MODIS Calibration Workshop

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and

MODIS Characterization Support Team (MCST)

Agenda

- Instrument and Performance Status Updates
  - 9:00-9:10 Introduction and Instrument Status: Jack Xiong
  - 9:10-9:25 IOT Status: Roy Yi
  - 9:25-9:40 L1B Status: James Kuyper
  - 9:40-9:55 TEB Status: Aisheng Wu
  - 9:55-10:10 RSB Status: Hongda Chen
  - 10:10-10:30 Spatial/Spectral Status: Jason Choi & Jack Xiong
- 10:30-10:45 Coffee Break
- Collection 6 Issues
  - 10:45-11:15 Intro + Proposed QA & TEB Changes: Brian Wenny
  - 11:15-11:45 Proposed RSB Changes: Junqiang Sun
  - Open Discussion
- 12:00-1:30 Lunch
- Science Discipline Presentations
  - 1:30-2:00 Geometric Calibration Status: Robert Wolfe
  - 2:00-2:20 Chris Moeller
  - 2:20-2:40 Eric Vermote
  - 2:40-3:10 Ewa Kwiatkowska
- 3:10-3:25 Coffee Break
  - 3:25-3:55 Special Issues: Jack Xiong
  - Open Discussion
- 4:45-5:00 Summary & Action Items: Jack Xiong & All

MCST Contacts

- Instrument operation: Roy Yi
- L1B and LUT: James Kuyper
- RSB Calibration: Junqiang Sun / Hongda Chen
- TEB Calibration: Aisheng Wu / Brian Wenny
- Spectral and Spatial: Jason Choi
- General Information: Brian Wenny and Jack Xiong

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)

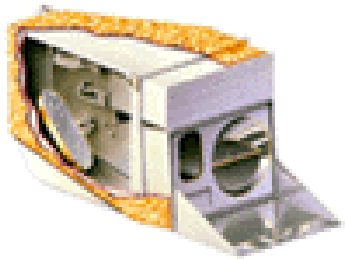
Acknowledgements

- 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

Instrument Status

- **Instrument Background (for reference purposes)**
- **On-orbit Calibration Activities**
- **Key Telemetry Trending**
  - **Instrument temperature**
  - **FPA temperature**
  - **Blackbody**
- **Summary of Instrument Status (operation/calibration)**

Instrument Background



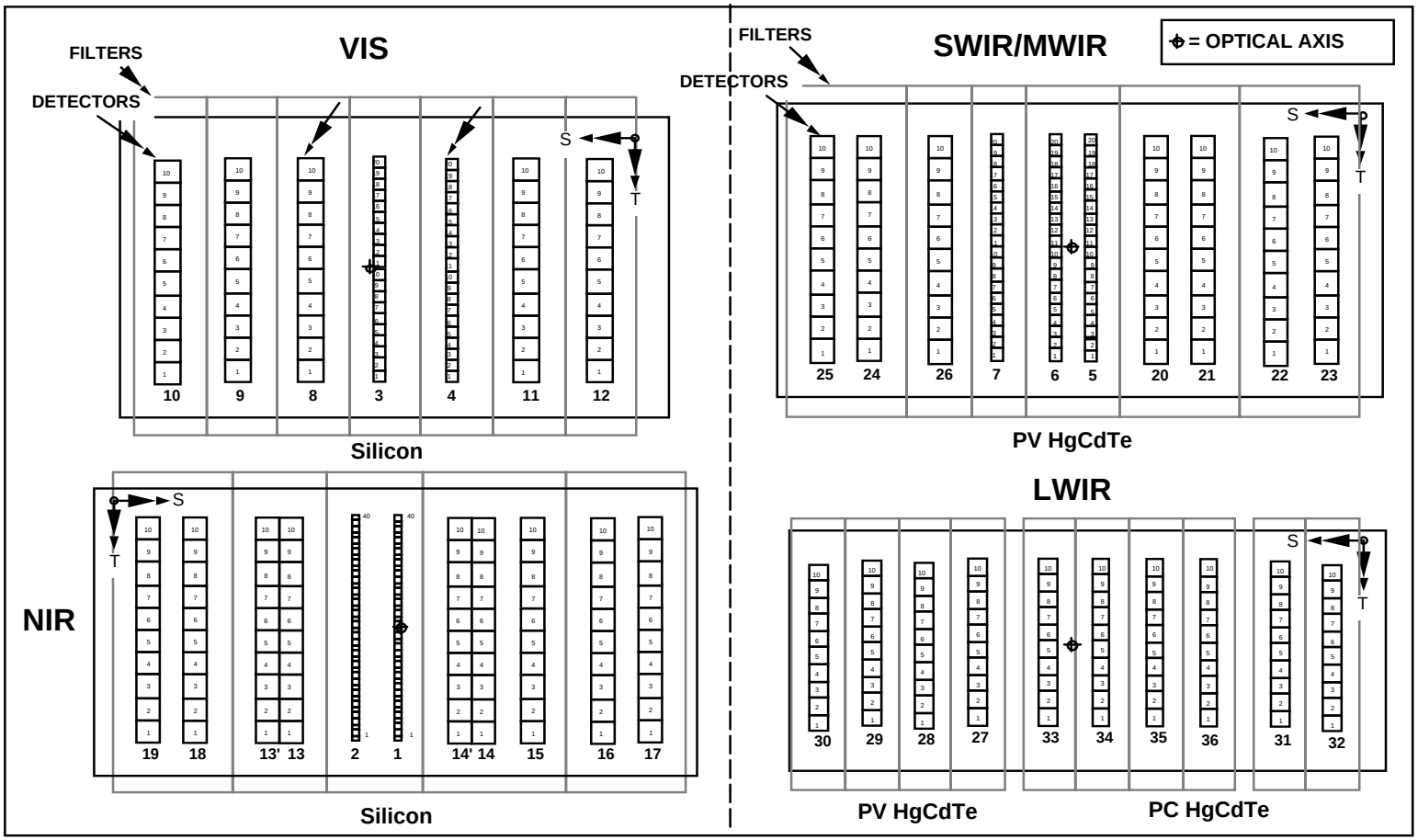
PFM **FM1**

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

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

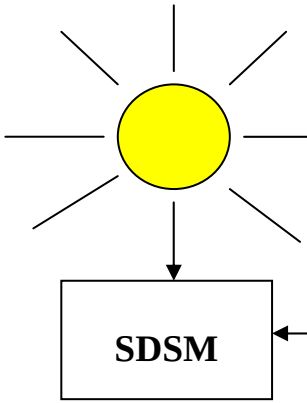
[2] Spectral Radiance values are (W/m^2-μm-sr)

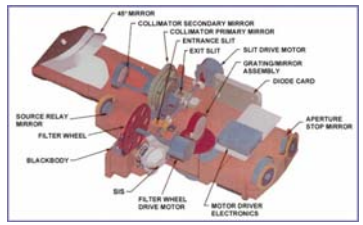
[4] NEΔT = Noise-equivalent temperature difference

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)

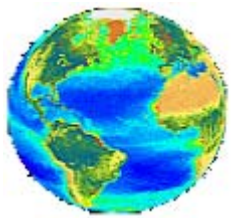
SDSM





Scan
Mirror

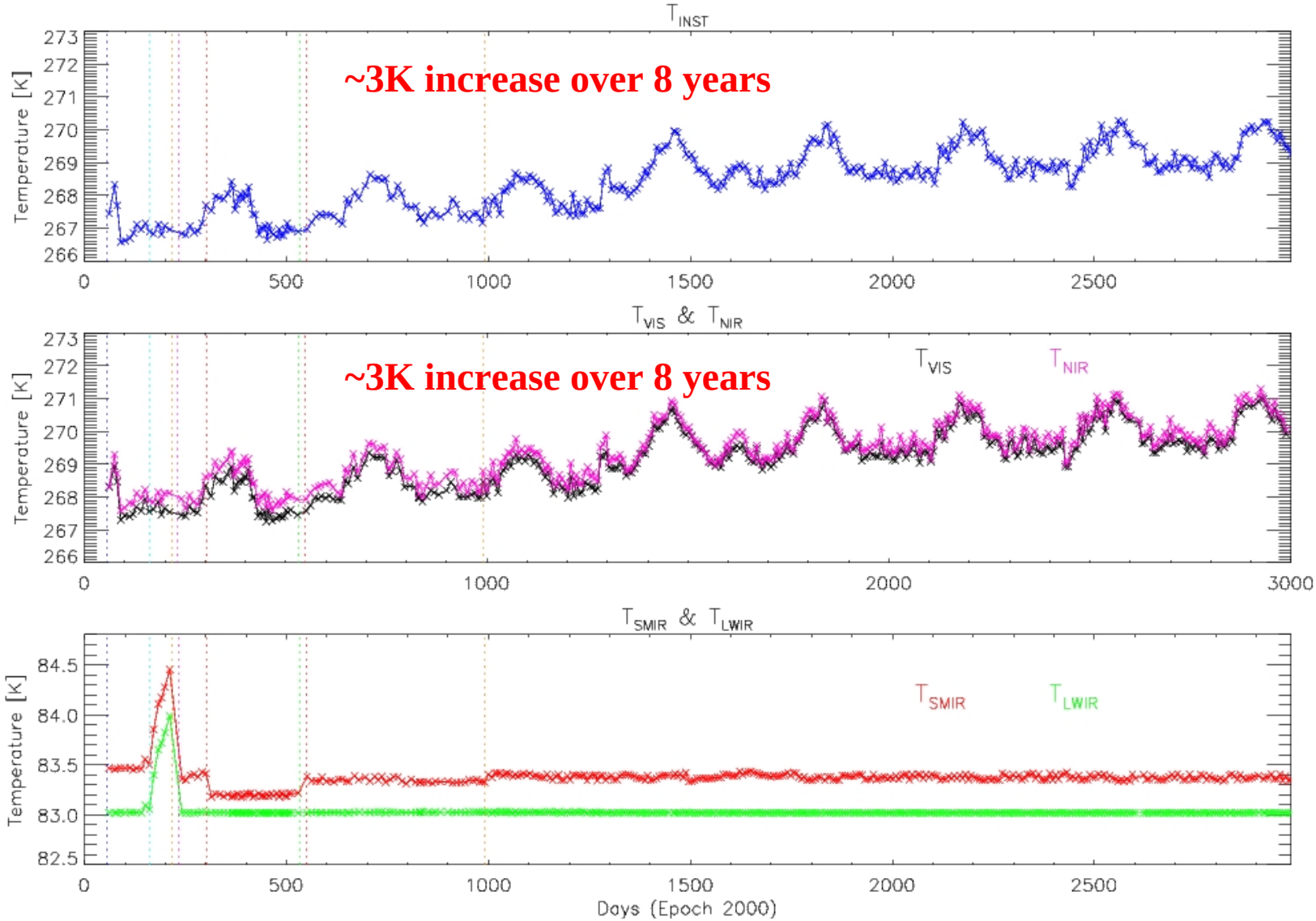
Moon



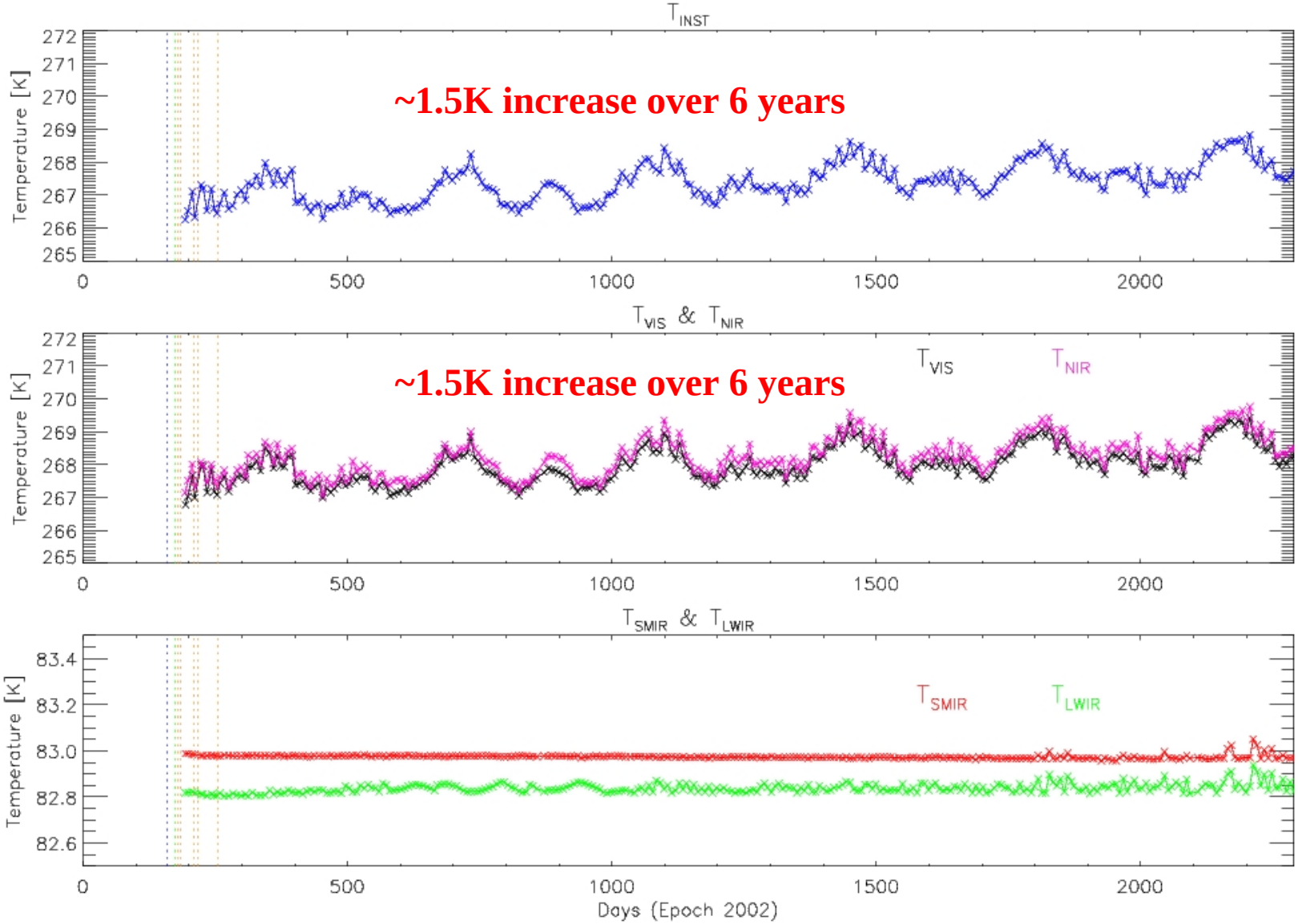
SRCA is currently operated at reduced frequencies (30W configuration removed). This has no impact on radiometric calibration.

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

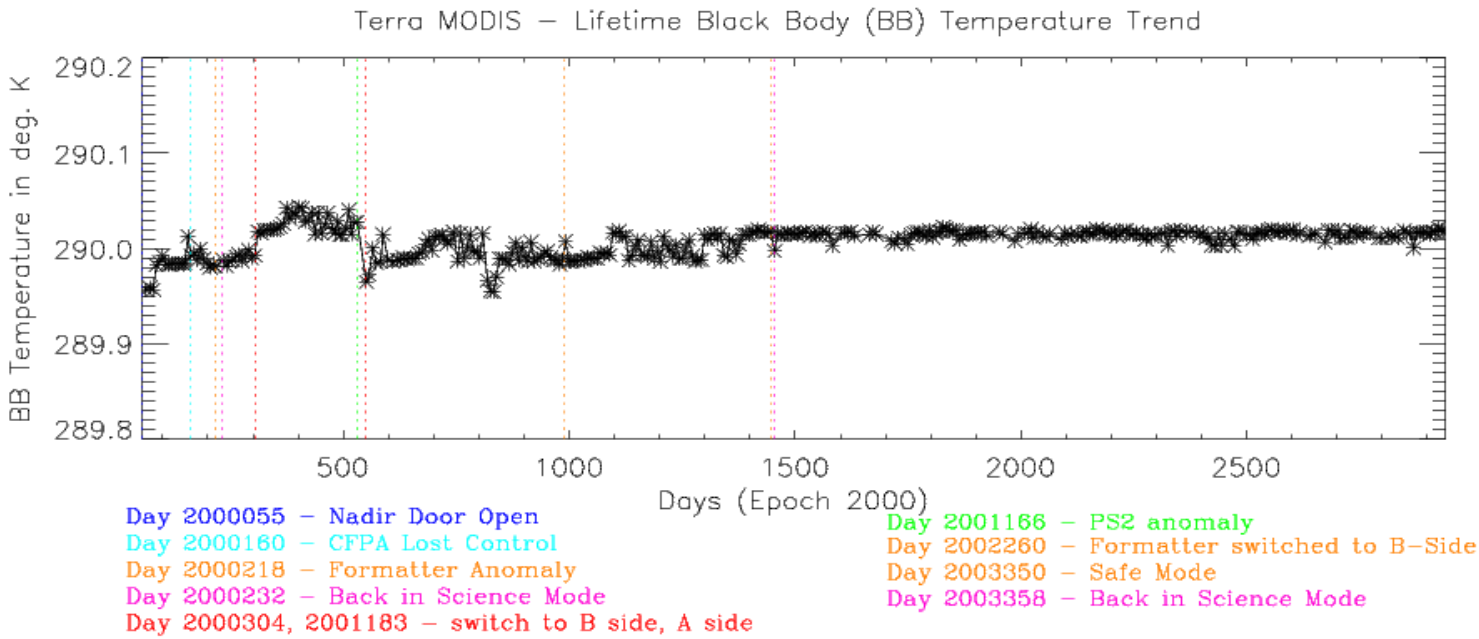
Terra Instrument and FPA Temperatures

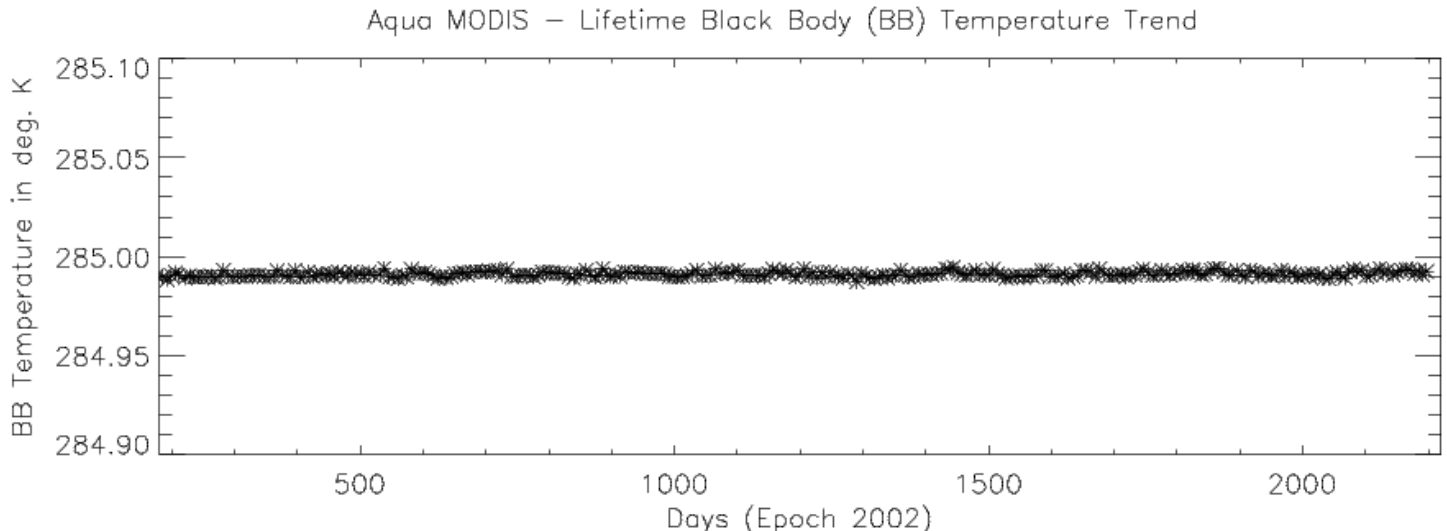


Aqua Instrument and FPA Temperatures



MODIS BB Temperatures





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) with SDSM operated normally; Aqua SD/SDSM continued to operate on a regular basis
  - SRCA 30W configuration removed (2005 for Aqua MODIS, 2006 for Terra MODIS); No impact on radiometric calibration
  - BB temperatures (290K for Terra, 285K for Aqua) remained to be stable
- 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 (over 6 years)
  - 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)

MODIS Instrument Operations

(Details provided in backup slides)

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)
    - Number of Supersets increased from 32 to 33
  - No change in SSR configuration (current SSR configuration considered "limit" of no loss operations with current TDRSS scheduling)
  - Three instances of SFE anomalies: one in Nov., one in Dec. 2007, and April 2008 (data loss occurred).
- MODIS Events
  - No new events since 01/31/2008

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
  - Currently a software fix is in place to correct for the hardware error. A meeting will be held to discuss possible hardware fixes.
- MODIS Events
  - No new events since 01/31/2008
  - Several calibration events were cancelled/ postponed to support S/C SSR anomaly analysis/resolution

Terra/MODIS OBC Operations

- Total Number of Terra OBC Operations Since Launch
  - SD/SDSM: 562
  - Blackbody: 63
  - SRCA: 265
    - (Includes Spectral, Radiometric, and Spatial)
  - Electronic Calibration: 55
  - Lunar Calibration: 78

Aqua/MODIS OBC Operations

- Total Number of Aqua OBC Operations Since Launch
  - SD/SDSM: 364
  - Blackbody: 23
  - SRCA: 139
    - (Includes Spectral, Radiometric, and Spatial)
  - Electronic Calibration: 35
  - Lunar Calibration: 53

Future Operational Considerations

- ***Aqua MODIS SD door movements***
- ***Aqua MODIS CFPA temperatures***

Detailed IOT information (weekly reports, history, anomaly reports, etc.) are available through the MCST website:

http://www.mcst.ssai.biz/IOT/index.shtml

MODIS Level 1B and LUT Status

(Details provided in backup slides)

Recent Code and L1B 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
  - 6 for Terra MODIS and 2 for Aqua MODIS in 2008 to date
  - 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

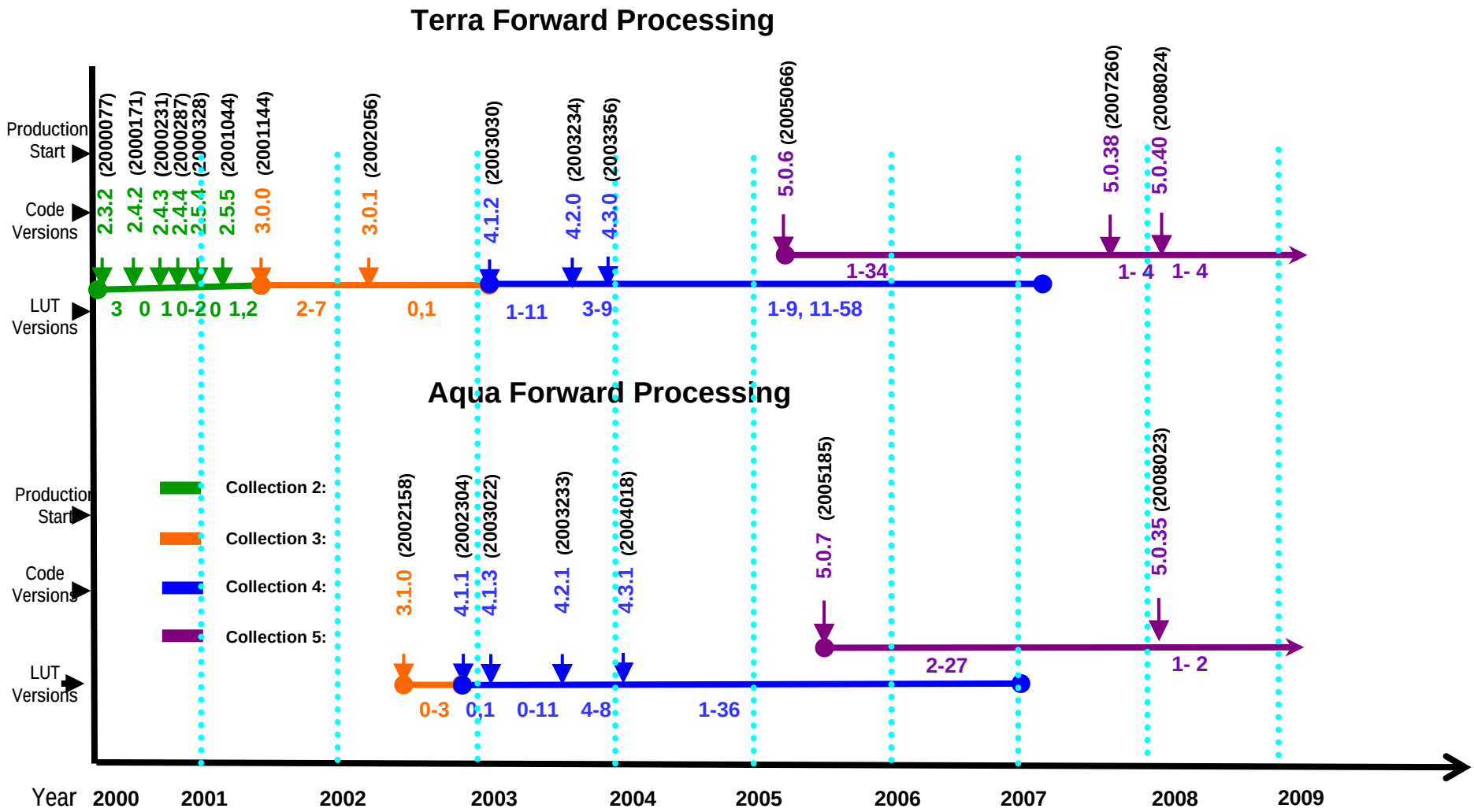
Number of MCST L1B Code and LUT Versions

(as of 5/12/2008)

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	6	1	0	0	2	10
Total	18	3	6	75	44	9	3	52	29	239

MODIS MOD_PR02 L1B Code/LUTs Major Production Changes Timeline



Most Recent 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	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.

Most Recent 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	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.

Collection 6 Code Changes for L1B

- Change to no longer interpolate the values of dead detectors from nearby good detectors.
  - Waiting since 2008-03-13 for MCST, Discipline approval of one-day Golden Tiles test results. This will be followed by a 16-day Golden Tiles test.
- Noisy detector (sub-sample) flagging
  - Results from first test run produced 2008-03-28. Will be released for MCST and Discipline approval as soon as internal review is complete.
- Special Handling for the case where SV DN==0.
  - Initial data collection completed 2008-04-28. Need to analyze data before deciding what special handling, if any, is needed for SV DN==0. Currently considering three options:
  - No special handling: current code
  - Mark as bad only if exactly 0
  - Mark as bad if the DN is below some threshold which will depend upon the band and the detector; it might also have time dependence

MODIS TEB Calibration Status

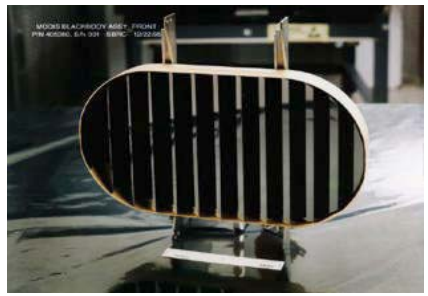
TEB Calibration Performance

- TEB Calibration Algorithm
- 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

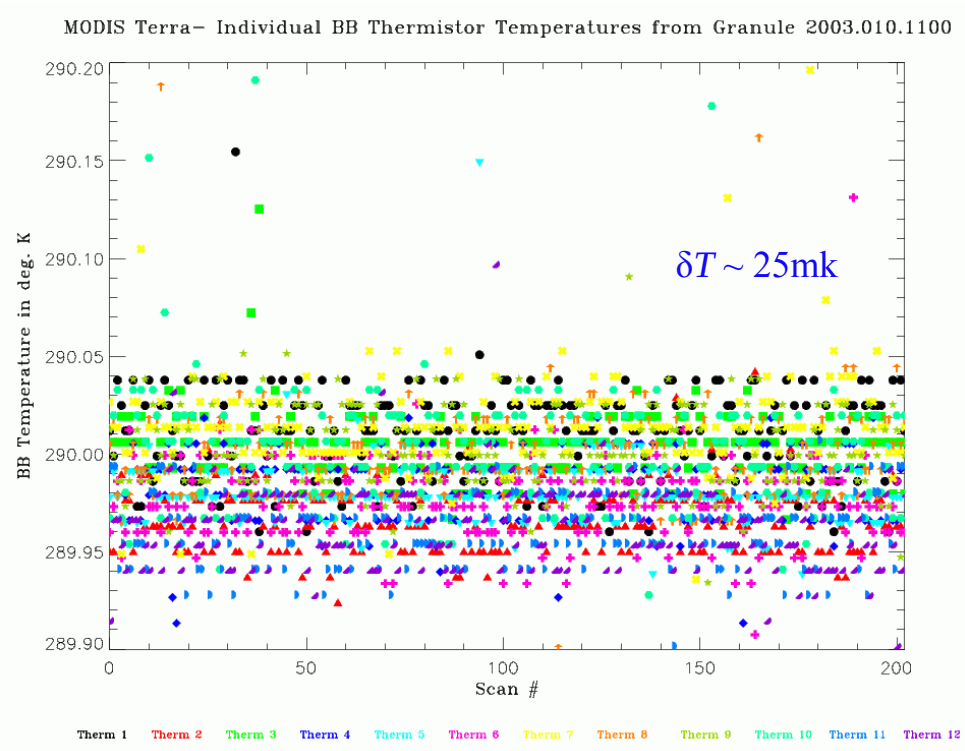
a0 & a2 derived from pre-launch or periodic warm-up/cool-down cycles (270-315 K) of the BB

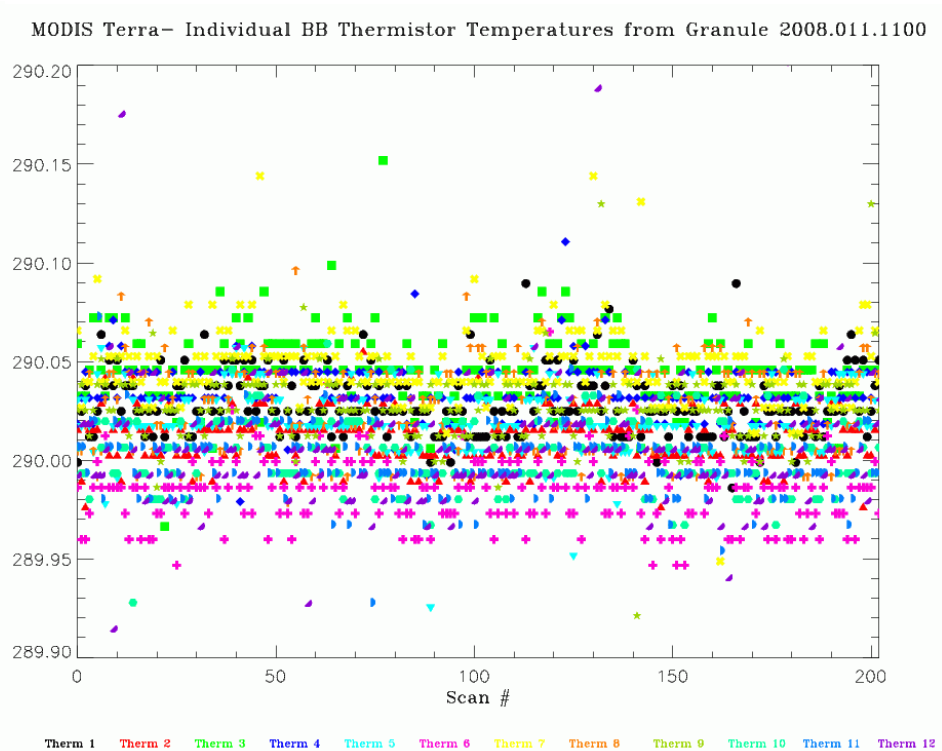
TEB On-orbit Performance

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 and 1 inoperable detector (B29 D6)**
- **Aqua MODIS**
  - **Stable short-term and long-term response trends**
  - **3 noisy detectors (1 new since last STM B29 D2) and 1 inoperable detector (B36 D5)**

