



Status of Aqua MODIS Reflective Solar Bands Calibration and Performance

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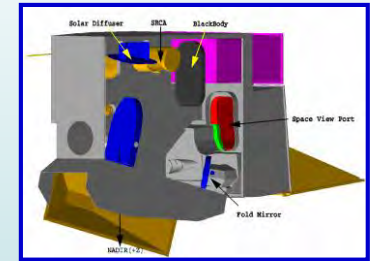
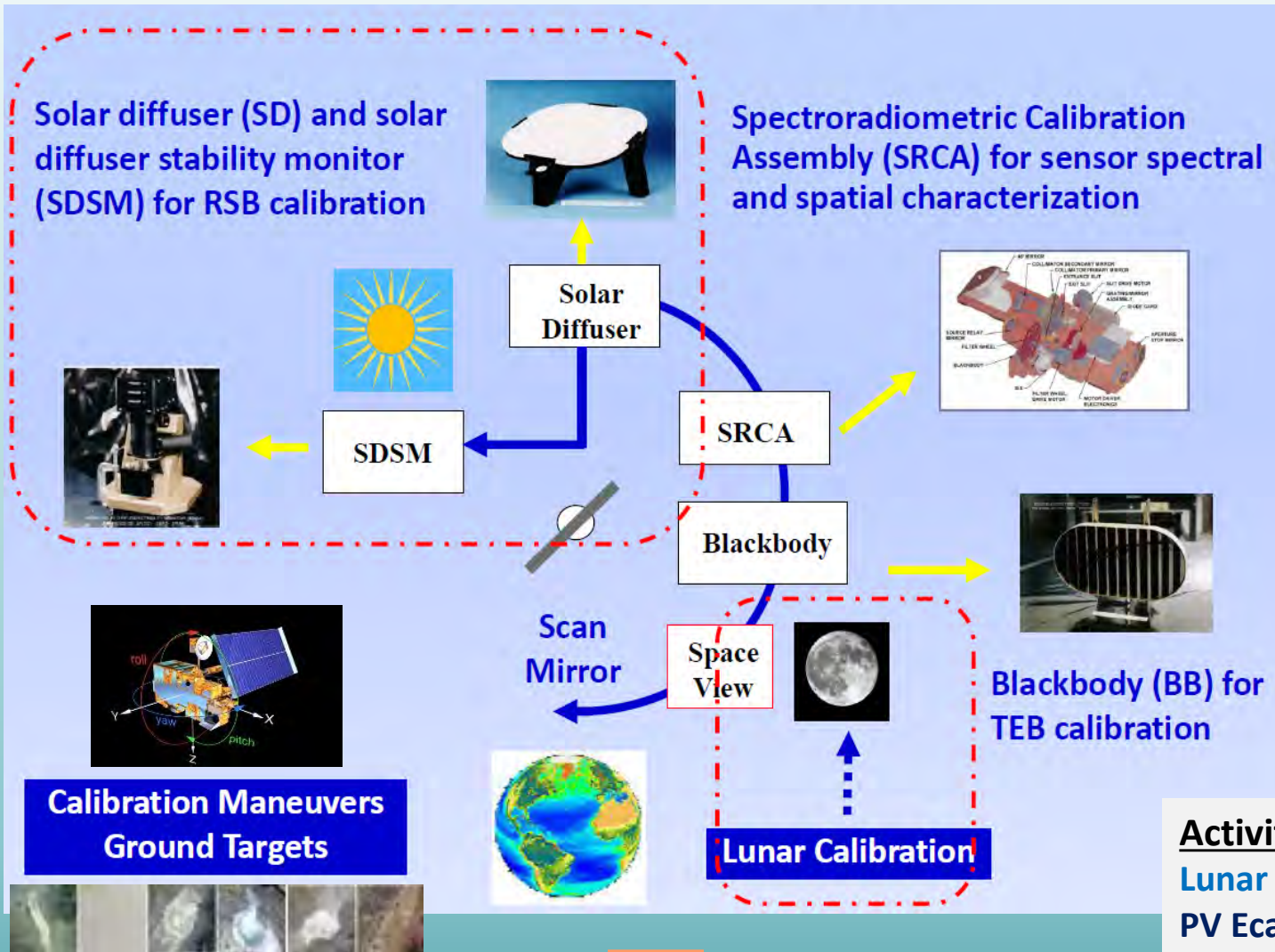
Outline

- **Calibration Methodologies**
- **On-orbit Performance**
- **Challenges and Future Improvements**
- **Summary**

Focus on Aqua MODIS ocean color reflective solar bands (RSB)

Backup slides for instrument background

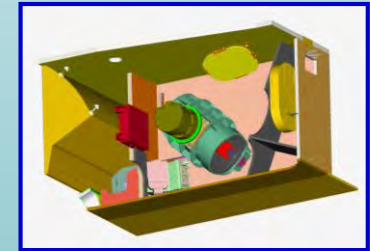
Calibration Methodologies



MODIS



VIIRS



Activities	Terra	Aqua
Lunar Roll:	149	123
PV Ecal:	88	67
SRCA:	412	289
BB:	95	57
SD/SDSM:	91	536

**Calibration Accuracy Requirements:
2% in reflectance and 5% in radiance**

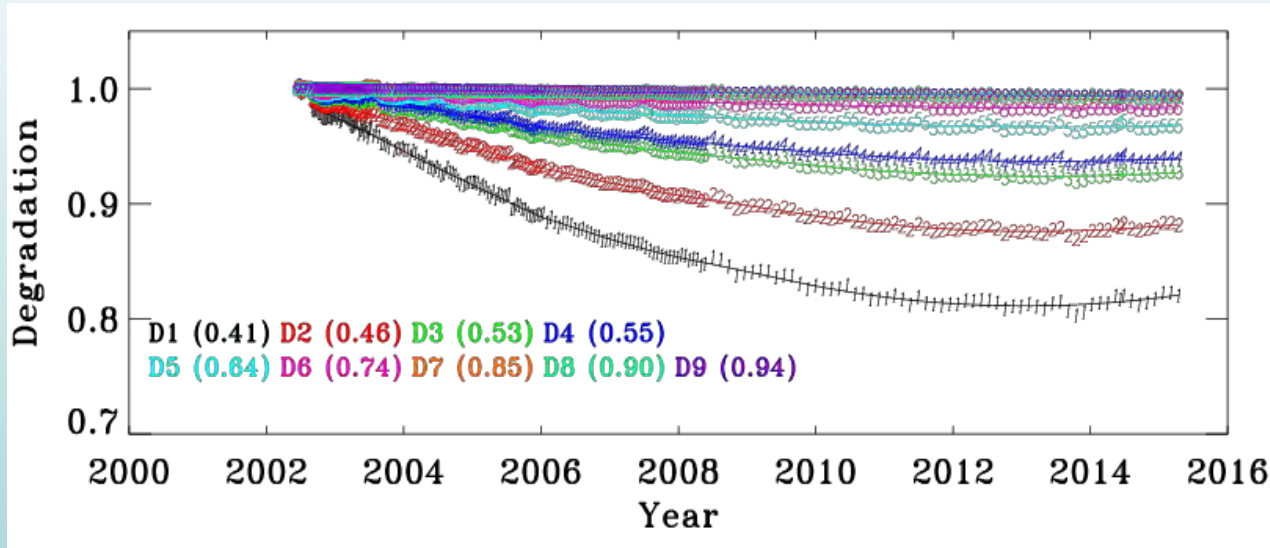
Calibration Methodology Implementation (C6)

