Terra MODIS Collection 6.1 Calibration and Cloud Product Changes

Version 1.0 (27 June 2017)

Authored by Chris Moeller and Richard Frey (University of Wisconsin)

Calibration (MOD021KM)

The Terra MODIS Photovoltaic (PVLWIR) bands 27-30 are known to experience an electronic crosstalk contamination. The influence of the crosstalk has gradually increased over the mission lifetime, causing for example, earth surface features to become prominent in atmospheric band 27, increased detector striping, and long term drift in the radiometric bias of these bands. The drift has compromised the climate quality of C6 Terra MODIS L2 products that depend significantly on these bands, including cloud mask (MOD35), cloud fraction and cloud top properties (MOD06), and total precipitable water (MOD07). A linear crosstalk correction algorithm has been developed and tested by MCST. It uses band averaged influence coefficients based upon monthly lunar views by Terra MODIS and has been adopted for implementation into C6.1 operational L1B processing (Wilson et al. 2017). In stressing test cases from selected time periods of the Terra mission lifetime, the correction algorithm maintains or restores the MODIS PVLWIR band radiances to nominal performance as indicated through comparisons to Aqua MODIS radiances. The Figure 1 example for band 29 shows that the crosstalk influence has increased over time, driving the Terra MODIS C6 brightness temperatures (red) away from the C6 Aqua MODIS brightness temperatures (blue). For crosstalk corrected C6.1 data (green), the Terra and Aqua MODIS brightness temperatures are brought much more closely into agreement.

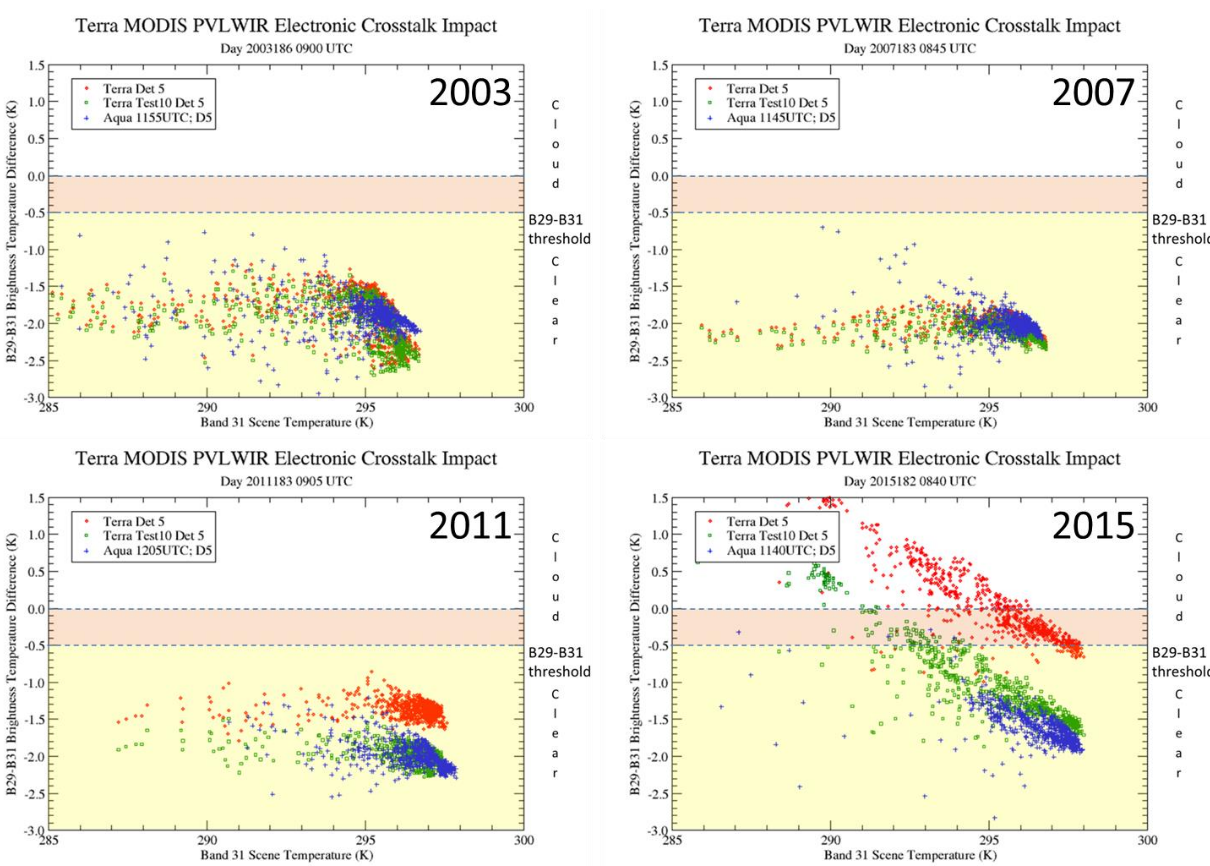


Figure 1. Terra MODIS B29-B31 brightness temperature difference examples for data scenes in four separate years. After crosstalk correction (green), B29-B31 differences closely match Aqua MODIS B29-B31 differences (blue) for all years. The initially very small correction increases through the mission.