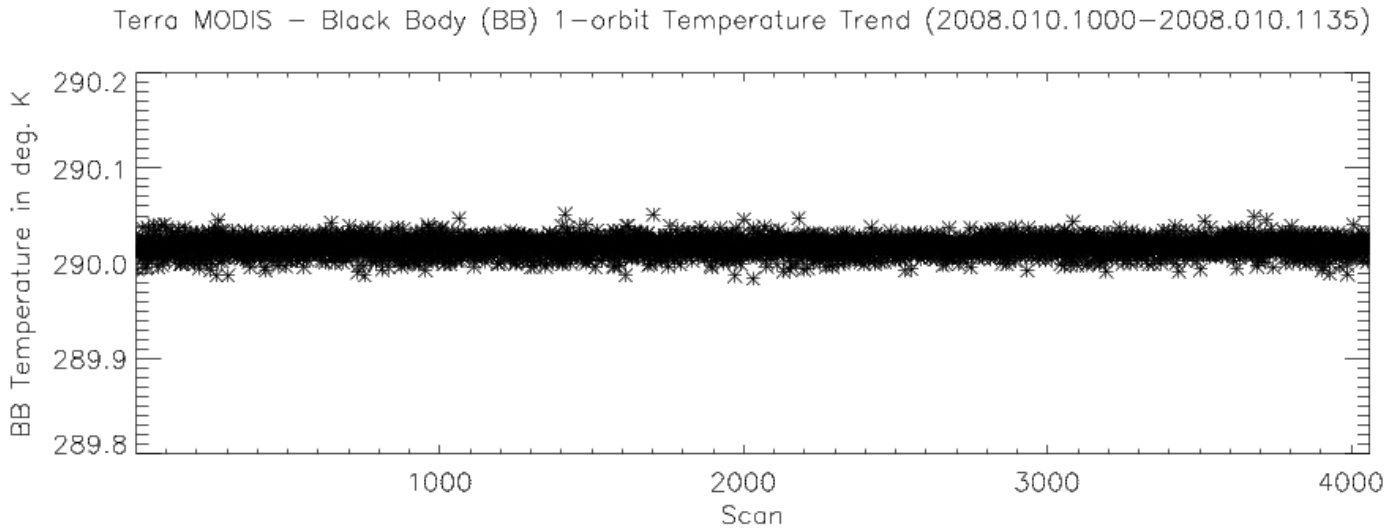
Terra BB Short-term Stability

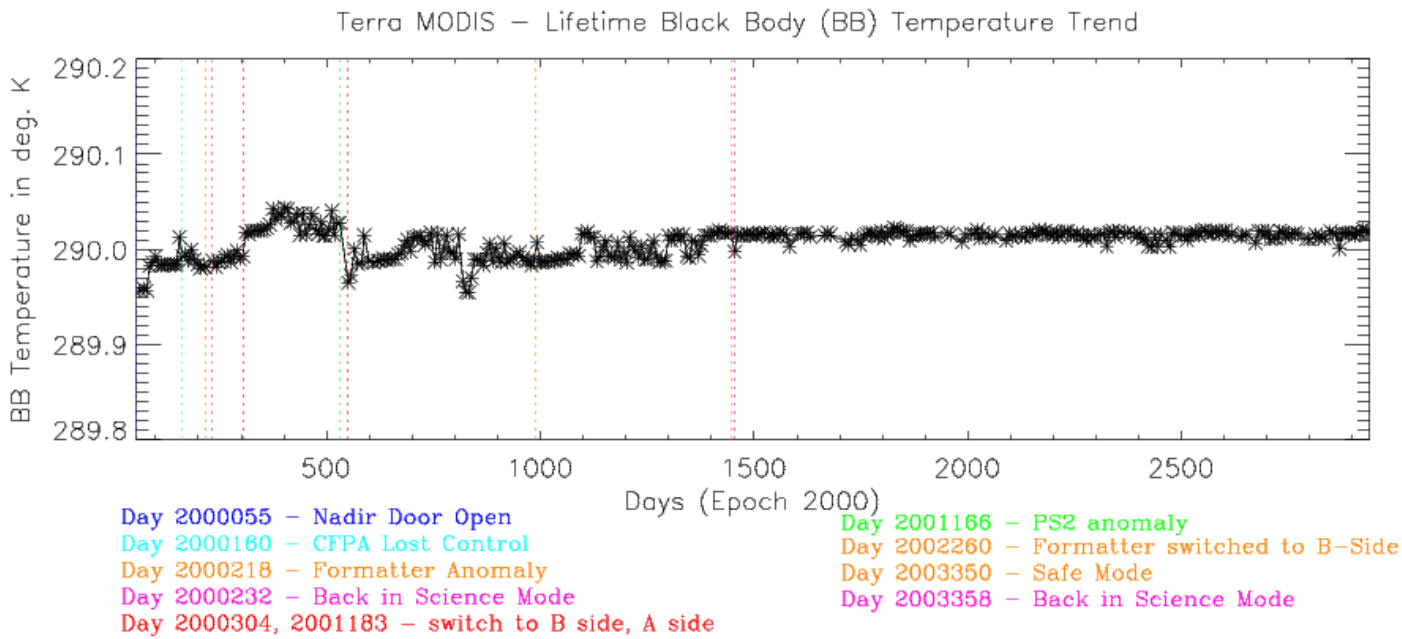




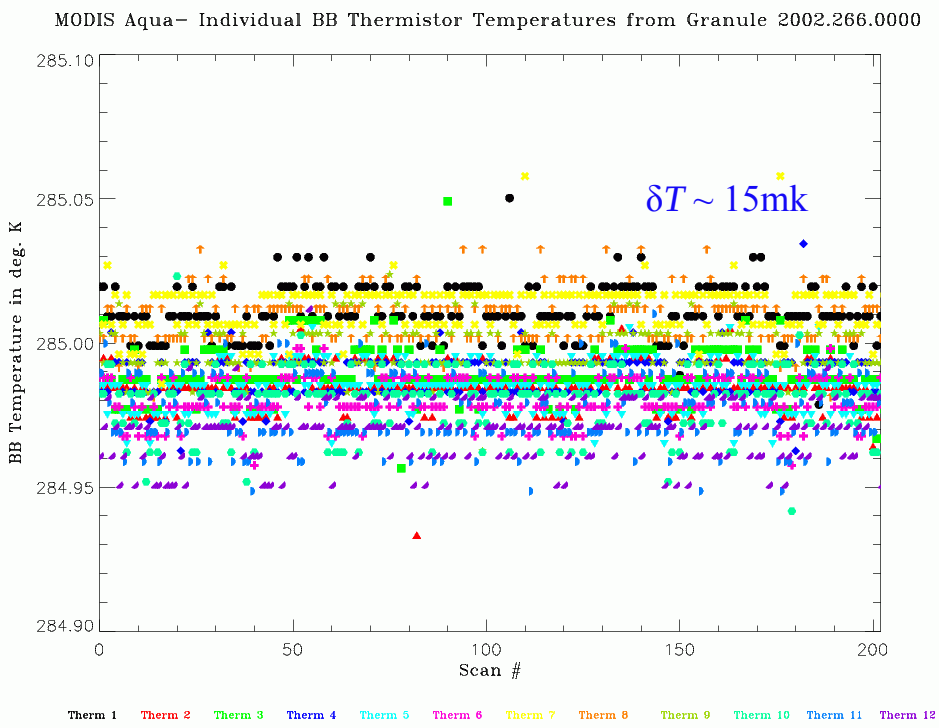
1-granule, scan-by-scan, 12 individual BB thermistors

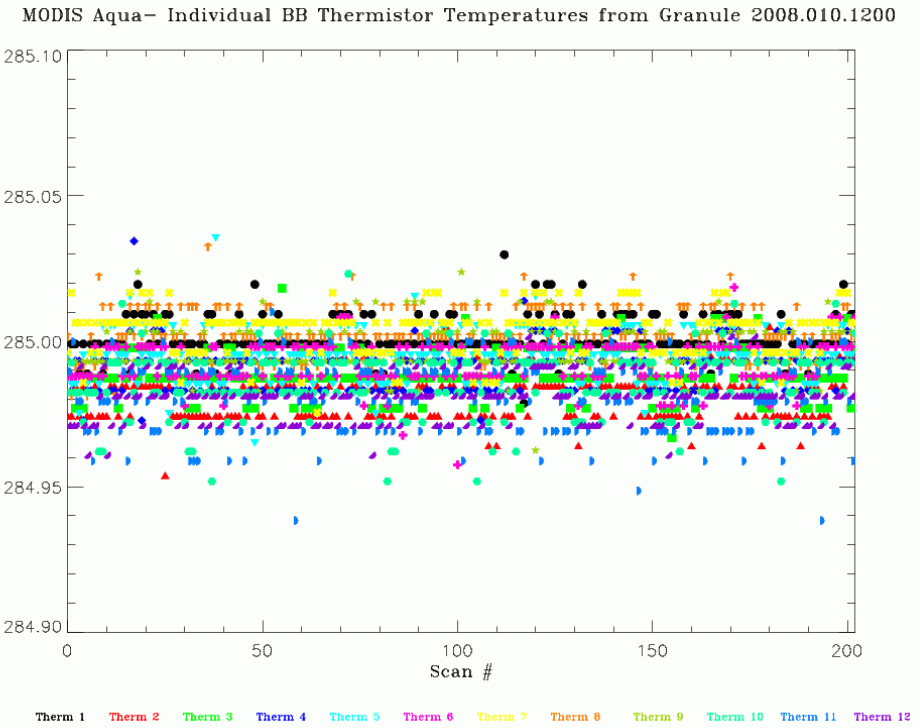
Terra BB On-Orbit Performance





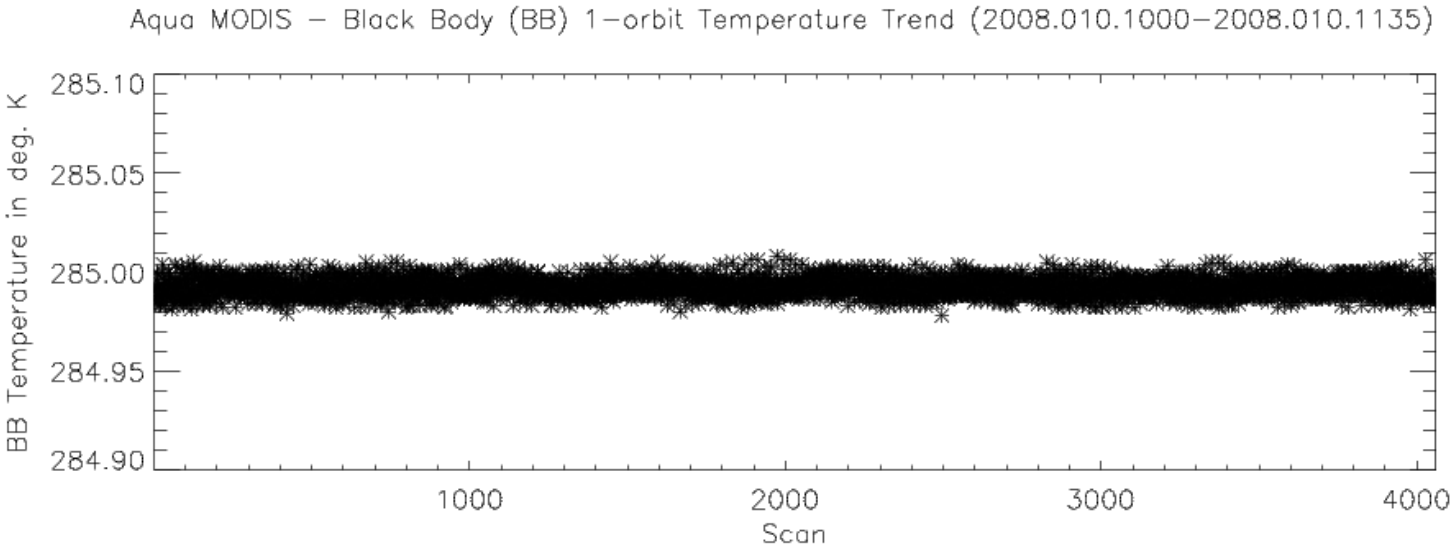
Aqua BB Short-term Stability

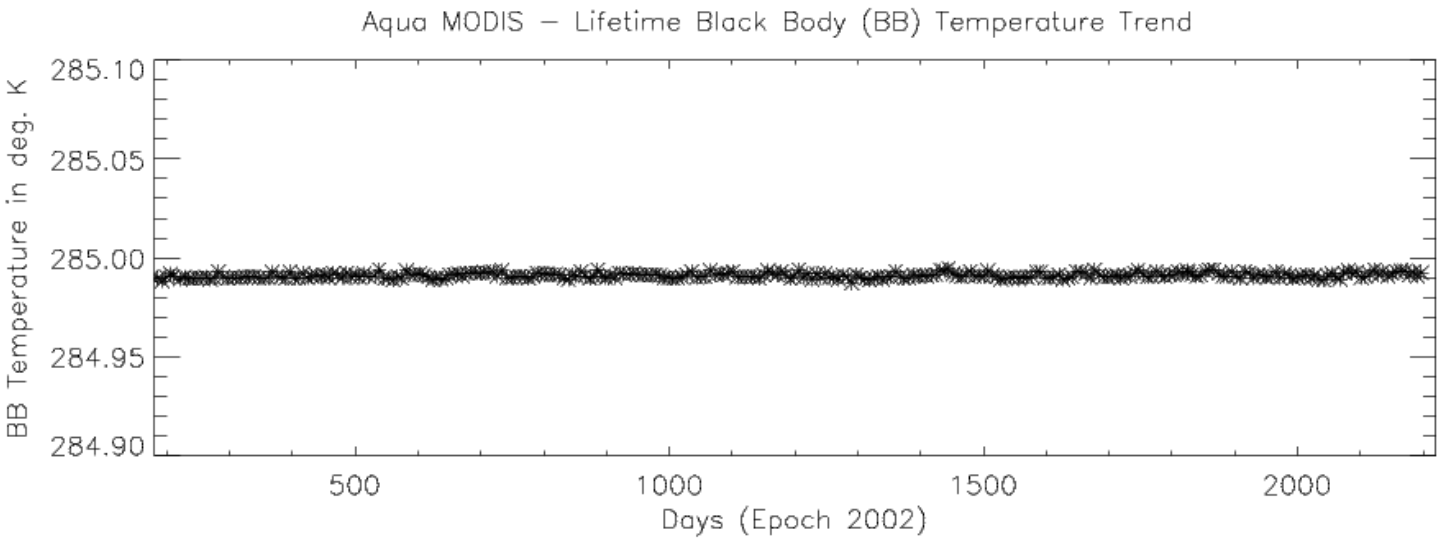




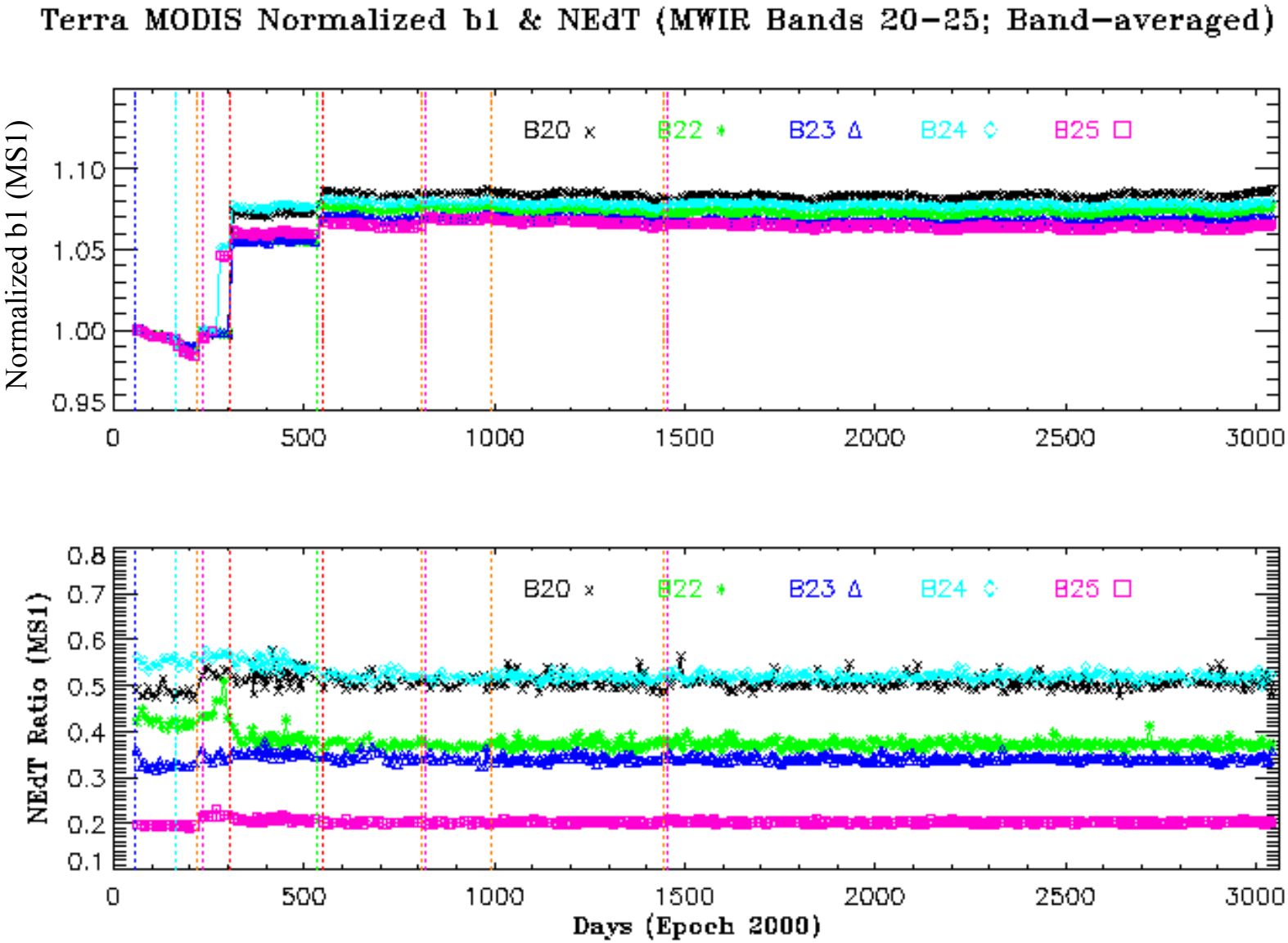
1-granule, scan-by-scan, 12 individual BB thermistors

Aqua BB On-Orbit Performance

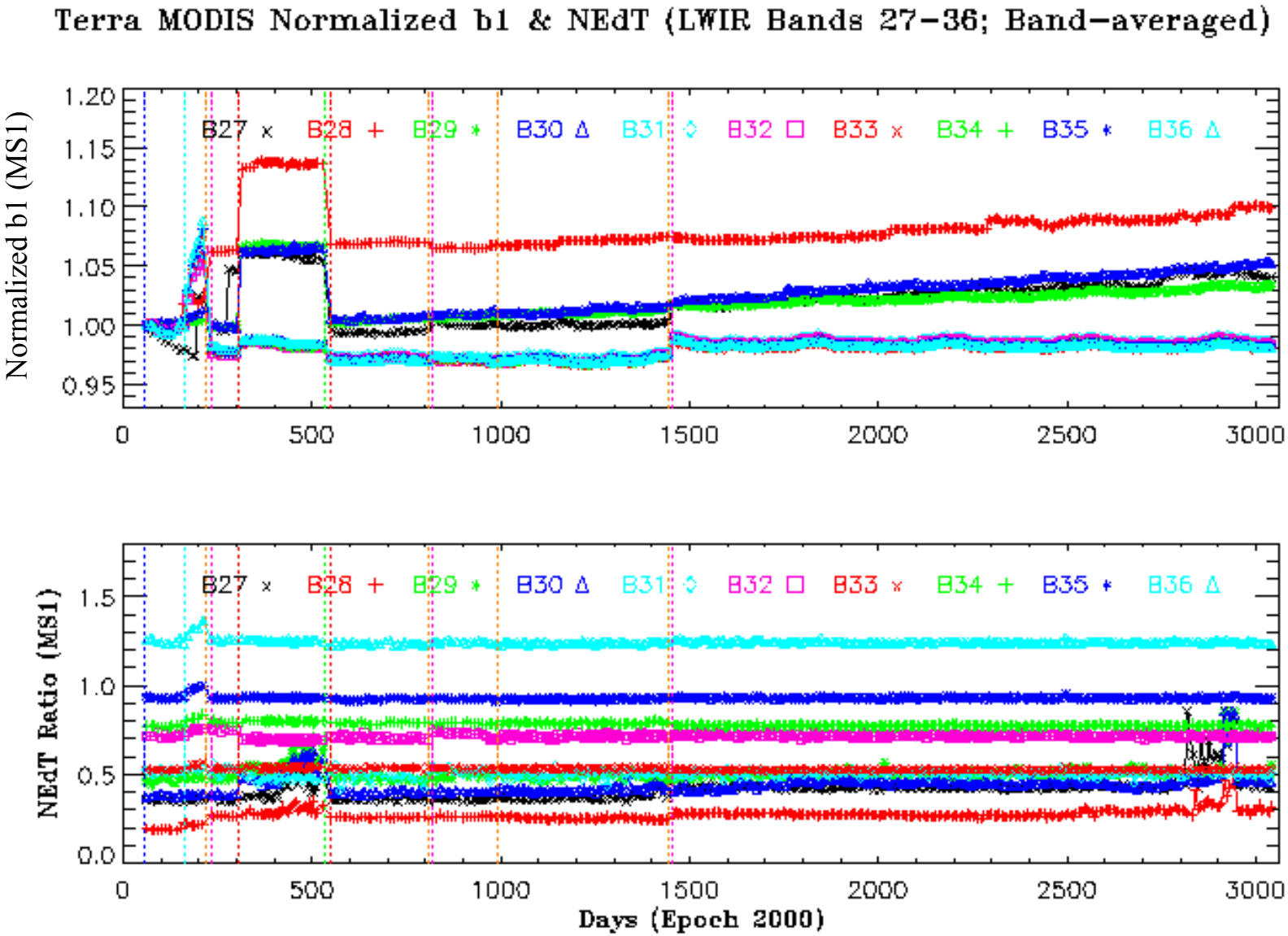




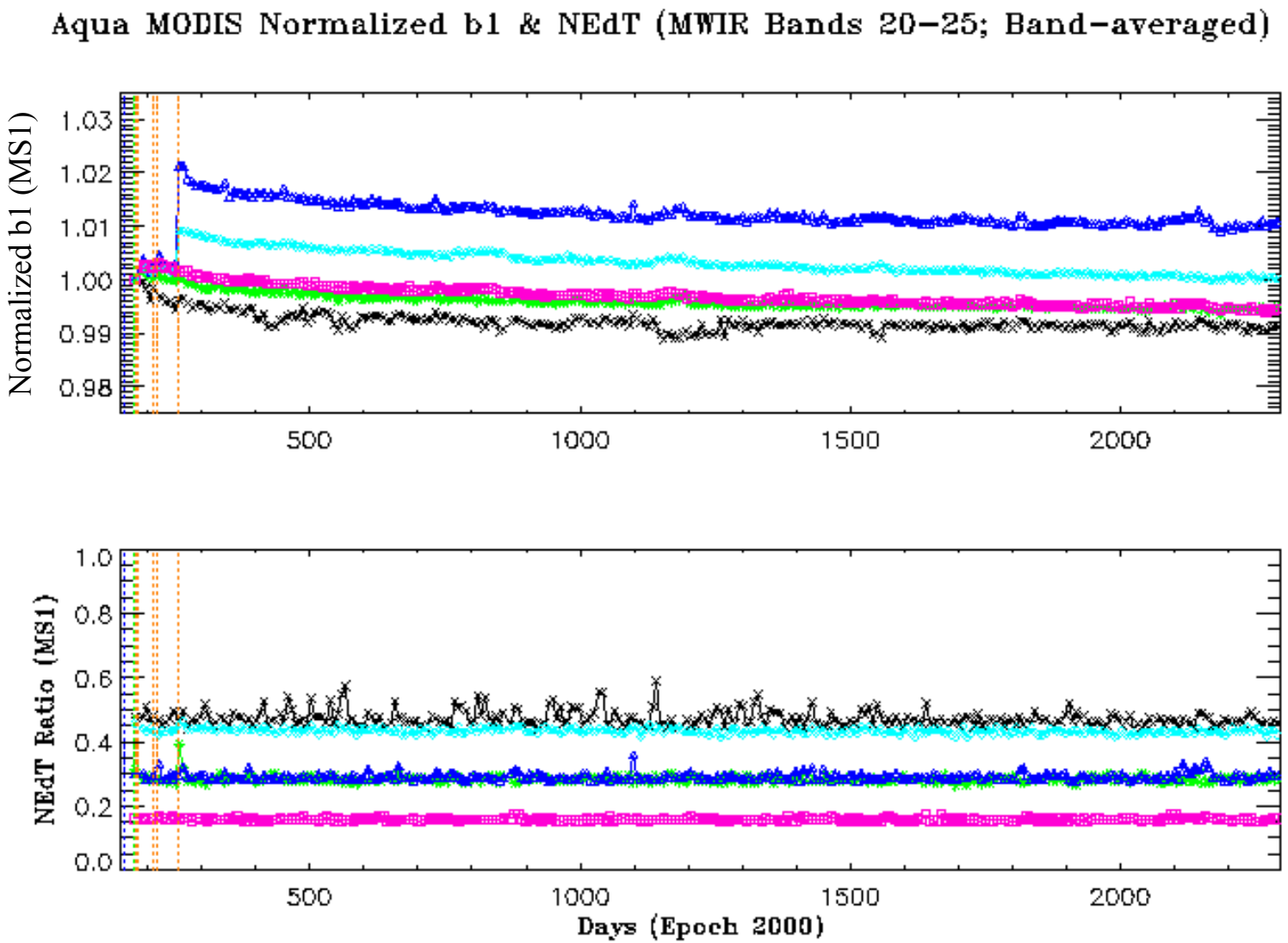
Terra TEB MWIR Response Trend



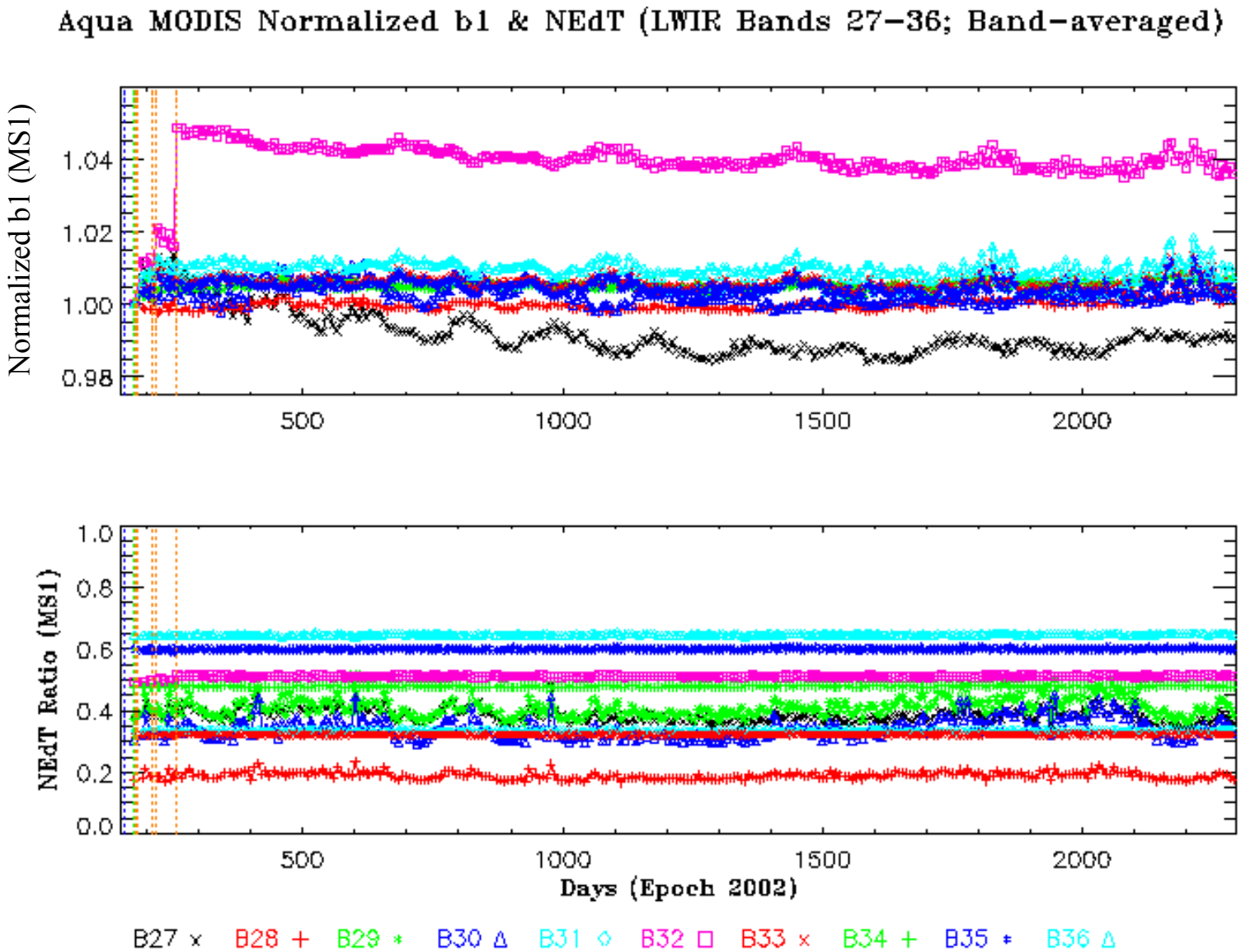
Terra TEB LWIR Response Trend



Aqua TEB MWIR Response Trend



Aqua TEB LWIR Response Trend



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

Detectors in Product Order

Day/Year	Band	20	21			27	29		B36
	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

MODIS RSB Calibration Status

Outline

- RSB calibration algorithm
- Noisy & inoperable RSB detector update
- RSB response trending
- RSB mirror side ratio trending
- Solar Diffuser degradation
- Summary of RSB overall performance

RSB Calibration Algorithm

- **Solar Diffuser (SD) Calibration**
  - SD Stability Monitor (SDSM)
    - 9 detectors with wavelengths from 410 ~ 940 nm
    - Data acquired form two paths: sun view and SD view

$$\Delta_{SD} = \frac{\left\langle dc^{D1}_{SD\_view} / dc^{D9}_{SD\_view} \right\rangle}{\left\langle dc^{D1}_{Sun\_view} / dc^{D9}_{Sun\_view} \right\rangle} \text{ for } \quad m_1 = \frac{\rho_{SD} \cdot \cos(\theta_{SD})}{dn^{*}_{SD} \cdot d^{2}_{Earth-Sun(SD)}} \Delta_{SD} \cdot \Gamma_{SDS}$$

- **Lunar Calibration**
  - Moon observations via the SV port at a near-constant phase angle
    - 9~10 lunar observations each year
    - Lunar coefficients used for RVS calculations (view geometry will be corrected, as well as an over-sampling factor for multiple scans)

$$m_1^{moon} = \frac{f_{vg}}{< dn^{*}_{Moon} >} \qquad f_{vg} = \frac{f_{phase-angle} \cdot f_{libration}}{d^{2}_{Sun-Moon} \cdot d^{2}_{Modis-Moon}} \cdot f_{oversampling}$$

- **Earth View Mirror Side Ratio**

Summary of RSB Overall Performance

- **Terra MODIS (8.5 years)**
  - No QA updates for RSB detectors since last workshop (01/2008)
  - Bi-weekly SDSM operation to track SD degradation
  - SD observations made every orbit, as SD door has remained open since July 2003 (with increased SD degradation).
  - Large response changes in VIS bands; noticeable mirror side differences (as high as 15% in band 8).

- **Aqua MODIS (6 years)**
  - No QA updates for RSB detectors since last workshop (01/2008)
  - SDSM operation and SD calibration are performed on tri-weekly basis to preserve remaining number of SD door movements.
  - Large response changes in VIS bands. Small mirror side differences (<1.5% in band 8).

