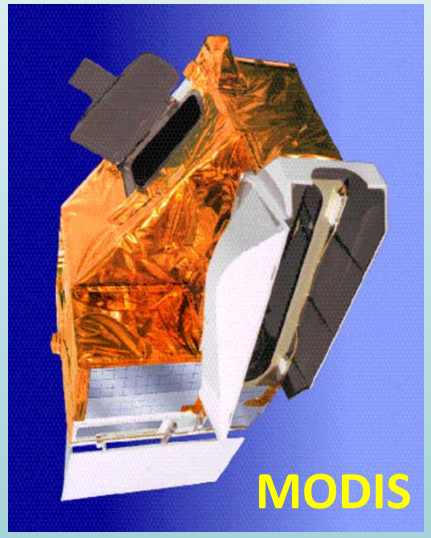
Terra and Aqua MODIS Instrument Status



Jack Xiong (618.0, NASA GSFC)

Contributions:

MODIS Characterization Support Team (MCST)

MODIS Science Team Meeting, Columbia, MD 21044 (April 29, 2014)

Outline

- Highlights (since last STM)
- Instrument Operations and Calibration Activities
- On-orbit Performance
- Collection 6 (C6) Status
- Challenging Issues and Future Efforts
- Summary

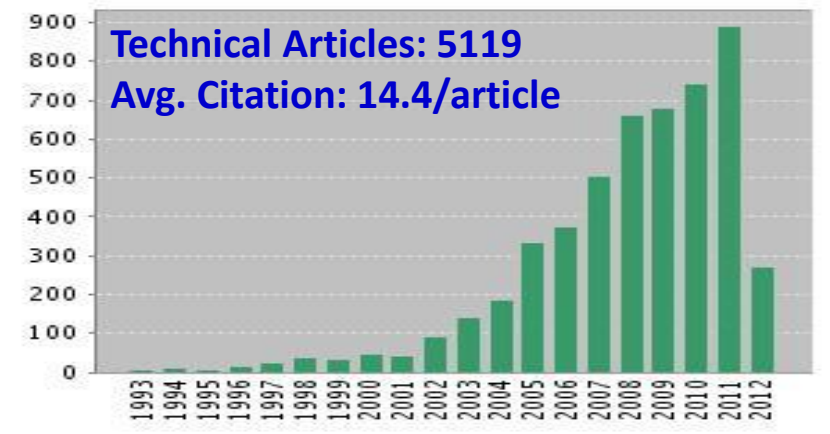
Highlights (since last STM) 1/2

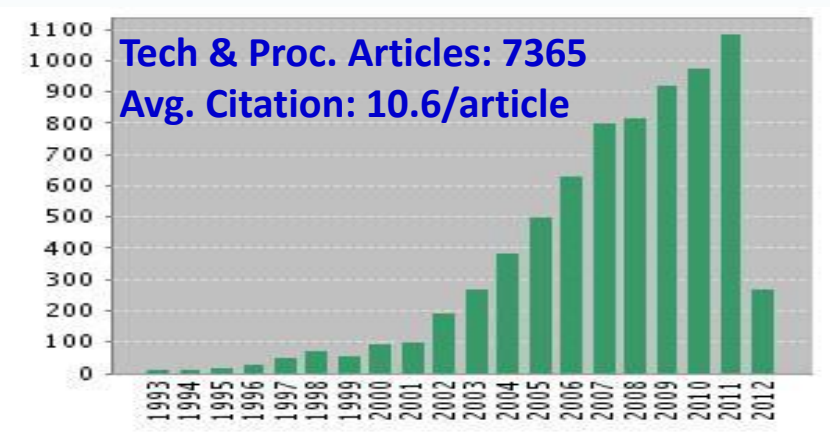
- **Both Terra MODIS (14 years) and Aqua MODIS (12 years) continue to operate and function normally**
  - No configuration changes in recent years
  - 2 new noisy detectors since last STM (T-MODIS B30 D7 in 2013 and B30 D4 in 2014)
- **L1B data processing**
  - C6 L1B reprocessing completed in 2012 and data released to public; forward processing started in 2012 and is currently at leading edge
  - Forward processing of C6 and C5 is expected to continue for a year after completion of the C6 land and atmosphere reprocessing
  - Update for Terra L1B to address trending in Terra band 5
- **L1B calibration LUT updates**
  - C6 new RVS approach applied to more VIS/NIR spectral bands
  - T-MODIS C5/C6 LUT updates: 14/14; A-MODIS C5/C6 LUT updates: 11/12
  - A number of special C6 LUTs delivered to OBPG

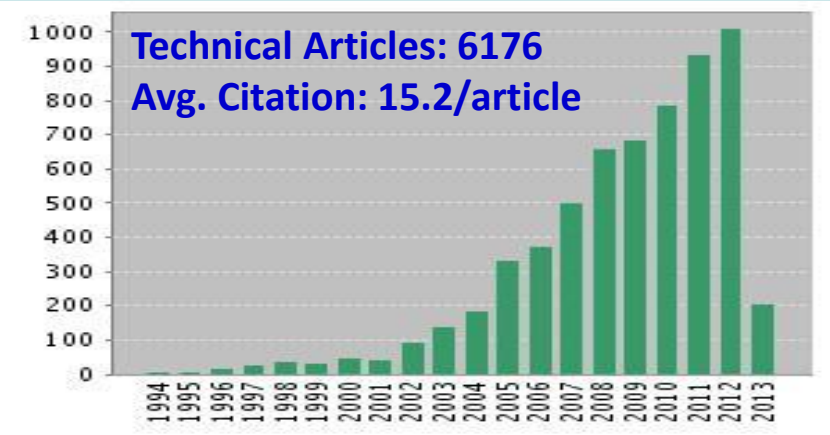
Highlights (since last STM) 2/2

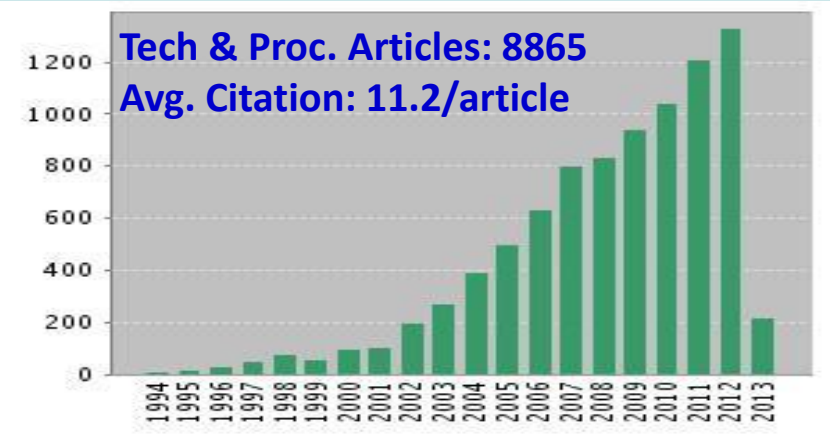
- **Terra MODIS Polarization Correction Working Meeting on Feb. 28, 2014**
  - 17 attendees all science discipline and MCST
  - 6 presentations on polarization correction and calibration improvement
- **Aqua MODIS CFPA Performance and Operation Review on April 14, 2014**
  - 1st: May 7, 2010
  - 2nd: April 24, 2012
  - 3rd: March 27, 2013
  - 4th: April 16, 2014
- **MODIS Calibration Workshop on May 1, 2014**
  - Bi-weekly MsWG meetings
  - Technical meetings on special topics with science discipline groups
- **Steady Increase of MODIS Publications**
  - Over 1200 new technical articles
  - Over 1100 new tech articles and proceedings combined

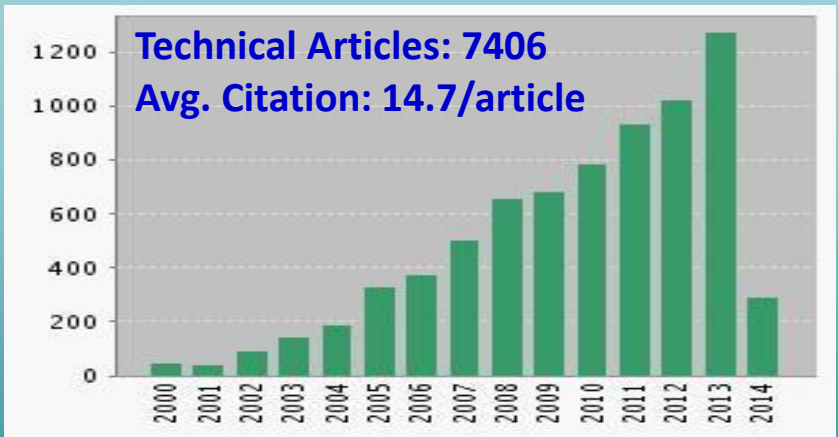
MODIS Publication Metrics

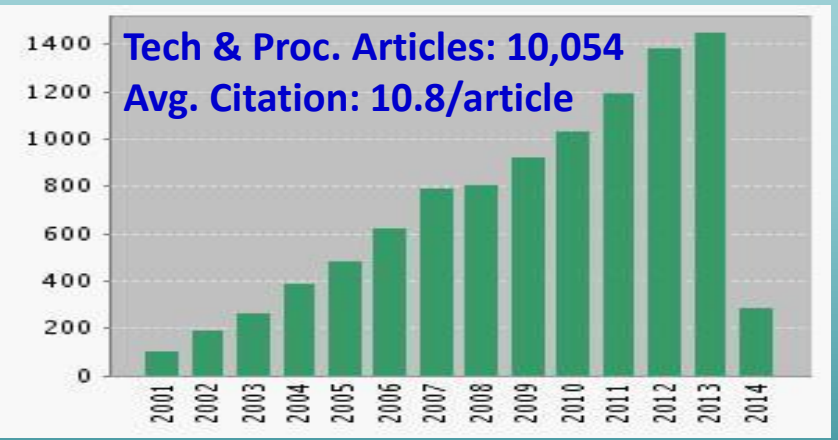












Instrument Operations and Calibration Activities

Terra MODIS

- Launch: Dec 18, 1999
- First light: Feb 24, 2000
- A-side: launch - Oct 30, 2000
- B-side: Oct 30, 2000 - June 15, 2001
- A-side: July 02, 2001 - Sept 17, 2002
- A-side electronics & B-side formatter: since Sept 17, 2002

- BB nominally set at 290 K
- SD door fixed at "open" since July 02, 2003
- SRCA operated with 2 10-W lamps since 2006
- CFPA controlled at 83 K (briefly at 85 K: 3-5 Aug 2000)

Aqua MODIS

- Launch: May 04, 2002
- First light: June 24, 2002
- B-side: launch - present

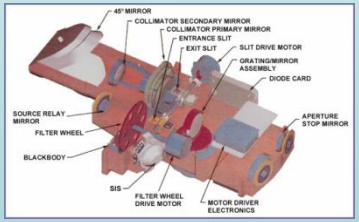
- BB nominally operated at 285 K
- SD calibration: gradually reduced frequency
- SRCA operated with 2 10-W lamps since 2005
- CFPA controlled at 83 K (small increase of CFPA temperatures since 2007)

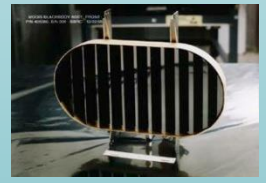
No Changes to Instrument Operation Configurations

