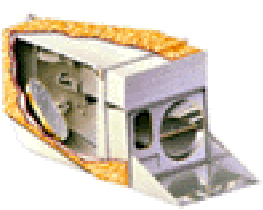
MODIS Operation, Calibration & Performance

Jack Xiong (NASA GSFC)

and

MODIS Characterization Support Team (MCST)

MODIS Science Discipline Representatives



MCST Workshop at MST Meeting (May 1, 2014)

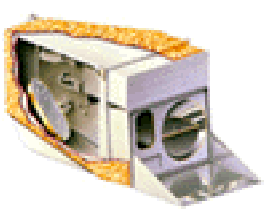
Introduction

- **Acknowledgements**
  - MODIS Characterization Support Team (MCST)
    - Instrument Operation Team (IOT)
    - Level 1B Group
    - Calibration Group (RSB, TEB, LUT delivery)
  - MODIS Sensor Working Group (MsWG)
    - Discipline Representatives (ocean, land, and atmosphere)
  - Others
    - NASA HQ (funding support for both Terra and Aqua missions)
    - MODIS Science Team (science contributions)
    - User Community

Agenda

<u>MODIS Operation, Calibration, and Performance</u>	
Introduction (Jack Xiong)	08:30 am
Instrument Operation Status (Jenn Dodd)	08:35 am
MODIS L1B and LUT Updates (Xu Geng)	08:45 am
Calibration and Performance (Brian Wenny)	08:55 am
Special Calibration Topics – Part 1 (Amit Angal)	09:10 am
Special Calibration Topics – Part 2 (Aisheng Wu)	09:35 am
MODIS Geo-location Status (Robert Wolfe/Gary Lin)	10:00 am
Summary and Future Work (Jack Xiong)	10:20 am
Break	10:30 am
<u>Science Discipline Presentations</u>	
MODIS TEB Cal/Val Updates (Simon Hook)	10:45 am
Recent Updates to the MODIS Terra Polarization Correction (Gerhard Meister)	11:00 am
SST Climate Data Records(Peter Minnett)	11:15 am
Terra MODIS – IASI Comparisons (Chris Moeller)	11:30 am
Atmosphere Discipline Cal/Val Updates (Rob Levy)	11:45 am
Discussions (All)	12:00 pm
Adjourn	12:15 pm

MODIS Instrument Operations Status



MCST Workshop at MST Meeting (May 1, 2014)

Terra Flight Operations

- Terra Spacecraft Status
  - 14+ years of successful operation
  - No major flight operation anomaly or extensive data losses since last STM
  - Solid State Recorder – 33 supersets allocated: no change since June 2007
  - Battery – Anomaly on 10/13/09 resulted in loss of 1 cell (out of 54 total). No impact on operations or power availability.
  - Orbit Maneuvers: Drag Make-up #73-83, Inclination Adjustment #35-38

Aqua Flight Operations

- Aqua Spacecraft Status
  - 12 years of successful operations
  - No major flight operation anomaly or extensive data losses since last STM
  - Solid State Recorder – Full allocation
  - Battery – Fully functional
  - AMSR-E – antenna operation recovery operation was successful in 12/4/2012 – currently operating at 2 rpm (instead of 40 rpm)
  - Orbit Maneuvers: Drag Make-up #71-83, Inclination Adjustment #37-42

MODIS Instrument Operations (Terra)

- **Terra MODIS is healthy and operating nominally**

- **Operational Configuration (No change since last STM)**
  - 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
  - BB temperatures set at 290K
  - Cold FPA (SMIR and LWIR) controlled at 83K
  - SD door fixed to "open" position since July, 2003
- **Events**
  - None
- **Concerns**
  - SSR allocation – further decrease could result in data loss

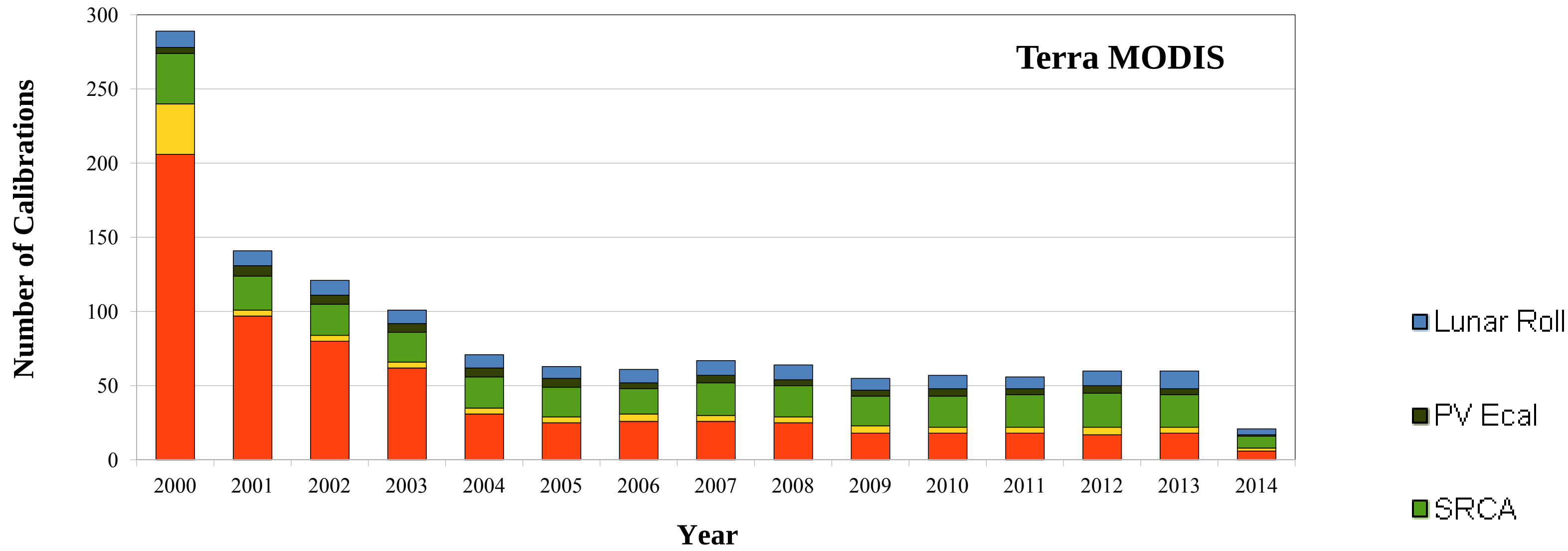
MODIS Instrument Operations (Aqua)

- **Aqua MODIS is healthy and operating nominally**

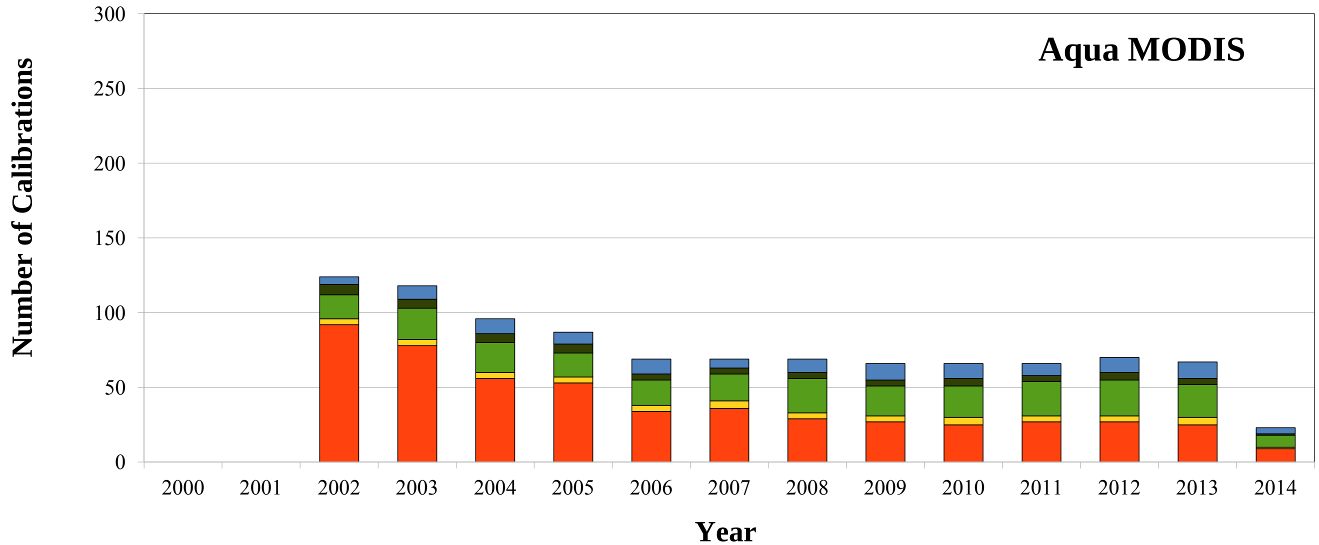
- **Operational Configuration (No change since last STM)**
  - Same B-side configuration since launch
  - BB temperatures set at 285K
  - Cold FPA (SMIR and LWIR) controlled at 83K
- **Events**
  - None
- **Concerns**
  - Loss of radiative cooler margin – Cold FPA not maintained at 83 K through entire orbit.

MODIS Calibration Operations

Terra



Aqua



Terra/Aqua MODIS OBC Operations

TERRA

Activity	PL to 04/13	04/13 – present	Total
SD/SDSM#	656	18	674
BB WUCD	84	5	89
SRCA*	373	23	396
Electronic Cal	80	4	84
Lunar Roll	123	13	136

AQUA

Activity	PL to 04/13	04/13 - present	Total
SD/SDSM#	493	27	520
BB WUCD	48	4	52
SRCA*	248	23	271
Electronic Cal	60	4	64
Lunar Roll	103	13	116

Open & Screened Activities counted independently

* Includes Spatial, Spectral and Radiometric

04/13 = last Science Team Meeting

SRCA Calibrations

- Terra – 396 SRCA Calibrations
- Aqua – 271 SRCA Calibrations
- Please note there was a minor reconciliation of the usage numbers

Lamp Power		10W				1W	
Lamp #		1	2	3	4	1	2
Terra	Usage (hr)	339.2	172.1	190.3	121.2	584.3	298.1
	Life (hr)	500	500	500	500	4000	4000
	percent	67.8%	Failed on 11-20-2004	Failed on 2-18-2006	24.2%	14.6%	7.5%
Aqua	Usage (hr)	330.7	188.0	205.7	122.2	525.0	287.9
	Life (hr)	500	500	500	500	5000	5000
	percent	66.1%	Failed on 4-14-2003	Failed on 6-28-2005	24.4%	10.5%	5.8%

Future Operational Considerations

- Aqua MODIS CFPA temperature control
  - Currently set at 83K with observed ~0.4 K orbital oscillation
  - Minimal impact on science data
  - Mitigation options are under investigation

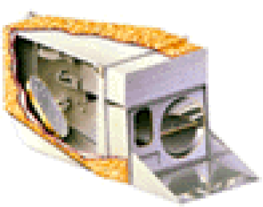
- Aqua SD/SDSM door movements
  - Passed projected lifetime limit on movements
  - No change in current frequency of SD calibration activities planned at this time

	PL to 04/13	04/13 to present	Total	Design Lifetime	% Used
Terra*	2146	0	2146	3022	71.01
Aqua+	3074	72	3146	3022	104.10

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

+ Aqua reached designed lifetime of door movement on DOY 2012/191 (July 2012).

MODIS Level 1B Code and LUT Status



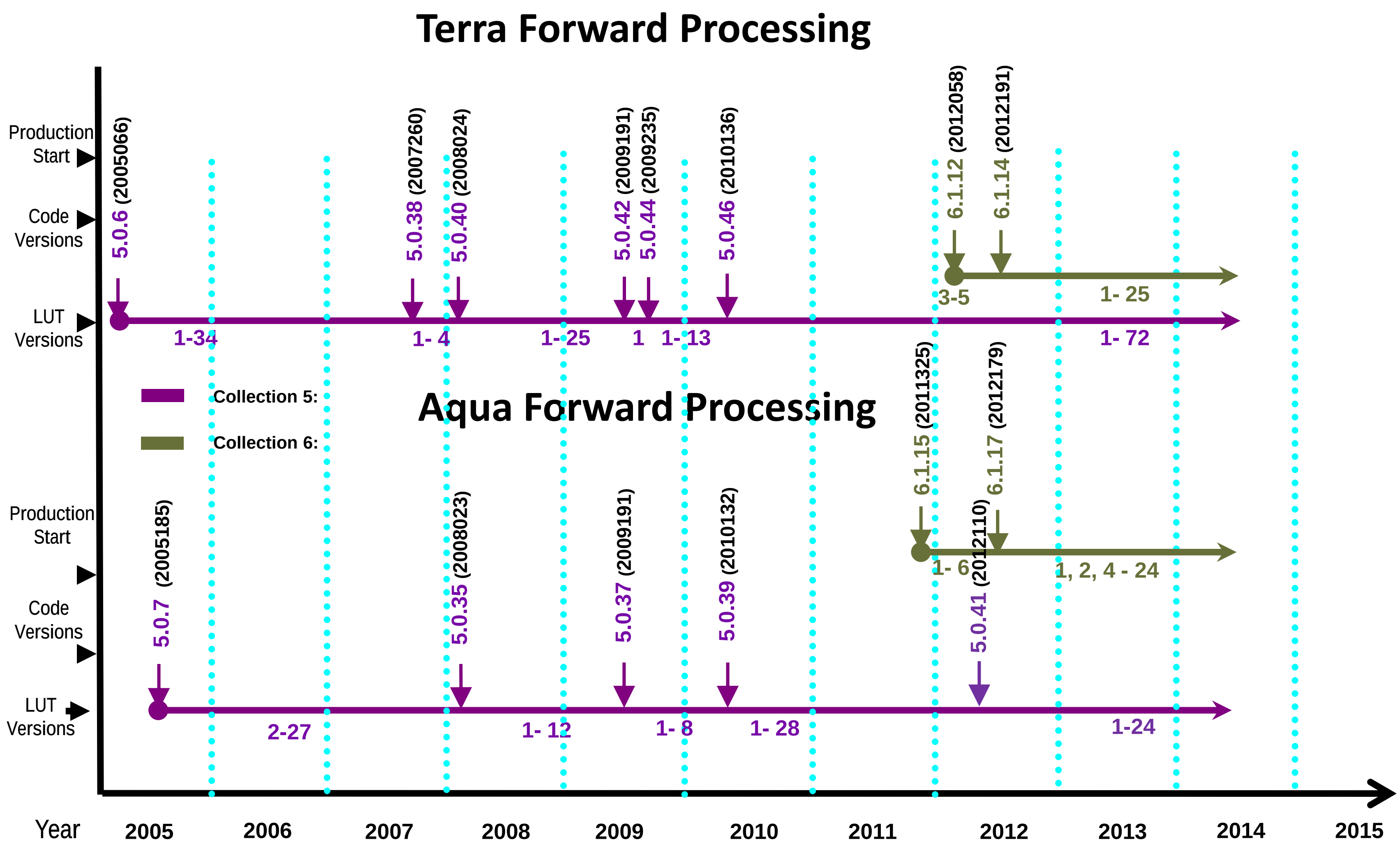
MCST Workshop at MST Meeting (May 1, 2014)

C5/C6 L1B Code and LUT Updates

- **Two separated sets of code and LUTs**
  - One for Terra MODIS and one for Aqua MODIS
- **Two versions**
  - C5 (2005 – present): Terra V5.0.46; Aqua: V5.0.41
  - C6 (2012 – present): Terra V6.1.14; Aqua: V6.1.17
- **No L1B code changes made since last STM**
- **L1B LUT updates (since the last STM (4/17/2013))**
  - Terra MODIS C5: 14; C6: 14; Aqua MODIS C5: 11; C6: 12
  - Most LUT updates were driven by response changes of VIS bands

MODIS MOD_PR02 L1B Code/LUTs

Major Production Changes Timeline (C5 & C6)



MCST L1B Code and LUT Updates

(as of 2014-05-01)

Year	Terra Code Versions	Terra LUTs C2	Terra LUTs C3	Terra LUTs C4	Terra LUTs C5	Terra LUTs C6	Aqua Code Versions	Aqua LUTs C3	Aqua LUTs C4	Aqua LUTs C5	Aqua LUTs C6	Total
2000	5	2	0	0	0	0	0	0	0	0	0	7
2001	3	1	5	0	0	0	0	0	0	0	0	9
2002	3	0	1	0	0	0	3	3	1	0	0	11
2003	3	0	0	19	0	0	3	0	17	0	0	42
2004	1	0	0	17	0	0	1	0	11	0	0	30
2005	2	0	0	18	10	0	2	0	11	6	0	49
2006	0	0	0	20	14	0	0	0	12	9	0	55
2007	1	0	0	1	13	0	0	0	0	11	0	26
2008	1	0	0	0	16	0	1	0	0	8	0	26
2009	2	0	0	0	18	0	1	0	0	8	0	29
2010	1	0	0	0	18	0	1	0	0	13	0	33
2011	1	0	0	0	18	0	2	0	0	15	1	37
2012	1	0	0	0	21	8	1	0	0	13	13	57
2013	0	0	0	0	15	14	0	0	0	11	11	51
2014	0	0	0	0	6	6	0	0	0	4	5	21
Total	24	3	6	75	149	28	15	3	52	98	30	483

Does not include internal deliveries, nor special deliveries to other groups

C6 L1B Major Code Changes

- **Interpolation for inoperable detectors no longer applied**
  - Explicit fill value (SI = 65531) now used in L1B
- **Noisy/Inoperable detector (sub-sample) QA flag**
  - SI is set to 65525 if sub-sample is inoperable
- **RVS model for the RSB changed from quadratic to quartic polynomial**
- **Revised algorithm for uncertainty calculation for RSB and TEB**

MODIS L1B Documents

http://mcst.gsfc.nasa.gov/content/l1b-documents

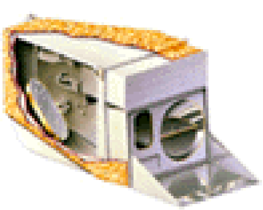
- ATBD
- High-Level Code Design
- LUTs Information Guide
- Product User Guide
- Data Dictionary
- File Specifications

http://mcst.gsfc.nasa.gov/l1b/product-information

http://mcst.gsfc.nasa.gov/l1b/l1b-lut-history

http://mcst.gsfc.nasa.gov/l1b/code-history

MODIS Calibration Status and Performance



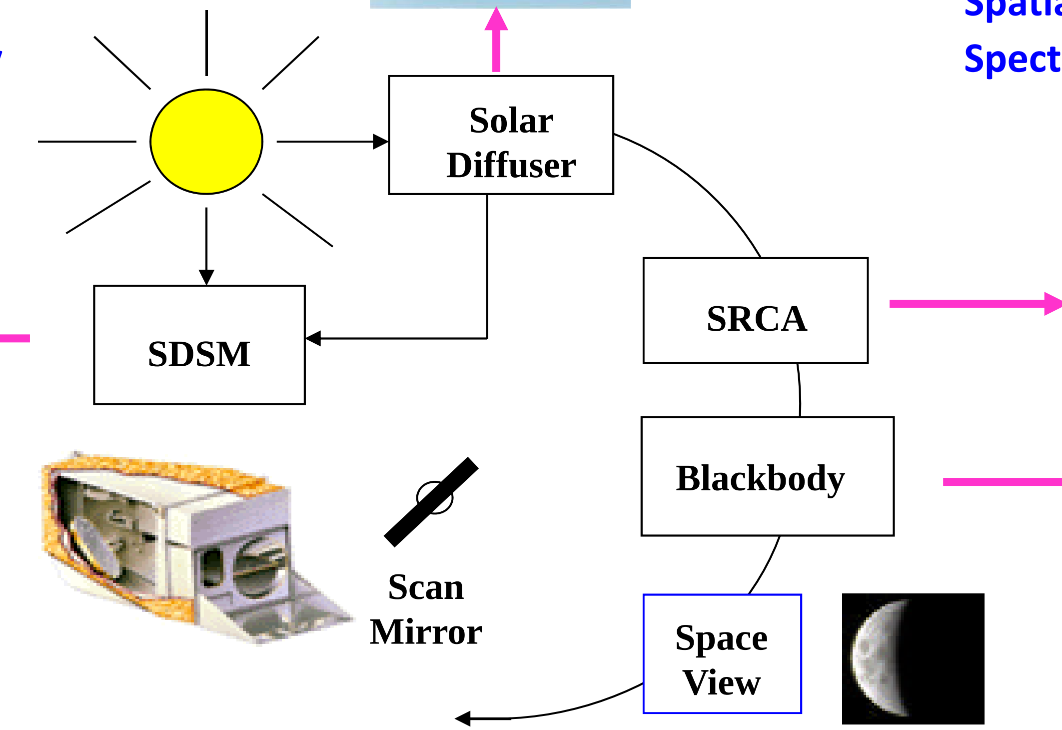
MCST Workshop at MST Meeting (May 1, 2014)

Outline

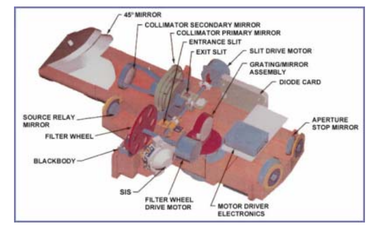
- Introduction
- RSB Performance
  - SD Degradation
  - Gain Trending: SD and Lunar
- TEB Performance
  - BB/CFPA Temperature
  - Gain Trending
- Summary

On-orbit Calibration Activities

SD/SDSM:
Weekly to tri-weekly

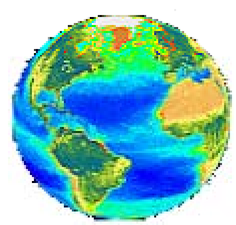


SRCA:
Radiometric: monthly
Spatial: quarterly
Spectral: tri-annual



BB: quarterly

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



Moon: monthly (nighttime orbits)
$0\text{-}20^{o}$ spacecraft roll maneuvers
55^{o} phase angle

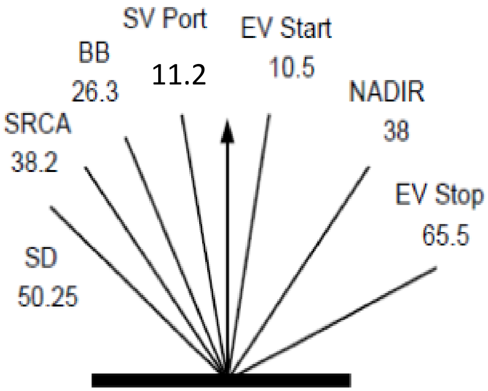
RSB Calibration

- ***EV Reflectance***

$$\rho_{EV} \cdot \cos(\theta_{EV}) = m_1 \cdot d^2_{Earth\_Sun} \cdot dn_{EV} \cdot (1 + k_{Inst} \cdot \Delta T_{Inst}) / RVS$$

- LUT needing to be regularly updated for RSB
  - m1: Inversely proportion to gain at the AOI of SD
  - RVS: Sensor Response versus Scan angle (normalized to SD view AOI to the scan mirror)
- Calibration Source
  - SD/SDSM calibration
  - Lunar observation
  - SRCA and EV mirror side (MS) ratios
  - Response trending from EV targets

MODIS scan mirror



Angle of Incidence (AOI)

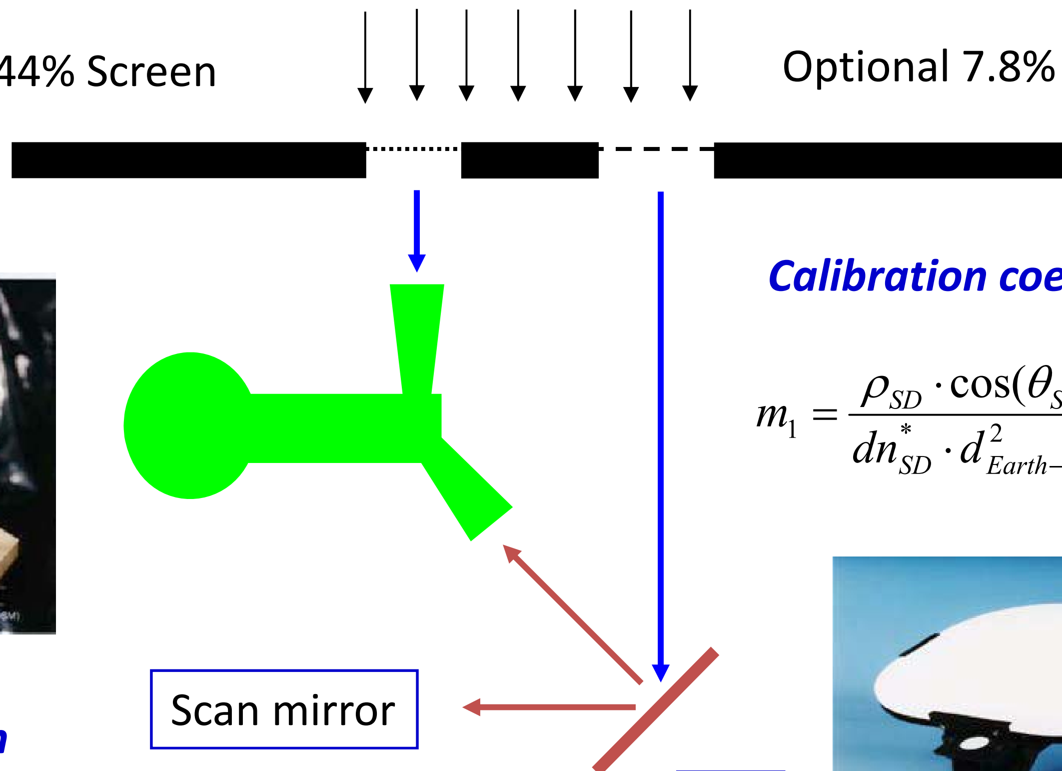
RSB SD Calibration

Sun

1.44% Screen

Optional 7.8% Screen

SDSM



Calibration coefficients

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

Scan mirror

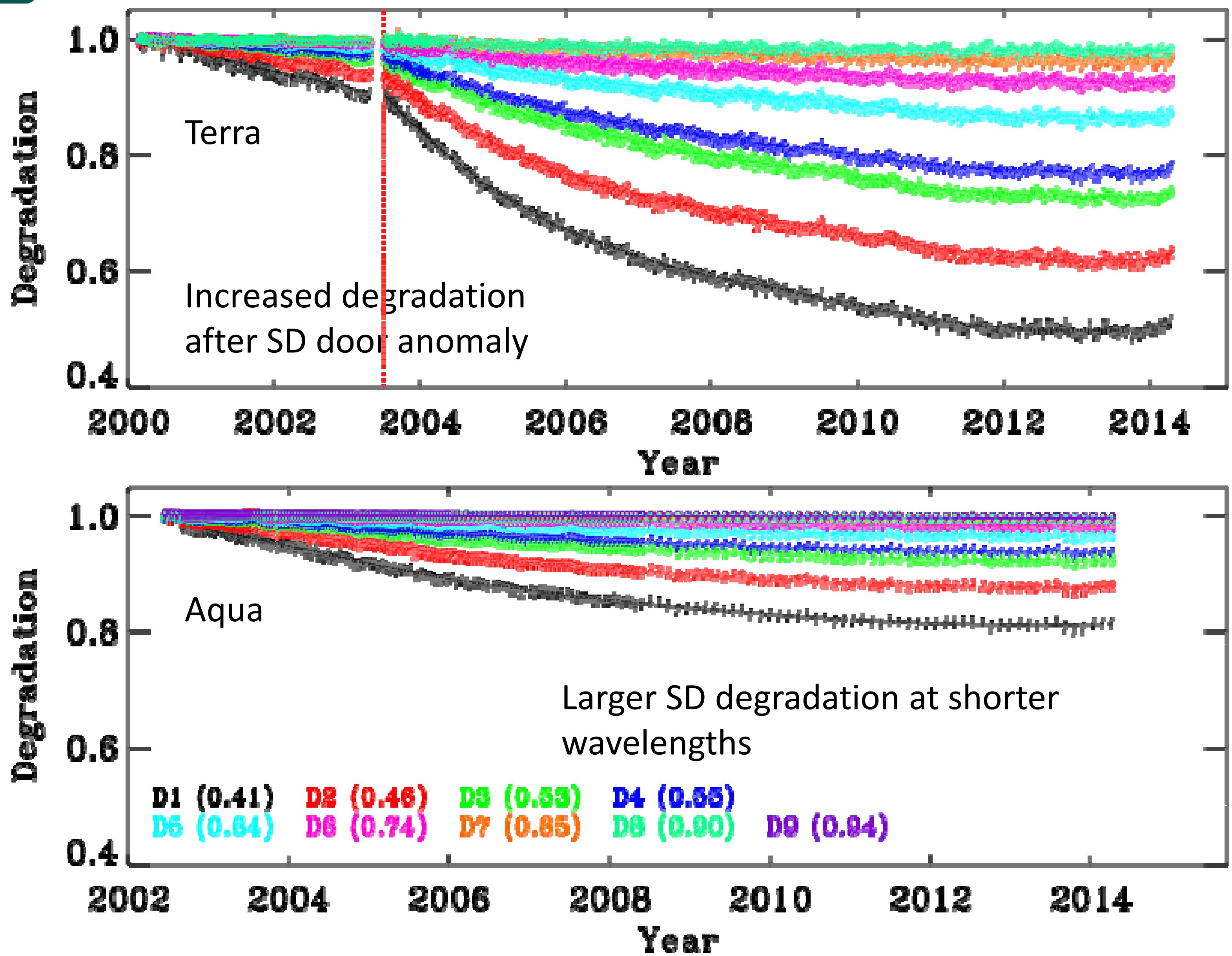
SD

SD degradation

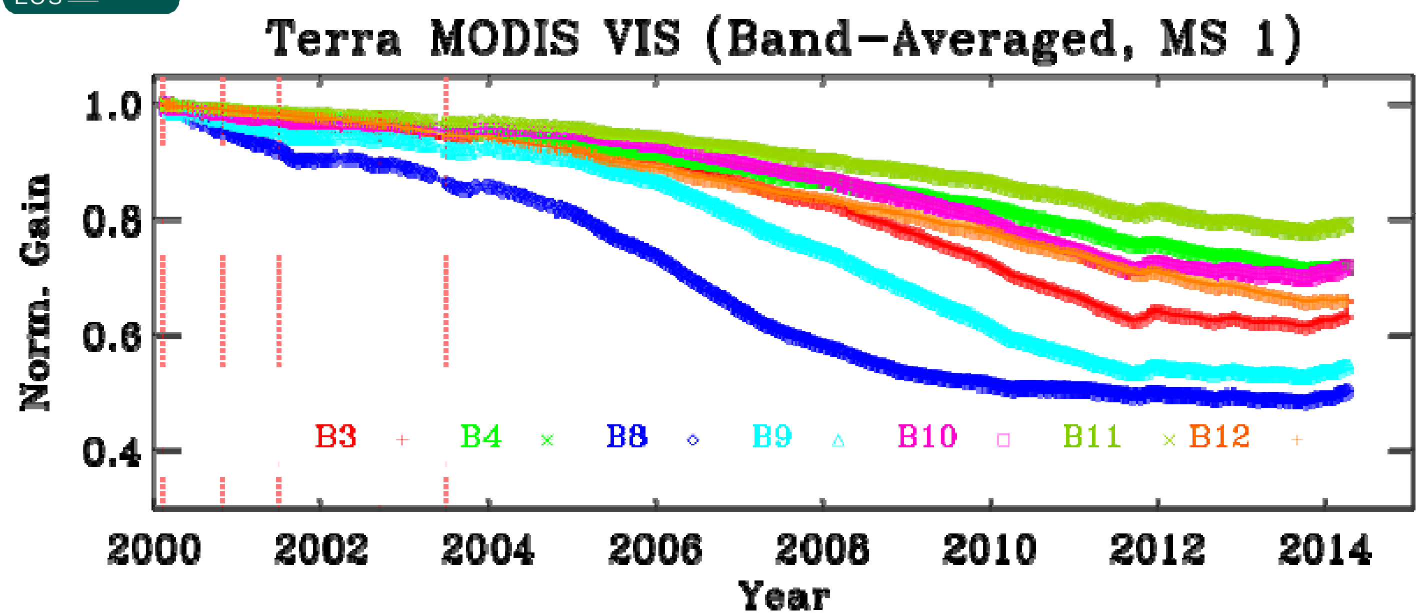
$$\Delta_{SD} = \frac{dc^i_{SD} / dc^9_{SD}}{dc^i_{Sun} / dc^9_{Sun}}$$

