SNPP, J1 VIIRS Calibration Analysis over Libya-4 site

MAIAC team

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2022-3-17

MODIS Calibration Over CEOS Desert Sites

Method:

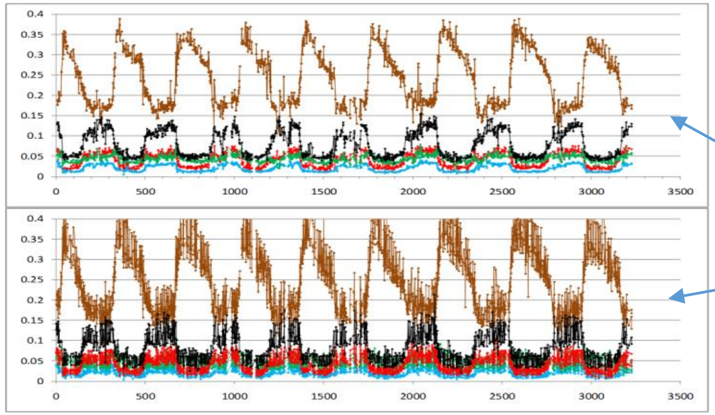
1) Perform MAIAC retrievals (CM, AOT, WV, BRDF etc.);

2) Compute TOA reflectance (R_n) for a fixed view geometry (VZA=0°, SZA=30°) and evaluate trends in both Terra and Aqua;

3) Apply de-trending and compute Terra-Aqua X-calibration factor (gain correction for Terra)

(Lyapustin et al., AMT, 2014)

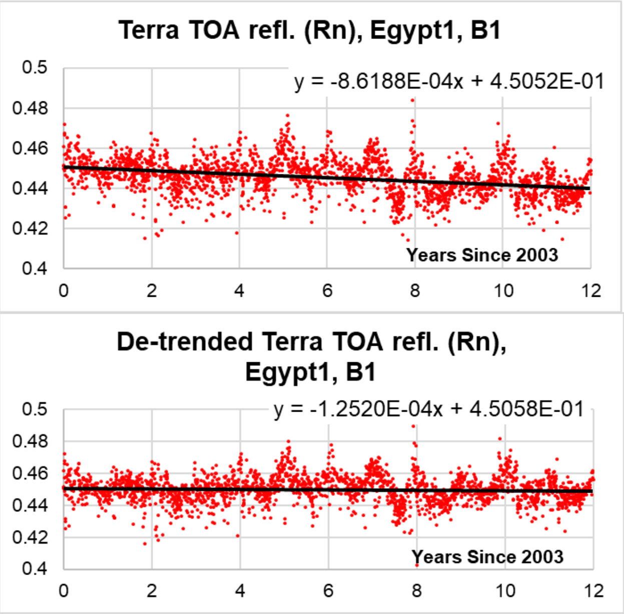
Lyapustin et al., 2012, RSE



BRDF normalization reduces variability by a factor of ~3-5!

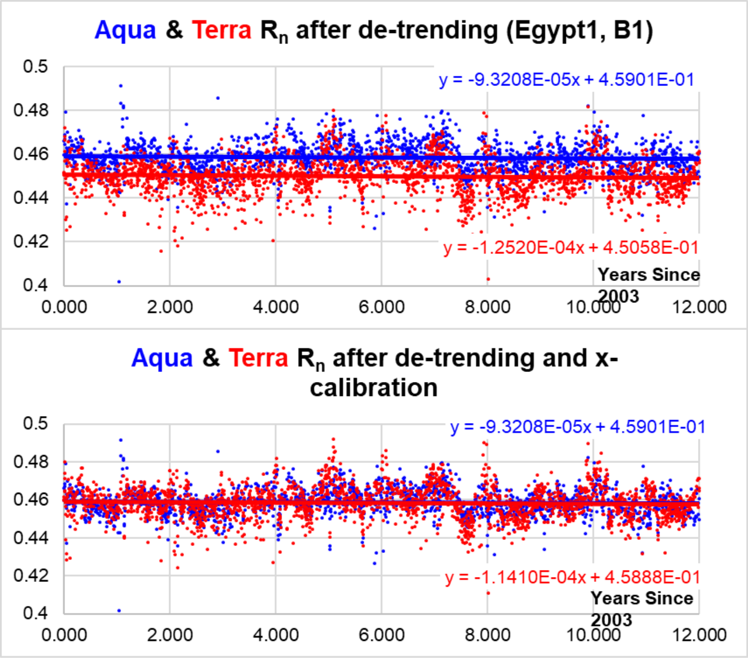
Normalized BRF_n

Original BRF
(Red, Green, Blue, NIR, SWIR)



Average trend/year/unit_refl.

	Δ_{Terra}	σ_{Terra}	Δ_{Aqua}	σ_{Aqua}
TOA_B01	-1.6884E-03	2.6114E-04	1.5848E-06	3.9377E-04
TOA_B02	7.7780E-04	2.4303E-04	-6.5120E-05	3.5583E-04
TOA_B03	-8.8922E-04	4.5314E-04	-3.1763E-04	2.8486E-04
TOA_B04	-5.6629E-04	3.2829E-04	-3.9831E-05	5.0202E-04
TOA_B05	1.9477E-04	3.3019E-04	4.5784E-06	3.3528E-04
TOA_B06	-3.9516E-04	3.0211E-04	-3.1194E-04	2.8191E-04
TOA_B07	2.0259E-04	2.4491E-04	-5.8419E-04	3.2705E-04
TOA_B08	-1.2627E-03	1.0018E-03	-5.5178E-04	1.0915E-04
TOA_B09	-3.9874E-04	5.2176E-04	1.3724E-04	2.1120E-04
TOA_B10	-7.2800E-04	8.2601E-04	-3.0632E-04	7.1498E-04



Average X-gain for Terra

	Average	Stdev
TOA_B01	1.018776	0.000949
TOA_B02	1.000523	0.001054
TOA_B03	0.989436	0.001268
TOA_B04	1.00109	0.001448
TOA_B05	0.98862	0.001855
TOA_B06	0.997128	0.000898
TOA_B07	0.999368	0.000373
TOA_B08	1.003774	0.000948
TOA_B09	1.0014	0.001488
TOA_B10	1.014141	0.002077

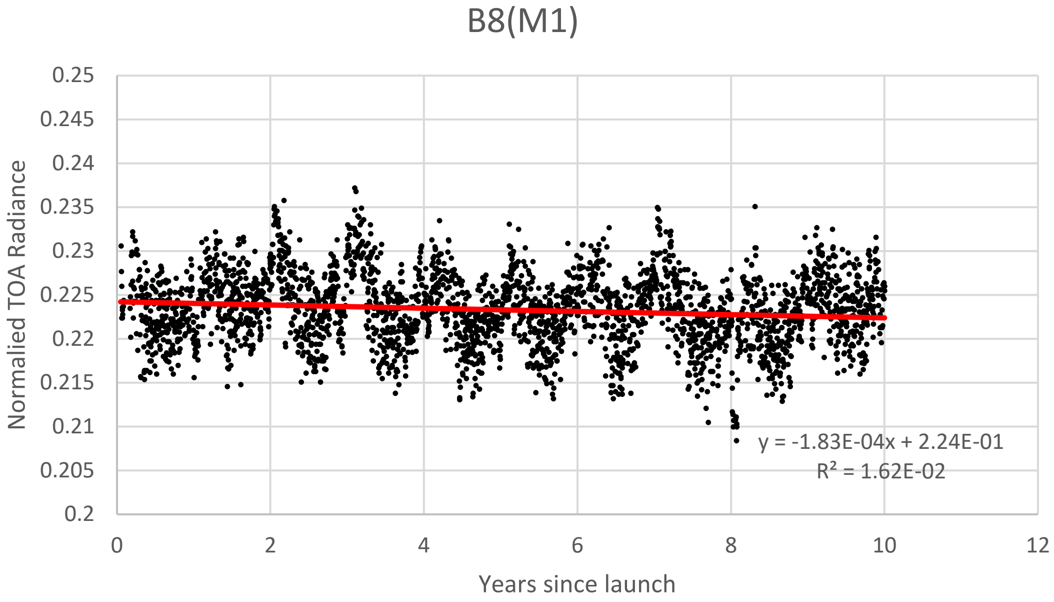
Developed calibration became a standard part of MODIS Land Discipline Processing in Collections C6 and C6.1.