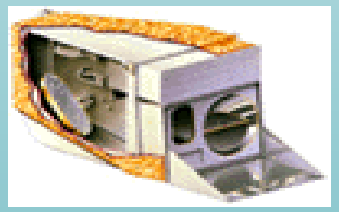
On-orbit Calibration and Characterization

Solar diffuser (SD) and solar diffuser stability monitor (SDSM) for reflective solar bands (RSB) calibration

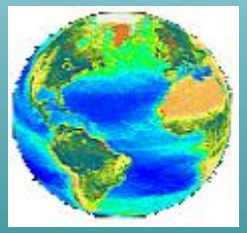
Spectroradiometric Calibration Assembly (SRCA) for instrument spectral and spatial characterization







Scan Mirror



Solar Diffuser

SDSM

SRCA

Blackbody

Space View

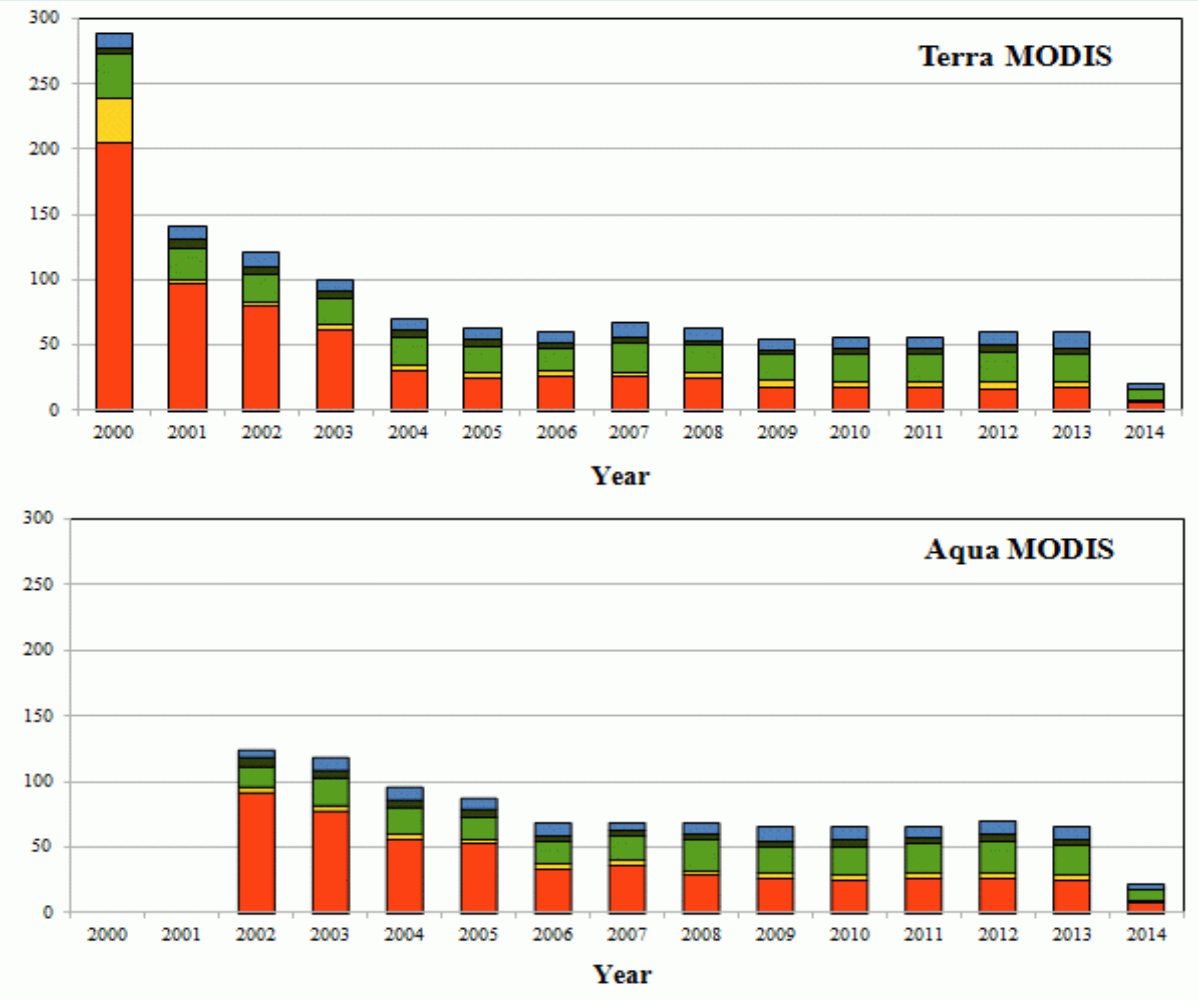
Blackbody (BB) for thermal emissive bands (TEB) calibration

Calibration Maneuvers

Lunar views through SV port

Calibration and Characterization Activities

Numbers of Calibration Events



	Terra	Aqua
Lunar Roll	136	116
PV Ecal	84	64
SRCA	396	271
BB	89	52
SD/SDSM	674	520

BB WUCD: 270 - 315K
SRCA: 3 modes

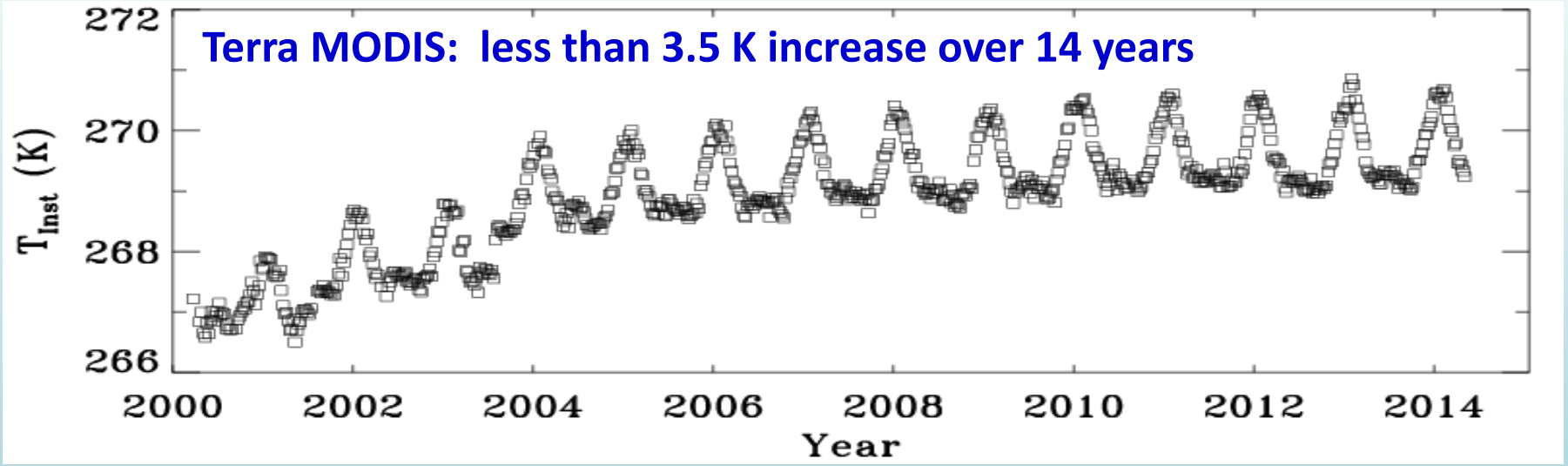
Others:
Maneuvers
Ground Targets
Inter-comparisons
Nighttime day mode ops

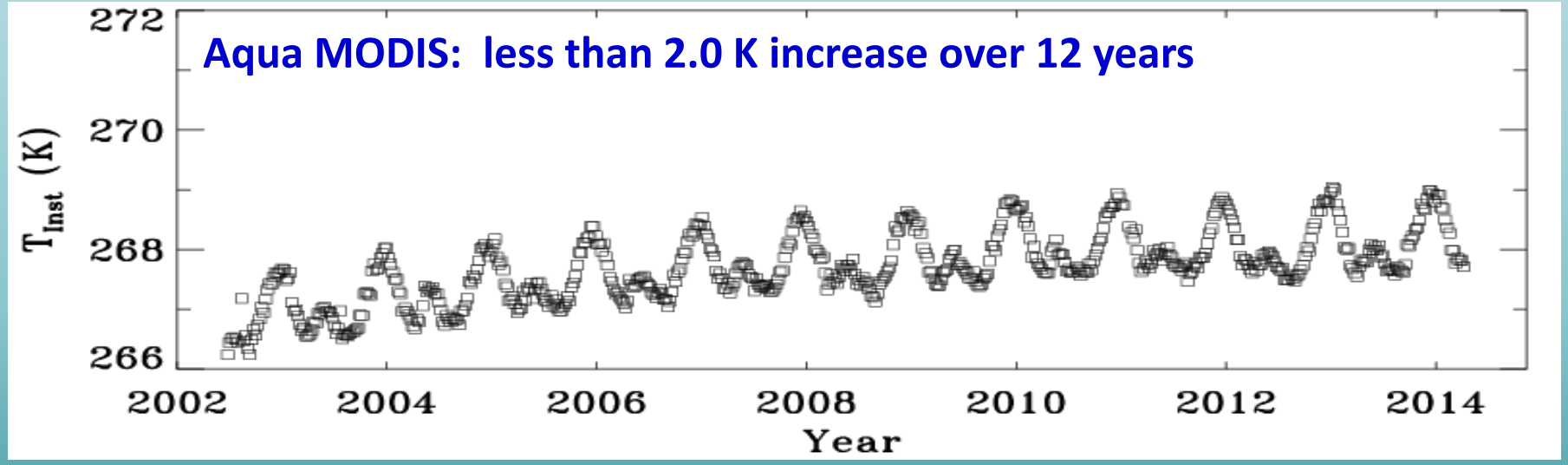
Details of Instrument Operation and Calibration: http://mcst.gsfc.nasa.gov/

On-orbit Performance

- **Instrument Temperatures**
- **On-board Calibrators (OBC)**
- **Radiometric**
  - Spectral band responses
  - Detector noise characterization
- **Spectral and Spatial**
  - Center wavelengths and bandwidths
  - Band-to-band registration (BBR)
- **Geolocation**