$$\Delta^9_{SD} = dc^9_{SD} / dc^9_{Sun}$$

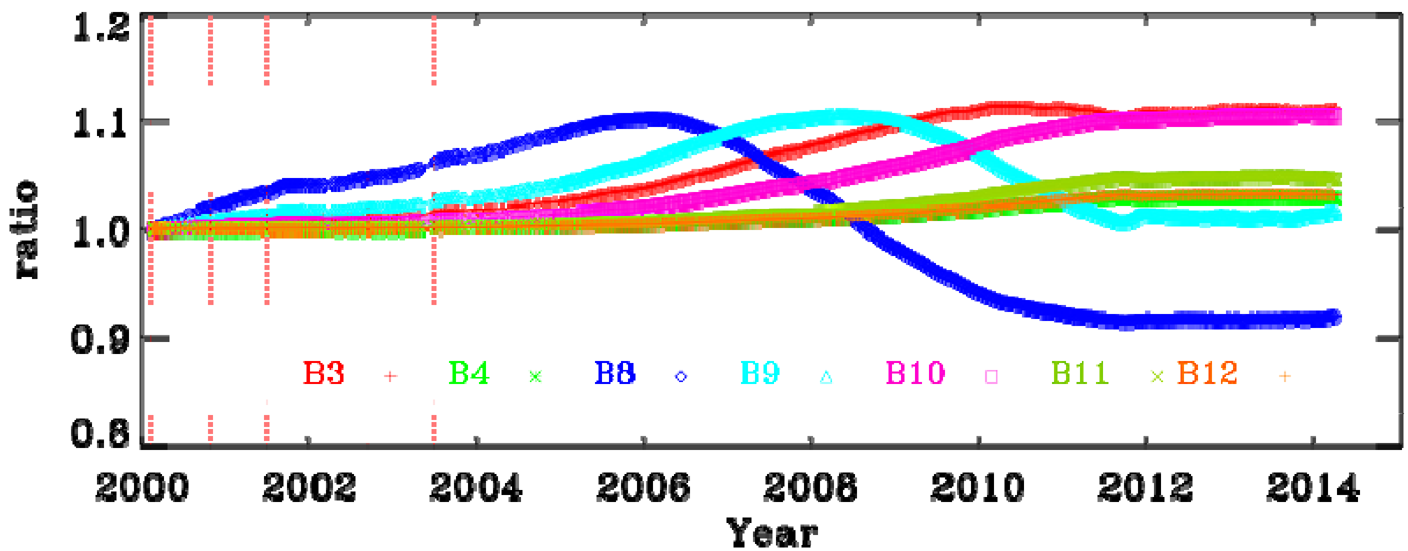
MODIS SD Degradation



MODIS RSB SD Gain Trending: Terra



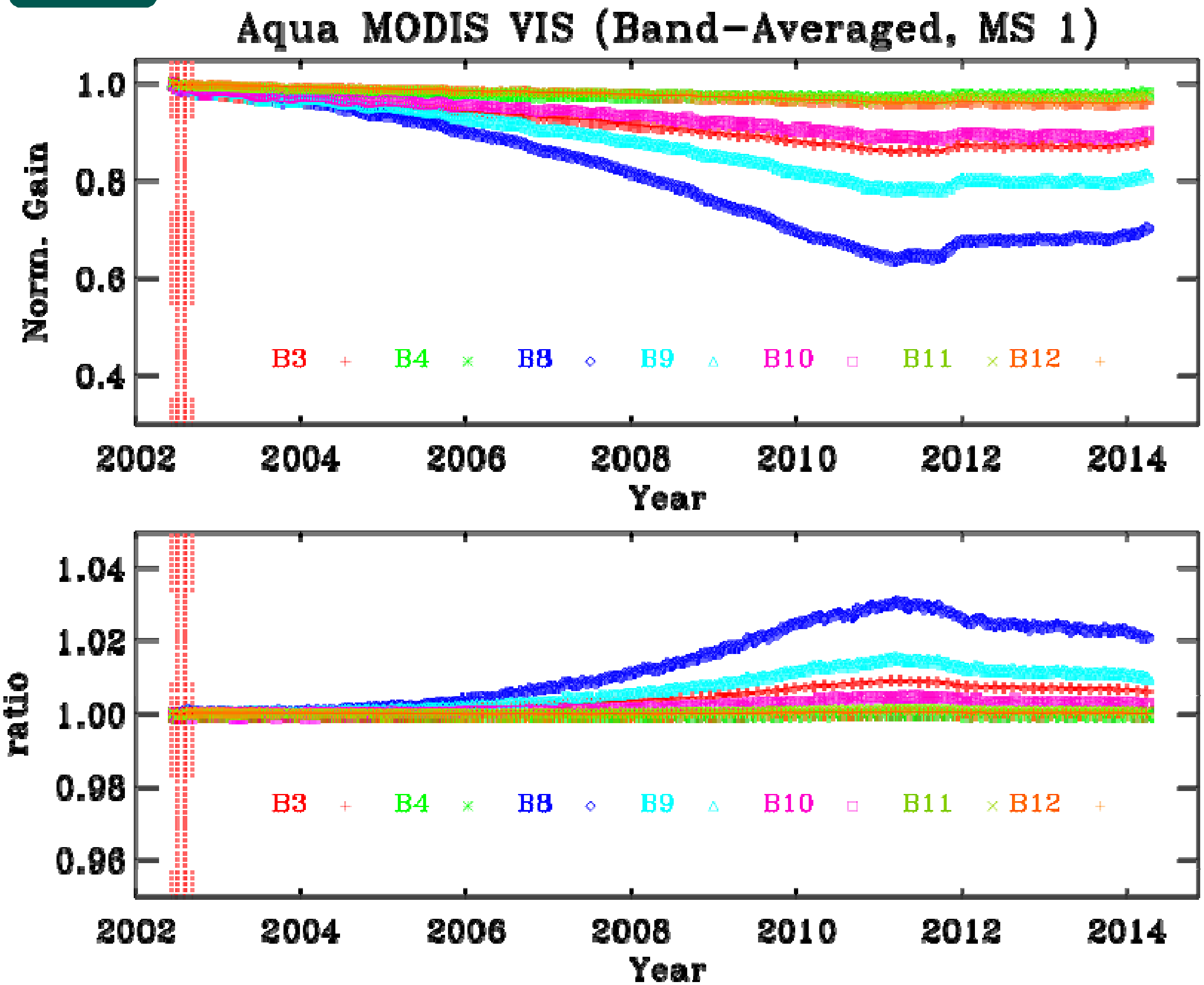
Most change observed for short-wavelength bands
~50% for Band 8



Mirror side differences
~10% for B8

SD AOI: 50.25°

MODIS RSB SD Gain Trending: Aqua

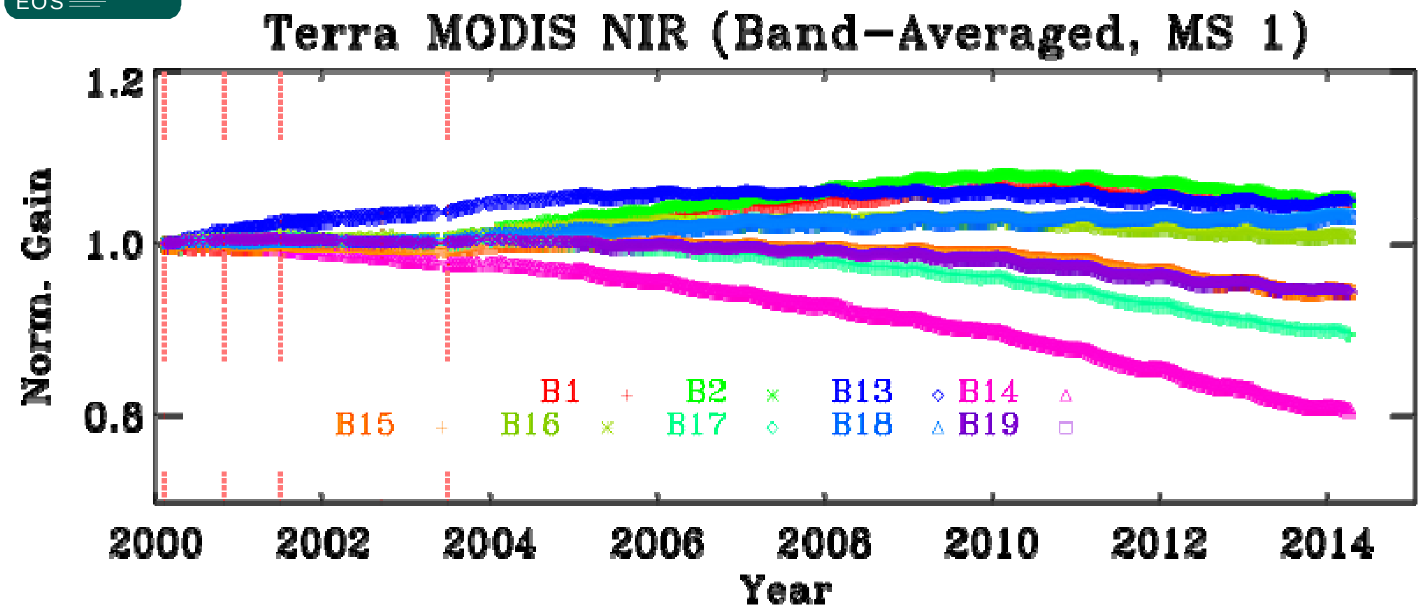


Most change observed for short-wavelength bands ~30% for Band 8

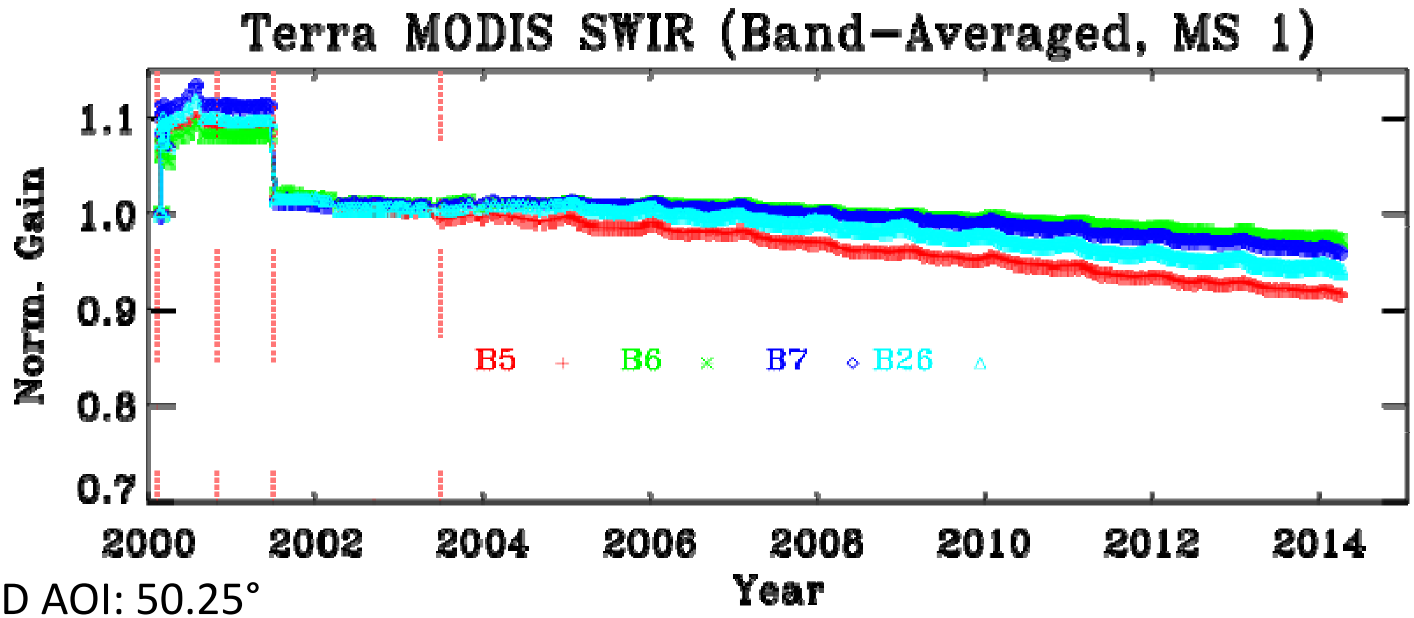
Mirror side differences <2% for all bands

SD AOI: 50.25°

MODIS RSB SD Gain Trending: Terra



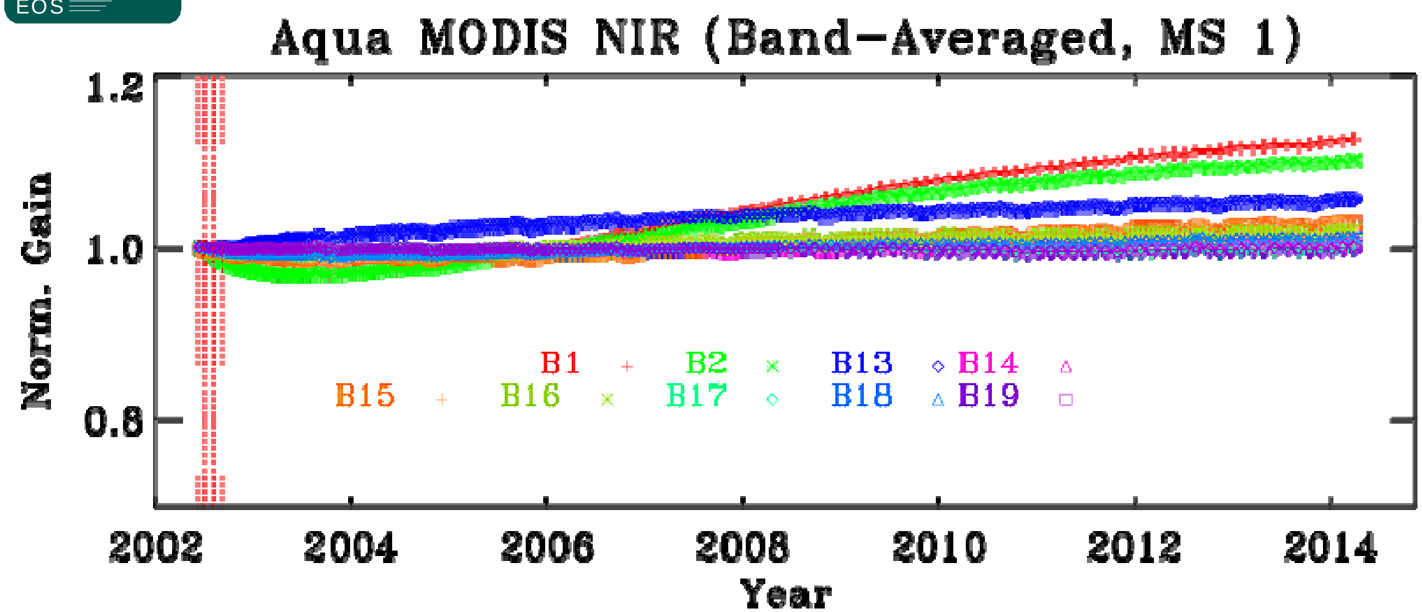
NIR largest change:
~20% for Band 14



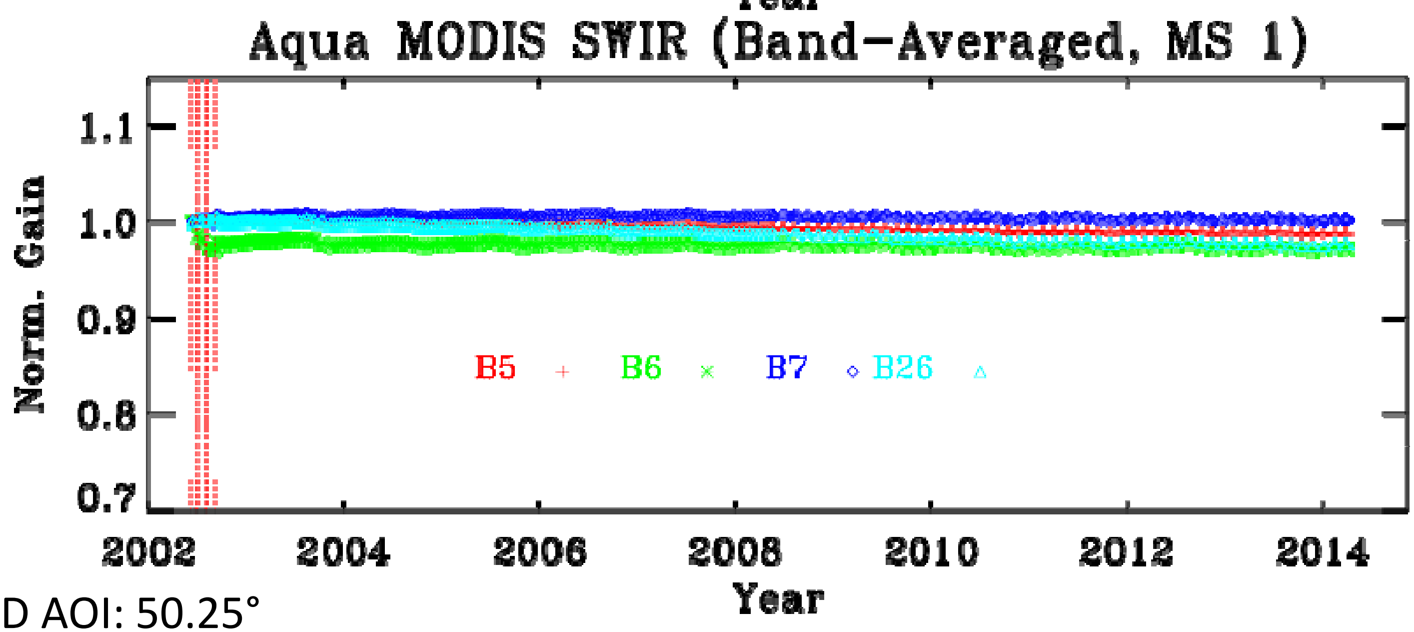
SWIR largest change:
~8% for Band 5

SD AOI: 50.25°

MODIS RSB SD Gain Trending: Aqua



NIR largest change: ~10% for Band 1

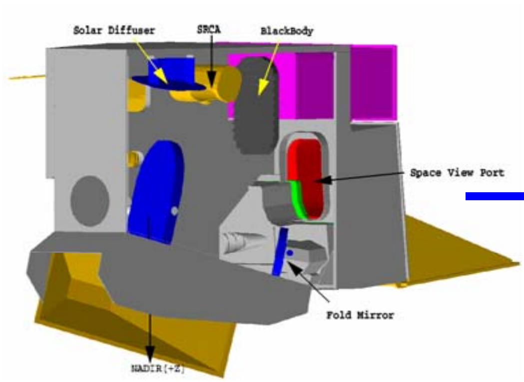


SWIR bands very stable

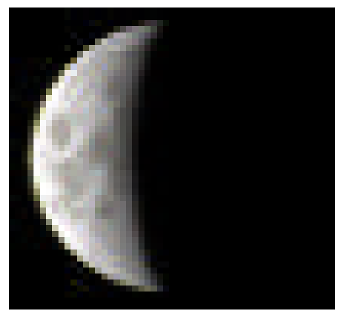
SD AOI: 50.25°

RSB Lunar Calibration

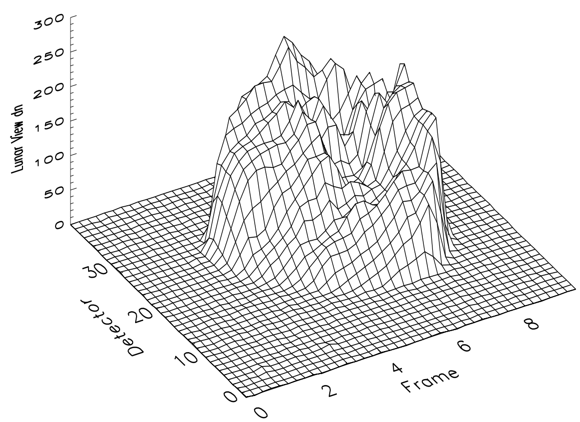
MODIS



Moon



MODIS Response



Lunar calibration coefficients

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

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

Bands 13-16 (Saturated)

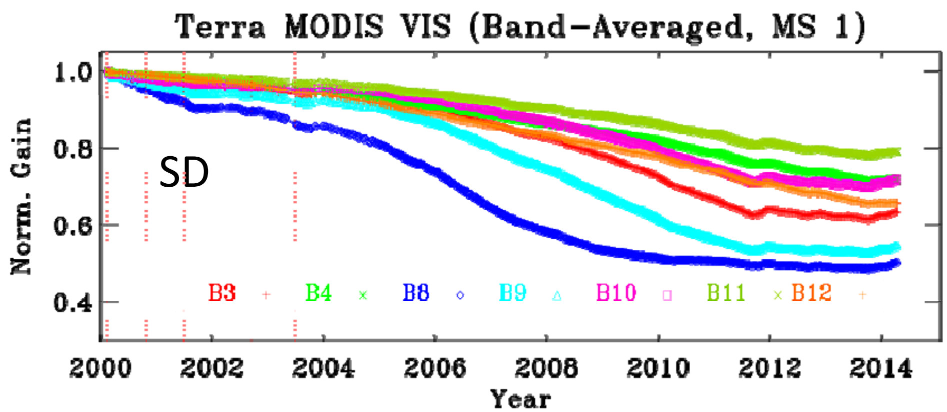
$$m_1^{moon} = m_{1,B18}^{moon} \cdot \frac{< dn^*_{Moon,B18} >}{< dn^*_{Moon} >}$$

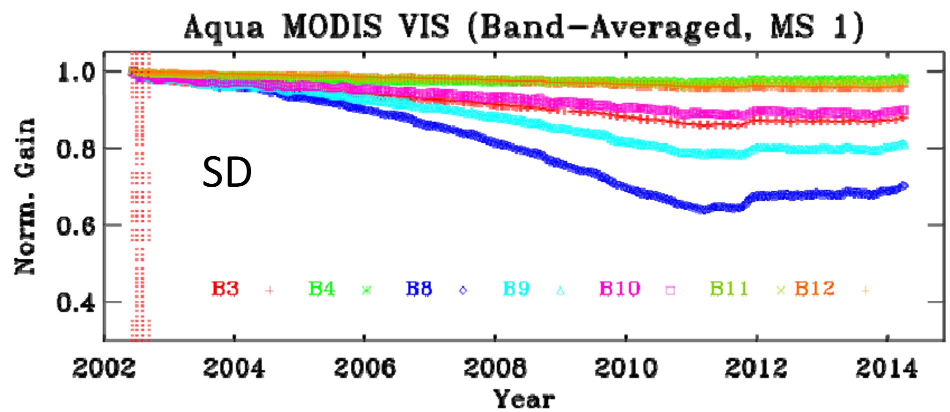
View geometry correction

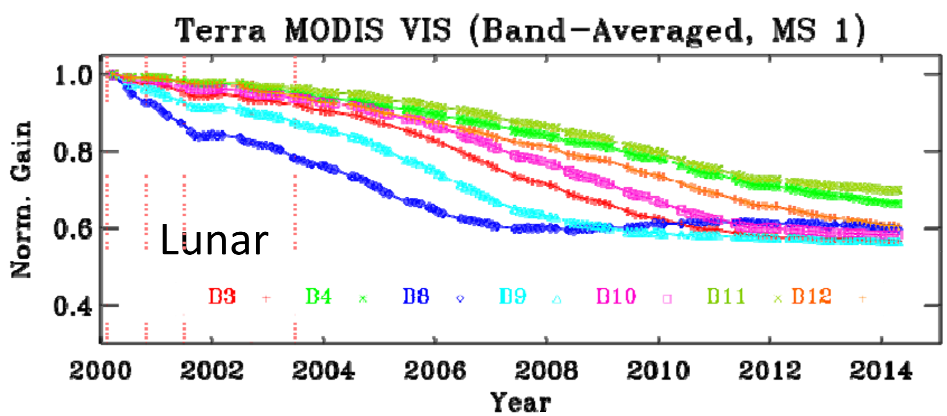
$$f_{vg} = \frac{f_{phase-angle} \cdot f_{libration} \cdot f_{oversampling}}{d^2_{Sun-Moon} \cdot d^2_{Moon-MODIS}}$$

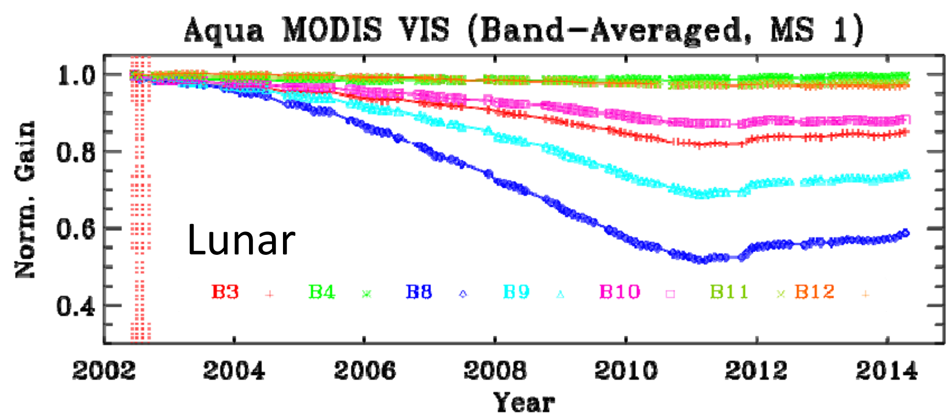
Oversampling effect also needs to be corrected if multiple scans are used

MODIS RSB SD & Lunar Gain Trending









SD & Lunar measurements used to derive the on-orbit RVS change

SV AOI: 11.25°

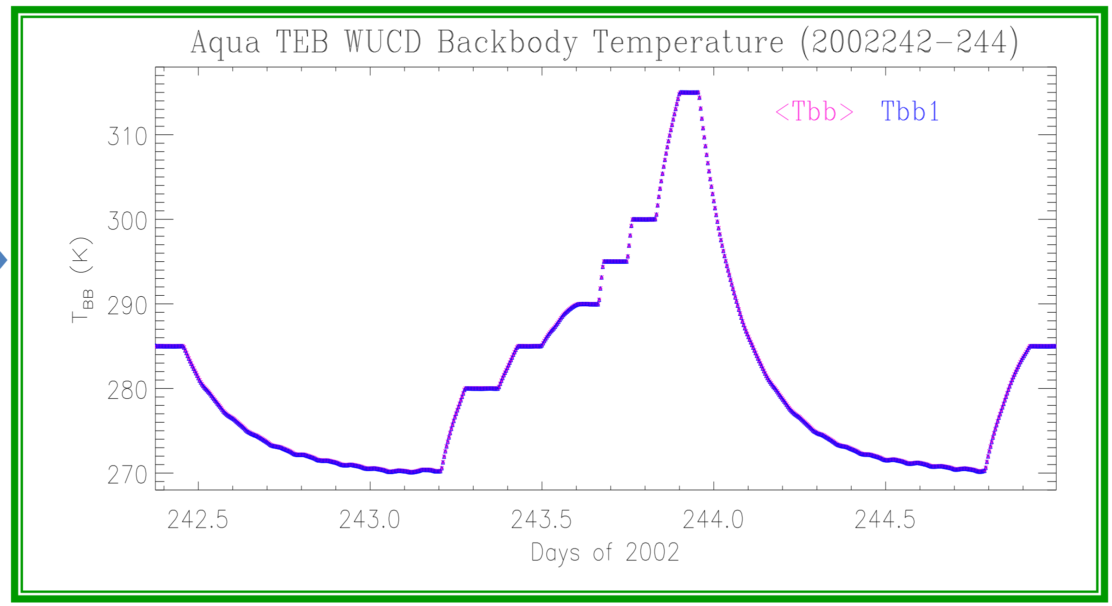
TEB Radiometric Calibration

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:

