



Status of MODIS, VIIRS, and OLI Sensors

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Acknowledgements:

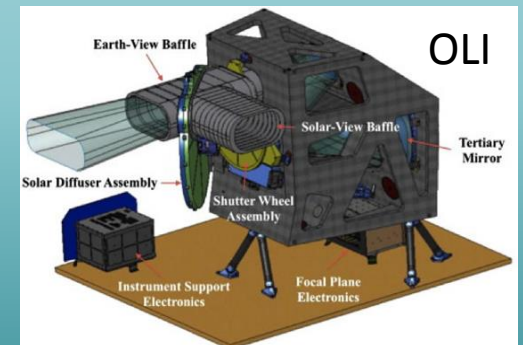
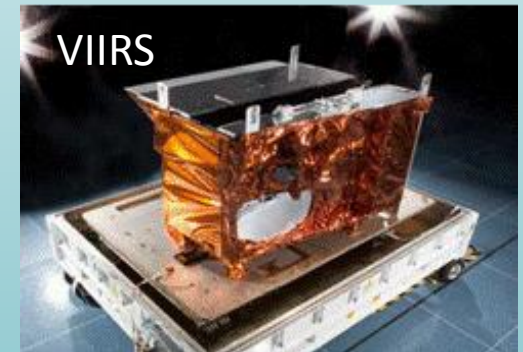
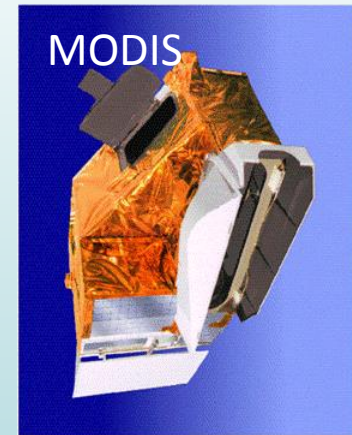
NASA MODIS Characterization Support Team (MCST)
NASA VIIRS Characterization Support Team (VCST)
USGS/NASA Landsat Calibration and Validation Team (CVT)
NOAA VIIRS SDR Team

Outline

- **Background**
 - MODIS, VIIRS, and OLI
- **On-orbit Calibration**
 - Strategies and Activities
- **On-orbit Performance**
 - Reflective Solar Bands (RSB)
- **Status of Sensor L1B Data Products**
- **Summary**
 - Challenging Issues and Future Effort

Background

- **MODIS on Terra and Aqua**
 - Terra: Dec. 18, 1999 – Present
 - Aqua: May 04, 2002 – Present
- **VIIRS on S-NPP and JPSS**
 - S-NPP: Oct. 28, 2011 – Present
 - JPSS-1: Launch in early 2017
 - JPSS-2: Currently in I&T phase
- **OLI on L8 and L9**
 - Landsat 8: Feb 11, 2013 – Present
 - Landsat 9: Transition from phase A to phase B in mid 2016



MODIS, VIIRS, and OLI Spectral Bands

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

Band #	Band	Center Wavelength (nm)	Bandwidth (nm)
1	Coastal/Aerosol	443.0	16.0
2	Blue	482.0	60.0
3	Green	561.4	57.3
4	Red	654.6	37.5
5	NIR	864.7	28.3
6	SWIR 1	1608.9	84.7
7	SWIR 2	2200.7	186.7
8	Panchromatic	589.5	172.4
9	Cirrus	1373.4	20.4

L8 carries a separate TIR sensor (TIRS)

MODIS bands 33-36 with wavelengths above 12 μm

On-orbit Calibration

- **MODIS (Aqua)**

- SD/SDSM calibration performed weekly first 2.5 years then bi-weekly to tri-weekly; a screen open/close mode for low/high gain bands; SD door opens only during SD/SDSM calibration
- Monthly SRCA radiometric mode
- Monthly lunar observations from SV port with phase angles @ -55°