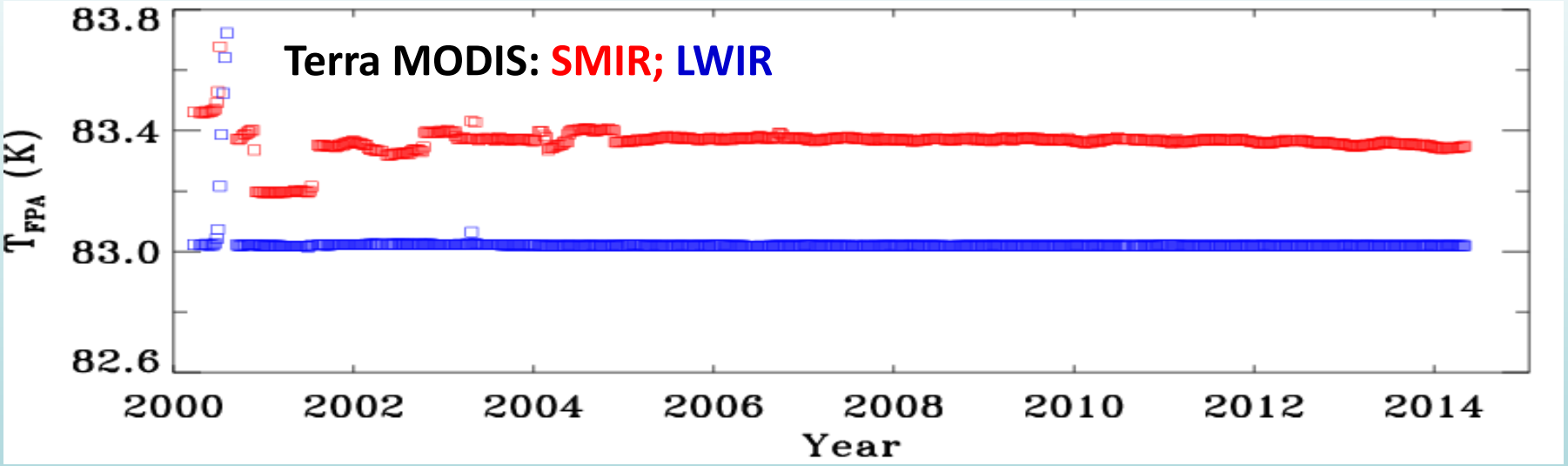
Instrument Temperatures

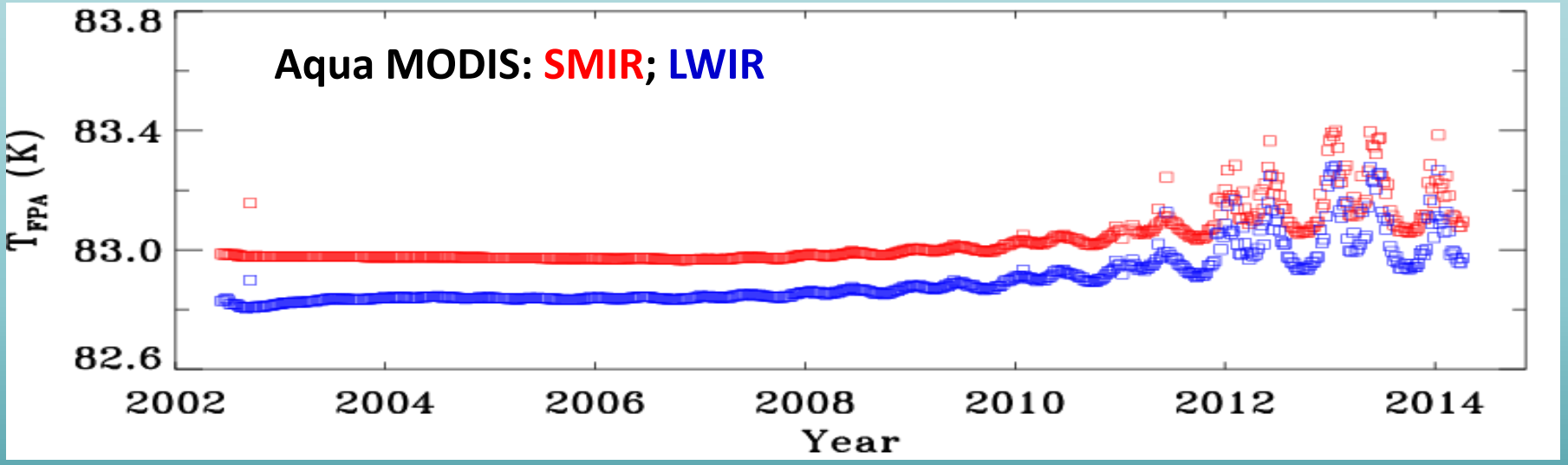




VIS & NIR FPA temperatures: similar to instrument temperatures

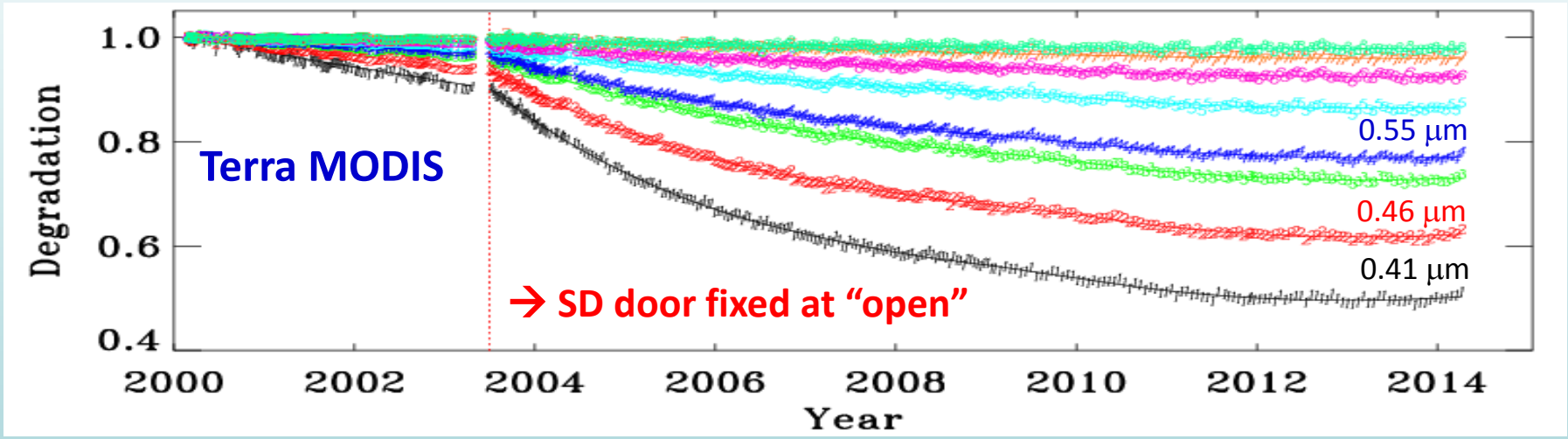
Cold FPA Temperatures

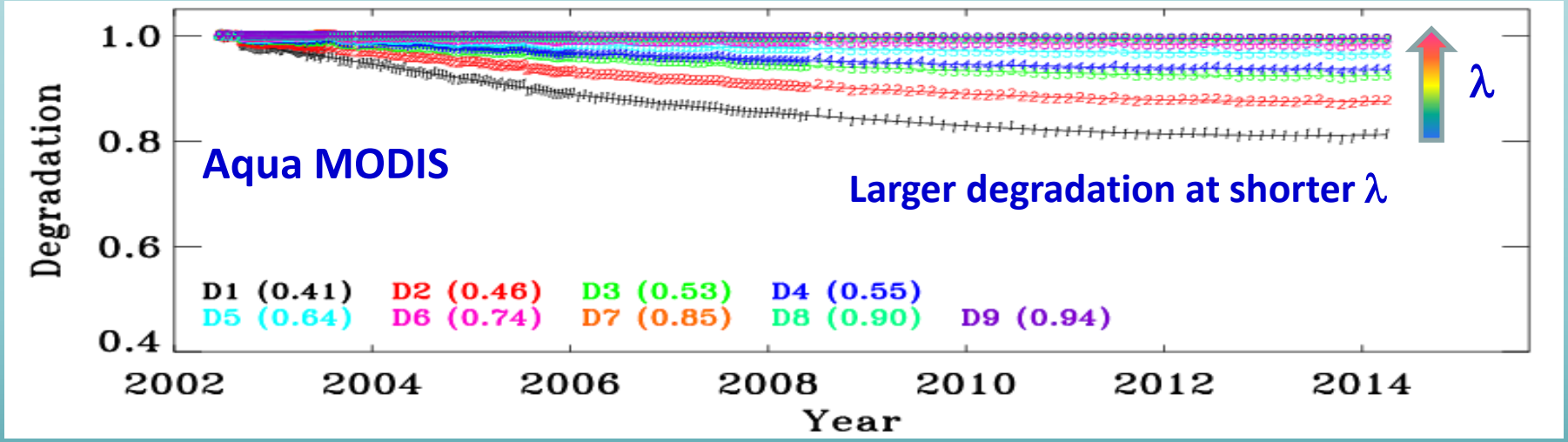




Aqua MODIS CFPA temperatures increase in recent years (0.7 K)

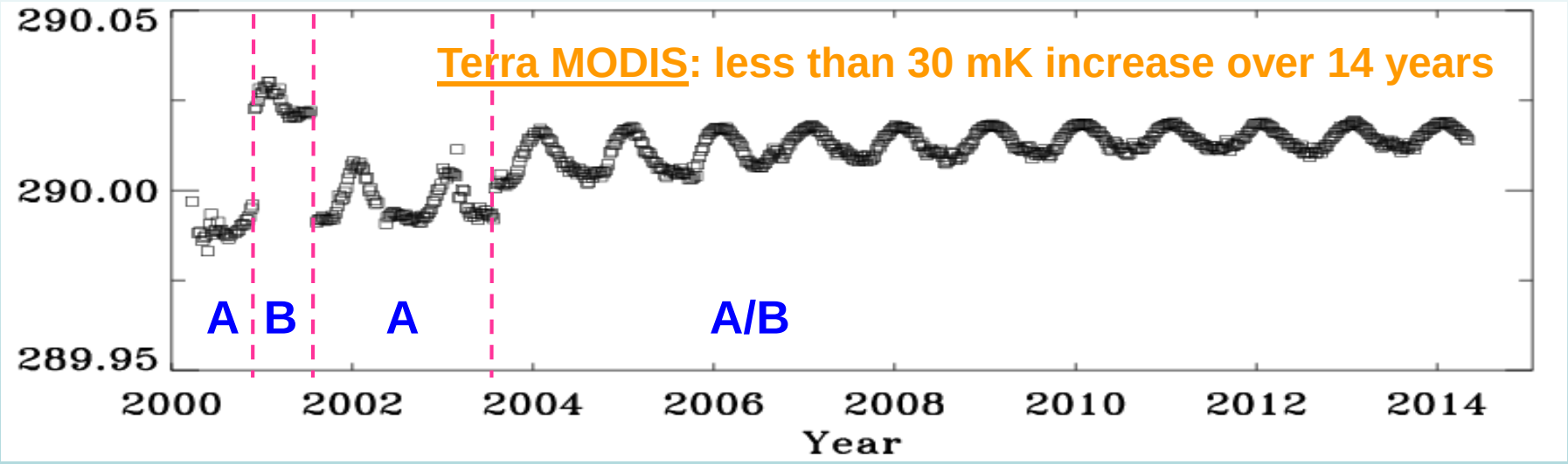
Solar Diffuser (SD) Degradation

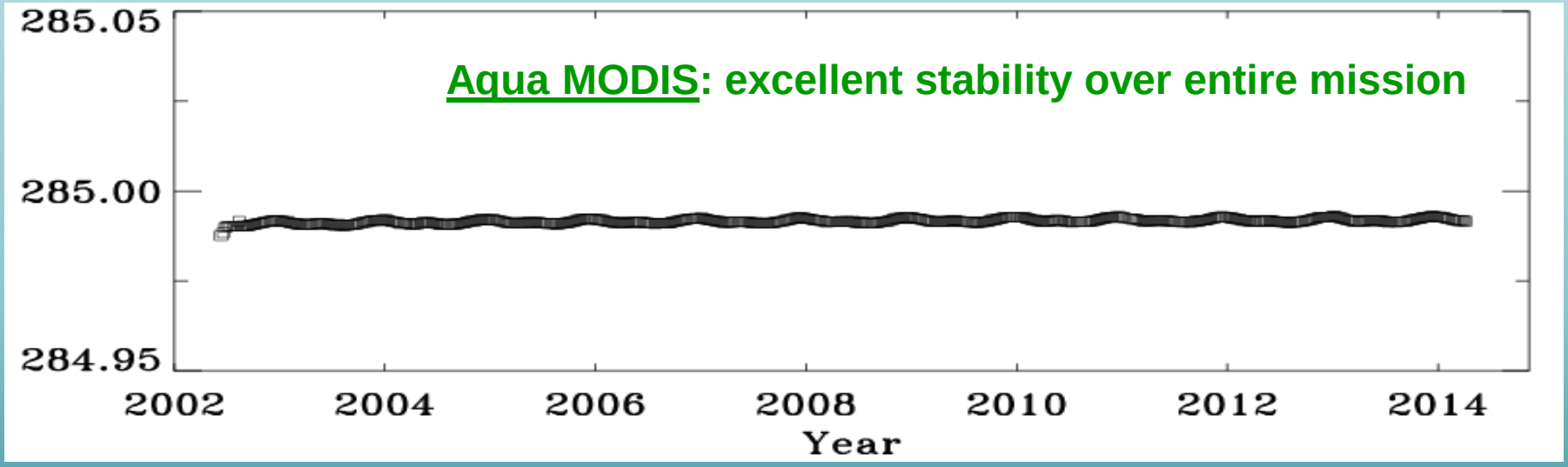




SD/SDSM calibration frequency has been gradually reduced in recent years

Blackbody Temperatures (nominal operation; **long-term**)