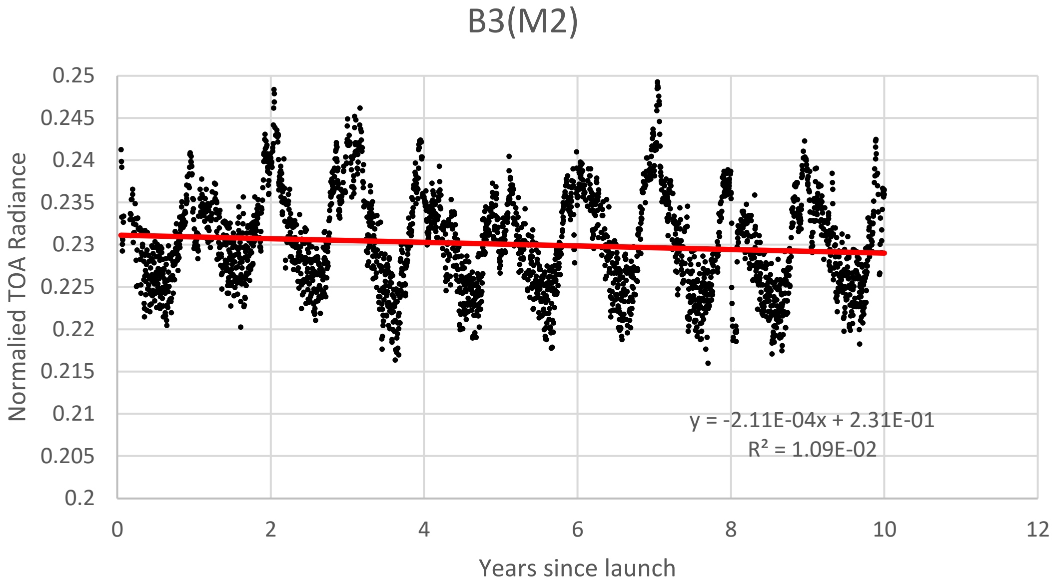
SNPP de-trending analysis

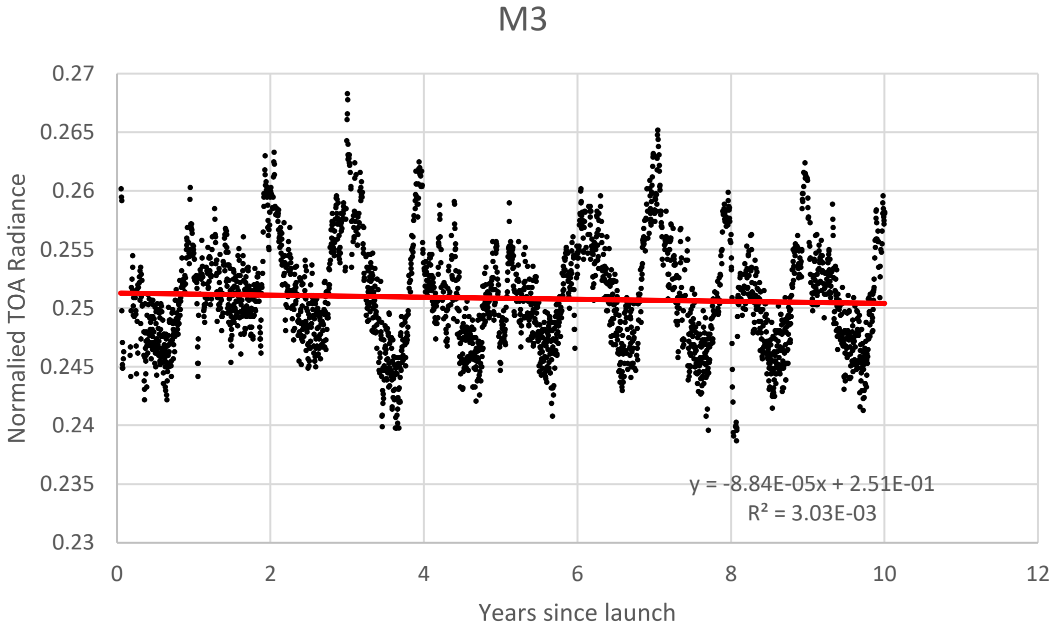
Use the latest versions of L1B data:

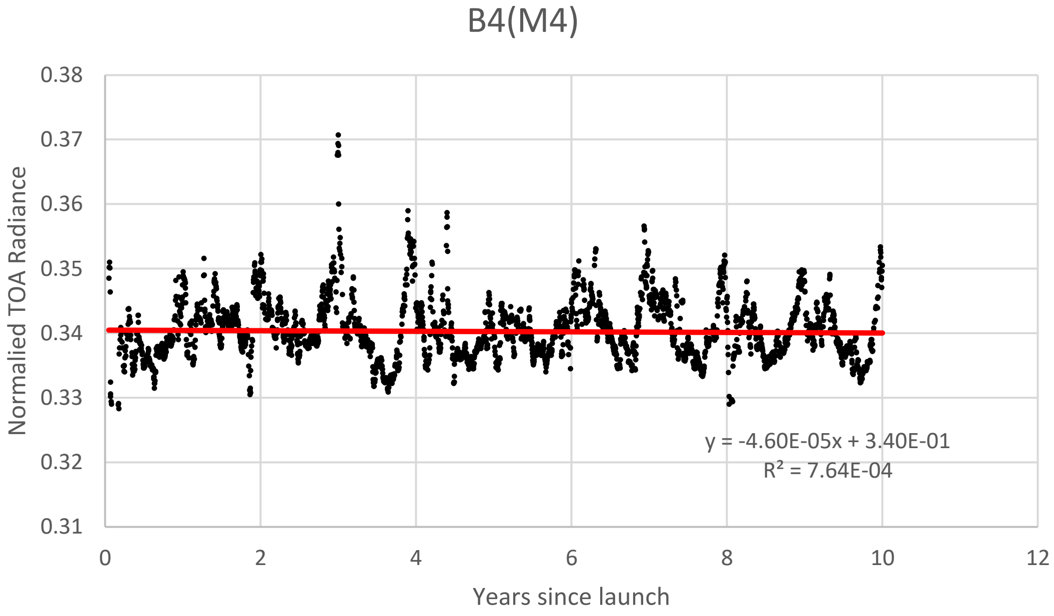
- MODIS C6.1 with polarization correction, de-trending and Terra-to-Aqua cross-calibration;
- VIIRS SNPP C2.0
- VIIRS N20 C2.1