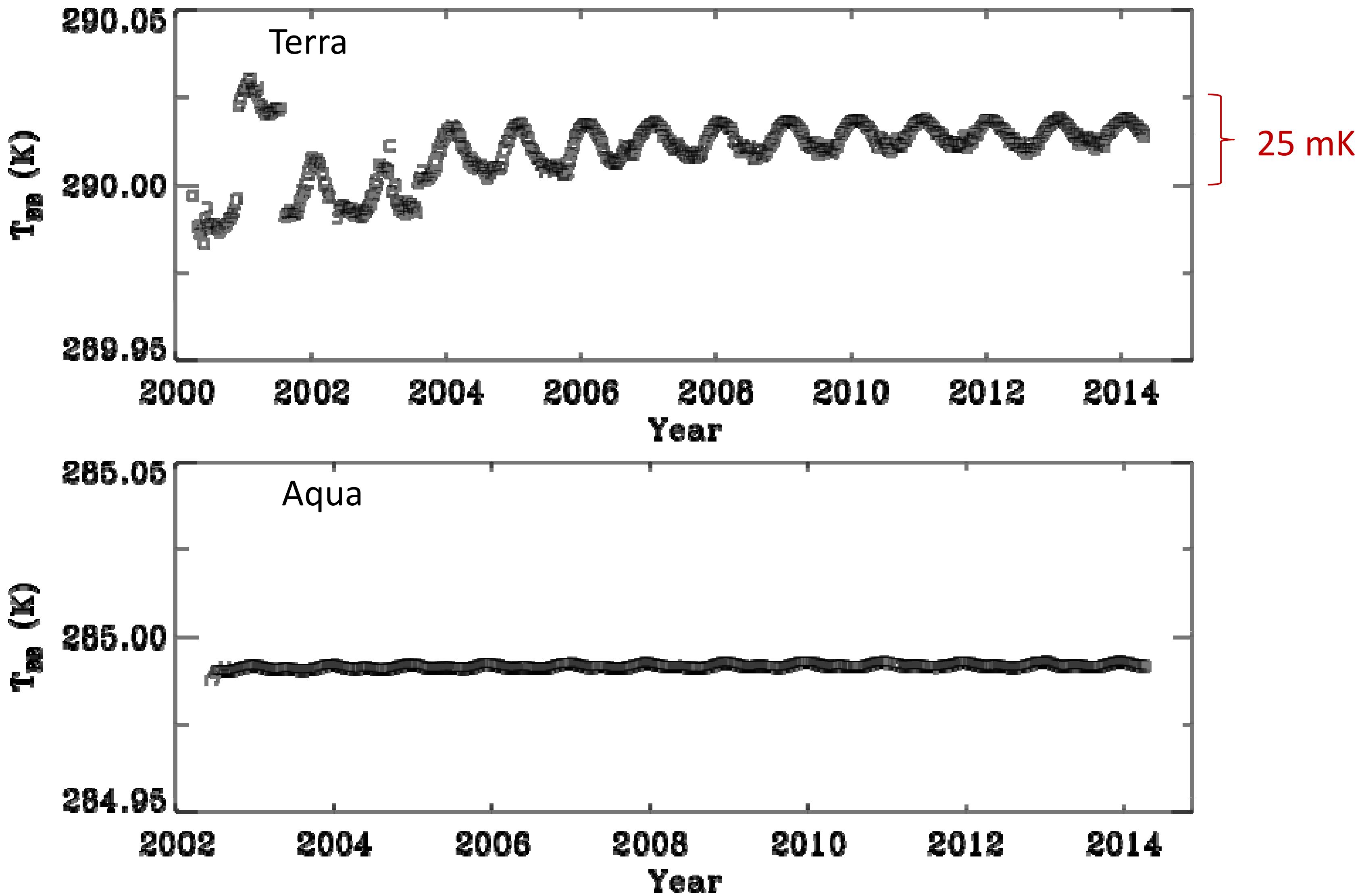
$$b_1 = \left(RVS_{BB}\cdot\varepsilon_{BB}\cdot L_{BB} + \left(RVS_{SV} - RVS_{BB}\right)\cdot L_{SM} + RVS_{BB}\cdot\left(1-\varepsilon_{BB}\right)\cdot\varepsilon_{cav}\cdot L_{cav} - a_0 - a_2\cdot dn_{BB}^2\right)/\, dn_{BB}$$



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

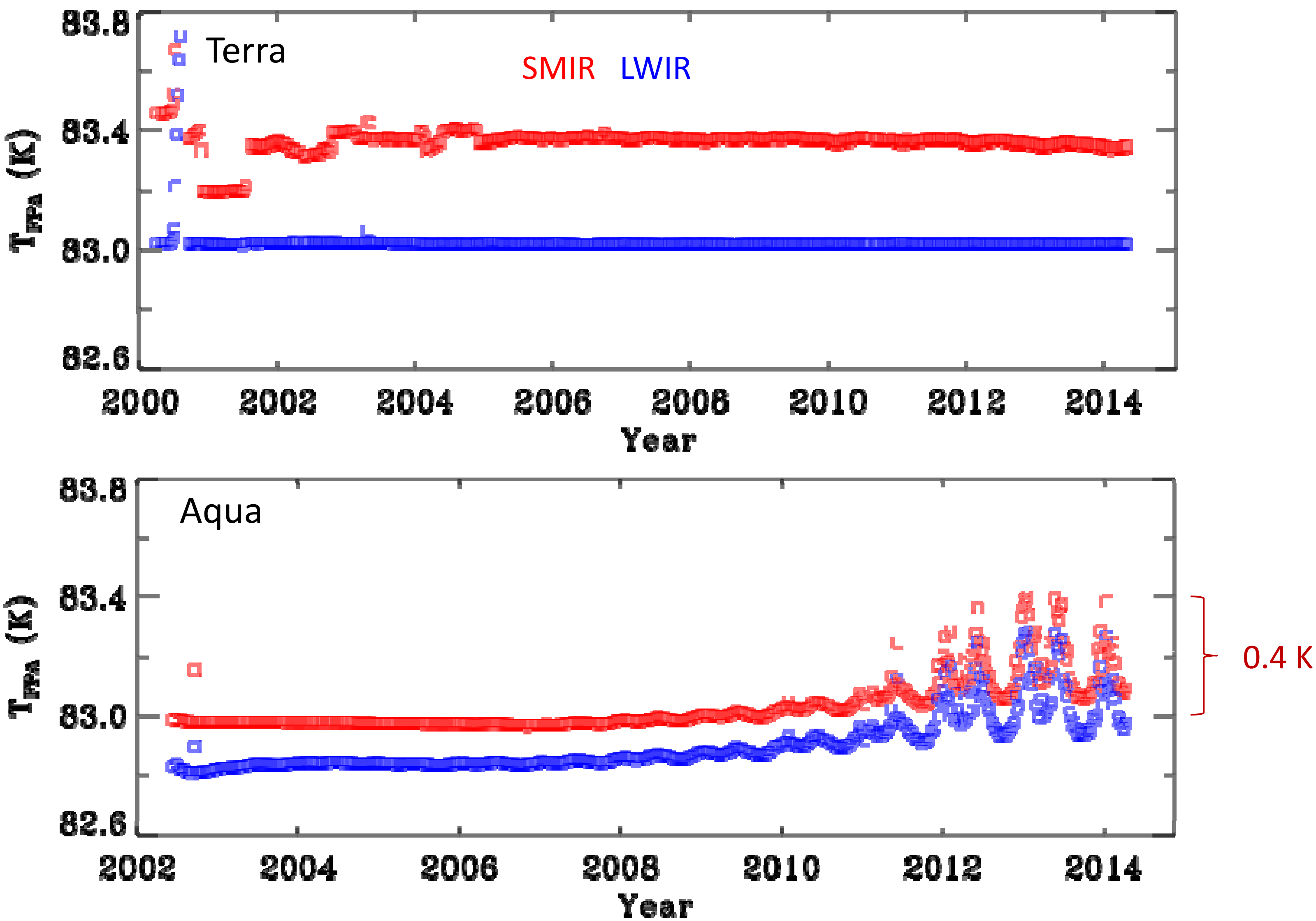
WUCD T_{BB}: 270 to 315K

Telemetry Trends (Blackbody)



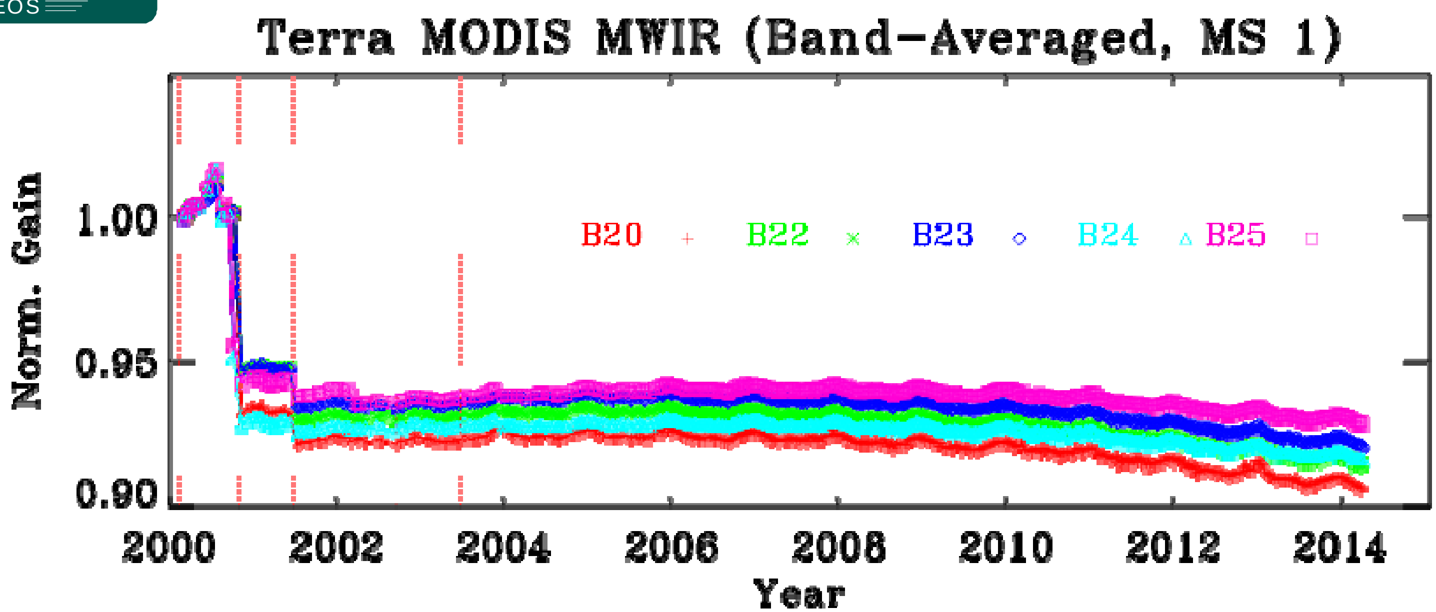
Weekly average (Cal events excluded)

Telemetry Trends (Cold FPA)

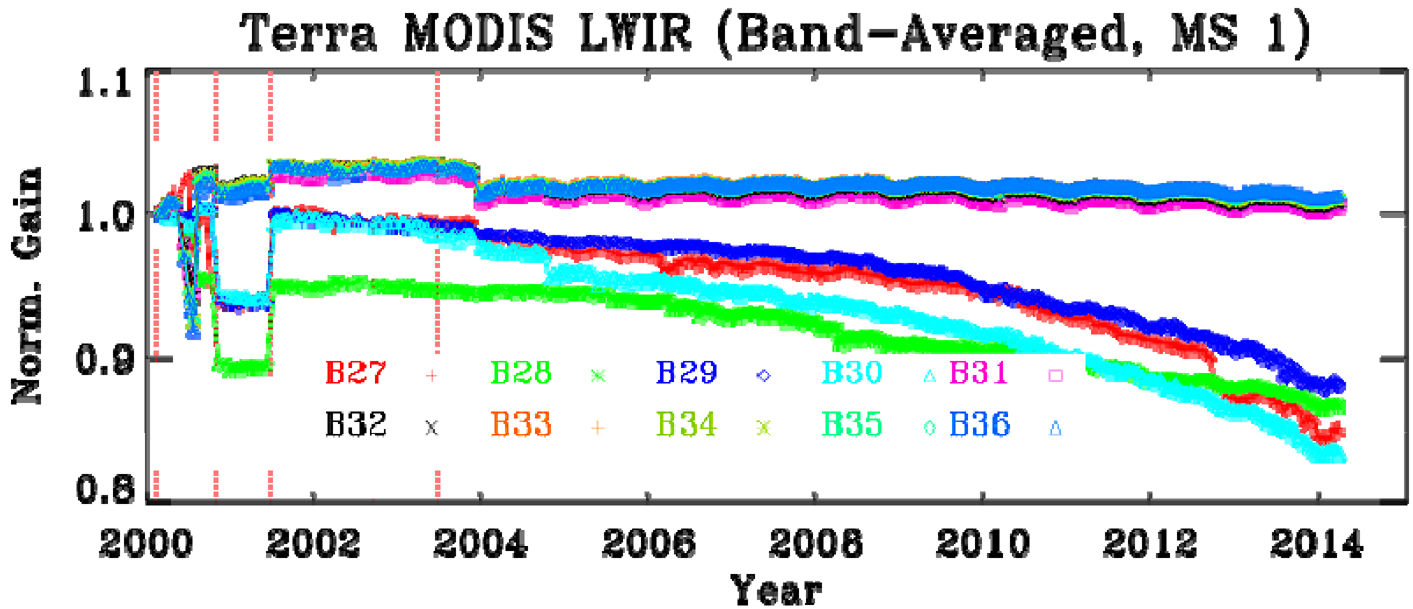


Weekly average (Cal events excluded)

Terra MODIS TEB Gain Trending

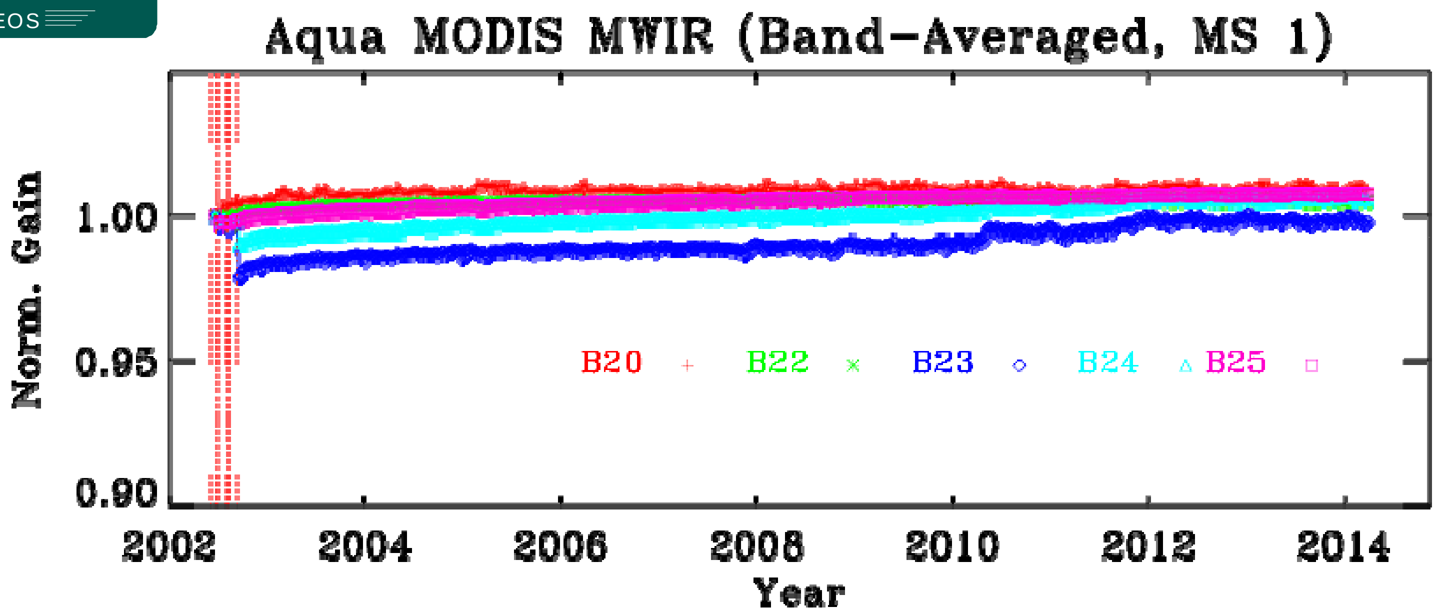


MWIR largest change:
~2% for Band 20

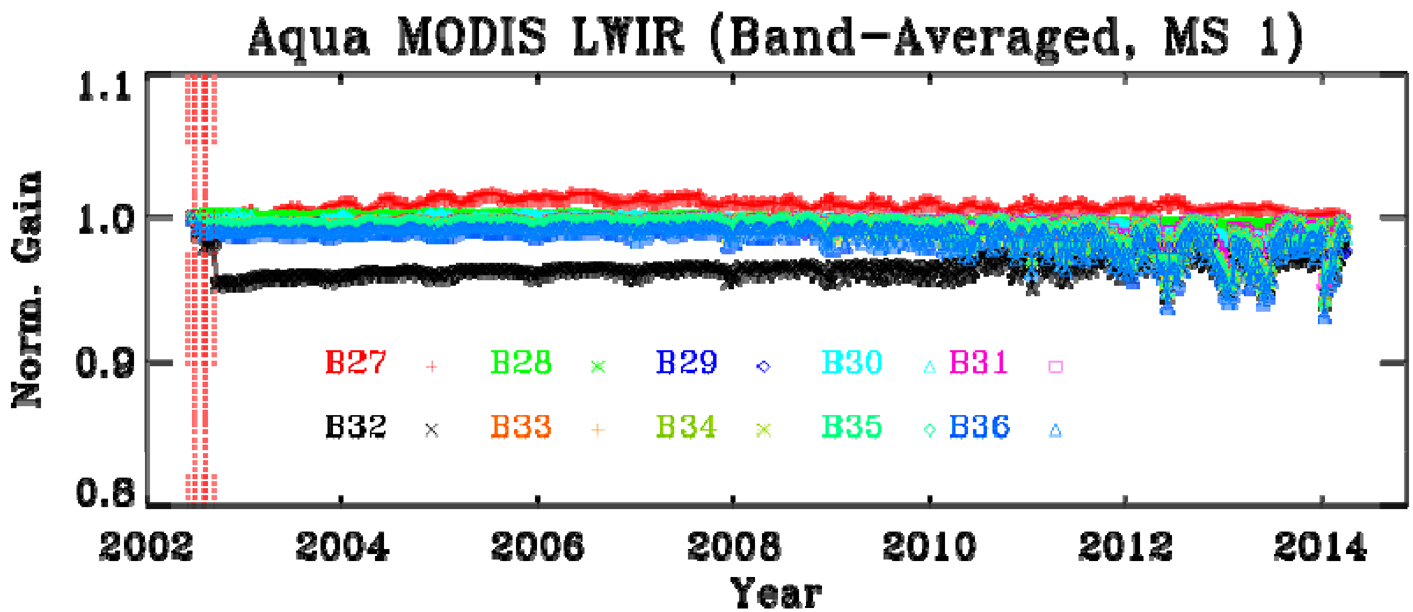


LWIR largest change:
~15% for Band 30

Aqua MODIS TEB Gain Trending



MWIR largest change: ~2% for Band 23



LWIR largest change: <2% for most bands

Increased fluctuations due to CFPA temp variations

MODIS Noisy Detector History

Detectors in Product Order

Terra

Band	Detector	Status	Date Classified
27	1	Noisy	Dec-03
	2	Noisy	Nov-08
	3	Noisy	Jul-07
	6	Noisy	Jul-00
	8	Noisy	Feb-06
28	1	Noisy	Jun-04
	8	Noisy	Dec-03
	9	Noisy	Nov-05
	10	Noisy	Apr-04
29	6	Inoperable	Aug-06
30	1	Noisy	Nov-08
	3	Noisy	Jun-06
	5	Noisy	Aug-00
	7	Noisy	May-13
	8	Noisy	Jan-01
33	1	Noisy	at launch
34	6	Noisy	Jun-00
	7	Noisy	at launch
	8	Noisy	at launch
36	1-10	Noisy	Pre- launch

Aqua

Band	Detector	Status	Date Classified
27	3	Noisy	Jan-05
29	2	Noisy	Feb-08
	8	Noisy	Dec-11
	6	Noisy	Feb-12
36	5	Inoperable	Pre-Launch

Total TEB Detectors = 160

Noisy Detectors:

Terra = 28, Aqua = 4

Inoperable Detectors:

Terra = 1, Aqua = 1

Terra Summary

- Terra MODIS (14+ years)
  - 1 new noisy detectors since last STM
  - SD/SDSM, and lunar observations used to track the RSB on-orbit gain change. Additional information from EV response from desert sites used for select RSB (Bands 1-4, 8 and 9)
  - Shorter wavelength VIS bands show larger degradation (strong wavelength, mirror side and scan-angle dependence), gain change of 50% and mirror side differences up to 10% seen in band 8 (412 nm) at the AOI of SD (50.25 °)
  - NIR bands gain change generally within 10% (exception few ocean bands)
  - SWIR bands gain change within 10% and MS difference within 0.5%
  - TEB gain change within 2% except for bands 27-30 (up to 15%)

Aqua Summary

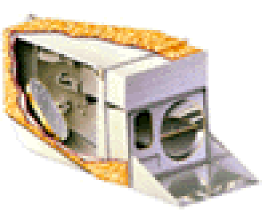
- Aqua MODIS (12+ years)
  - No new noisy/inoperable detectors since last STM
  - SD/SDSM, and lunar observations used to track the RSB on-orbit gain change. Additional information from EV response from desert sites used for select RSB (Bands 8 and 9)
  - Shorter wavelength VIS bands show larger degradation (strong wavelength, mirror side and scan-angle dependence), gain change of 30% and mirror side differences up to 5% seen in band 8 (412 nm) at the AOI of SD (50.25°)
  - NIR bands gain change generally within 5% (except bands 1,2 and 13)
  - SWIR bands gain change within 2% and MS difference within 0.1%
  - TEB gain changes within 2%.

Summary

- Both Terra and Aqua MODIS continue to operate normally
- Instrument on-board calibrators remain capable of all designed functions
- Overall sensor performance has been satisfactory
  - On-orbit spectral and spatial performance remains stable

- Challenges: Aging instruments, RVS changes, Polarization, EV Response
- Dedicated calibration and characterization effort, including good communication with the science and user community, is becoming increasingly important for future improvement

MODIS Calibration Special Topics



MCST Workshop at MST Meeting (May 1, 2014)

Outline

- Collection 6 m1 and RVS overview
- Terra band 10 EV-based RVS implementation
- EV-based RVS for other RSB
  - Terra and Aqua bands 10-12 , Aqua bands 1-4
- Long-term performance of MODIS SWIR bands
  - Terra band 5 correction
- Impacts of polarization on MODIS calibration
- Aqua CFPA performance and impacts on calibration
- TEB RVS on-orbit methodology and performance
- Terra band 27 cross-talk status

Background

- In Collection 6, RSB calibration coefficients (m1) and RVS are derived using measurements from the on-board calibrators, supplemented by the EV trends (from pseudo-invariant desert targets) at different AOI
  - Mainly applied to VIS bands (Aqua bands 8, 9 and Terra bands 1-4, 8, and 9)
  - Starting 03/2014, the EV-based RVS is also applied to Terra band 10
  - Approach to be extended to Aqua bands 1-4, 10-12 and Terra bands 11-12 if needed
- Detector-dependent RVS
  - Mainly applied to VIS bands (Aqua bands 8-12, Terra bands 3, 8-12)
  - Can be extended to apply to other RSB
- Time dependent RVS applied to bands 13-16
  - Approach developed to monitor bands 13-16 lunar calibration stability (some pixels saturate when viewing the Moon)

Terra band 10 EV-based RVS

- At the 01/08 MsWG, Gerhard Meister (OBPG) presented the test results for the Terra band 10 ocean-color products using the special LUT delivered by MCST

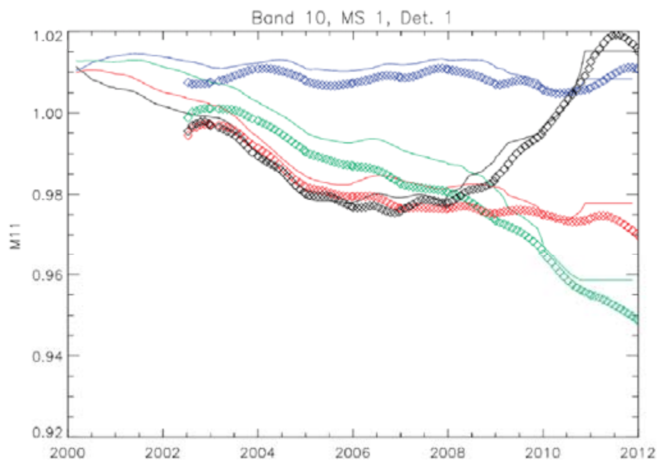
- As a part of this special LUT, the EV-based m1/RVS algorithm was extended to apply to Terra band 10

- The special LUT delivered by MCST produced very similar results to the OBPG correction and OBPG recommended implementing this correction in Collection 6

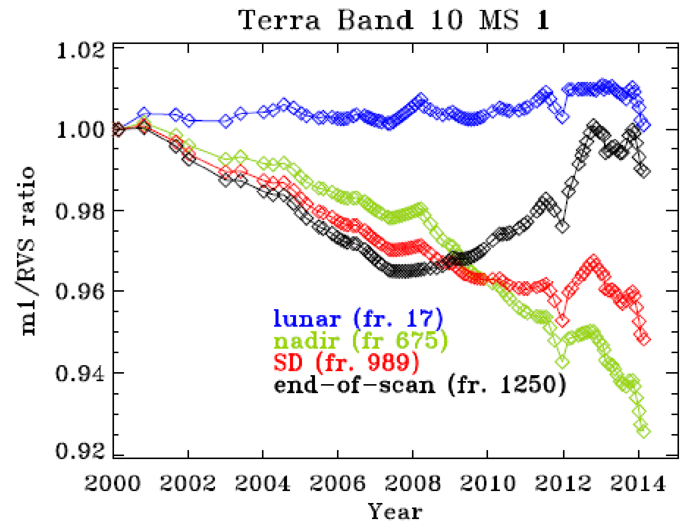
- A gradual implementation (partial incorporation in each LUT update) in the forward C6 was started in March, 2014 and is in progress with the eventual goal of synchronizing the OBPG and forward C6 LUT

Results

Gain corrections for 488nm:
SeaWiFS = solid line, Aqua = diamonds



Scan angles (frame): lunar (22), nadir (675), Solar diffuser (989), end-of-scan (1250)



No observable bias at lunar AOI

Drift observed at all other AOI

Results show comparison of Terra band 10 with SeaWiFS & Aqua MODIS used as references

Slide Courtesy: G. Meister, OBPG

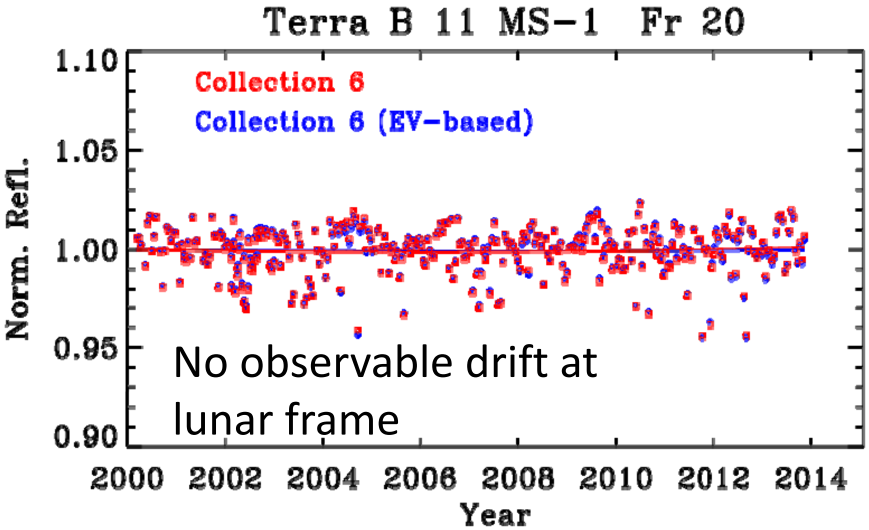
EV-based RVS for bands 11 and 12

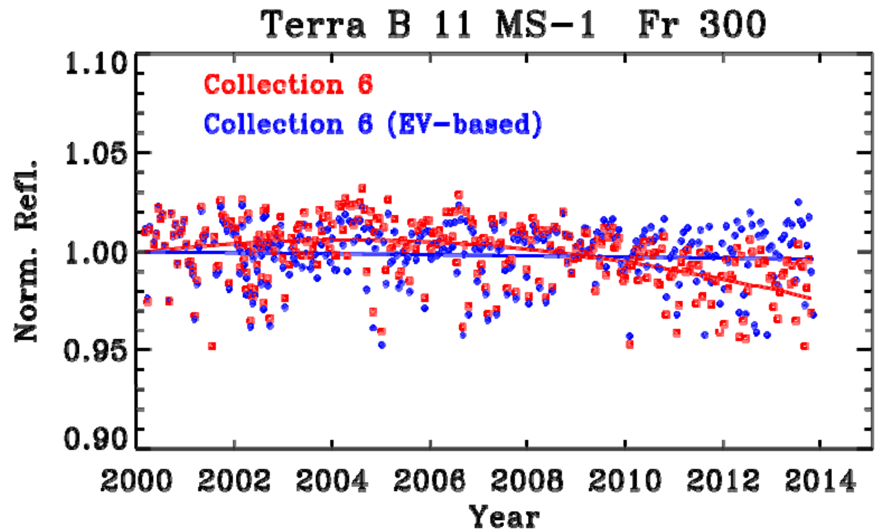
- Terra C6 RVS uses on-board calibrators (SD & lunar) in addition to EV and SRCA mirror side ratios for bands 11-12
  - Bands 8-10 used EV response from desert sites to derive the LUT

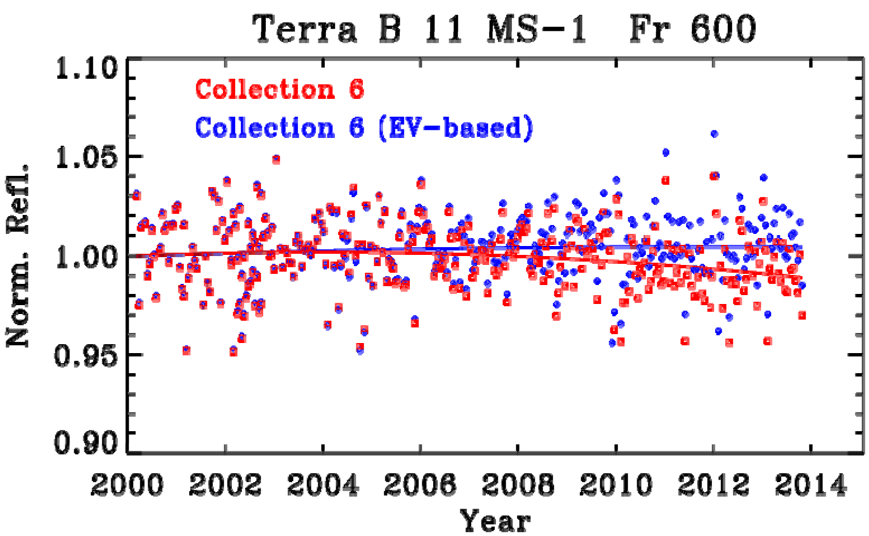
- Due to the high gain of bands 11 and 12, an alternative target needs to be identified
  - A ratio approach using ocean sites with a spectrally overlapping band can be used to evaluate the long-term trending. Assumption: Long-term stability of the reference band