MODIS RSB Noisy & Inoperable Detectors

- **No QA updates for RSB detectors since last workshop (01/2008)**

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

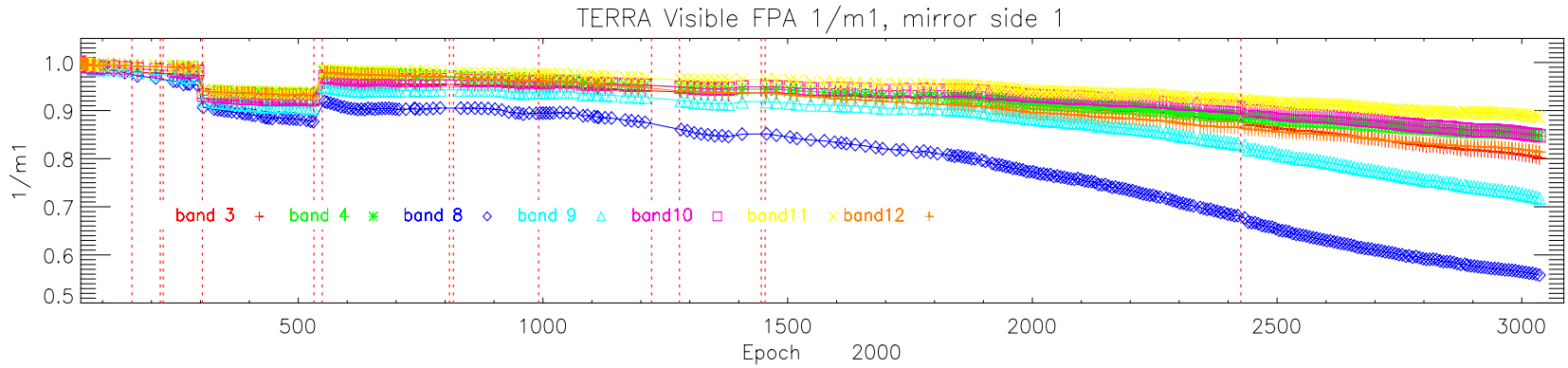
Aqua

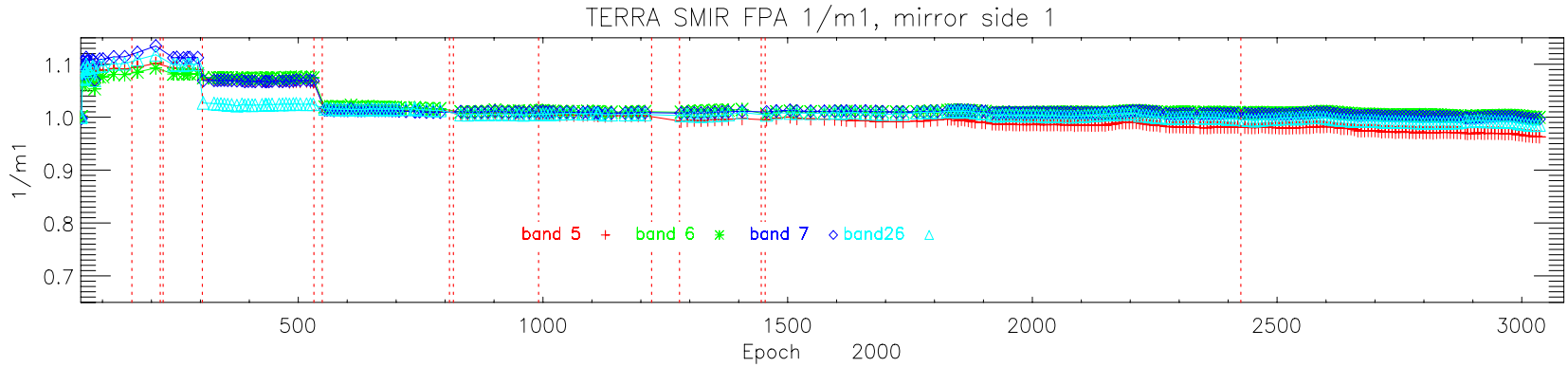
Day/Year	Band	5	6									
	SNR Spec	74	275									
	Detector	20	2	4	5	6	7	9	10	12-16	17	18-20
175/2002	Nadir Dorr Open	0	0	0	0	0	470	470	0	0	100	0
189/2002	Back from Safe Mode	0	0	470	470	0	470	470	0	0	470	0
255/2002	Back from Safe Mode	0	0	0	0	0	470	470	0	0	470	0
266/2002	Back from Safe Mode	0	0	0	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

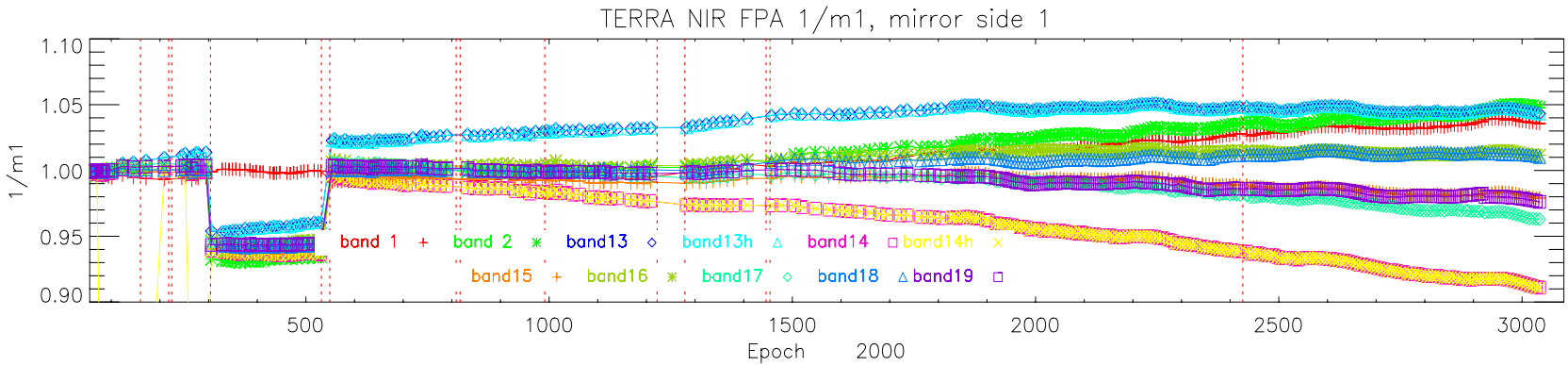
In Spec | Near Spec | Out Spec | Inoperable

Detectors in Production order

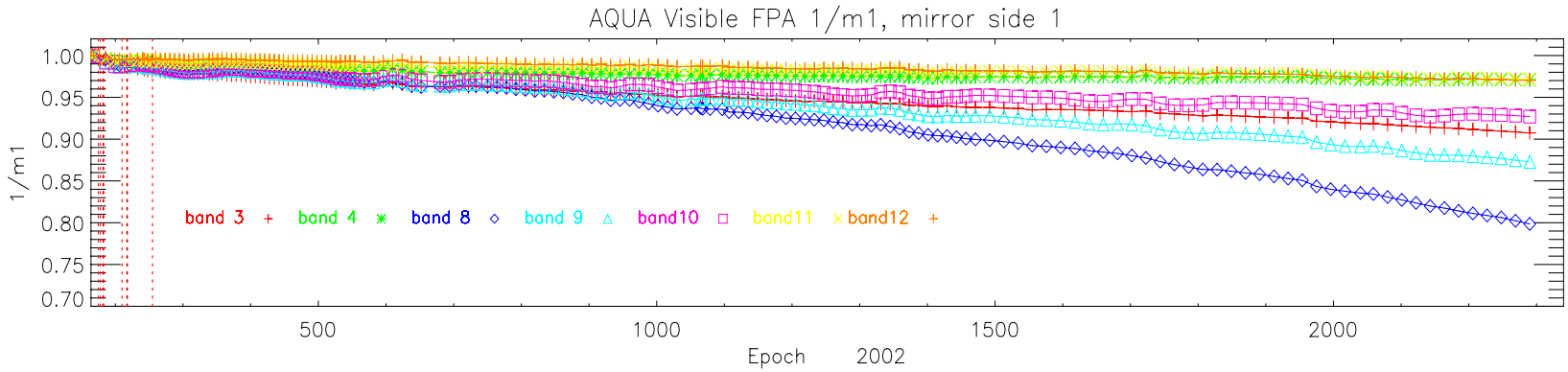
Terra RSB Response Trending

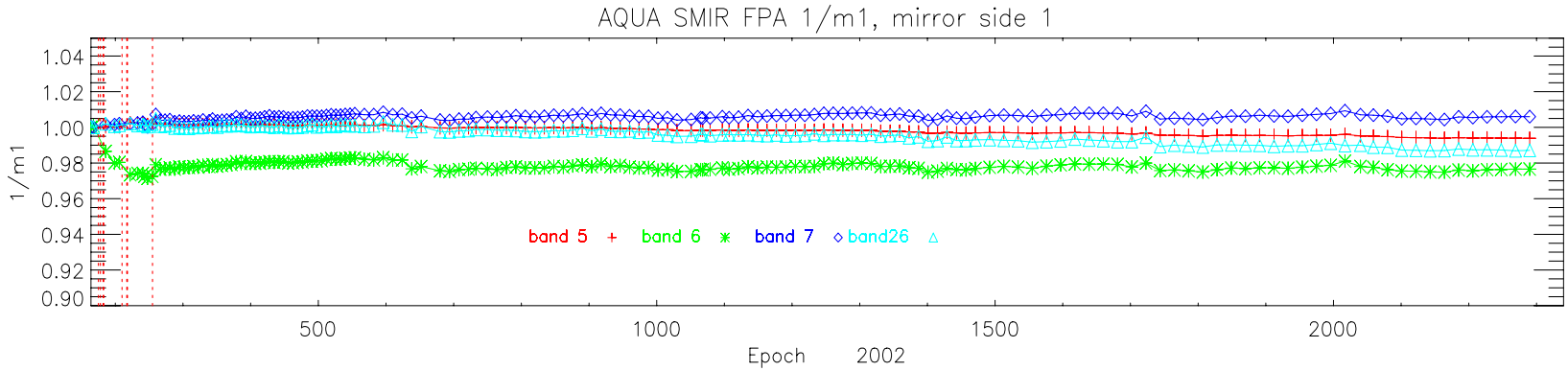


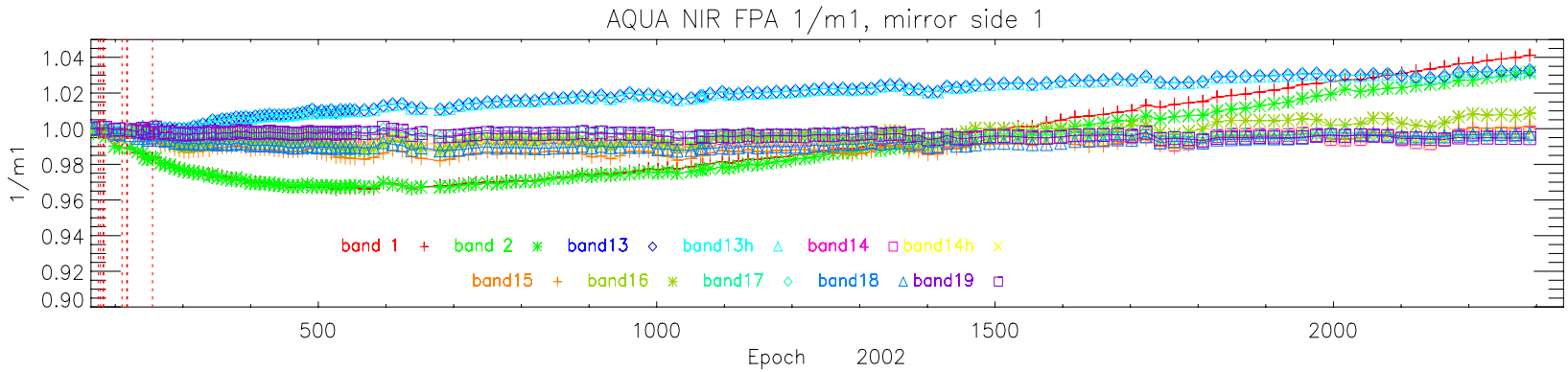




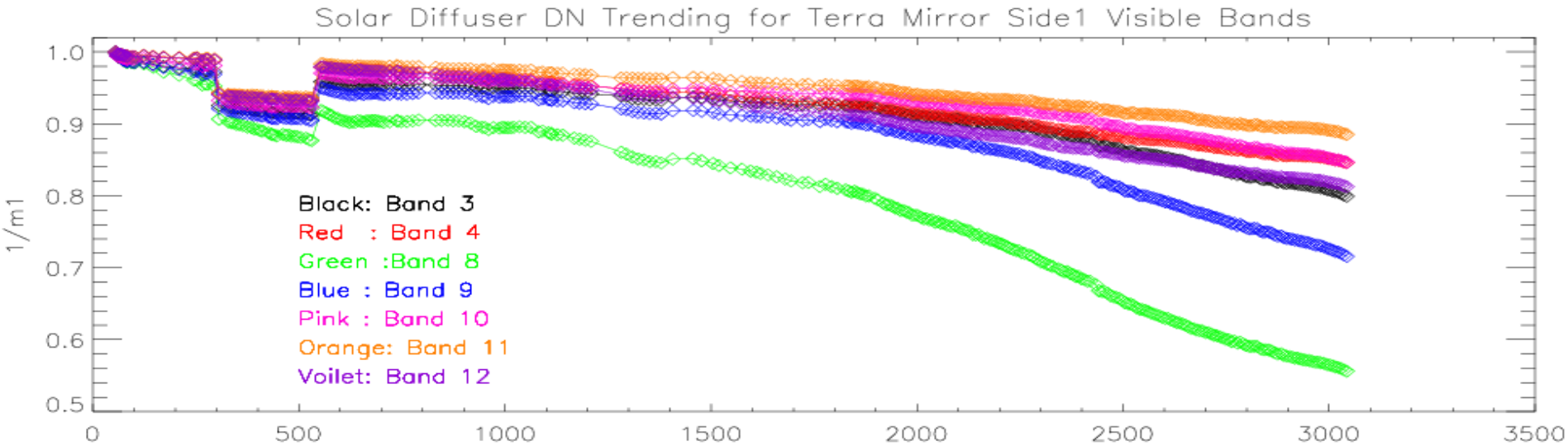
Aqua RSB Response Trending

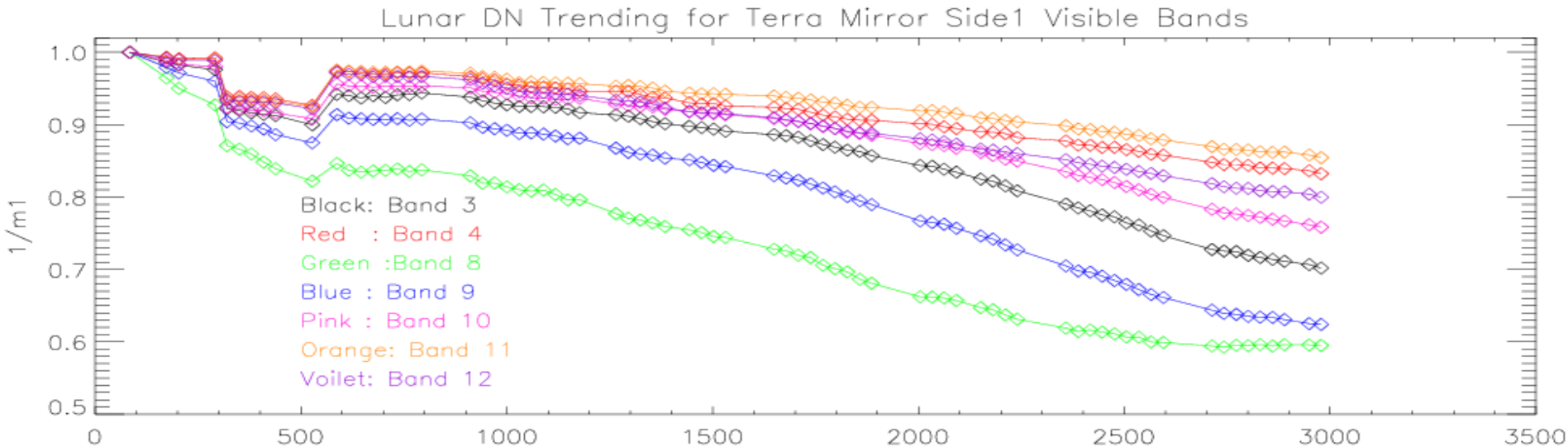






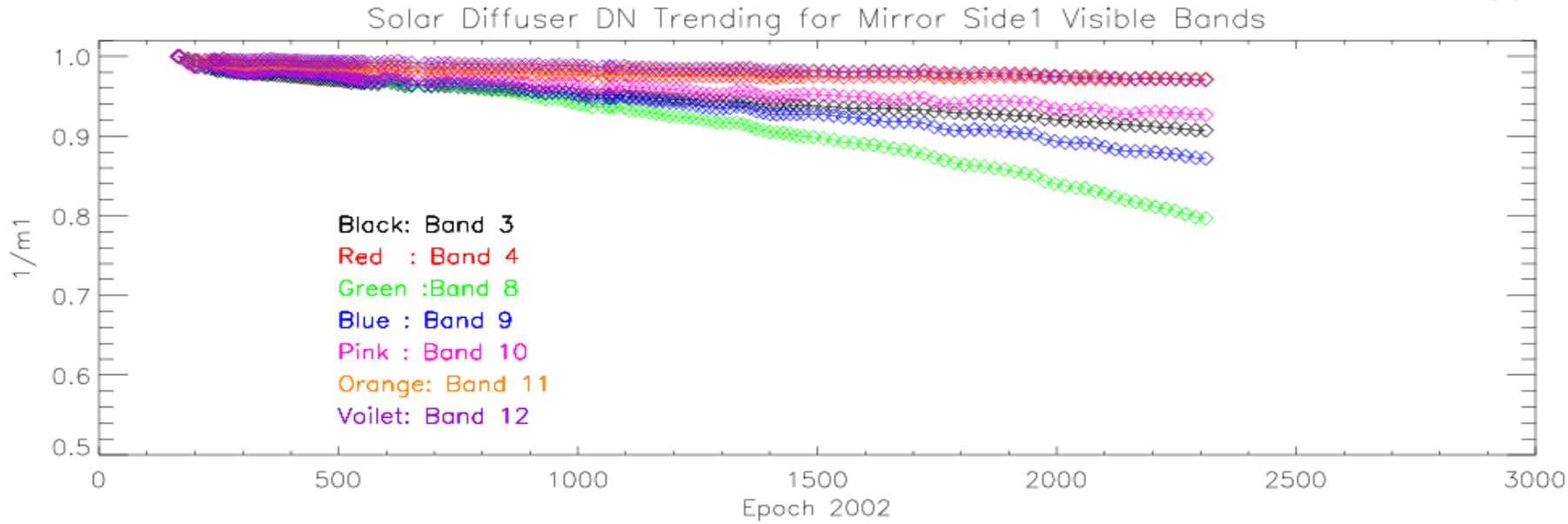
Terra RSB Response Trending (Moon/SD)

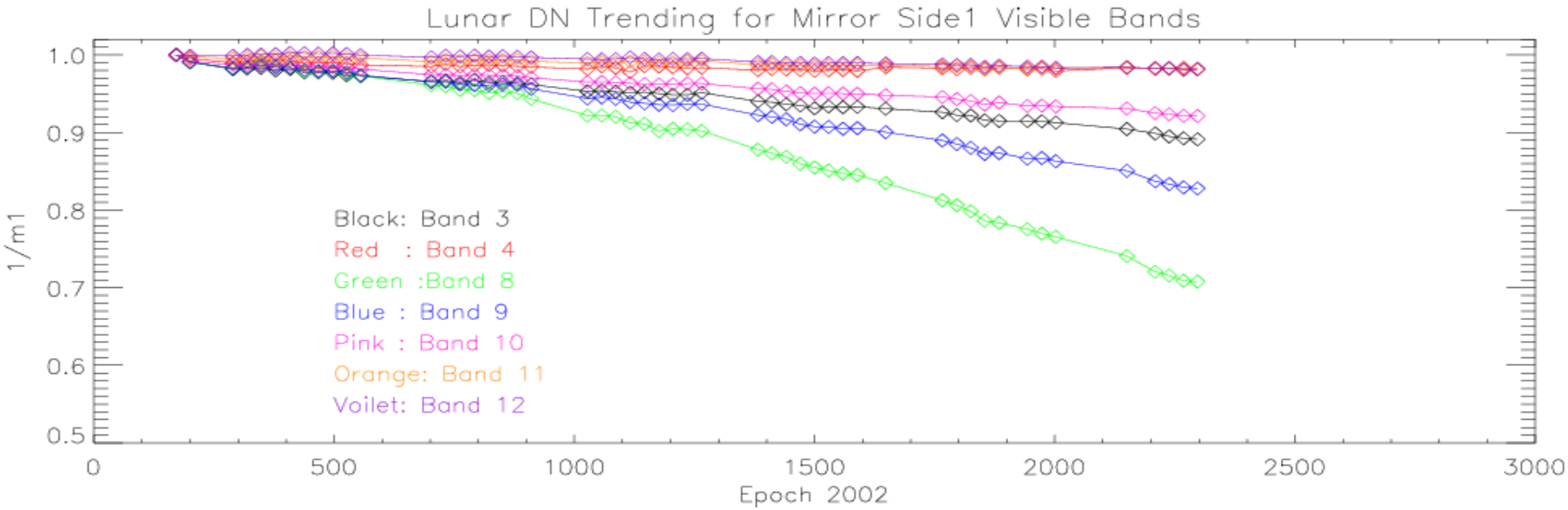




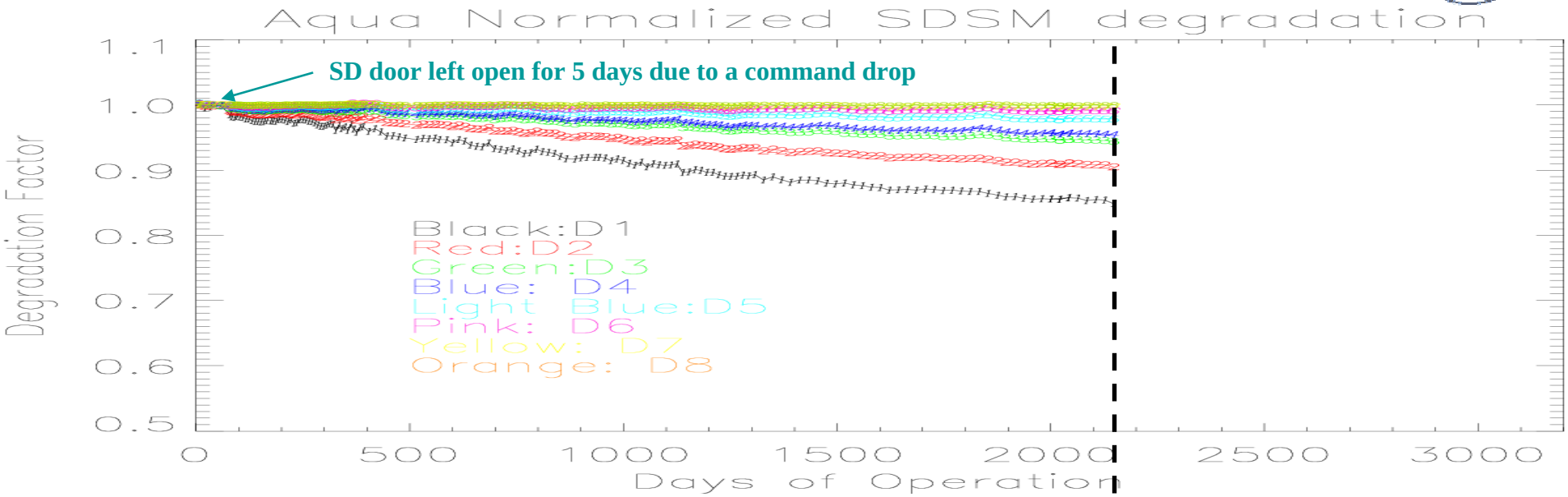
SD and Lunar responses (trending) are used to track MODIS scan mirror reflection versus scan angle (RVS)

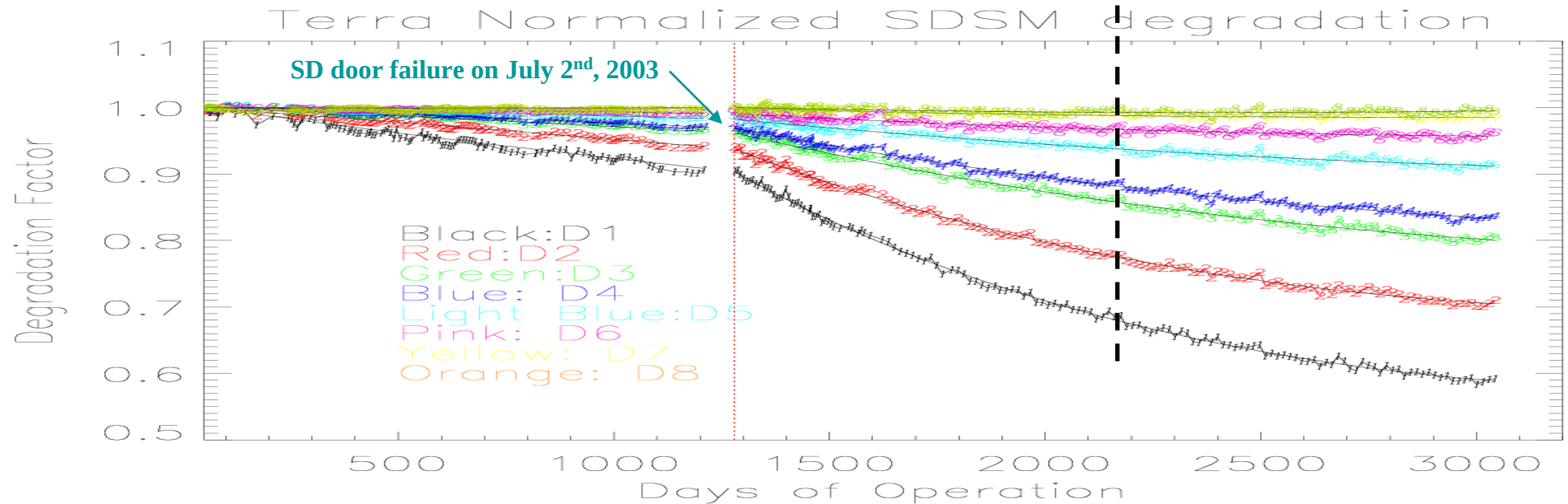
Aqua RSB Response Trending (Moon/SD)