VIIRS SNPP Normalized TOA Radiance Time Series

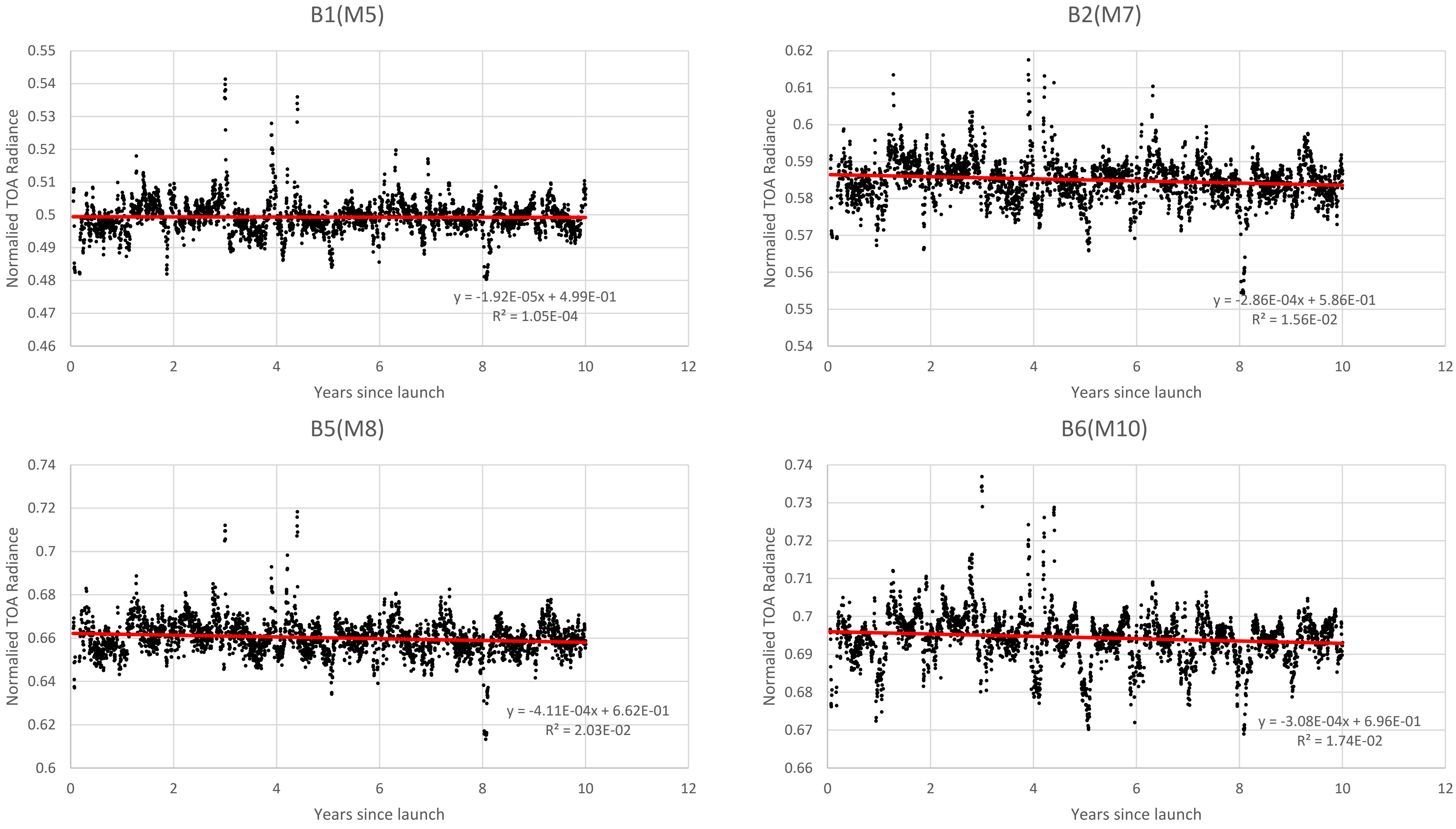


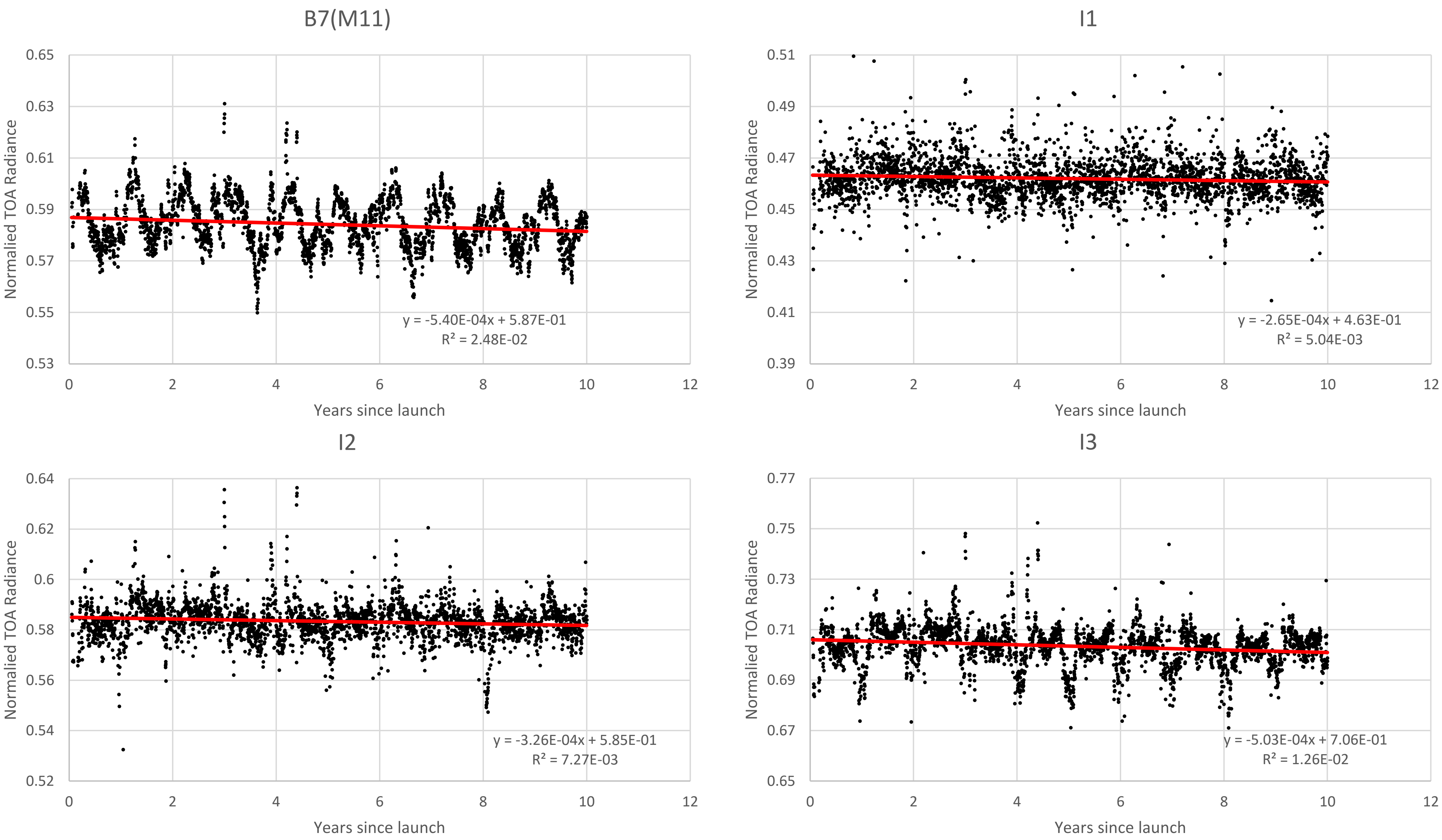






VIIRS SNPP Normalized TOA Radiance Time Series




B7(M11)
0.65
0.63
0.61
0.59
0.57
0.55
0.53
Normalied TOA Radiance
y = -5.40E-04x + 5.87E-01
R² = 2.48E-02
0
2
4
6
8
10
12
Years since launch
I1
0.51
0.49
0.47
0.45
0.43
0.41
0.39
Normalied TOA Radiance
y = -2.65E-04x + 4.63E-01
R² = 5.04E-03
0
2
4
6
8
10
12
Years since launch
I2
0.64
0.62
0.6
0.58
0.56
0.54
0.52
Normalied TOA Radiance
y = -3.26E-04x + 5.85E-01
R² = 7.27E-03
0
2
4
6
8
10
12
Years since launch
I3
0.77
0.75
0.73
0.71
0.69
0.67
0.65
Normalied TOA Radiance
y = -5.03E-04x + 7.06E-01
R² = 1.26E-02
0
2
4
6
8
10
12
Years since launch

VIIRS SNPP Calibration Trends

(Trend/year/unit of refl.)

Band	Intercept	Slope	P-value	Slope/Intercept
M1	0.2242	-1.8270E-04	8.8904E-12	-8.1489E-04
M2	0.2311	-2.1129E-04	2.1332E-08	-9.1418E-04
M3	0.2513	-8.8398E-05	3.2539E-03	-3.5179E-04
M4	0.3405	-4.5983E-05	1.3975E-01	-1.3506E-04
M5	0.4994	-1.9228E-05	5.8342E-01	-3.8500E-05
M7	0.5865	-2.8608E-04	2.0223E-11	-4.8782E-04
M8	0.6622	-4.1128E-04	2.1183E-14	-6.2111E-04
M10	0.6960	-3.0836E-04	1.4817E-12	-4.4305E-04
M11	0.5868	-5.4046E-04	2.6773E-17	-9.2096E-04
I1	0.4634	-2.6469E-04	1.4626E-04	-5.7124E-04
I2	0.5850	-3.2645E-04	5.0449E-06	-5.5804E-04
I3	0.7060	-5.0329E-04	1.8086E-09	-7.1288E-04

