	-	0.10	0.13	0.11	0.27	0.03	0.05	0.06	0.05	0.05	0.05	0.02	0.02	0.13	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	0.10	0.24	0.03	0.06	0.32	0.05	0.05	0.04	0.02	0.02	0.10	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	0.10	0.23	0.03	0.05	0.30	0.27	0.04	0.04	0.02	0.02	0.11	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	0.10	0.23	0.03	0.05	0.29	0.08	0.05	0.05	0.03	0.02	0.12	0.10	0.06	0.47	0.65	0.26	0.24	0.33	0.36	0.36	0.44
118/2004	-	0.26	0.11	0.10	0.26	0.03	0.05	0.16	0.36	0.05	0.16	0.02	0.03	0.12	0.10	0.06	0.33	0.41	0.27	0.21	0.29	0.32	0.32	0.43
158/2004	-	0.28	0.12	0.09	0.25	0.03	0.05	0.16	0.37	0.05	0.21	0.03	0.03	0.12	0.10	0.07	0.31	0.40	0.27	0.22	0.28	0.31	0.31	0.43
162/2004	-	0.26	0.12	0.10	0.27	0.03	0.05	0.16	0.37	0.05	0.20	0.02	0.03	0.13	0.14	0.06	0.32	0.42	0.27	0.22	0.30	0.34	0.34	0.43
175/2004	-	0.28	0.12	0.10	0.26	0.03	0.12	0.17	0.35	0.05	0.17	0.03	0.02	0.12	0.17	0.06	0.30	0.41	0.27	0.21	0.28	0.32	0.32	0.43
034/2005	-	0.28	0.11	0.10	0.22	0.03	0.10	0.16	0.45	0.05	0.16	0.04	0.02	0.12	0.17	0.06	0.31	0.39	0.26	0.21	0.28	0.31	0.31	0.43
130/2005	-	0.31	0.11	0.10	0.22	0.03	0.40	0.15	0.40	0.05	0.14	0.03	0.06	0.12	0.17	0.07	0.40	0.40	0.26	0.21	0.31	0.34	0.34	0.43
309/2005	-	0.30	0.12	0.10	0.21	0.03	0.09	0.14	0.35	0.30	0.18	0.03	0.04	0.12	0.18	0.06	0.31	0.40	0.24	0.21	0.27	0.30	0.30	0.43
053/2006	-	0.30	0.11	0.10	0.21	0.27	0.13	0.15	0.40	0.19	0.16	0.03	0.04	0.12	0.16	0.11	0.33	0.39	0.28	0.21	0.28	0.31	0.31	0.43
155/2006	-	0.26	0.11	0.10	0.21	0.11	0.10	0.14	0.46	0.10	0.15	0.03	0.05	0.11	0.14	0.26	0.31	0.41	0.24	0.21	0.28	0.31	0.31	0.44
241/2006	-	0.26	0.11	0.10	0.22	0.10	0.10	0.14	0.36	0.10	0.11	0.03	0.11	0.12	0.15	0.16	0.29	0.39	0.25	0.22	0.28	0.32	0.32	0.43
193/2007	-	0.28	0.11	0.19	0.20	0.11	0.07	0.14	0.35	0.10	0.11	0.03	0.10	0.12	0.13	0.14	0.27	0.36	0.25	0.21	0.27	0.30	0.30	0.43
308/2008	-	0.26	0.26	0.25	0.19	0.18	0.16	0.15	0.32	0.13	0.12	0.04	0.06	0.16	0.23	0.25	0.30	0.38	0.25	0.21	0.27	0.30	0.30	0.43
327/2008	-	0.35	0.26	0.26	0.26	0.18	0.16	0.15	0.32	0.13	0.12	0.04	0.06	0.27	0.23	0.25	0.30	0.38	0.25	0.21	0.27	0.30	0.30	0.43

[1]Spacecraft Deep Space Maneuver

Near Spec | Out of Spec | Inoperable

– 2 new noisy detectors since last Science Team Meeting

(Band 27 detector 2 and band 30 detector 1)

Aqua MODIS Noisy Detector History

Detectors in Product Order

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	2	8	5
Pre-launch	-	0.05	0.16	0.28	near 0.2	0.10	0.02	0.02	1.34
175/2002	Nadir door open	0.03	0.23	0.23	near 0.2	0.09	0.02	0.02	1.28
183/2002	Back from safe mode	0.03	0.20	0.25	near 0.2	0.09	0.02	0.02	1.31
218/2002	Back from safe mode	0.03	0.19	0.26	near 0.2	0.09	0.02	0.02	1.32
255/2002	Back from safe mode	0.03	0.23	0.20	near 0.2	0.09	0.02	0.02	1.36
102/2003	-	0.03	0.43	0.19	near 0.2	0.09	0.02	0.02	1.31
201/2003	-	0.03	0.18	0.18	near 0.2	0.09	0.02	0.02	1.29
010/2005	-	0.03	0.17	0.19	near 0.2	0.23	0.02	0.02	1.35
359/2007	-	0.03	0.18	0.21	near 0.2	0.13	0.02	0.05	1.34
038/2008	-	0.03	0.19	0.19	near 0.2	0.14	0.05	0.05	1.34

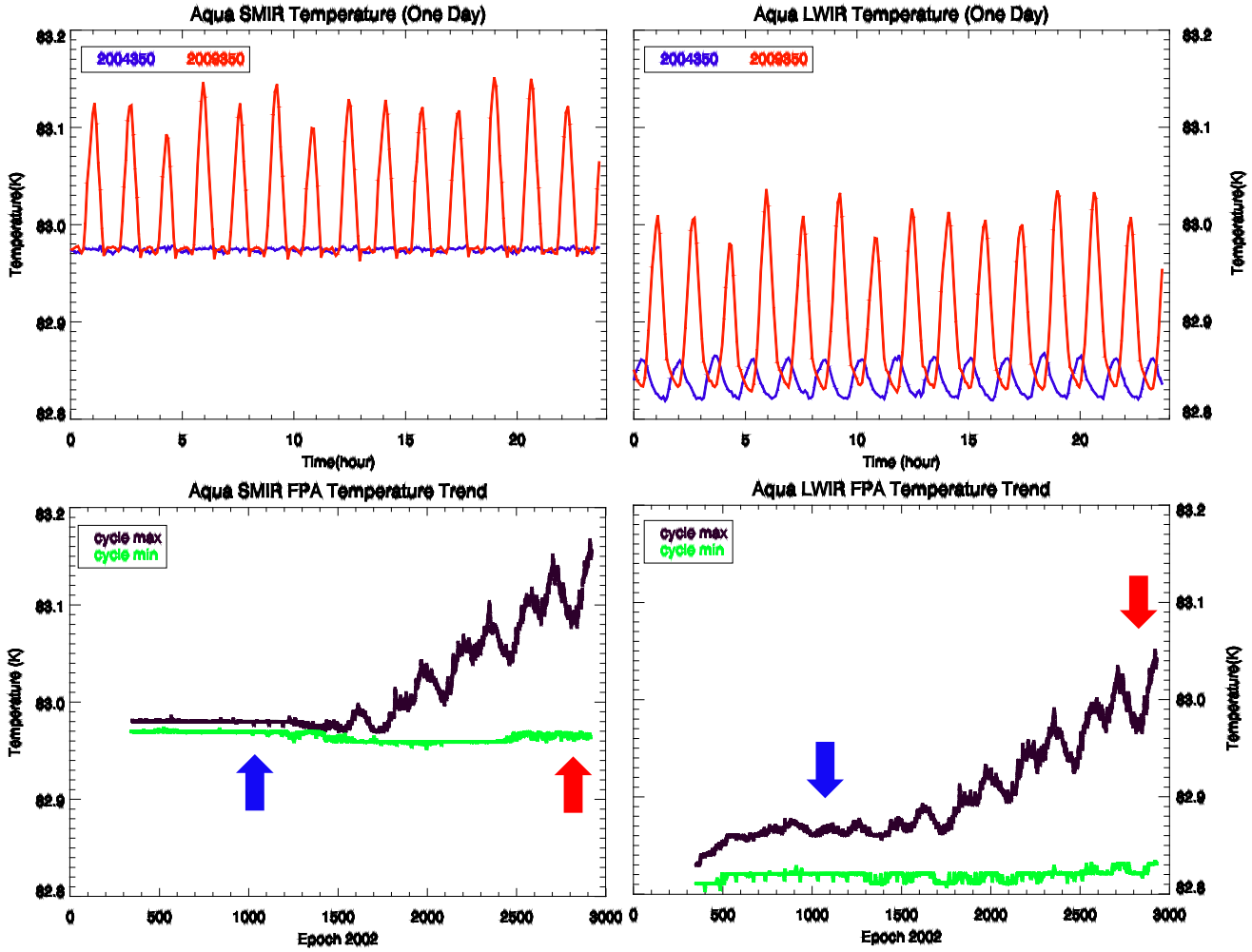
Near Spec | Out of Spec | Inoperable

– No new noisy and inoperable detector since last Science Team Meeting

MODIS TEB Calibration Performance

- MODIS TEB Calibration Algorithm
- Terra and Aqua MODIS TEB On-orbit Performance
  - Black Body Stability
  - Detector Response & Noise performance
  - Noisy Detector History
  - Aqua CFPA Temperature Concern

Aqua MODIS CFPA Temperature Fluctuation



- The cooler is controlled using SMIR temperature. → slight oscillation in LWIR temperature (as in 2004) is normal.
- Starting 2005, the fluctuation amplitude increases. → a concern
- The fluctuation is at orbital frequency (b1 calibration is scan-based). → no impact on L1B product

TEB On-orbit Performance Summary

- BB temperatures remain stable (Terra 290K and Aqua 285K).
- Stable short-term and long-term detector response
  (excluding sensor configuration changes and instrument reset events)
- Terra PV band detectors on LWIR CFPA (band 27-30) slowly becoming noisy
- Terra MODIS has 23 noisy detectors and 1 inoperable detector
  (2 new noisy detectors since last Science Team Meeting)
- Aqua MODIS has 3 noisy detectors and 1 inoperable detector.
- Aqua cooler margin is a concern for CFPA short-term stability
  (unable to completely control the CFPA to the setting temperature)
- Current Aqua CFPA temperature fluctuation has no impact on L1B product