Terra MODIS high latitude simultaneous nadir overpasses (SNOs) with MetOp-A IASI provide insight on MODIS long term radiometric trending. C6 biases and trends easily exceed 1 K in bands 27 and 30 over the eight year period in Figure 2, indicating that the MODIS C6 L1B radiances of these bands are not useful for climate science. The sharp increase in the B27 bias for April 2016 reveals a significant change in band 27 performance after the February 2016 Terra safe mode event. The safe mode event resulted in a significant increase in electronic crosstalk for all PVLWIR bands. Bands 28 and 29 show trends that are closer to 0.5 K over the period. Although these are smaller trends, they nevertheless impact L2 products. Further, evidence from these products suggests that the trends are significantly larger for each PVLWIR band in warm scenes such as exist in the low latitudes of the tropical zone. Unfortunately, there are no low latitude SNOs between Terra and MetOp-A with which to verify this behavior in L1B radiances.

The MODIS C6.1 biases and trending are significantly reduced compared to C6 (Figure 2). In B27 the trend reduces from about -2 K for these SNO scenes down to about 0.5 K over the 8 year period, (and would be less but for the April 2016 data point after the safe mode). The band 30 trend, while significantly reduced in C6.1, is still about 1.0 K, suggesting that the crosstalk correction is not as effective for this band as for the other PVLWIR bands. Trends in band 28 and 29 are reduced to < 0.2 K. Biases in all bands are smaller (closer to zero) in C6.1.

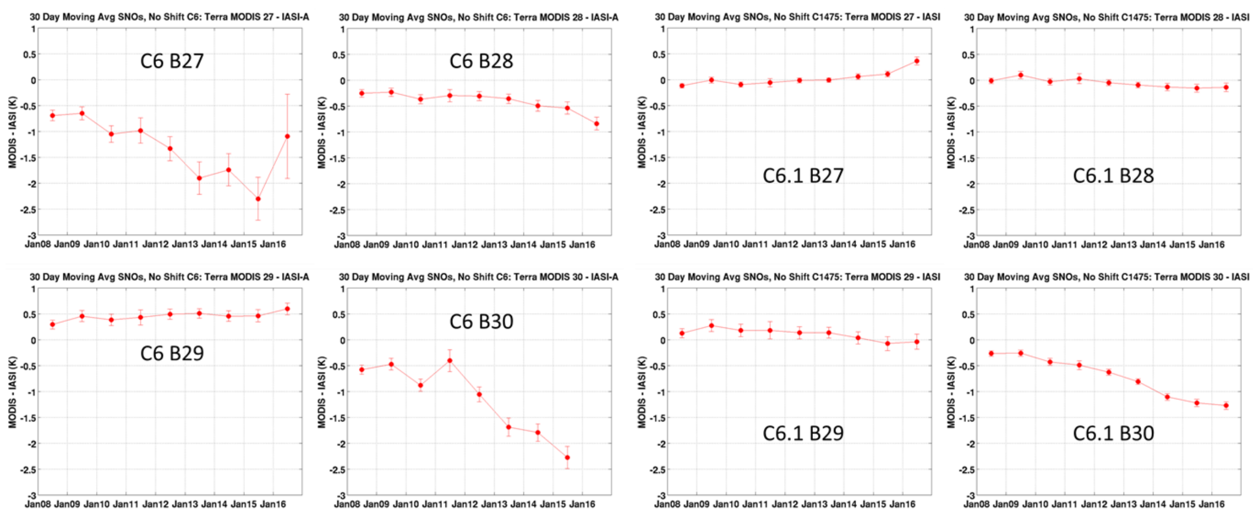


Figure 2. Terra MODIS radiometric bias trends based upon high latitude SNO comparisons with MetOp-A IASI for C6 (left 4 panels) and for C6.1 (right 4 panels). After crosstalk correction (C6.1), radiometric trends are greatly reduced, with exception of B30 which still shows trending over the 8+ years of data.