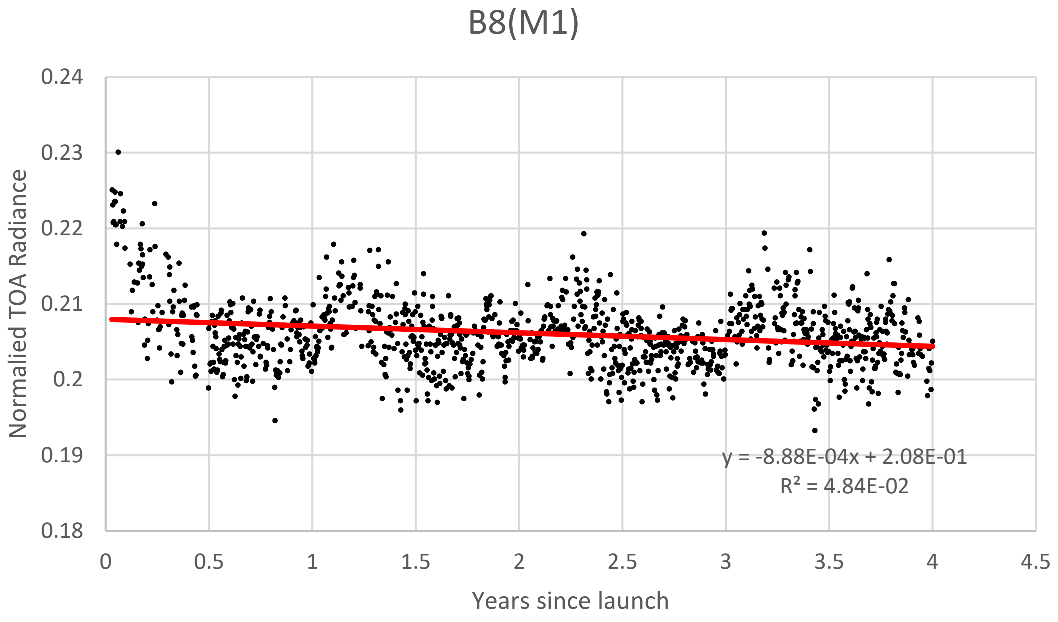
Red means statistically significant trend at P=0.05

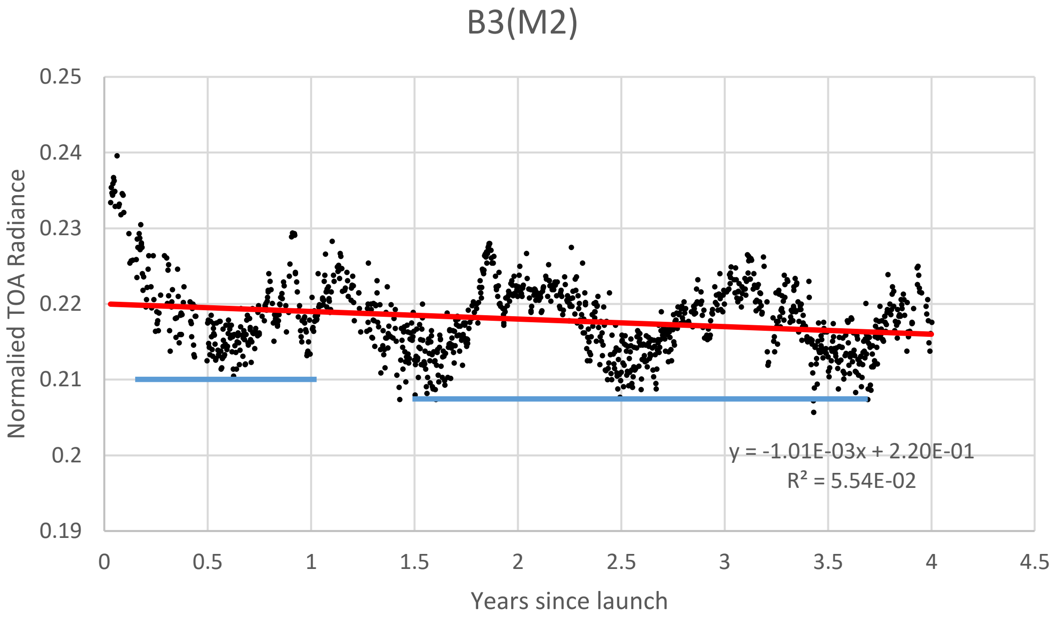
VIIRS NPP: After De-Trending

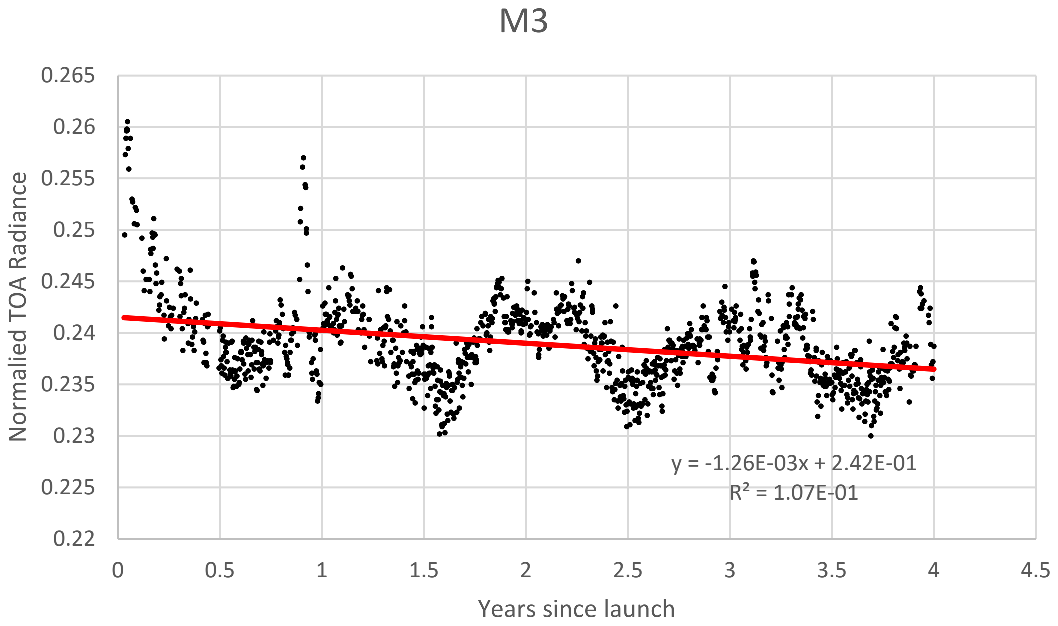
Band	Intercept	Slope	P-value
M1	0.2242	8.9935E-06	7.3869E-01
M2	0.2311	1.8523E-07	9.9617E-01
M3	0.2513	9.3169E-06	7.6342E-01
M4	0.3405	1.2660E-05	6.8979E-01
M5	0.4995	5.3570E-06	8.7837E-01
M7	0.5864	1.4888E-05	7.2618E-01
M8	0.6621	1.6737E-05	7.5485E-01
M10	0.6960	2.1351E-05	6.2294E-01
M11	0.5869	2.0340E-05	7.4903E-01
I1	0.4634	2.0940E-05	7.6512E-01
I2	0.5850	1.9214E-05	7.8832E-01
I3	0.7059	3.3754E-05	6.8669E-01