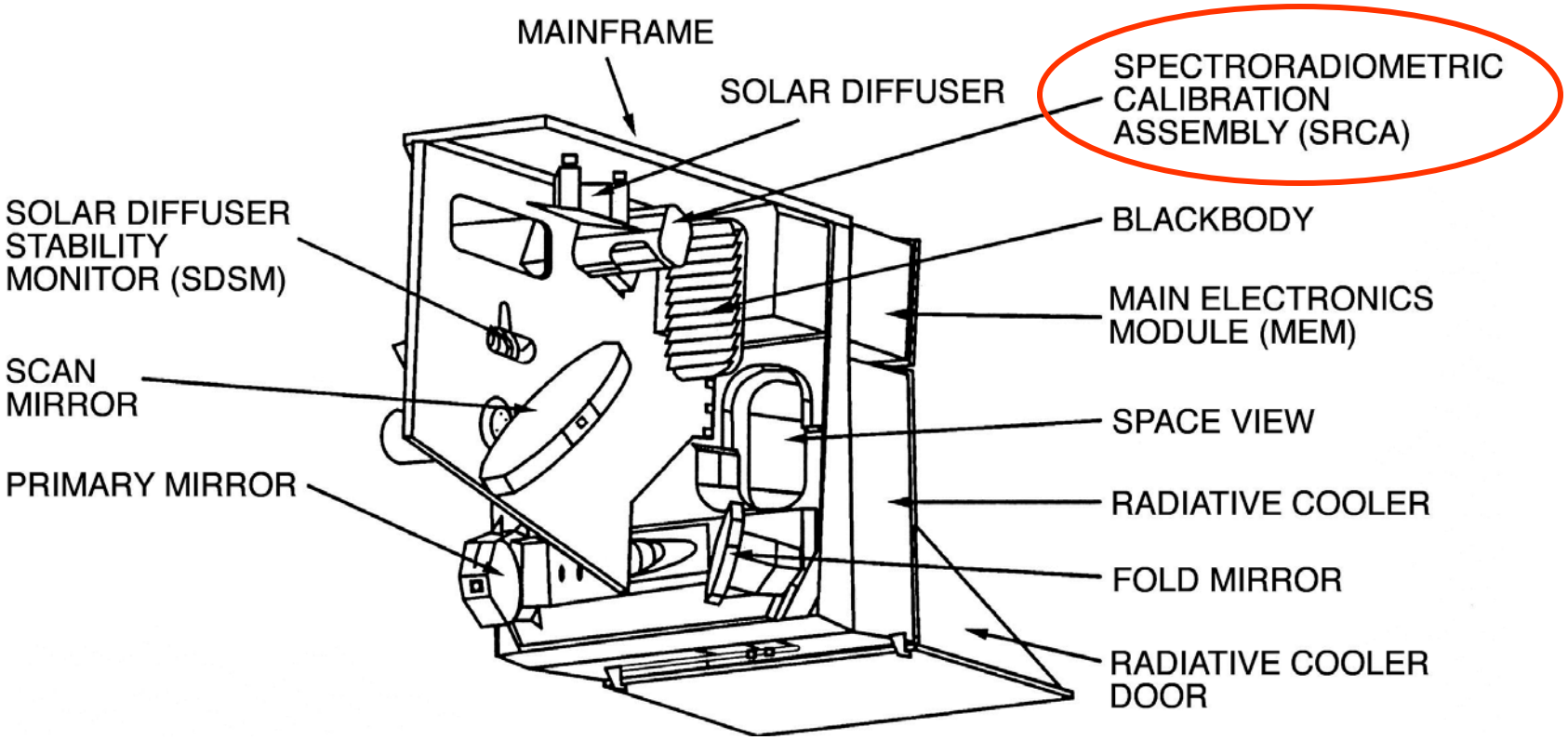
MODIS Spectral and Spatial Performance

SRCA Group

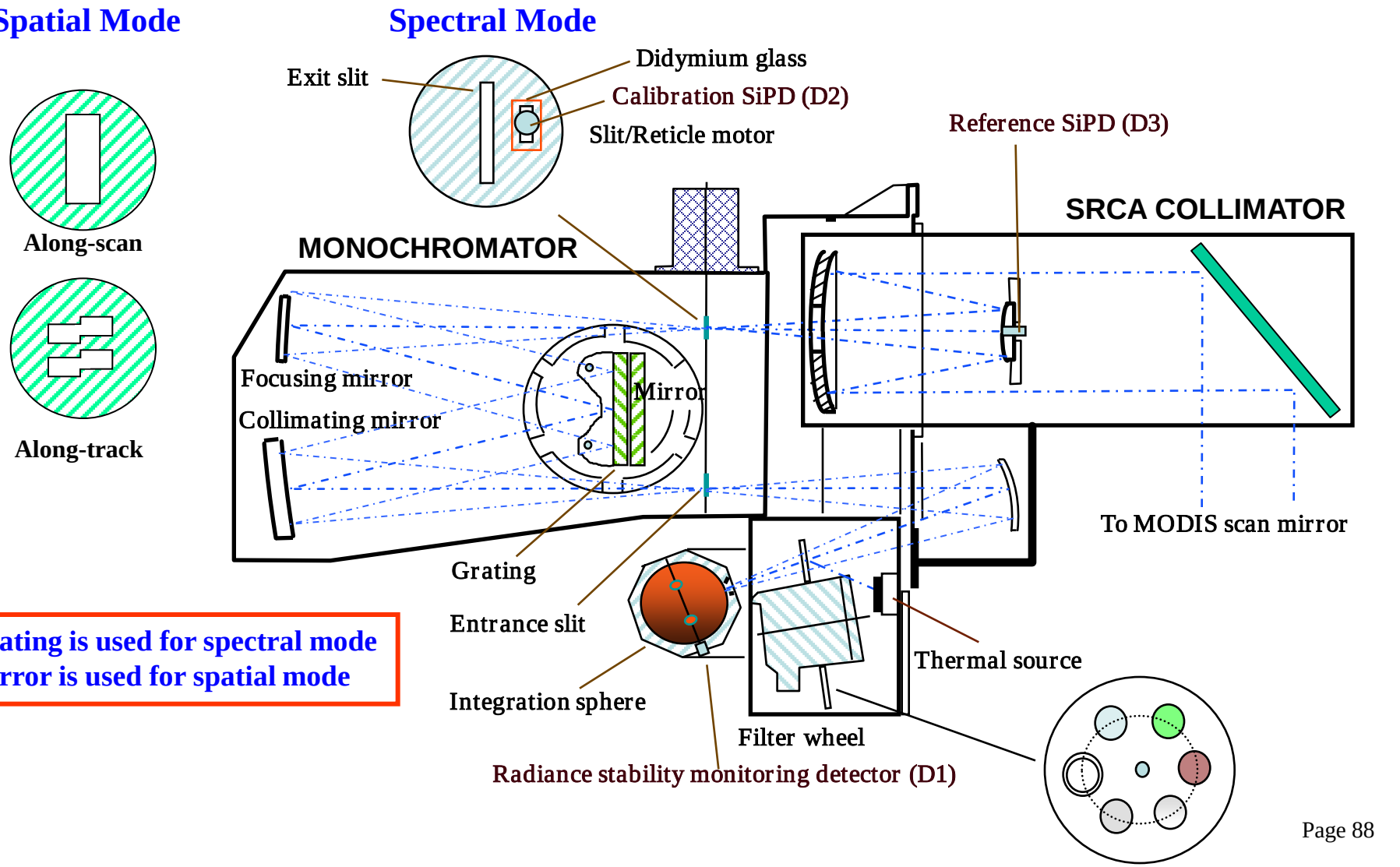
MODIS Spectral and Spatial Performance

- Spectro-Radiometric Calibration Assembly (SRCA)
  - Spectral mode
  - Spatial mode
- Spectral Characterization Results (VIS/NIR only)
  - Center wavelengths
  - Bandwidths
- Spatial Characterization Results (all bands)
  - Band-to-band Registration (BBR)
    - Along-scan and along-track
- Performance Summary
- SRCA Lamp Status