- **Same overall calibration methodologies with slightly different implementations for MODIS L1B data collections**
 - C3: June 2002 – Nov 2002
 - C4: Nov 2002 – Feb 2007
 - C5: July 2005 – Present
 - C6: Feb 2012 – Present
- **Calibration Methodologies for C6**
 - Absolute: reflectance-based calibration via on-board SD BRF
 - Relative (changes over time and at different viewing angles): sensor responses to SD, Moon, SRCA, and selected CEOS endorsed EV targets to cover different AOIs
 - Bands 8 and 9: the EV response trends are also used at SD AOI
 - Other considerations: no direct impact for current ocean color products

On-orbit Performance

- **SD Degradation**
- **Changes in Spectral Band Responses (Gains and RSR)**
- **Response Versus Scan-angle (RVS)**
- **Detector Signal-to-Noise Ratios (SNR)**
- **Spatial and Spectral Performance (Backup Slides)**

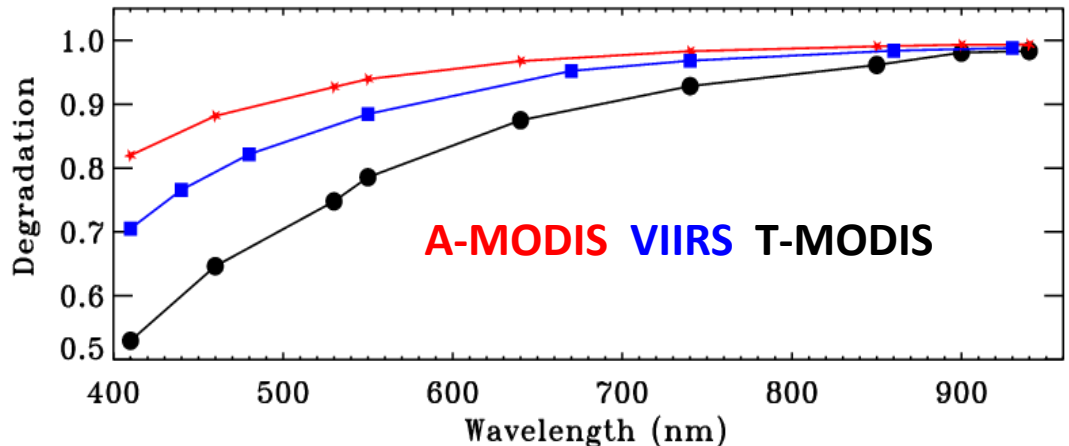
Solar Diffuser (SD) Degradation



Large SD degradation at short wavelength
Recent increase of BRF (wavelength dependent)

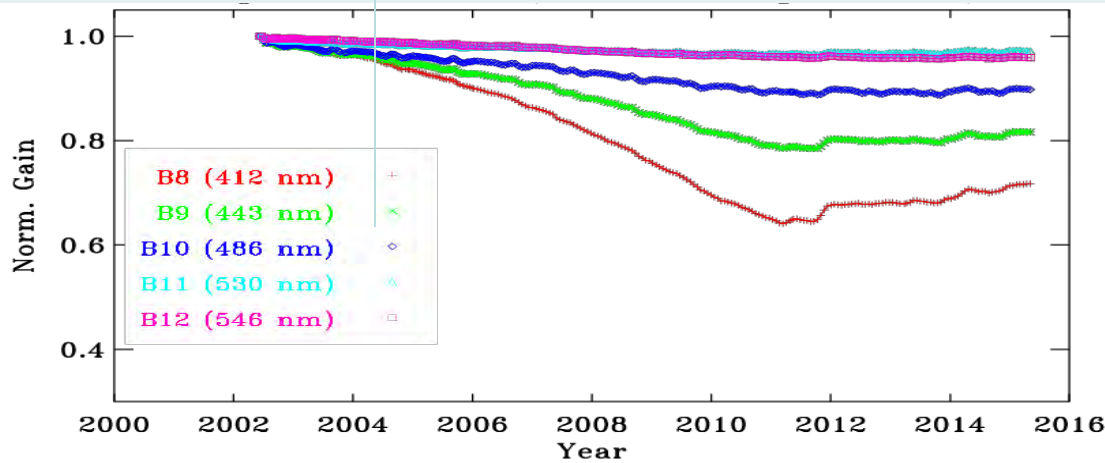
Results as of May 2015

Similar wavelength-dependent SD degradation for Terra MODIS, Aqua MODIS, and S-NPP VIIRS

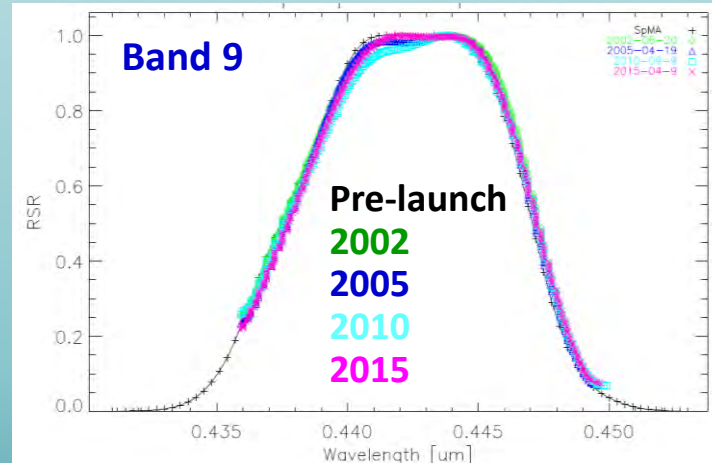
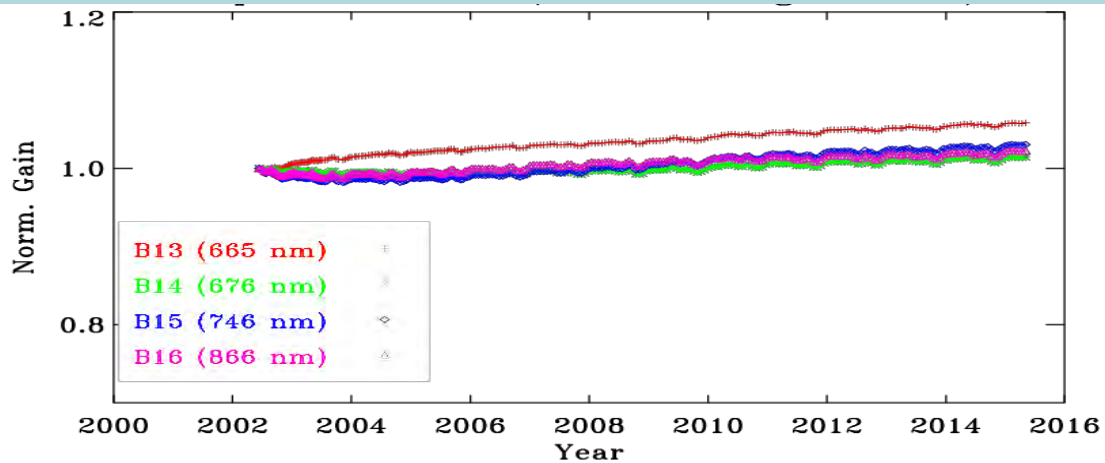
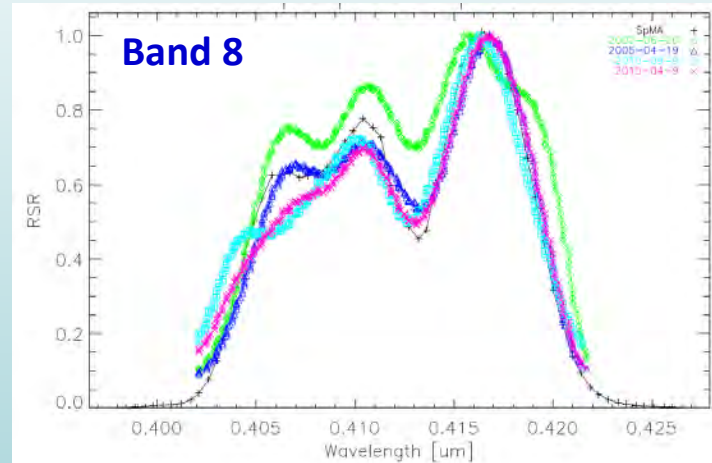