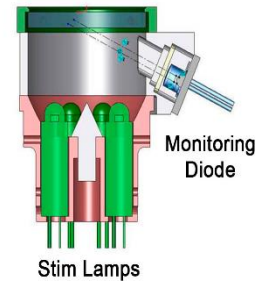
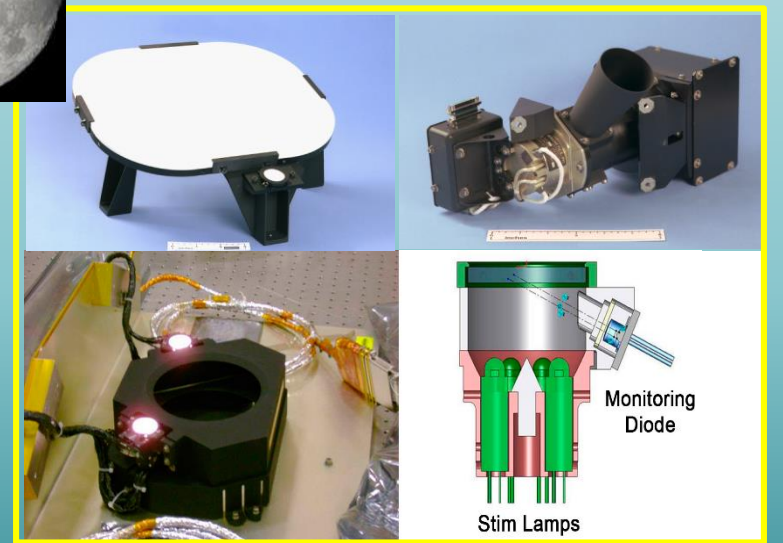
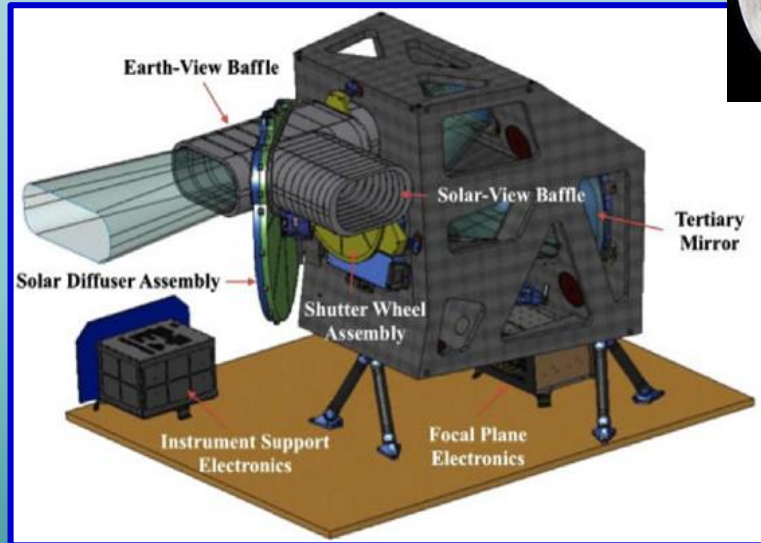
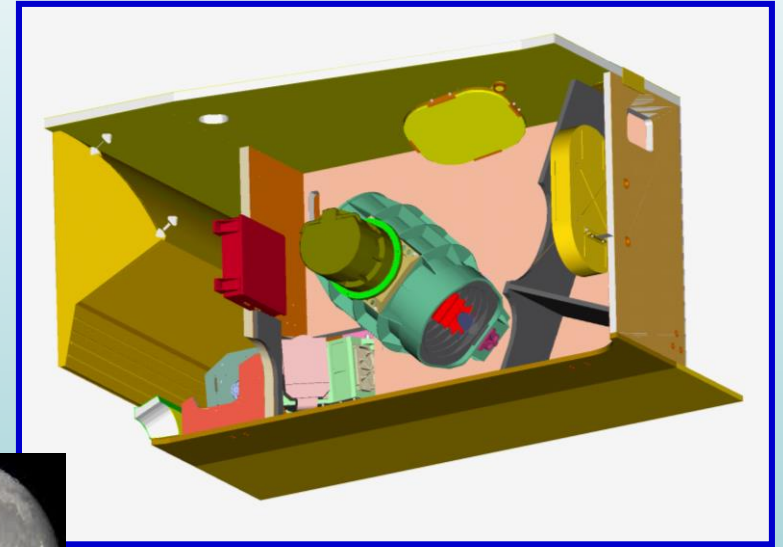
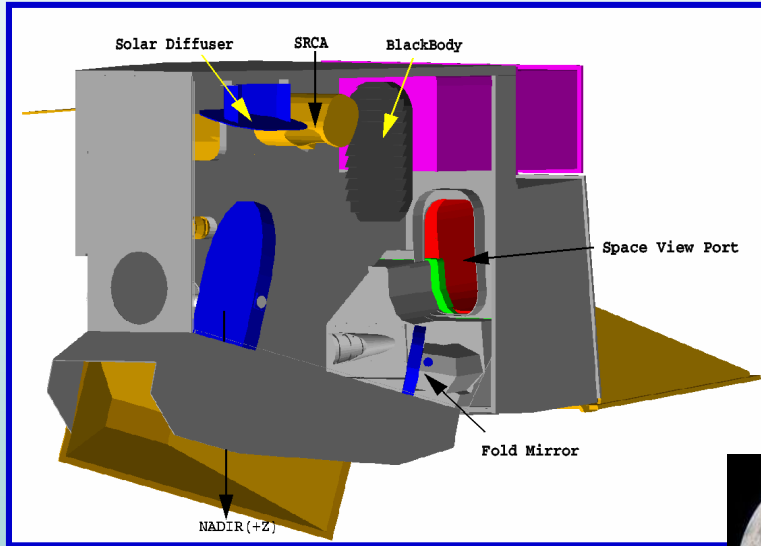
- **VIIRS (S-NPP)**