SRCA in MODIS



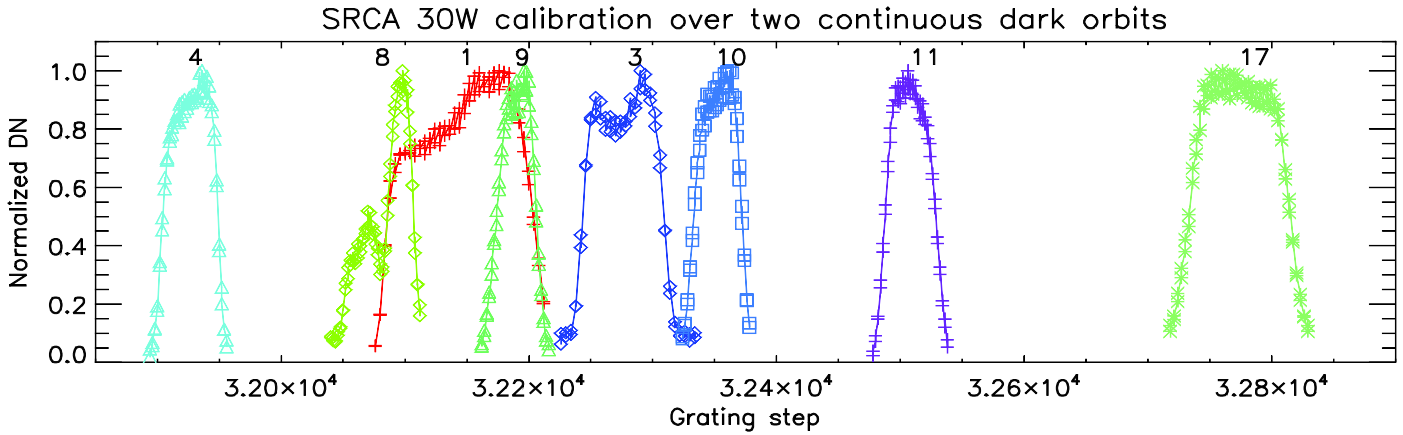
SRCA Spectral and Spatial Mode

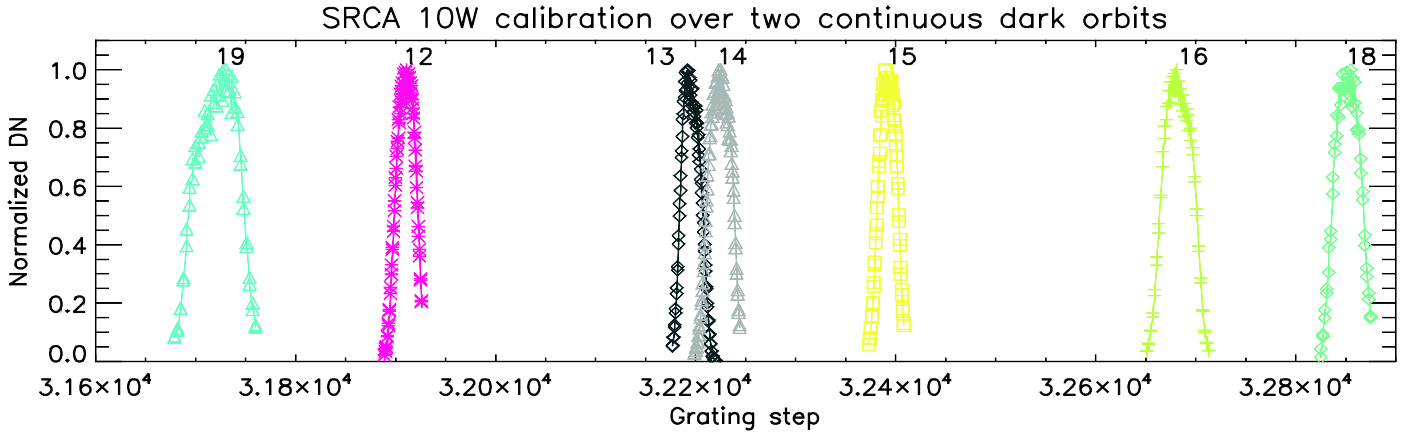


Grating is used for spectral mode
Mirror is used for spatial mode

SRCA Spectral Responses

Relative Responses Prior to Corrections

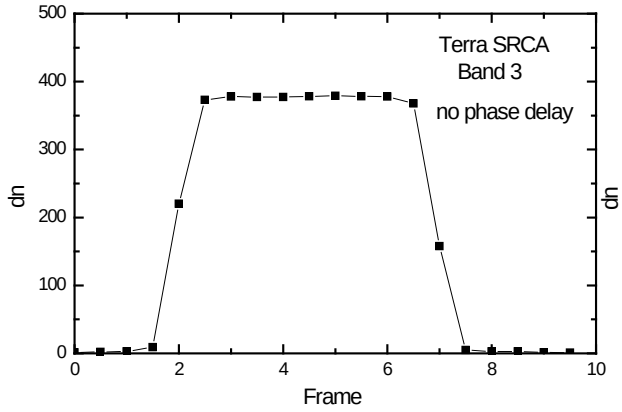


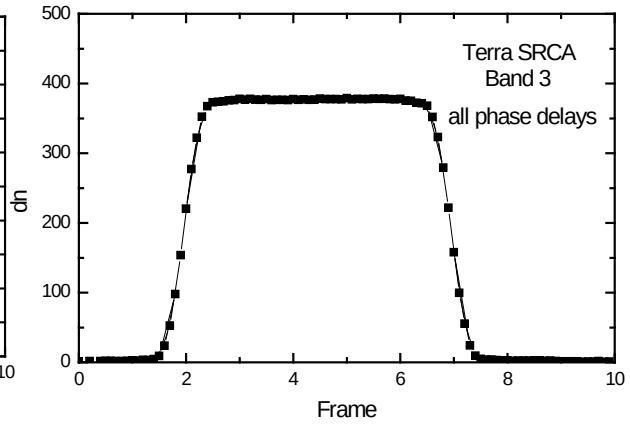


Grating step -> θ

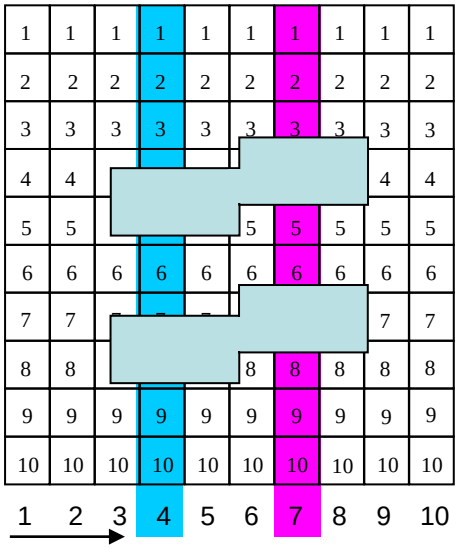
$$\lambda_C = \frac{2A}{m} \cdot \sin(\theta_C + \theta_{off}) \cdot \cos\beta$$

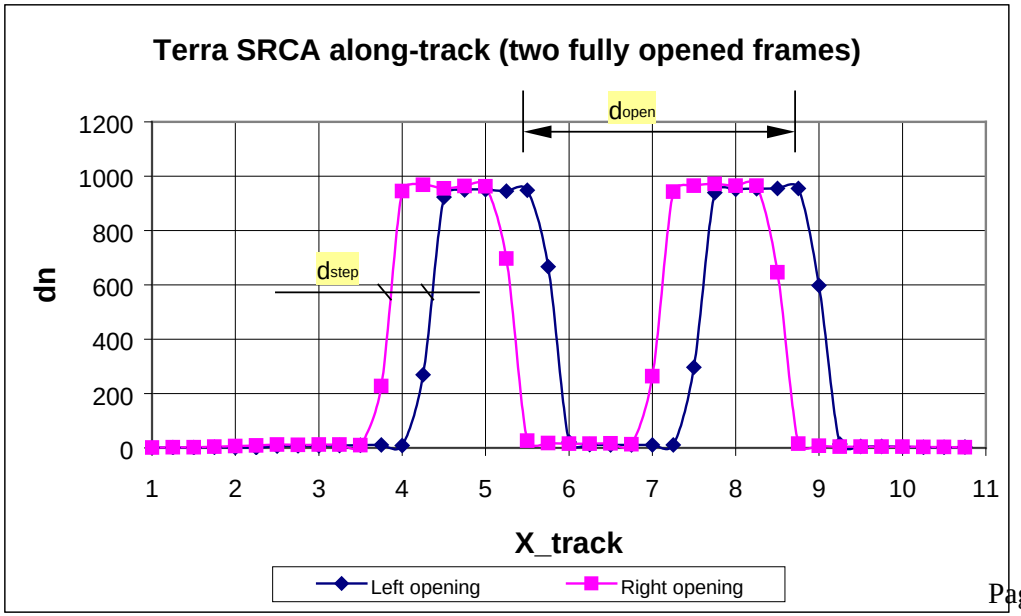
Along-scan & track Positions



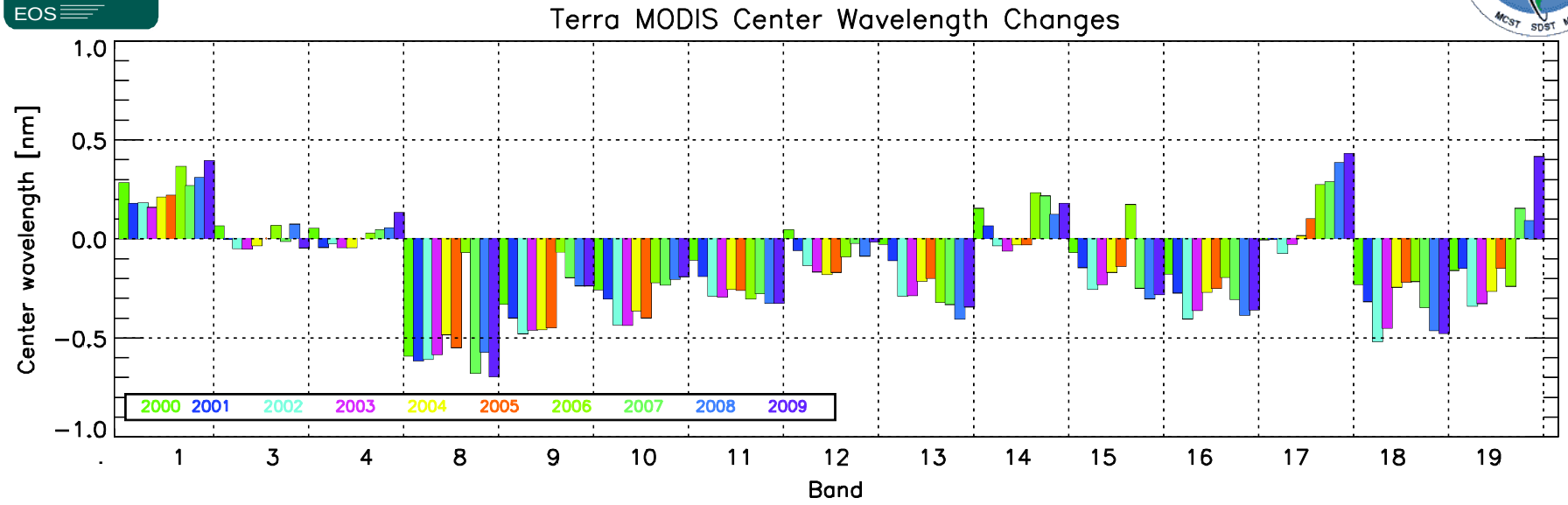


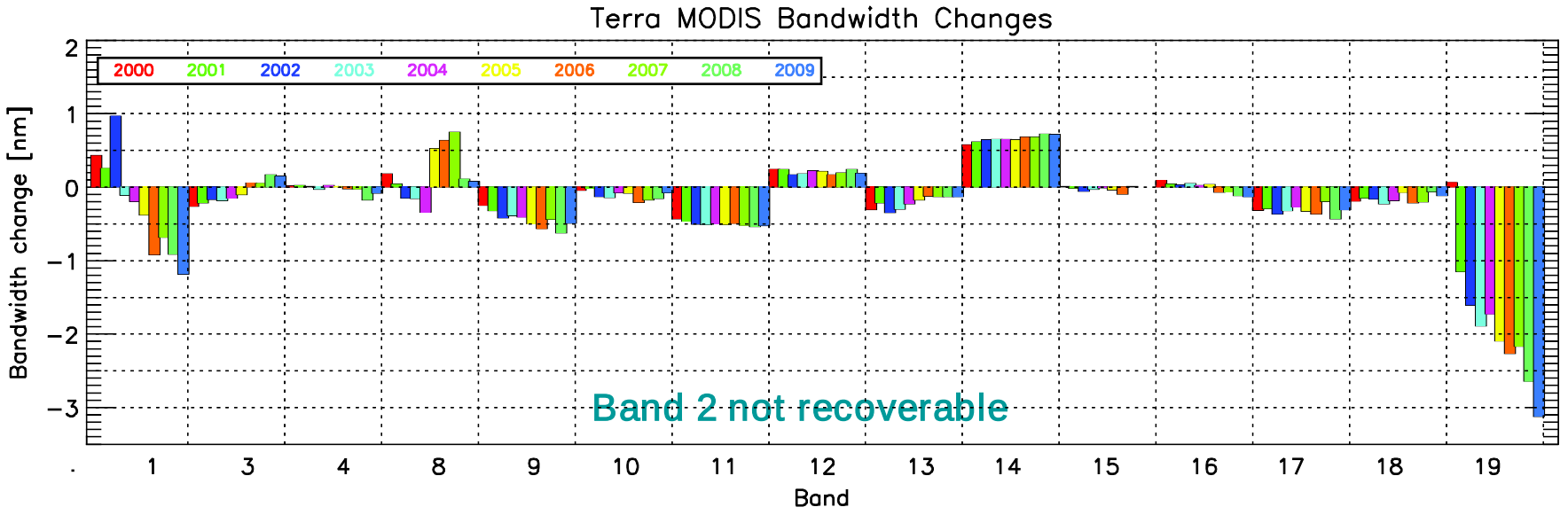
$$\bar{x}(b,ch) = \frac{\sum_{x=0}^{N_x} dn(b,ch,x) \cdot x}{\sum_{x=0}^{N_x} dn(b,ch,x)}$$