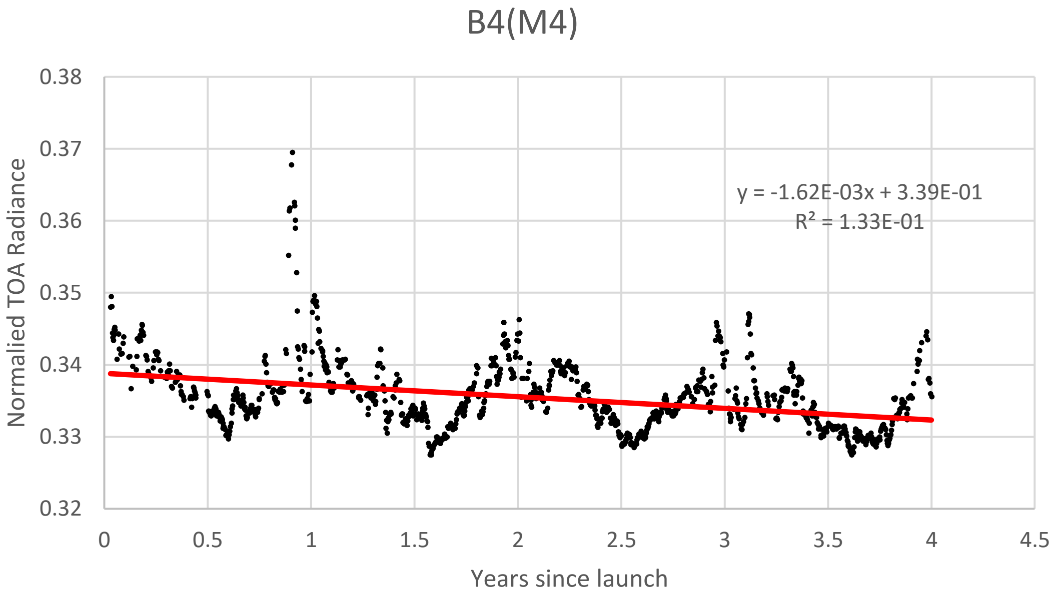
J1 De-Trending Analysis

VIIRS J1 Normalized TOA Radiance Time Series

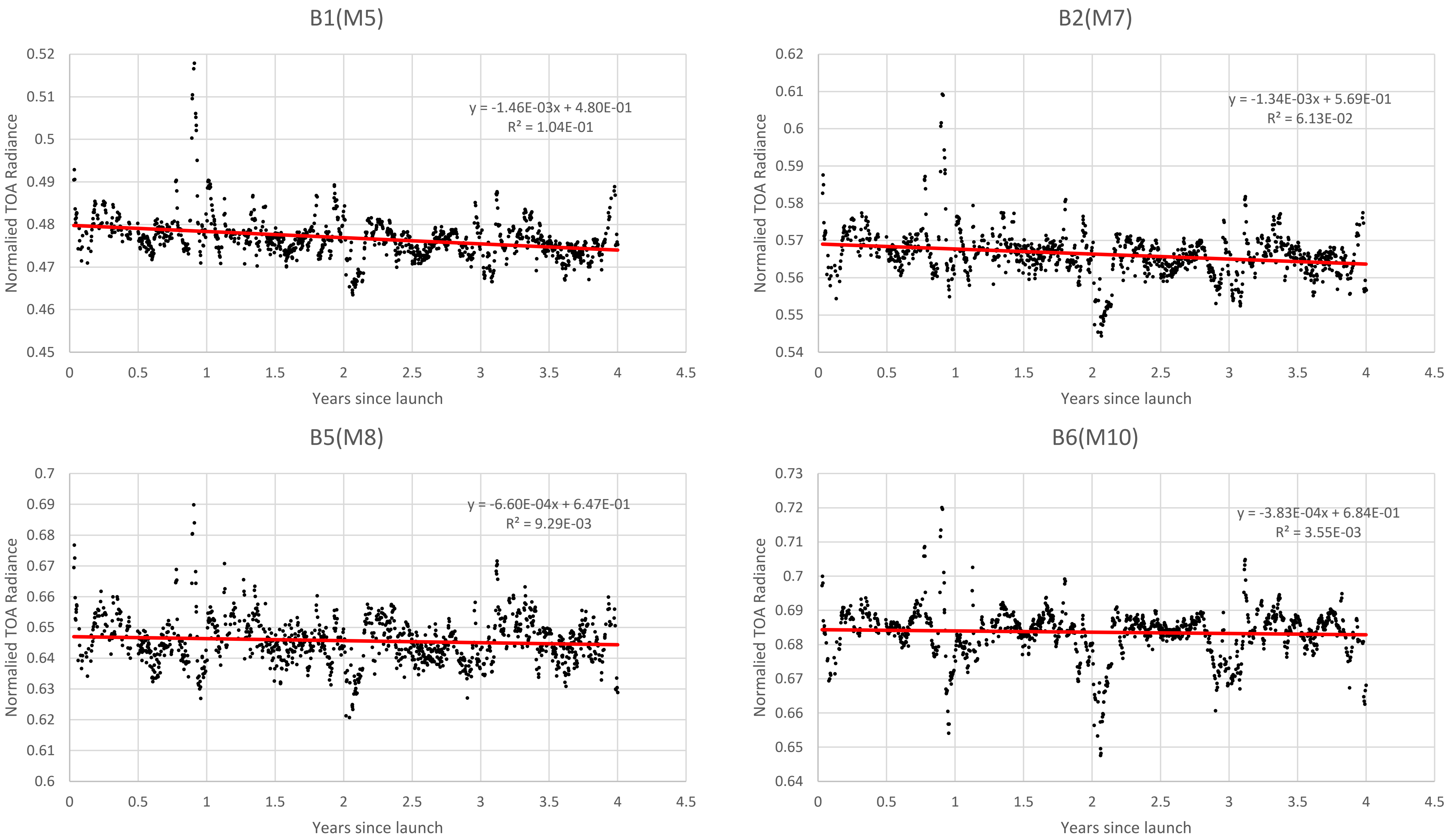


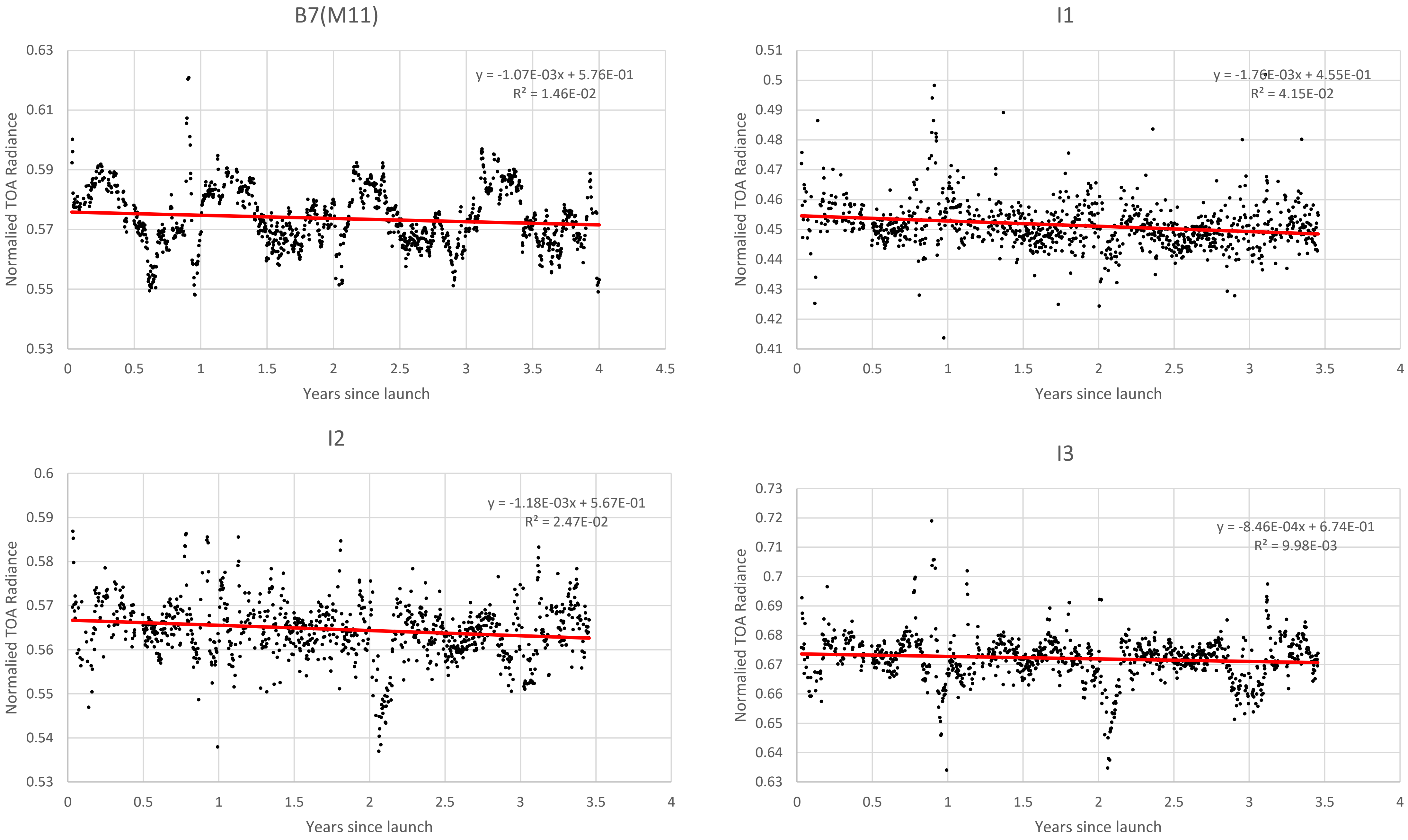






VIIRS J1 Normalized TOA Radiance Time Series

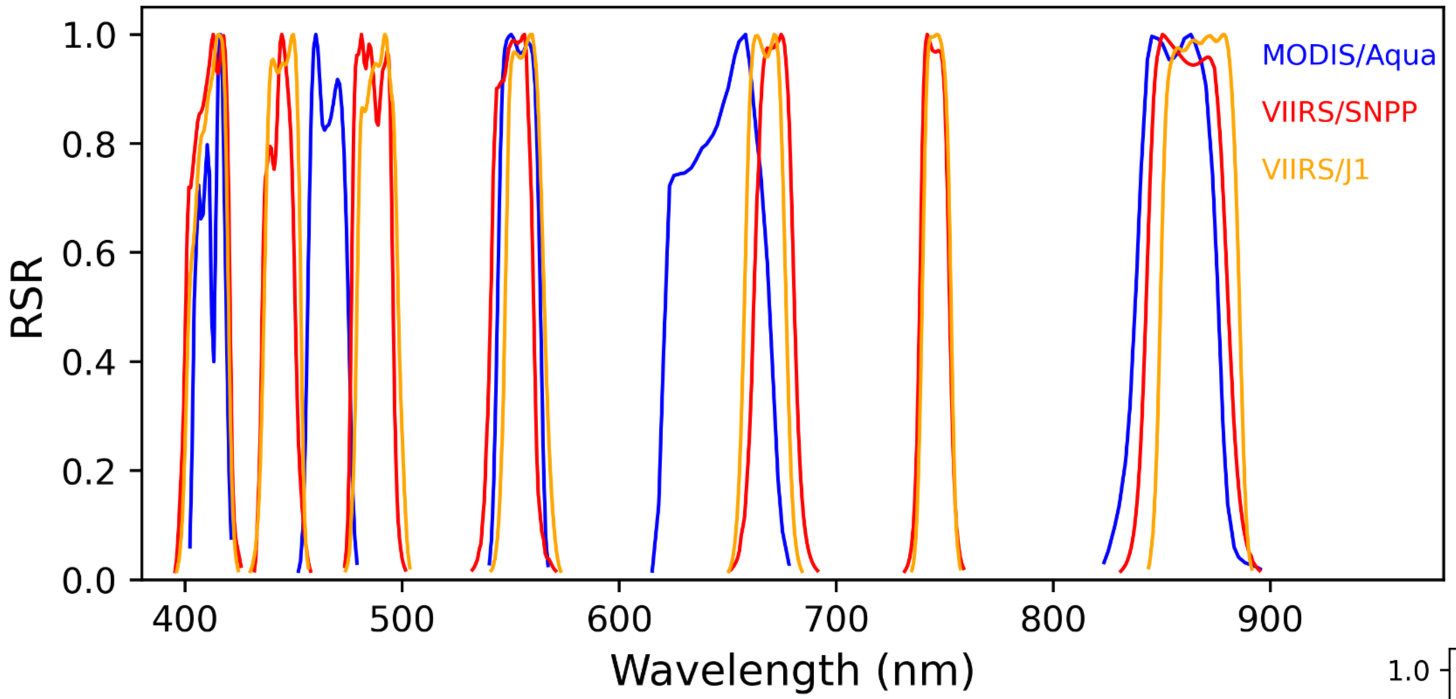



B7(M11)
y = -1.07E-03x + 5.76E-01
R² = 1.46E-02
Normalied TOA Radiance
Years since launch
I1
y = -1.76E-03x + 4.55E-01
R² = 4.15E-02
Normalied TOA Radiance
Years since launch
I2
y = -1.18E-03x + 5.67E-01
R² = 2.47E-02
Normalied TOA Radiance
Years since launch
I3
y = -8.46E-04x + 6.74E-01
R² = 9.98E-03
Normalied TOA Radiance
Years since launch