Changes in Spectral Band Responses (Gains and RSRs)

Gains

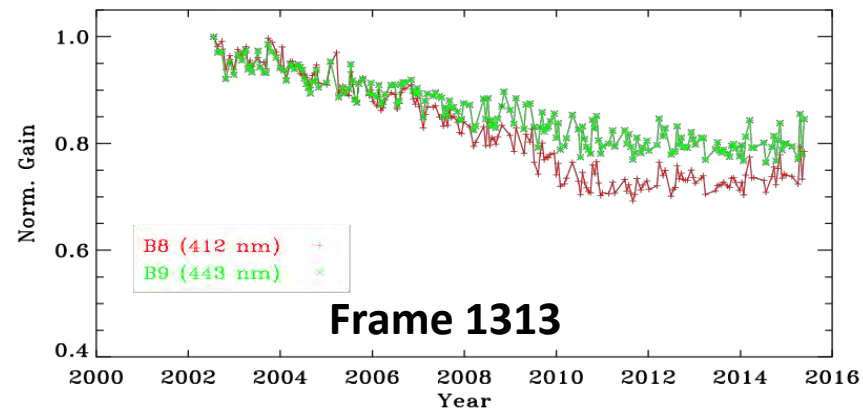
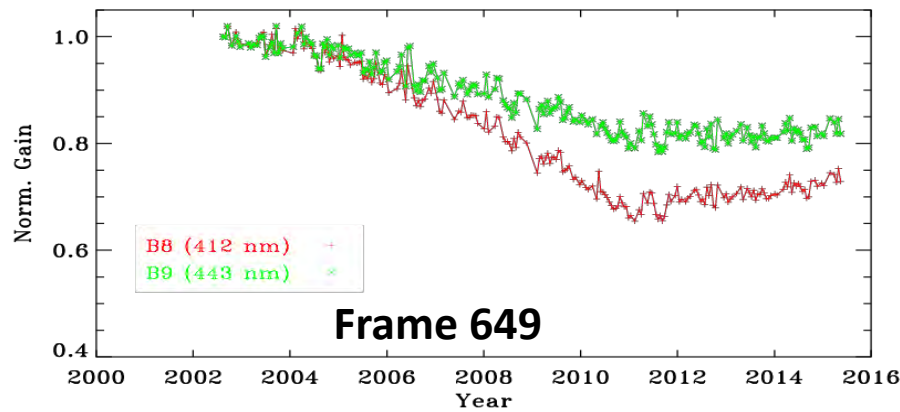
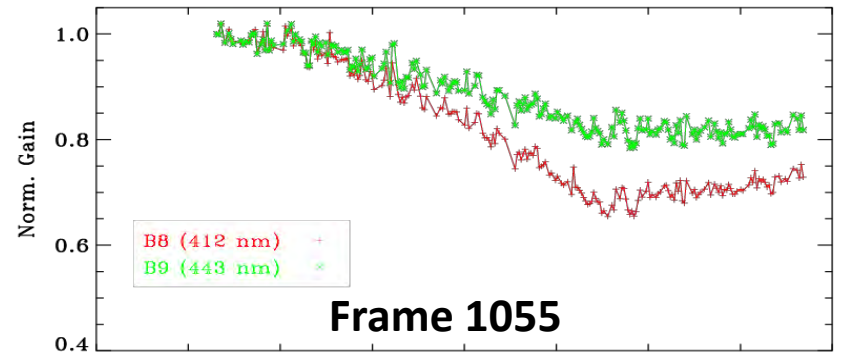
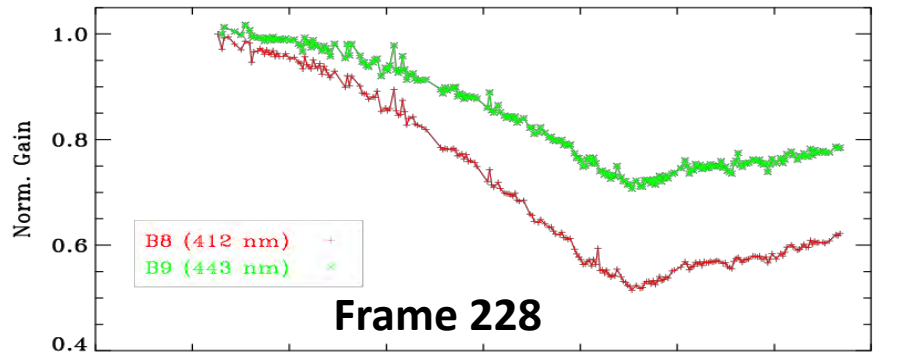
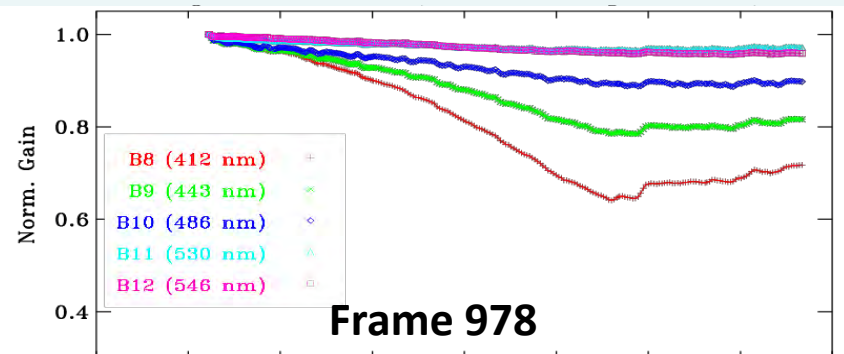
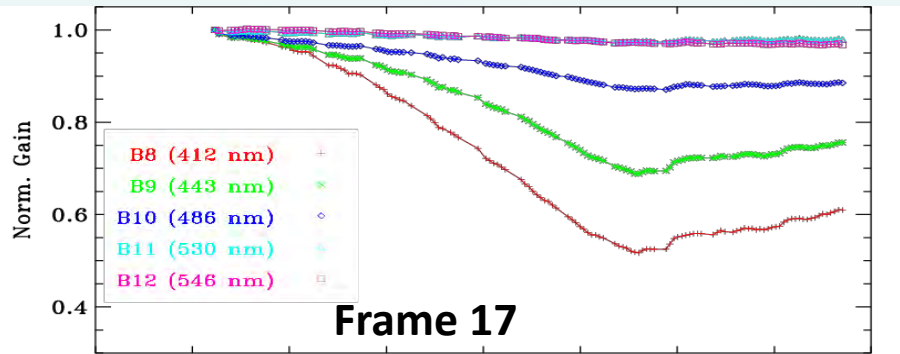


