Impact of Terra MODIS Collection 6 on Long-term Trending with L7 ETM+ Reflective Solar Bands

Amit Angal[1], Xiaoxiong (Jack) Xiong[2], Gyanesh Chander[3], Taeyoung (Jason) Choi[4] , and Dennis L. Helder[5]

[1] Science Systems and Application Inc. [2]NASA GSFC [3]SGT/USGS EROS [4] Sigma Space Corp. [5] SDSU

Introduction

➢ Terra MODIS makes continuous observations over a wide Field of View (± 55°) in 36 spectral bands with wavelengths from 0.4 to 14.4 µm and at nadir spatial resolutions of 0.25 km, 0.5 km, and 1 km.

➢L7 ETM+ acquires earth scene measurements via six multispectral bands from 0.45 to 12.36 µm at 30 m spatial resolution.

➢The calibration uncertainties of the MODIS Top-of-Atmosphere (TOA) reflectance products are ±2% and a 5% uncertainty requirement has been specified for the L7 ETM+ at-sensor spectral radiances.

➢Our previous work [1, 2] focused on monitoring the long-term radiometric calibration stability of ETM+ and MODIS using the pseudo-invariant calibration sites (PICS) from the North African desert (Libya 4, Mauritania 1/2, Algeria 3, Algeria 5 and Libya 1).

➢The results from that study showed long-term drifts in the TOA reflectance trending for the short wavelength bands of Terra MODIS using the Libya 4 site with similar result obtained from other Saharan test sites.

➢As an extension and improvement to the previous work, in this paper, the L7 ETM+ TOA reflectance trends are compared with both the Collection 5 (C5) and Collection 6 (C6) TOA reflectance products to establish the impact of MODIS C6 on the long-term studies from the two sensors.

Improvements in MODIS Collection 6

➢Several enhancements have been made to the L1B data production through major version releases [3].

➢Although, the format of a C6 MODIS L1B granule is identical to the corresponding C5 products, the improved radiometric accuracy especially in the short wavelength bands will significantly enhance the quality of the downstream science products.

➢In C5 and previous algorithms, the on-orbit RVS change was solely tracked using the solar diffuser and lunar gain measurements with a linear approximation.

➢In C6, this approach was improved by supplementing the on-board measurements with the response trending from the PICS to accurately characterize the gain change at all scan-angles.

➢This approach is applied to Bands 1-4, 8, and 9 of Terra MODIS and result in mitigating the long-term drifts observed in the C5 trending.

Methodology and Data Processing

➢All available ETM+ and MODIS images over the six sites were chosen for this analysis.

➢Identical ROIs were chosen for each of three datasets (ETM+, MODIS C5, and MODIS C6) processed for this study.

Table I. ROI co-ordinates and dimensions for the PICS.

Sites	WRS-2 Path/Row	Min_Lat	Max_Lat	Min_Long	Max_Long	UTM Zone	Area (km)
Libya 4	181/40	28.45	28.65	23.29	23.49	34	20 x 22
Mauritania 1	201/47	19.3	19.5	-9.4	-9.2	29	21 x 21
Mauritania 2	201/46	20.75	20.95	-8.88	-8.68	29	21 x 23
Algeria 3	192/39	30.22	30.42	7.56	7.76	32	19 x 22
Libya 1	187/43	24.4	24.6	13.2	13.4	33	20 x 22
Algeria 5	195/39	30.92	31.12	2.13	2.33	31	19 x 23

➢Near-simultaneous nadir acquisitions were selected to minimize the impact of site and atmospheric bidirectional reflectance distribution function (BRDF).

➢All the L7 ETM+ data products were generated using the LPGS and the MODIS data products were generated using the MODAPS collection 5 and 6 release (C5 and C6).

➢The retrieved TOA reflectances are dependent upon the sensor and solar zenith angle as well as the relative azimuth between the sun and the imaging sensor.

➢A semi-empirical BRDF model has been used to derive the model coefficients on a wavelength and sensor-specific level

➢The detailed procedure and methodology associated with the BRDF correction has been documented in [2].