- SD calibration performed every orbit (no SD door but with a fixed screen); SDSM operated on a daily basis for first 3.5 years and 3 times/week starting from May 16, 2014 (also with a short duration time)
- Monthly lunar observations from the SV port with phase angles @ -51°

- **OLI (Landsat 8)**

- Working lamps daily; backup lamps every 16 days; pristine lamp every 6 months
- Working diffuser every ~ 8 days; pristine diffuser every 6 months
- Monthly lunar observation from EV port with phase angles @ $+5^{\circ}$ to $+9^{\circ}$

Instrument On-board Calibrators



On-orbit Performance

- **MODIS (Aqua)**

- Wavelength-dependent SD degradation - large at short wavelength
- Large changes in VIS and NIR; small changes in SWIR
- Changes in sensor responses versus scan-angle (RVS)

- **VIIRS (S-NPP)**

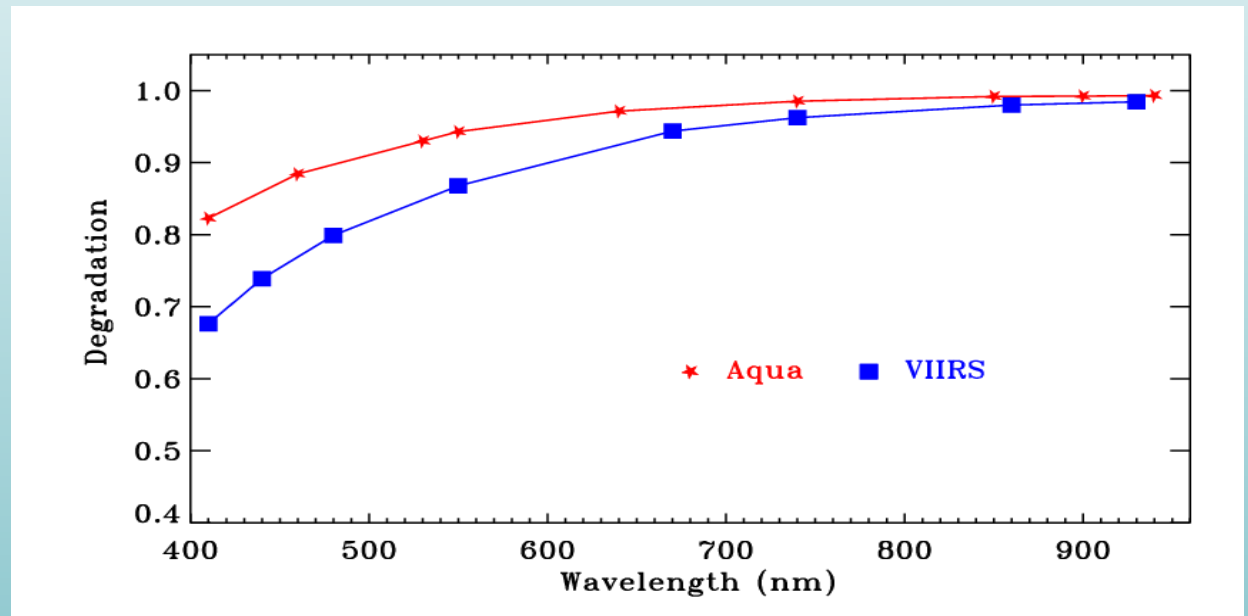
- Wavelength-dependent SD degradation - **Similar to MODIS**
- Large changes in NIR and SWIR (due to mirror contamination)
- On-orbit modulated RSR (wavelength dependent optics degradation)