RSRs



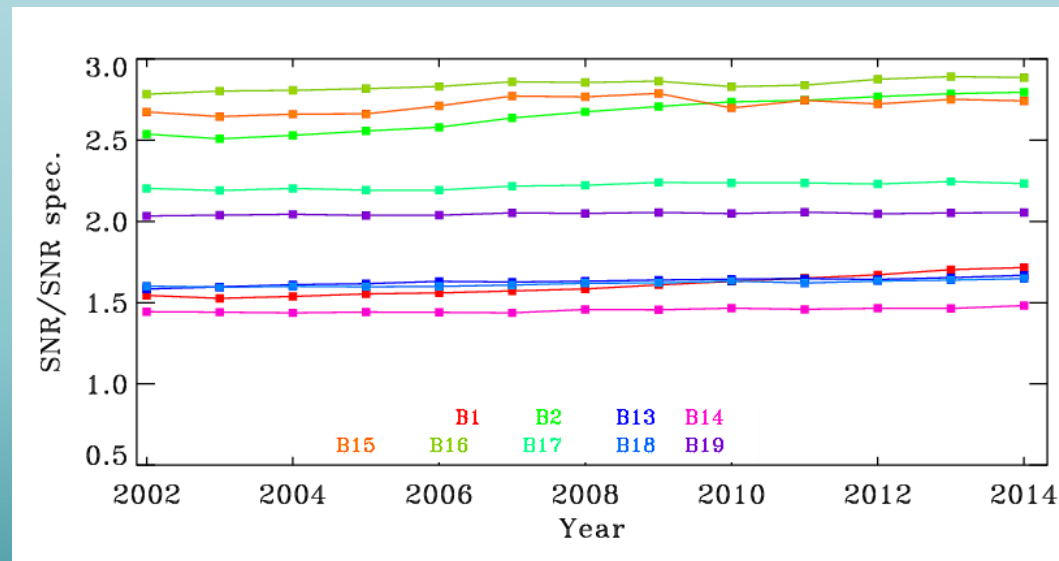
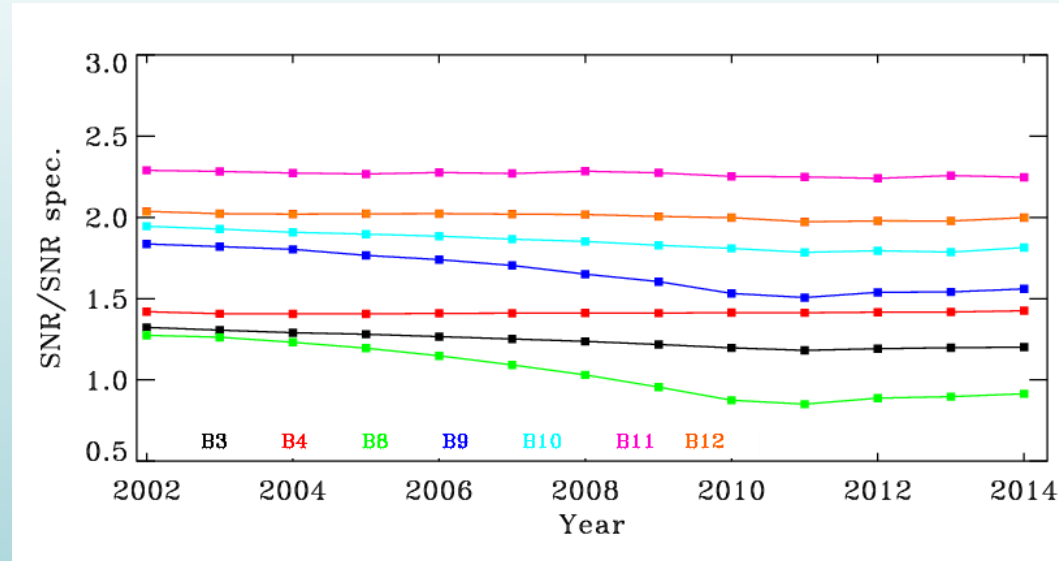
Changes in spectral band responses are wavelength, AOI, and mirror side dependent
Larger changes at shorter wavelengths; small MS difference in Aqua MODIS

Responses Versus Scan-angle (RVS)



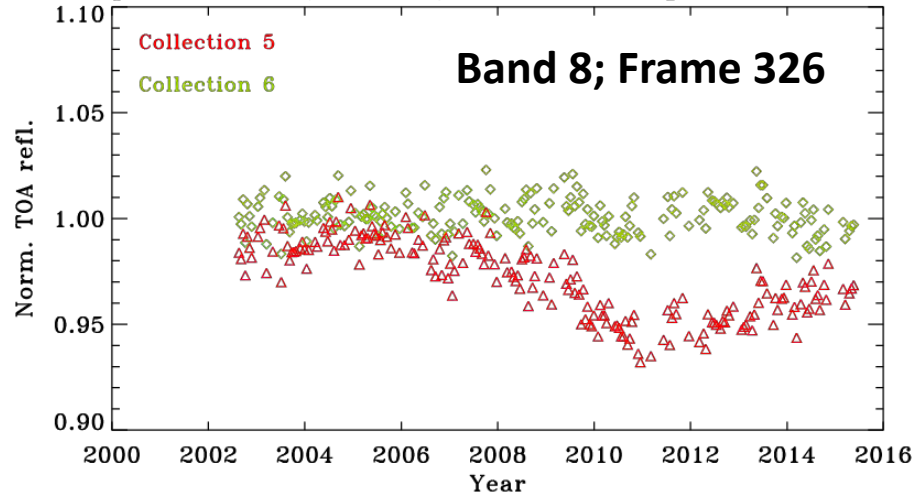
Detector Signal-to-Noise Ratios (SNR)

- 36 spectral bands (490 individual detectors)
- RSB detector SNRs are characterized using SD with and w/o screen and SV responses
- Aqua MODIS: 10 noisy detectors (2 from pre-launch; 3 at launch) and 15 inoperable detectors (13 in Band 6); none in OC bands
- Band 8 SNR has been below its specification since 2008 due to decrease of detector response