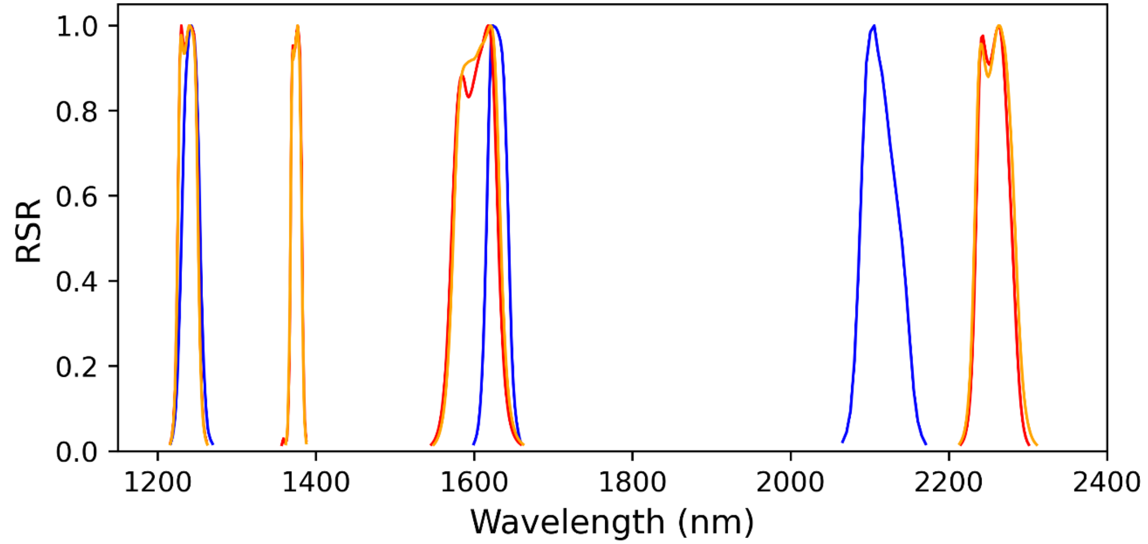
VIIRS J1 Calibration Trend

Band	Intercept	Slope	P-value	Slope/Intercept
M1	0.2080	-8.8800E-04	4.4238E-14	-4.2699E-03
M2	0.2200	-1.0068E-03	6.0009E-16	-4.5762E-03
M3	0.2415	-1.2574E-03	5.4765E-30	-5.2065E-03
M4	0.3388	-1.6162E-03	1.7656E-37	-4.7706E-03
M5	0.4798	-1.4629E-03	2.4186E-29	-3.0487E-03
M7	0.5690	-1.3449E-03	1.5532E-17	-2.3635E-03
M8	0.6470	-6.5979E-04	1.0607E-03	-1.0197E-03
M10	0.6844	-3.8257E-04	4.3247E-02	-5.5900E-04
M11	0.5758	-1.0741E-03	3.9124E-05	-1.8654E-03
I1	0.4545	-1.7381E-03	2.5234E-16	-3.8240E-03
I2	0.5666	-1.0723E-03	3.8296E-09	-1.8927E-03
I3	0.6732	-5.1134E-04	1.3994E-02	-7.5959E-04