- **OLI (Landsat 8)**

- Only band with significant trend is 443 nm (Coastal Aerosol) ~1 % degradation over 3 years; other bands stable to within ~0.3% or better
- All calibration techniques (diffusers (2), lamps (3), and lunar) consistent to within 0.3% or better
- $\pm 0.5\%$ scatter in SWIR lunar data (apparently a result of lunar irradiance model)
- Reflectance calibration consistent to within 5% with field (vicarious) measurements (better than 3% for most bands)

MODIS and VIIRS SD Degradation

SD degradation monitored by the on-board SDSM



SD degradation: strong wavelength dependence

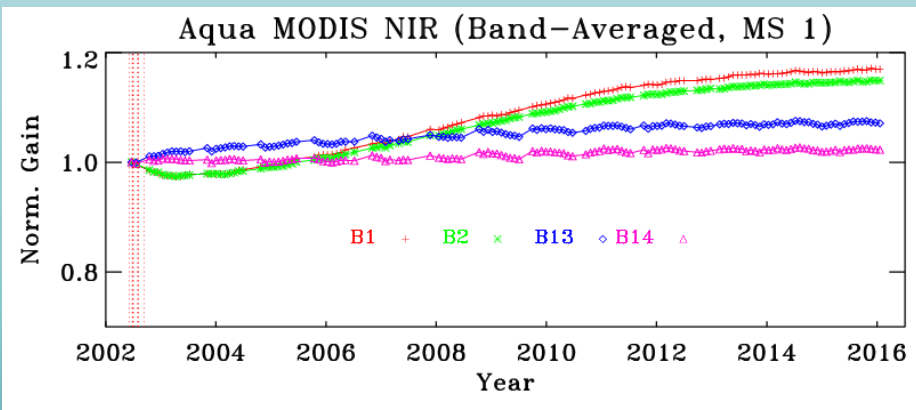
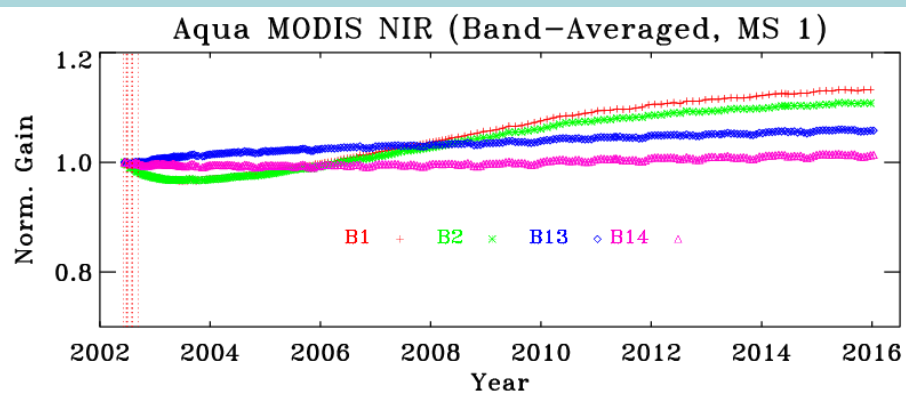
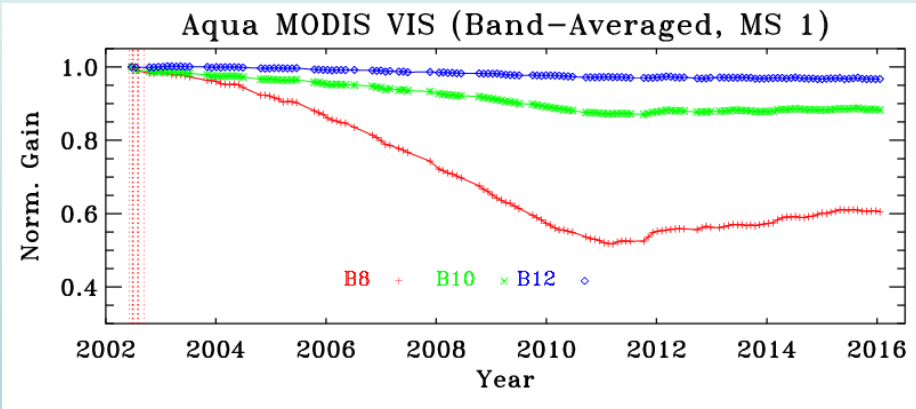
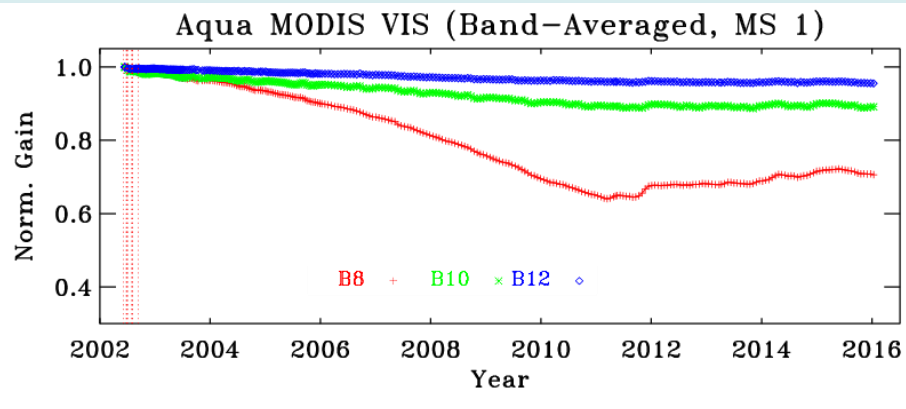
S-NPP VIIRS: no SD door