Cloud Mask (MOD35)

The slow warming of observed brightness temperatures (BTs) in the 8.6 µm atmospheric water vapor absorption band (band 29) increased the numeric value of an 8.6 minus 11.1 µm brightness temperature difference (BTD) used in the algorithm to detect ice clouds over water surfaces. Over time, the confidence of clear sky reported by this cloud test began to lessen in actual clear sky scenes and impacted the cloud mask final result: first to probably clear, then to probably cloudy, and finally to confident cloud in some cases. This is illustrated in Figure 3 where the fraction of confident clear pixels from 60S-60N over oceans is plotted as a function of time (trend). One sees a decrease beginning in about 2011 but then a sharp decrease from about 2013. The variability in the clear fraction (observed) also decreases after this date, indicating that cloud vs. clear discrimination has become severely compromised in oceanic regions of the world.

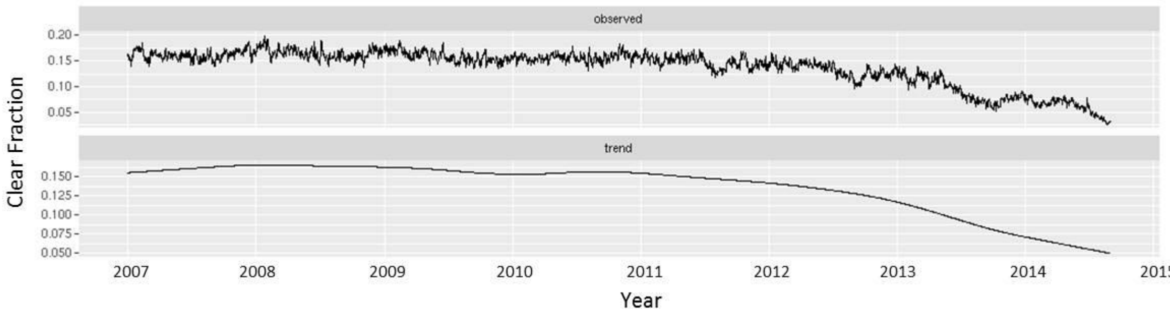


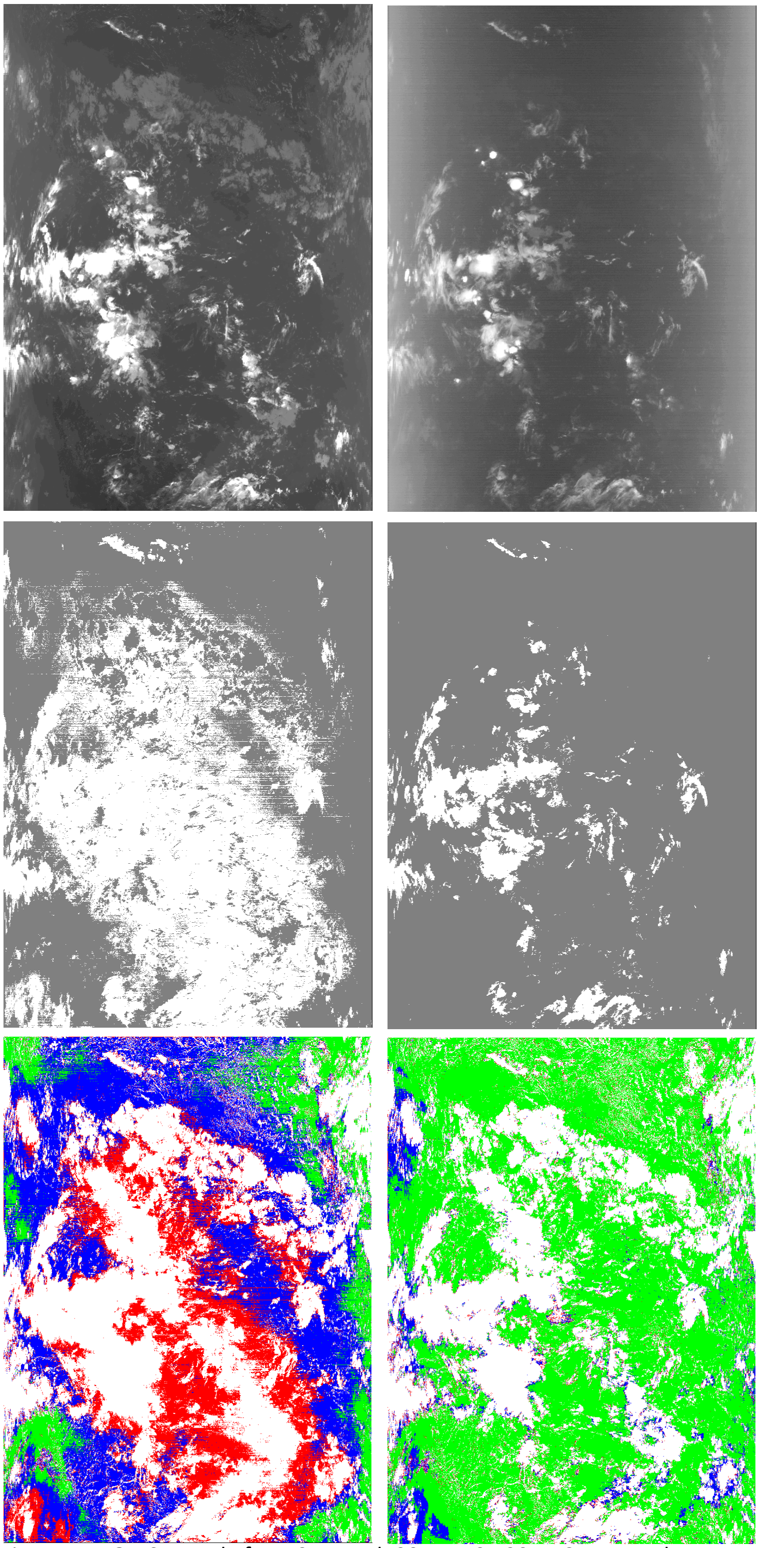
Figure 3. Fraction of confident clear pixels in the MODIS cloud mask (MOD35) as a function of time, from 60S to 60N latitude, water surfaces only.