TOA Reflectance Trending

➢ The TOA reflectance was computed on a band-by-band basis for both sensors over the selected ROI for each site. The multi-year TOA reflectance trending for the spectrally matching Terra MODIS (C5 denoted in red and C6 denoted in orange) and L7 ETM+ (denoted in blue) bands are shown in Figure 1.

➢ The following observations should be noted: a) the visible annual oscillations can be attributed to surface and atmospheric BRDF b) the band-dependent offset are because of the differences in spectral bandpasses. c) A long-term drift of up to 8% observed in the C5 trending for MODIS B3 and a marginal, but evident degradation observed in MODIS B1, 2 and 4. However, MODIS C6 trends (denoted in orange) show a major improvement in mitigating the degradation observed in these bands as evident from any absence of a long-term drift (within 2%) d). The results from the MODIS B6 and 7 are essentially the same for the C5 and C6.

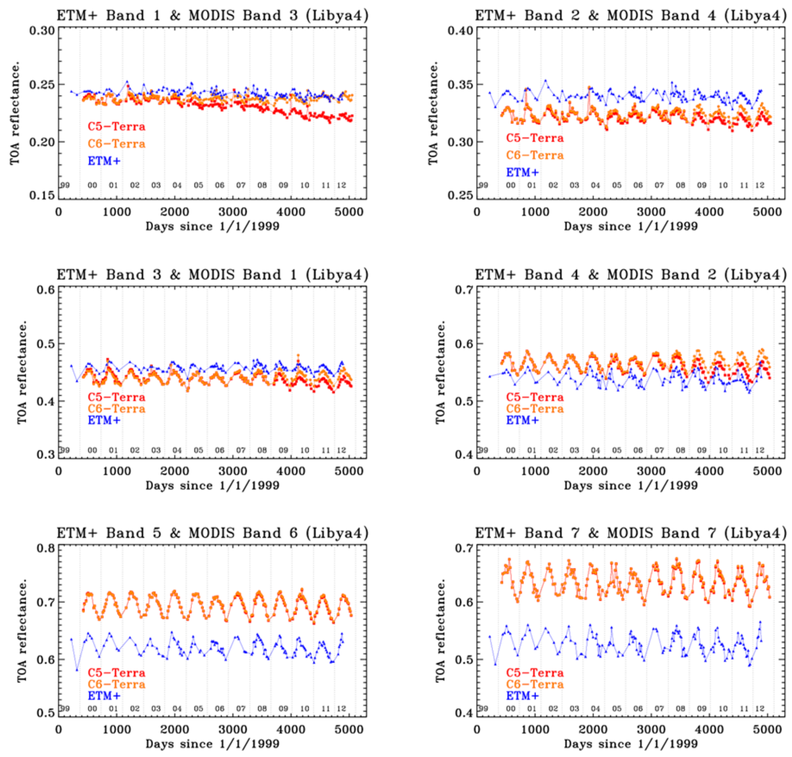

Figure 1. TOA Reflectance trending for L7 ETM+ and Terra MODIS (C5 and C6).

➢Figure 2 shows the BRDF normalized reflectance trending for the three data-sets for the spectrally matching shorter wavelength bands. Some residual season pattern is still evident in the BRDF normalized reflectance trending; however, the associated long-term drift in MODIS C5 and improvement in the corresponding C6 products is more evident.

➢Table II summarizes the long-term reflectance change for each of the three datasets over the Libya 4 site. In addition to the long-term drift in the reflectance, the percent standard error values are also presented.

➢Table II. Long-term drifts observed in the TOA reflectance trending from Libya 4.