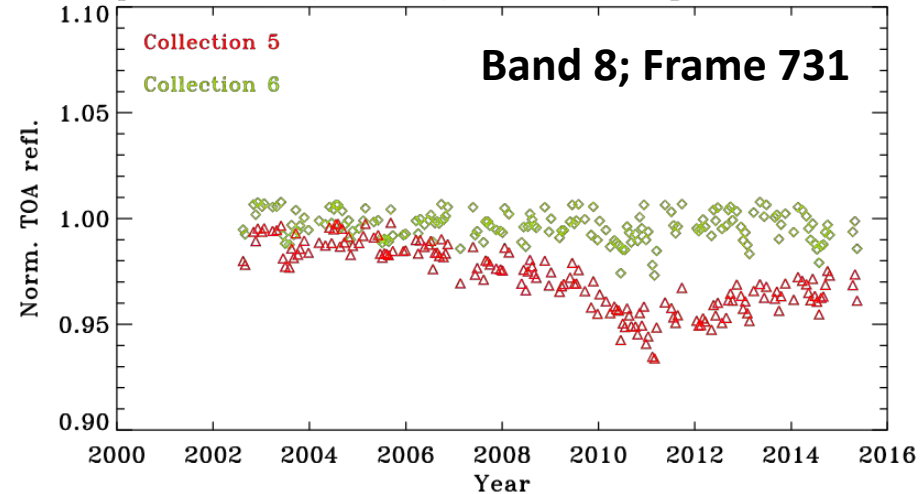


Comparison of C5 and C6 L1B Performance

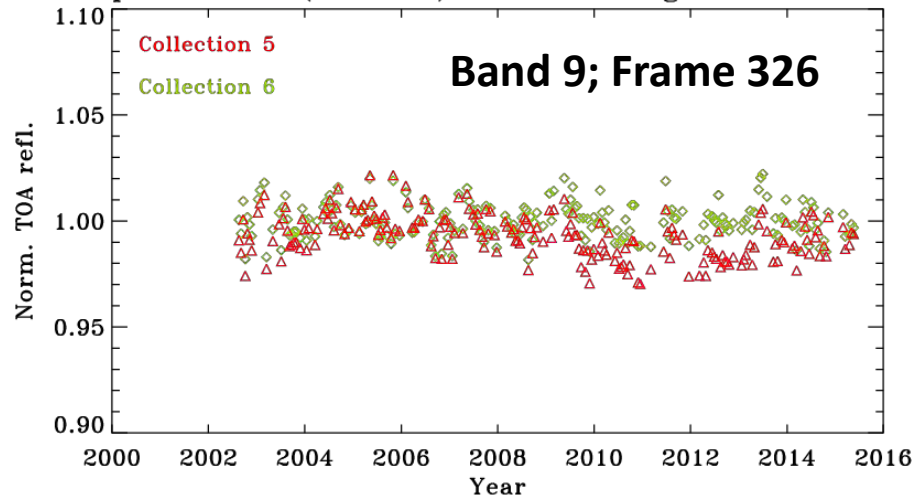
Aqua Band 8 (412 nm) refl. trending at Frame 326



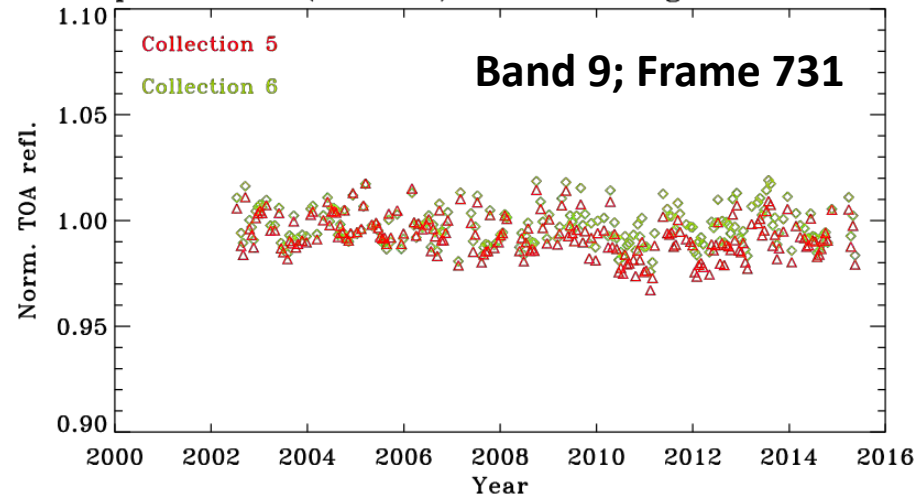
Aqua Band 8 (412 nm) refl. trending at Frame 731



Aqua Band 9 (443 nm) refl. trending at Frame 326



Aqua Band 9 (443 nm) refl. trending at Frame 731



Challenges and Future Improvements

- **Large changes in SD BRF and large changes in detector responses at short wavelengths (ocean bands)**
 - SD degradation spatial uniformity and its dependence on illumination/viewing geometry
 - Time dependent RVS for all VIS/NIR bands and detector dependent RVS for some ocean color bands (primarily for bands 8-12)
 - RVS updates using EV response trending at different AOI (e.g. Aqua bands 8-9)
 - Potential changes in polarization sensitivity (primarily for bands 8-12)
- **Future improvements:**
 - Reducing SD degradation characterization uncertainty (temporal and spatial)
 - Testing different RVS characterization methods (relative approach with reference bands; relative response over AOI using a single EV site)
 - Improving data fitting strategies (temporal and angular)
 - Minimizing polarization impact on response trending and fitting