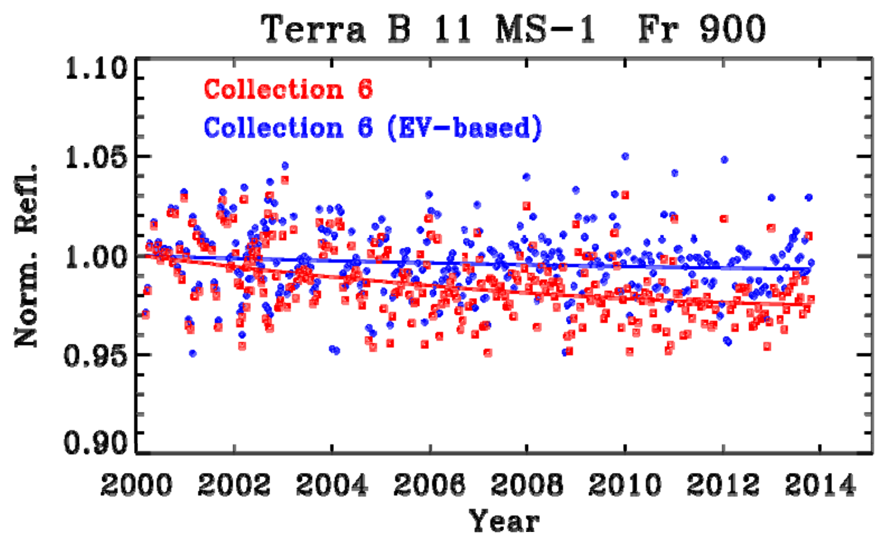
- Long-term stability for bands 11 and 12 using an ocean target with band 4 as a reference
  - Band 12 (546 – 556 nm) overlaps with Band 4 (545 – 565 nm). Band 4 is also the nearest matching band to Band 11 (526 – 536 nm)
  - EV-based RVS derived to correct any long-term drifts

Results:
Band 11 TOA reflectance comparison



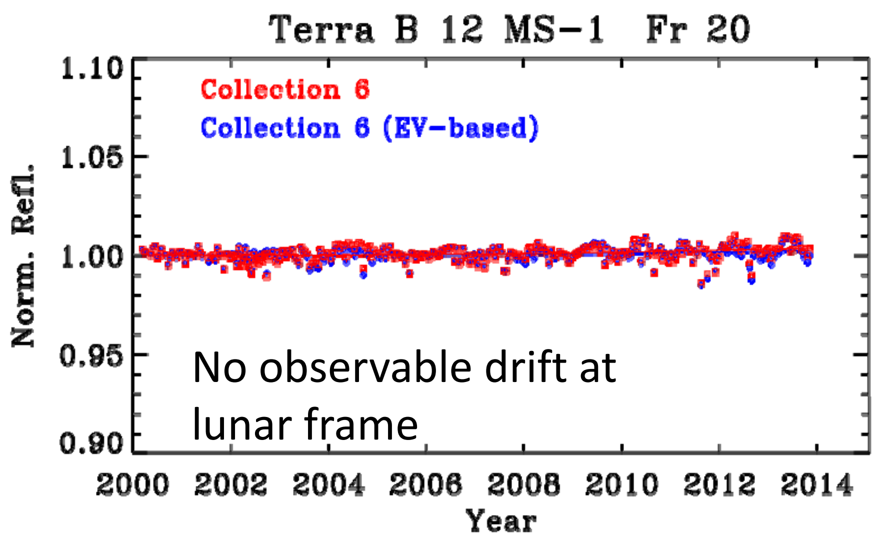


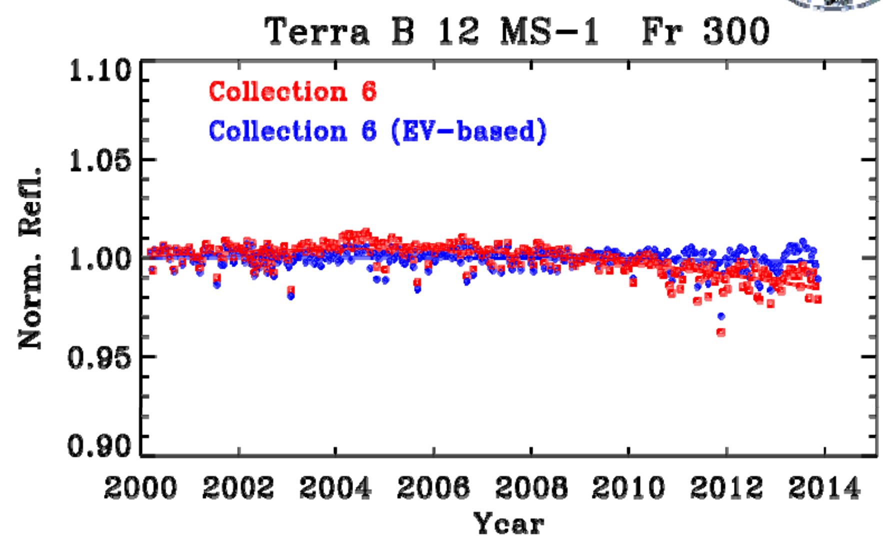


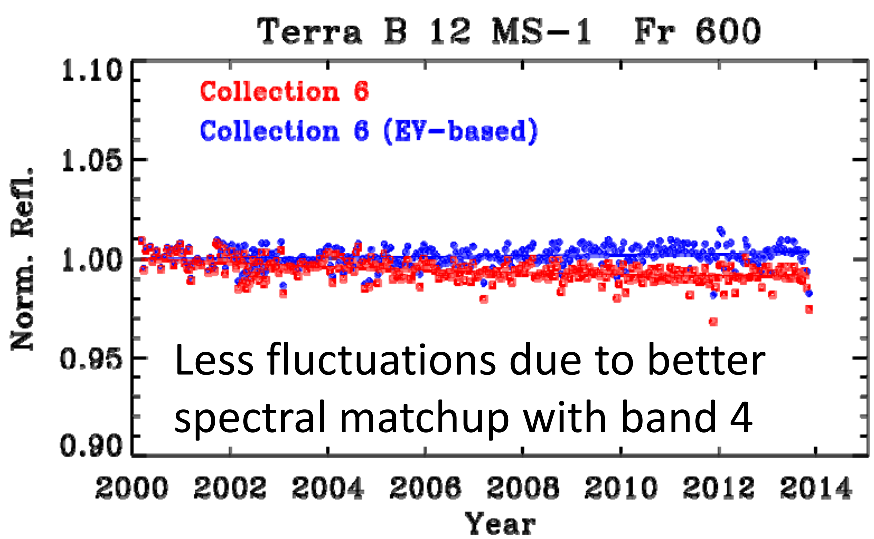


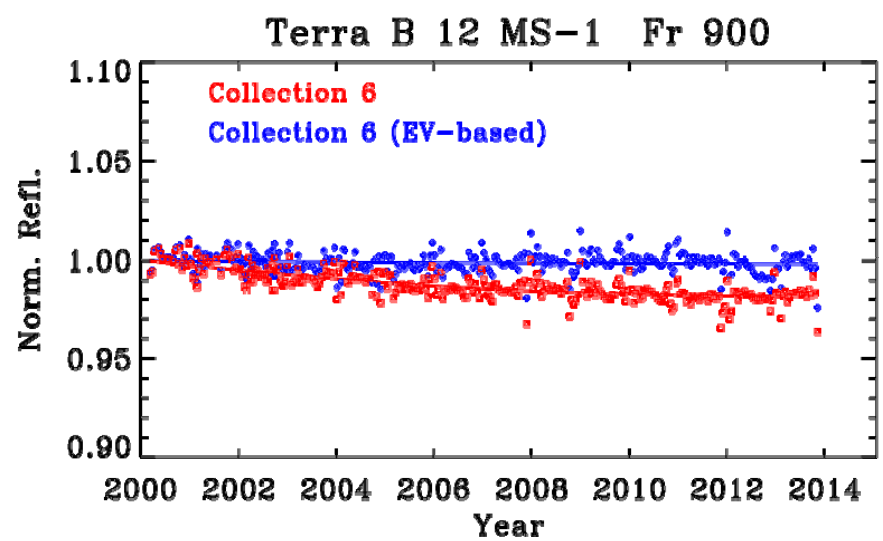
Improvement in the long-term trend after correction for EV-based RVS

Results:
Band 12 TOA reflectance comparison



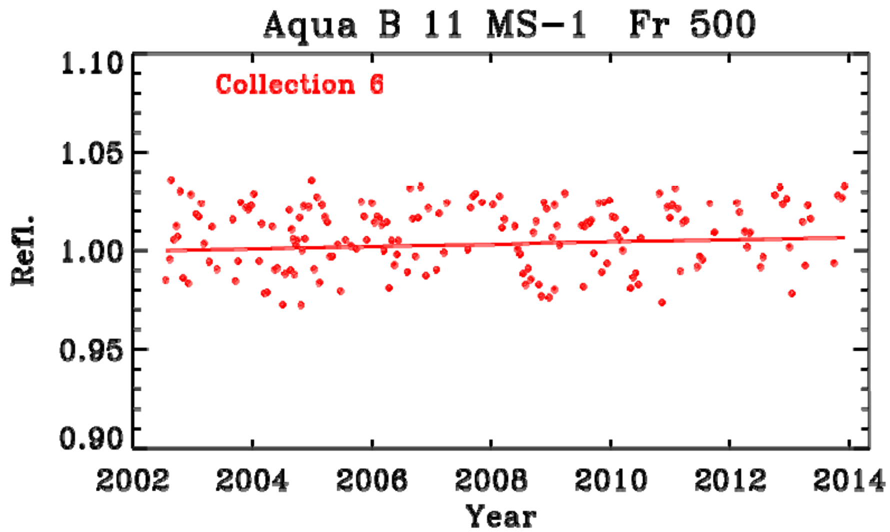


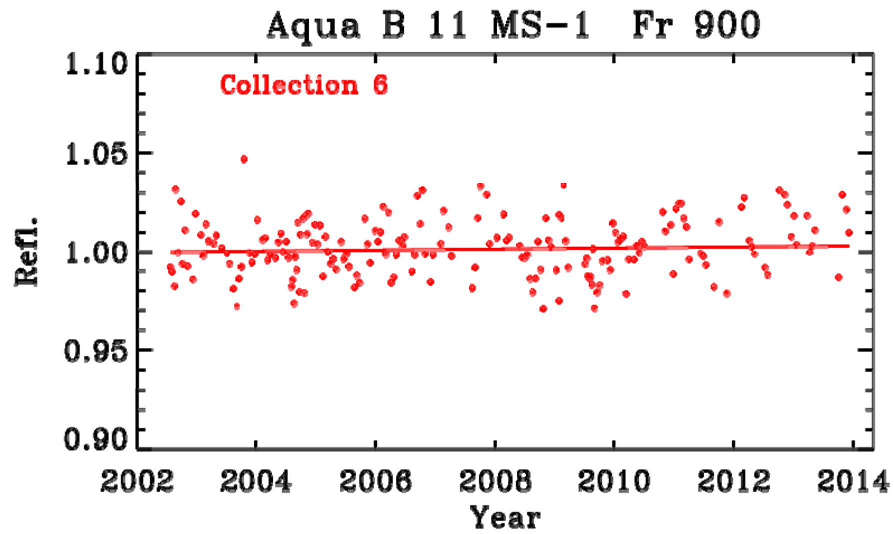


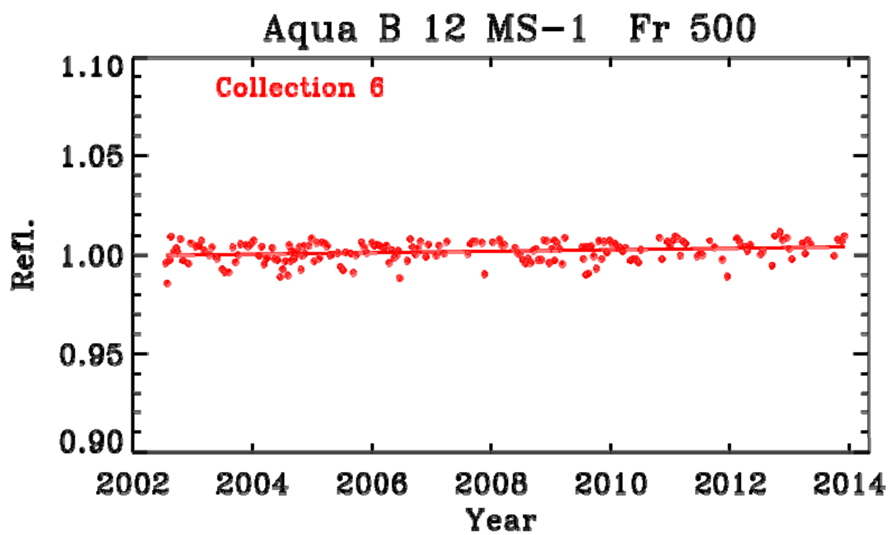


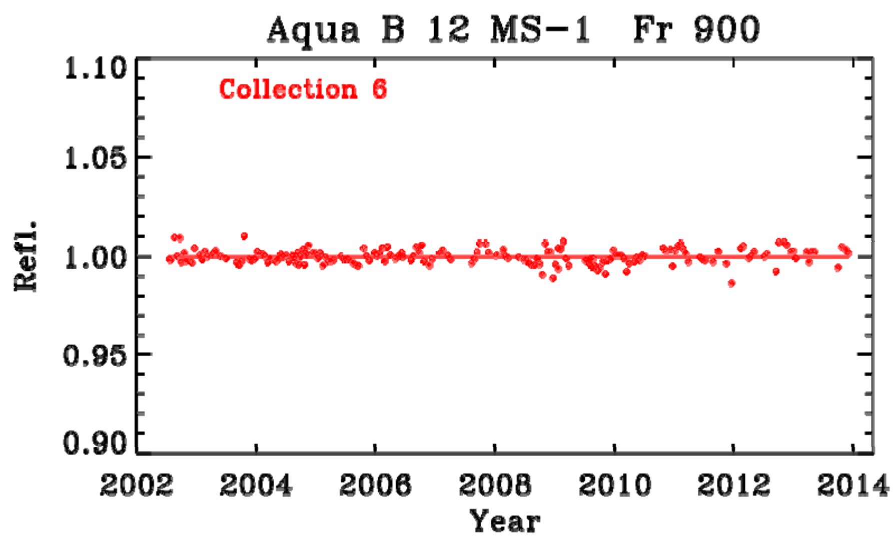
Improvement in the long-term trend after correction for EV-based RVS

Results:
Band 11 & 12 TOA reflectance comparison







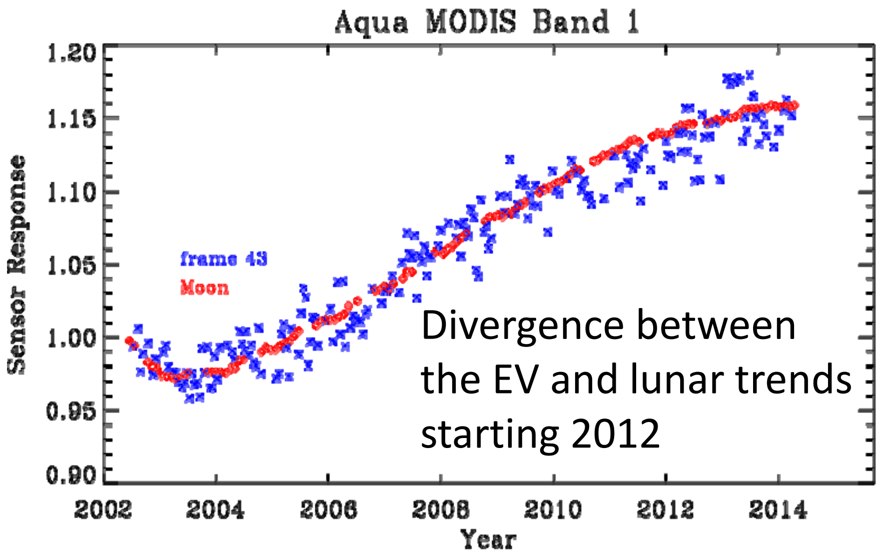


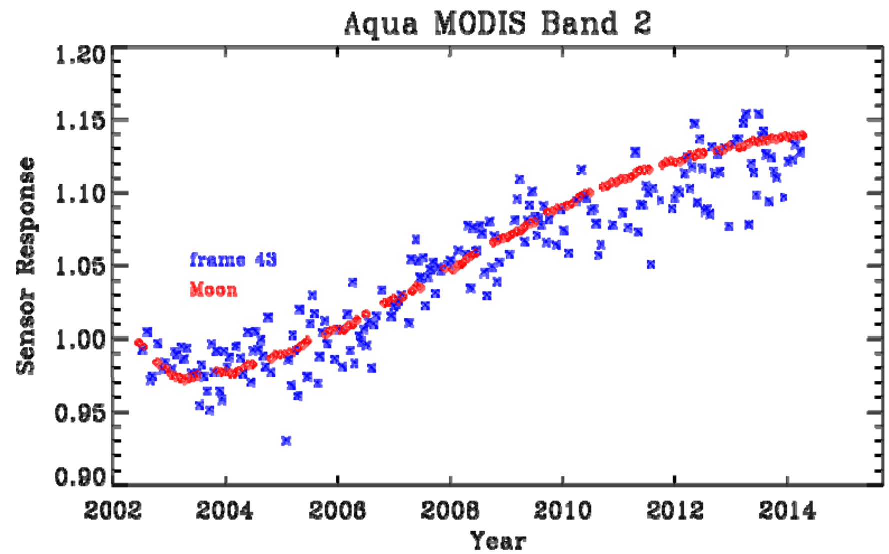
No observable drift at any AOI for Aqua MODIS

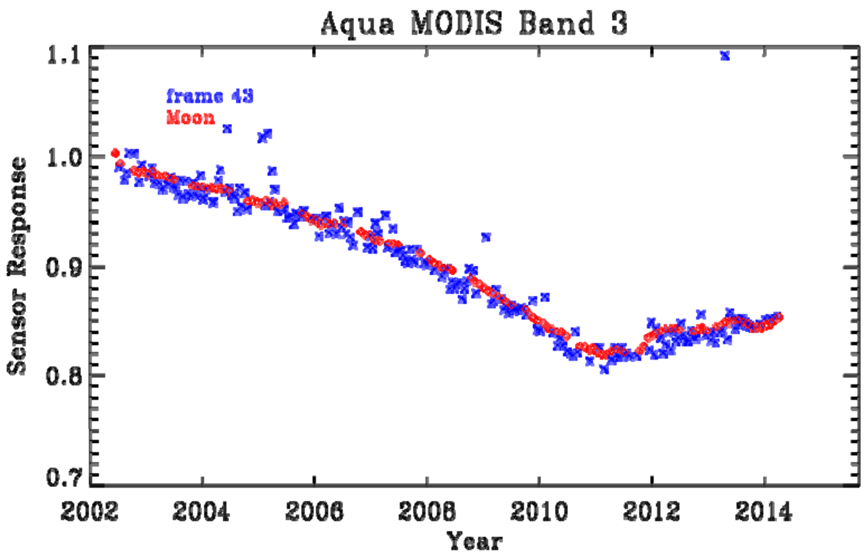
Aqua EV-based RVS for bands 1-4

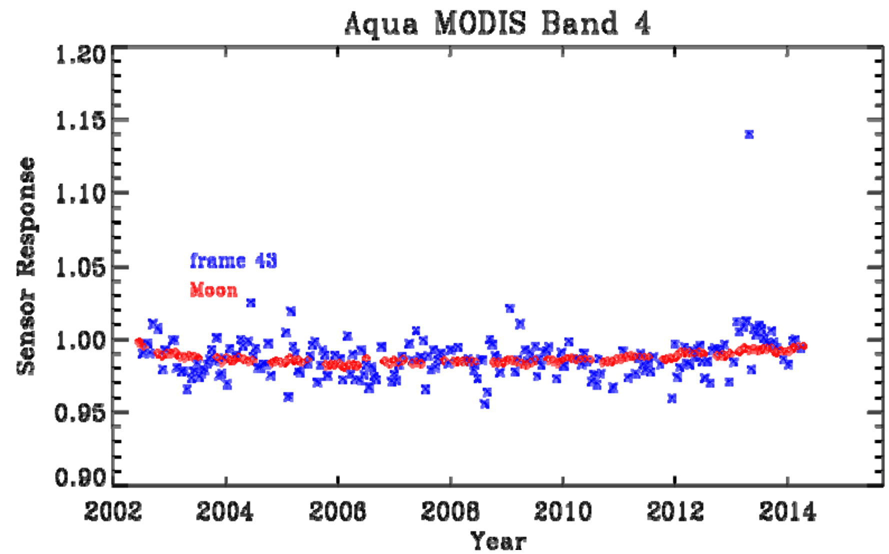
- Aqua C6 RVS uses on-board calibrators (SD & lunar) in addition to EV and SRCA mirror side ratios for bands 1-4
  - Bands 8 and 9 used EV response from desert sites to derive the LUT
- EV-based RVS approach extended to apply to bands 1-4
  - Use the same sites as used for bands 8 and 9 (Libya 1, Libya 2 and Libya 4)
- Bands 3 and 4 show excellent long-term stability with no observable long-term drift
  - On-board calibrators sufficient for an accurate characterization of the on-orbit sensor change
- Bands 1 and 2 indicate a drift starting mid-2012 predominantly at the start of scan
  - Disagreement between the EV-response and on-orbit lunar response (similar to Terra MODIS)