SD Degradation Trending



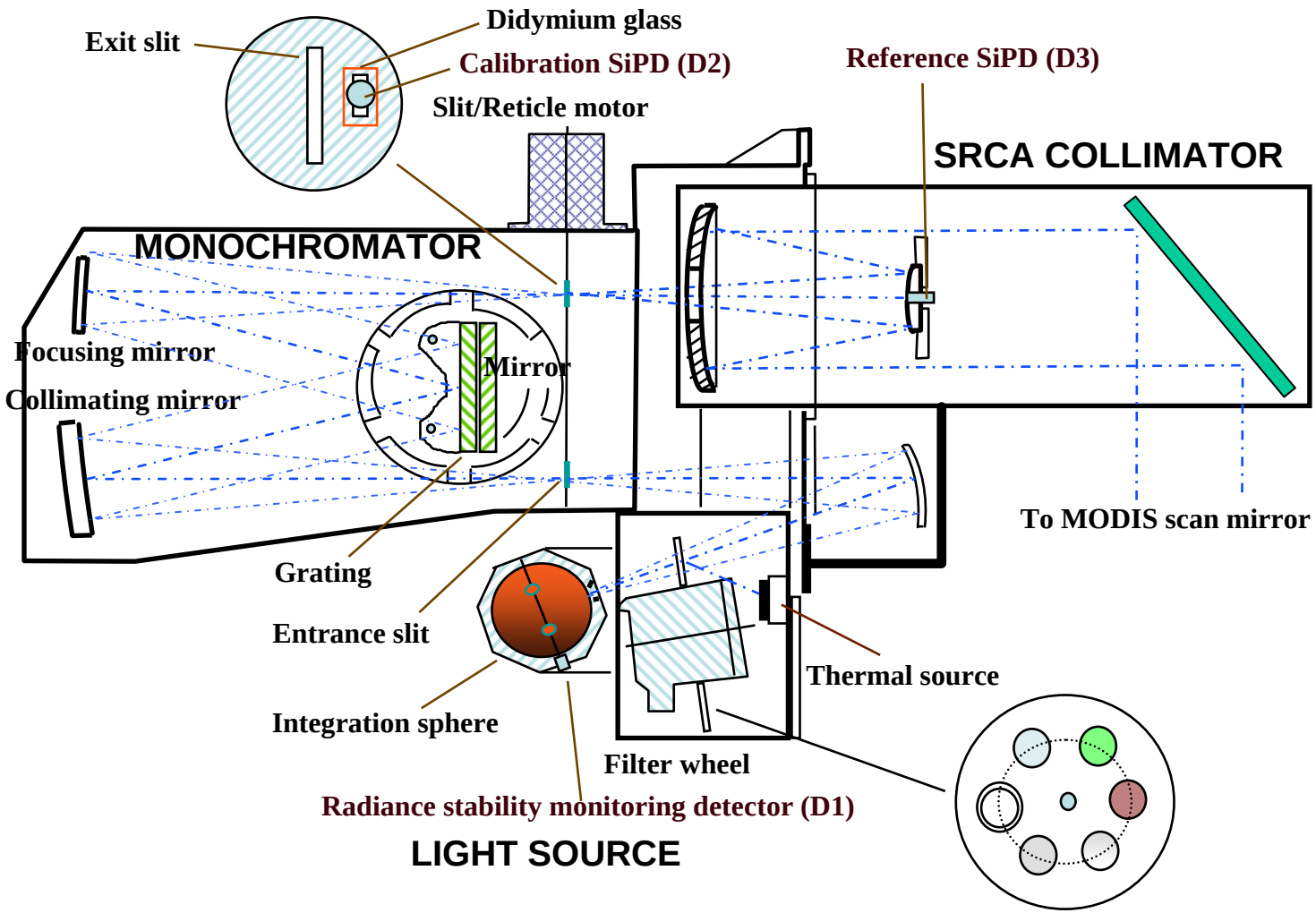


MODIS Spatial and Spectral Calibration Status

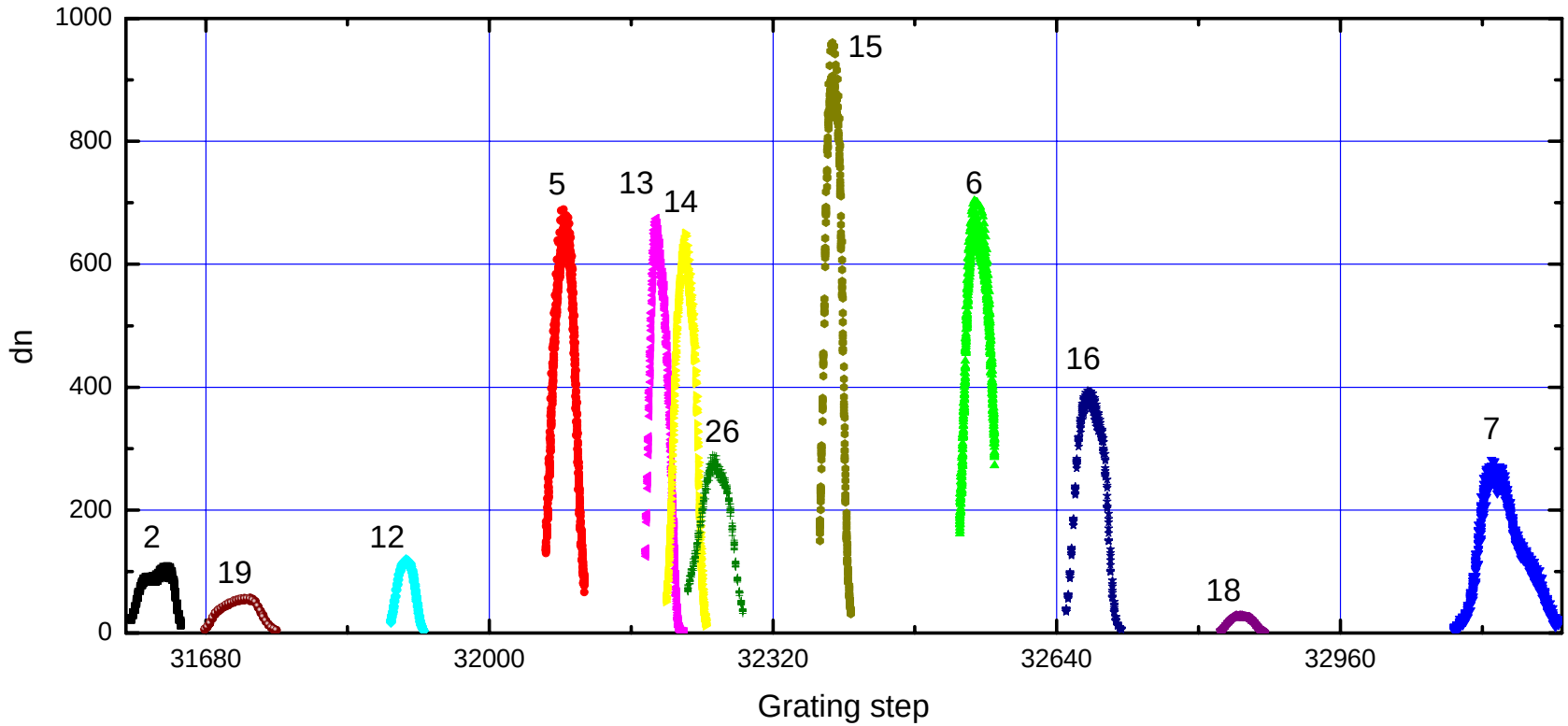
Spatial and Spectral Characterization

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

SRCA Spectral Mode



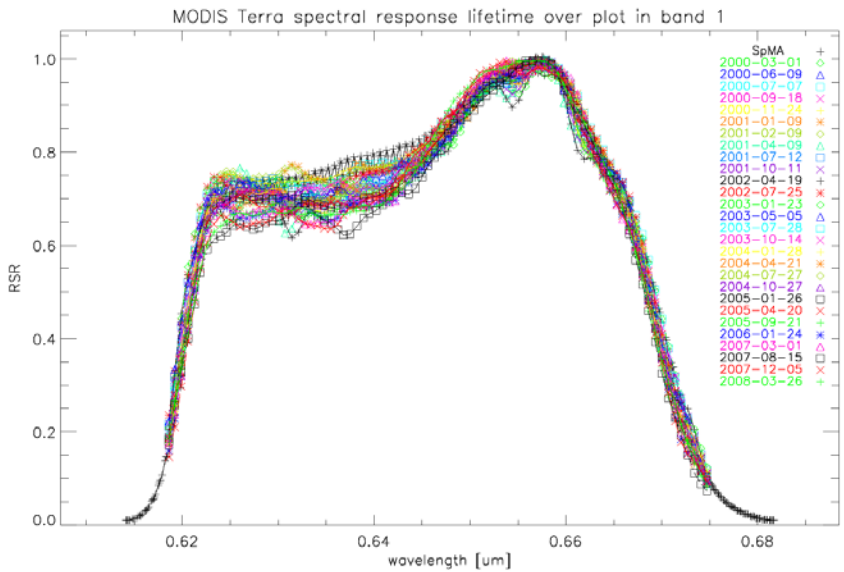
SRCA Spectral Responses

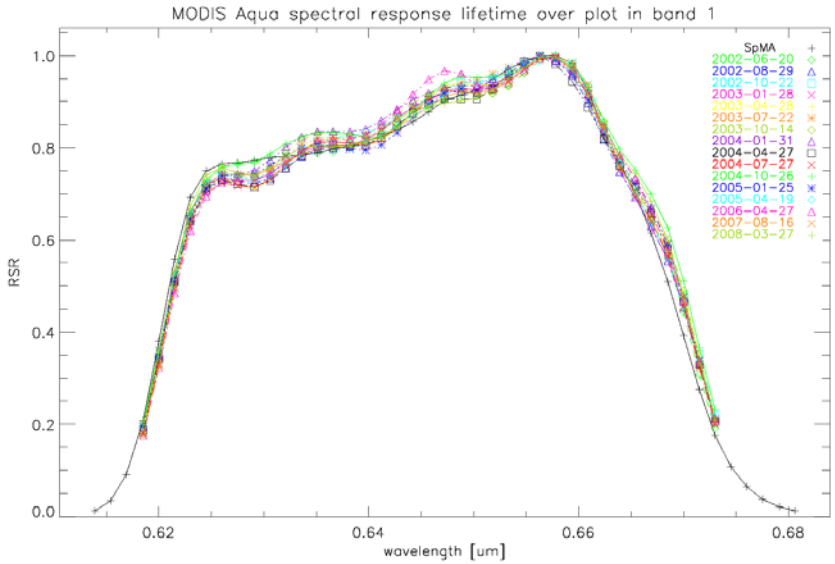


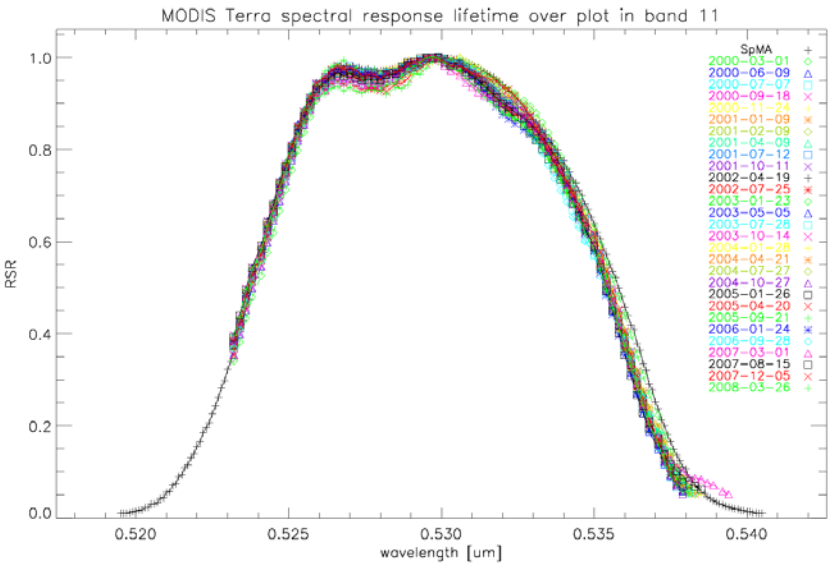
Grating step -> θ

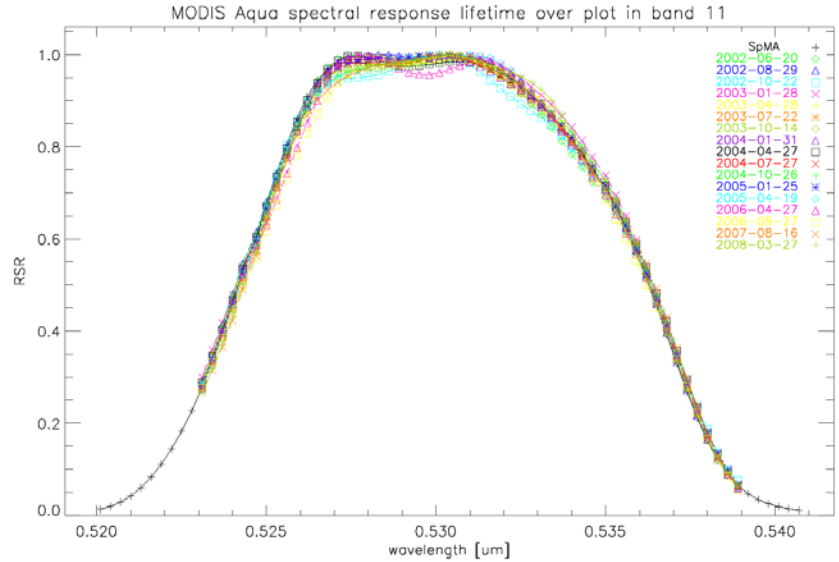
$$\lambda_C = \frac{2A}{m} \cdot \sin(\theta_C + \theta_{off}) \cdot \cos\beta$$

SRCA Spectral Responses

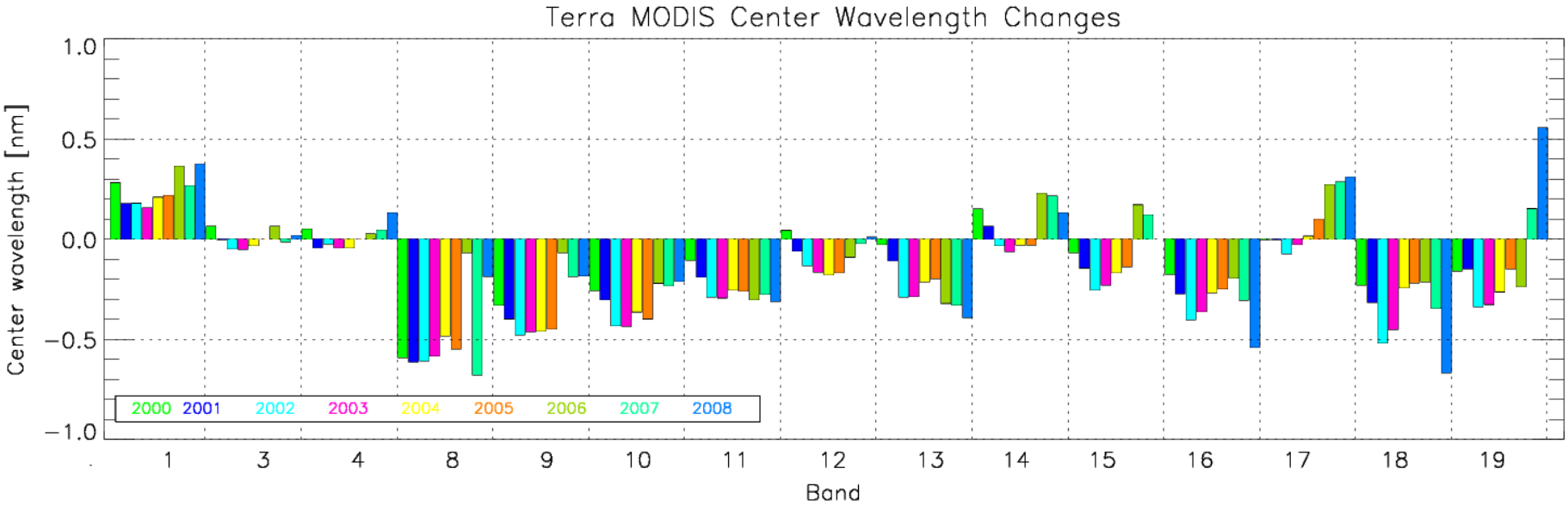


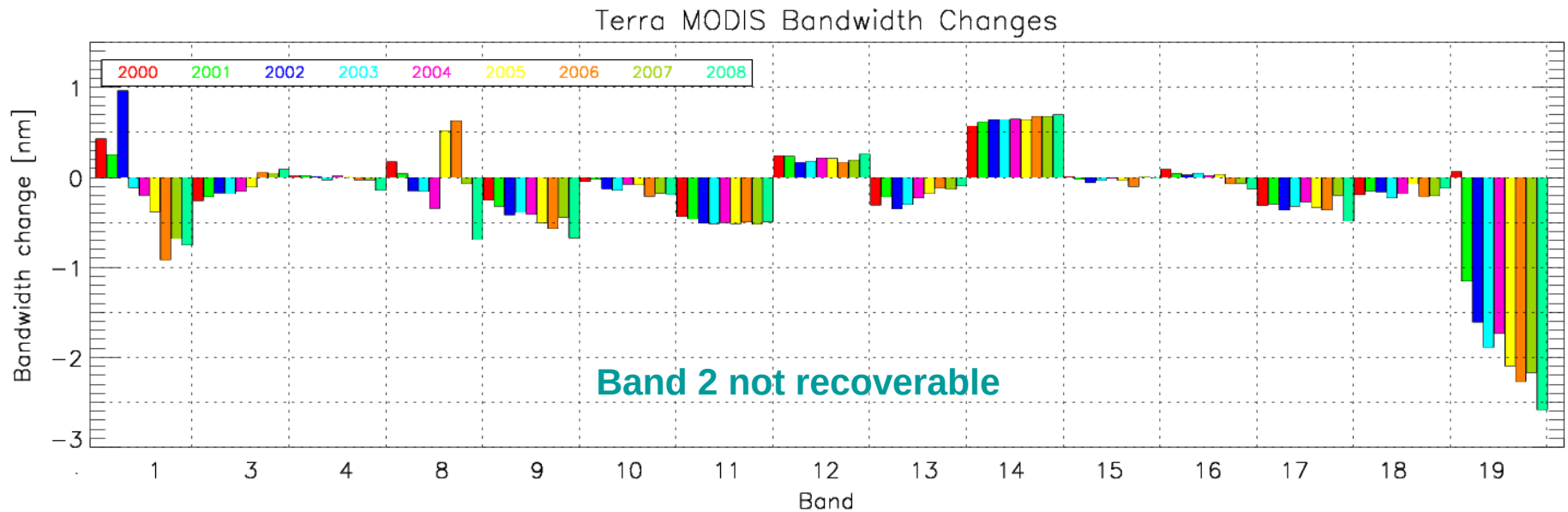




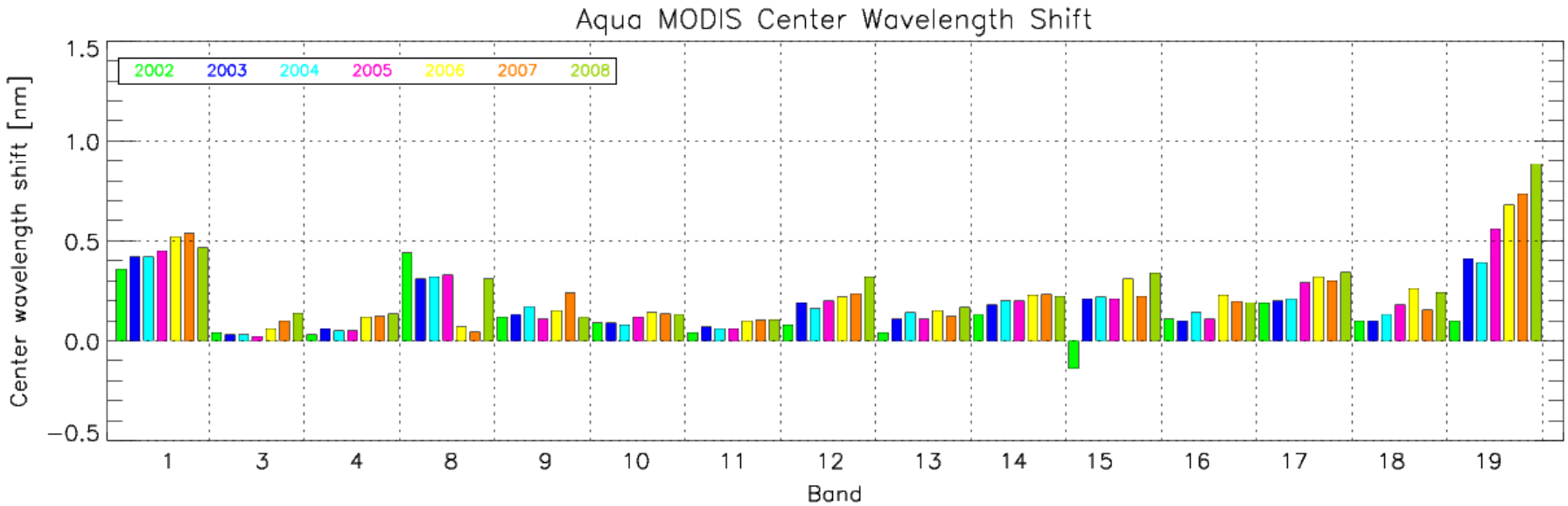


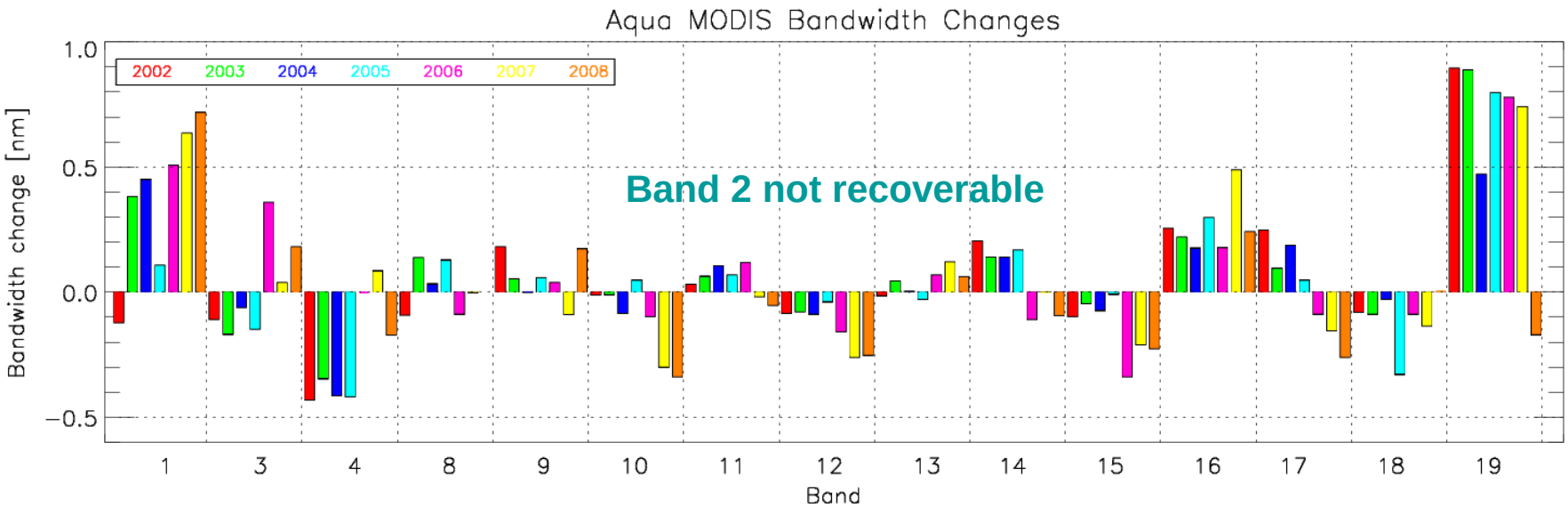
Terra Center Wavelength Trend





Aqua Center Wavelength Trend





SRCA Spectral Mode Summary

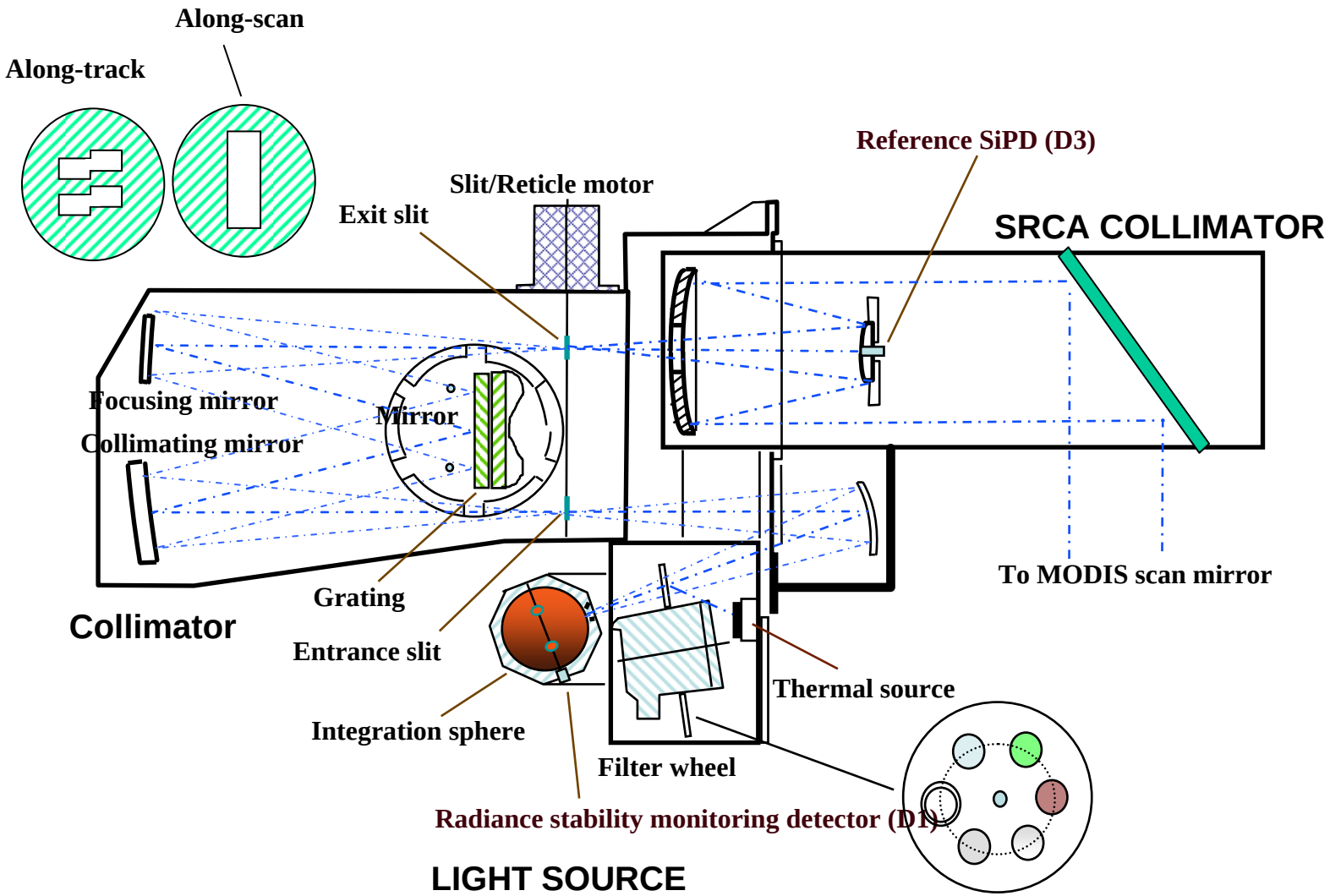
- CW and BW changes are less than 0.5 nm, except for bands 1 and 19 which have large bandwidths (50 nm)

- The SRCA spectral mode results showed that Terra and Aqua MODIS spectral performances are stable on-orbit.

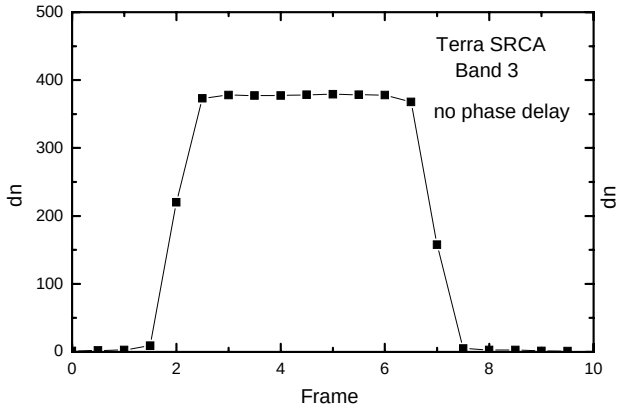
SRCA Spatial Mode

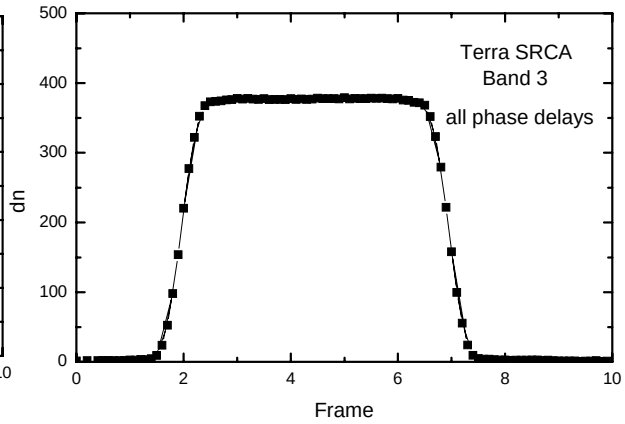
- The SRCA spatial mode provides band-to-band registration (BBR) trending both along-scan (detector based) and along-track (band-based) for MODIS 36 bands.
- The specification for BBR is ±100m for both along-scan and along-track.

SRCA Spatial Mode

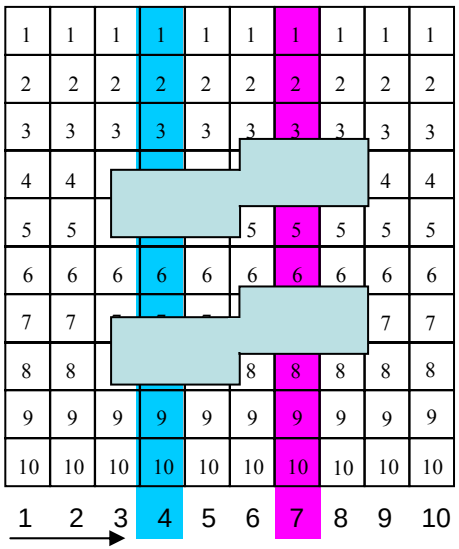


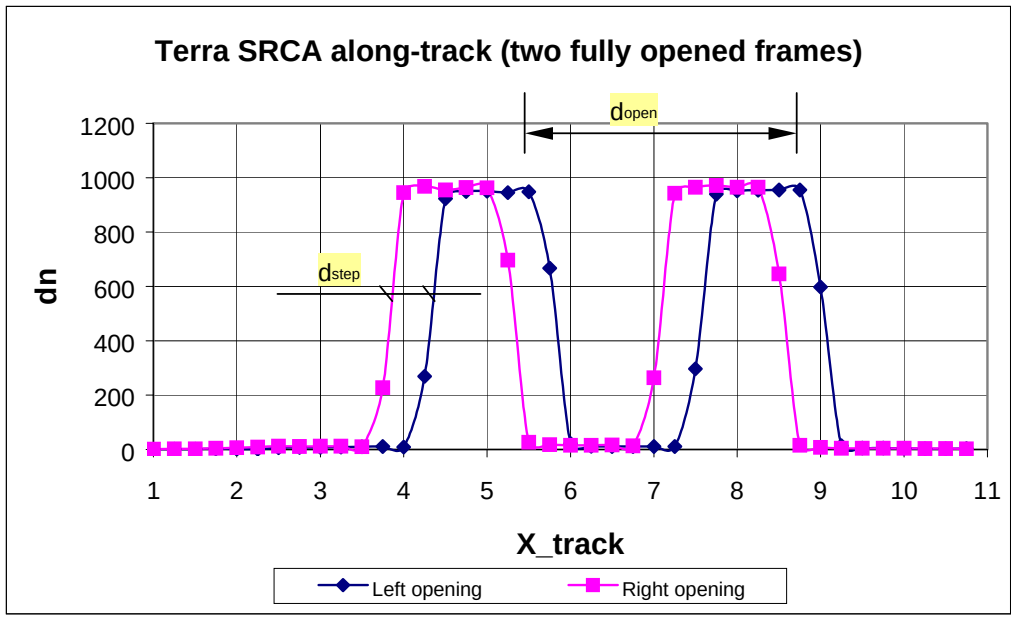
Along-scan & track positions



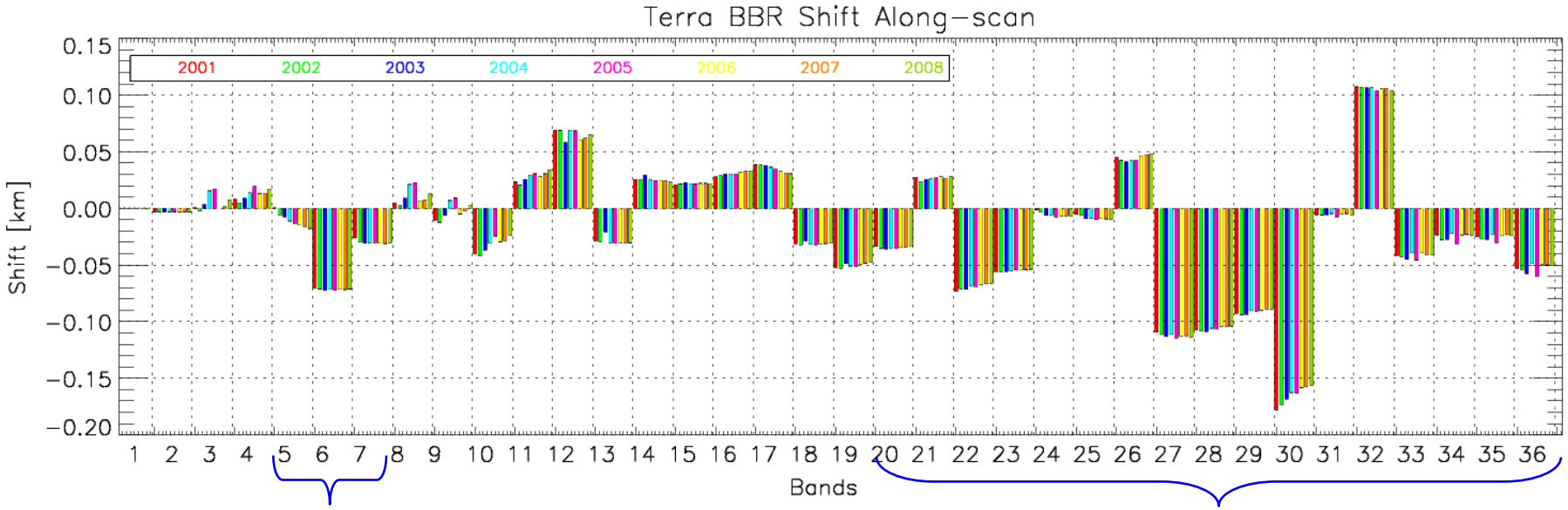


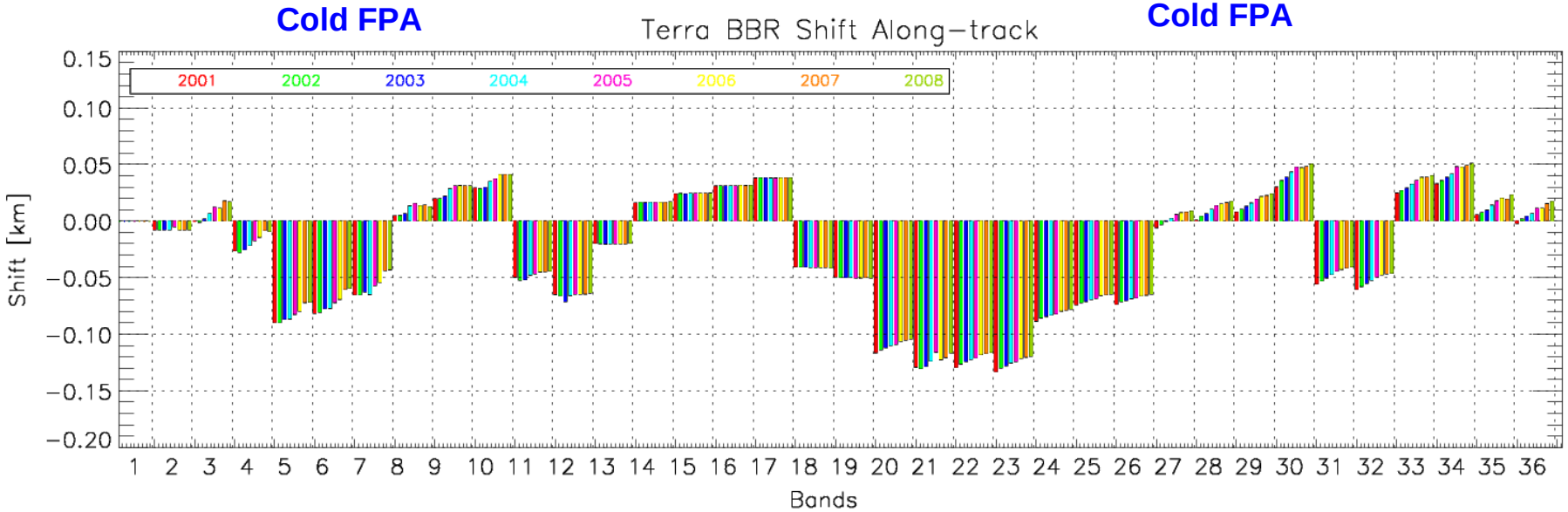
$$\bar{x}(b,ch) = \frac{\sum_{x=0}^{N_x} dn(b,ch,x) \cdot x}{\sum_{x=0}^{N_x} dn(b,ch,x)}$$