Summary

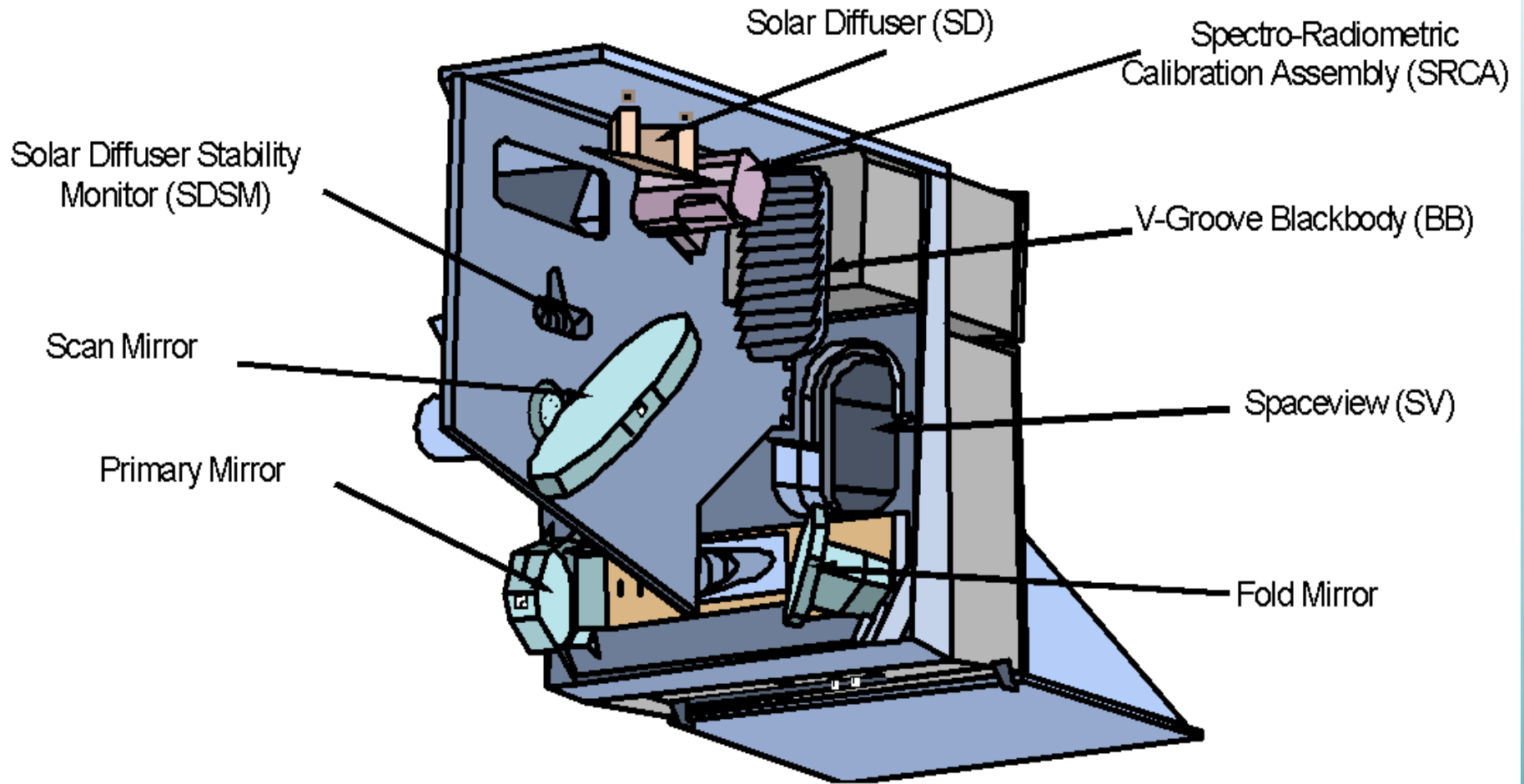
- **Aqua MODIS has successfully operated for 13 years**
- **Instrument operation conditions have been stable and its on-board calibrators continue to operate and function normally**
- **Extensive and dedicated effort by MCST to support MODIS L1B calibration and data production**
 - MsWG and Calibration Workshop
 - Direct communication with NASA OBPG
 - Frequent LUT updates
 - Close relationship with NASA VCST (similar solar and lunar calibration for VIIRS)
- **Future work planned to address various challenging issues**
 - Changes in VIS/NIR response versus scan-angle (RVS)
 - Changes in VIS/NIR polarization sensitivities (esp. for Terra MODIS)
 - Uncertainty due to correction for large SD and mirror degradation
 - SD degradation correction for SWIR bands (not directly tracked by the SDSM)
 - Issues due to aging instruments

Backup Slides

Instrument Background

- **MODIS on EOS Terra and Aqua Spacecraft**
 - Terra launched in October 1999
 - Aqua launched in May 2002
- **Scanning Radiometer (2-side mirror)**
 - 36 spectral bands: VIS (0.4 μm) to LWIR (14.4 μm)
 - 3 spatial resolutions: 250 m, 500 m, and 1 km
 - 12 bits
 - 4 focal plane assemblies (FPA): VIS, NIR, SMIR, LWIR
 - On-board calibrators (OBC): SD, SDSM, SRCA, BB, and SV
- **MODIS Characterization Support Team (MCST)**
 - Instrument operation
 - L1B algorithm and LUT
 - On-orbit calibration and characterization

MODIS Instrument and On-board Calibrators

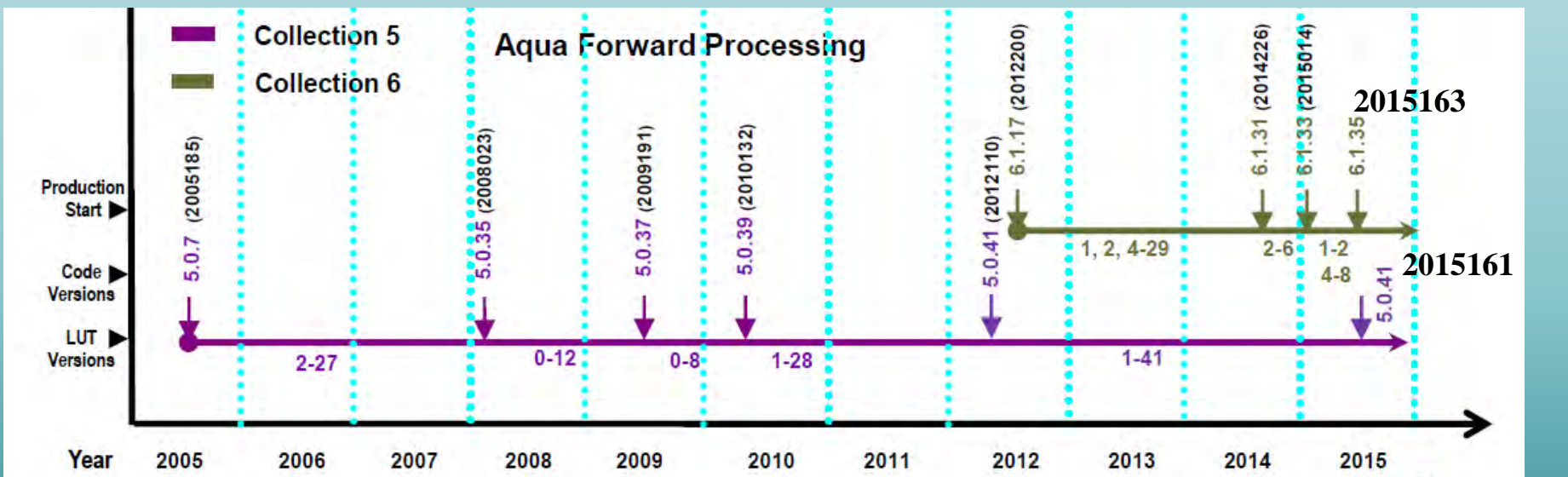
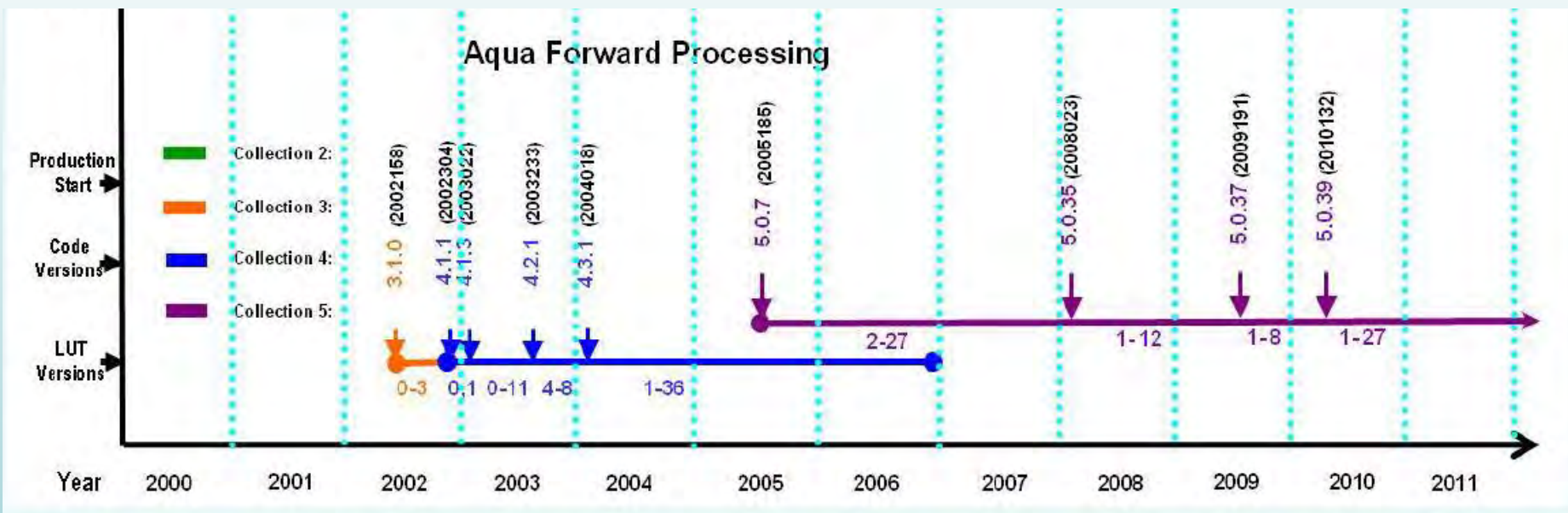