Aqua MODIS: SD door opens only during SD/SDM calibration

Aqua MODIS Radiometric Responses

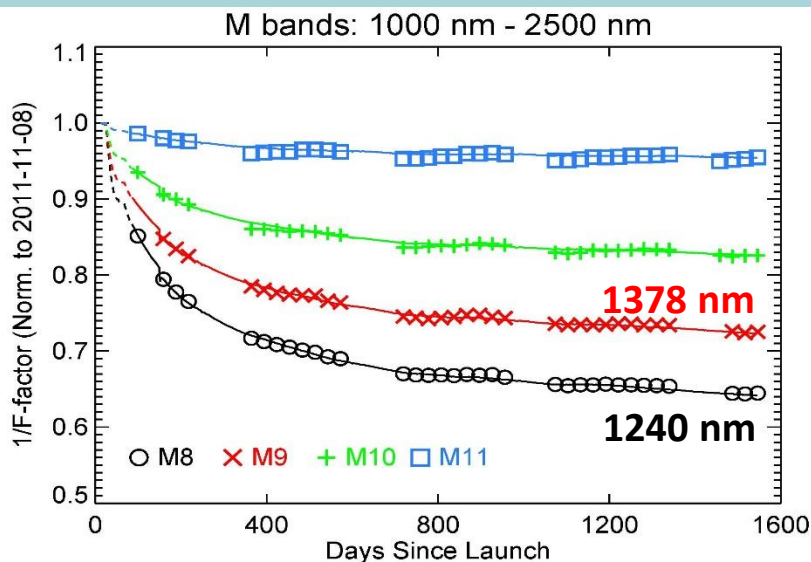
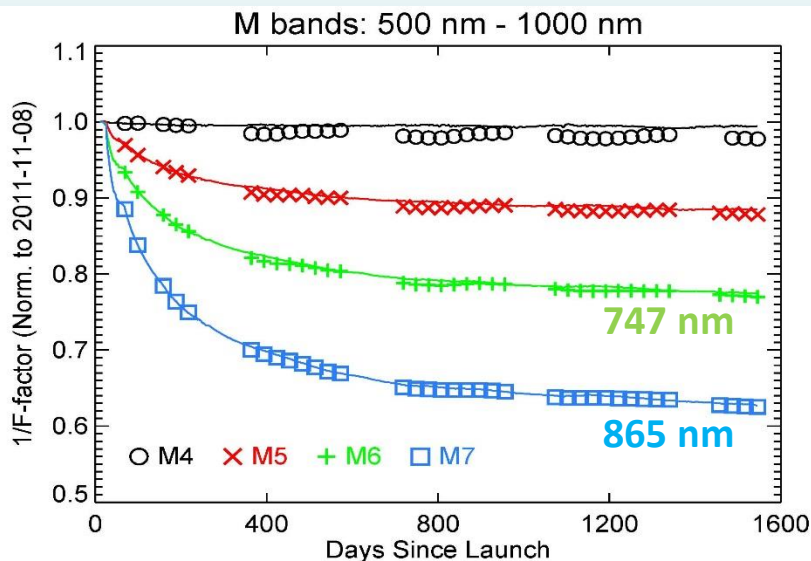
SD View (AOI=50.2°)