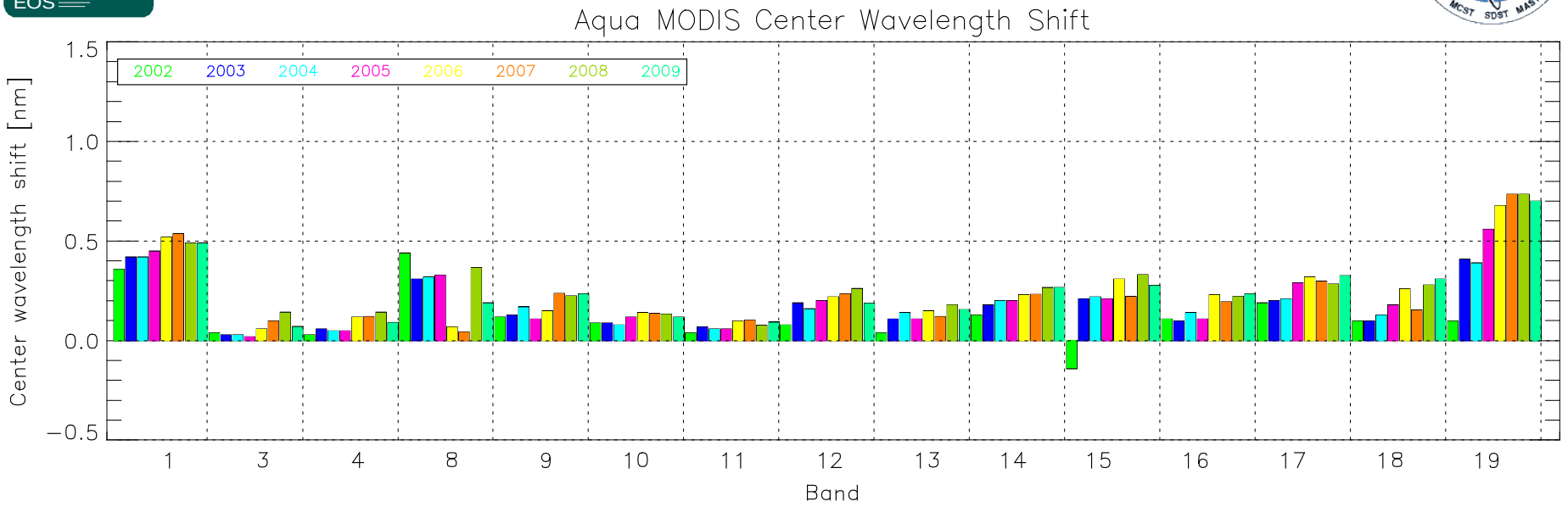


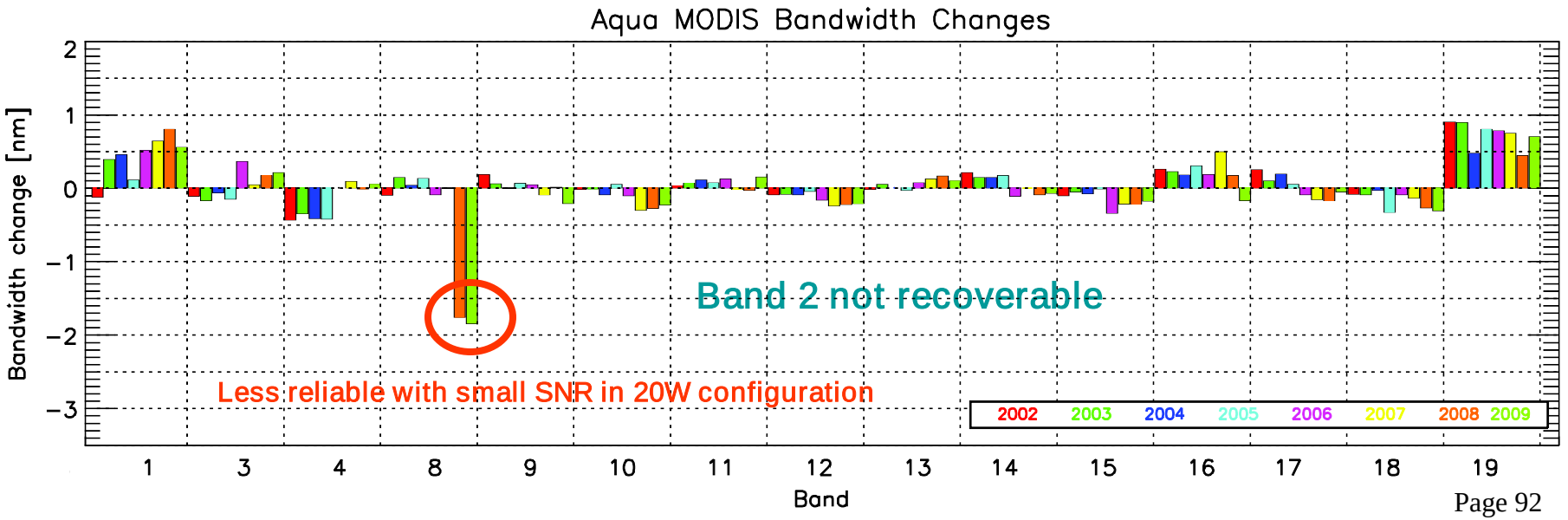
Terra MODIS Spectral Performance



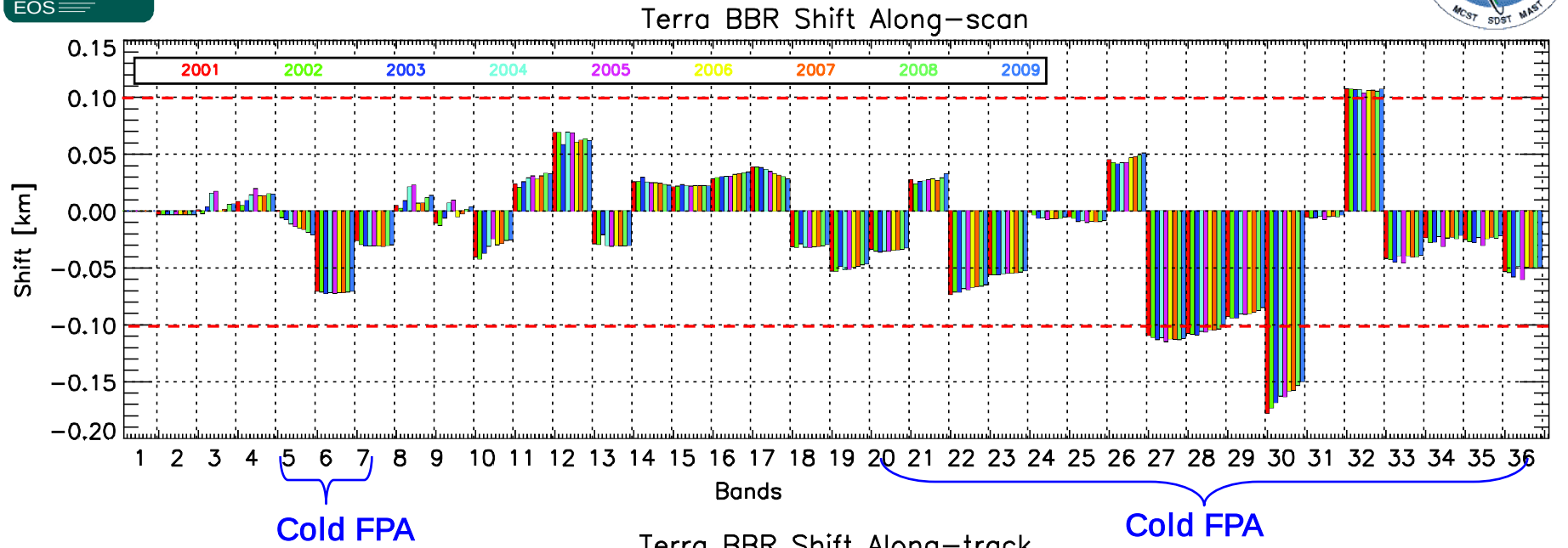


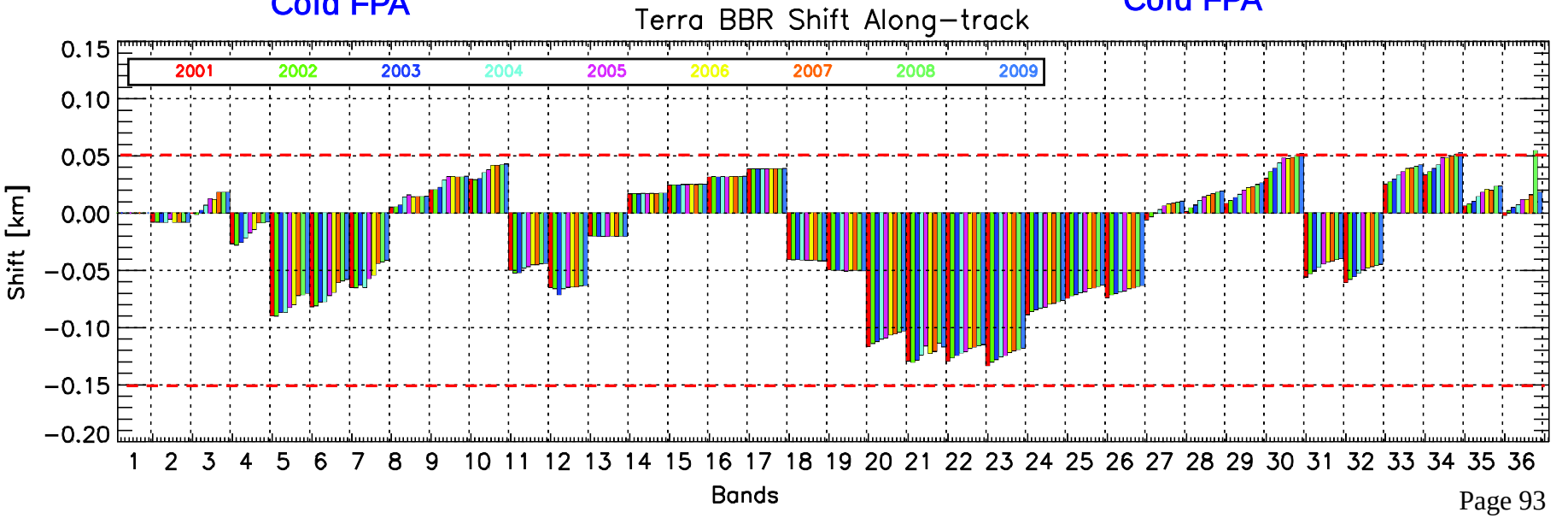
Aqua MODIS Spectral Performance



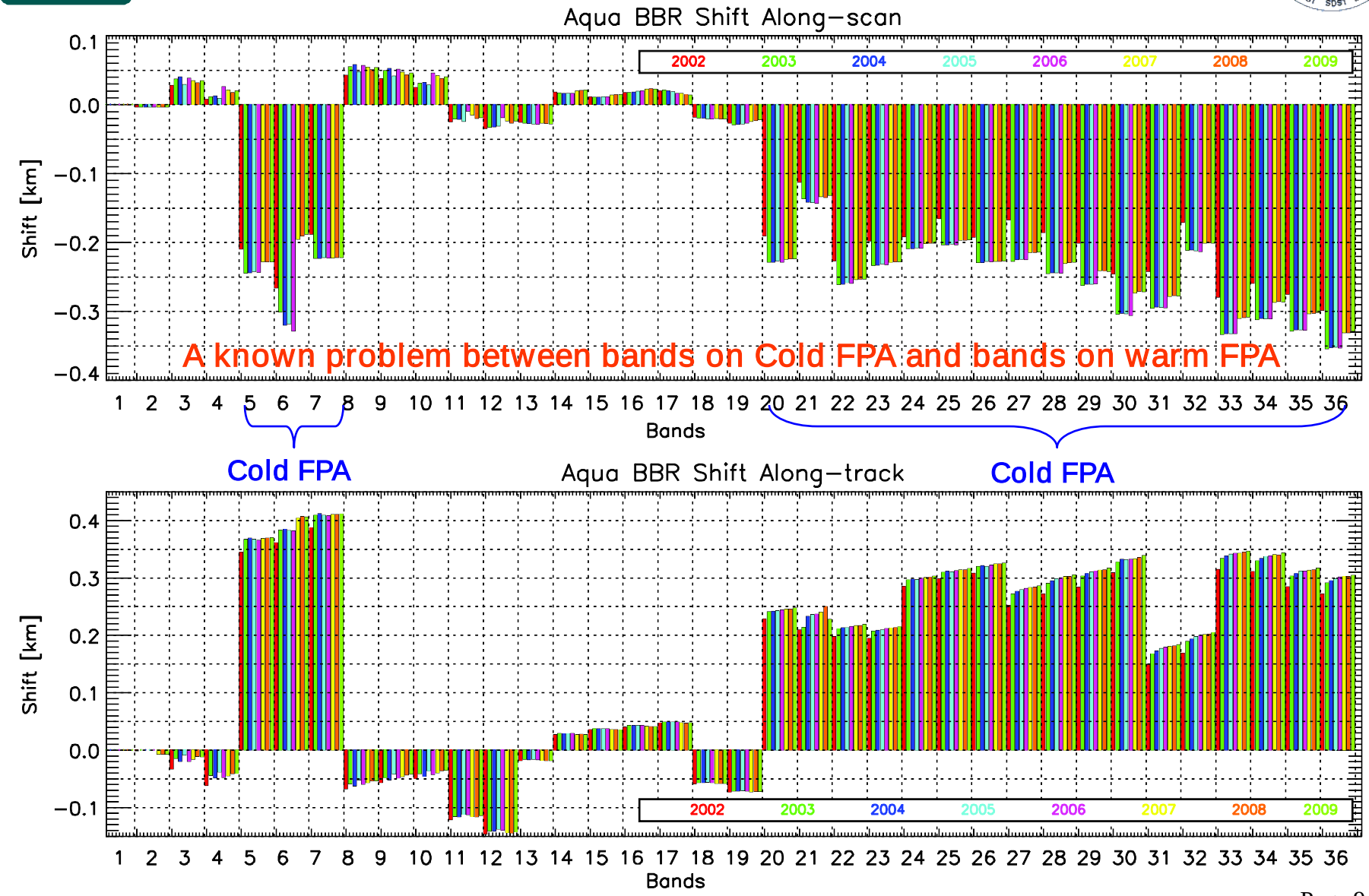


Terra MODIS Spatial Performance





Aqua MODIS Spectral Performance



Performance Summary

- SRCA Spectral Mode
  - Terra and Aqua MODIS spectral performances are stable on-orbit (VIS/NIR only).
  - CW and BW changes are less than 0.5nm except for bands 1 and 19 (large BW bands > 45nm)
    - Terra and Aqua band 8 results from 20W configuration are not reliable because of low SNR.
- SRCA Spatial Mode
  - The SRCA spatial mode provides stable on-orbit BBR trending for both along-scan and along-track directions (all 36 bands).
    - Terra bands 27, 28 and 30 are out-of-spec (relative to band 32).
    - Aqua MODIS had large BBR offsets (in both directions) between bands on Cold FPA and bands on warm FPA (a known problem since pre-launch).

SRCA Lamp Status

- As of 1-8-2010

Lamp Power		10W				1W	
Lamp #		1	2	3	4	1	2
Terra	Usage	288.6	172.1	190.3	96.7	576.4	282.0
	Life	500	500	500	500	4000	4000
	percent	57.7 %	**Failed on 11-20-2004**	**Failed on 2-18-2006**	19.3%	14.4%	7.1%