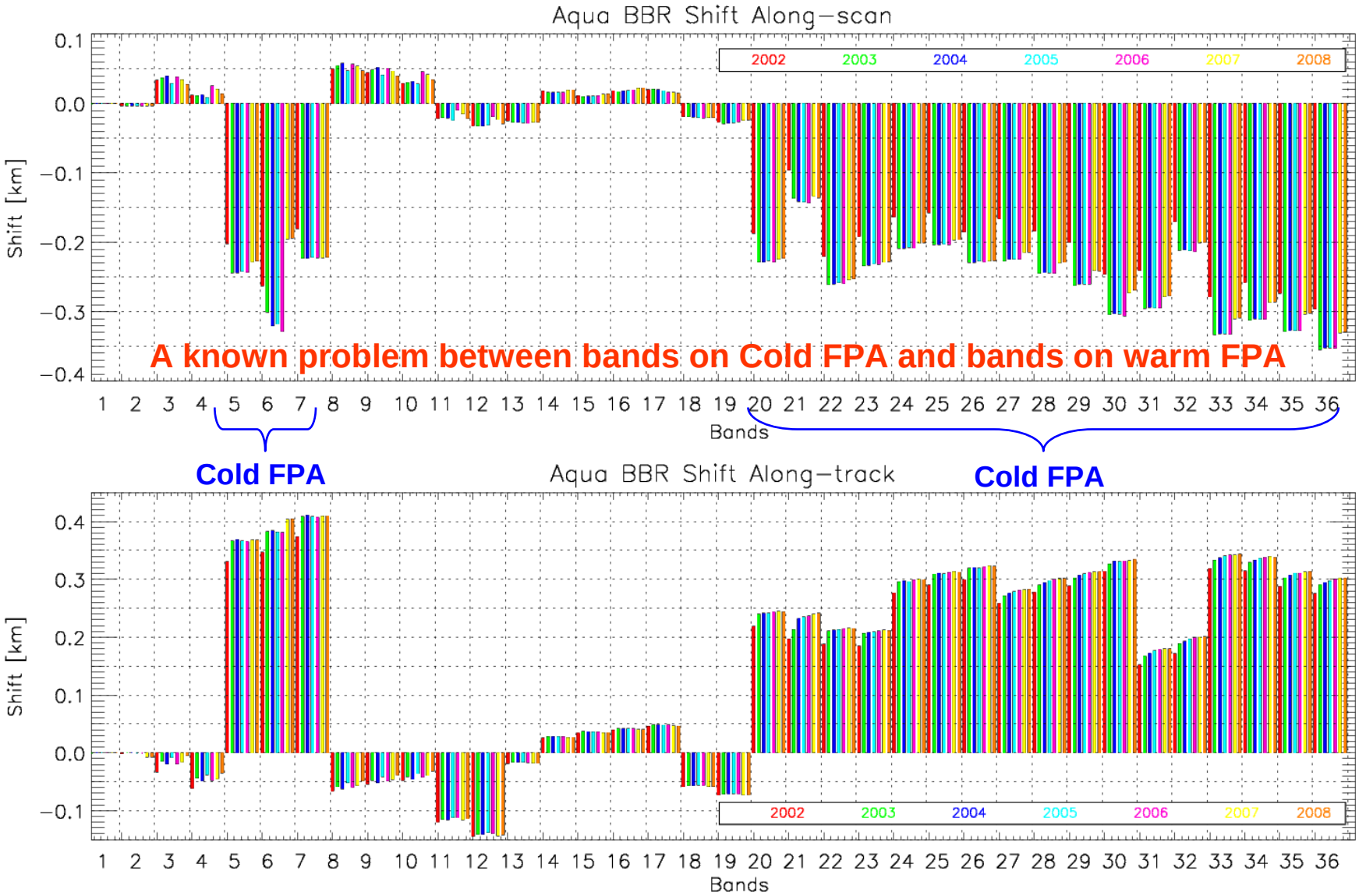


Terra BBR

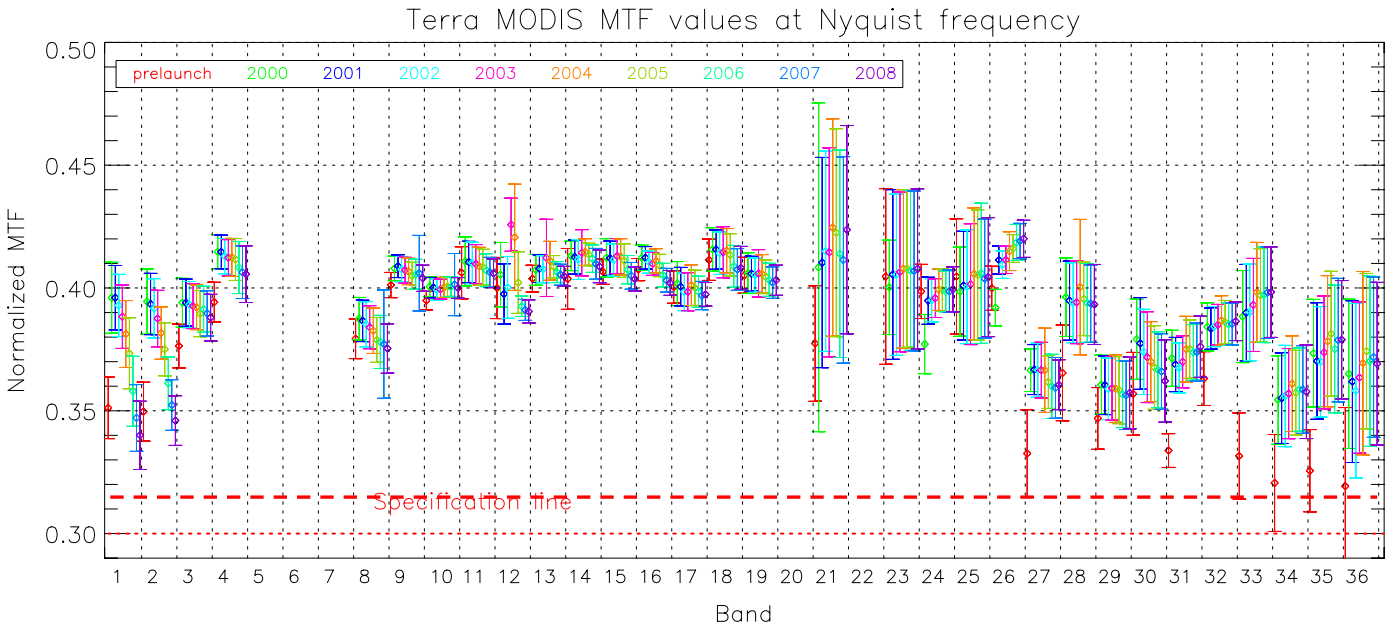

Terra BBR Shift Along−scan
2001
2002
2003
2004
2005
2006
2007
2008
Shift [km]
0.15
0.10
0.05
0.00
−0.05
−0.10
−0.15
−0.20
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36
Bands
Cold FPA
Cold FPA

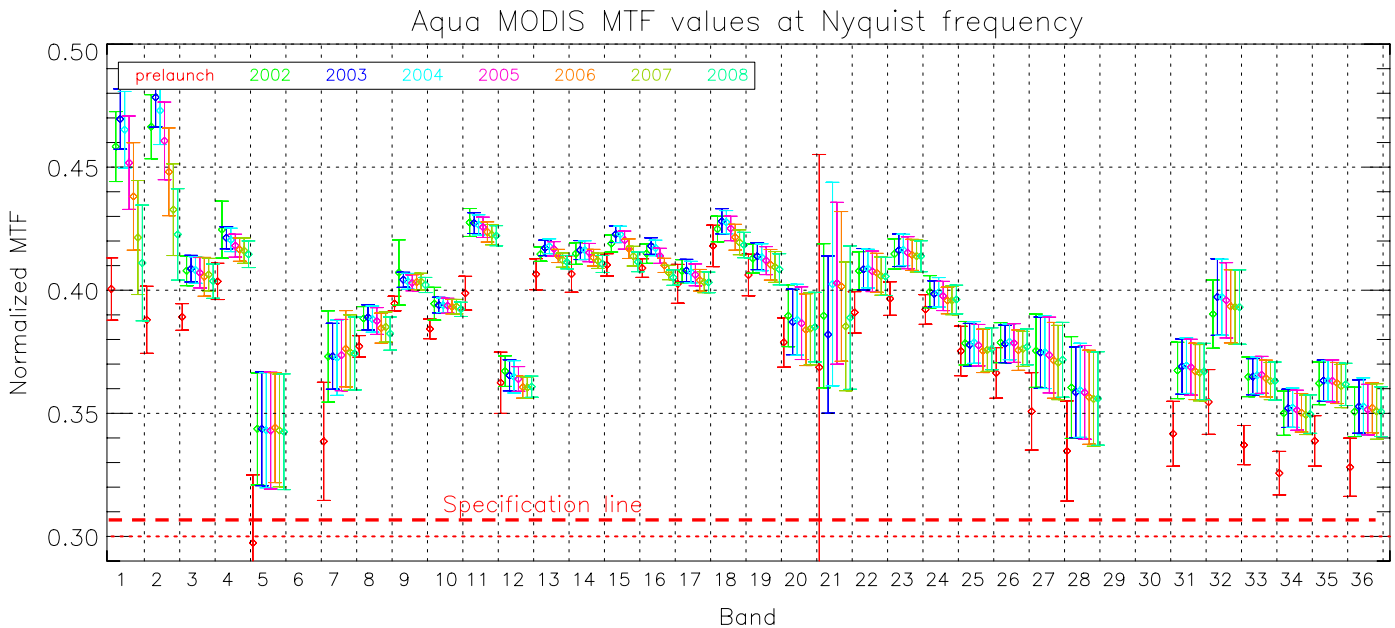

Terra BBR Shift Along−track
2001
2002
2003
2004
2005
2006
2007
2008
Shift [km]
0.15
0.10
0.05
0.00
−0.05
−0.10
−0.15
−0.20
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36
Bands

Aqua BBR


Aqua BBR Shift Along−scan
Shift [km]
0.1
0.0
−0.1
−0.2
−0.3
−0.4
2002
2003
2004
2005
2006
2007
2008
A known problem between bands on Cold FPA and bands on warm FPA
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
Bands
Cold FPA
Cold FPA
Aqua BBR Shift Along−track
Shift [km]
0.4
0.3
0.2
0.1
0.0
−0.1
2002
2003
2004
2005
2006
2007
2008
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
Bands

Terra & Aqua MTF





SRCA Spatial Mode Summary

- Terra MODIS BBR: meet specifications except along-scan BBR B32 and B30.
- Aqua MODIS BBR: a known problem between Cold FPA bands and warm FPA bands.
- MTF parameters continue to exceed design requirement.

MODIS Collection 6
MCST Proposed Changes to L1B

(slides in separate presentation package)

Special Issues

- **Terra MODIS (bands 8-9) Mirror Side Difference**
- **Aqua MODIS SD Operation**
- **Aqua MODIS CFPA Temperature Control**
- **Terra and Aqua MODIS Calibration Consistency**

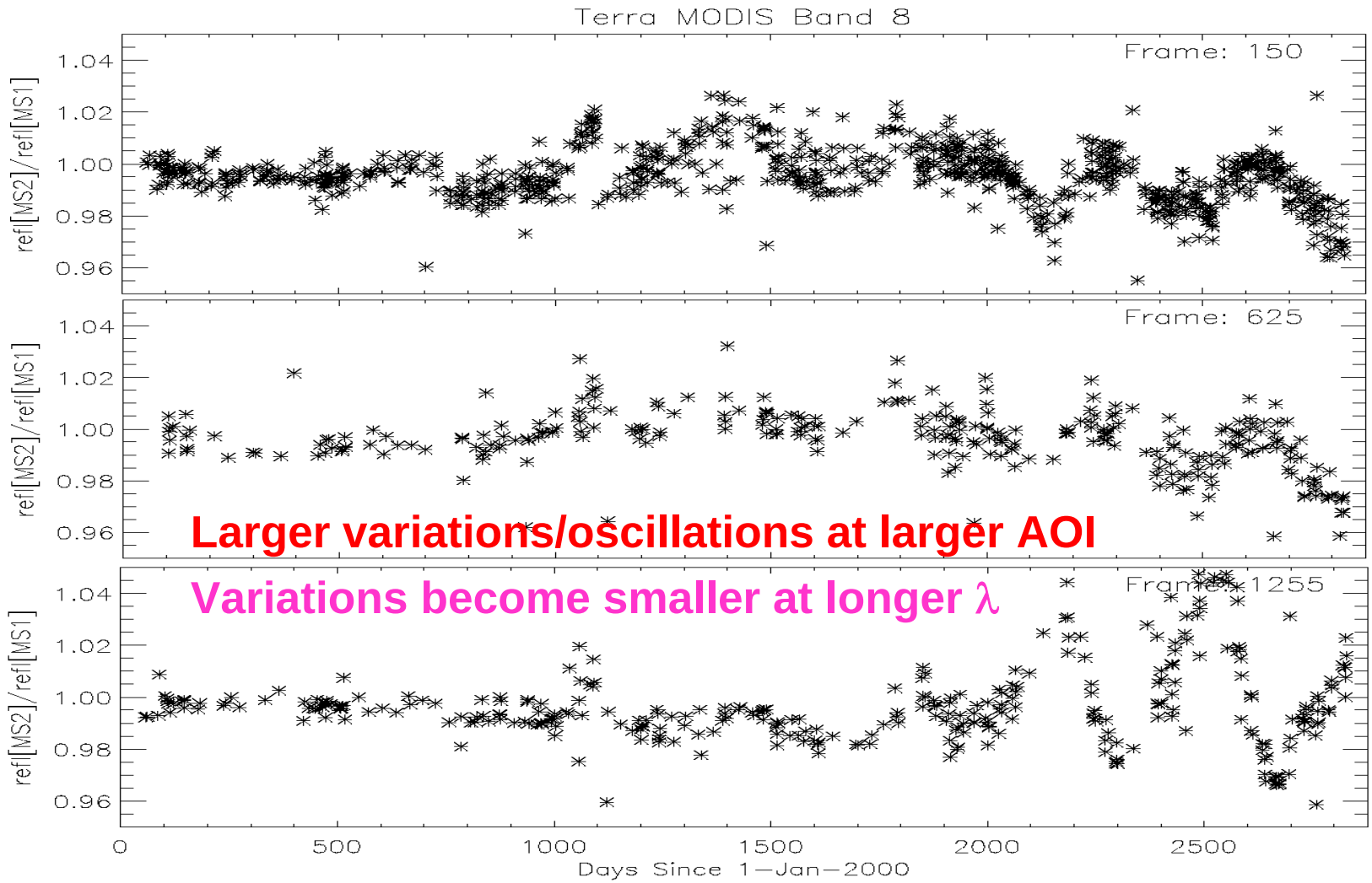
Terra MODIS Mirror Side Difference

- Large mirror side difference for Terra MODIS bands 8 and 9 (effect noticeable in L1B reflectance / radiance, starting from 2003)
  - MS difference increases with time (with a seasonal oscillation)
  - MS difference increases with angle of incidence (AOI)
  - MS difference varies with latitude (solar zenith angles) – worse at polar regions
  - Time-dependent polarization parameters are needed
    - Large impact on science data products using Terra bands 8 and 9

- **No mirror side difference thus far in Aqua MODIS**

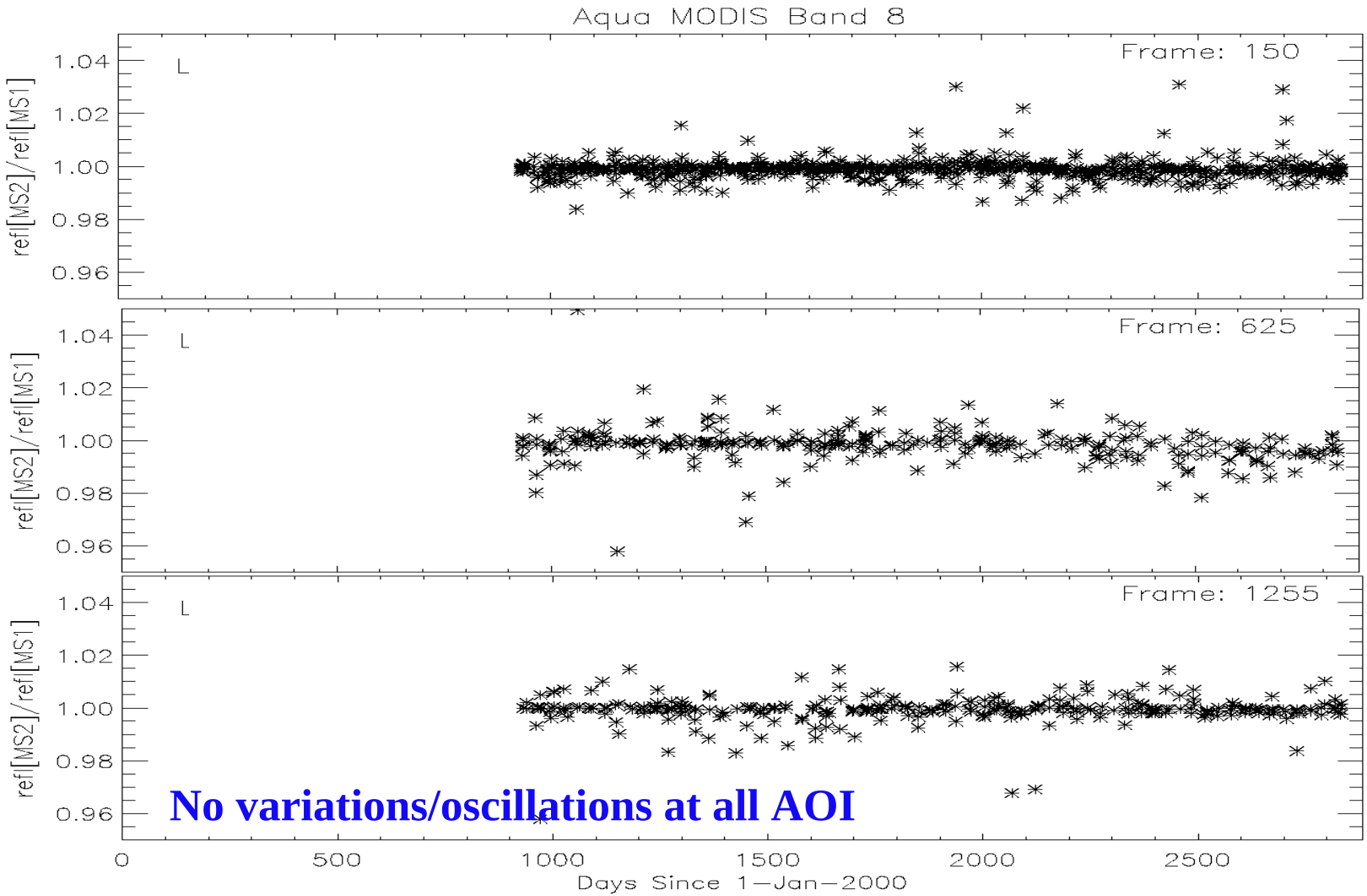
Mirror Side Difference

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 AOI

Mirror Side Difference

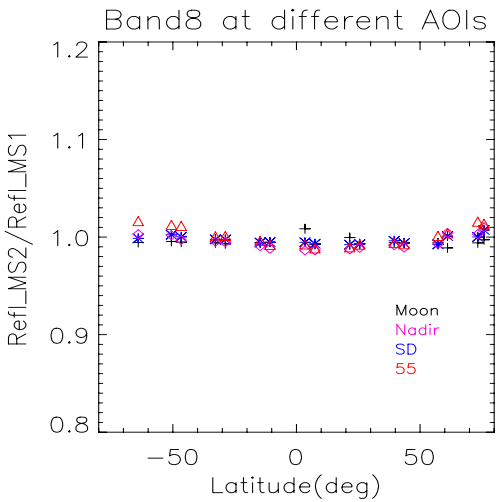
Terra MODIS VIS bands 3, 8, 9, 10 reflectance MS differences at different AOIs as a function of latitude
(2-orbit data on 2003244)