SV View (AOI=11.2°)

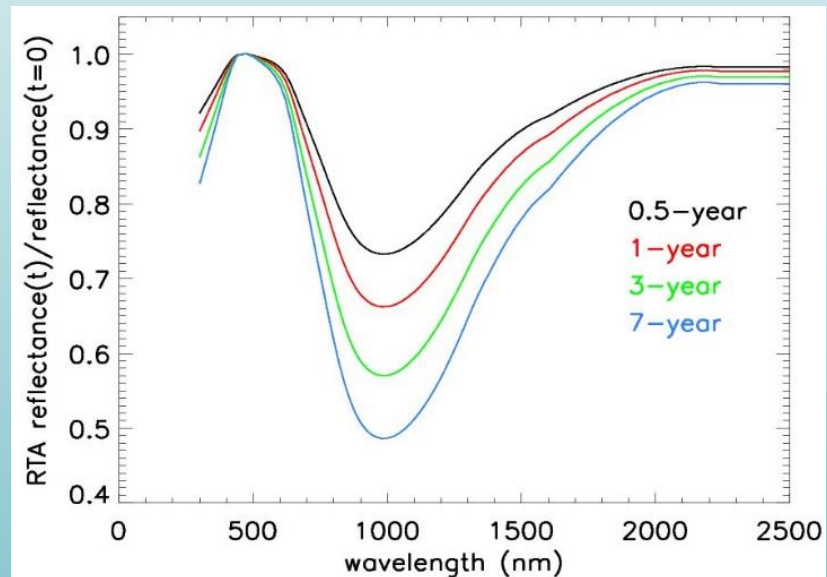


Wavelength, AOI, and Mirror-side dependence; small changes for SWIR bands

S-NPP VIIRS Radiometric Responses



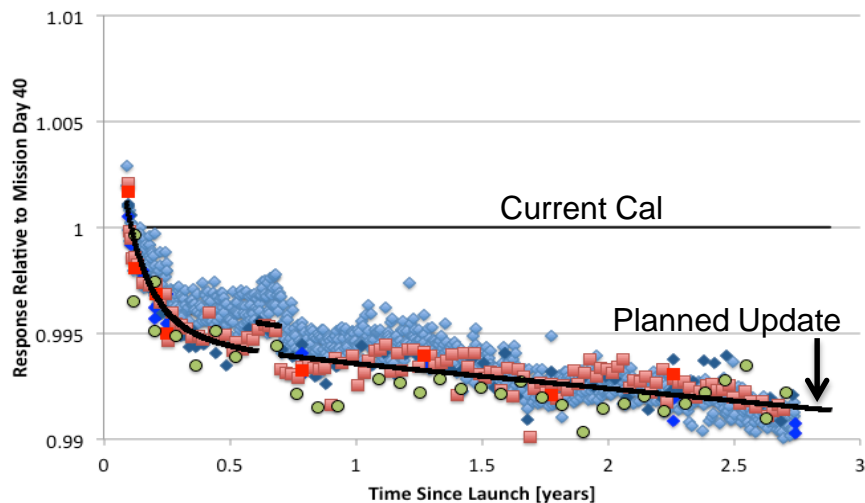
wavelength dependent optics degradation (large at NIR/SWIR)