Aqua	Usage	281.3	188.0	205.7	99.6	517.1	274.9
	Life	500	500	500	500	5000	5000
	percent	56.3%	**Failed on 4-14-2003**	**Failed on 6-28-2005**	19.9%	10.3%	5.5%

MODIS Collection 6 Calibration and L1B Changes

MODIS Characterization Support Team

1/25/10

Outline

- Introduction
- Collection 6 LUT Changes Summary
  - RSB
  - TEB
  - QA
  - L1B Code
- Science Testing Status

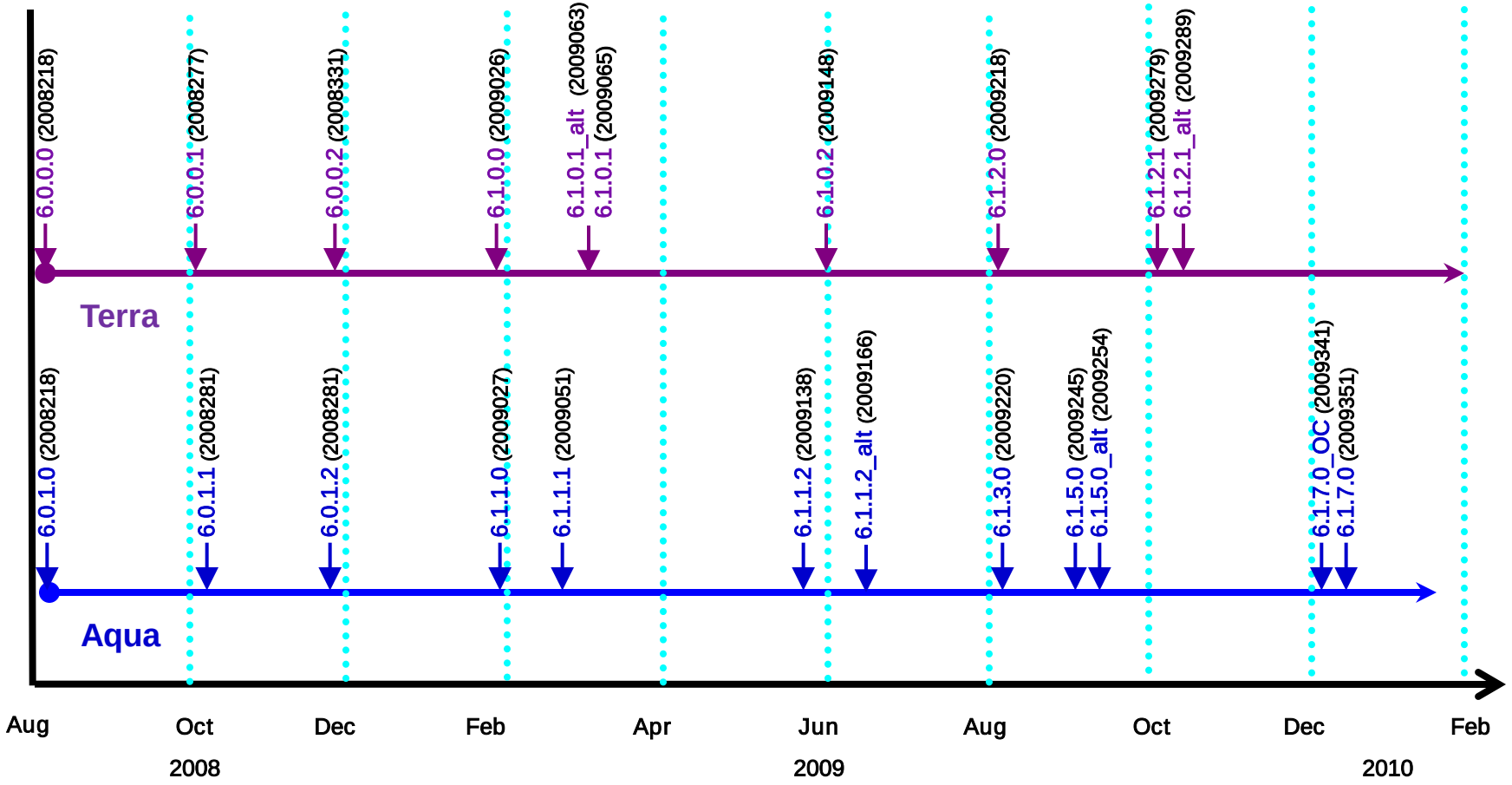
MCST Collection 6 Information will be available on mcst.gsfc.nasa.gov

Introduction

- MODIS Collection History
  - Collection 2: Terra Launch – June 2001
  - Collection 3: June 2001 – Jan. 2003
  - Collection 4: Dec. 2002 – early 2007
  - Collection 5: Feb 2005 – present
  - Collection 6: Test L1B datasets available

MCST Collection 6 History

- Prototype delivery (V6.0.0.0/V6.0.1.0) – Aug. 2008
- 1st official LUT delivery (V6.1.0.0/V6.1.1.0) – Jan. 2009

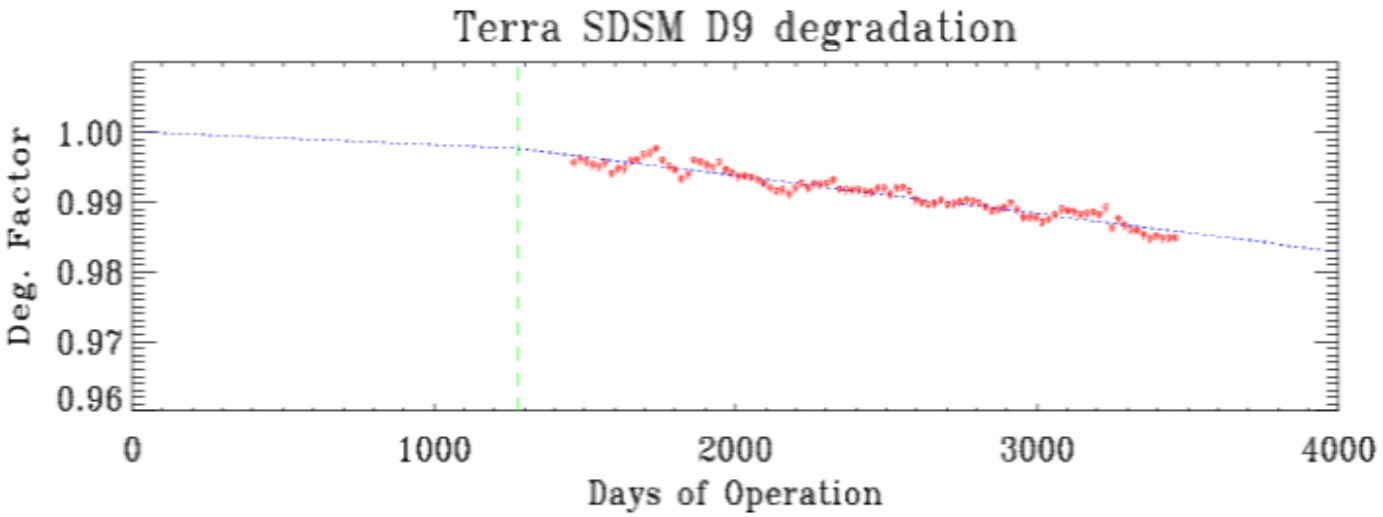


RSB V6 Changes

- RSB LUT Improvements
  - SD D9 Degradation
  - Δm1 correction
  - Time Dependent RVS – B13-16
  - Detector Dependent RVS – B8-12
  - Aqua: MS2 RVS
  - Refit coefficients for entire mission
- RSB LUT Alternative Approach
  - LUTs derived using EV and lunar data