VIIRS X-Cal to MODIS Aqua

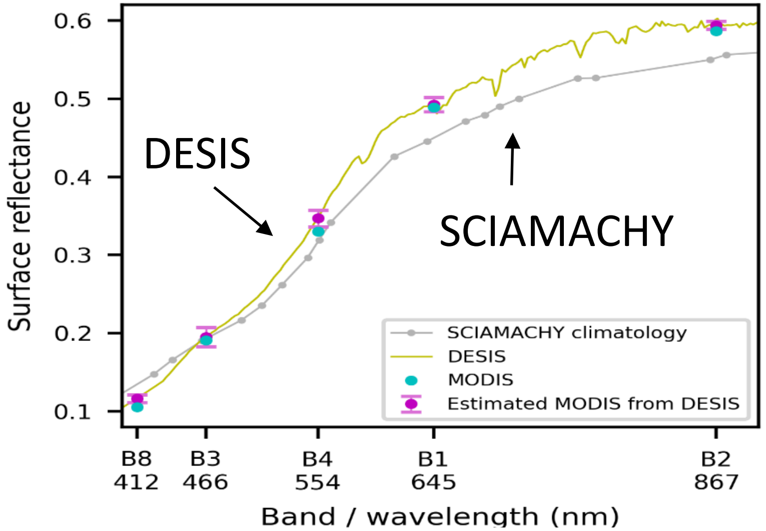


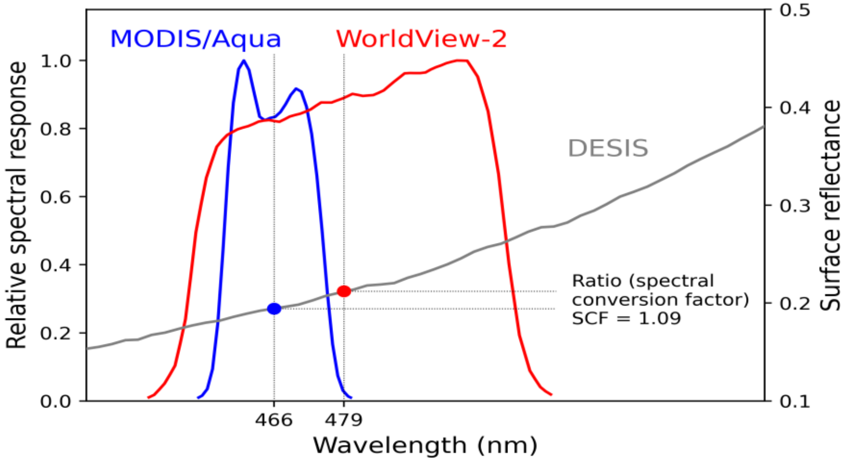
Because bands are different, sensors measure different reflectance over the same targets (with spectral dependence), we need to account for the RSR differences



Spectral Conversion Factor

- DESIS - DLR Earth Sensing Imaging Spectrometer, on ISS since 2018 (400-1000nm, spectral sampling at 2.55 nm and res. of 3.5 nm; 30m spatial resolution and ~ 30km swath).
- By our request, 97 DESIS measurement granules were collected over Libya-4 during 2018–2021. 3 are good.





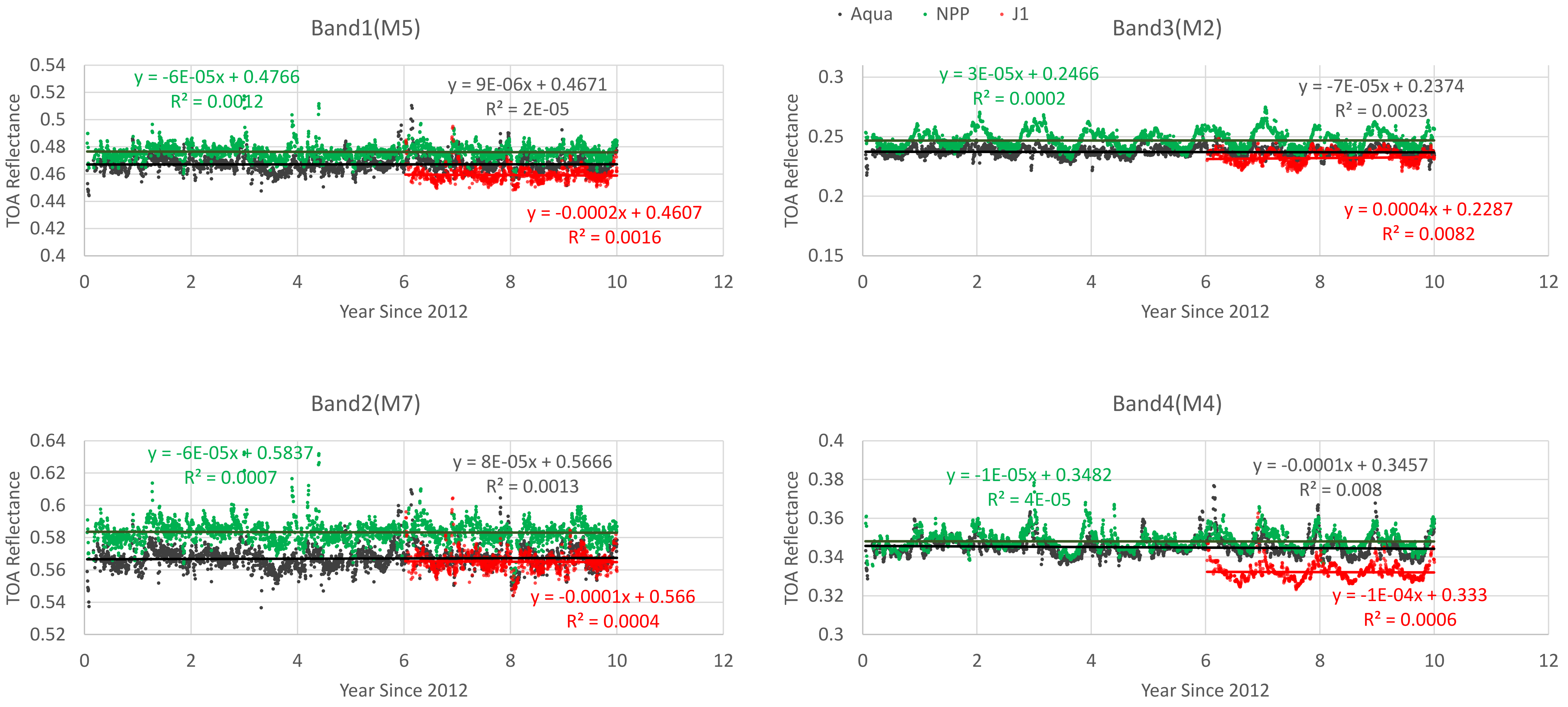
- Spectral convolution of surface reflectance
  - $\rho_{simulated} = \frac{\sum \rho_\lambda E_\lambda RSR_\lambda d\lambda}{\sum E_\lambda RSR_\lambda d\lambda}$
  - ρ_λ: DESIS surface reflectance with high spectral resolution
  - E_λ: solar irradiance
  - RSR_λ: spectral response function

- BRDF normalization factor
  - $c(\lambda) = \frac{BRF\ from\ fixed\ view\ geometry\ (SZA\ 20°, VZA\ 0°, RAA\ 0°)}{BRF\ from\ various\ DESIS\ view\ geometries}$
  - BRDF from MODIS MAIAC
  - $\rho^n_{simulated}(\lambda) = \rho_{simulated}(\lambda) * c(\lambda)$

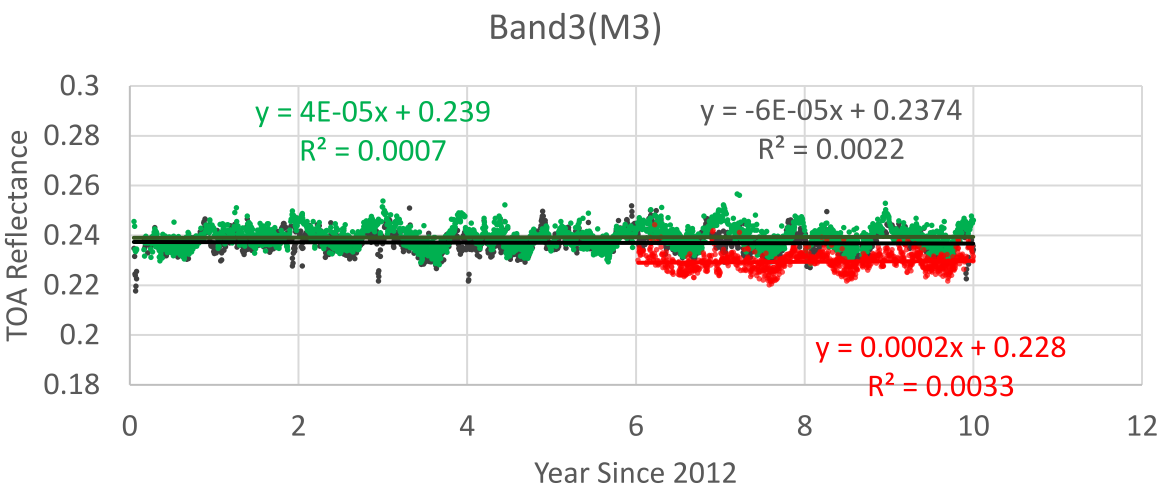
Spectral conversion factor (SCF)