Results:
EV & Lunar comparison

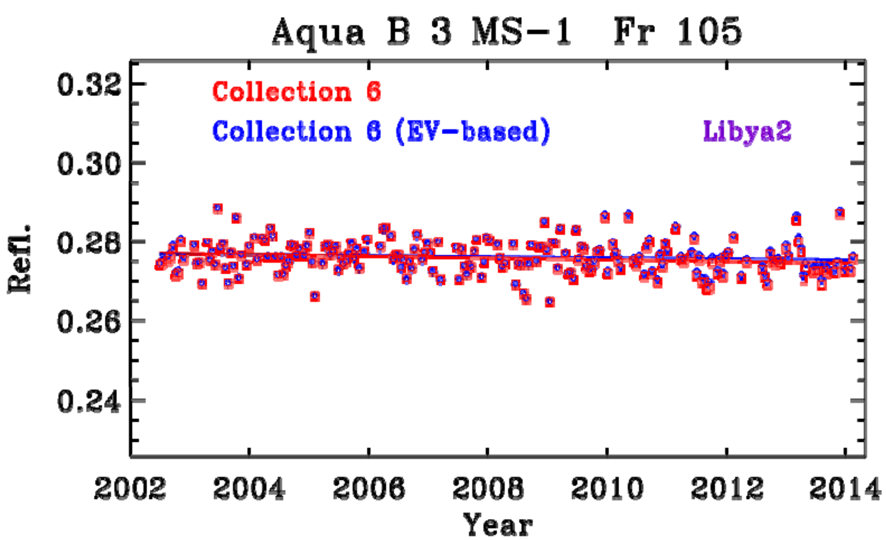


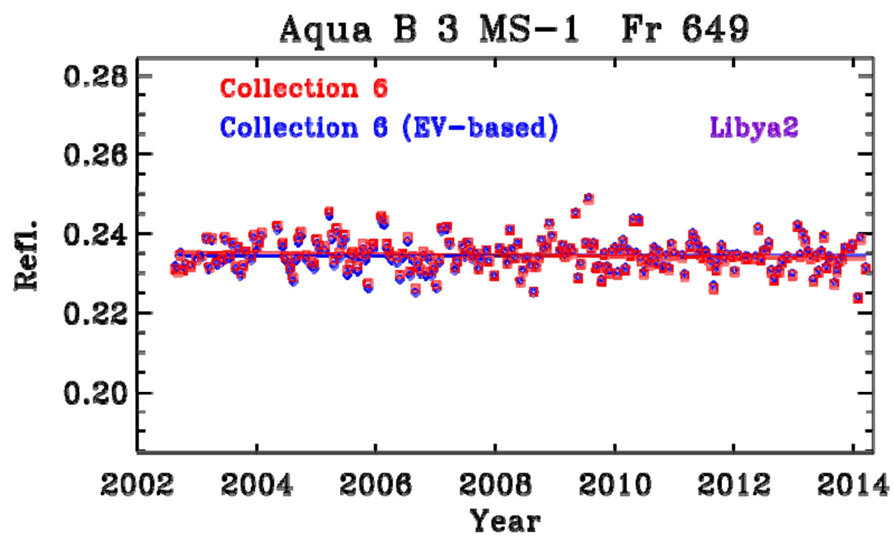


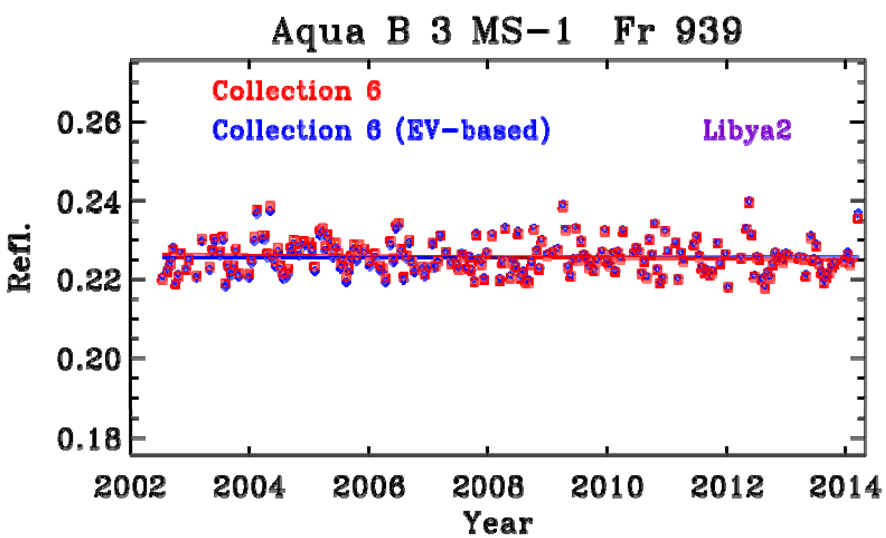


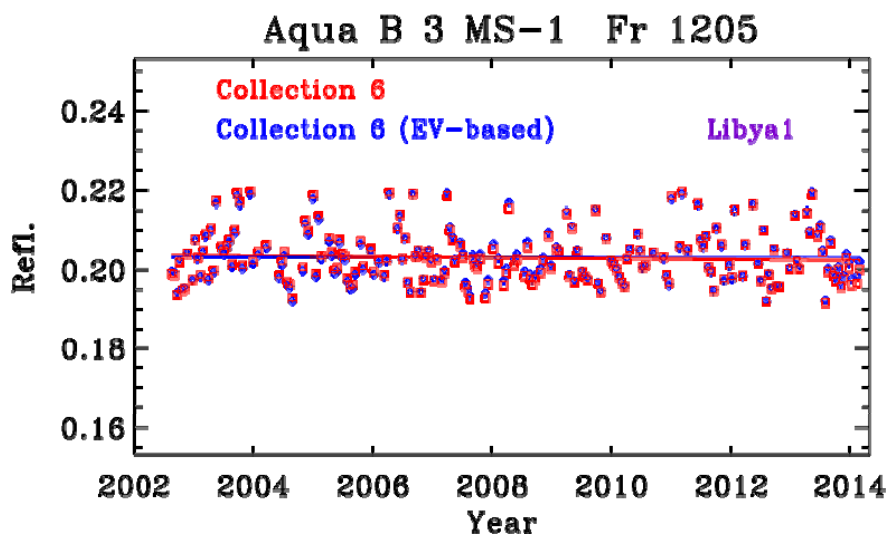


Results:
Band 3 TOA reflectance comparison

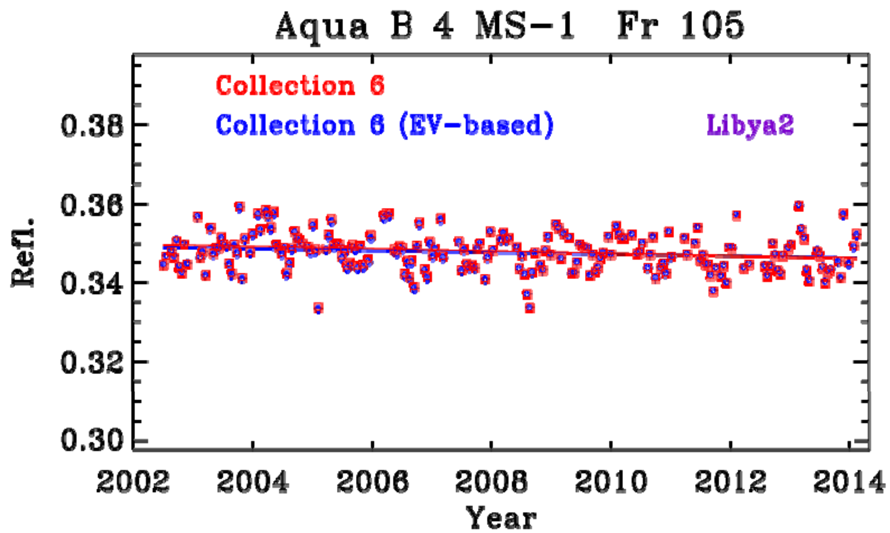


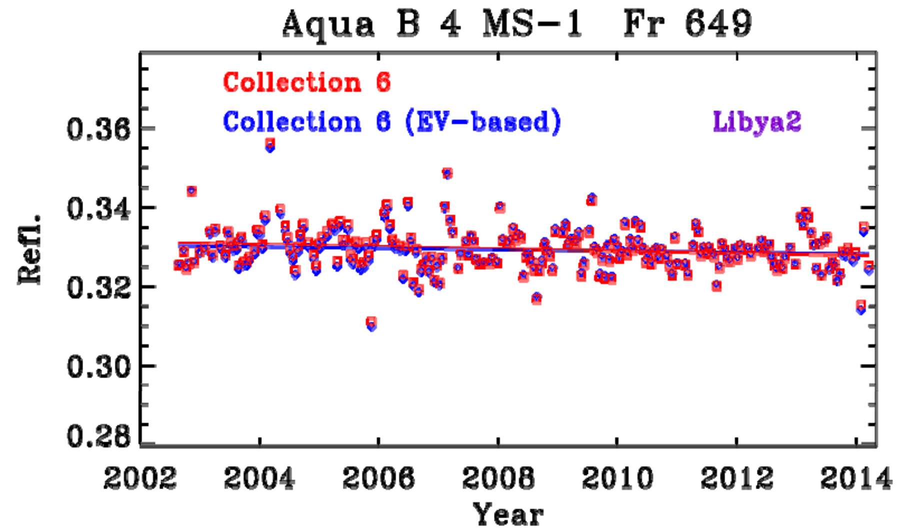


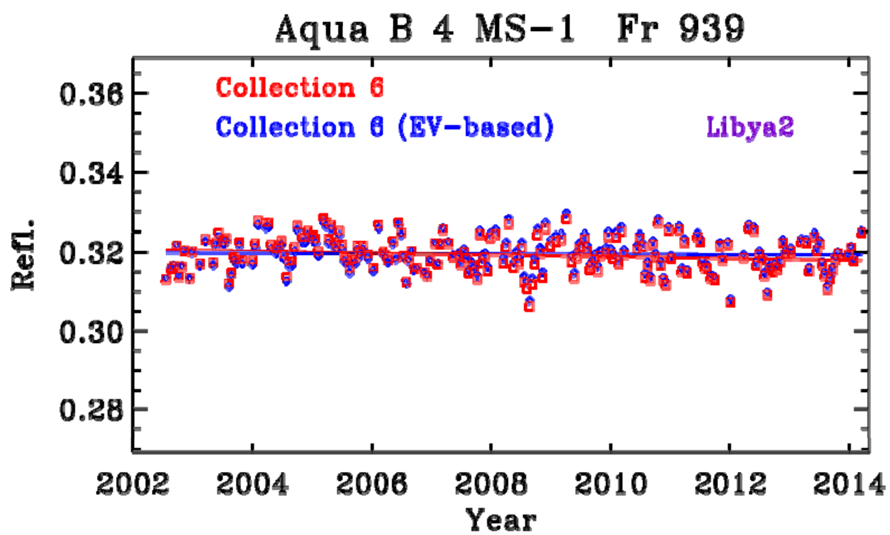


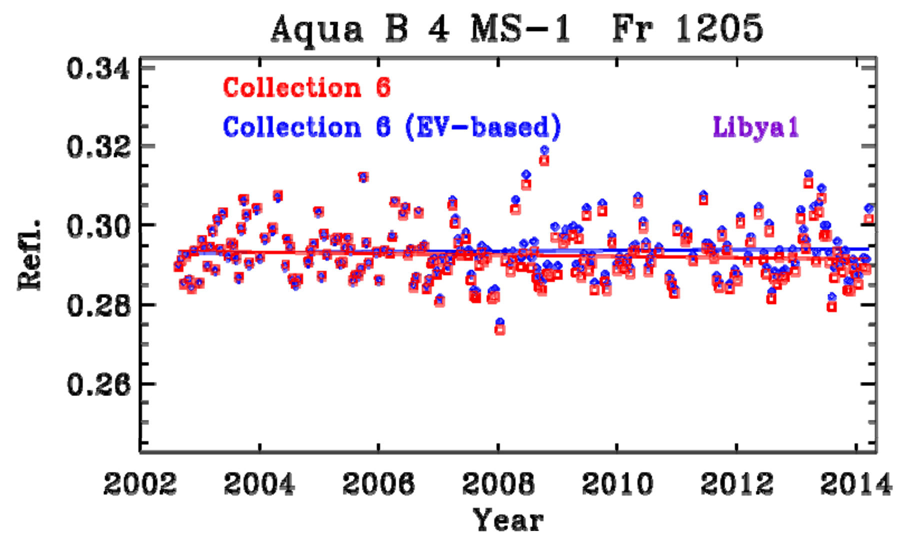


Results:
Band 4 TOA reflectance comparison

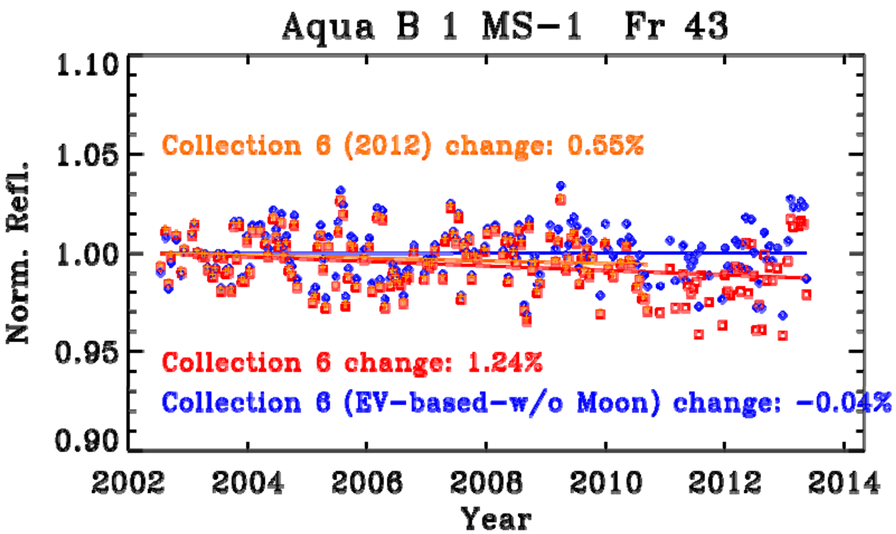


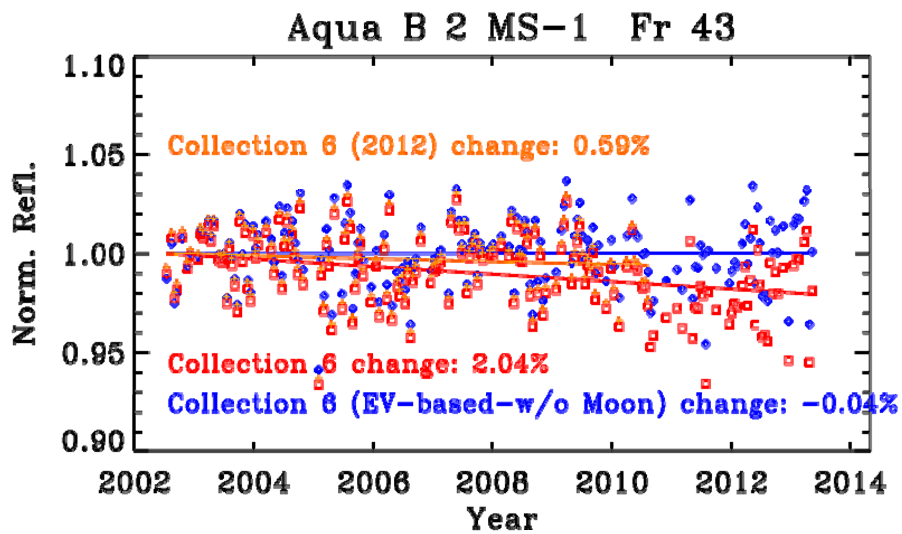


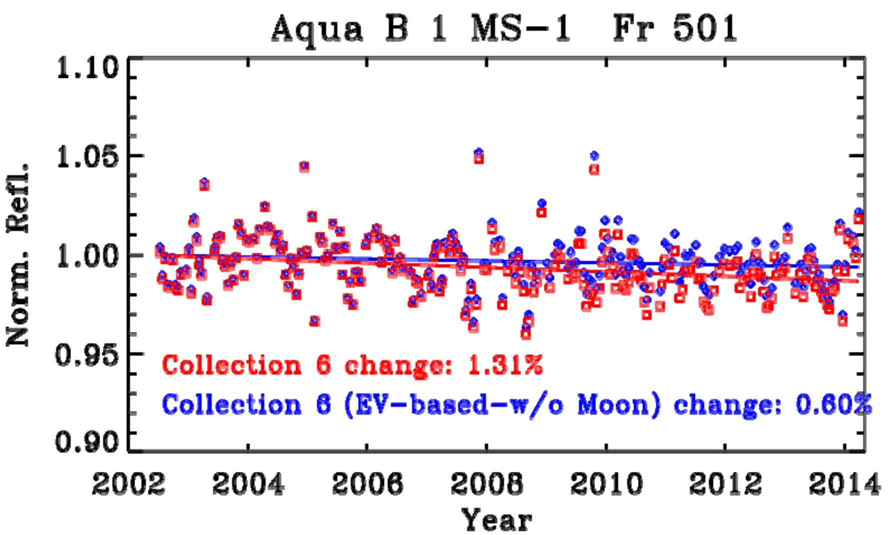


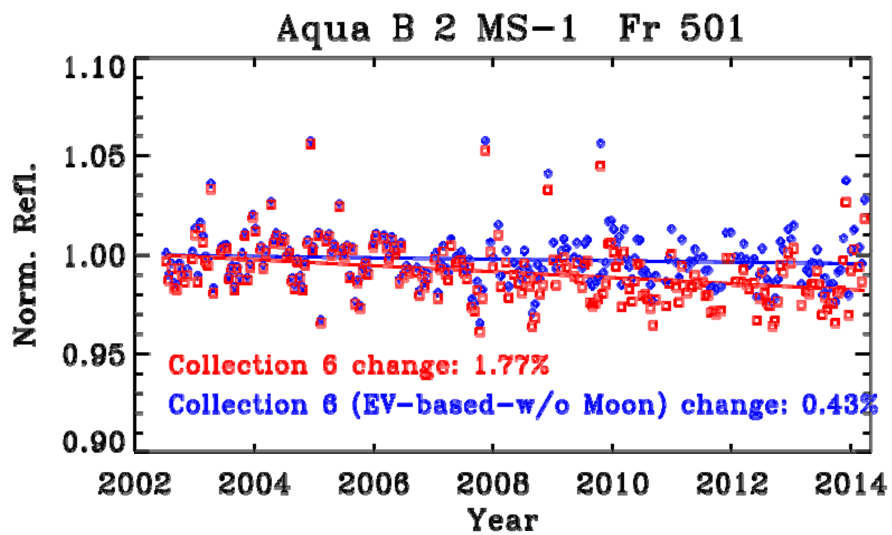


Results:
Normalized TOA reflectance comparison

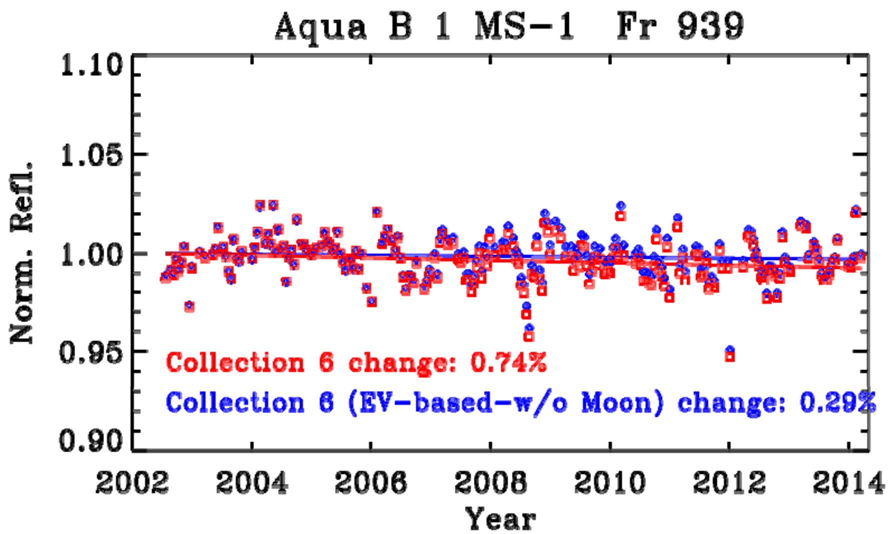


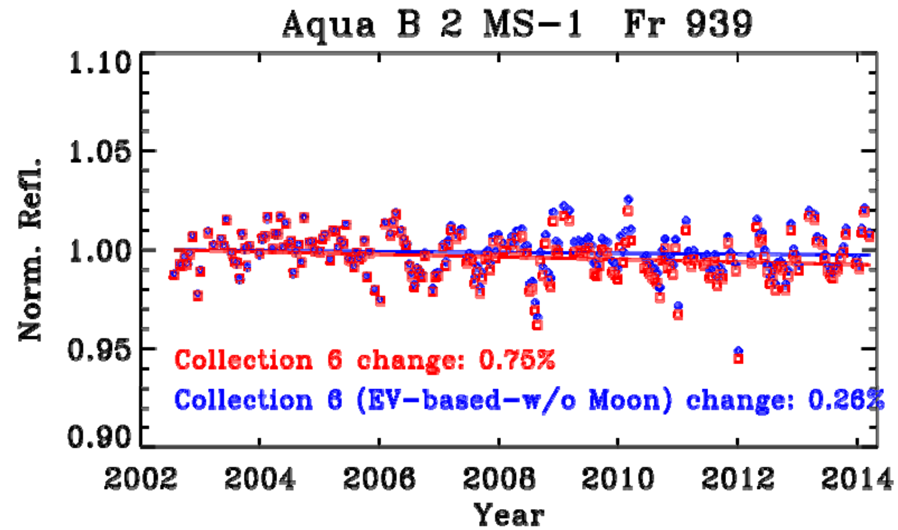


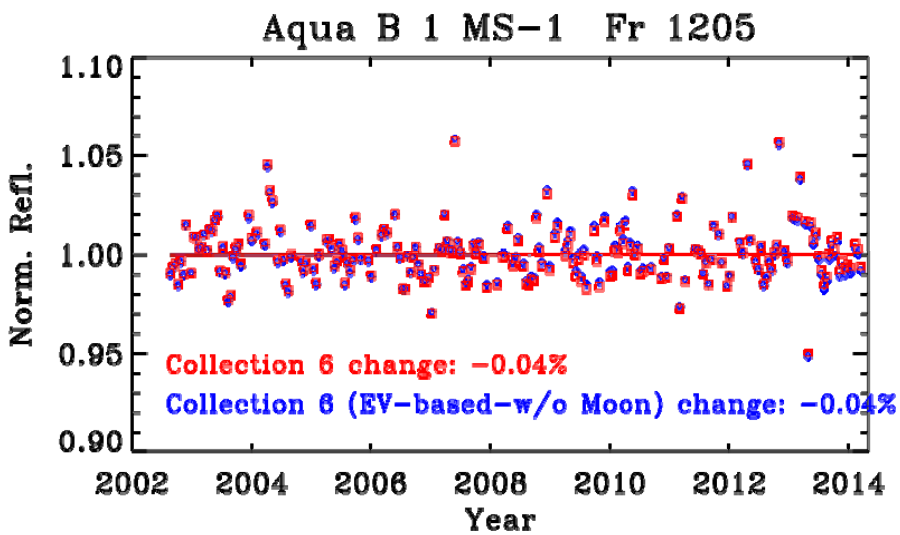


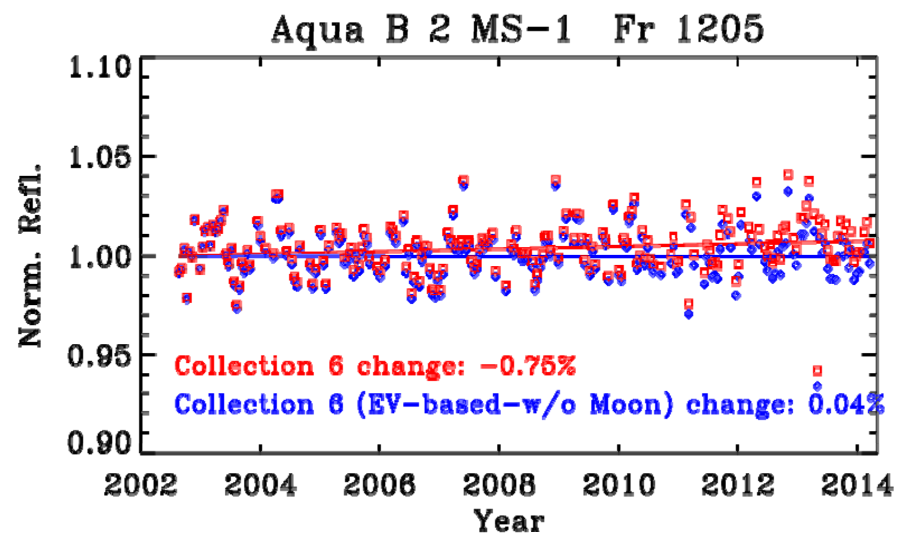


Results:
Normalized TOA reflectance comparison









Summary

- Enhanced RSB RVS approach implemented in MODIS Collection 6
  - Long-term drifts observed in the VIS/NIR bands (Terra bands 1-4, 8, 9 and Aqua bands 8, 9) reduced

- Extension of the EV-based RVS approach to bands 11 and 12
  - Use of a ratioing approach using ocean sites to overcome the saturation experienced while viewing a desert target

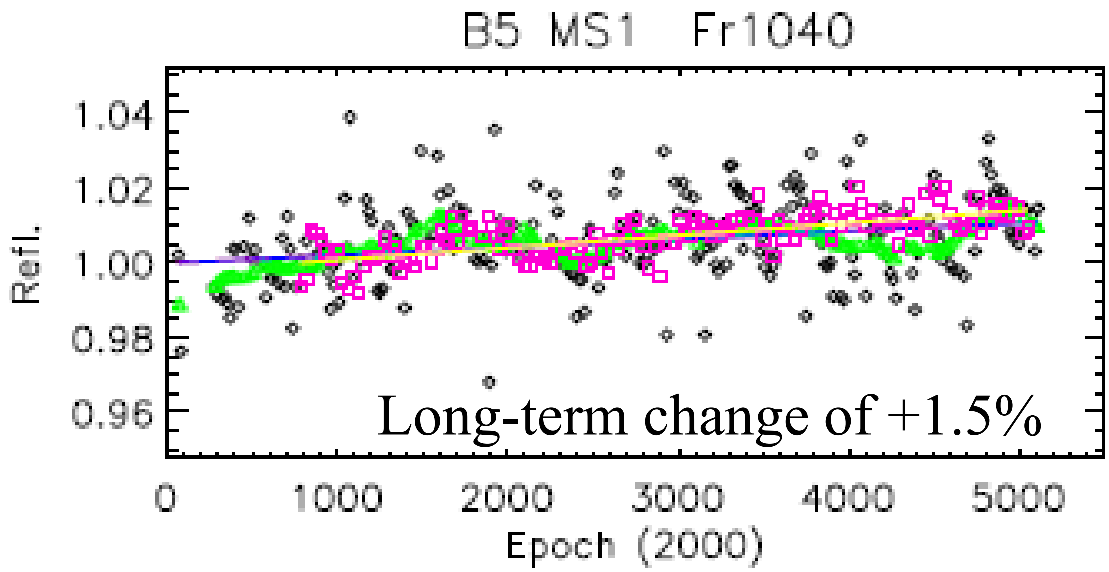
- EV-based RVS has been formulated and implemented for Aqua bands 1-4
  - Bands 3 and 4 do not indicate a long-term drift suggesting that the on-board calibrators are sufficient in capturing the sensor's change
  - Discrepancy between the EV response and on-board lunar measurements for bands 1 and 2. Similar trend observed for Terra bands 1 and 2. Impact restricted to start of the scan for bands 1 and 2.

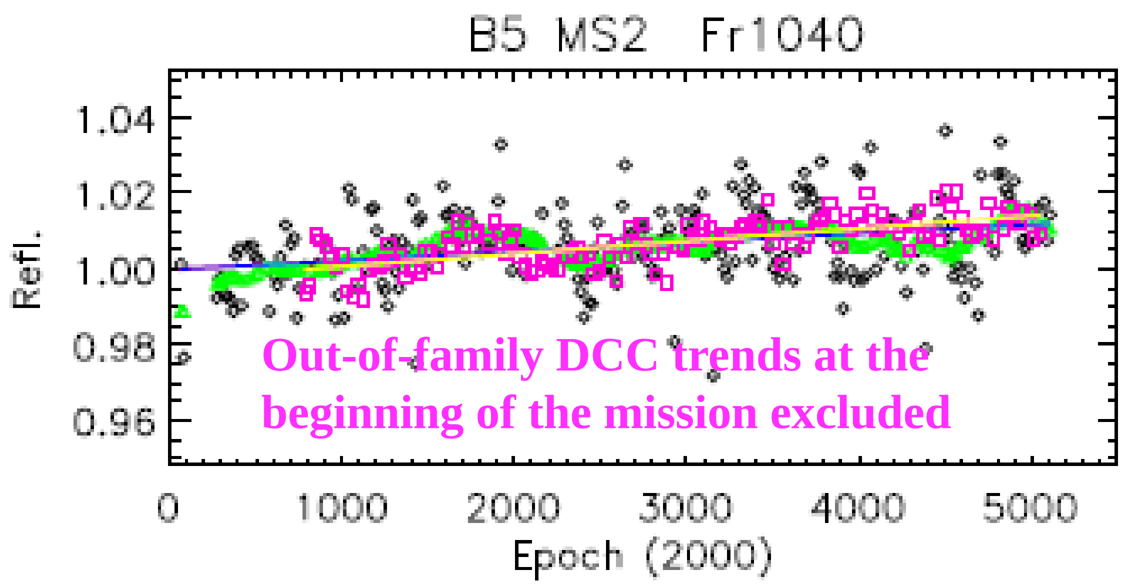
Terra MODIS band 5 correction

- MODIS RSB calibration performed using a SD with its degradation monitored using the SDSM (wavelength coverage:412-936 nm)
  - Consequently, no correction for SD degradation is applied beyond 940 nm (SWIR bands)
  - Terra SDSM D9 (936 nm) change over ~14 years on-orbit is measured to be ~2.3% . Aqua SDSM D9 change over ~12 years is 0.6%
  - The gain for Band 5 (1.24 µm) and other SWIR bands is computed without factoring in the possible degradation of the SD

- Pseudo-invariant desert targets already in use to track the long-term stability of the VIS/NIR bands. Similar desert response at the SD AOI can be tracked to evaluate the long-term change in Terra band 5
  - As an independent validation, data from Deep Convective Cloud (DCC) has also be evaluated (data courtesy David Doelling/Raj Bhatt, NASA Langley)

EV-based Evaluation of Terra Band 5 stability





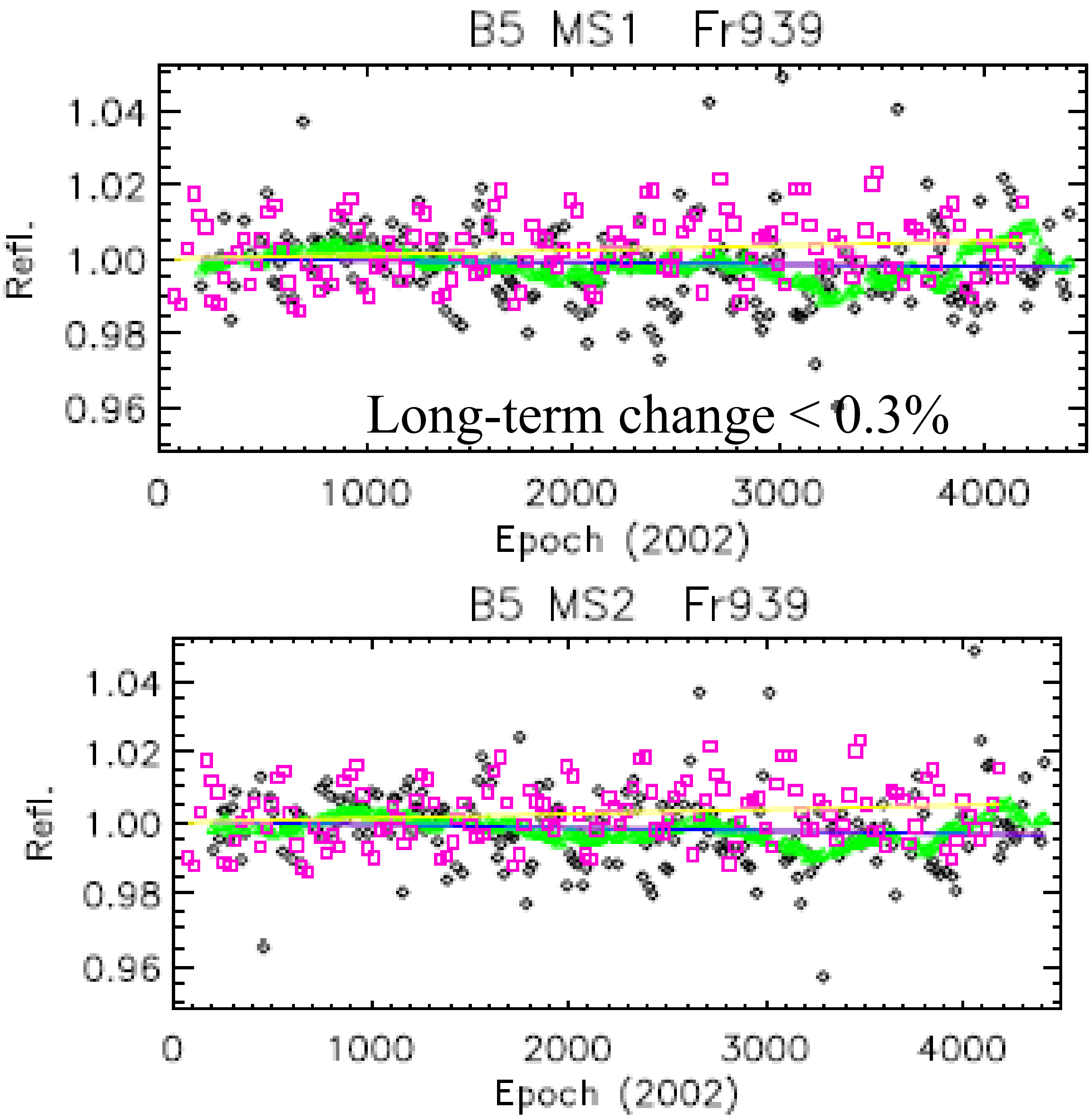
TOA EV reflectance from Libya 4 (BRDF correction applied)

Moving window yearly average of the TOA reflectance trends

DCC trends

Measurements normalized to the first point of the fitted curve

EV-based Evaluation of Aqua Band 5 stability



TOA EV reflectance from Libya 2 (BRDF correction applied)

Moving window yearly average of the TOA reflectance trends

DCC trends

Measurements normalized to the first point of the fitted curve

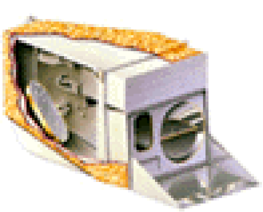
Summary

- A systematic upward drift (~1.5%) is observed across all AOI for Terra band 5 from EV reflectance trending
  - Aqua Band 5 shows a long-term change < 0.3%
  - No observable drift seen in other SWIR bands (inoperable detectors, low signal levels need to be carefully accounted)
- Similar to the VIS/NIR bands, MCST proposed (approved via MsWG) implementing an EV-based correction for Terra band 5 to correct for the long-term drift (~1.5%)
- MCST to deliver a code to insert the band 5 correction into the archive of C6 L1B (leaving everything else same)
  - Details regarding the correction phase-in period (forward LUT) is being worked out

Challenges and Future Work

- o VIS/NIR band gain changes and its impact on deliverable LUT
- o Long-term SD degradation
- o EV-based RVS algorithm extension to other RSB
  - o Terra band 10-12, Aqua 1-2
  - o Continued monitoring for all RSB
- o Enhanced RVS algorithm approaches
- o Long-term performance of the MODIS SWIR bands
- o Impacts of polarization on the EV-based RVS (discussed in the next talk)
- o TEB issues (discussed in the next talk)

On-Orbit Monitoring for MODIS Polarization Impact



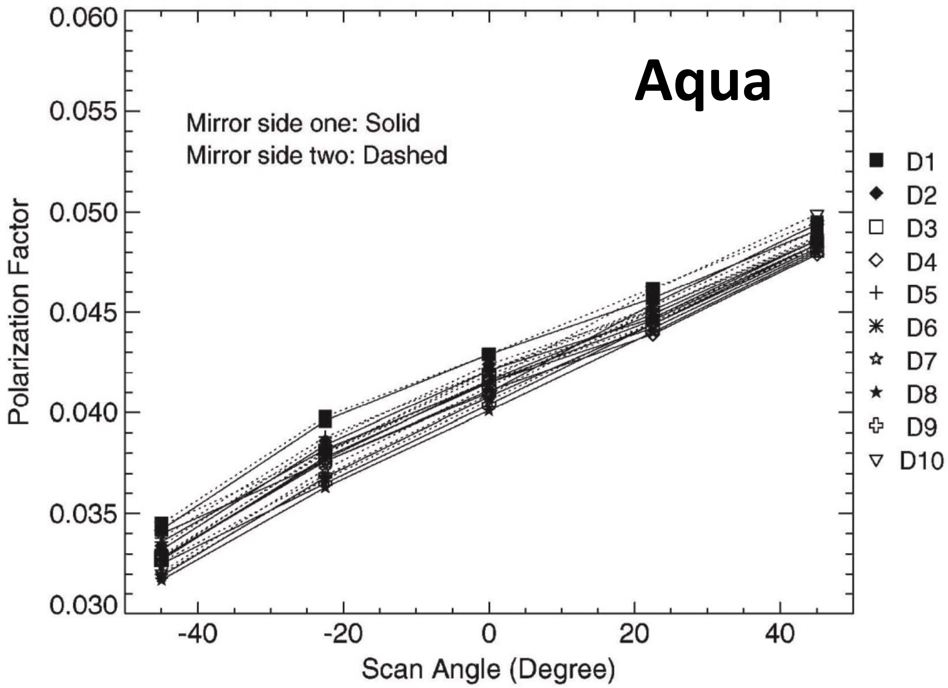
MCST Workshop at MST Meeting (May 1, 2014)