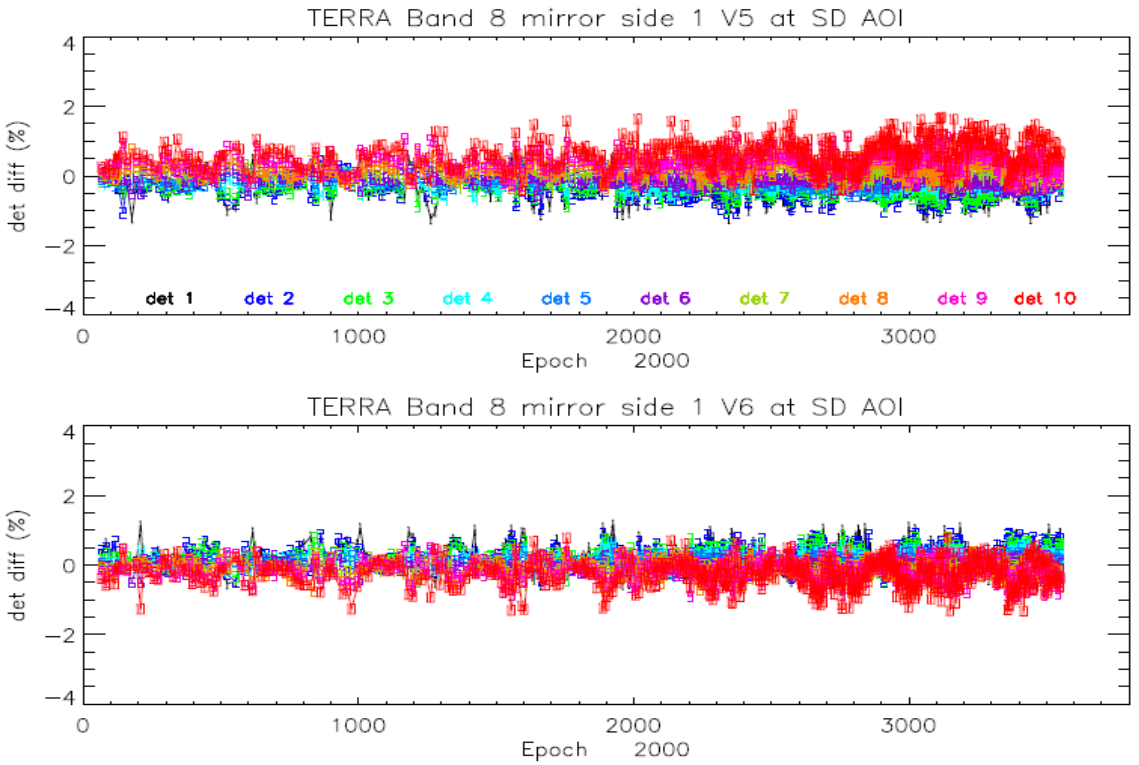
RSB V6 LUT – SDSM D9

- V5: Assumed no SDSM Detector 9 degradation
- V6: SD Degradation analysis now includes correction for D9 on-orbit degradation



RSB V6 LUT – Δm1 Correction

- V5: Detector dependent m1
- V6: Detector dependent m1 with correction applied to account for detector differences within a band.
- Improves striping performance.

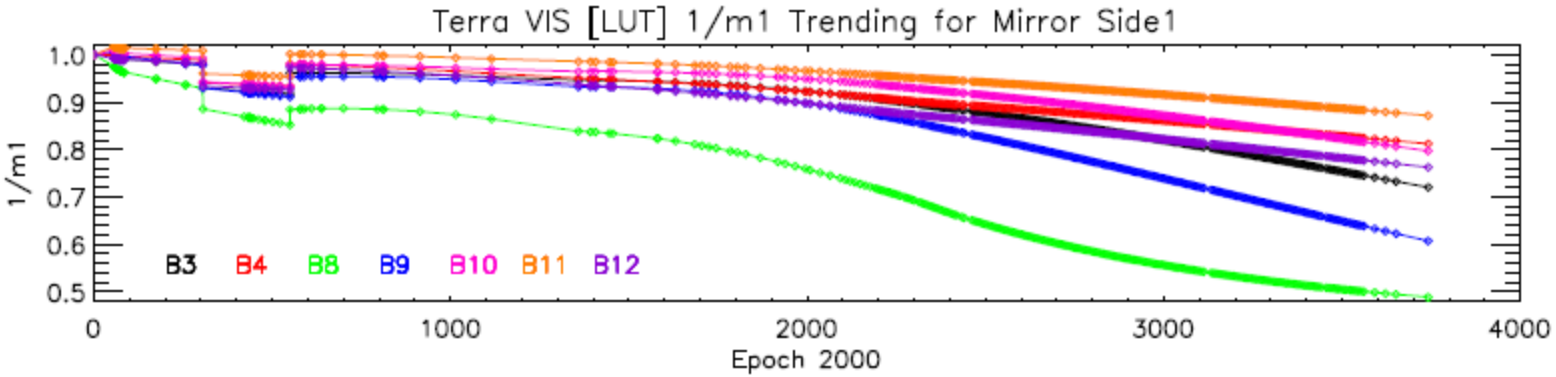


RSB V6 LUT – RVS

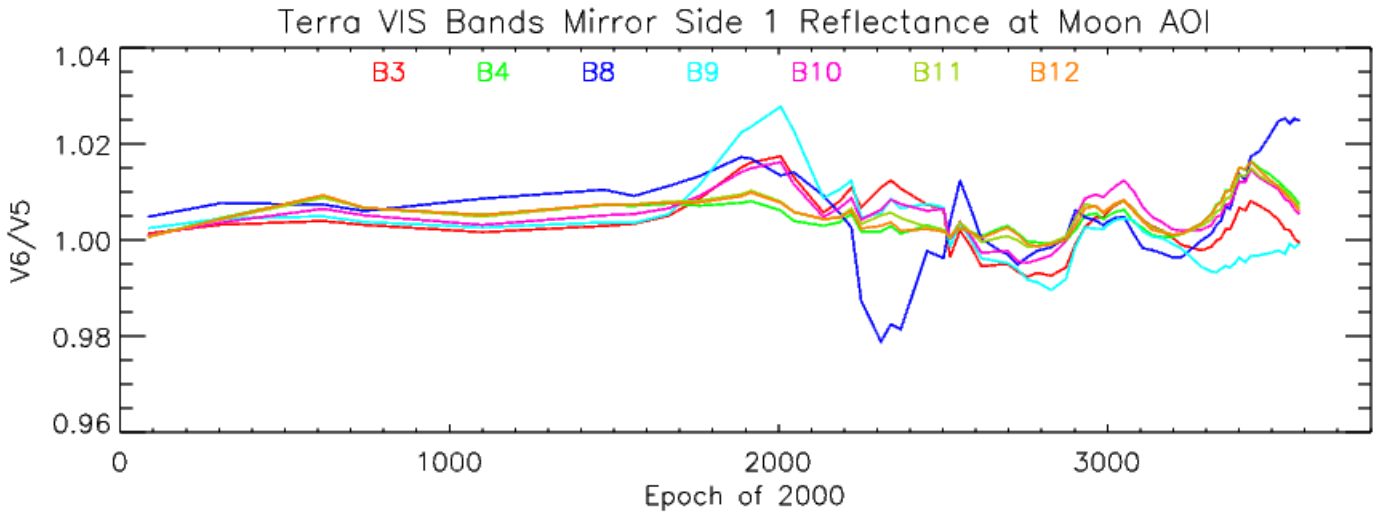
- V5: RVS band averaged
- V6:
  - Time-dependent RVS for bands 13-16
    - Major improvement in lunar algorithm
  - Detector–dependent RVS derived for bands 8-12
  - Aqua RVS mirror side dependence derivation methodology modified to match that of Terra

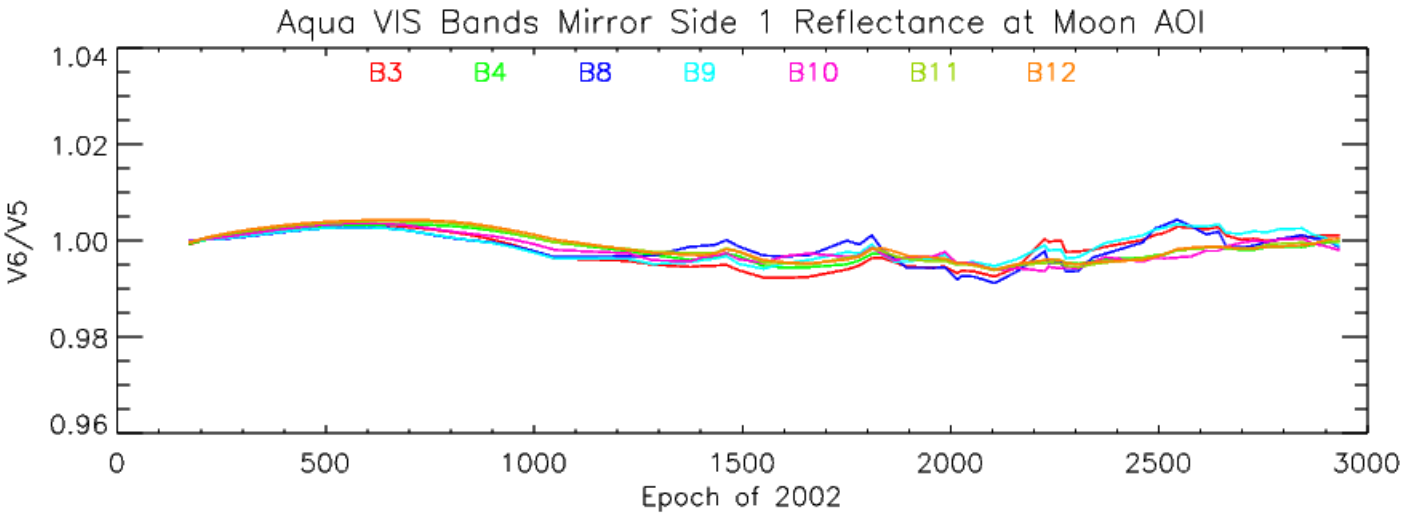
RSB V6 LUT

- Reprocess coefficients for mission lifetime to date
  - Long-term trending has smooth performance



RSB V6 LUT – L1B Impact





V6 Expected Impact on L1B*
Terra: ± 2%
Aqua: ± 1%

*Actual differences are band, detector, mirror side, AOI, & time dependent

RSB V6 LUT – Alternative Approach

- MCST developed RSB LUTs (m1 & RVS) derived only from EV and lunar data
  - Tied to historical SD measurements with forward LUTs independent of SD calibration.
  - Developed and delivered prototype LUTs to Ocean Group (OBPG) for testing.
    - Early results from ongoing testing by OBPG indicate improvement in Ocean products.