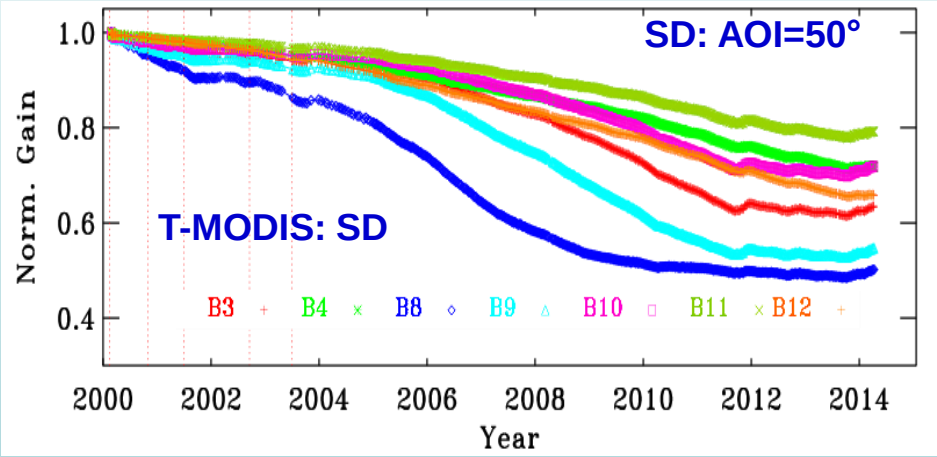


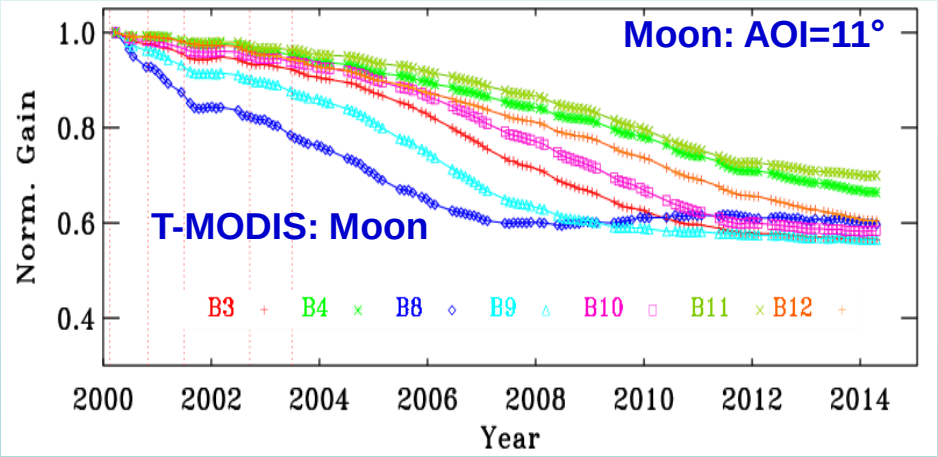
Radiometric Performance Summary

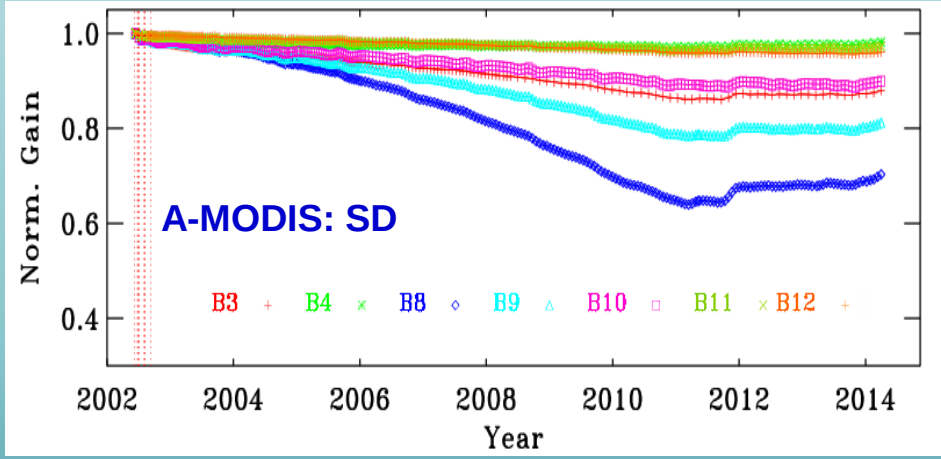
- **Changes in RSB responses are wavelength, mirror side, and scan angle dependent**
  - Shorter wavelength VIS bands show larger degradation
  - MS difference in Aqua MODIS is much smaller than Terra MODIS
  - A few NIR bands show gain increases over time
  - Changes in SWIR responses are very small (located on CFPA)
- **TEB responses are generally very stable**
  - Less than 2% changes over entire mission except for Terra LWIR PV bands
  - Changes up to 15% in Terra LWIR PV bands (27-30)
  - Small variations in Aqua LWIR PC bands (due to changes in CFPA temperatures)
- **Overall SNR and NEdT performance remains satisfactory**
  - Most post-launch noisy detectors have been in the LWIR PV bands (27-30)
  - Only 3 new noisy detectors (Terra B30 D7 and D4; Aqua B29 D6) in last 5 years

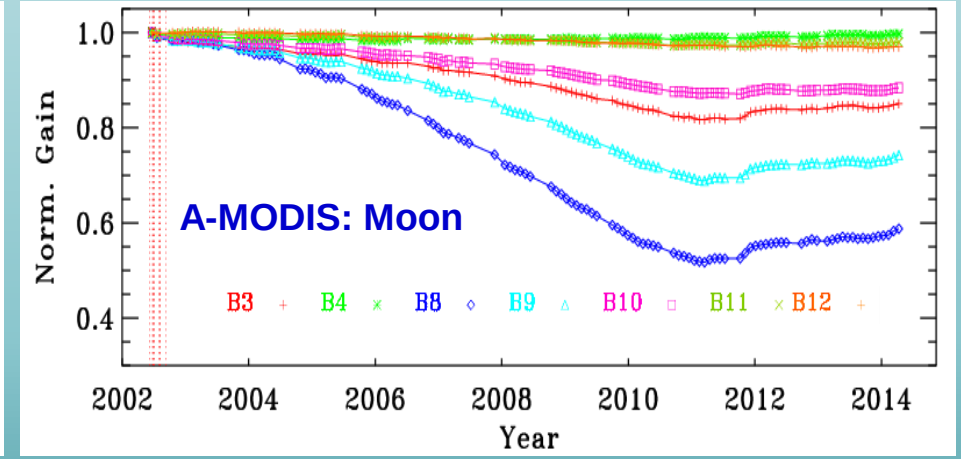
Spectral Band Responses (VIS)

Band Averaged, Mirror Side 1







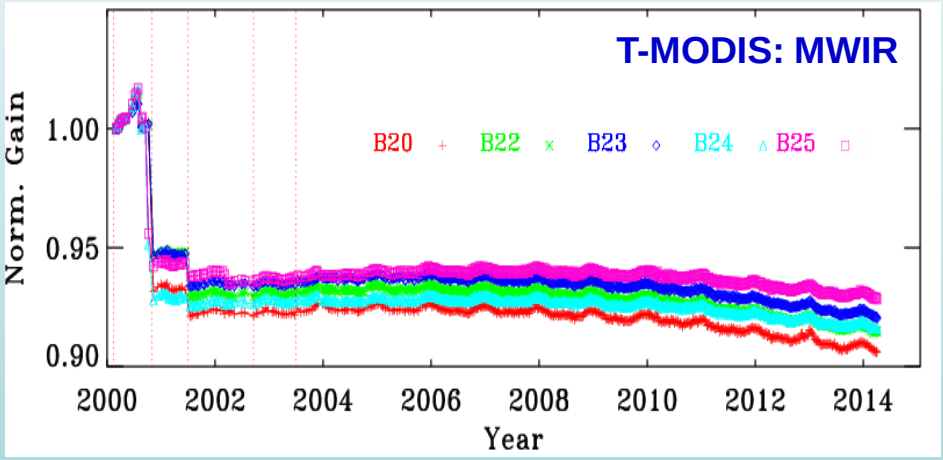


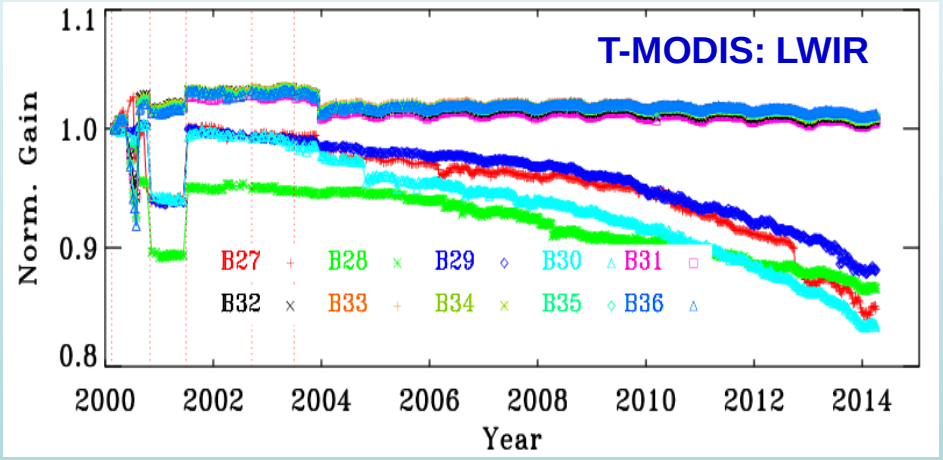
Larger changes at shorter wavelengths

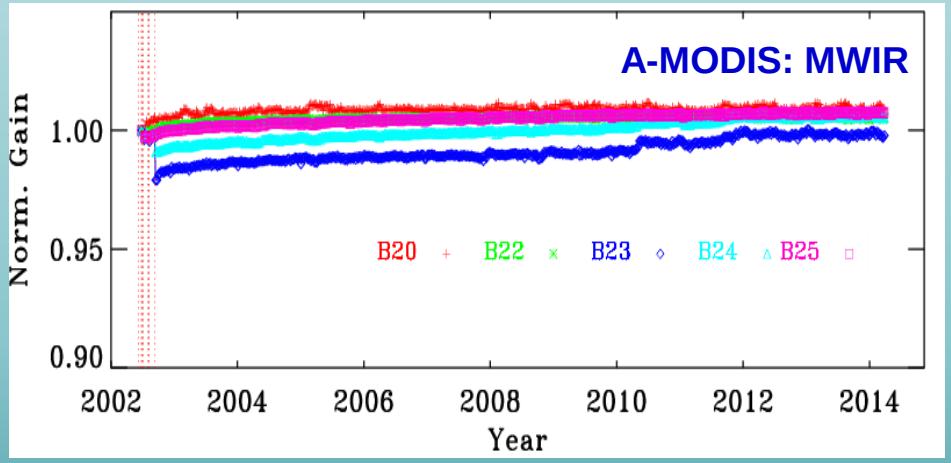
Wavelength, AOI, and mirror side dependent (small MS diff. in A-MODIS)