The electronic crosstalk correction discussed above (Wilson, et al., 2017) was made to the calibration algorithm for bands 27-30 and greatly improves the performance of the cloud mask. An example of the change in the 8.6 – 11.1 BTD test and resulting output cloud mask is shown in Figure 4. Parts a and b show 11.1 and 13.9 µm imagery, respectively, from this nighttime scene located in the tropical eastern Pacific. Parts c and d are depictions of the 8.6 – 11.1 BTD test where the white areas indicate confidence of clear sky < 0.5 (clouds) before and after the calibration correction, respectively. Note that the cloudy regions in part d correspond closely to the 13.9 µm imagery that shows mainly high and presumably ice clouds. Parts e and f are similar to c and d but illustrate changes in the final output cloud mask. Green is clear, blue is probably clear, red is probably cloudy, and white is confident cloudy. The improvement in discrimination between clear and cloudy pixels is dramatic.

Other tests impacted by the calibration changes are the 6.7 µm (band 27) BT high cloud test and polar night 6.7 – 11 µm BTD clear sky restoral test, the polar night 7.3 - 11 µm (band 28 – band 31) BTD cloud test and clear sky restoral test (using different thresholds), and the night ocean 8.6 – 7.3 BTD cloud test. Threshold changes were made to the latter test to mitigate over-clouding over colder waters. Globally, the largest improvement to MOD35 is through the 8.6 – 11.1 BTD test as shown in Figure 4.

IR Cloud Phase and Cloud Top Pressure

Two other MODIS atmosphere products were impacted by the drift and subsequent correction in 8.6 and 7.3 µm radiances. The IR cloud phase, found in the MOD06 cloud product files, was severely impacted as far too many clouds were labeled as ice phase. We have determined that the calibration change has fixed the problem with no additional changes necessary. In the CO2 slicing cloud top pressure algorithm, a ratio of observed minus calculated 8.6 to 11.1 µm radiances ("beta ratio") is used to screen out unreliable retrievals over water phase clouds. Previous to the calibration correction, too many clouds were determined to be middle or high level (cloud top pressure too low). In this case also, we have determined that the crosstalk correction has mitigated the problem.



Parts a (left) and b (right)

Parts c (left) and d (right)

Parts e (left) and f (right)

Figure 4. MODIS granule from 31 March 2014 at 05:30 UTC. Parts a, b are MODIS bands 31, 35 (11.1, 13.9 µm), parts b, c show results of 8.6-11.1 µm BTD ice phase cloud test for pre- and post- crosstalk calibration correction, parts e,f are final mask results for pre- and post- crosstalk calibration correction.

See text for color definitions.

Reference

Wilson, T., A. Wu, A. Shrestha, X. Geng, Z. Wang, C. Moeller, R. Frey, and X. Xiong. Development and Implementation of an Electronic Crosstalk Correction for Bands 27-30 in Terra MODIS Collection 6. *Remote Sens*., 9, 569, 2017, doi:10.3390/rs9060569.