TEB V6 Changes

- A0/A2 Derivation strategy
- Reprocess coefficients for entire mission
  - A0, A2, Band 21 b1
- Aqua B33, 35, & 36 Saturation Temp adjusted

TEB V6 LUT – A0/A2 Strategy

Aqua	**V5**	**V6**
B20, 22-30	PL a0/a2	no change
B21	a0 = 0 and a2 = 0	no change
B31-32	Warm-up a0/a2	**a0 = 0, cool-down a2**
B33-36	a0 = 0, PL a2	no change

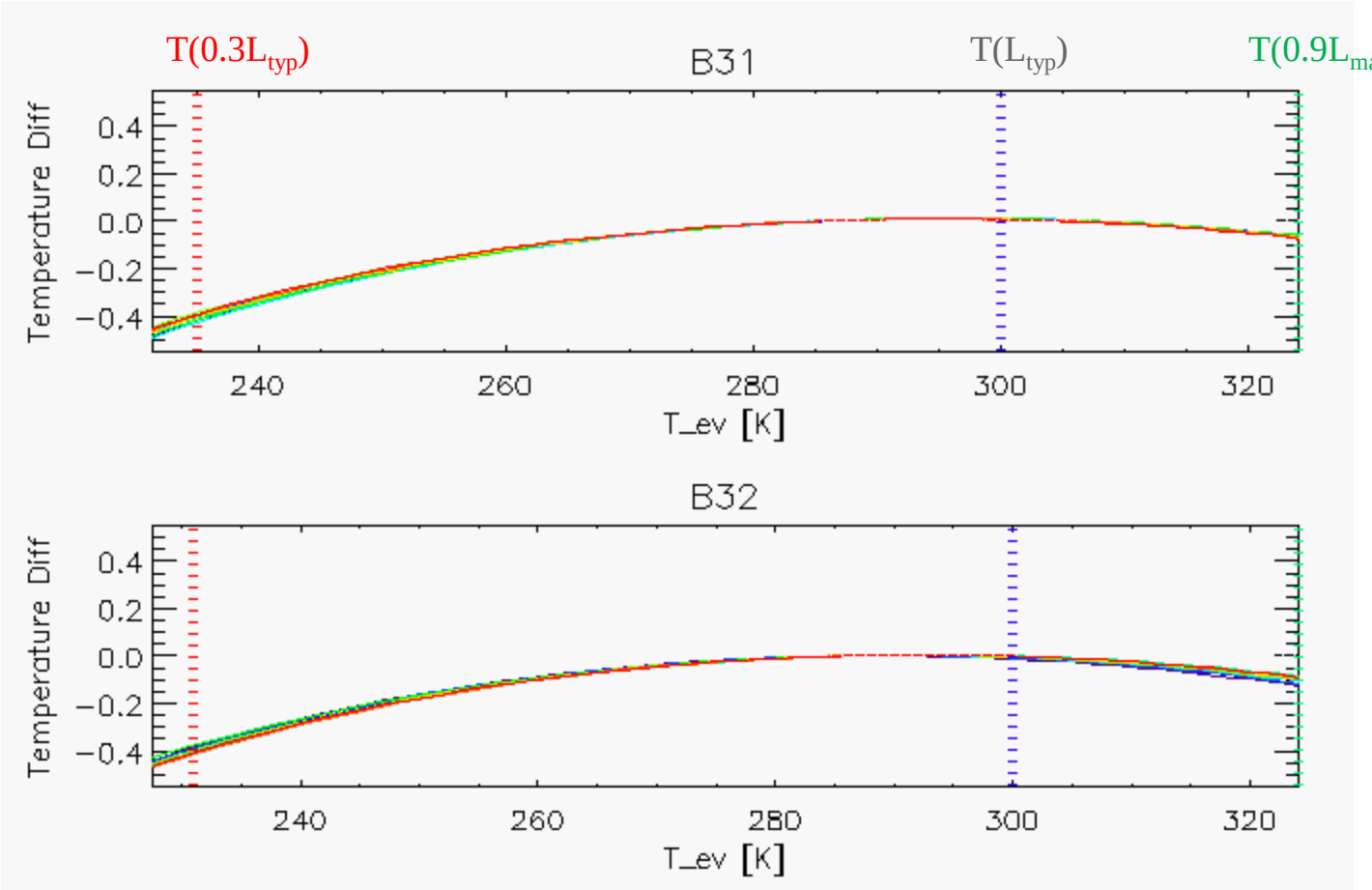
Terra	**V5**	**V6**
B20, 22-30	Warm-up a0/a2	**Cool-down a0/a2**
B21	a0 = 0 and a2 = 0	no change
B29, 31-32	Warm-up a0/a2	**a0 = 0, cool-down a2**
B33-36	a0 = 0, warm-up a2	a0 = 0, **cool-down a2**

Coefficients derived from quarterly BB Warm-up & Cool-down Activities

V6 Approach improves TEB performance for low temperature scenes

TEB V6 LUT Impact - Aqua

$\Delta T = C6 - C5$

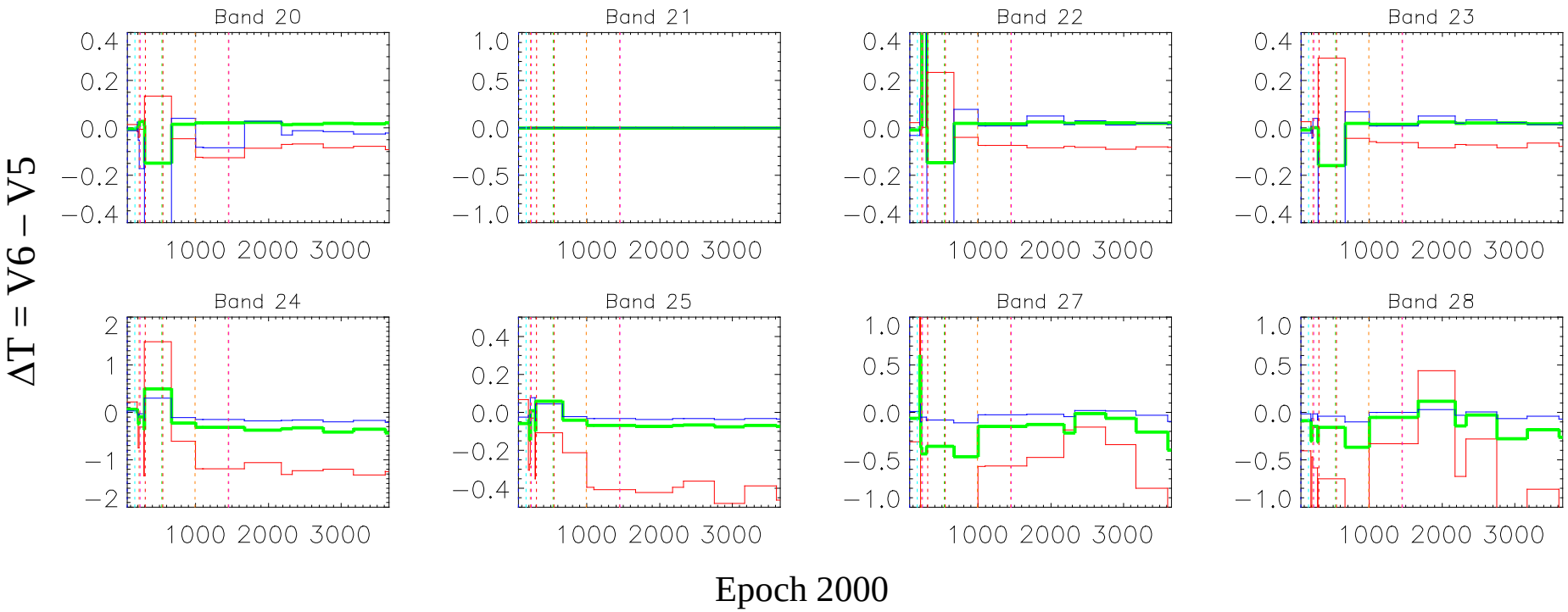


C6 Land Test Granule 2003001.1115

TEB V6 LUT Impact – Terra B20-28

EV Radiance Levels

0.3 L_{typ} L_{typ} 0.9 L_{max}

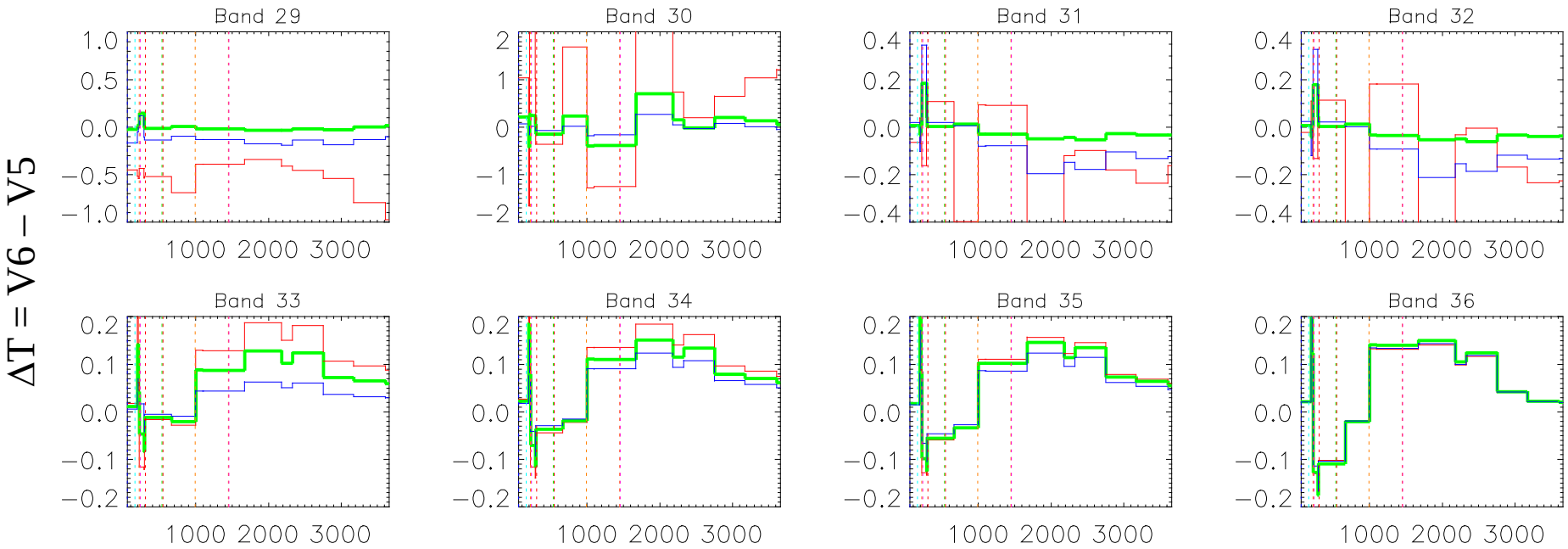


At L_{typ} impact is minimal, at low EV scene temps V6 is generally colder than V5