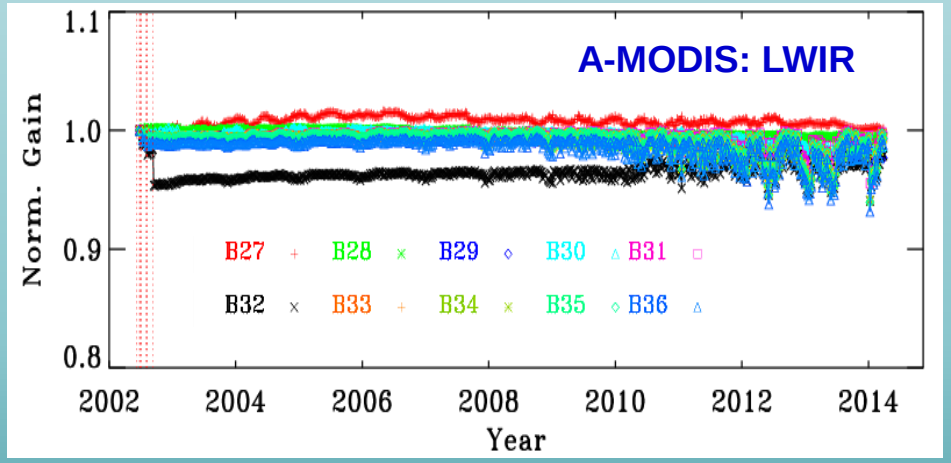
Spectral Band Responses (MWIR & LWIR)

Band Averaged, Mirror Side 1









Noticeable variations in Aqua MODIS LWIR response are due to variations in its CFPA temperatures (loss of cooler margin)

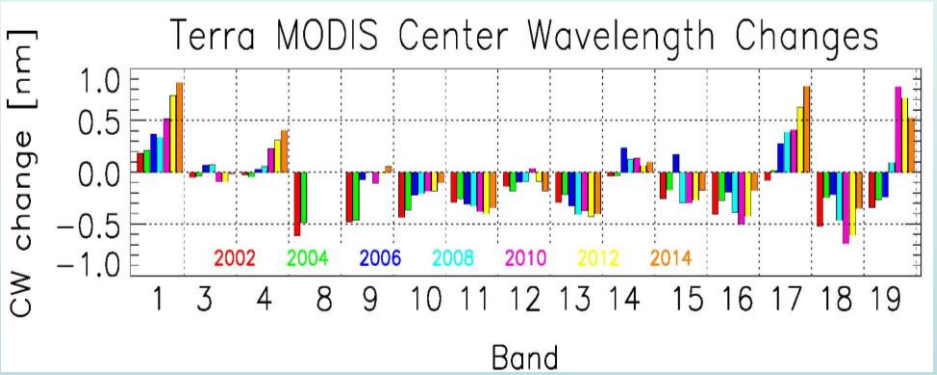
Detector Noise Characterization

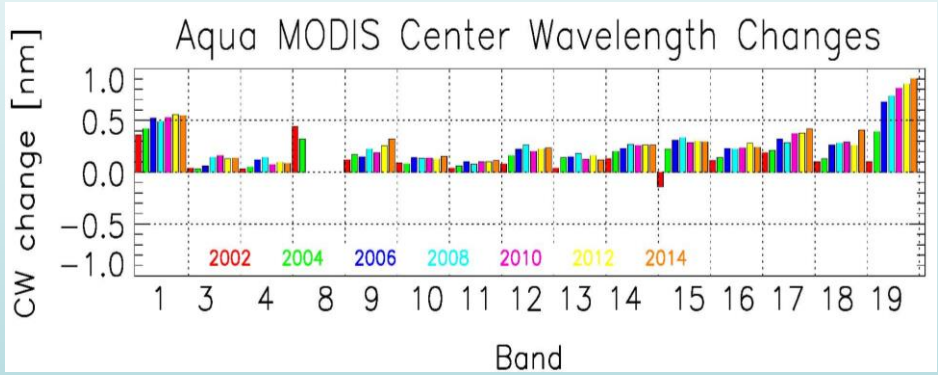
- **36 Spectral Bands with 490 individual detectors**
  - 3 new noisy detectors since 2009 (Aqua B29 D6, Terra B30 D7 and D4)
- **Terra: 47 noisy detectors (30 from pre-launch : 35 at launch) and no inoperable detectors**
  - B30 D4 became noisy recently (2014)
  - B29 D6 set to inoperable (2016)
- **Aqua: 7 noisy detectors (2 from pre-launch: 3 at launch) and 15 inoperable detectors (13 in Band 6)**

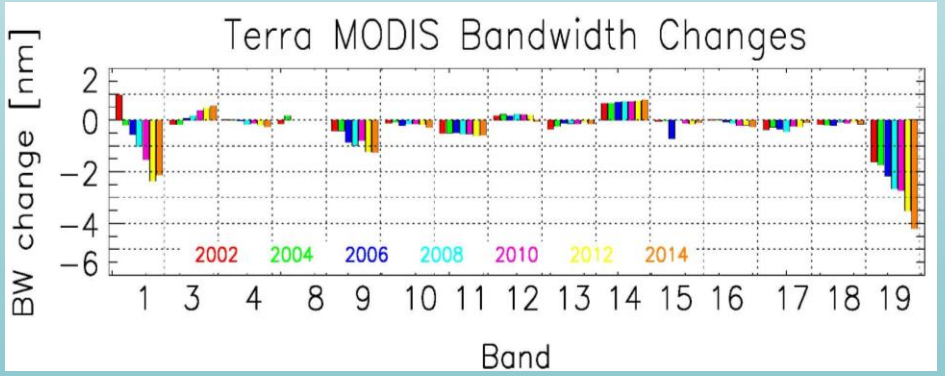
Time	Event	Noisy Band (Detector)
Pre-launch		B7(all), B36(all)
2000055.1527	Nadir Door Open	B5(4,16), B7(all), B33(1), B34(7,8), B36(all)
2000160.0000	CFPA Lost Control	B5(4,16), B7(all), B30(5) B33(1), B34(7,8), B36(all)
2000218.2210	Formatter Anomaly	B5(4,16), B7(all), B27(6), B30(5), B33(1), B34(6,7,8), B36(all)
2000304.1420	Switch to B-Side	B5(4,16), B7(all), B27(6), B30(5), B33(1), B34(6,7,8), B36(all)
2001019.1415	N/A	B5(4,16), B7(all), B27(6), B30(5, 8), B33(1), B34(6,7,8), B36(all)
2001183.2245	Switch to A-Side	B5(4), B7(all), B27(6), B30(5, 8), B33(1), B34(6,7,8), B36(all)
2002078.1615	Safe Mode	B5(4), B7(all), B27(6), B28(3), B30(5,8), B33(1), B34(5,6,7,8), B36(all)
2003350.1305	Safe Mode	B5(4), B7(all), B27(1,6), B28(8), B30(5,8), B33(1), B34(6,7,8), B36(all)
2005130.1345	SAA (Day)	B5(4), B7(all), B27(1,6), B28(1,8), B29(6), B30(5,8), B33(1), B34(6,7,8), B36(all)
2005309.1510	N/A	B5(4), B7(all), B27(1,6), B28(8,9), B29(6), B30(5,8), B33(1), B34(6,7,8), B36(all)
2006155.0210	SAA (Night)	B5(4), B7(all), B27(1,6), B28(8), B29(6), B30(3,5,8), B33(1), B34(6,7,8), B36(all)
2007193.1155	SAA (Day)	B5(4), B7(all), B27(1,6), B28(8), B29(6), B30(3,5,8), B33(1), B34(6,7,8), B36(all)
2008308.0900	SAA (Night)	B5(4), B7(all), B27(1,2,6), B28(8), B29(6), B30(1,3,5,8), B33(1), B34(6,7,8), B36(all)
2013125.1740	SAA (Night)	B5(4), B7(all), B27(1,2,6), B28(8), B29(6), B30(1,3,5,7,8), B33(1), B34(6,7,8), B36(all)

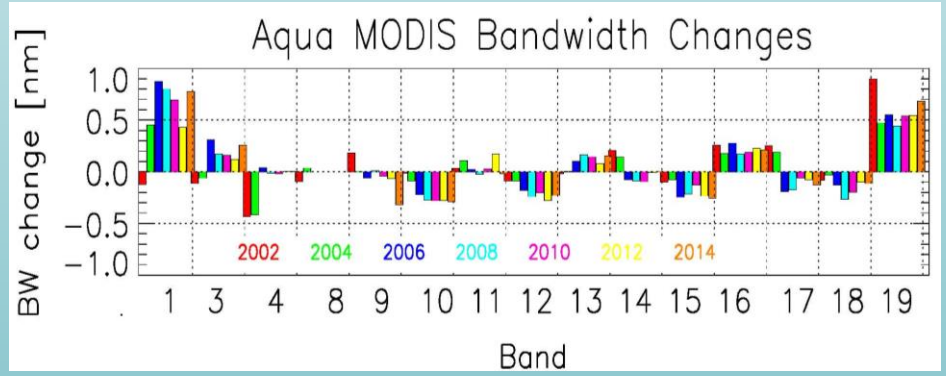
Time	Event	Noisy Band (Detector)	Inoperable Band (Detector)
Pre-launch		B6(17), B20(10)	B5(20), B6(2,12-14,16,18-20), B36(5)
2002175.2324	Nadir Door Open	B6(7,9,17)	B5(20), B6(2,4-6,10,12-16,18-20), B36(5)
2005010.1715	(Day)	B6(7,9,17), B27(3)	B5(20), B6(2,4-6,10,12-16,18-20), B36(5)
2007359.1020	N/A	B6(7,9,17), B27(3), B29(8)	B5(20), B6(2,4-6,10,12-16,18-20), B36(5)
2008038.1750	(Day)	B6(7,9,17), B27(3), B29(2,8)	B5(20), B6(2,4-6,10,12-16,18-20), B36(5)
2012022.1510	SAA (Day)	B6(7,9,17), B27(3), B29(2,6, 8)	B5(20), B6(2,4-6,10,12-16,18-20), B36(5)