	MODIS C5		MODIS C6		ETM+	
ETM+ band	Drift (%)	STD. error	Drift (%)	STD. error	Drift (%)	STD. error
1	8.398	1.7	0.495	1.442	2.458	1.285
2	2.17	1.114	0.181	1.046	1.072	1.139
3	3.435	1.18	-0.338	1.113	0.524	1.09
4	3.488	1.062	-0.528	0.945	1.417	2.012
5	1.258	0.613	0.817	0.619	1.689	1.283
7	1.751	1.876	1.294	1.888	2.274	2.567

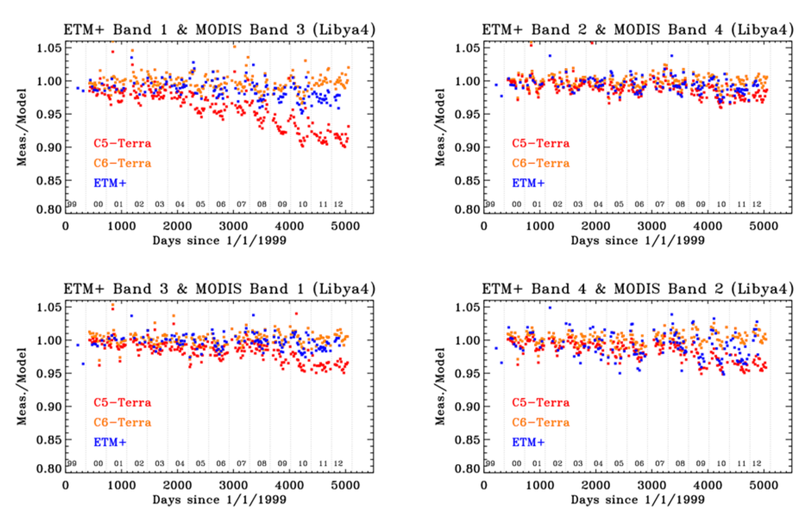

Figure 2. BRDF-normalized TOA Reflectance trending for short wavelength bands of the L7 ETM+ and Terra MODIS (C5 and C6) over the Libya 4 site.

T-test to Evaluate the Long Term Trends

➢ A commonly used test for the slope of the regression line is the Student's T-test.

➢The slope of a regression line is tested for null slope with the null hypothesis stating that no long-term drift is observed and alternative hypothesis stating that the slope is significant therefore indicating a temporal drift. The p-value denoting the probability of the test-statistic under null-hypothesis is tested at a 5% level.

➢The results from all six African CEOS PICS are included in the below table. It summarizes the p-values for each of three datasets on a per-band basis.

Table III. T-test for slope of the TOA reflectance regression fit parameters over the CEOS reference PICS.