TEB V6 LUT Impact – Terra B29-36

EV Radiance Levels

0.3 L_{typ} L_{typ} 0.9 L_{max}



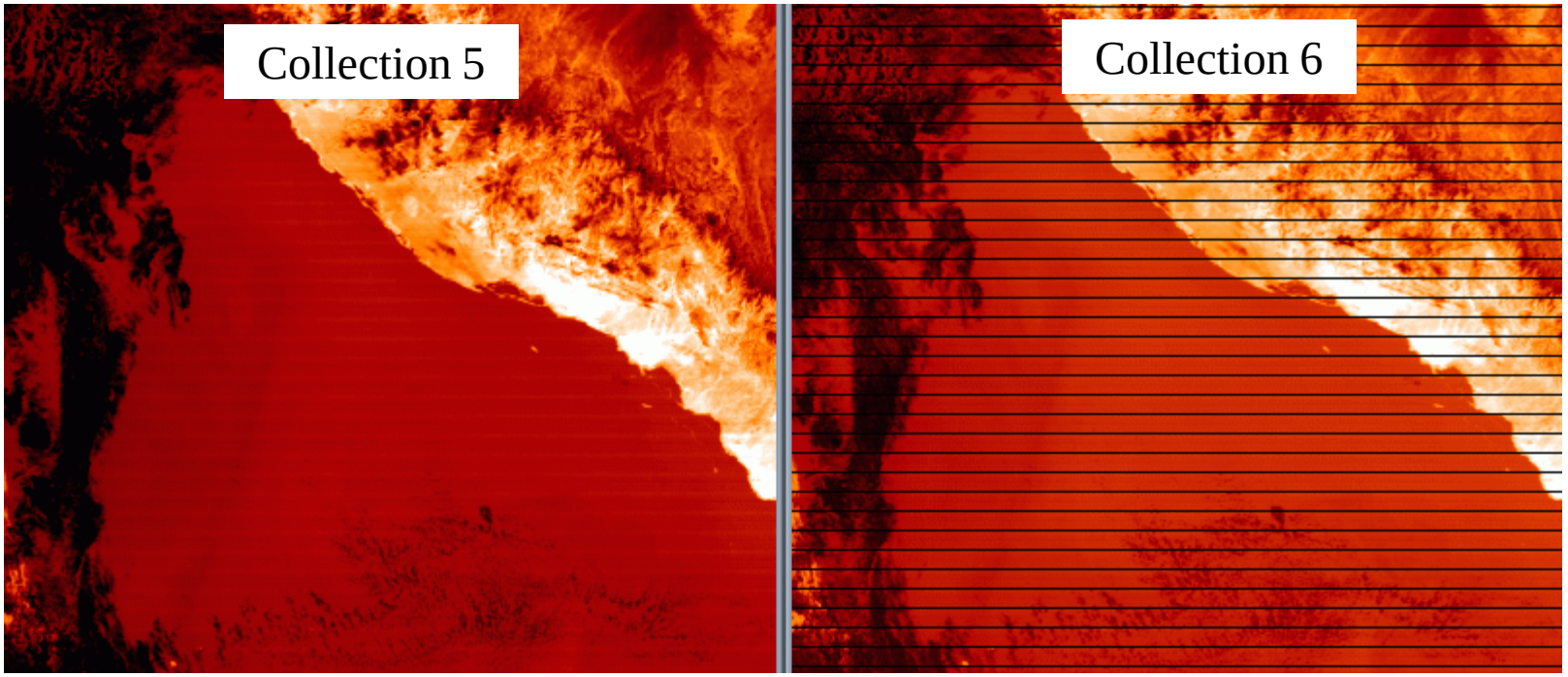
Epoch 2000

QA V6 Improvements

- Fill Values replace Interpolation in L1B for Inoperable Detectors
  - Code change needed
- Subframe level QA flags
  - Code change needed
  - New QA LUT

QA V6 LUT – Fill vs Interpolation

- V5: Inoperable detectors filled with interpolated value from adjacent detectors
- V6: Science Team request to have no interpolation, explicit fill value for inoperable detectors



Terra Band 29

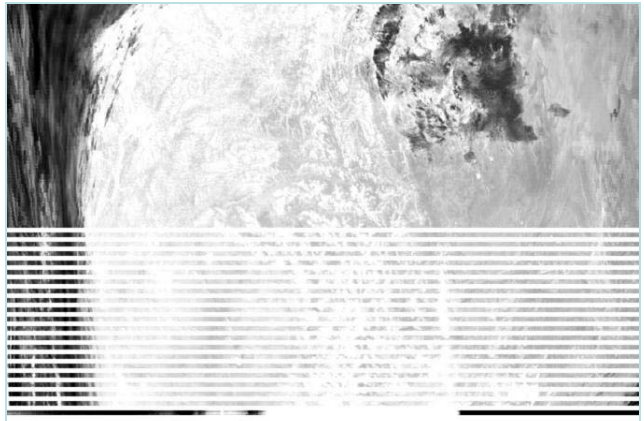
QA V6 LUT – Subframe Flags

- V5: QA flags only on detector level
- V6: L1B code change implemented to allow QA flags at subframe level.
  - New QA LUT
  - Terra Band 2 Detectors 29 & 30 Subframe 1 flagged as ‘Noisy’ for V6 (known crosstalk issue)

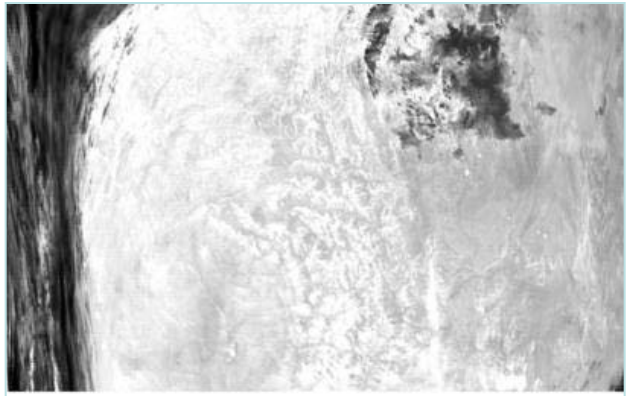
V6 L1B Code Change

- Sector Rotation Anomaly Fix
  - Anomaly in TEB data during certain sector rotation events (lunar calibrations)

Anomaly causes artificially high radiance band immediately before sector rotation



Collection 5

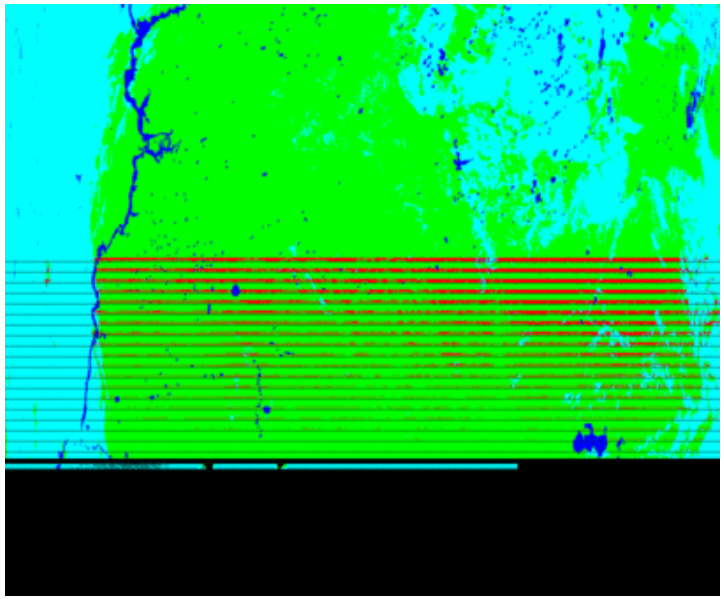


Collection 6

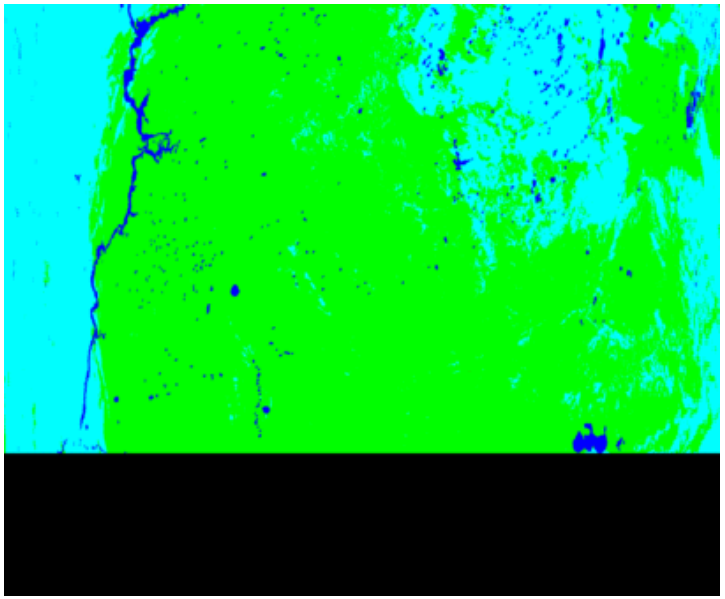
Plots courtesy of S. Devadiga

V6 L1B Code Change

Fire Granule MYD14.A2008343.2235



C5 Fire Product using C5 L1B



C5 Fire Product using C6 L1B

Plots courtesy of S. Devadiga

V6 L1B Status

- V6 LUTs latest updates
  - Aqua V6.1.7.9 (12/17/09)
  - Terra V6.1.2.1 (10/06/09)
  - LUT updates delivered ~ every 3 months

- V6 L1B data currently available
  - Terra: Jan 1-16, 2003
  - Aqua: Jan 1-31, 2003
  - https://ladsweb.nascom.nasa.gov

V6 L1B Status

- Science Testing in progress
  - Test V5 Products generated using V6 L1B (Jan. 2003 L1B)
  - Terra & Aqua – Land
  - Aqua only – Atmosphere
  - Ocean (OBPG) generated test products for Aqua using both the official and alternate LUTs.
- All V6 L1B, Geolocation, & Cloud Mask/Profiles products will be generated and archived in LAADS