Sensor Specification and Primary Applications

Primary Use	Band	Bandwidth (nm)	Spectral Radiance ¹	Required SNR	Primary Use	Band	Bandwidth (μm)	Spectral Radiance ¹	Required NEΔT(K)
Land/Cloud/Aerosols Boundaries	1	620 - 670	21.8	128	Surface/Cloud Temperature	20	3.660 - 3.840	0.45 (300K)	0.05
	2	841 - 876	24.7	201		21	3.929 - 3.989	2.38 (335K)	0.2
Land/Cloud/Aerosols Properties	3	459 - 479	35.3	243		22	3.929 - 3.989	0.67 (300K)	0.07
	4	545 - 565	29	228		23	4.020 - 4.080	0.79 (300K)	0.07
	5	1230 - 1250	5.4	74	Atmospheric Temperature	24	4.433 - 4.498	0.17 (250K)	0.25
	6	1628 - 1652	7.3	275		25	4.482 - 4.549	0.59 (275K)	0.25
	7	2105 - 2155	1	110	Cirrus Clouds Water Vapor	26	1.360 - 1.390	6	150 (SNR)
Ocean Color/ Phytoplankton/ Biogeochemistry	8	405 - 420	44.9	880		27	6.535 - 6.895	1.16 (240K)	0.25
	9	438 - 448	41.9	838		28	7.175 - 7.475	2.18 (250K)	0.25
	10	483 - 493	32.1	802	Cloud Properties	29	8.400 - 8.700	9.58 (300K)	0.05
	11	526 - 536	27.9	754	Ozone	30	9.580 - 9.880	3.69 (250K)	0.25
	12	546 - 556	21	750	Surface/Cloud Temperature	31	10.780 - 11.280	9.55 (300K)	0.05
	13	662 - 672	9.5	910		32	11.770 - 12.270	8.94 (300K)	0.05
	14	673 - 683	8.7	1087	Cloud Top Altitude	33	13.185 - 13.485	4.52 (260K)	0.25
	15	743 - 753	10.2	586		34	13.485 - 13.785	3.76 (250K)	0.25
	16	862 - 877	6.2	516		35	13.785 - 14.085	3.11 (240K)	0.25
Atmospheric Water Vapor	17	890 - 920	10	167		36	14.085 - 14.385	2.08 (220K)	0.35
	18	931 - 941	3.6	57	¹ Spectral Radiance values are (W/m ² -μm-sr)				
	19	915 - 965	15	250					

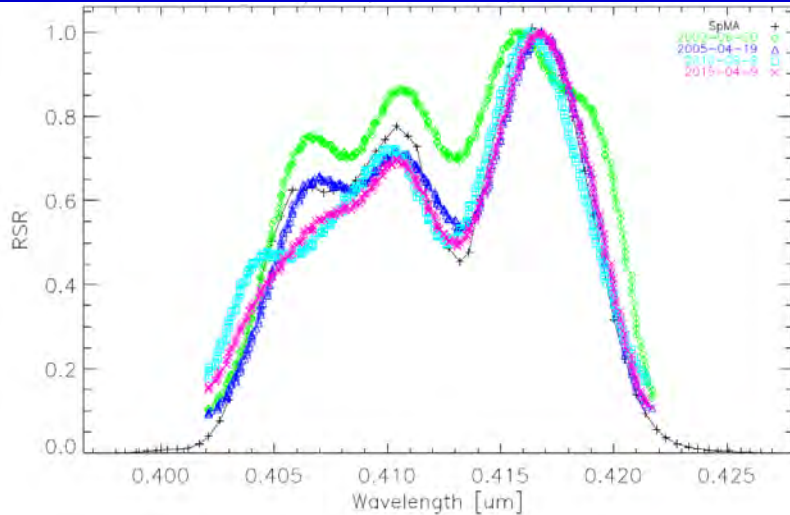
- 20 reflective solar bands (RSB: bands 1-19, and 26) from 0.41 - 2.2μm
- 16 thermal emissive bands (TEB: bands 20-25, 27-36) from 3.5 - 14.4μm

History of MODIS L1B and LUT Updates

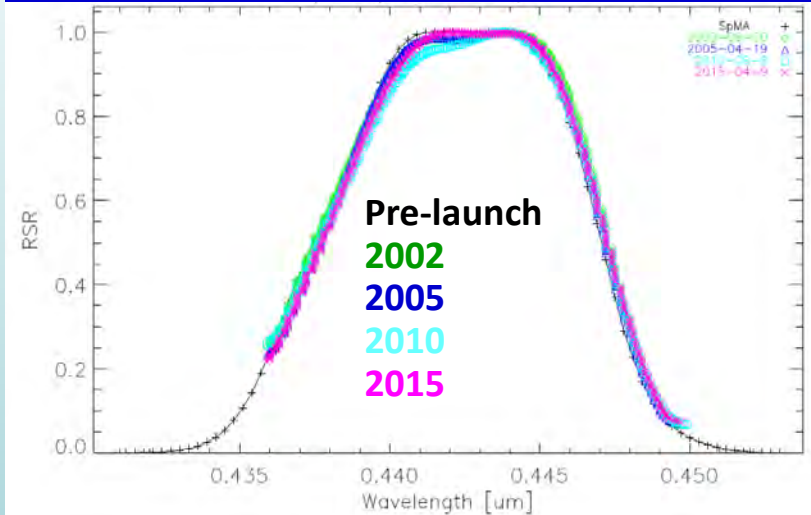


Changes in Relative Spectral Responses (RSRs) for Aqua MODIS Bands 8, 9, 10, and 11