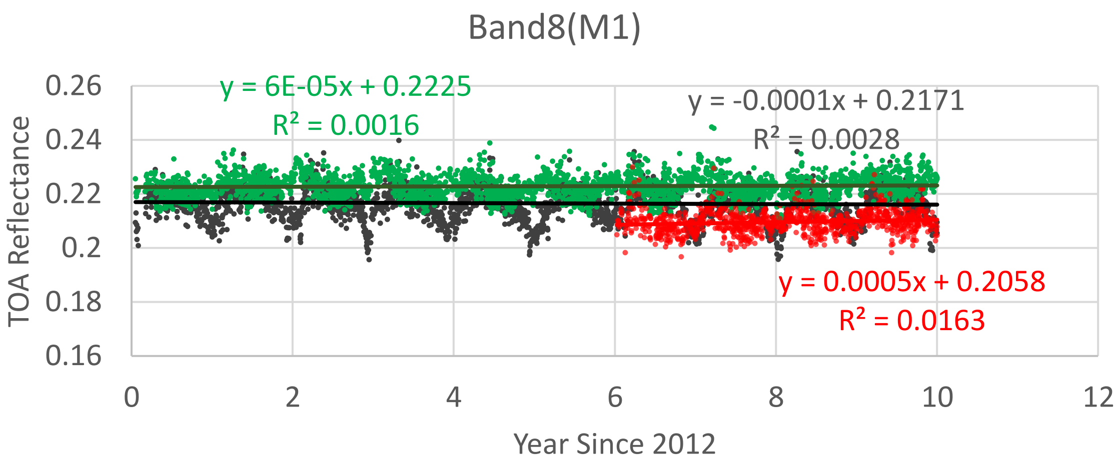
- SCF = $\frac{\rho^n_{simulated\ (DG\ sensors)}}{\rho^n_{simulated\ (MODIS/Aqua)}}$

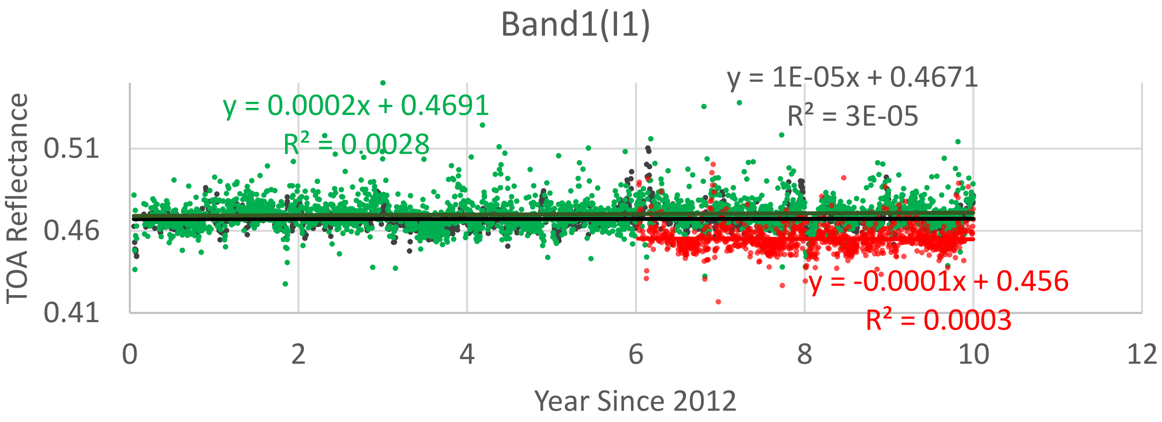
VIIRS X-Calibration to MODIS Aqua

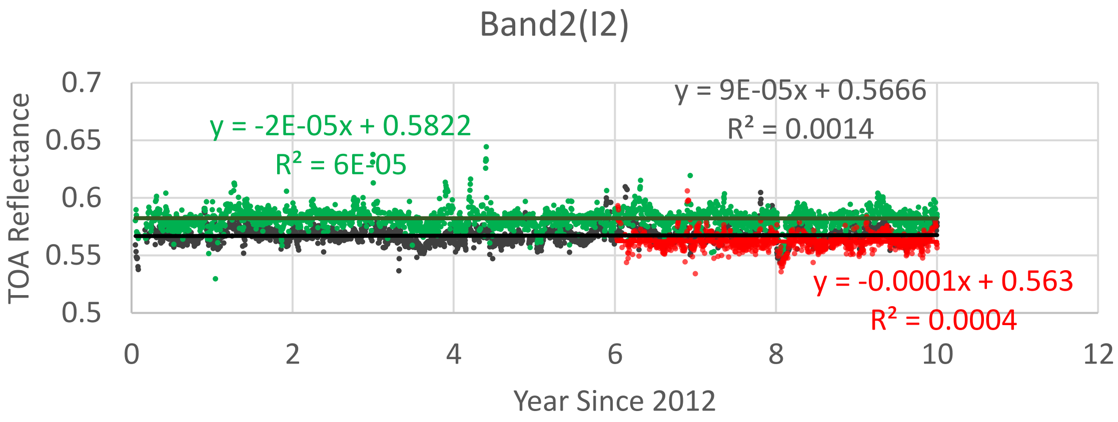


VIIRS X-Calibration to MODIS Aqua









VIIRS BRDF is multiplied by the Spectral Conversion Factor (this effectively “shifts” the VIIRS band to the MODIS reference band), and VIIRS normalized TOA reflectance is computed at the MODIS wavelength. This way, both surface and atmospheric RT computations are done at the same wavelength ensuring 1:1 comparison.

Aqua/VIIRS NPP/VIIRS J1 X-calibration Summary

	Spectral Ratio		X-calibration Coefficients		
Band	**Aqua/NPP**	**Aqua/J1**	**Aqua/NPP**	**Aqua/J1**	**NPP/J1**
B8/M1	0.960	1.001	0.9711	1.0374	1.0683
B3/M2	1.197	1.191	0.9603	1.0253	1.0677
B3/M3	0.889	0.882	0.9906	1.0253	1.0351
B4/M4	1.026	0.978	0.9905	1.0373	1.0472
B1/M5	0.959	0.962	0.9810	1.0164	1.0361
B2/M7	1.001	0.999	0.9723	1.0033	1.0319
M8	-	-	-	-	1.0237
M10	-	-	-	-	1.0169
M11	-	-	-	-	1.0187
I1	1.016	1.004	0.9937	1.0164	1.0228
I2	1.001	0.998	0.9744	1.0087	1.0352
I3	-	-	-	-	1.0495

This Study vs Xiong et al., 2020

Desert – Dome C (Deep Convective Clouds)

	Xiong et al., 2000 (in %)			X-calibration Coefficients		
Band	**(A-NPP)/NPP**	**(A-J1)/A**	**(NPP-J1)/J1**	**Aqua/NPP**	**Aqua/J1**	**NPP/J1**
B8/M1	-	2.1-4.2	6.3-7.0 (1.0)	0.9711	1.0374	1.0683
B3/M2	-	5.0-5.3 (M2/B9)	4.7-6.1 (6.4)	0.9603	1.0253	1.0677
B3/M3	-	-	4.3-4.9	0.9906	1.0253	1.0351
B4/M4	-	2.4-3.2	3.4-5.2 (9.1)	0.9905	1.0373	1.0472
B1/M5	-	-	4.7-5.5 (3.1)	0.9810	1.0164	1.0361
B2/M7	-	0.6-2.8	2.8-3.5 (3.7)	0.9723	1.0033	1.0319
M8	-	-	2.2-3.3 (2.2)			1.0237
M10	-	-	1.5-5.2 (2.1)			1.0169
M11	-	-	0.8-4.1 (2.4)			1.0187
B1/I1	-	2.9-3.6	3.7-3.8 (6.1)	0.9937	1.0164	1.0228
B2/I2	-	0.9-2.7	3.1-3.6 (5.9)	0.9744	1.0087	1.0352

Xiong X, Angal A, Chang T, Chiang K, Lei N, Li Y, Sun J, Twedt K, Wu A. MODIS and VIIRS Calibration and Characterization in Support of Producing Long-Term High-Quality Data Products. Remote Sensing. 2020; 12(19):3167. https://doi.org/10.3390/rs12193167

AOD Before and After X-Calibration