Spectral Characterization Performance





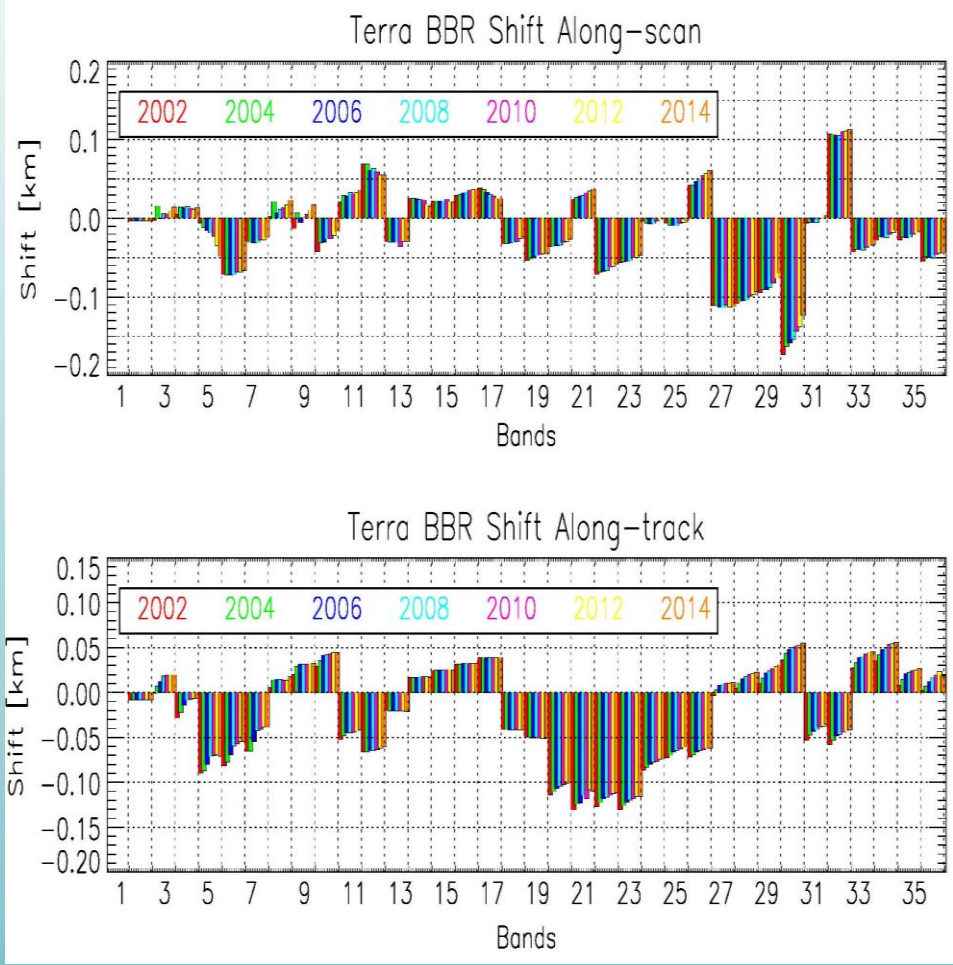


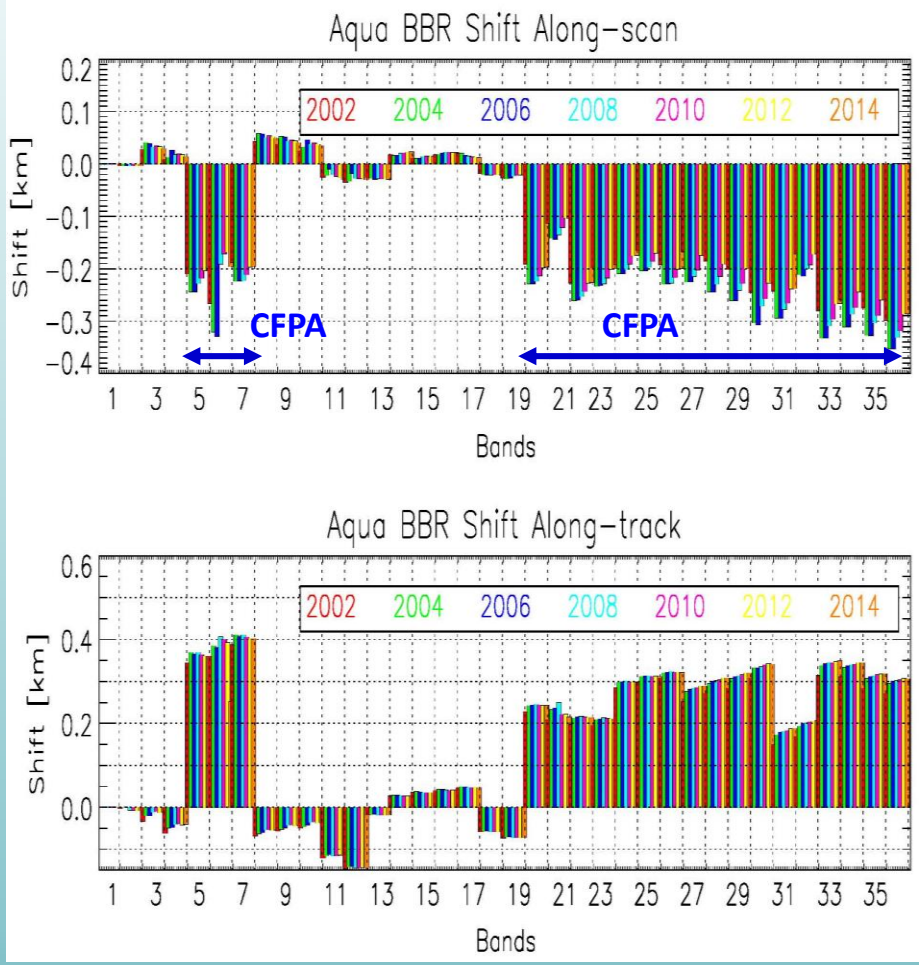


CW and BW changes are within 0.5 nm and 1.0 nm, respectively, for most VIS/NIR bands

Relatively large changes are observed for bands with broad bandwidths (bands 1, 18, 19)

Spatial Characterization Performance

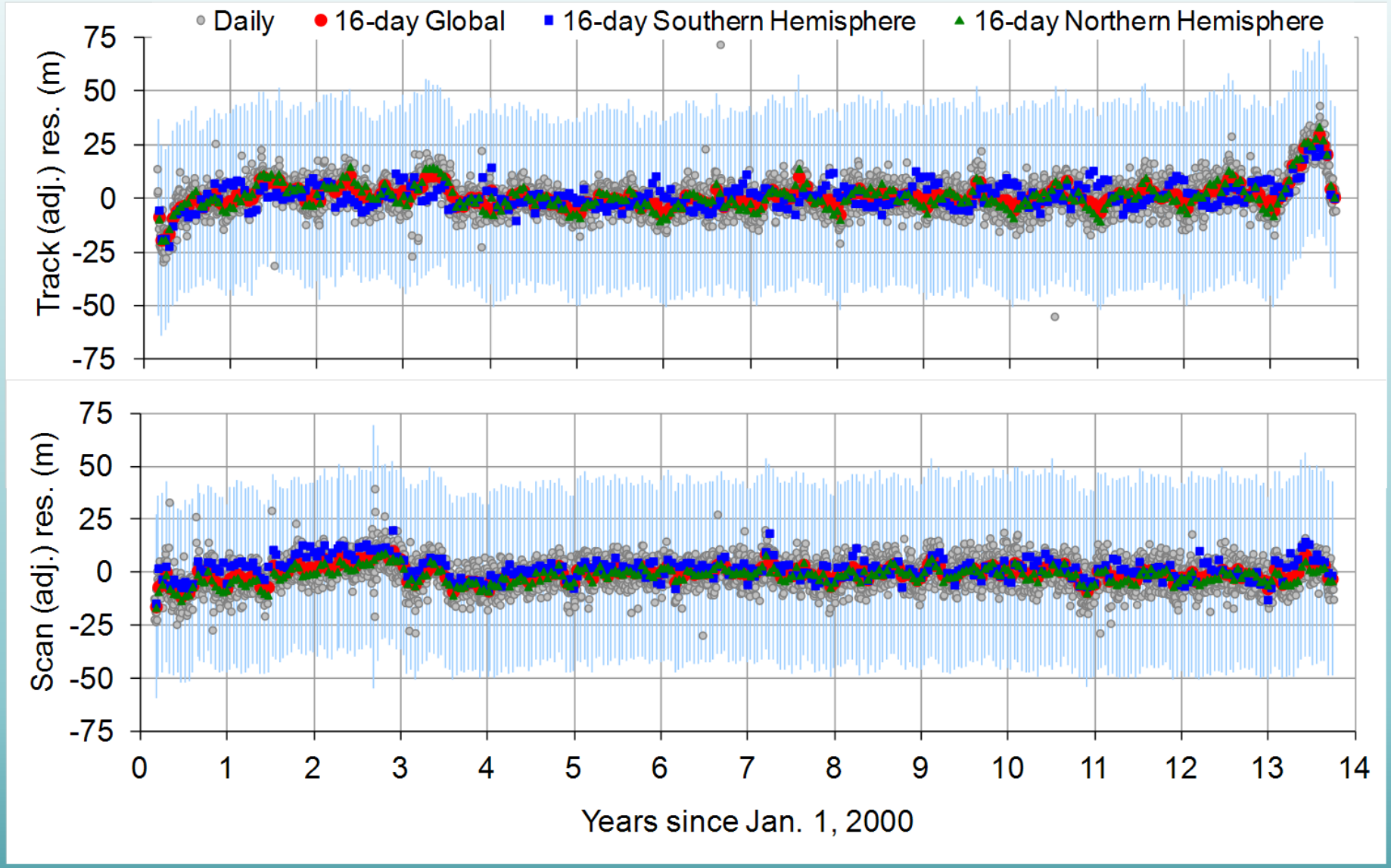




Terra BBR: within spec (±0.1 km) for all band pairs (except for along scan B30 and B32)