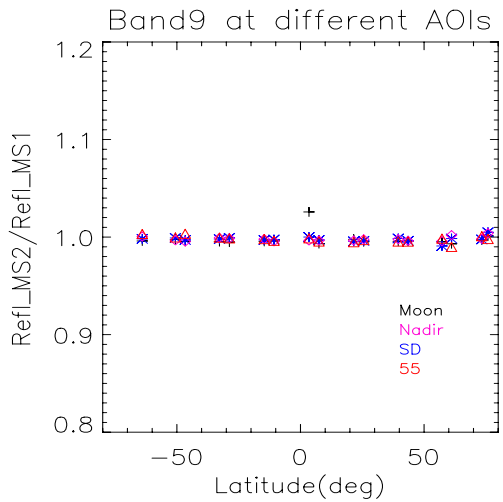
Band 8
412nm

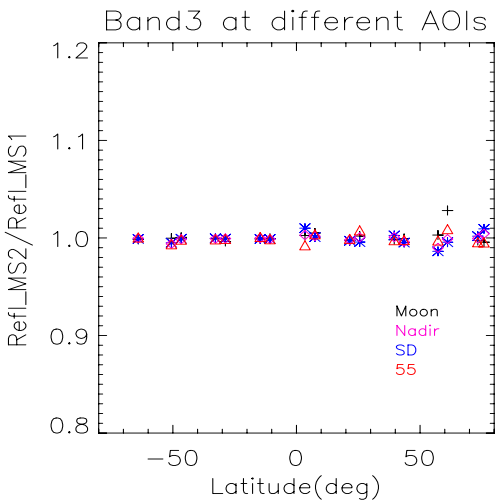
Band 9
443nm

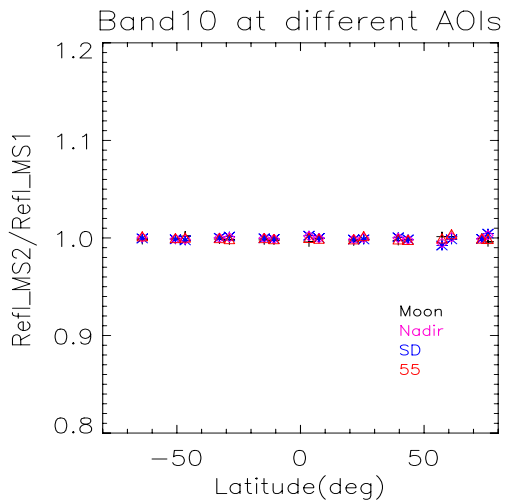
Band 3
469nm

Band 10
488nm



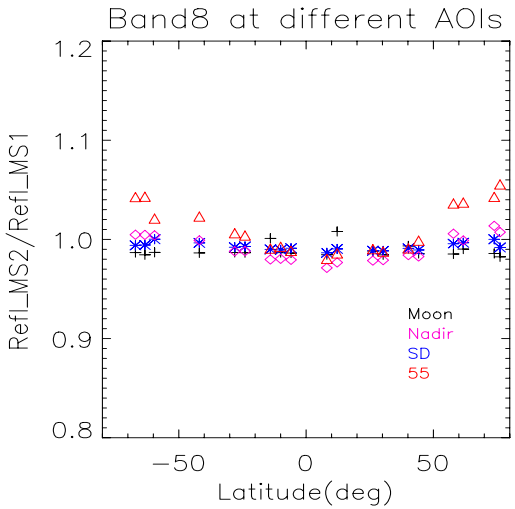


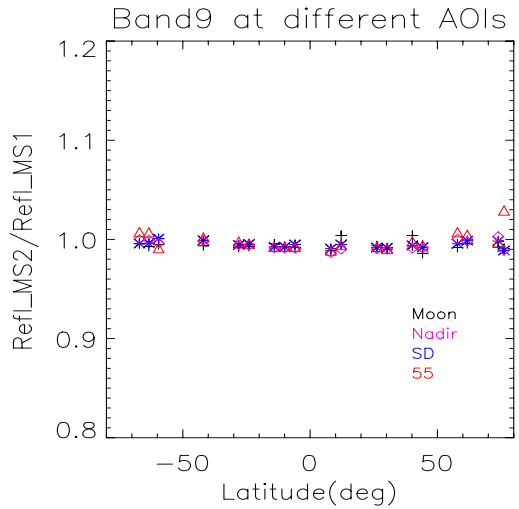


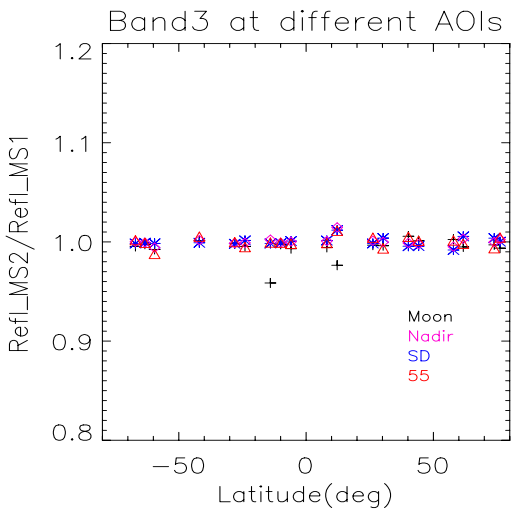


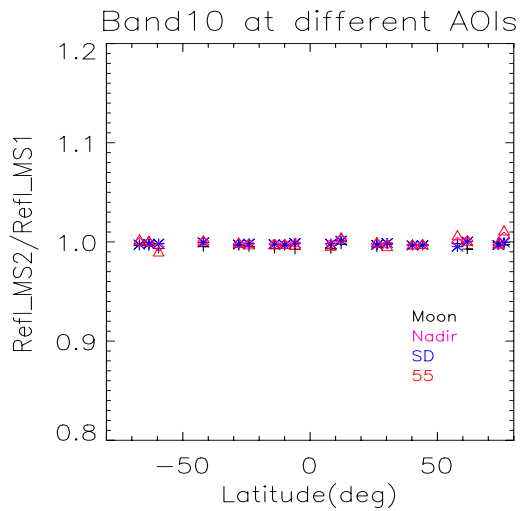
Mirror Side Difference

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



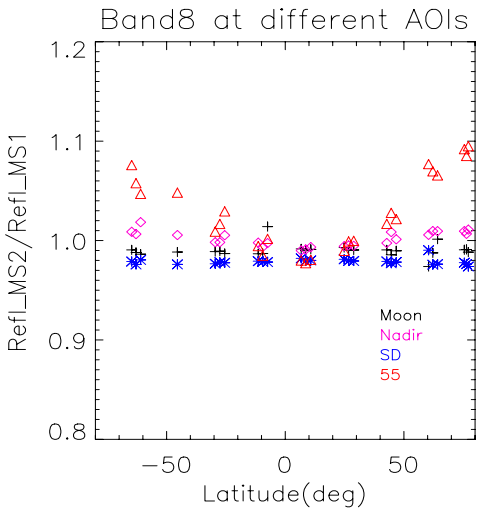


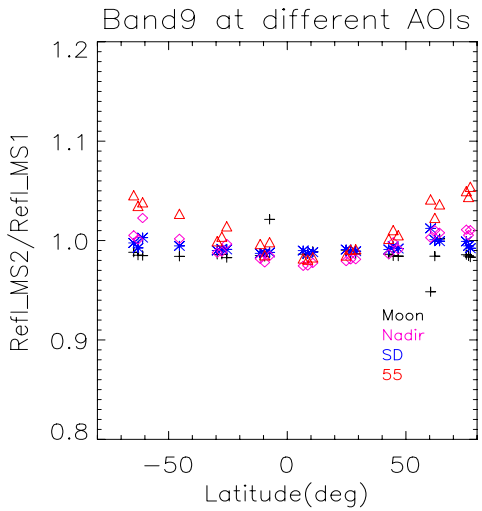


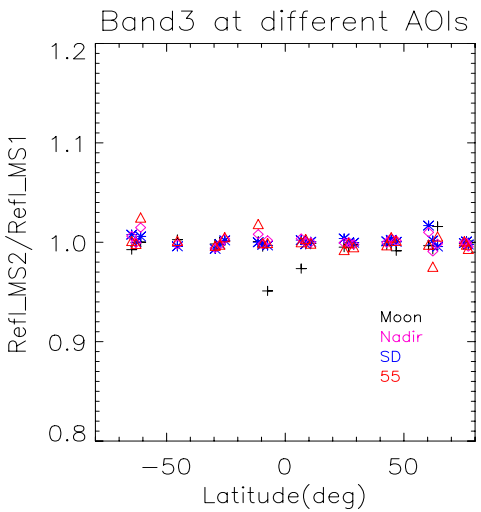


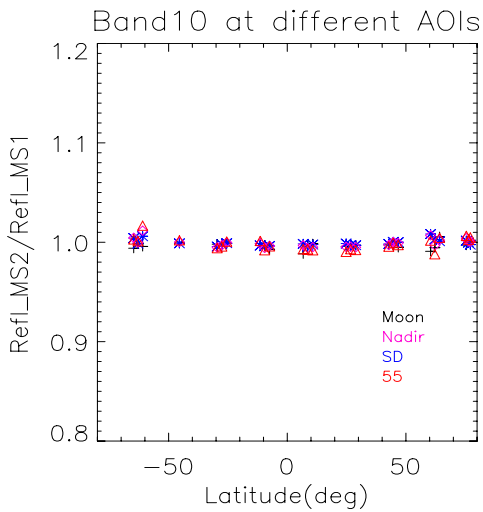
Mirror Side Difference

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



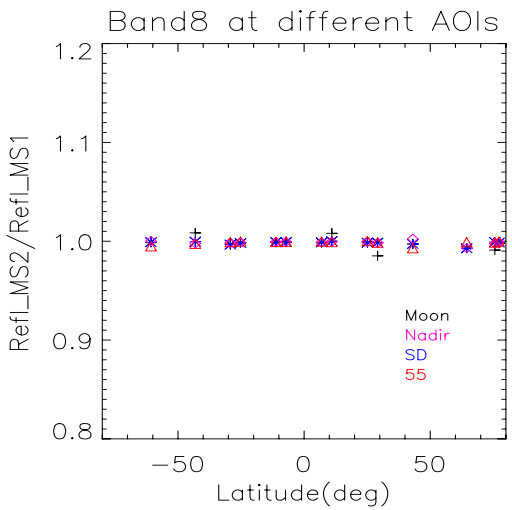


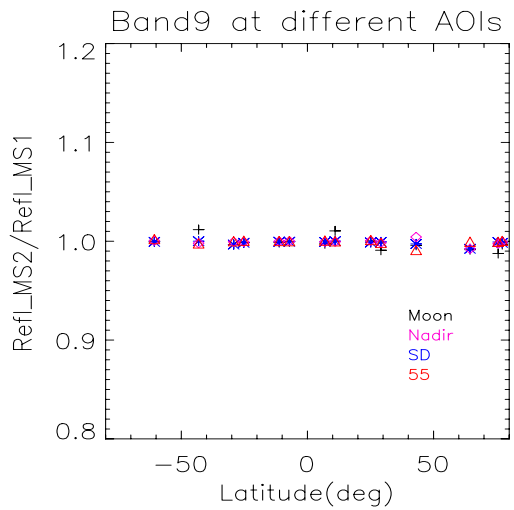


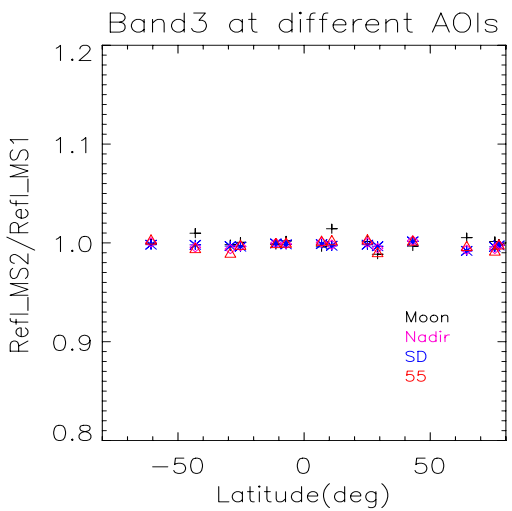


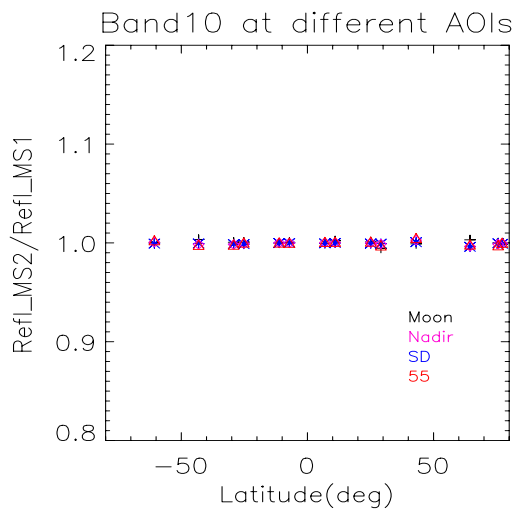
Mirror Side Difference

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



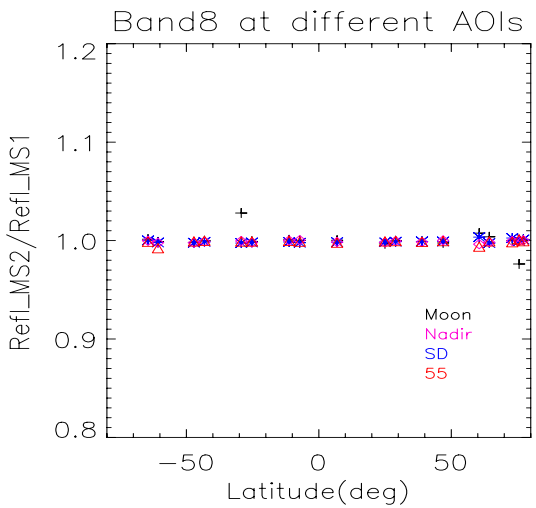


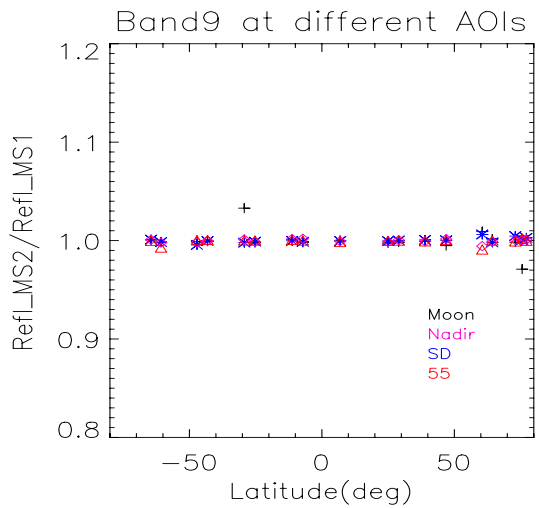


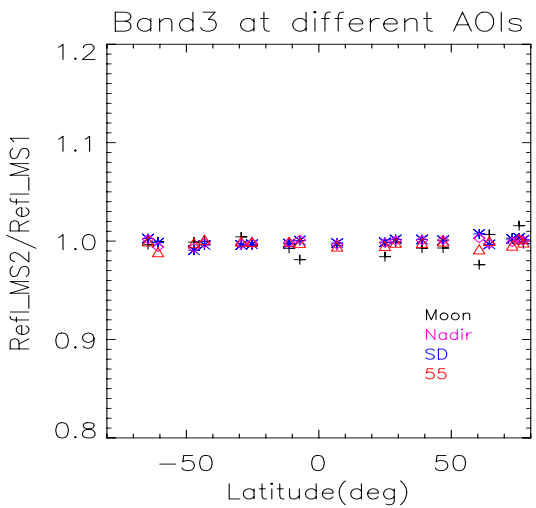


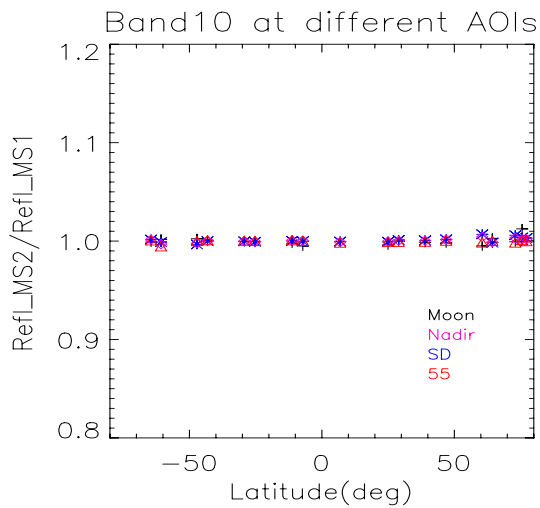
Mirror Side Difference

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



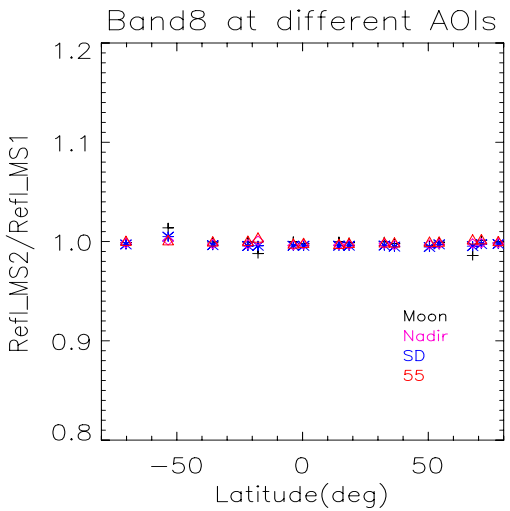


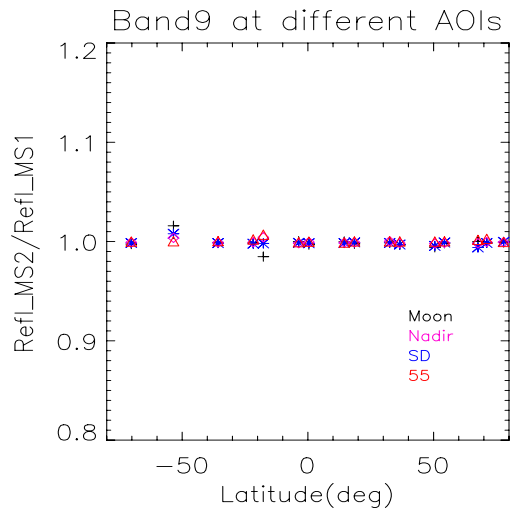


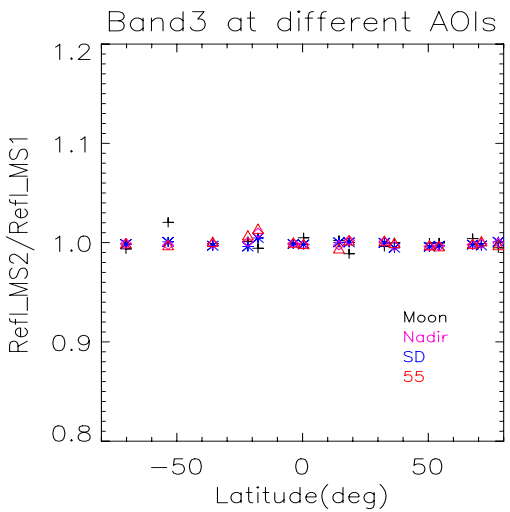


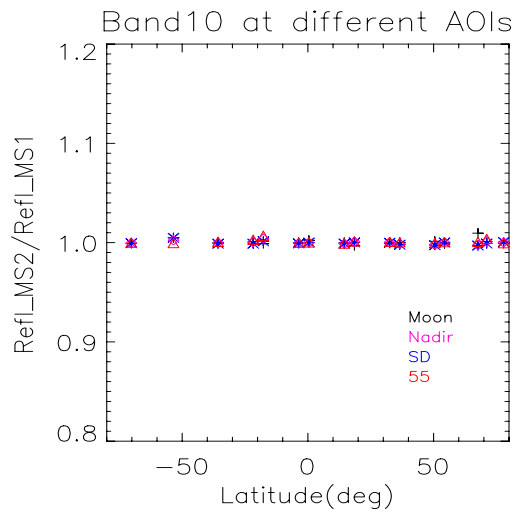
Mirror Side Difference

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









Aqua MODIS SD Operation

- Typical RSB calibration consists of a pair of SD/SDSM operations, one with and one without SD screen
- Regularly scheduled SD/SDSM operations
  - Weekly: 2002/247 to 2003/181
  - Bi-weekly: 2003/188 to 2005/360
  - Tri-weekly: 2006/009 to present
- SD door movements
  - Expected life / Current: 3022 / 2716
  - Current rate: 2.9 years
  - Proposed usage (reducing half of SD screen open calibration): 4.4 years

- **No impact on Terra MODIS (as its door fixed at open with screen)**

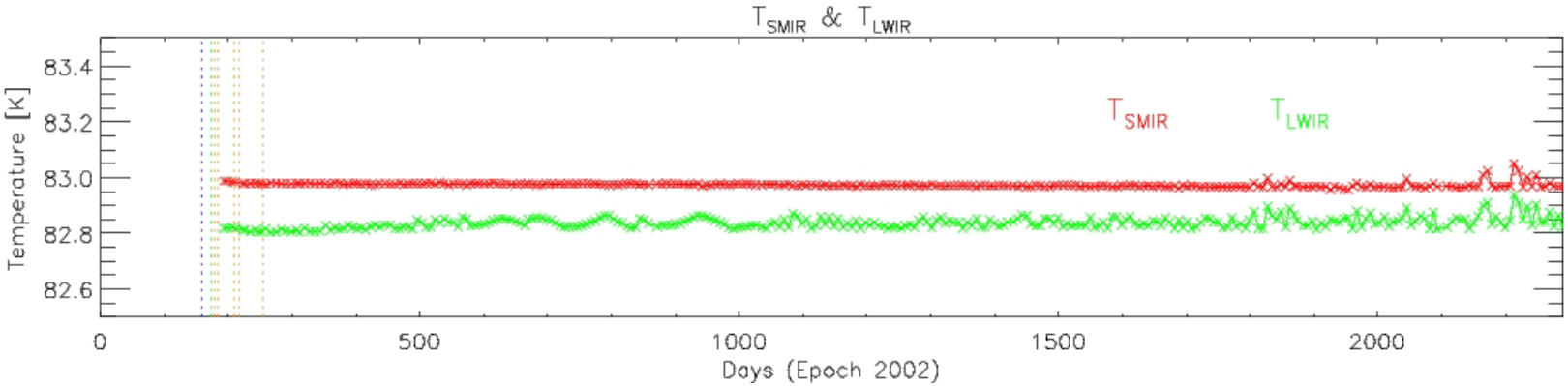
Aqua MODIS FPA Temperature

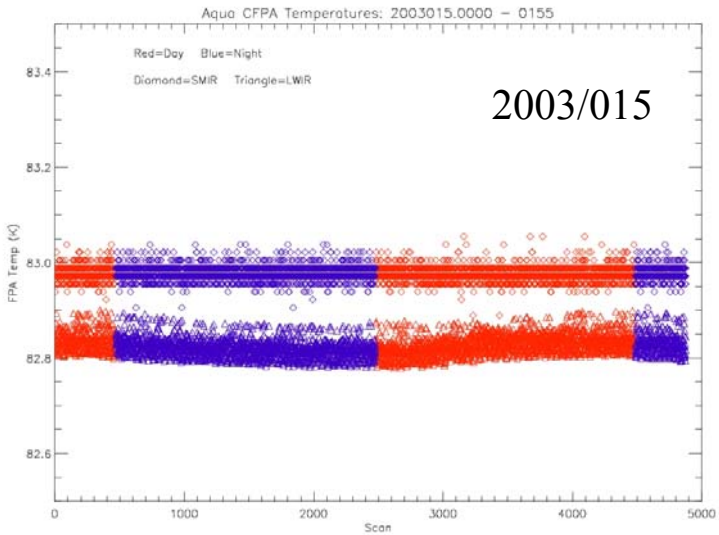
- Decrease of Aqua MODIS cooler margin has gradually reduced its capability to control the CFPA temperature at 83K (set since launch)
  - No immediate impact on TEB calibration as scan by scan calibration is used in L1B
  - Impact of continuous increase of CFPA temperature variations needs to be evaluated

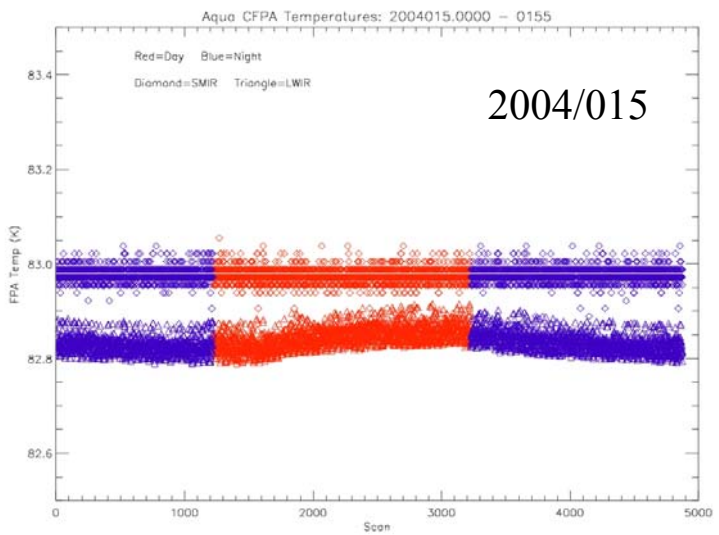
- Future considerations/options
  - Set CFPA to a higher temperature (e.g. 85K)
  - Perform an outgas

- **Terra MODIS CPFA temperatures remain well-controlled**

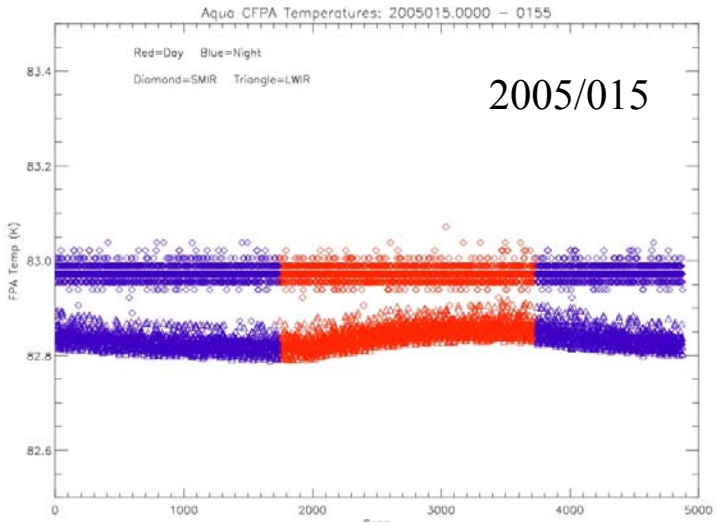
Aqua MODIS FPA Temperature

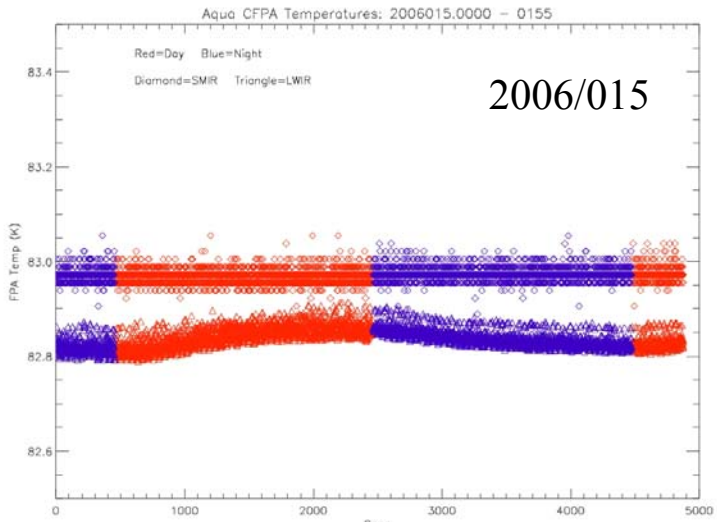


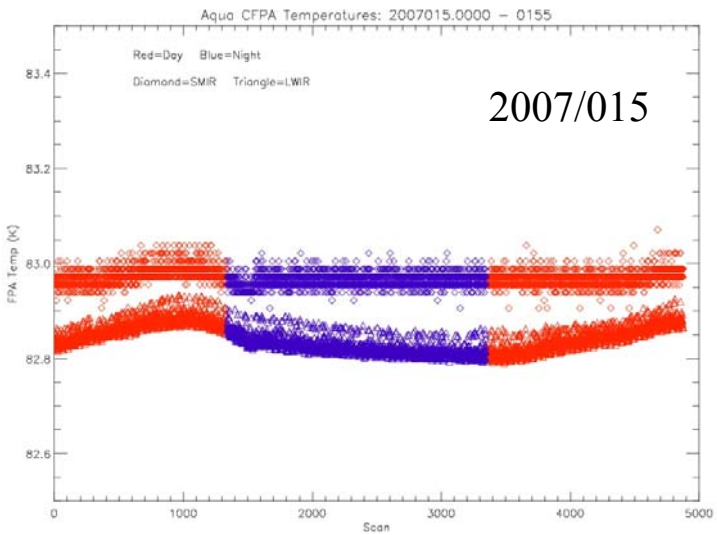


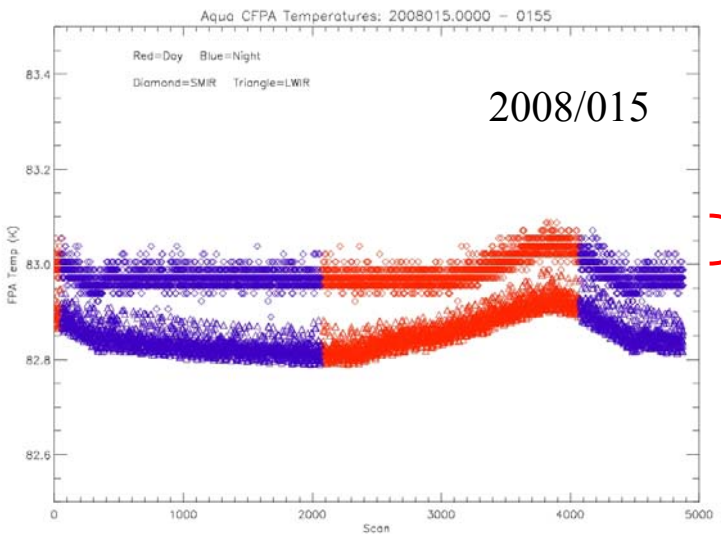


Aqua MODIS FPA Temperature









} 0.1 K

MODIS Calibration Consistency

- Independent calibration performed for each MODIS: pre-launch and on-orbit
- Factors that could impact calibration consistency
  - TEB: Emissivity characterization, RVS (normalized at BB AOI)
  - RSB: BRF, RVS (normalized at SD AOI), OOB response and xtalk (noticeable in SWIR bands), optical degradation impact

- Information needed to make Terra and Aqua MODIS calibration consistent
  - Lunar observations
  - Ground targets (vicarious calibration)
  - Challenges (absolute, reference, lots of work for all bands)

Summary

- Both Terra (~8.5 years) and Aqua MODIS (~6 years) have shown satisfactory operation and performance
  - Key on-board calibrators continue to function well
  - Overall performance of Aqua MODIS is better than Terra MODIS
- Collection 6 issues have been identified with implementation plan and progresses made
  - Coordination (issues and schedule) with science groups is required
- Large optics (SD and scan mirror) degradation remains challenging
  - Detector dependent RVS will be applied in C6
  - Polarization correction parameters are proposed for C6
- Continuous effort must be made to maintain instrument calibration and data quality, including Terra and Aqua MODIS calibration consistency
  - In addition to MCST effort, input and support from science groups, instrument vendor (SBRS), and other expertise are needed

Backup Slides

IOT Backup Slides

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)

PFM SRCA Calibration

- 262 SRCA Calibrations
  - Including: 37 Full Spectral, 52 Full Spatial, 97 Full Radiometric

- Lamp Usage in hours: total (on orbit)
  - 10W Lamps, 500hr life: 1) 271.6 (137.1) 2) 172.1 (53.0)
    3) 190.3 (62.0) 4) 88.9 (27.4)
  - 1W Lamps, 4000hr life: 1) 573.2 (30.4) 2) 282.0 (5.6)

PFM SD/SDSM Calibration

- 562 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.

PFM Other Door Movements/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)

FM1 SRCA Calibrations

- 133 SRCA Calibrations
  - Including: 15 Full Spectral, 29 Full Spatial, 54 Full Radiometric

- Lamp Usage in hours: total (on orbit)
  - 10W Lamps, 500hr life: 1) 263.5 (63.3) 2) 188.0 (12.3)
    3) 205.7 (27.2) 4) 91.1 (33.4)
  - 1W Lamps, 5000hr life: 1) 514.0 (14.5) 2) 274.9 (5.1)

FM1 SD/SDSM Calibrations

- 364 SD/SDSM Calibrations
  - 184 SD Door Open, 189 SD Door Screened
  - 2716 (1062 on orbit) of 3022 Solar Diffuser Door Movements

FM1 Other Door Movement/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

L1B Backup Slides

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 Itwk/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

*PGE02 V4.0.7 and V4.0.9 are never used in data production

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	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.

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)

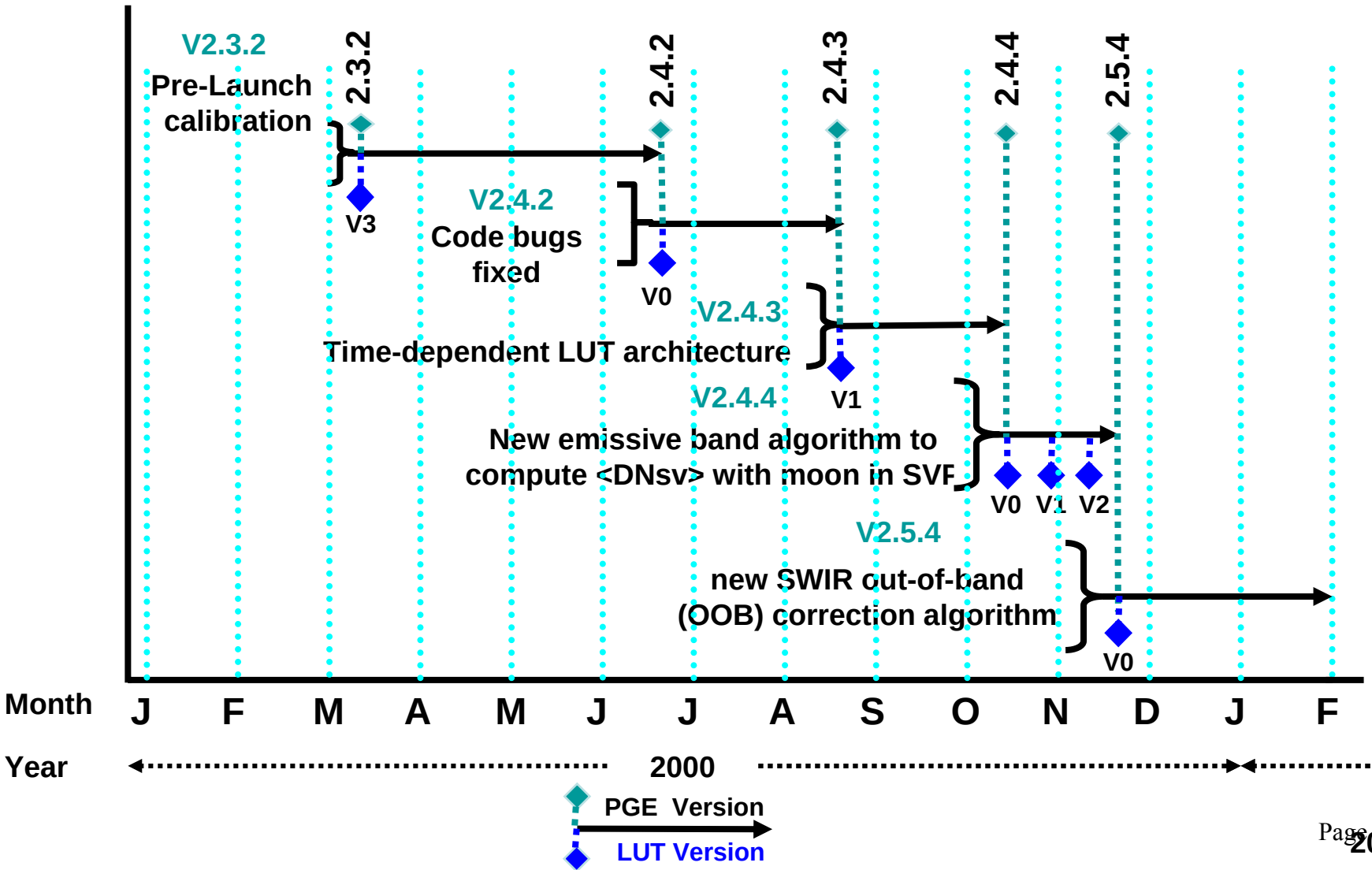
PGE02 Version	LUT Patch Version	LUT Changes
V5.0.6_Terra	1, 2, 3, 4, 5, 6, 7, 8, 9, 10,11,12,13,14,15,16, 17,18,19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34	• Updates of the coefficients for calculating a0 and a2, and of the value of b1 for each Band 21 detectors using the newly developed 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_RefSB)

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_RefSB)
V5.0.40_Terra	1, 2, 3, 4	• Continuous Reflective Calibration Coefficient updates (m1, Sigma_m1, RVS_RefSB) • EMISSIVE LUTS update (a0/a1, band 21 b1)

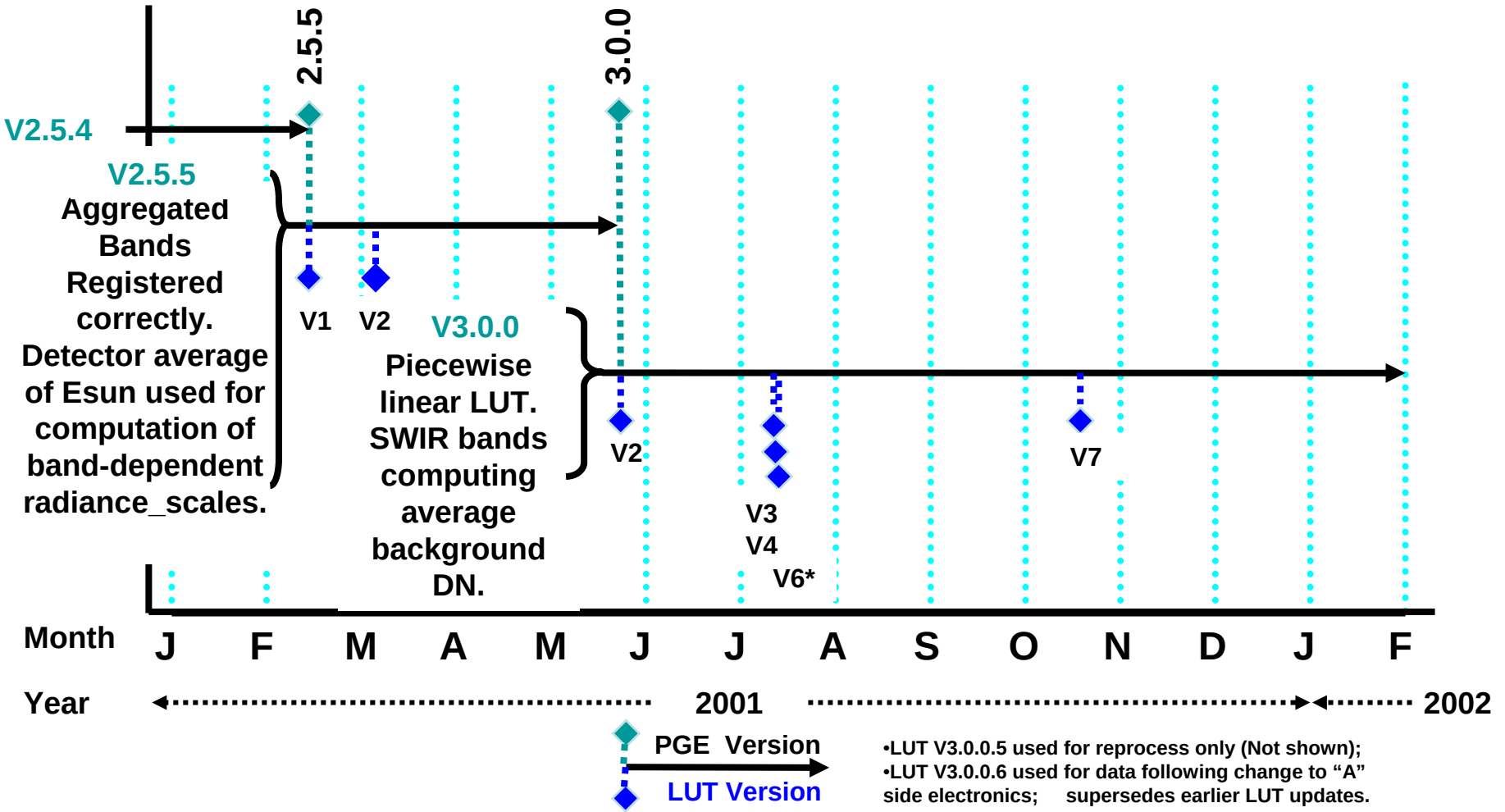
Major 2000 Production Changes in MOD_PR02 TERRA L1B Code/LUTs

(Forward Processing)



Major 2001 Production Changes in MOD_PR02 TERRA L1B Code/LUTs

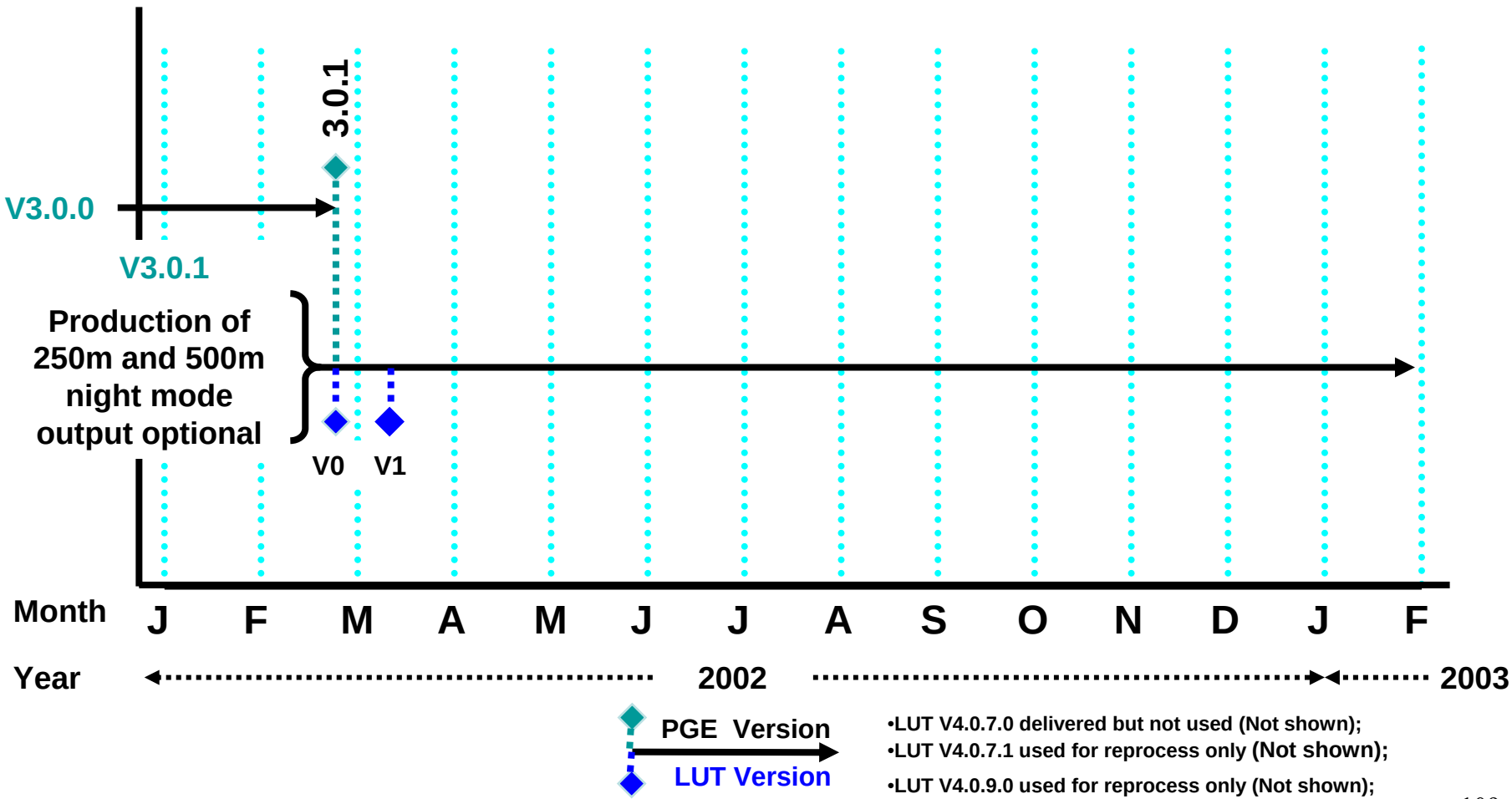
(Forward Processing)



- LUT V3.0.0.5 used for reprocess only (Not shown);
- LUT V3.0.0.6 used for data following change to "A" side electronics; supersedes earlier LUT updates.