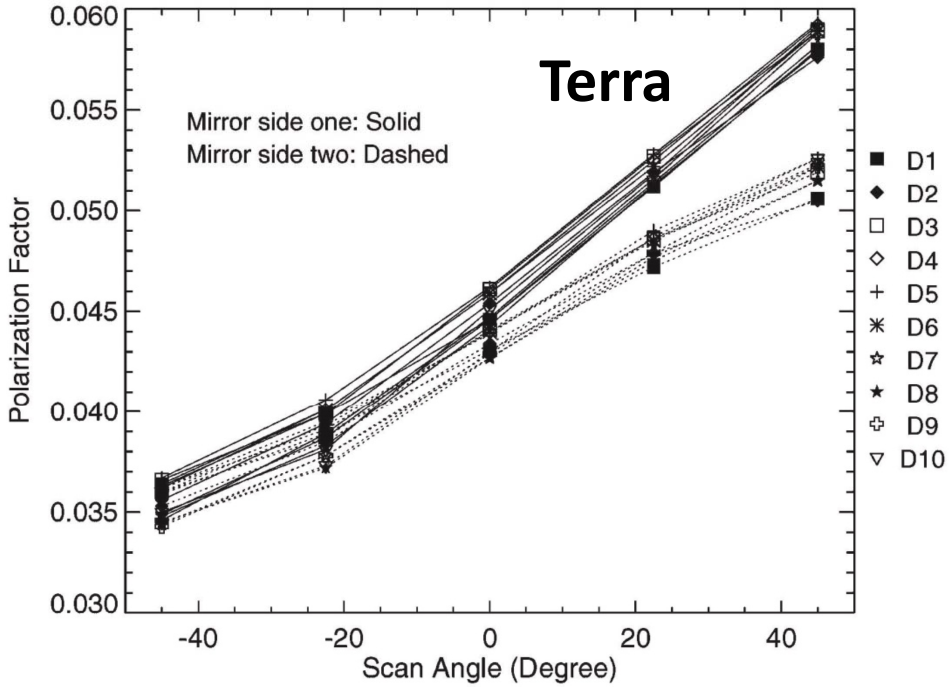
Outline

- Introduction
- MODIS pre-launch polarization assessment
- Polarization impact on MS response ratio
- Polarization impact on radiometric stability
- MCST Internal tests of polarization correction

MODIS Pre-launch Polarization Results

MODIS band 8 (0.412 µm)





→ **AOI from 10.5 to 65.5°**

MODIS Polarization Correction

$$L_m = L_t \{ 1 + f\, a \cos[2(\mu + \delta)] \} \quad \text{(MCST)} \quad (1)$$

$$L_m = M_{11} L_t + M_{12} Q_t + M_{13} U_t \qquad \text{(OBPG)} \ (2)$$

f and ***μ*** are degree of the incident light's polarization and angle
a and ***δ*** are instrument's polarization factor and phase angle

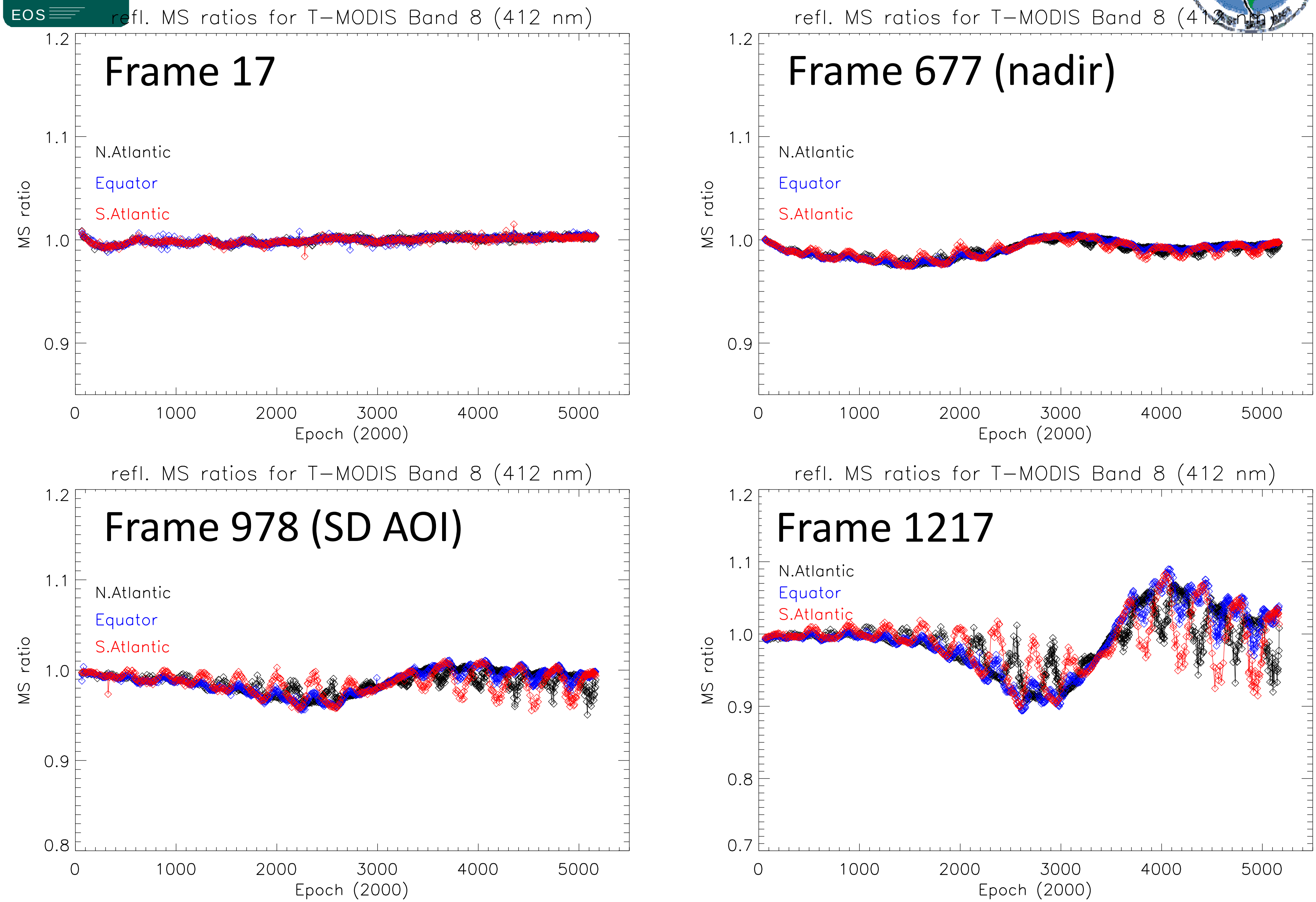
Equalize (1) and (2)

$m_{12} = M_{12} / M_{11}$; $m_{13} = M_{13} / M_{11}$; $q_t = Q_t / L_t$; $u_t = U_t / L_t$

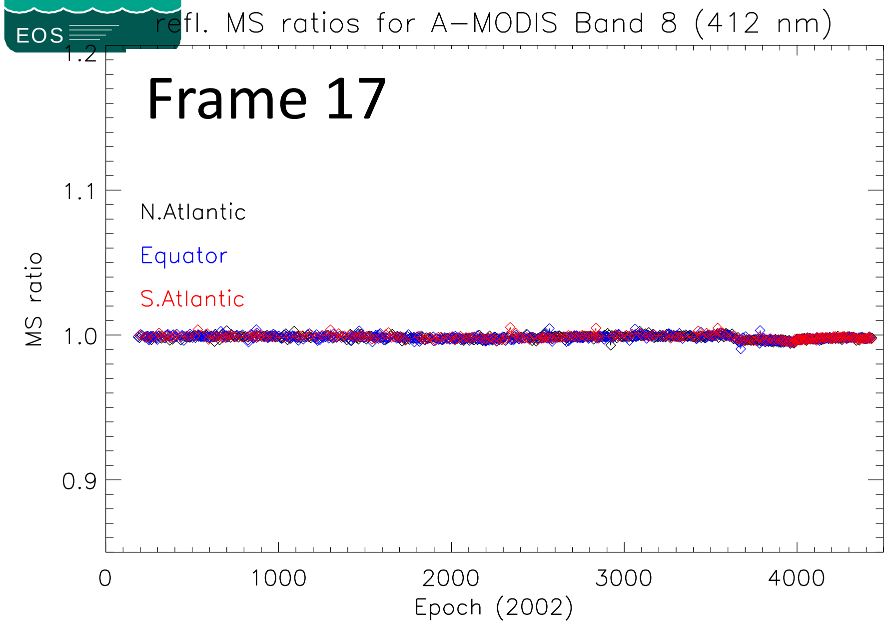
incident light: $$f = \sqrt{q_t^2 + u_t^2} \qquad \tan(2\mu) = \frac{u_t}{q_t}$$

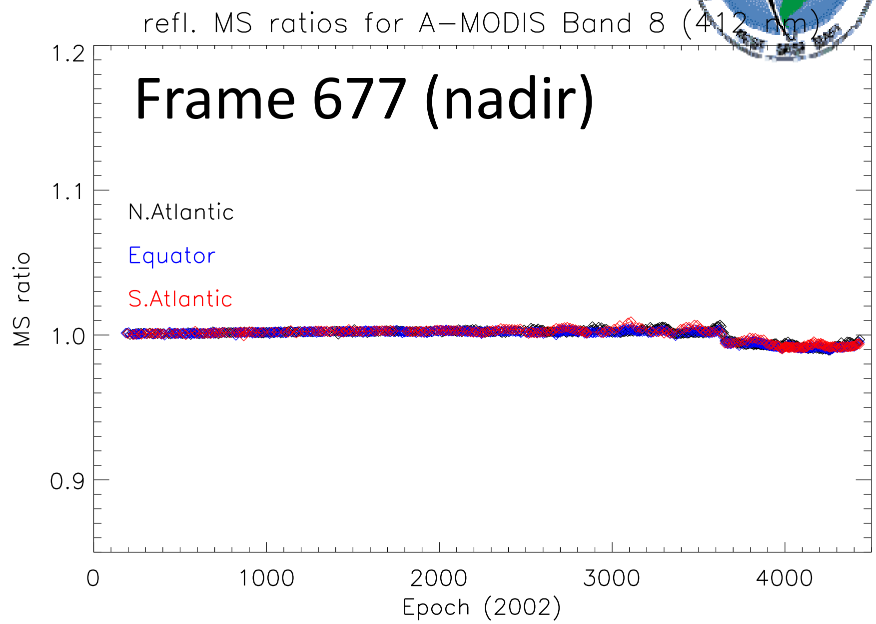
instrument: $$a = \sqrt{m_{12}^2 + m_{13}^2} \qquad \tan(2\delta) = -\frac{m_{13}}{m_{12}}$$

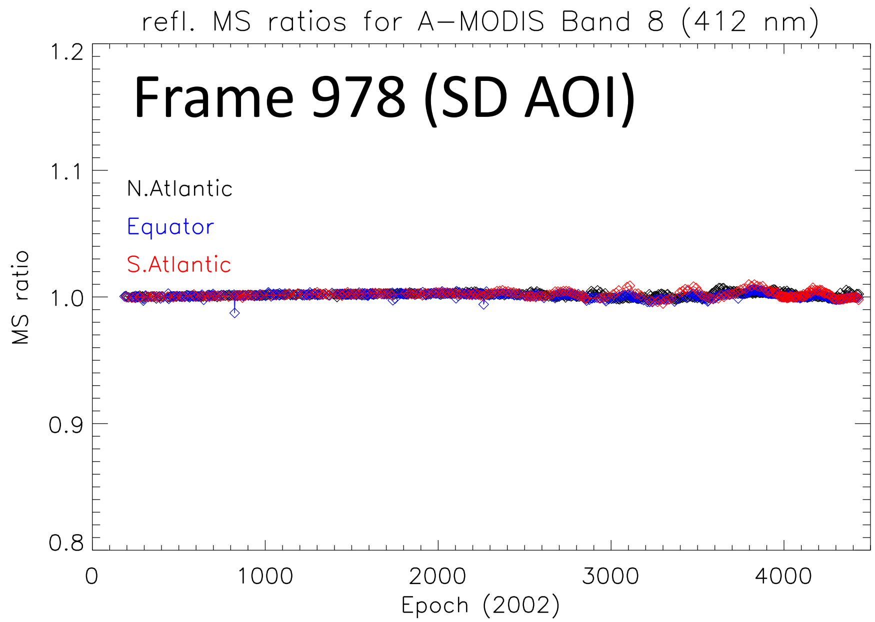
Terra mirror-side response ratio

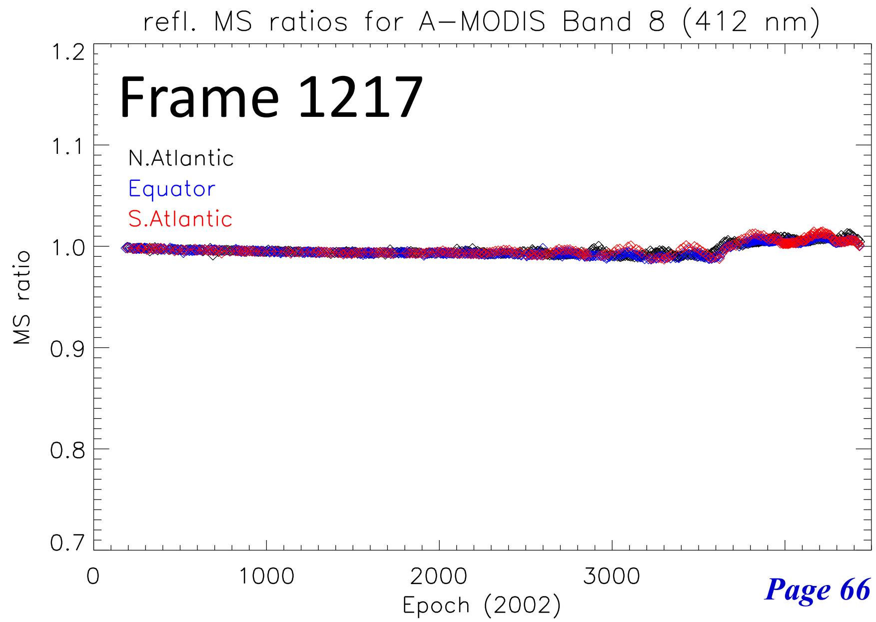


Aqua mirror-side response ratio

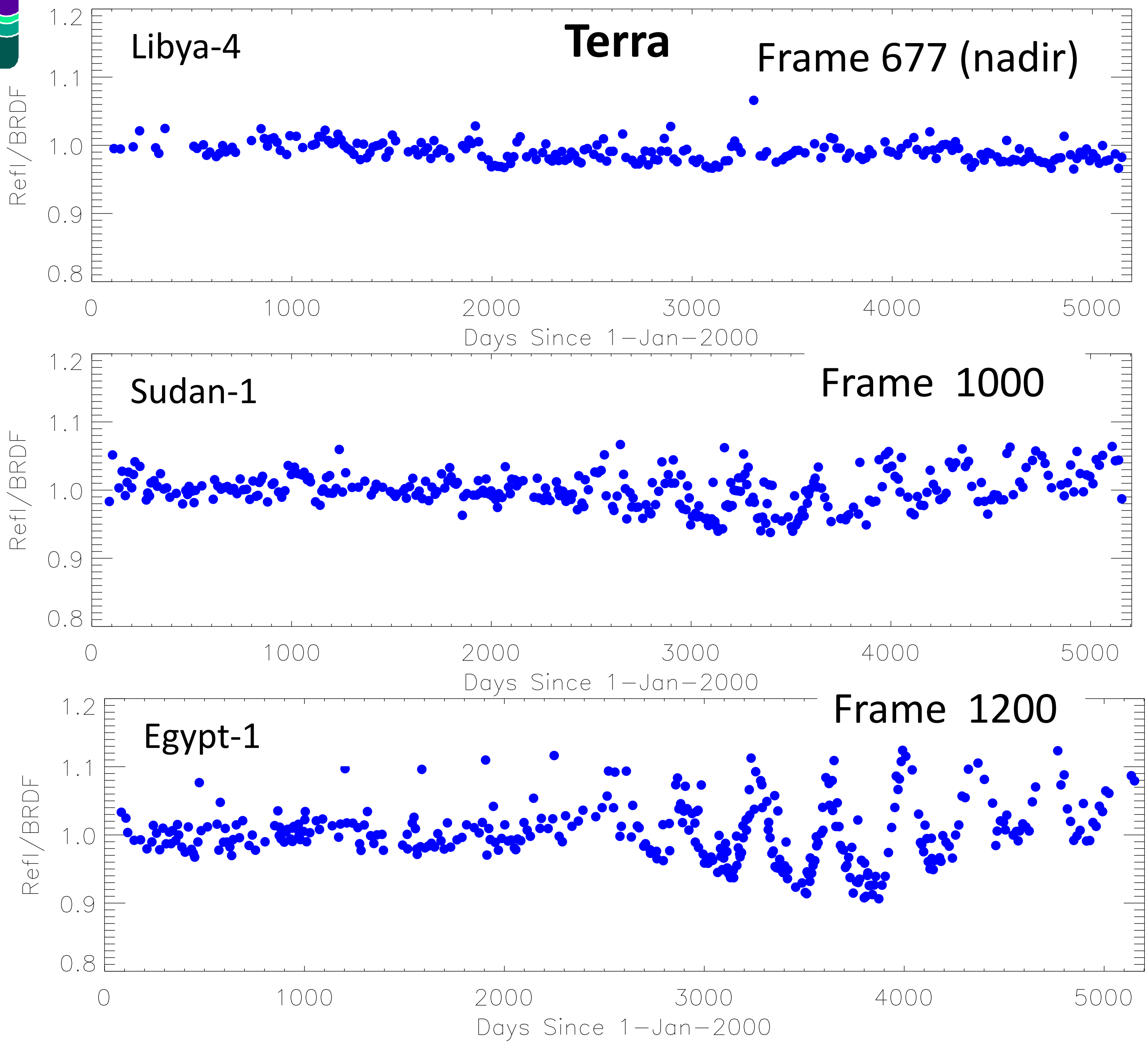




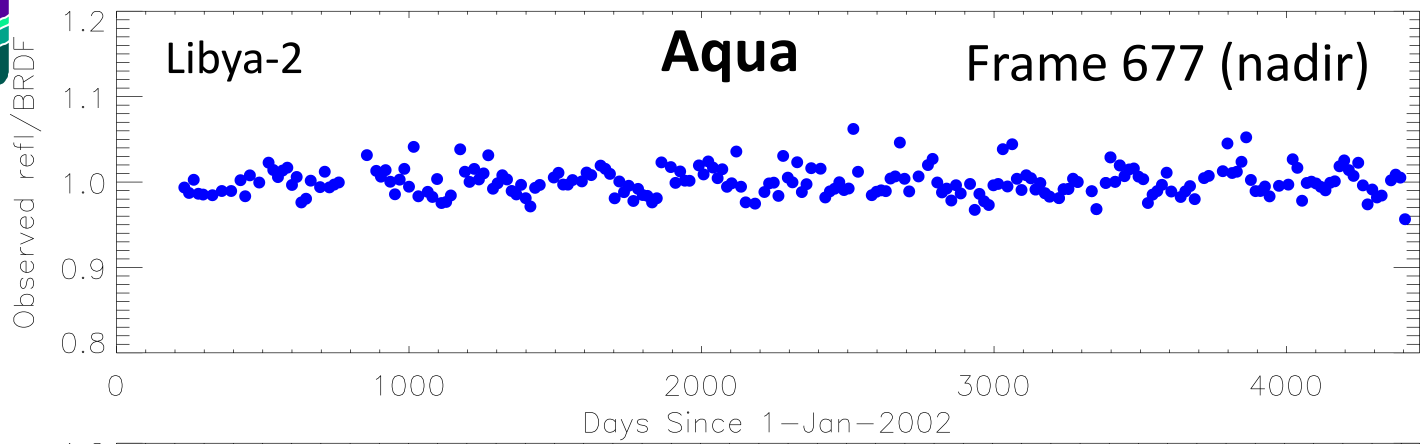


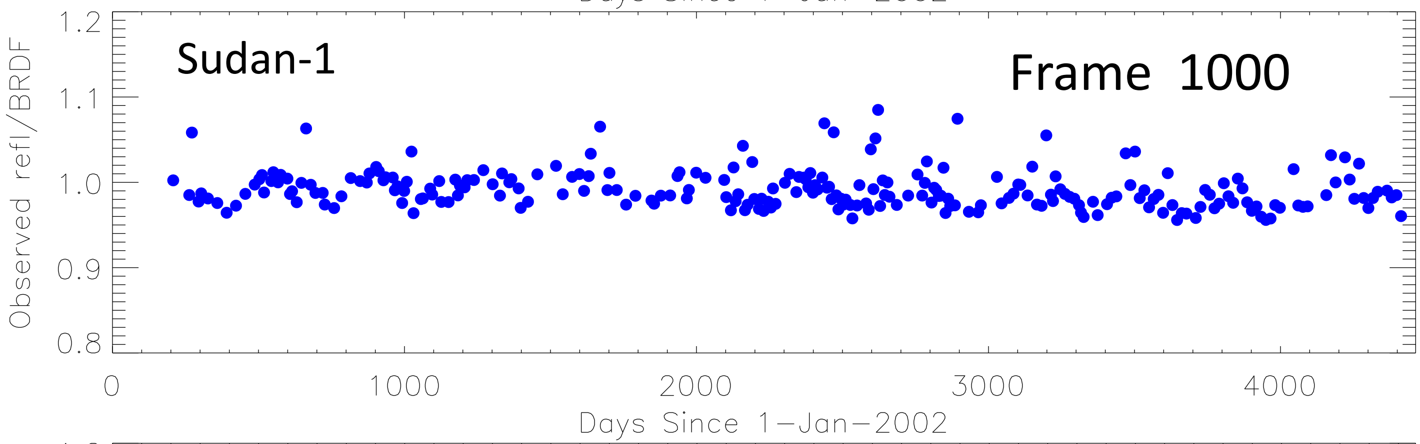


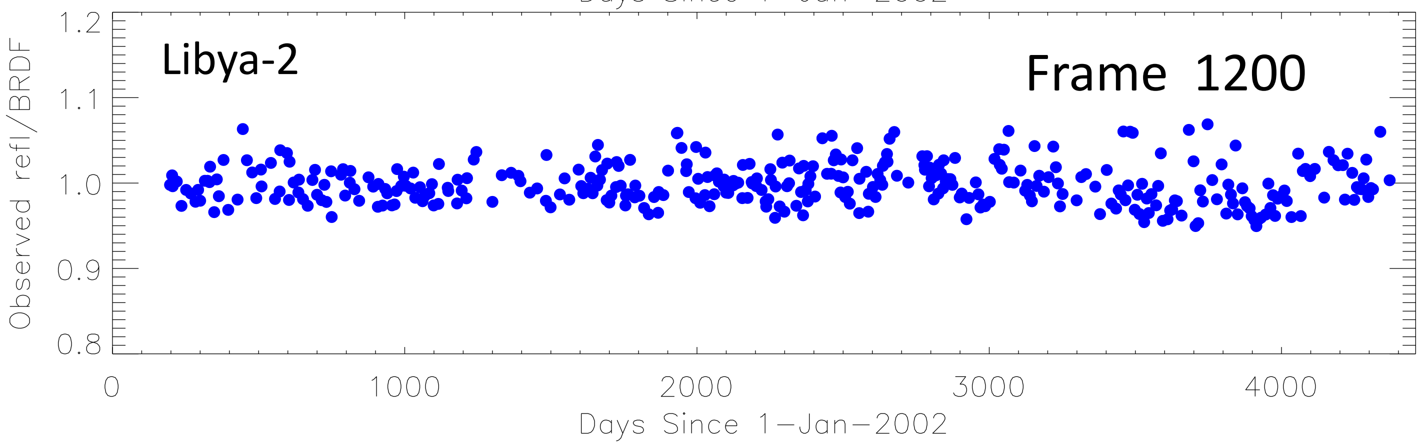
MODIS Reflectance Trends for band8 (C6)



MODIS Reflectance Trends for band8 (C6)

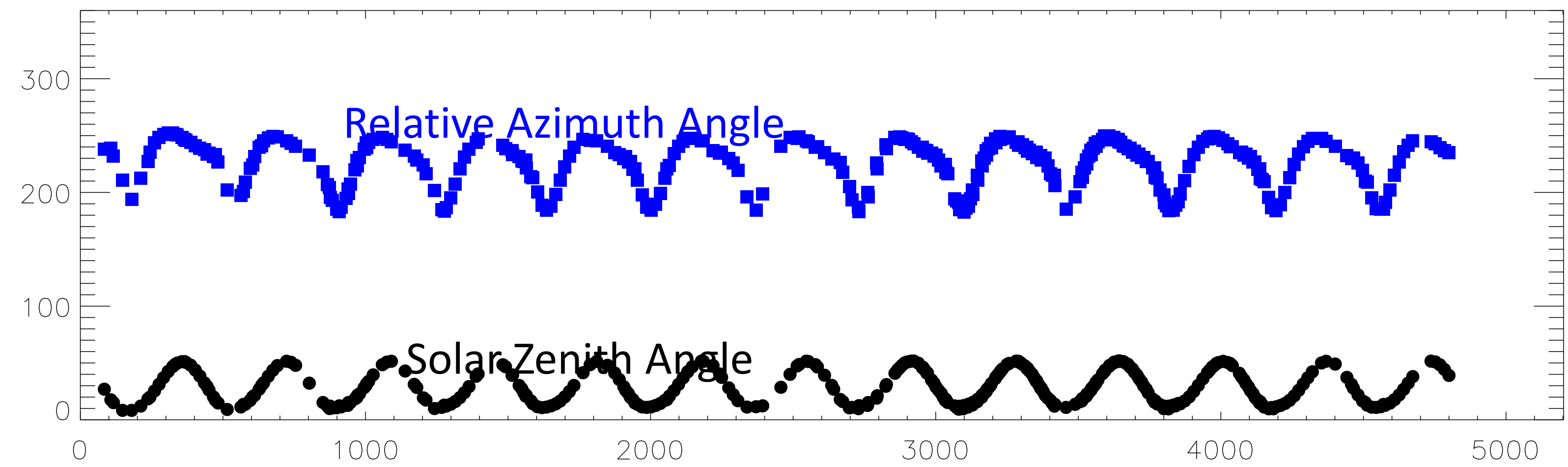




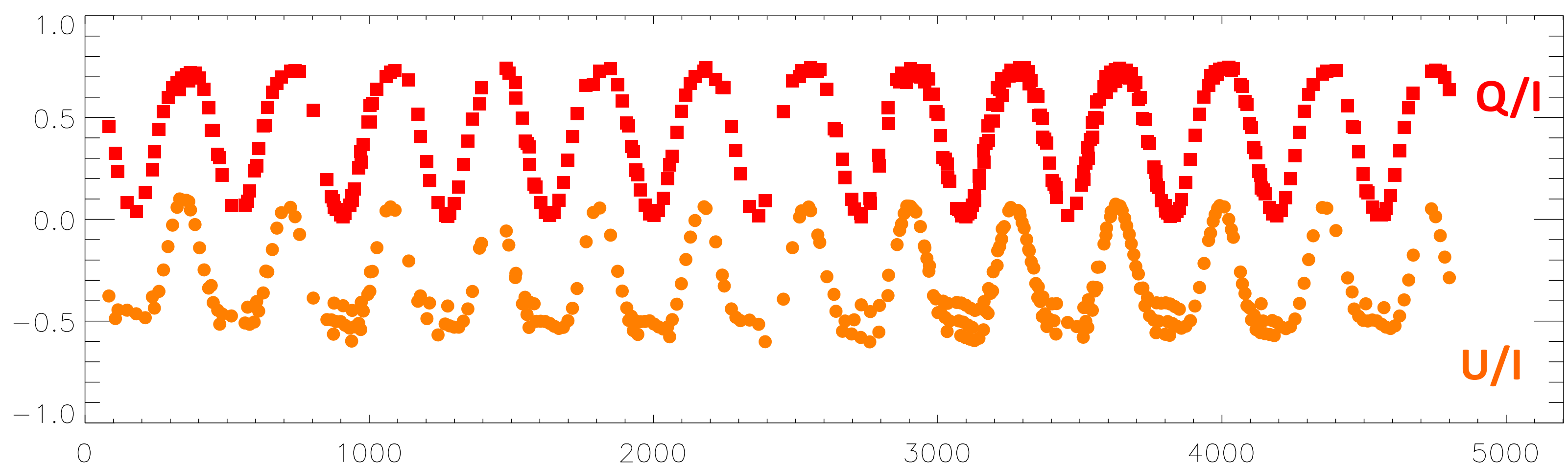


Inputs and outputs of 6SV for desert

Inputs for desert data (Egypt-1) at frame 1200

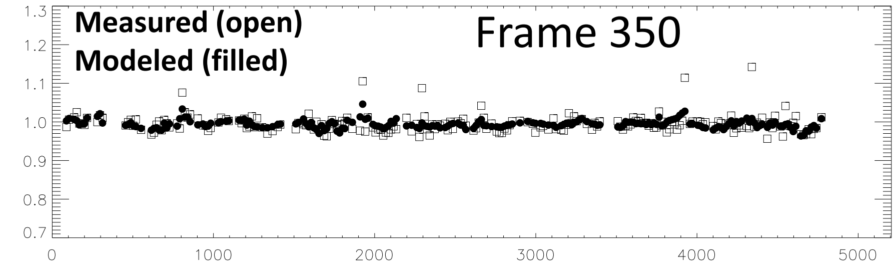


Outputs

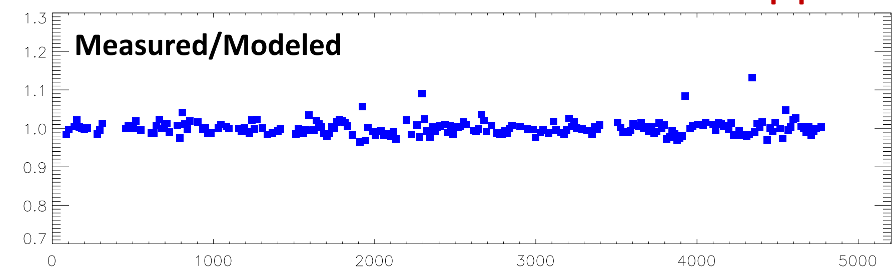


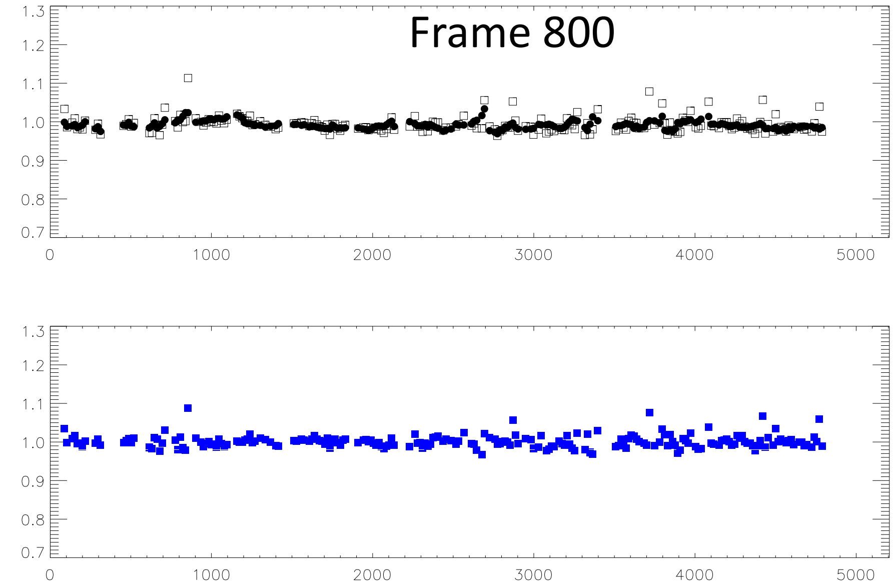
*Currently, assuming no polarization effect at the desert surface