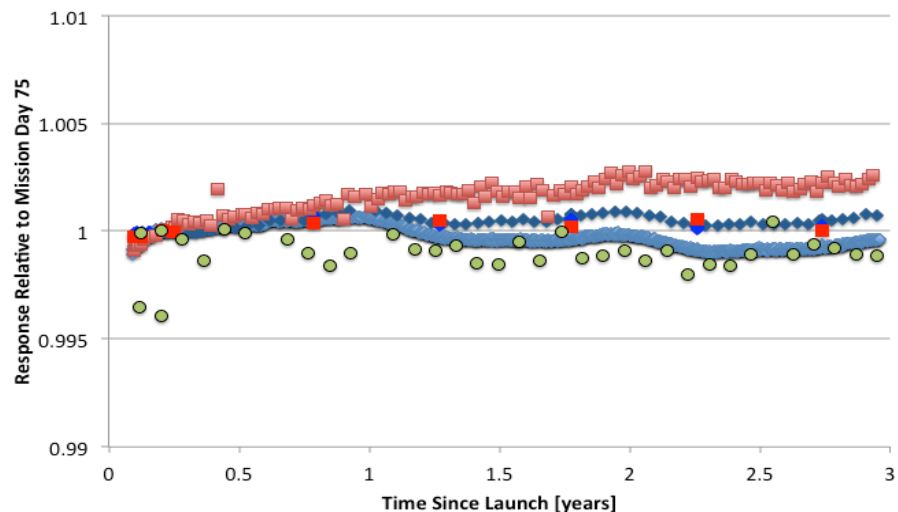
On-orbit modulated RSR

Landsat-8 OLI Radiometric Responses

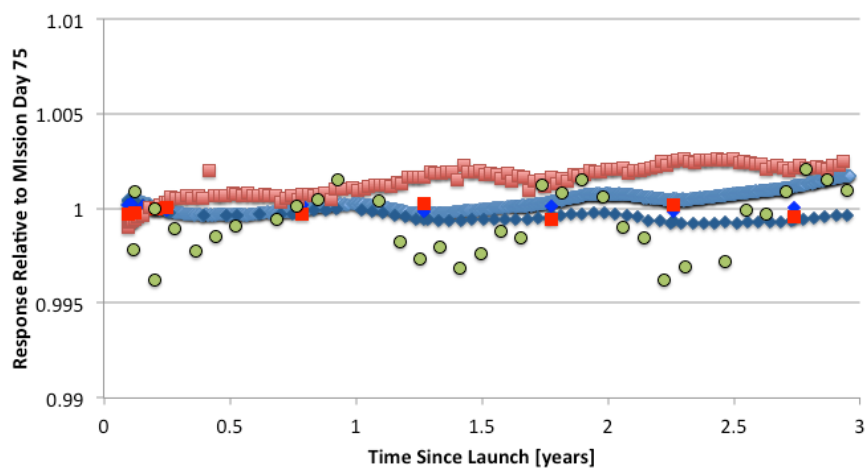
OLI CA Band 1 Trends: Band Average



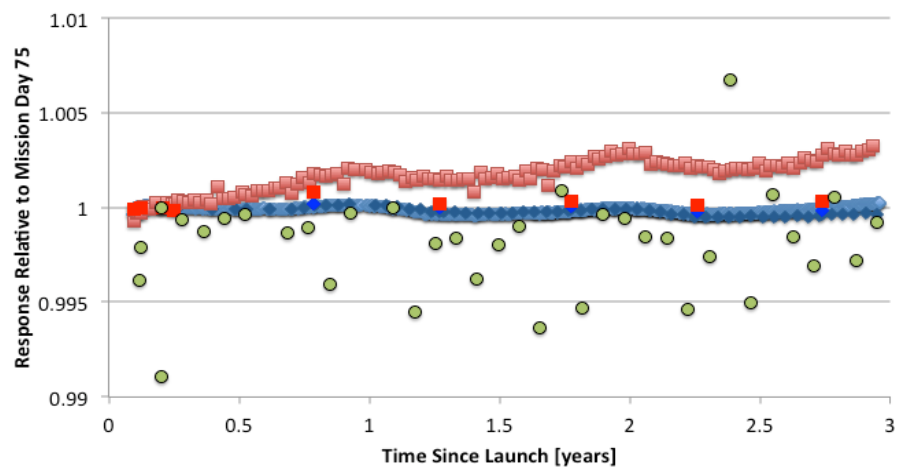
OLI NIR Band 5 Trends: Band Average



OLI SWIR2 Band 7 Trends: Band Average



OLI Cirrus Band 9 Trends: Band Average



◆ stim lamp (working)
 ◆ stim lamp (backup)
 ◆ stim lamp (pristine)

■ solar (working)
 ■ solar panel (pristine)
 ● Lunar

◆ stim lamp (working)
 ◆ stim lamp (backup)
 ◆ stim lamp (pristine)

■ solar (working)
 ■ solar panel (pristine)
 ● lunar

Status of MODIS Level 1B Data Products (C6)