Major 2002 Production Changes in MOD_PR02 TERRA L1B Code/LUTs

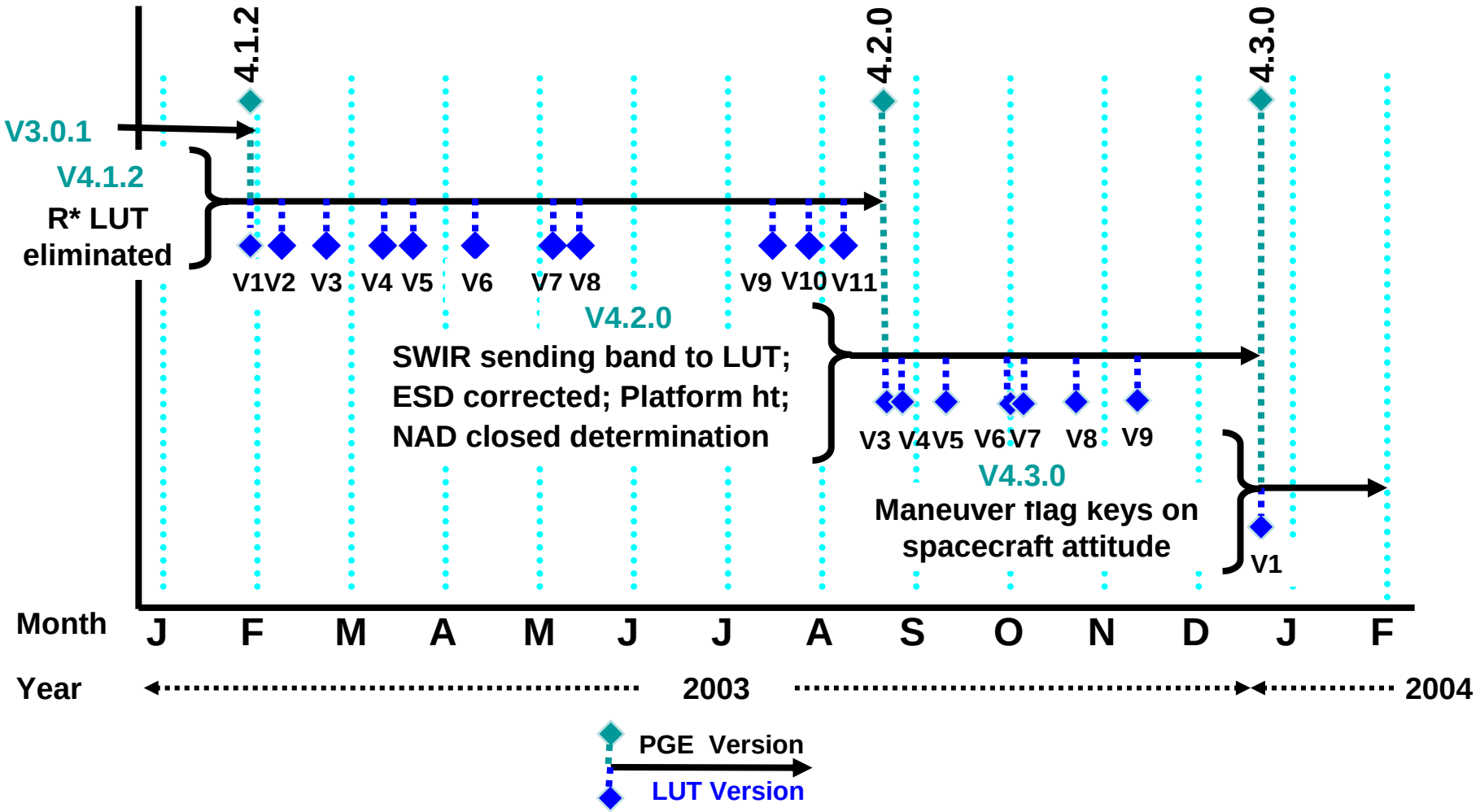
(Forward Processing)



- LUT V4.0.7.0 delivered but not used (Not shown);
- LUT V4.0.7.1 used for reprocess only (Not shown);
- LUT V4.0.9.0 used for reprocess only (Not shown);

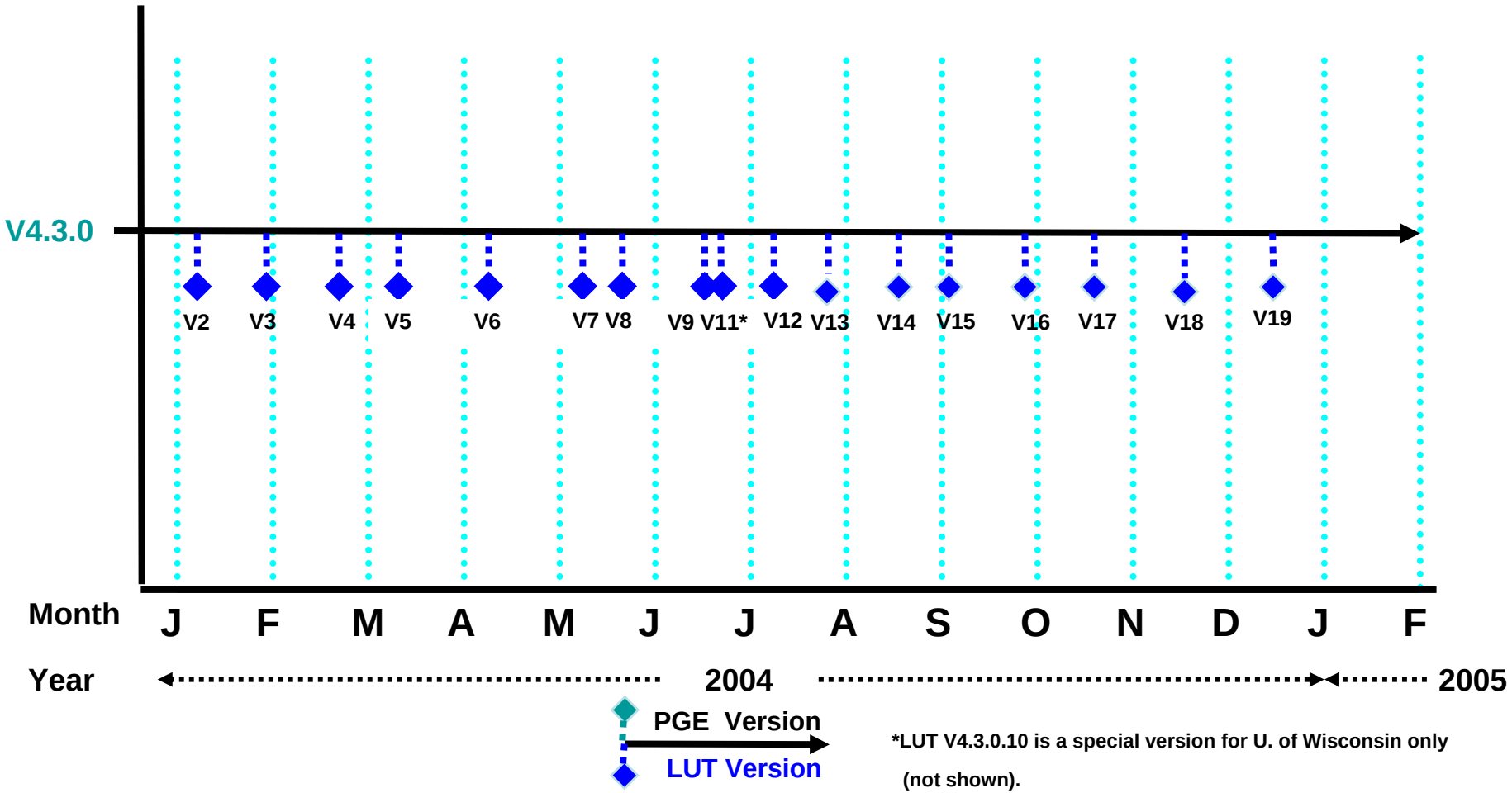
2003 Production Changes in MOD_PR02 TERRA L1B Code/LUTs

(Forward Processing)



2004 Production Changes in MOD_PR02 TERRA L1B Code/LUTs

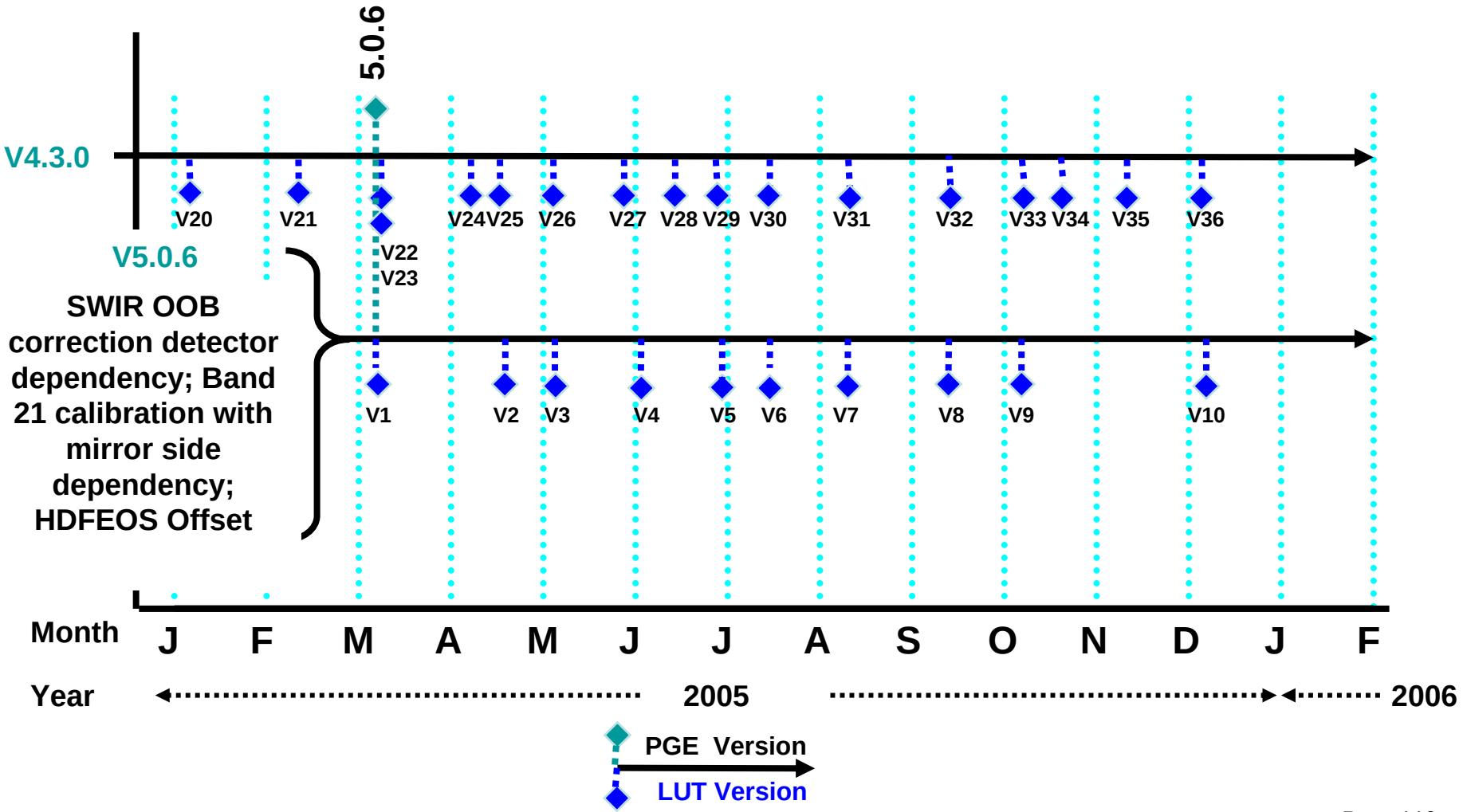
(Forward Processing)



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

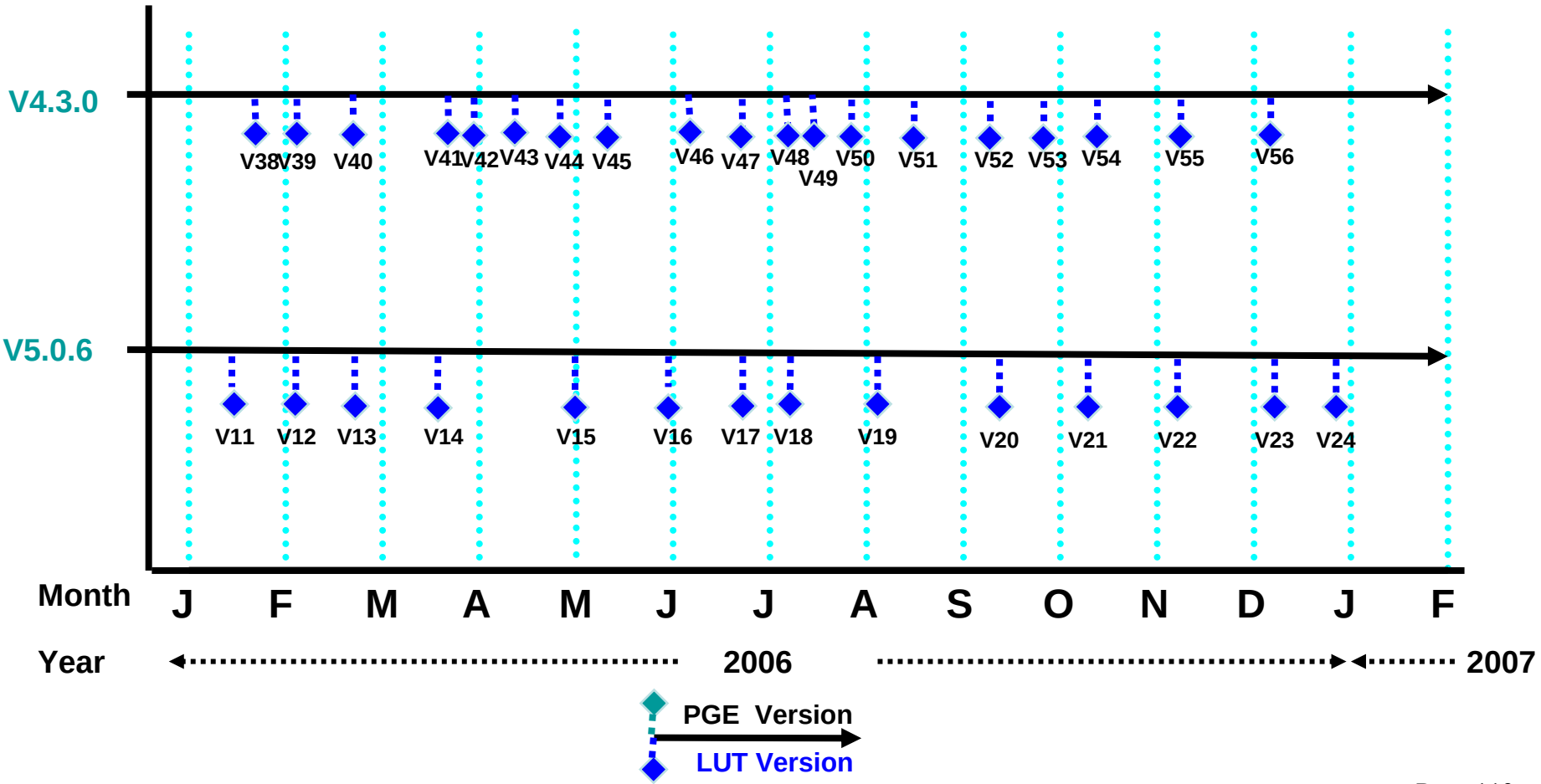
2005 Production Changes in MOD_PR02 TERRA L1B Code/LUTs

(Forward Processing)



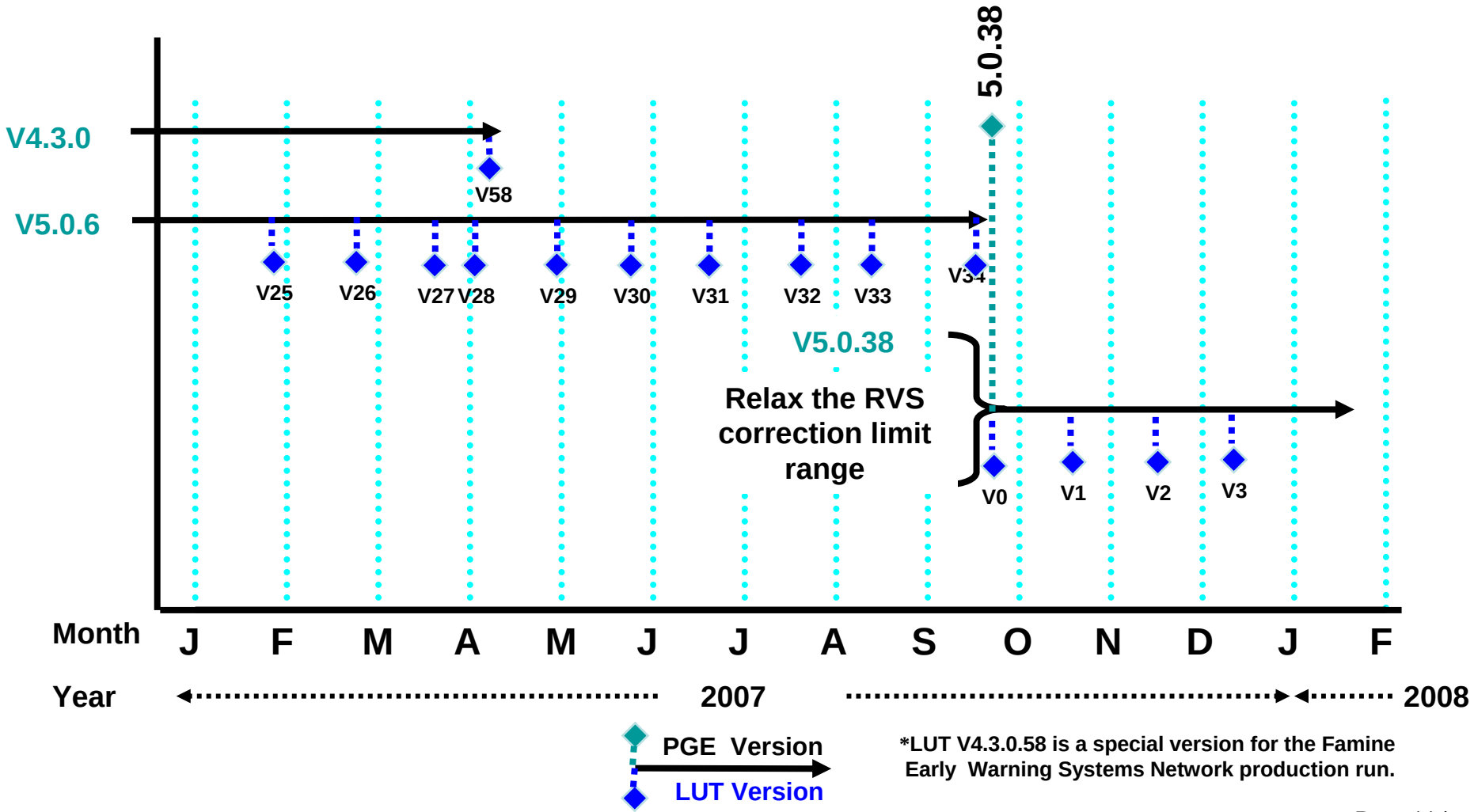
2006 Production Changes in MOD_PR02 TERRA L1B Code/LUTs

(Forward Processing)



2007 Production Changes in MOD_PR02 TERRA L1B Code/LUTs

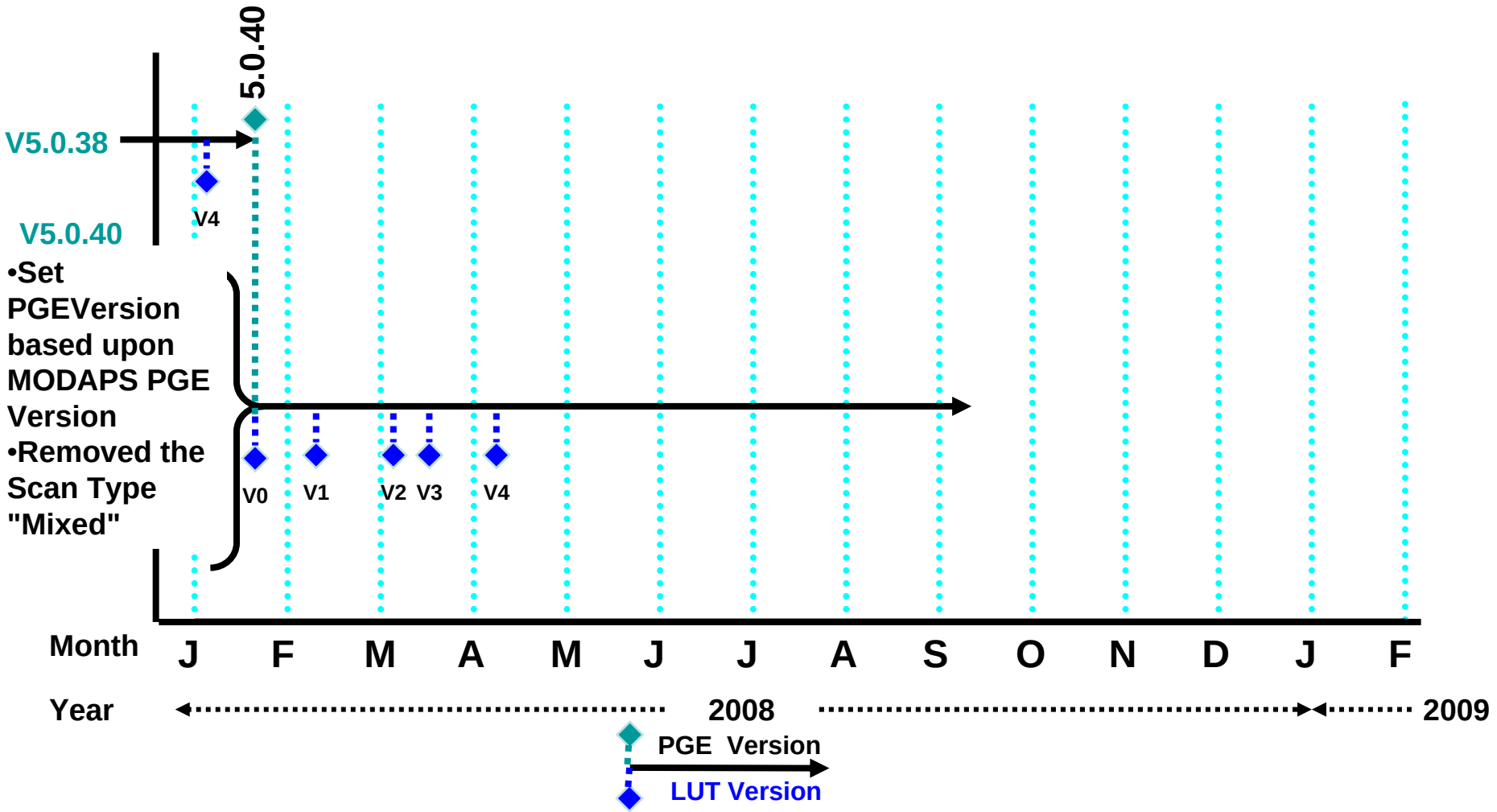
(Forward Processing)



*LUT V4.3.0.58 is a special version for the Famine Early Warning Systems Network production run.

2008 Production Changes in MOD_PR02 TERRA L1B Code/LUTs

(Forward Processing)



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	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.

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

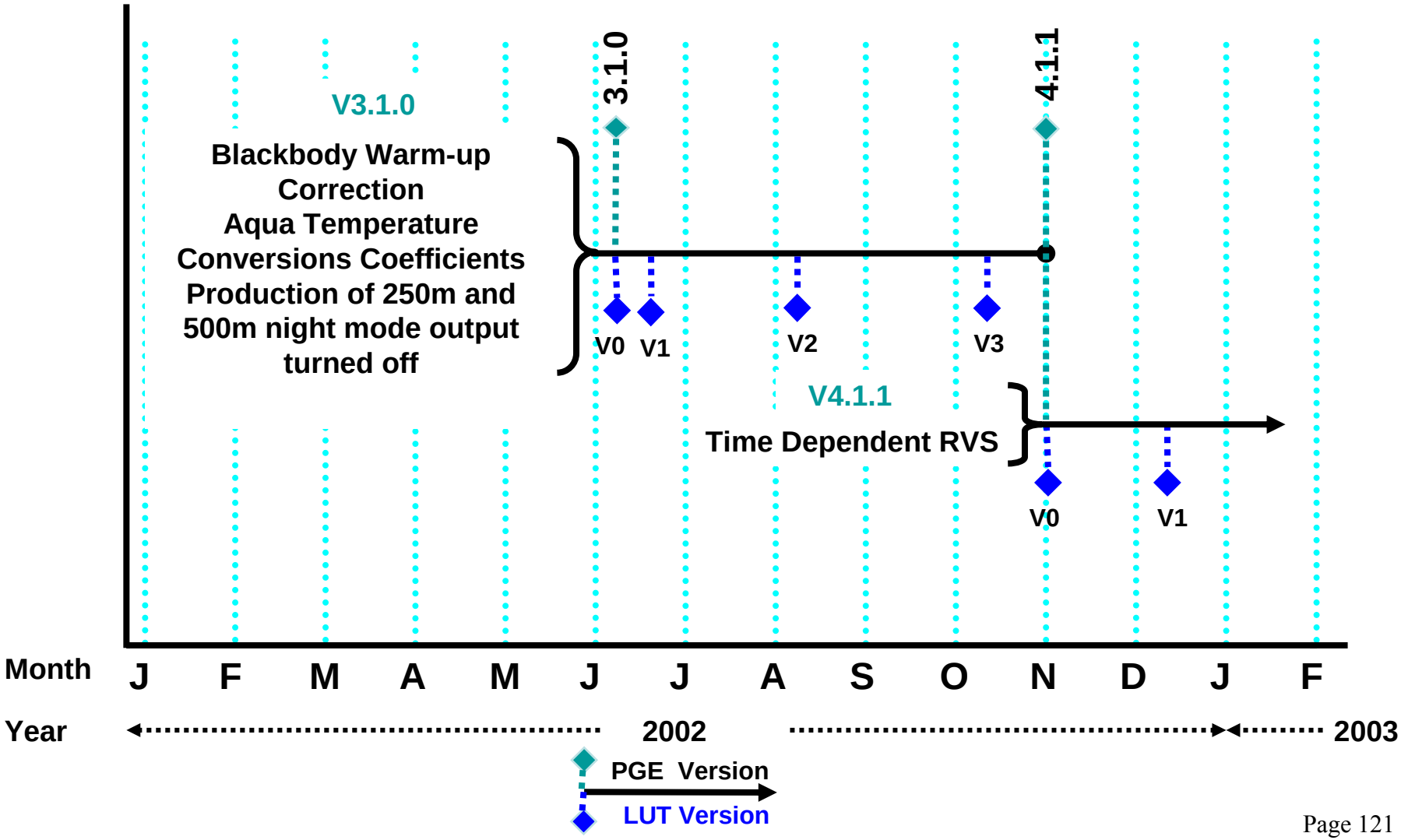
V4.3.1_Aqua	1, 2, 3, 4, 5, 6, 7, 8, 9,
	10, 11, 12, 13, 14, 15,
	16, 17, 18, 19, 20, 21,
	22, 23, 24, 25, 26, 27,
	28, 29, 30, 31, 32, 33,
	34, 35, 36
		• LUTs updated from V4.2.1.8
		• Reflective Calibration Coefficients reworked for reprocessing as of Version 1
		  • Improved SD sun angles used
		  • 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	1, 2	• Continuous Reflective Calibration Coefficient updates (m1, Sigma_m1, and/or RVS_RefSB) • Detector quality flags QA table: “Noisy” flags were set for B29/D8 as of 2007359 and B29/D2 as of 2008038

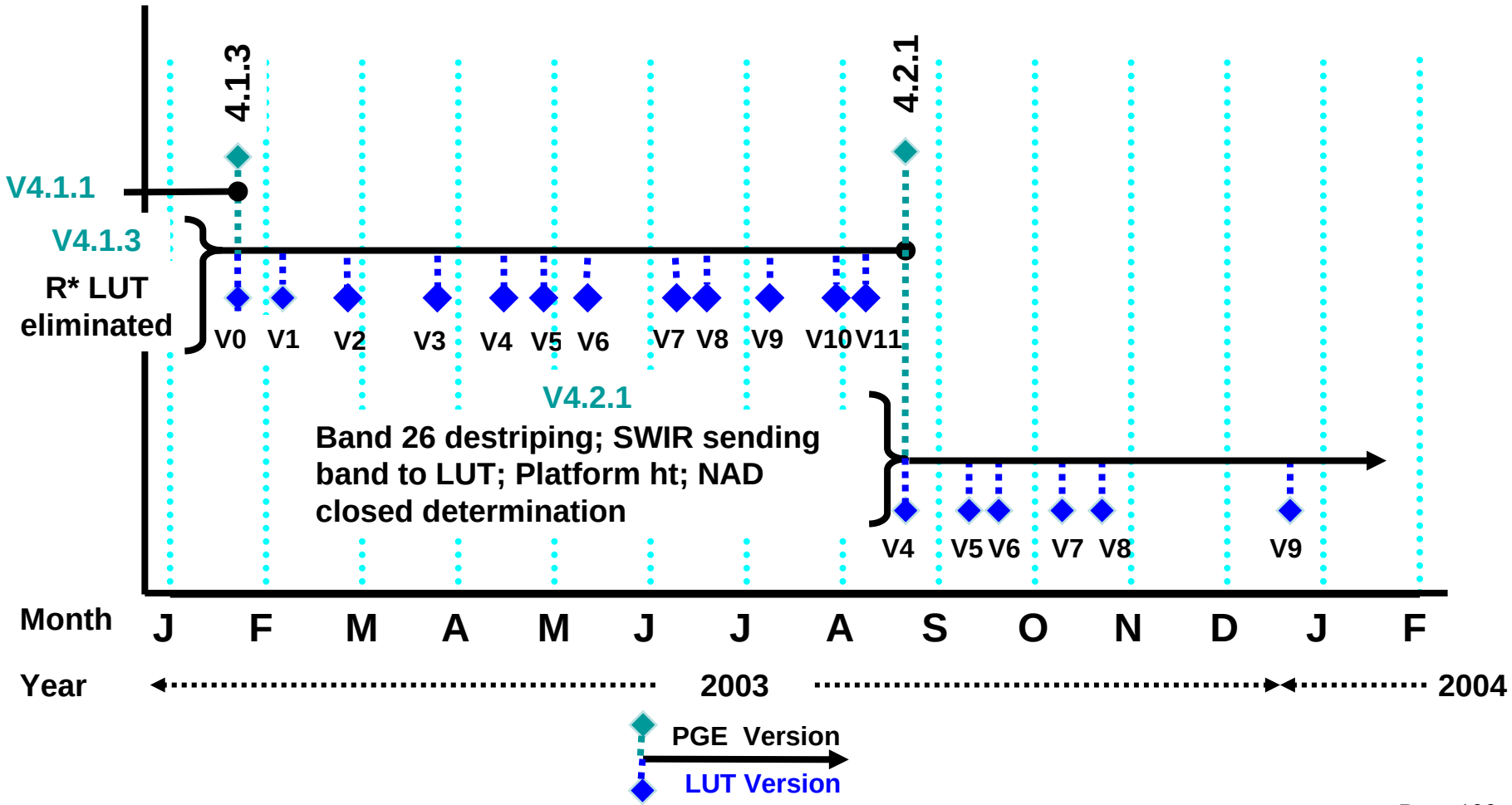
2002 Production Changes in MOD_PR02 AQUA L1B Code/LUTs