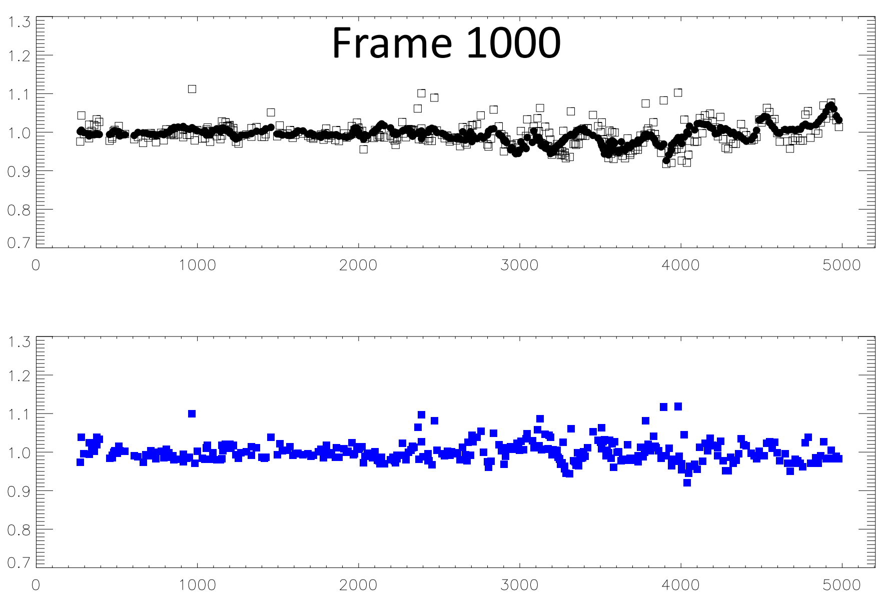
Comparison of measured & modeled* Terra b8 refl. for desert

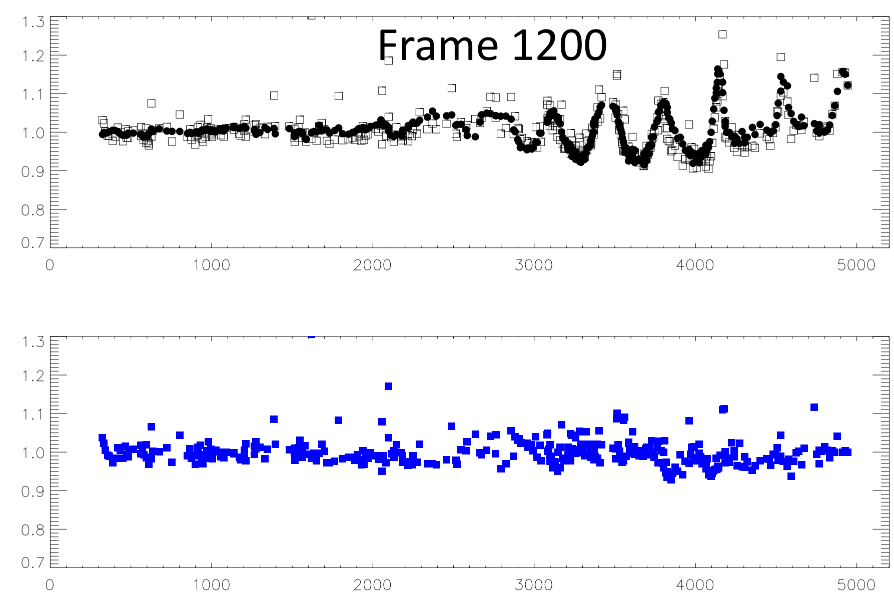


*Based on the OBPG approach

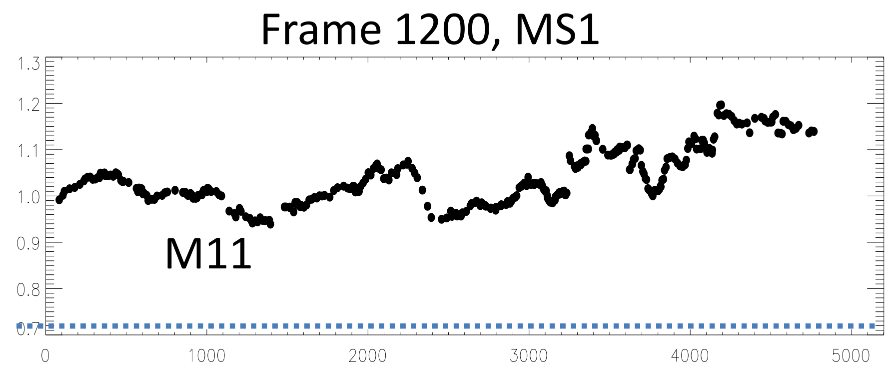


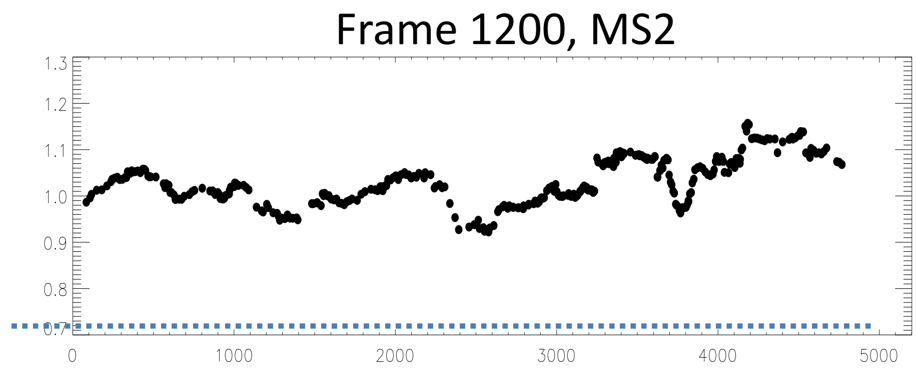


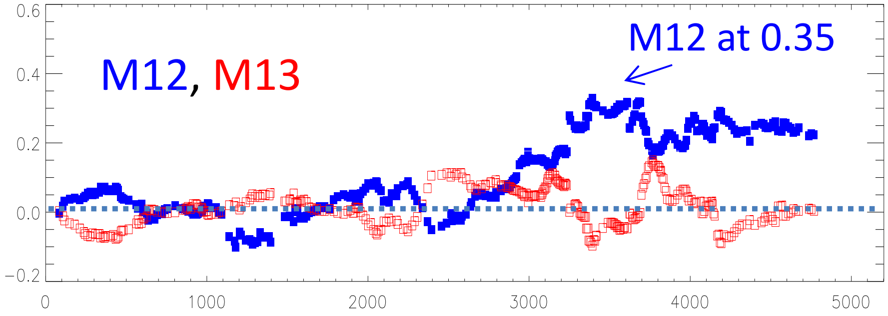


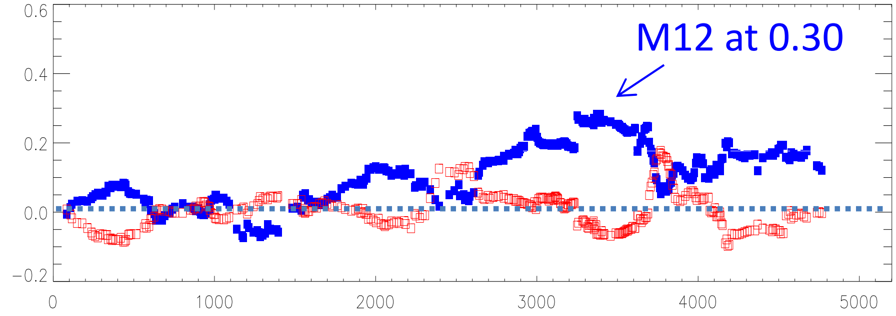


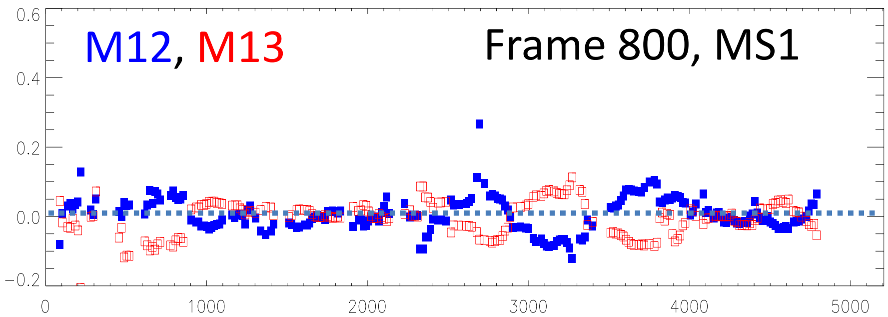
Terra B8 polarization parameters (desert)









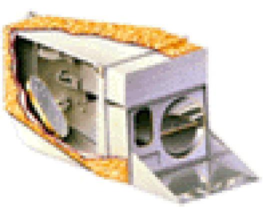


*Results are obtained by fitting to the measured desert data collected over an one-year period (moving forward)

Summary

- MODIS pre-launch tests show polarization factor is up to 5 - 6% at end of scan and Terra MODIS mirror side (MS) 1 is more sensitive than MS 2
- On-orbit trends indicate Terra MODIS polarization sensitivity increases significantly over time (MS ratio and reflectance trends)
- With simulated polarized light by atmospheric scattering, MCST can track MODIS sensor's polarization parameters using pseudo invariant desert sites
- Results show that Terra band8 polarization factor increases to nearly 35% (MS 1) at end of scan in 2010 and gradually decreases.

Assessment of Aqua MODIS Cold FPA Temperature Anomaly Impact

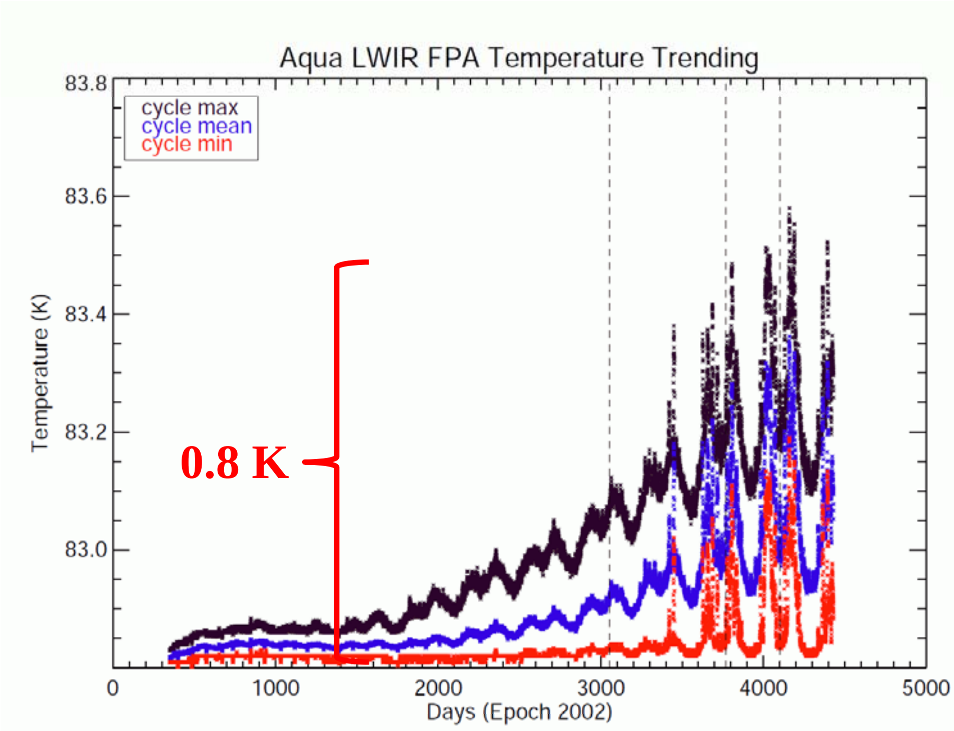


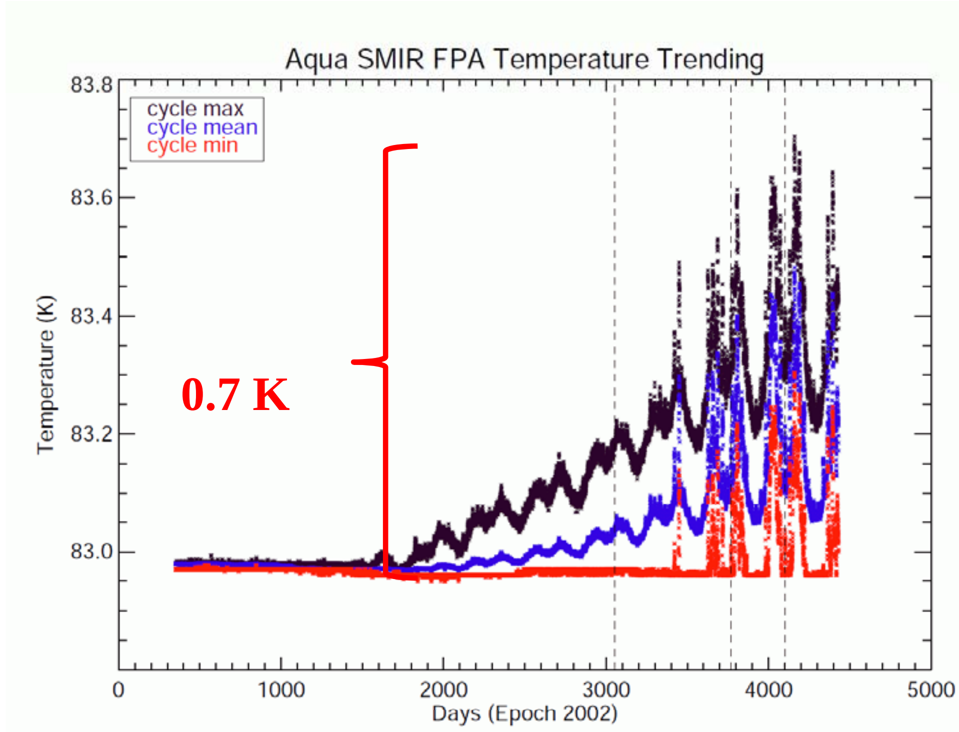
MCST Workshop at MST Meeting (May 1, 2014)

Current Status

- CFPA temperature peak during summer months with maximum **~83.7 K** in mid-2013.
- CFPA orbital/seasonal oscillation – max/min difference **~0.8 K**
- Radiative cooler margin lost for CFPA setpoint of 83 K during intermittent periods through annual cycle.
- Majority of impacts on L1B products occur during BB Warmup/Cooldown activities

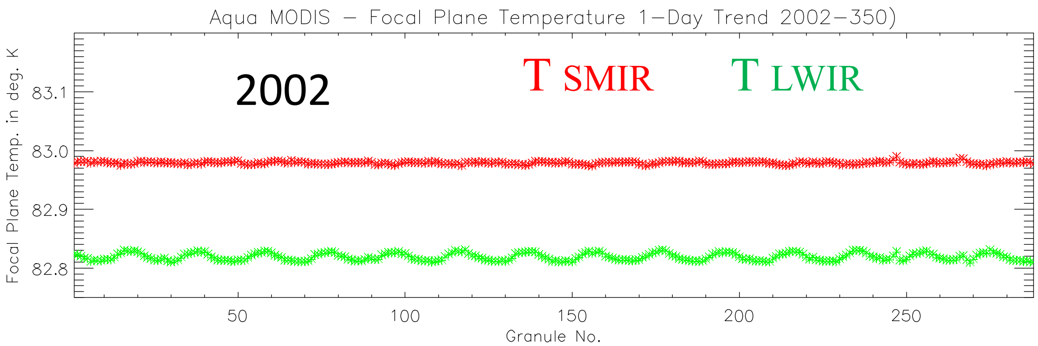
Aqua CFPA Oscillations Long-term trend

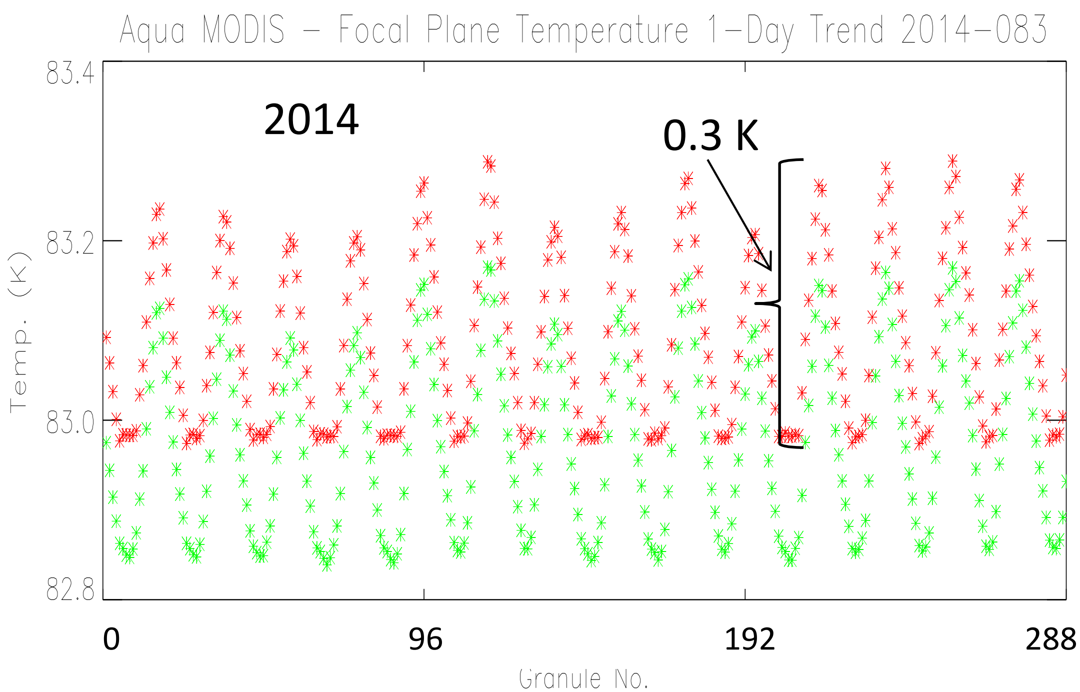


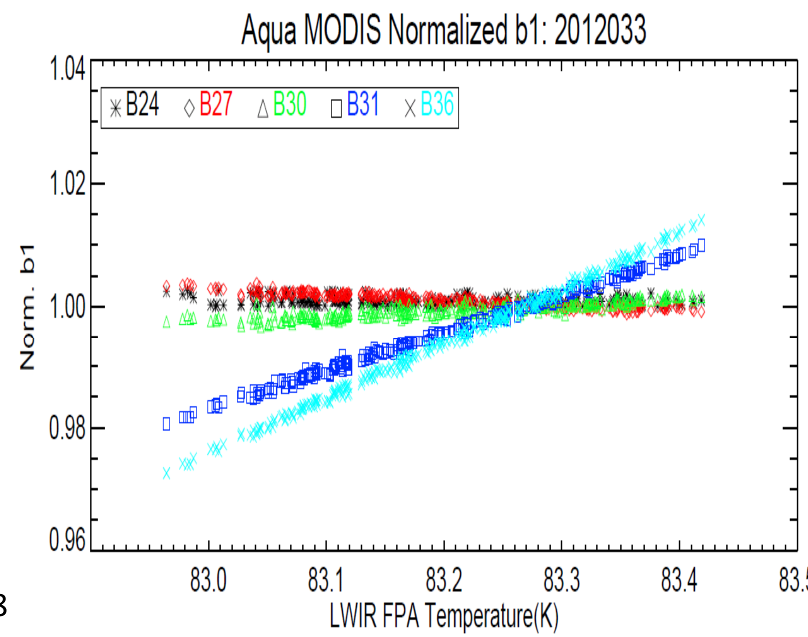


Max/Min of 4 orbits

Aqua CFPA Oscillations
Short Term (1day) trend

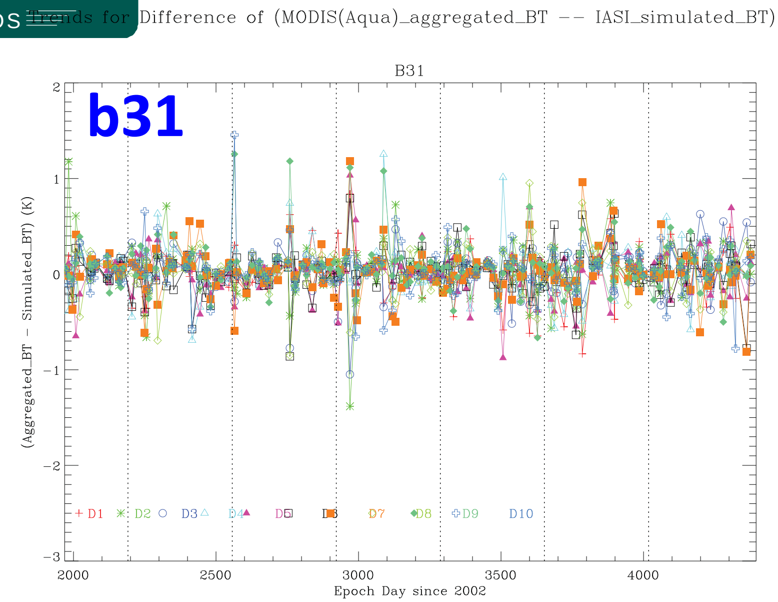


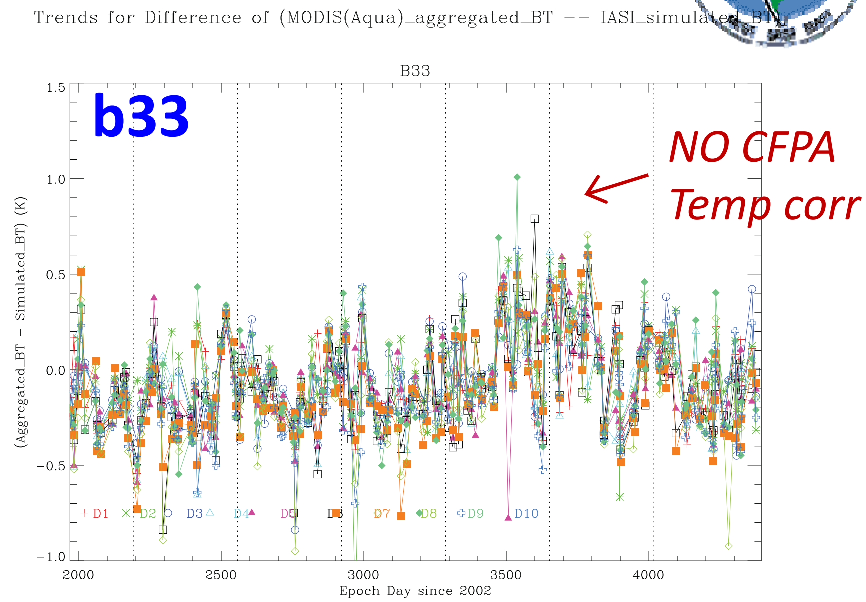


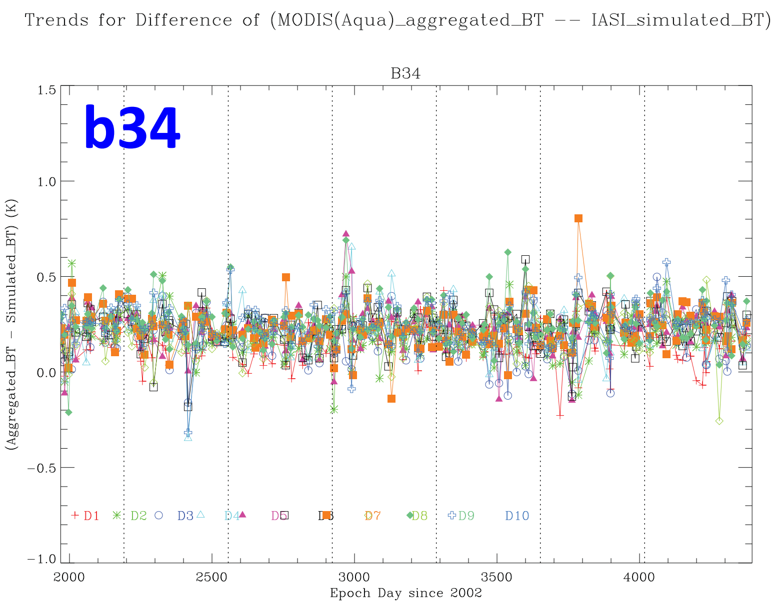


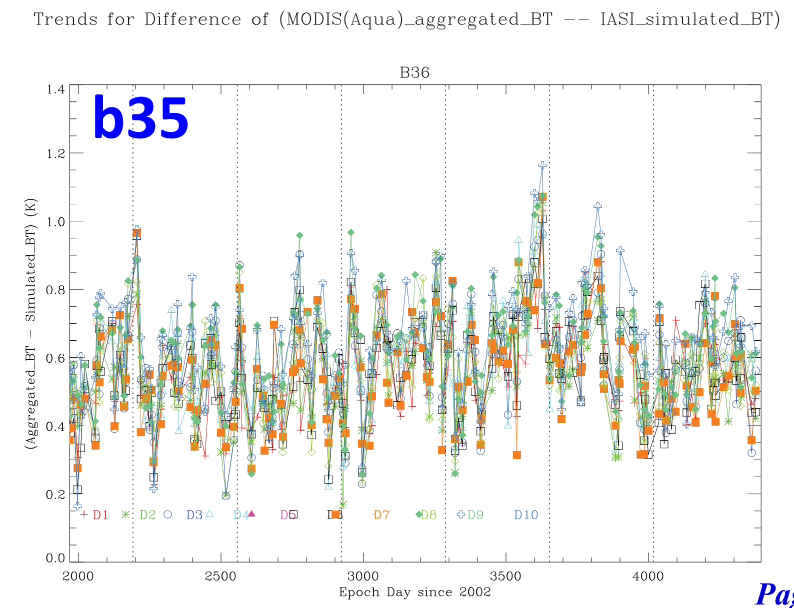
Granule average

Aqua MODIS/Metop-A IASI Comparison Trends



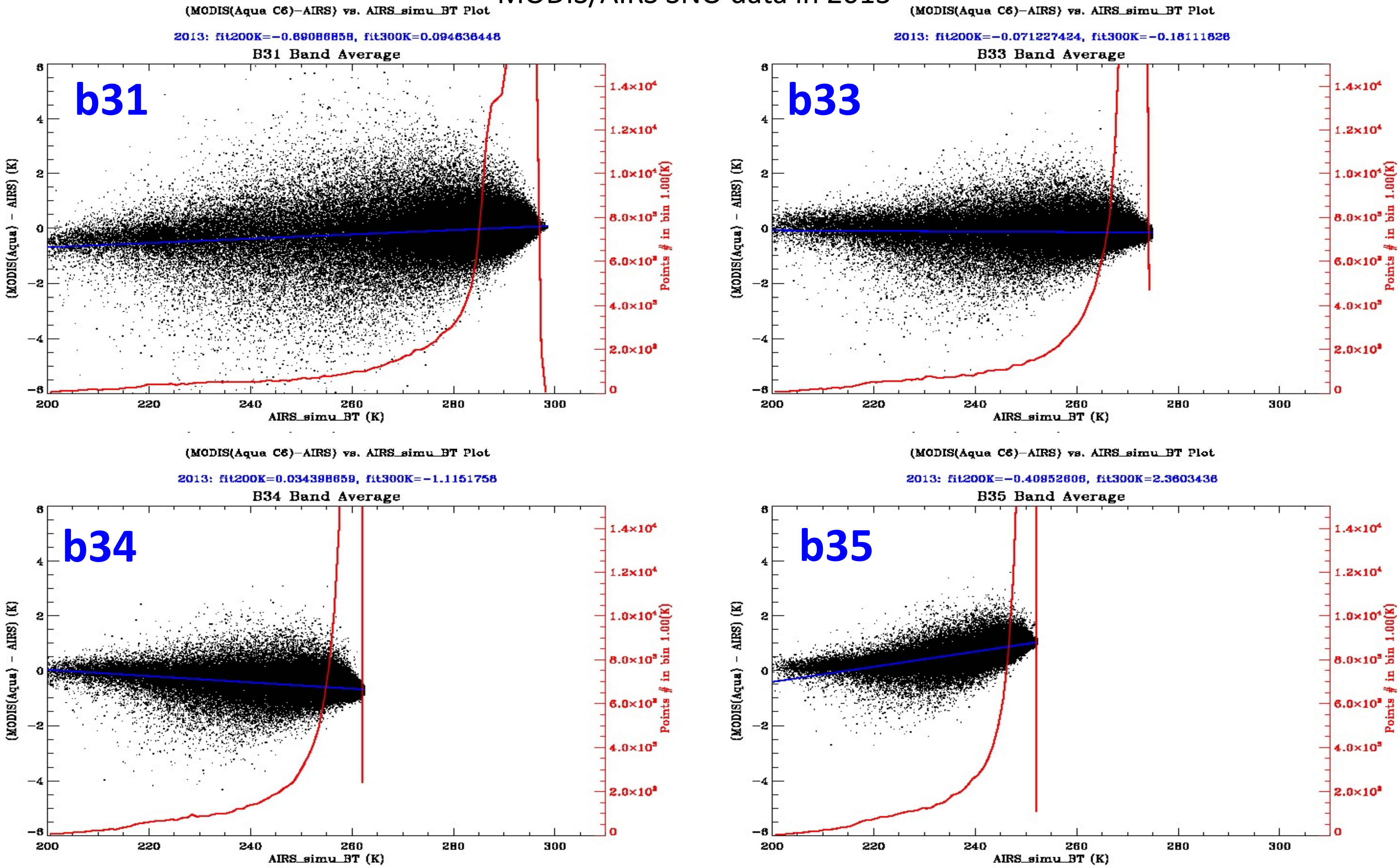






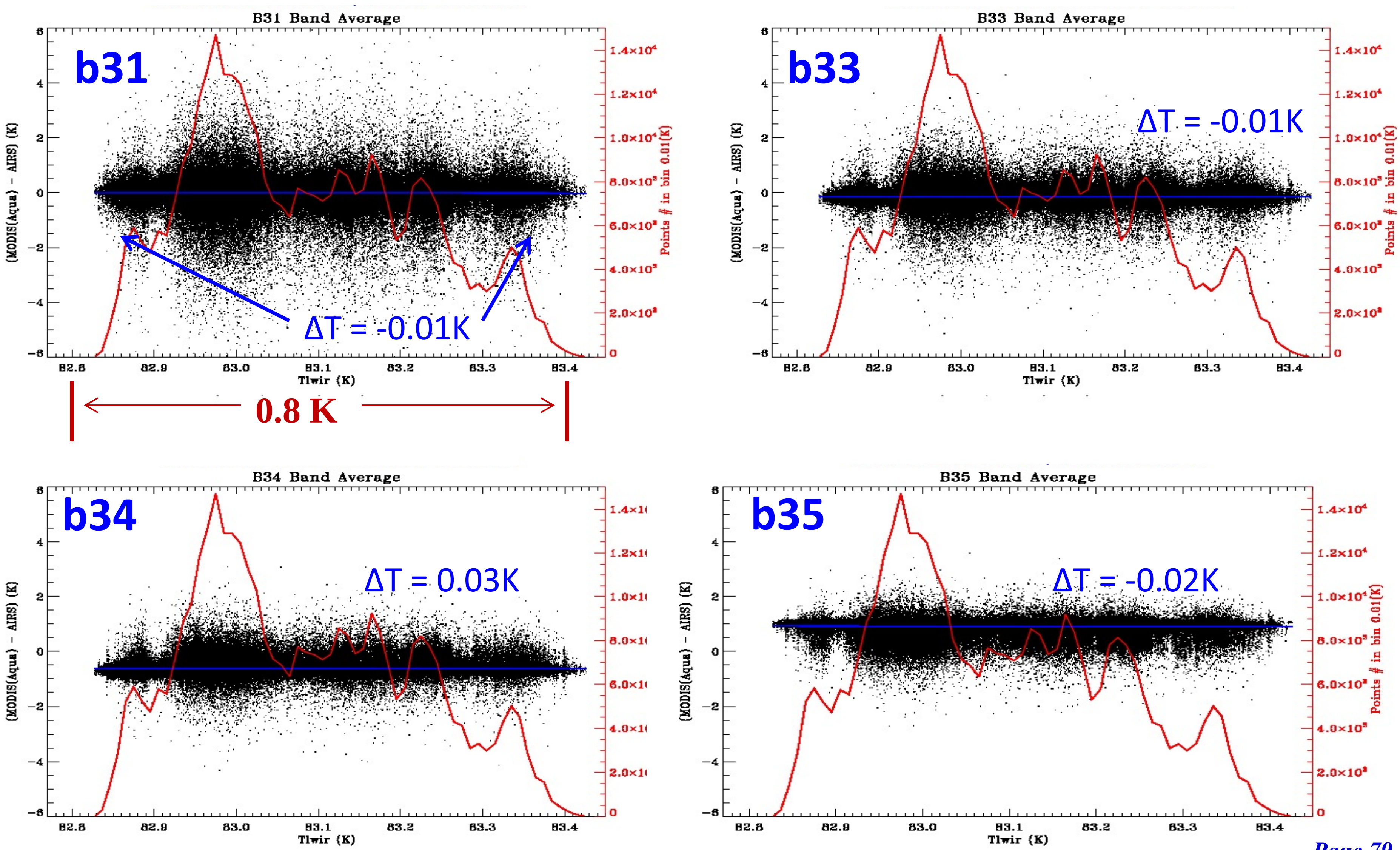
Assessment of Aqua CFPA temperature anomaly impact using AIRS