- **Collection 6 (C6) L1B products released to public July 2012 for Aqua and Nov 2012 for Terra**
- **C6 L1B data can be downloaded from:**
<http://ladsweb.nascom.nasa.gov/>
- **New improvements since C6 release**
 - ✓ *Correction applied to reduce Terra B5 (and potentially other SWIR bands) long-term drift as MODIS SDSM can only track SD degradation in VIS and NIR spectral region*
 - ✓ *More bands included the earth view trending at different AOIs for RVS characterization*
 - ✓ *Polarization corrected trending for RVS characterization (under performance evaluation)*

Status of S-NPP VIIRS Land SIPS SDR (L1B) Products

- **NASA Land SIPS SDR Code/LUTs and data reprocess (C1.0 and C1.1)**
 - Jan 31, 2013: LUTs from launch to Jan 2013 based on Mx6.3 algorithm with smoothed functions to remove outliers for consistent Land SIPS reprocess Collection 1.0 (**C1.0**).
 - Dec 23, 2013: LUTs from launch to Nov 2013 based on Mx7.2 algorithm for Land SIPS reprocess **C1.1**, including on-orbit modulated RSR, the DNB Stray Light Correction algorithm, and improved fitting functions; **starting from C1.1, monthly LUT updates**
 - Starting from Nov 2014, same C1.1 LUTs, in Mx8.4 format, have been delivered to Atmosphere SIPS
- **NASA SIPS L1B/LUTs for mission reprocess (V1.1.0) – a joint effort for all SPIS**
 - VIIRS L1A data and L1B software/LUT are developed under NASA EDOS/SIPS.
 - SNPP VIIRS L0 data as the input for L1A, which is the input for L1B software.
 - First L1B software V1.1.0 and LUTs V1.1.0.1 were released in Jan 2016 for SIPS evaluation.
 - LUTs generations are based on corrected solar vector (error fix), on-orbit SD/SDSM screen transmission & SD BRDF, modulated RSR, and consistent fitting methods for mission tables.
- **Data can be downloaded from: <https://ladsweb.nascom.nasa.gov/>**

Status of L8 OLI Level 1B Data Products (Level 1T in Landsat Lingo)

- **USGS is adopting a collection processing strategy for Landsat data. Collection 1 processing of Landsat 4 TM – Landsat-8 OLI scheduled to begin late Spring 2016**
- **L1T data (radiometrically and geometrically corrected) can be downloaded from:**
 - <http://earthexplorer.usgs.gov>
 - <http://glovis.usgs.gov>
- **Radiometric changes for reprocessing – first collection**
 - Update OLI relative gain applicable time periods
 - Update OLI band 1 calibration trend to reflect degradation
 - Provide reflectance based calibration coefficients for Landsat-4 TM → Landsat-7 ETM+ consistent with Landsat-8 OLI
 - Implement TIRS stray light correction
 - Update Landsat-5 TM bands 1 and 3 calibration trend

Status of JPSS-1 VIIRS Calibration and Characterization

Pre-launch Calibration and Characterization:

- Component (e.g. mirrors, filters) and sub-system (e.g. SDSM, rotating telescope) level testing
- Sensor level testing
 - ✓ Ambient: *08/24/2013 - 01/19/2014*
 - ✓ Pre-TVAC: *05/16/2014 - 07/16/2014*
 - ✓ TVAC: *07/16/2014 - 10/30/2014*
 - ✓ Post-TVAC: *11/24/2014 - 12/15/2014*
- Observatory level (integrated with other sensors) testing: April, 2016

Preparation for On-orbit Operation and Calibration (led by NOAA SDR team)

- LUTs development for SDR processing
 - ✓ Initial version released in July 2015
 - ✓ “at launch” quality LUTs delivered in Dec. 2015 (except for a few DNB LUTs to be developed after SC TVAC testing)

Challenging Issues and Future Efforts

- **MODIS (Aqua):**
 - Large changes in VIS/NIR responses: mirror side, wavelength, and AOI dependent => RVS
 - Potential on-orbit changes in sensor polarization sensitivity (VIS and NIR bands)
 - SD degradation correction for SWIR calibration
- **VIIRS (S-NPP):**
 - Large changes in NIR/SWIR responses: wavelength and time dependent => modulated RSR(t)
 - Large SD degradation (no SD door) and correction for SWIR calibration
- **Future Efforts**
 - Improve MODIS RSB RVS characterization: using ground targets; exploring new methodologies, removing/reducing impact due to polarization
 - Examine S-NPP VIIRS and Aqua MODIS calibration consistency via different approaches and methodologies
 - Assess OLI reflectance-based calibration and radiance-based calibration