(Forward Processing)



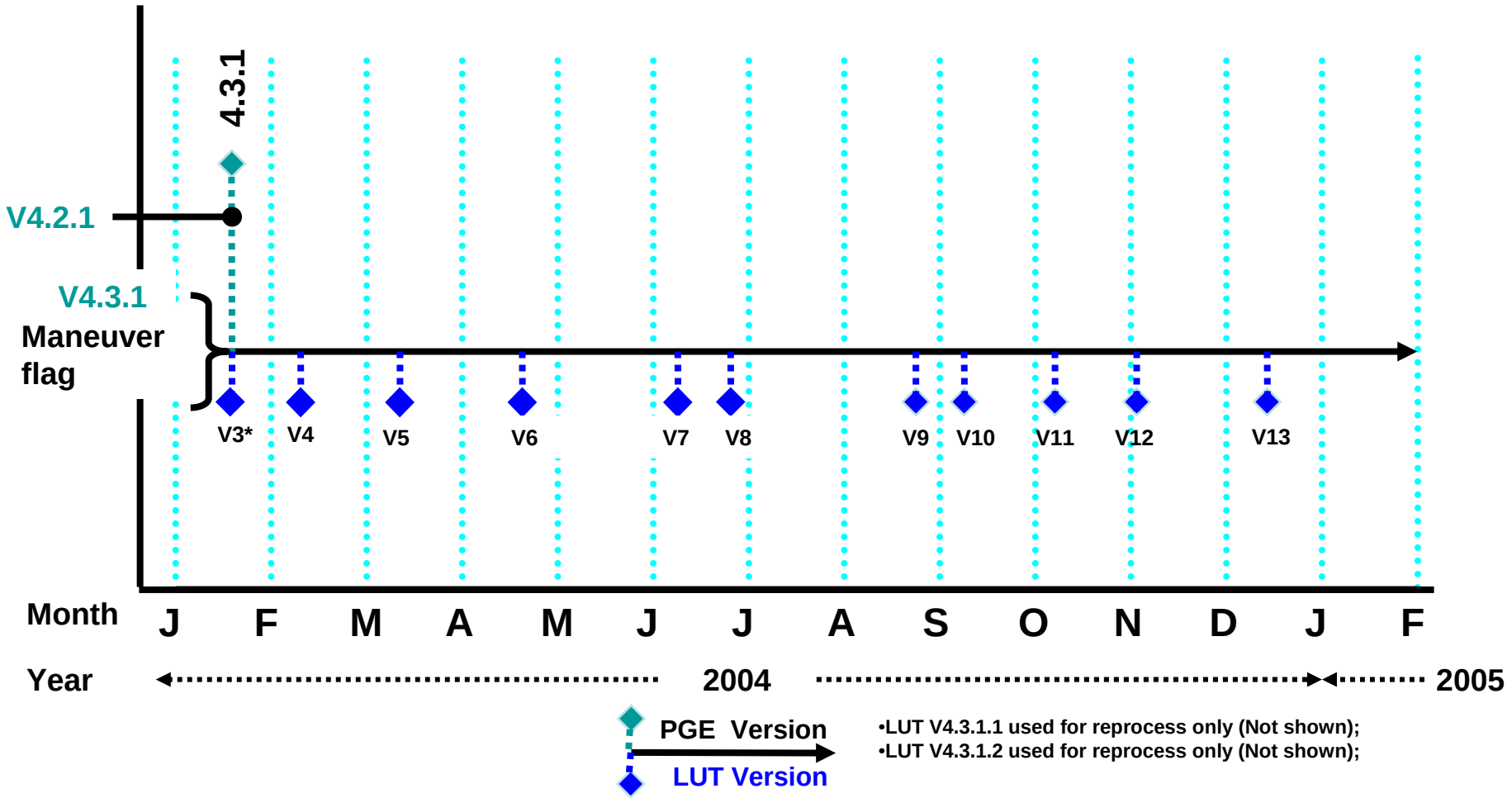
2003 Production Changes in MOD_PR02 AQUA L1B Code/LUTs

(Forward Processing)



2004 Production Changes in MOD_PR02 AQUA L1B Code/LUTs

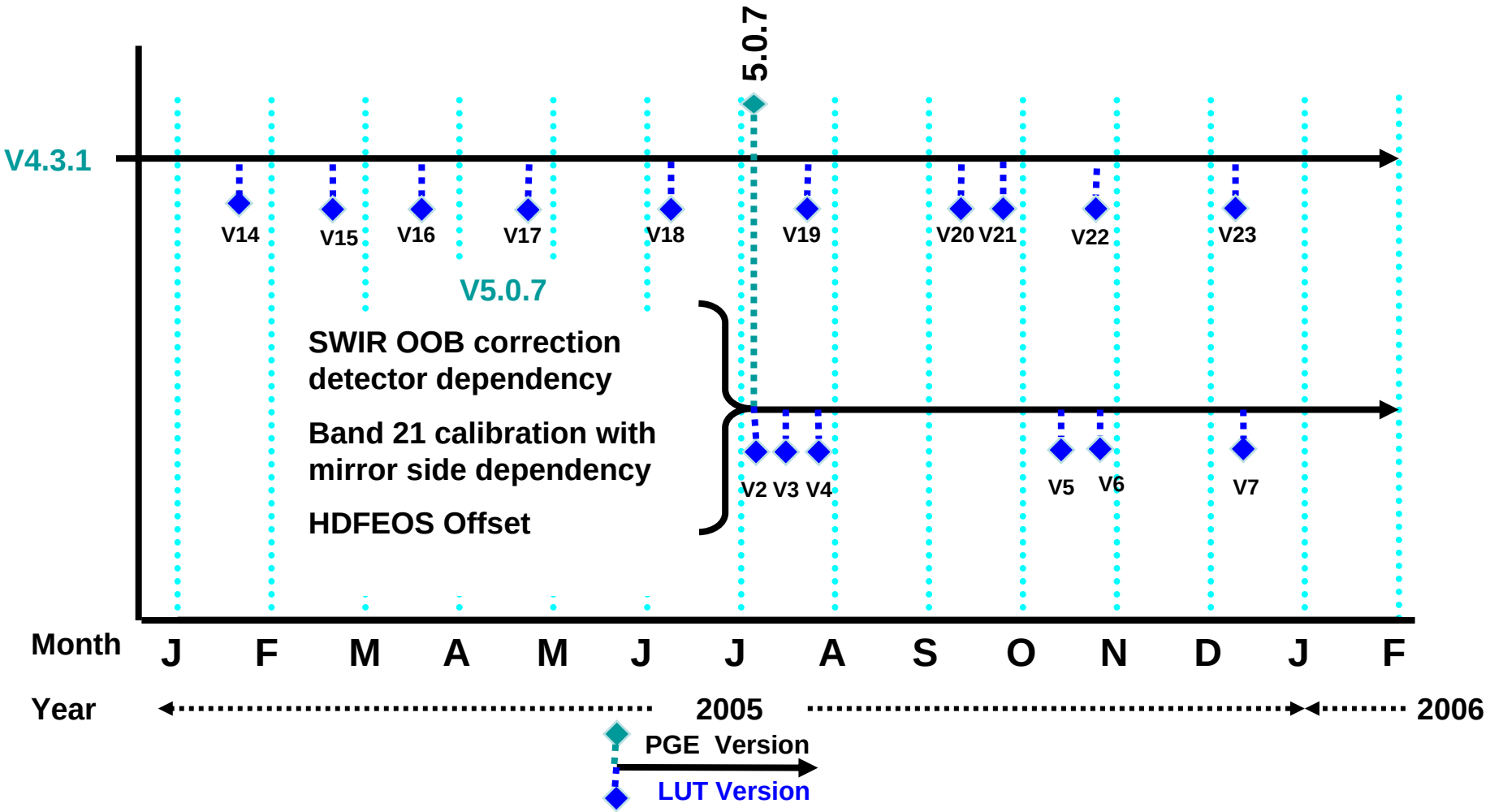
(Forward Processing)



•LUT V4.3.1.1 used for reprocess only (Not shown);
•LUT V4.3.1.2 used for reprocess only (Not shown);

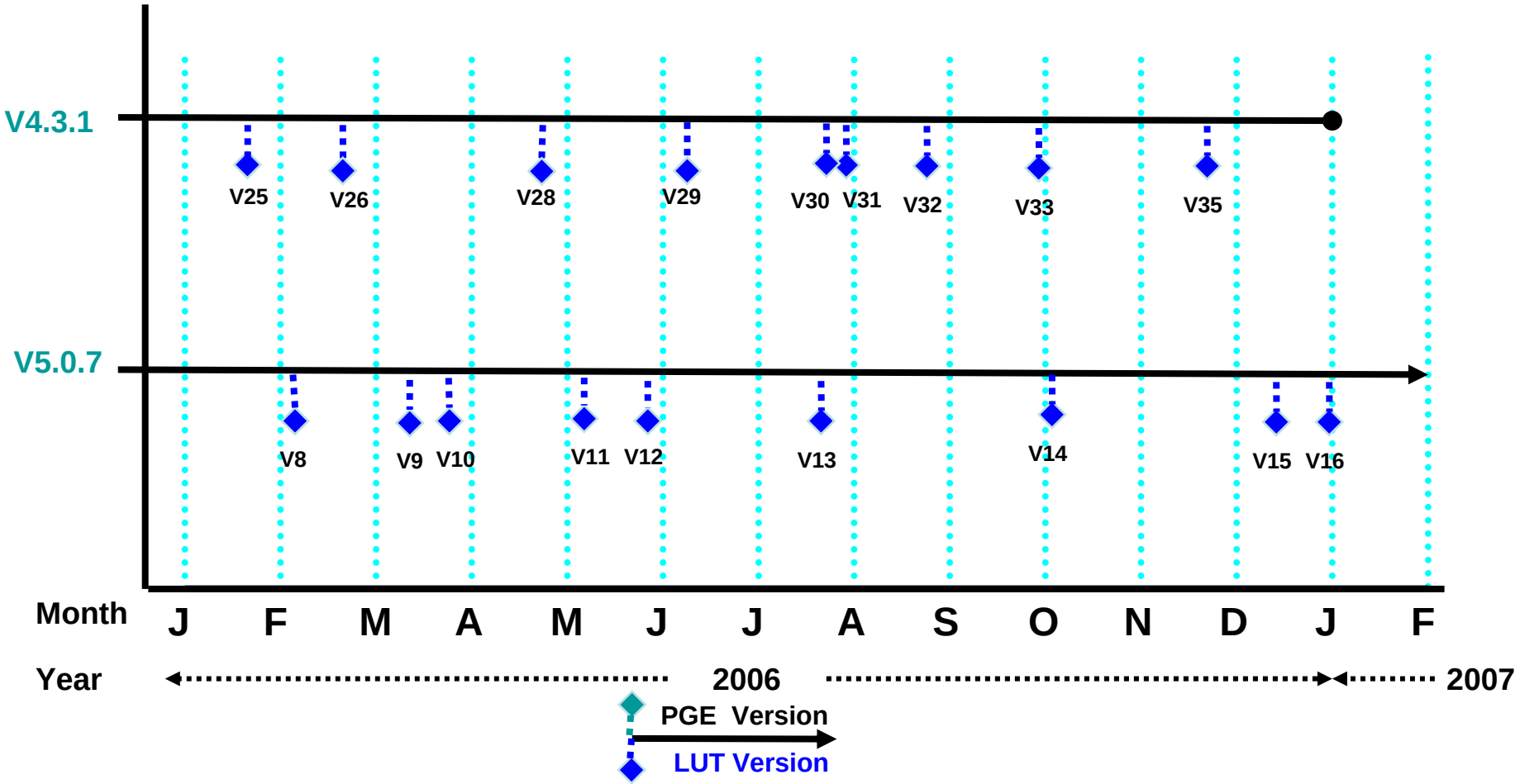
2005 Production Changes in MOD_PR02 AQUA L1B Code/LUTs

(Forward Processing)



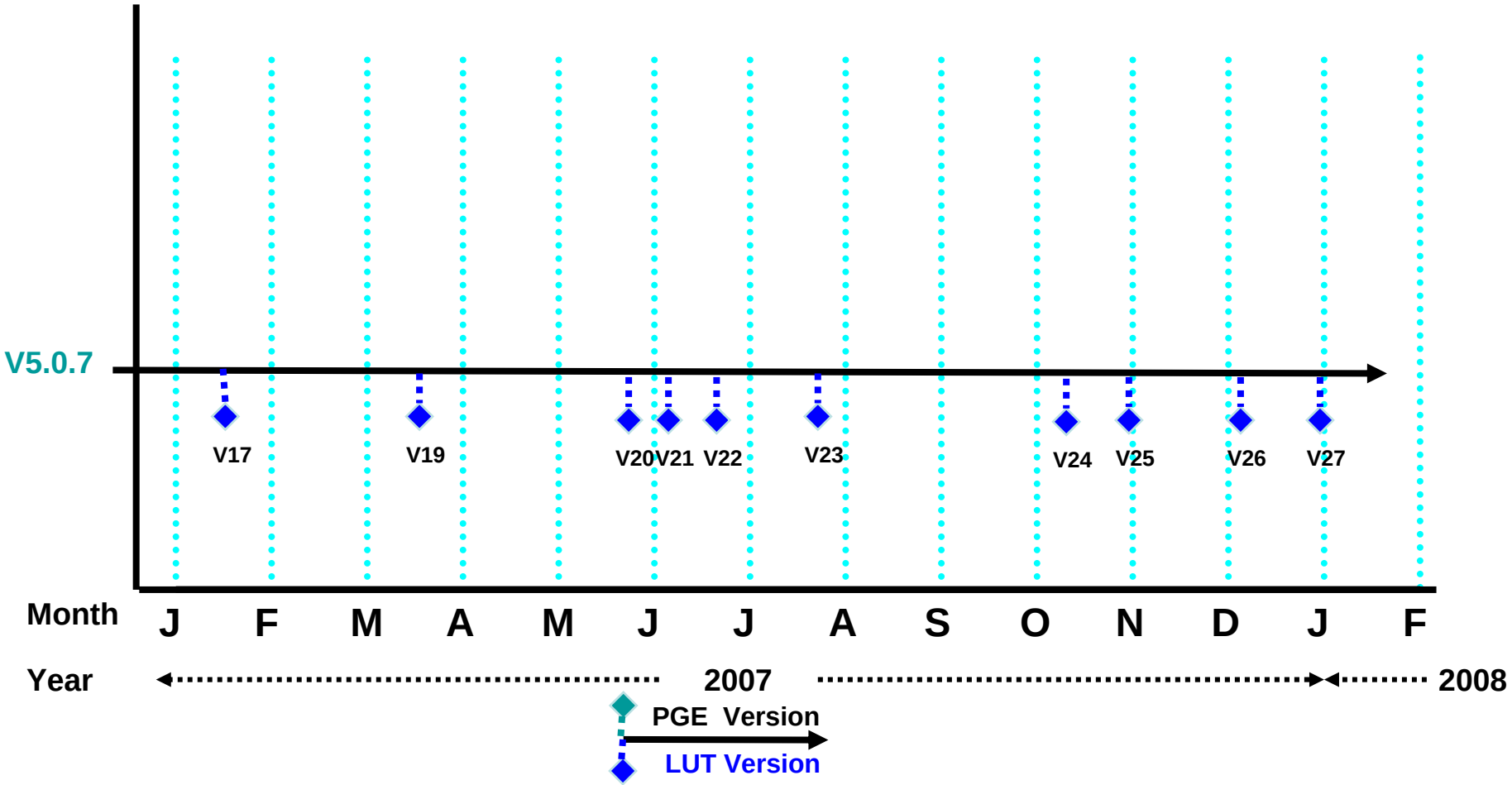
2006 Production Changes in MOD_PR02 AQUA L1B Code/LUTs

(Forward Processing)



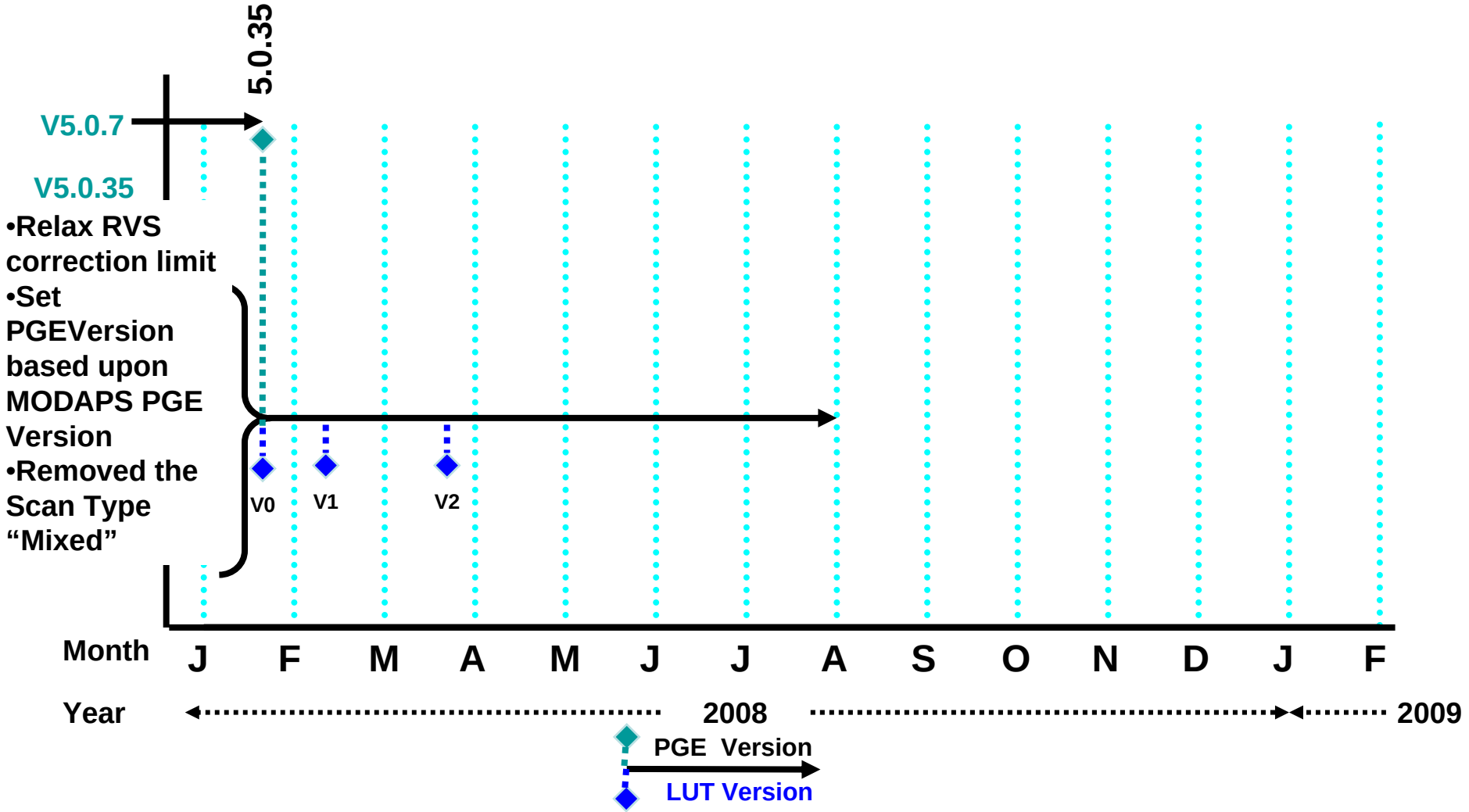
2007 Production Changes in MOD_PR02 AQUA L1B Code/LUTs

(Forward Processing)



2008 Production Changes in MOD_PR02 AQUA L1B Code/LUTs

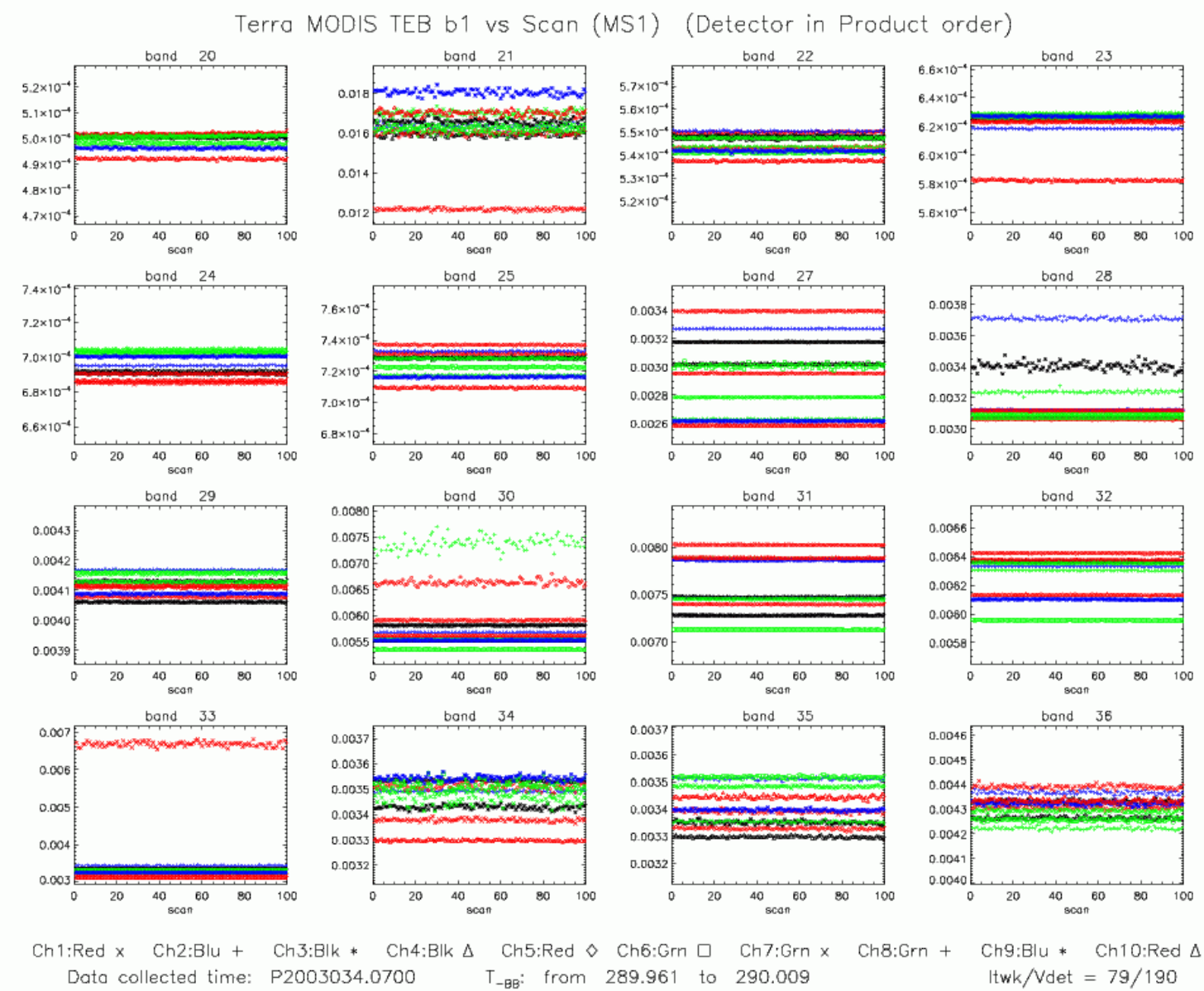
(Forward Processing)



TEB Backup Slides

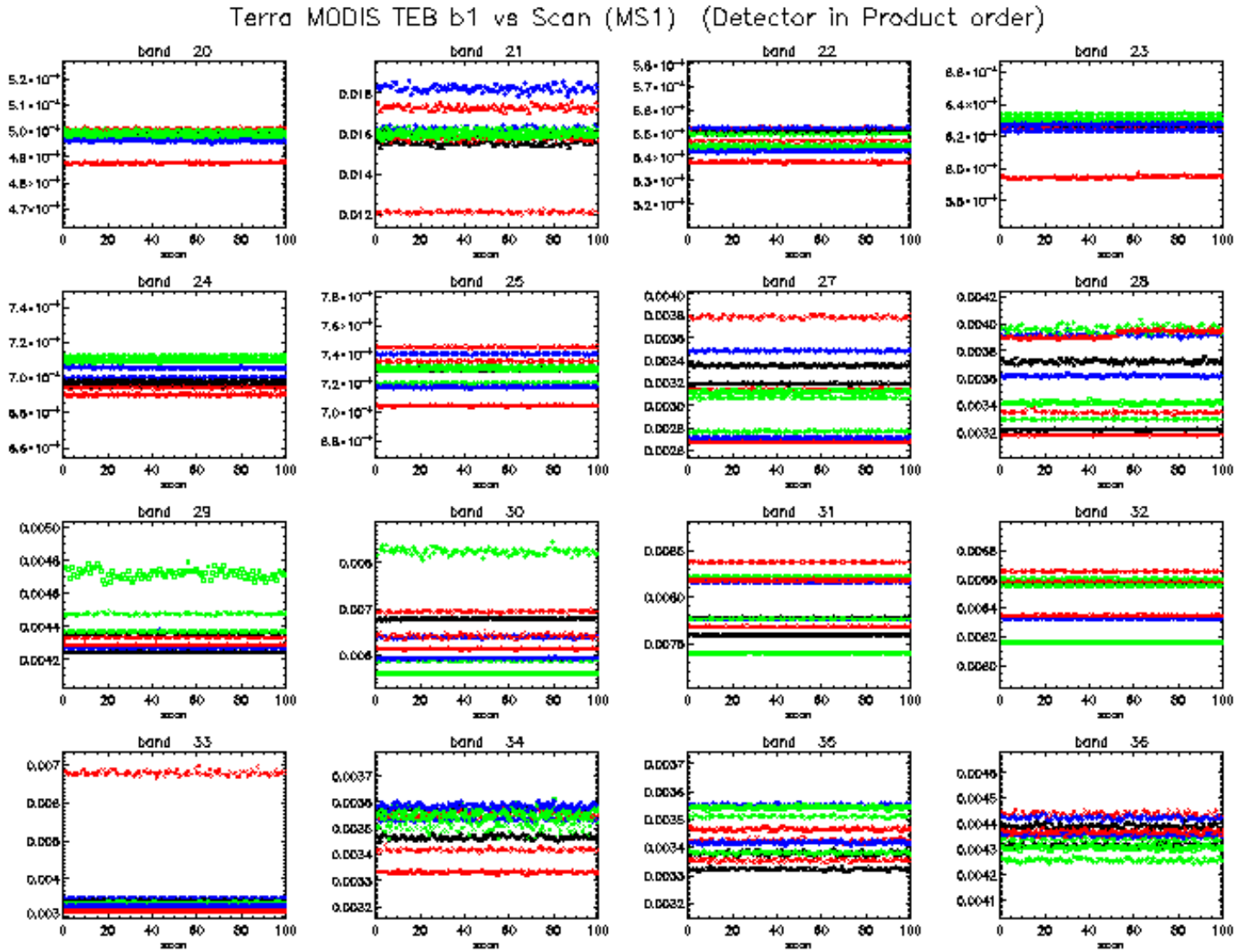
Terra b1 Short-term Stability

2003034.0700



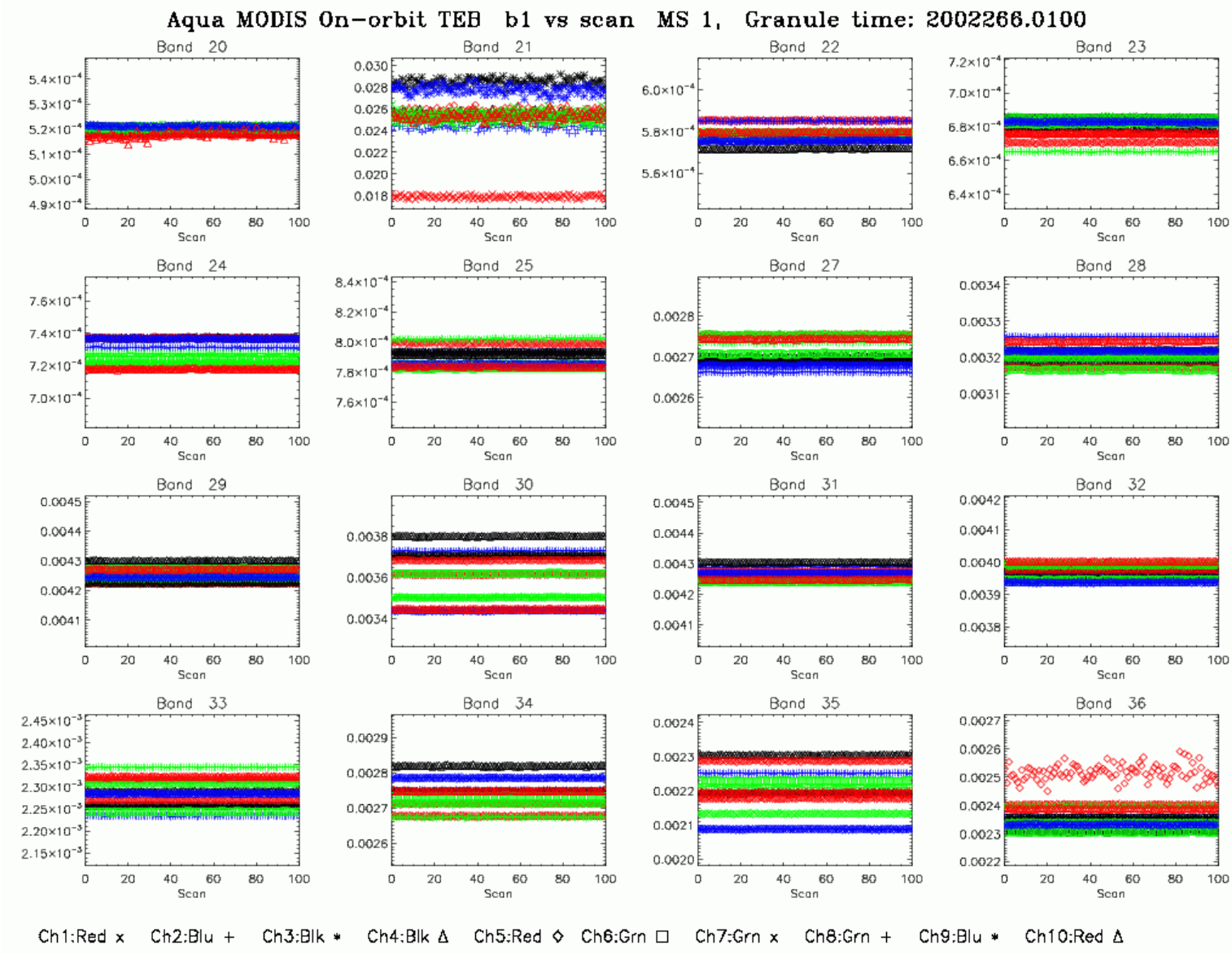
Terra b1 Short-term Stability

2008119.0335



Aqua b1 Short-term Stability

2002266.0100



Aqua b1 Short-term Stability

2008010.1135