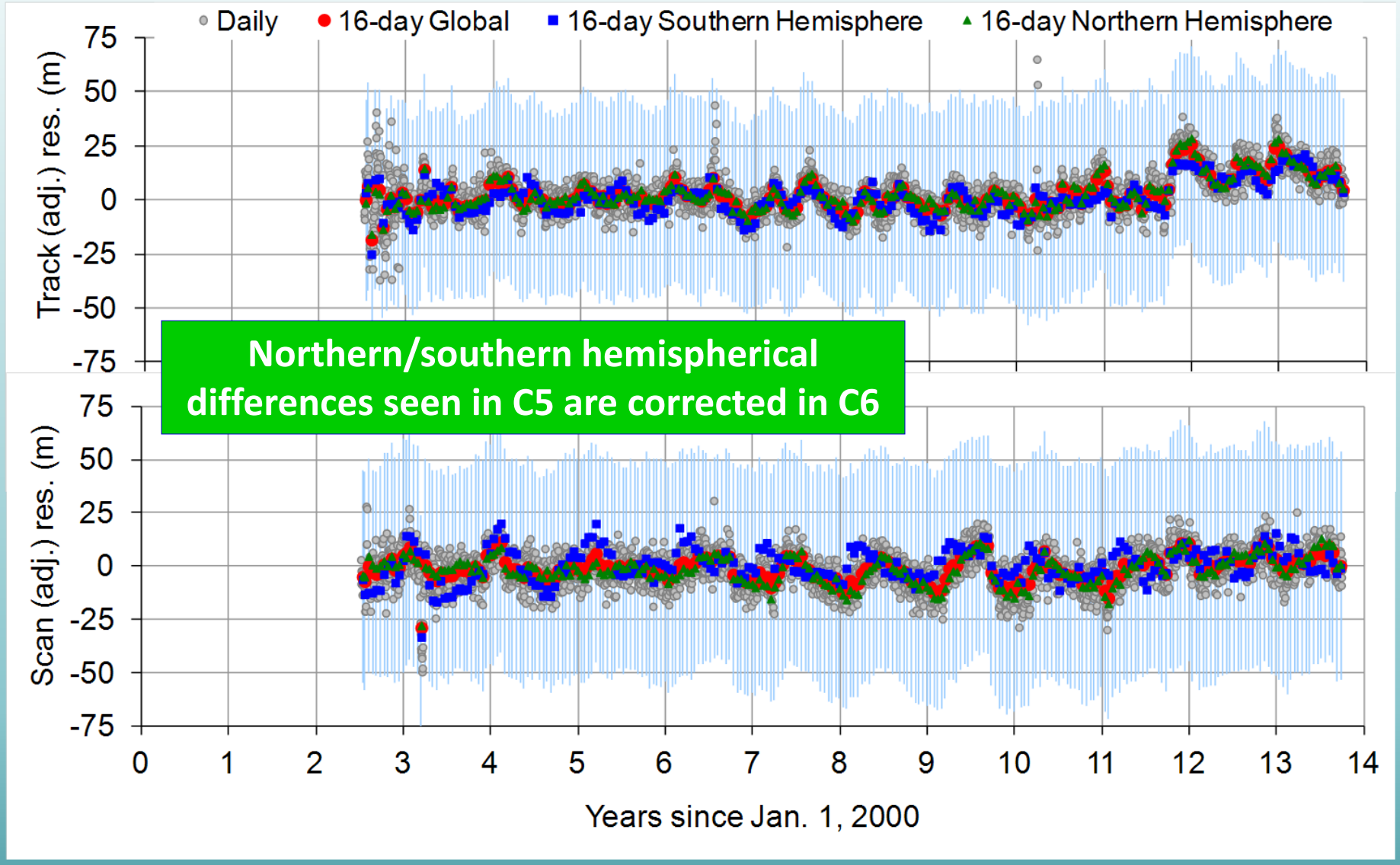
Aqua BBR: a known issue since pre-launch

Terra MODIS Geolocation Results (C6)



Robert Wolfe et al. RMSE Track: 43 m Scan: 44 m

Aqua MODIS Geolocation Results (C6)



Robert Wolfe et al. RMSE Track: 46 m Scan: 53 m

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)**

Details to be discussed in MODIS Calibration Workshop (May 1, 2014

Terra MODIS PC Working Meeting (Feb 28, 2014)

Coordinators: Steve Platnick and Jack Xiong

Presentations:

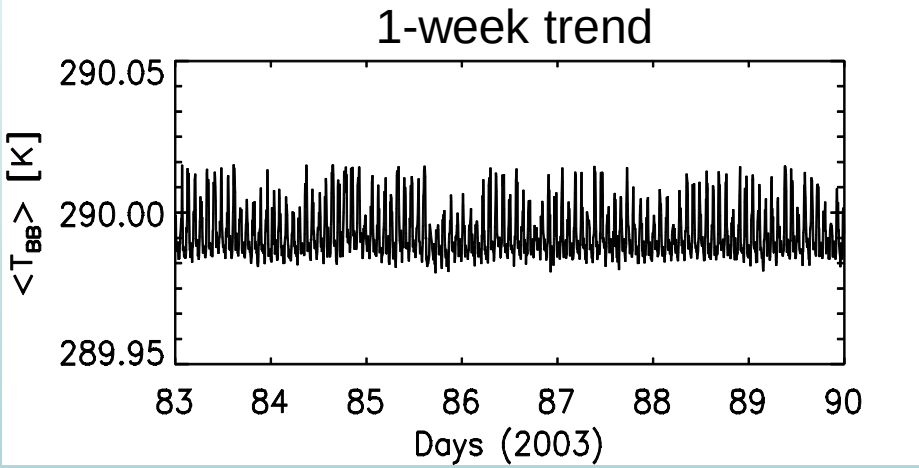
- MODIS Collection-6 RSB Calibration and Polarization Impact (MCST/Wu)
- Polarization Sensitivity and Corrections for the MODIS Terra Ocean Color products (OBPG/Meister)
- MODIS dark-target aerosol product: Issues related to calibration and polarization (Atmosphere/Levy)
- The Effects of Polarization Calibration Correction On Terra/MODIS Deep Blue Aerosol Retrievals (Atmosphere/Hsu)
- Science Impact of MODIS Terra Calibration Degradation/Polarization Sensitivity (Vegetation and Aerosol Data Products) (Land/Atomsphere/Lyapustin)
- MODIS Polarization Correction for Terra Bands 1-4 and 8 (Land/Vermote)

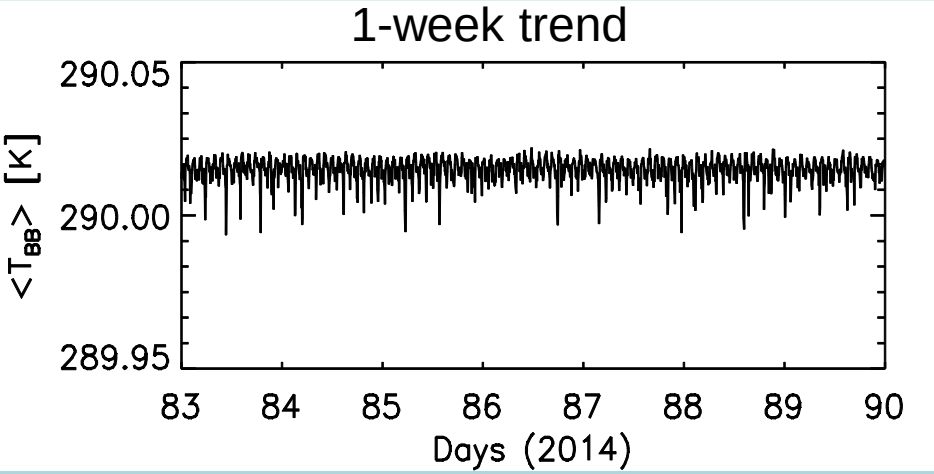
Summary

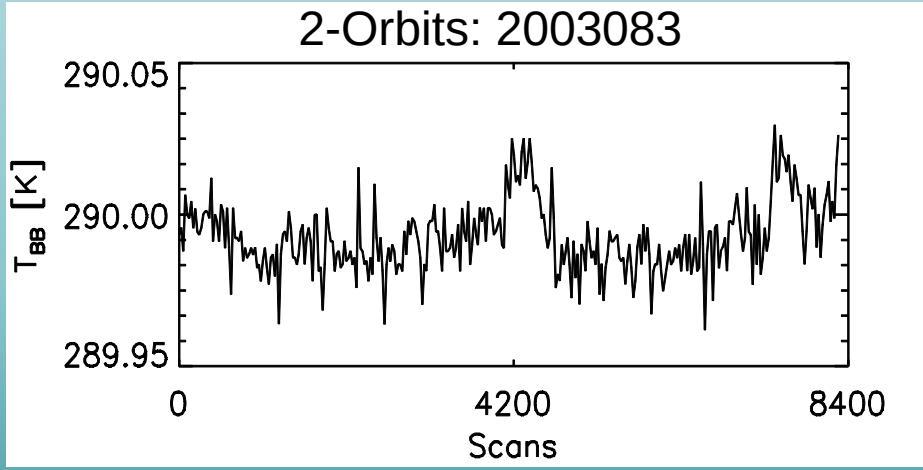
- **Both Terra MODIS (14 years) and Aqua MODIS (12 years) and key on-board calibrators continue to operate and function normally**
  - Only 2 new noisy detectors since last STM
- **Extensive calibration effort by MCST in support of C6 (and C5) L1B data processing**
  - Many regular and special LUTs (C5 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**

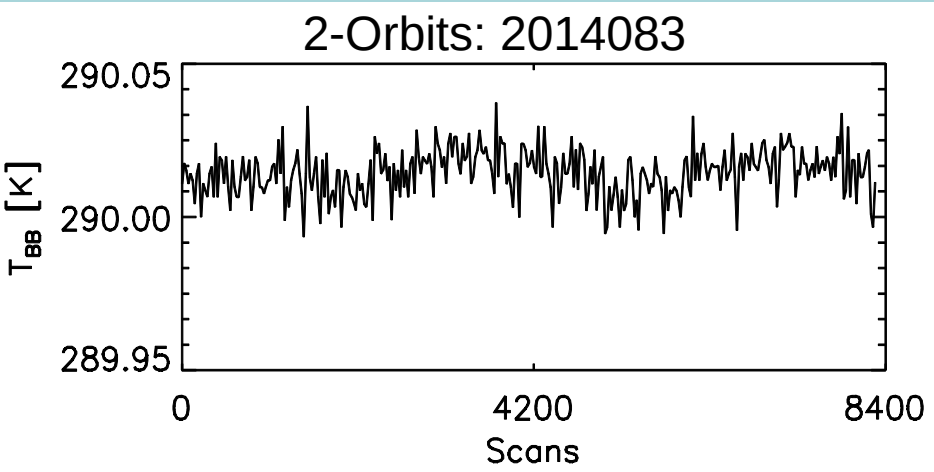
Blackbody Temperatures (nominal operation)