MODIS/AIRS SNO data in 2013



Assessment of Aqua CFPA temperature anomaly impact using AIRS

MODIS/AIRS SNO data in 2013



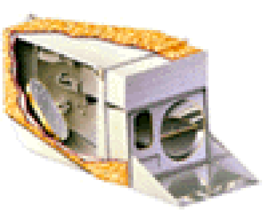
Summary

- Aqua MODIS continues to operate nominally
  - A decrease in radiative cooler margin has been observed since ~2007.
  - CFPA temperature not able to be stably controlled at set point of 83 K
    - Orbital and seasonal variations observed
  - Scan-by-scan calibration captures much of the impact of the CFPA variation
  - Collection 6 includes an improved default b1 algorithm and temperature correction to the a0/a2 analysis.

- EV saturation for bands 33, 35 & 36 during WUCD activities has increased.

- MCST continues monitoring of CFPA performance and is prepared to implement any of the proposed mitigation strategies in the event of increasing adverse impacts on science data products

Tracking Stability of MODIS Thermal Emissive Band RVS



MCST Workshop at MST Meeting (May 1, 2014)

Approaches to track TEB RVS stability

1) Track BT stability by reference to AWS near-surface temperature measurements at Dome C

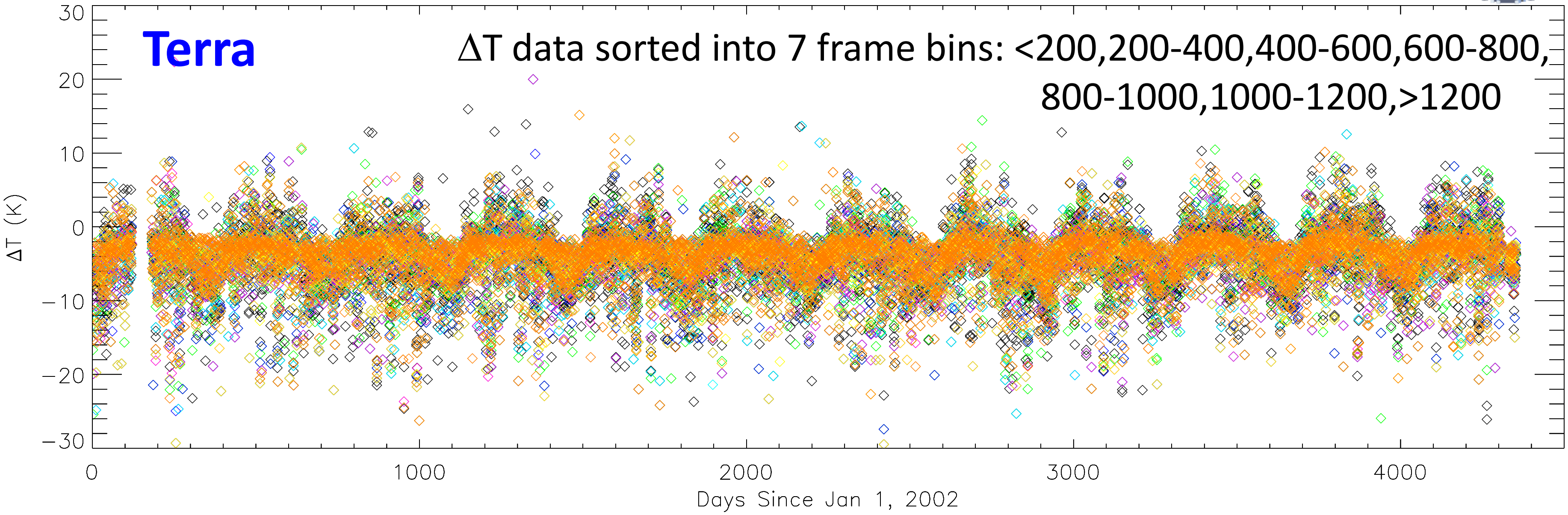
2) Use Dome C overpasses from 16-day repeatable orbits to track the stability of response

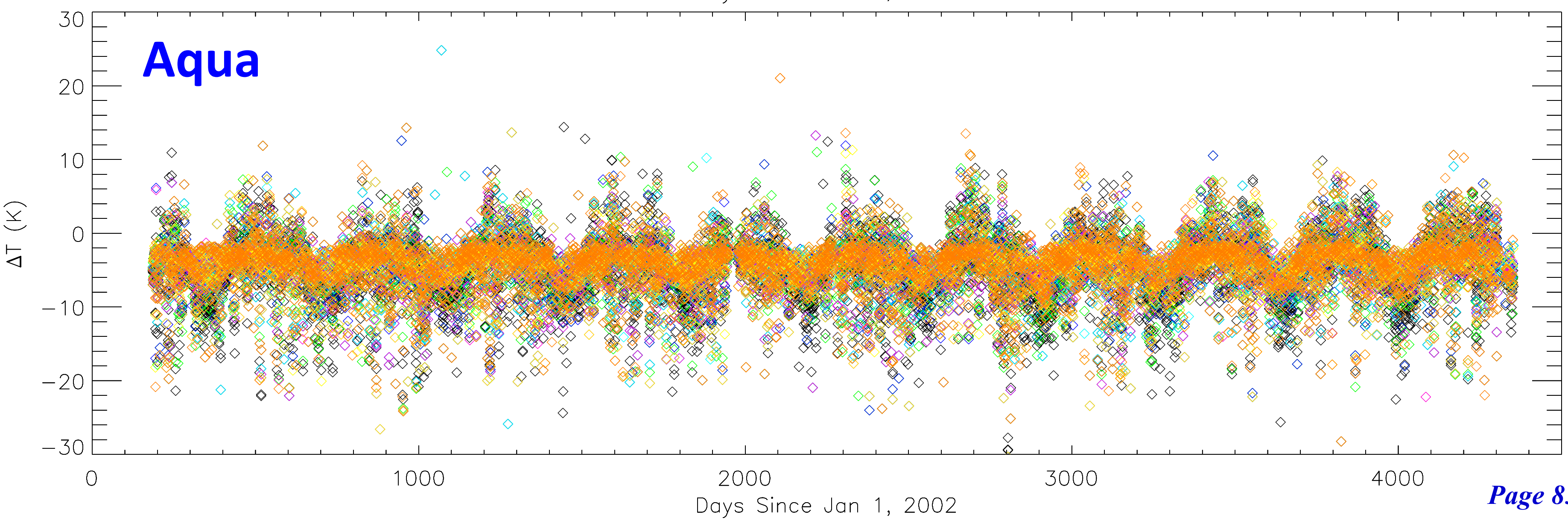
3) Monitor BT at other AOI in reference to BT at BB AOI over ocean

4) Track temperature stability by reference to instrument cavity temperature measurements for large AOI (> 55^o)

5) Comparison of Aqua MODIS/AIRS SNO data for all AOI

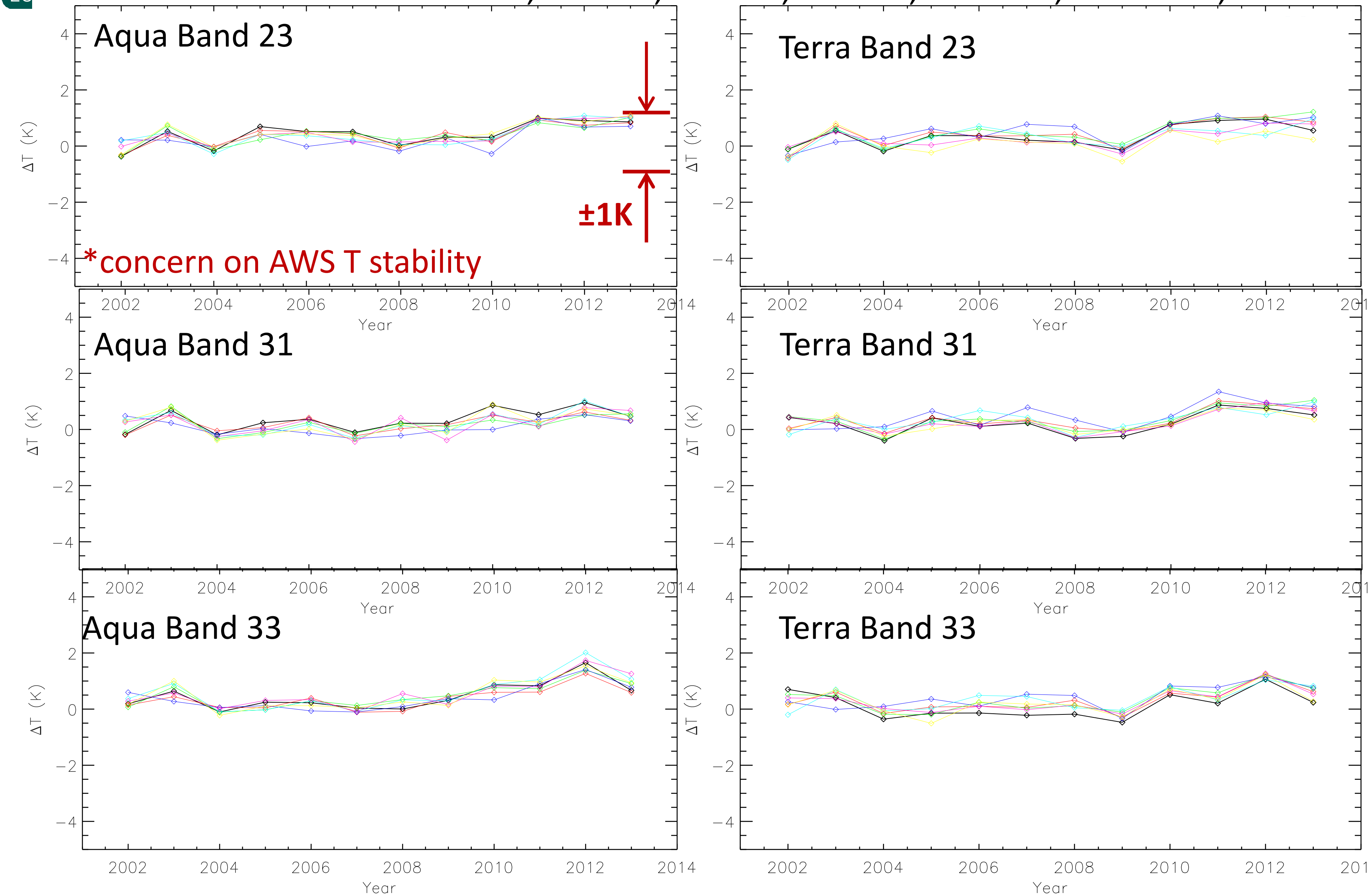
Band 31 RVS Stability (Dome C AWS)



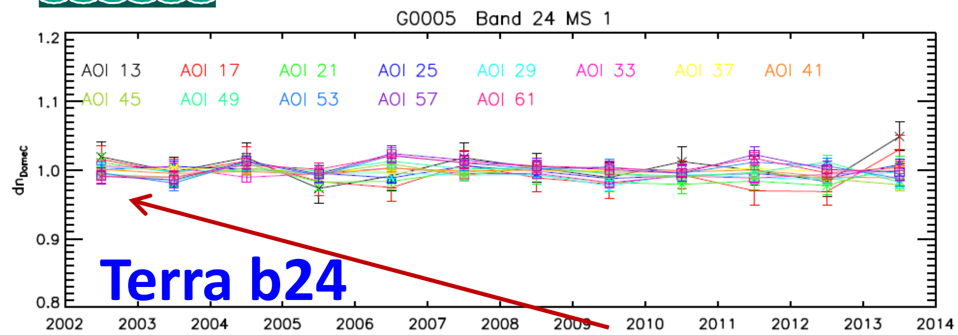


MODIS TEB RVS Stability* (Dome C AWS)

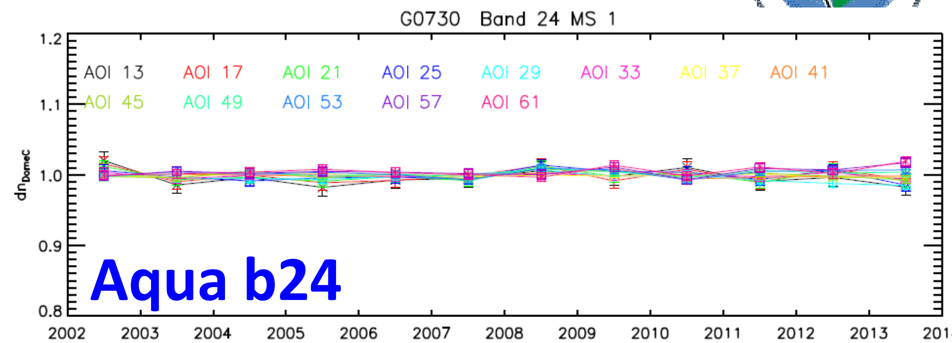
ΔT sorted into 7 frame bins: <200,200-400,400-600,600-800,800-1000,1000-1200,>1200

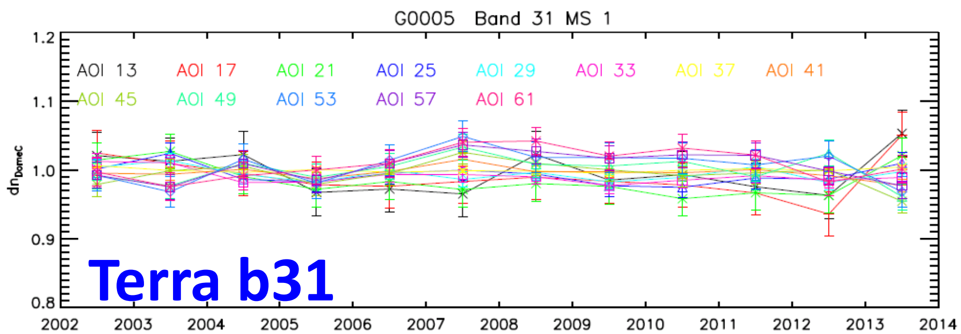


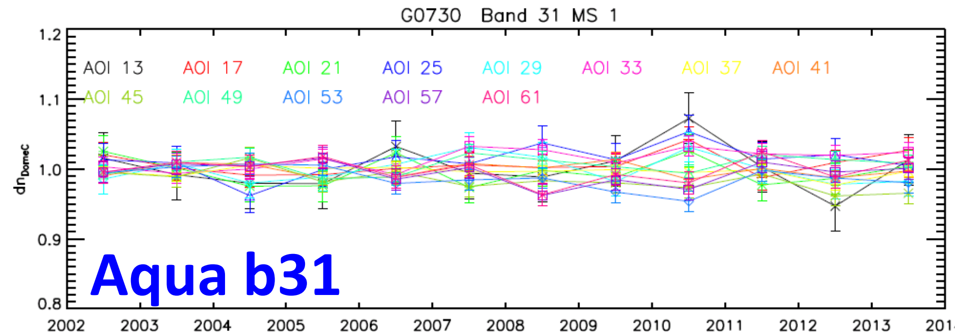
RVS Stability (Dome C 16D Overpasses)

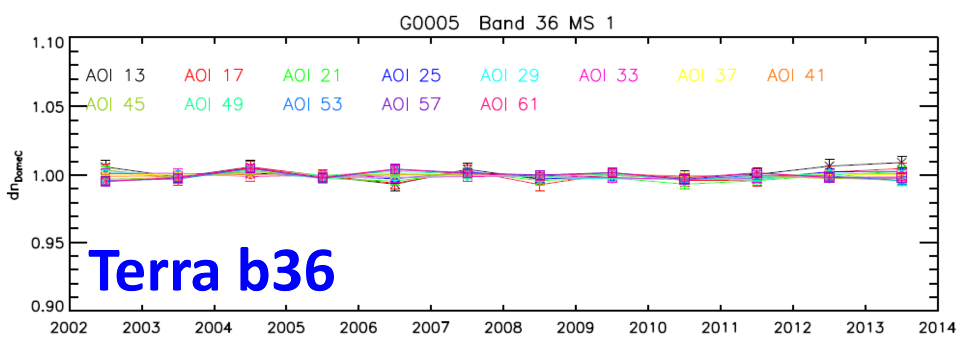


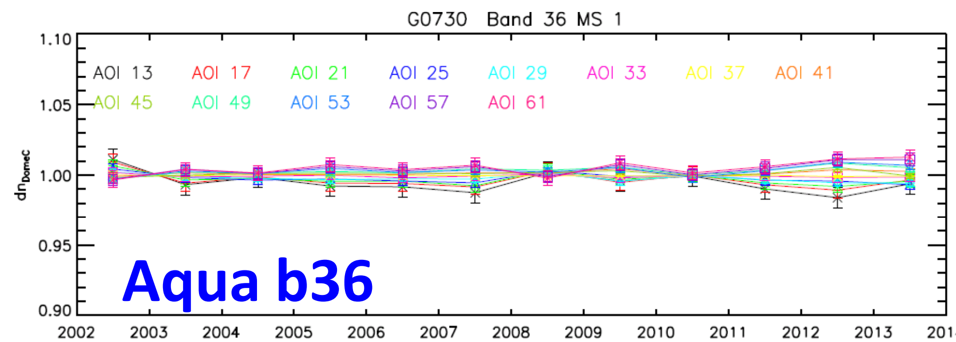
Normalized to fitted line





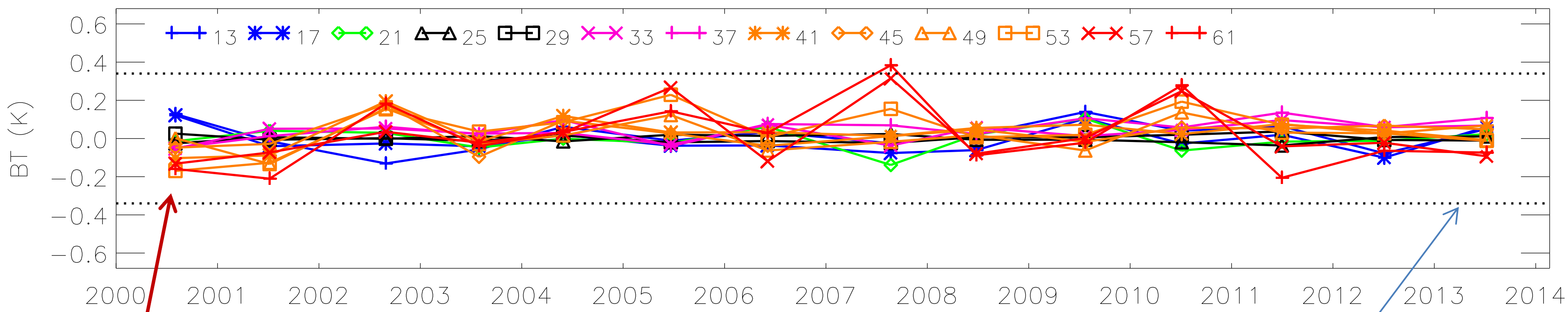






RVS Stability (Clear Ocean)

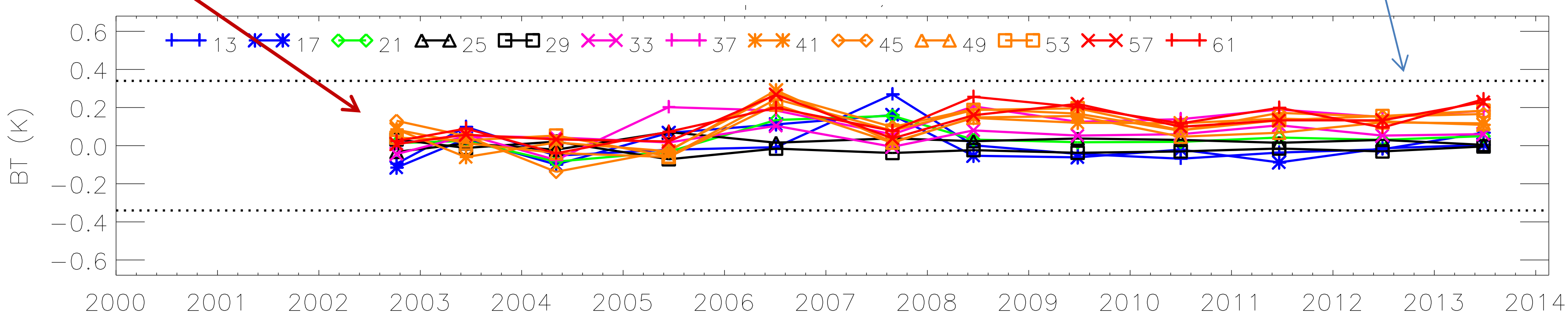
Terra b31



Normalized to fitted line

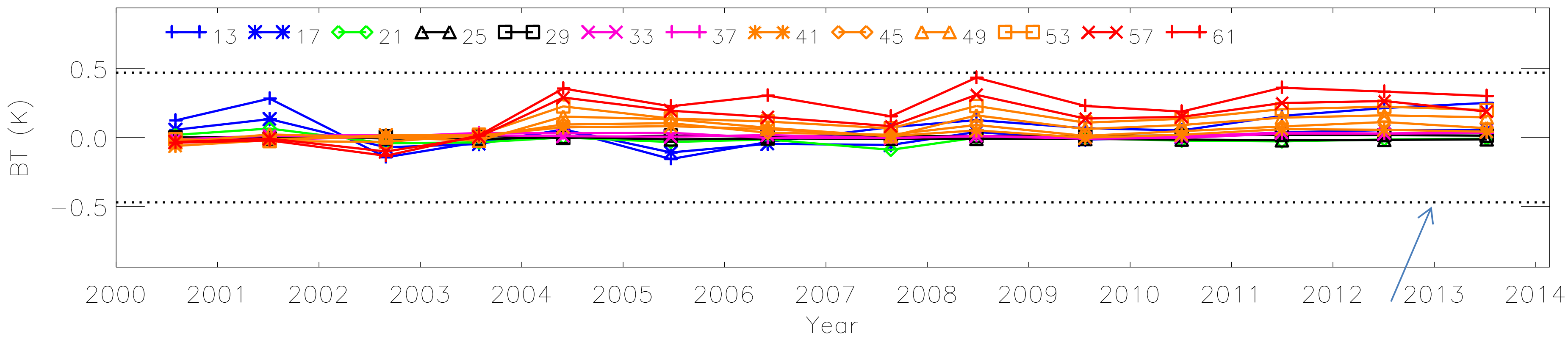
±0.5%

Aqua b31



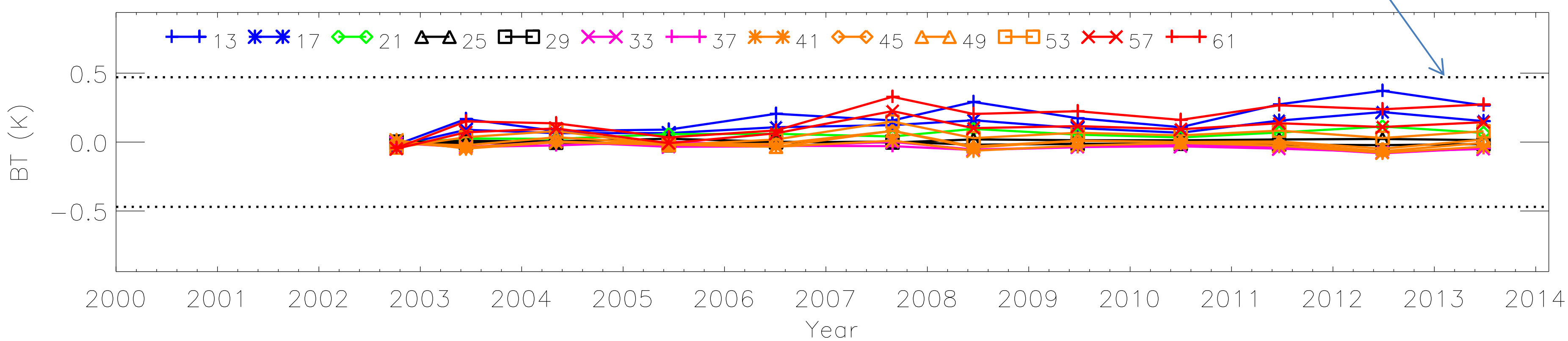
RVS Stability (Clear Ocean)

Terra b36



±1.0%

Aqua b36



Summary

- Overall Conclusion: Based the several approaches used to track the RVS stability, it indicates no apparent changes noticed in all AOIs

- The TEB RVS may be evolving in very small changes, i.e. a few tenth of degree. However, the variability of the surface features makes it difficult to confirm such small changes and apply corresponding corrections

Summary on Terra Band 27 Crosstalk

- Terra band 27 was found to have electronic crosstalk from bands 28, 29 & 30, which is time and detector dependent
- Impact due to crosstalk can be as large as 8K in the calculation of brightness temperature
- A linear algorithm is used to correct the crosstalk effect with coefficients derived using lunar roll measurements
- The crosstalk correction algorithm is able to reduce Terra b27 temperature drifts to within 1K
- It is recommended to conduct further tests in the science product and have the b27 crosstalk correction in L1B. MCST is working on similar correction for other bands with much smaller crosstalk impact

Summary

- **Both Terra MODIS (14 years) and Aqua MODIS (12 years) and key on-board calibrators continue to operate and function normally**
  - Only 2 new noisy detectors since last STM
- **Extensive calibration effort by MCST in support of C6 (and C5) L1B data processing**
  - Many regular and special LUTs (C5 and C6) derived and delivered for data production
- **Future work to address existing and new challenging issues**
  - VIS/NIR response versus scan-angle (RVS) and polarization sensitivities
  - Uncertainty due to correction for large SD degradation and SD degradation correction for SWIR bands
  - Undesirable features and unpredictable changes (aging instruments)
- **Dedicated calibration and characterization effort and close interaction and communication with the science and user community**

Challenging Issues and Future Efforts

- **Changes in VIS/NIR response versus scan-angle (RVS)**
  - Band (detector) and mirror side dependent
- **Large SD degradation at shorter wavelengths, especially in Terra MODIS**
  - Potential increase of calibration uncertainty due to correction for large SD degradation
  - SD degradation at SWIR wavelengths not directly tracked
- **Impart due to on-orbit changes in Terra VIS/NIR polarization sensitivity**
  - Band (detector), mirror side, and AOI dependent
  - No noticeable changes in Aqua MODIS thus far
- **Aging instruments**
  - Undesirable features and unpredictable changes
  - Gradual increase of Aqua MODIS CFPA temperatures (loss of cooler margin)
  - Calibration impact due to potential satellite MLT drift
- **Senior Review (early 2015)**