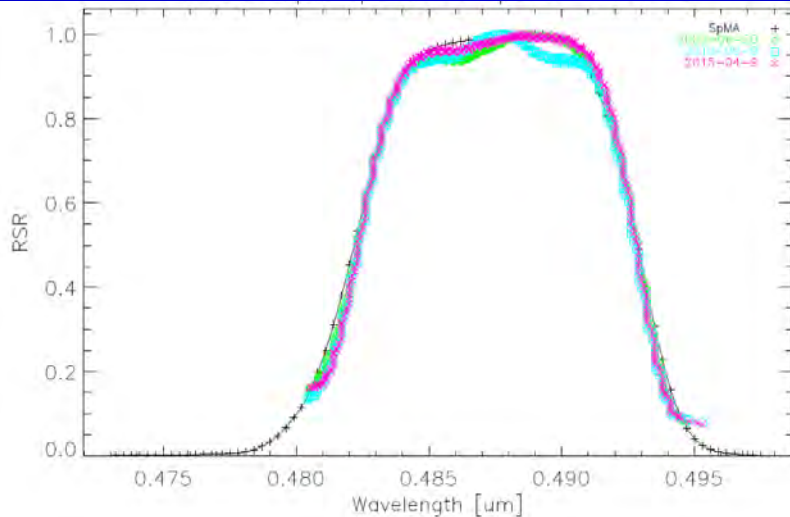
Aqua MODIS Band 8



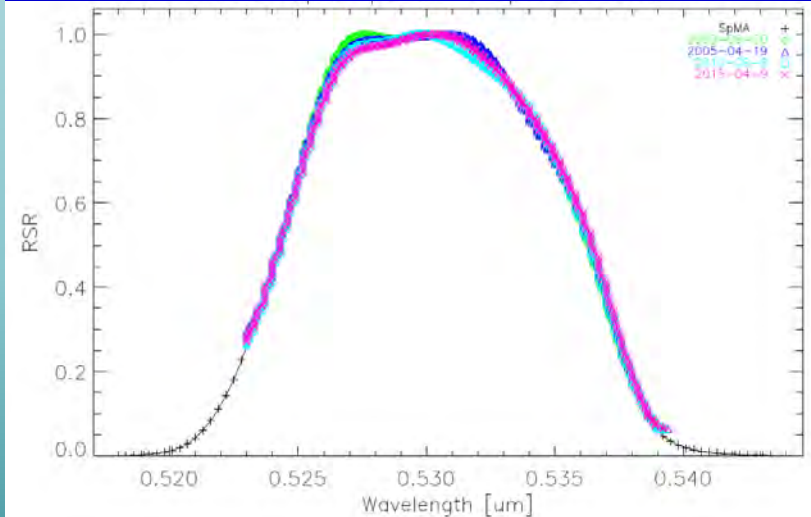
Aqua MODIS Band 9



Aqua MODIS Band 10

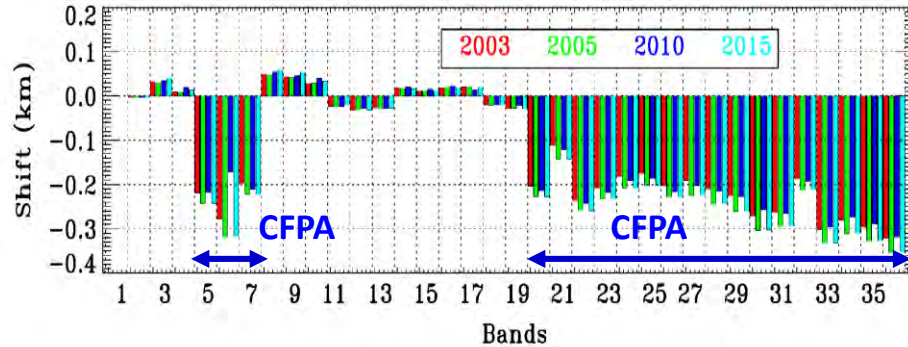


Aqua MODIS Band 11

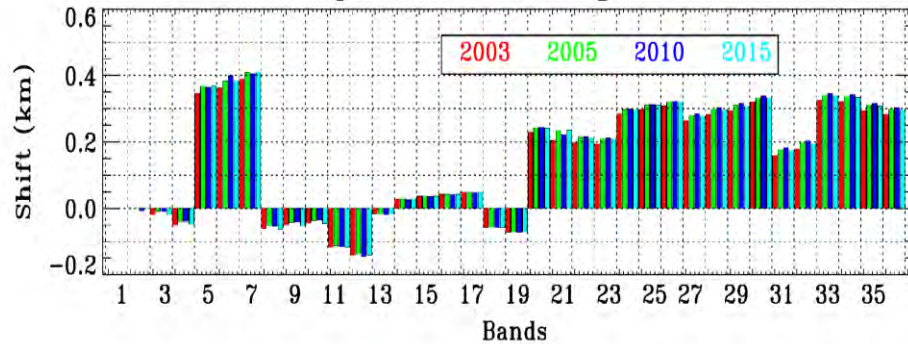


Spatial and Spectral Performance

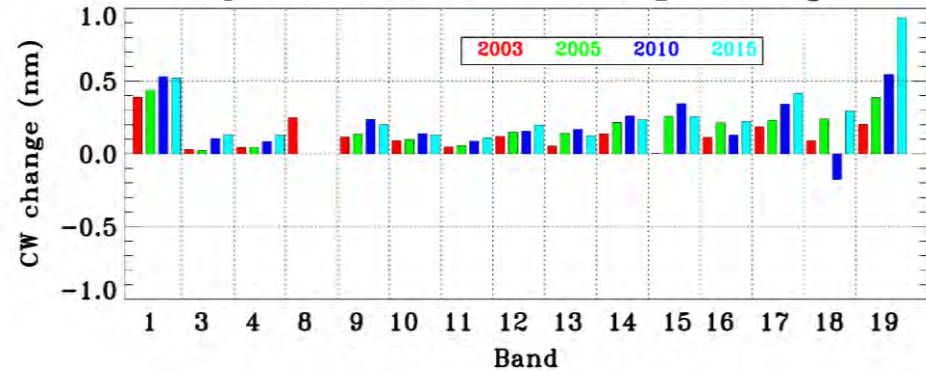
Aqua BBR Shift Along-scan



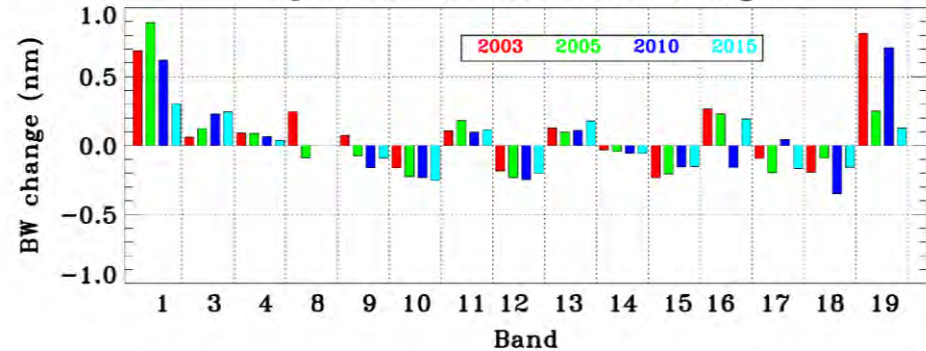
Aqua BBR Shift Along-track



Aqua MODIS Center Wavelength Changes



Aqua MODIS Bandwidth Changes



CW and BW changes are within 0.5 nm and 1.0 nm, respectively, for most VIS/NIR bands
(Relatively large changes for bands with broad bandwidths, such as bands 1, 18, 19)
Aqua BBR: a known issue since pre-launch;