	MODIS Collection 5			MODIS Collection 6			ETM+		
ETM+ Band	t-value	p value	Ho, slope=0	t-value	p value	Ho, slope=0	t-value	p value	Ho, slope=0
Libya4									
1	-21.869	0.00000	Reject	1.4773	0.92942	Fail to Reject	-7.18342	0.00000	Reject
2	-5.452	0.00000	Reject	1.99012	0.97601	Fail to Reject	-2.11901	0.01795	Reject
3	-6.86856	0.00000	Reject	2.1307	0.98282	Fail to Reject	-1.35451	0.08923	Fail to Reject
4	-6.23257	0.00000	Reject	2.48815	0.99312	Fail to Reject	-1.3086	0.09714	Fail to Reject
5	-1.46592	0.07209	Fail to Reject	-0.77673	0.21915	Fail to Reject	-2.83073	0.00303	Reject
7	-1.20148	0.11547	Fail to Reject	-1.0327	0.15154	Fail to Reject	-2.21889	0.01458	Reject
Mauritania-1									
1	-7.90716	0.00000	Reject	-0.20799	0.41773	Fail to Reject	-1.85447	0.03321	Reject
2	-2.62083	0.00470	Reject	-0.05394	0.47852	Fail to Reject	-1.68627	0.04737	Reject
3	-9.16278	0.00000	Reject	-0.36838	0.35652	Fail to Reject	-1.63148	0.053	Fail to Reject
4	-8.3987	0.00000	Reject	0.01091	0.50435	Fail to Reject	-1.92757	0.02845	Reject
5	-4.00252	0.00005	Reject	-3.04818	0.00135	Reject	-2.84901	0.00272	Reject
7	-2.2391	0.01319	Reject	-1.79373	0.03741	Reject	-2.07154	0.02054	Reject
Mauritania-2									
1	-5.89081	0.00000	Reject	-0.79323	0.21432	Fail to Reject	-0.17139	0.4321	Fail to Reject
2	0.00827	0.50329	Fail to Reject	-0.46163	0.32244	Fail to Reject	1.76223	0.95978	Fail to Reject
3	-3.11232	0.00106	Reject	0.93109	0.82347	Fail to Reject	2.90726	0.99783	Fail to Reject
4	-3.97421	0.00005	Reject	1.2994	0.90223	Fail to Reject	0.16303	0.56462	Fail to Reject
5	0.8382	0.79850	Fail to Reject	1.24763	0.89304	Fail to Reject	0.65247	0.7423	Fail to Reject
7	2.03468	0.97833	Fail to Reject	1.16473	0.87707	Fail to Reject	0.28201	0.61078	Fail to Reject
Algeria-3									
1	-7.68746	0.00000	Reject	1.23112	0.88998	Fail to Reject	-2.29919	0.01154	Reject
2	-2.28638	0.01170	Reject	1.42461	0.92192	Fail to Reject	-1.00547	0.15856	Fail to Reject
3	-3.77262	0.00012	Reject	0.90683	0.81695	Fail to Reject	-0.45255	0.3266	Fail to Reject
4	-3.69565	0.00017	Reject	-0.69961	0.24292	Fail to Reject	1.23284	0.88279	Fail to Reject
5	-2.64871	0.00460	Reject	-2.4847	0.00728	Reject	-0.76961	0.24879	Fail to Reject
7	-2.5011	0.00686	Reject	-2.5537	0.00603	Reject	-0.67995	0.25285	Fail to Reject
Libya-1									
1	-9.2001	0.00000	Reject	0.92921	0.82303	Fail to Reject	-3.81744	0.00011	Reject
2	-3.48531	0.00030	Reject	0.79875	0.78728	Fail to Reject	-2.84861	0.0026	Reject
3	-11.2869	0.00000	Reject	0.73822	0.76933	Fail to Reject	-1.68721	0.04719	Reject
4	-8.19729	0.00000	Reject	1.31629	0.90511	Fail to Reject	-1.72006	0.04416	Reject
5	-2.30889	0.01100	Reject	-1.21584	0.11285	Fail to Reject	-3.38288	0.00053	Reject
7	-1.51946	0.06514	Fail to Reject	-0.77901	0.21851	Fail to Reject	-1.97866	0.02526	Reject
Algeria-5									
1	-10.4213	0.00000	Reject	3.35369	0.99952	Fail to Reject	-3.90618	0.0001	Reject
2	-0.78166	0.21766	Fail to Reject	3.94767	0.99994	Fail to Reject	-1.32197	0.09497	Fail to Reject
3	-6.58185	0.00000	Reject	2.03628	0.97835	Fail to Reject	0.68676	0.7523	Fail to Reject
4	-4.94686	0.00000	Reject	2.30174	0.98856	Fail to Reject	-0.09865	0.46098	Fail to Reject
5	-2.37809	0.00934	Reject	-1.89004	0.03042	Reject	-1.89055	0.04399	Reject
7	-2.64813	0.00447	Reject	-2.44886	0.00778	Reject	-1.34993	0.09325	Fail to Reject

Summary

➢ Temporal analyses of satellite observations provide unparalleled information regarding the various characteristics of the Earth's surface and atmosphere.

➢ Both the L7 ETM+ and Terra MODIS RSB are widely used to derive a variety of science products and an accurate on-orbit characterization of the sensor change is imperative for a meaningful interpretation of derived scientific parameters.

➢ A long-term drift of up to 6% was observed in the short-wavelength RSB of Terra MODIS in the C5 products. Various enhancements as developed by MCST were incorporated in the subsequent C6 products.

➢ Long-term TOA reflectance trending from desert PICS confirm that the drift is significantly reduced to be within the specified calibration uncertainty (2% in TOA reflectance) of MODIS RSB.

➢ Consequently, a better long-term agreement is observed between MODIS C6 and L7 ETM+ in comparison with MODIS C5.

➢ In addition, a long-term drift of about 3% has been observed in the Band 1 of L7 ETM+. Further effort is underway to achieve an improved consistency of the observed ETM+ drift across all ground targets.

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