Terra MODIS: short-term



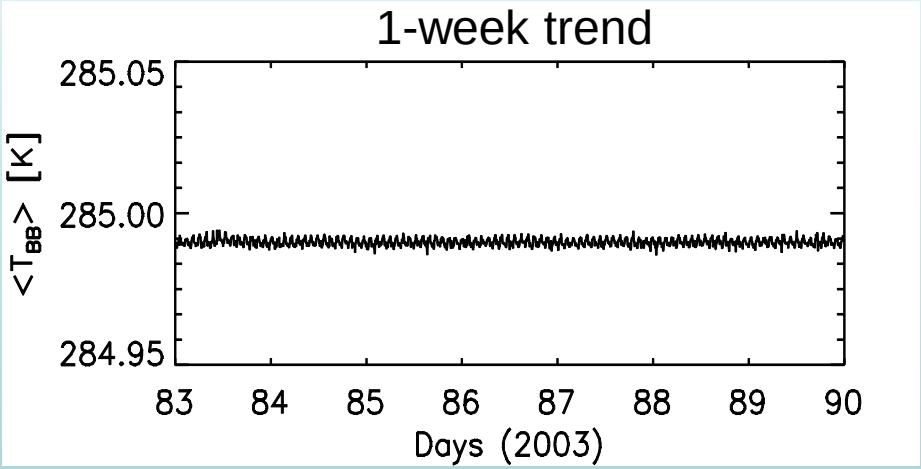


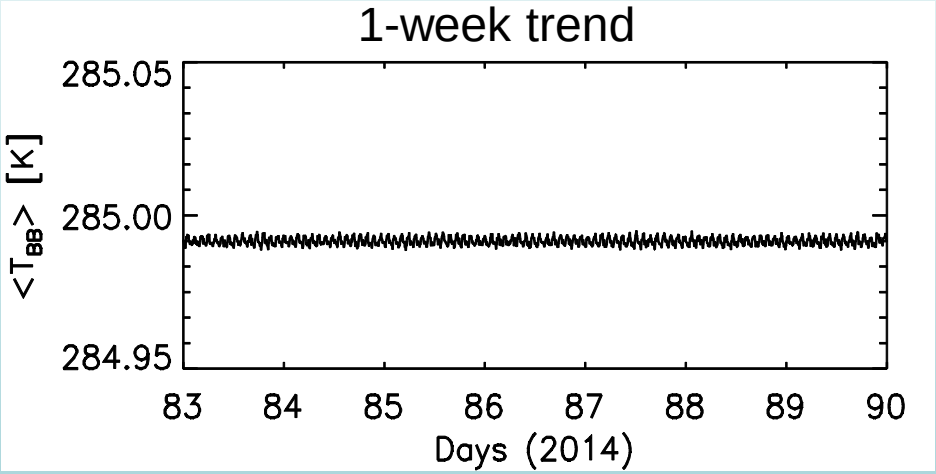


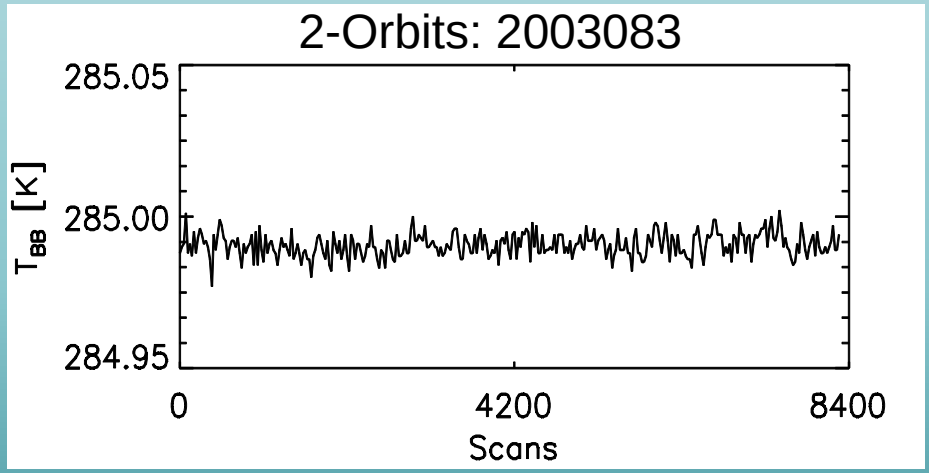


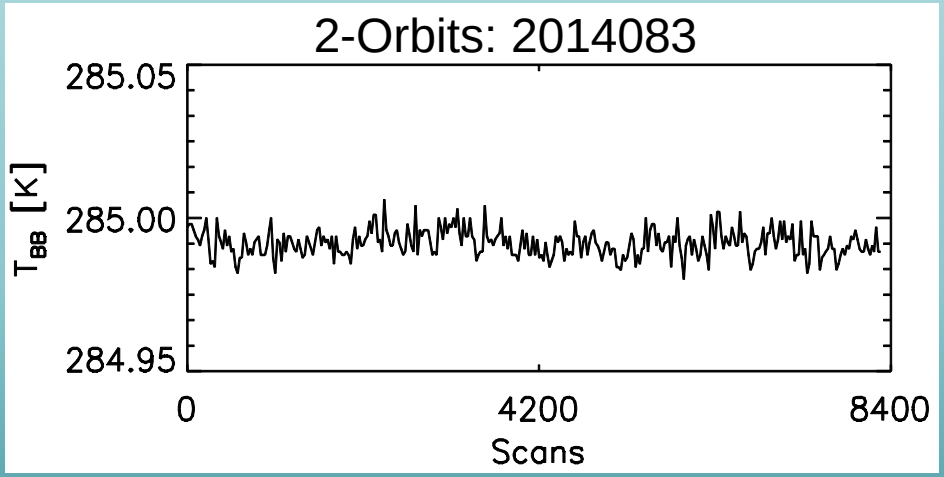
Blackbody Temperatures (nominal operation)

Aqua MODIS: short-term



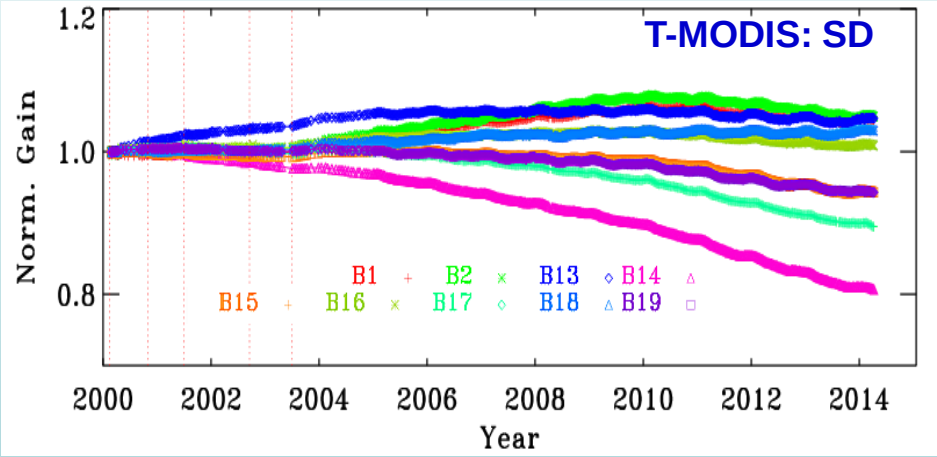


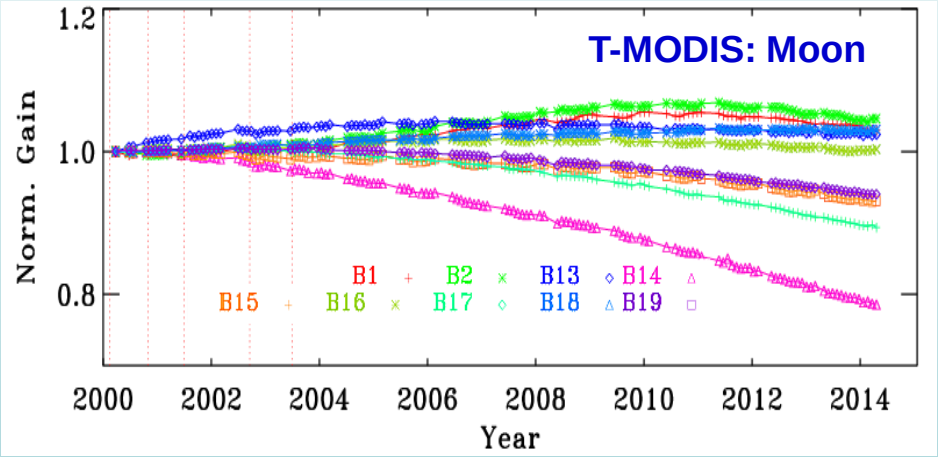


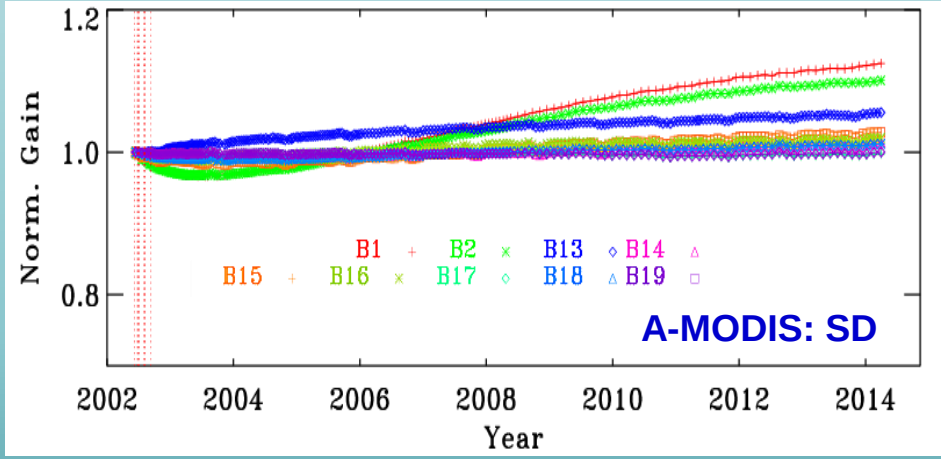


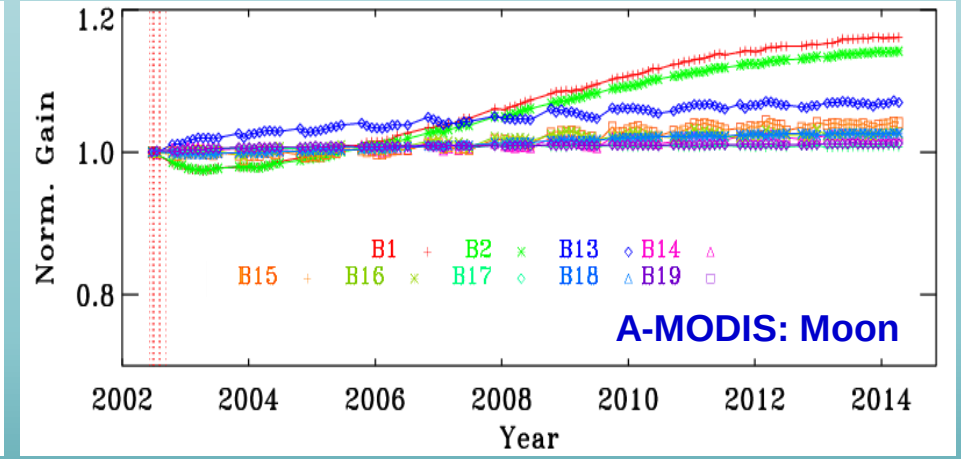
Spectral Band Responses (NIR)

Band Averaged, Mirror Side 1









Some NIR bands show gain increase over time

Collection 5 (C5) Forward Processing Status

- Forward processing (C5 Land and C51 Atmosphere) is typically 1-2 days behind real time.
- NRT processing is completed typically 2 hours after acquisition of data
- The C4.1 LST (C4 code with C5 L1 input) is processed and archived at LAADS
- C5/C5.1/C4.1 processing could be continued for a year after completion of C6 land and atmosphere reprocessing.
- Products from C5 processing is expected to be available from DAAC for a year after completion of the C6 reprocessing.

Collection 6 (C6) Reprocessing Status

- **L1, Geolocation, and L1B**
  - C6 reprocessing of Aqua and Terra completed in 2012.
  - Forward processing of Terra and Aqua L1B started in 2012 and is currently at leading edge.
  - C6 Products have been available to public since late 2012 from LAADS.
  - Forward processing of C6 and C5 is expected to continue for a year after completion of the C6 land and atmosphere reprocessing.
  - MCST continues to derive and deliver forward LUT updates for the two processing streams as needed
  - Update expected for Terra L1B to address trending in Band 5.

Collection 6 (C6) Reprocessing Status

- **Atmosphere Products**
  - C6 reprocessing of Cloud Mask and Atmospheric Profile completed and forward processing is at leading edge.
  - Reprocessing of other L2 products from Aqua MODIS started on 12-06-2013. Processing completed for the mission period 2002185 – 2013177.
  - Reprocessing of Terra is expected to start after completion of the Aqua.
- **Land Products**
  - Evaluation of C6 algorithm changes is in progress.
  - Reprocessing for the first tier of products expected to start in June 2014.
  - Reprocessing will use L1B with correction for the polarization in Terra and Aqua.

Details in Science Discipline Reports on Data Product & Algorithm Status