MCST Internal Memo

Date: December 11, 2020
From: Xu Geng, Na Chen, Kevin Vermeesch
To: MODIS Science Team members
Subject: Proposed code/LUT changes for MODIS Collection 7 Level 1B
Memo #: M1164

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1. INTRODUCTION

MCST has been dedicated to improving calibration algorithms in the Level 1B (L1B) for collection 7 (C7) reprocessing of both Aqua and Terra MODIS. The code changes in the C7 L1B are focused on the electronic crosstalk correction. Many other major C7 improvements are achieved through look-up-table (LUT) updates. In this memo, the code and LUT updates in the C7 L1B are summarized.
The data format of the C7 MODIS product is planned to change to HDF5/NetCDF4 from HDF4, which has been used since the beginning of MODIS data production. A C7 API has been developed by the Land Data Operational Products Evaluation (LDOPE) to facilitate the transition of output to HDF5/NetCDF4. MCST will rely on the C7 API instead of making changes to the L1B code. The various details associated with the C7 API are not discussed in this document.

2. COLLECTION 7 CODE CHANGES

Two specific improvements have been implemented for the C7 L1B.

A. Electronic crosstalk correction to selected thermal emissive bands/detectors

After the electronic crosstalk correction was applied to the Terra MODIS PV LWIR bands in C6.1, MCST assessed the crosstalk impact on the remaining bands for both Aqua and Terra MODIS [1-3]. In the C7 L1B, the crosstalk correction will be extended to selected detectors in the Terra MWIR (bands 20 to 25) and Aqua MWIR and PV LWIR bands (bands 27 to 30). The same methodology applied in C6.1 for the Terra MODIS PV LWIR bands will be used in C7. The linear crosstalk correction algorithm can be described using the formula below,

$$dn_i(S,F) = dn_i^*(S,F) - \sum_j c_{i,j} \cdot dn_j^*(S, F + \Delta F_j)$$

where *S, F* represent scan/frame number, *dn** is contaminated signal after the background subtraction, *i,j* are indices for receiving and sending detectors, $c_{i,j}$ is the crosstalk correction coefficients, and ΔF_j is the frame shift [3].
The crosstalk corrections are applied to the background subtracted response measured by the onboard Blackbody and Earth-View sector. The correction coefficients in the formula are derived

from the scheduled lunar observations and served as the L1B input in the form of a time-dependent LUT. In addition to all detectors in the Terra MODIS PV LWIR bands, selected detectors from Terra MWIR and Aqua MWIR and PV LWIR bands will have the crosstalk correction applied in C7. The affected detectors in C7 are listed in Table 1 for both Aqua and Terra. An example in Figure 1 shows the improvement of Aqua band 24 detector 1 in C7.

Table 1 Selected detectors added for the electronic crosstalk correction in the C7 L1B

Instrument	Band (Detectors, in product order)
Terra MODIS	22 (8), 23 (1, 10), 24 (1)
Aqua MODIS	20 (1), 22 (1), 23 (1), 24 (1), 25 (1), 27 (1), 29 (1, 2, 6), 30 (1)

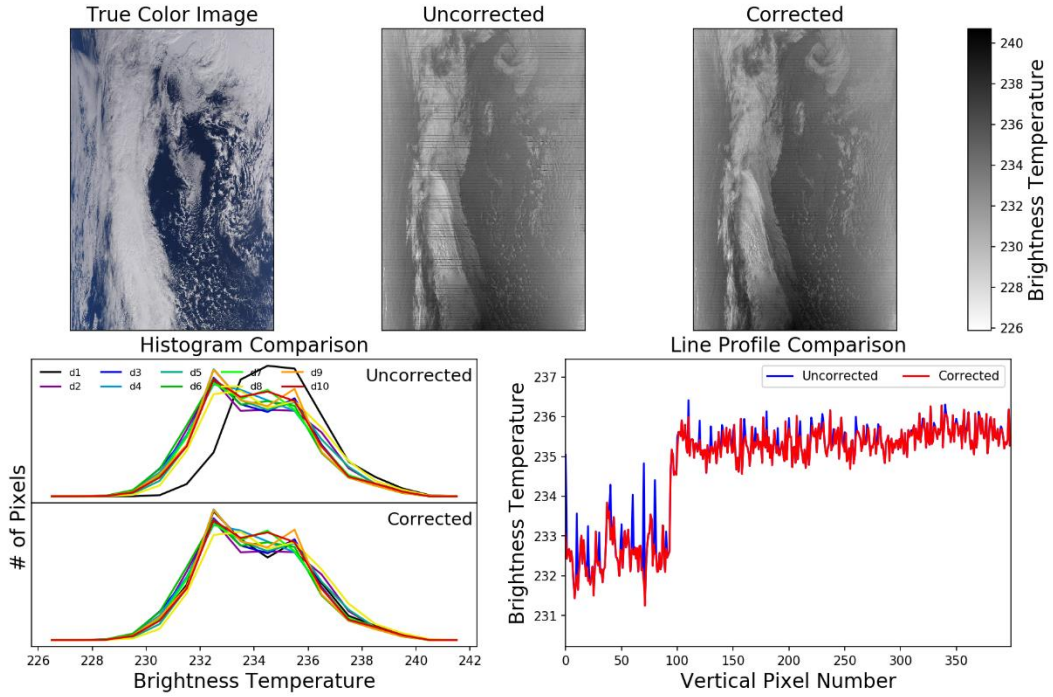

Figure 1. Improvement from the crosstalk correction in Aqua band 24

B. Improvement to the crosstalk correction at edges of scans

MODIS bands are spatially co-registered. In the crosstalk correction, a frame shift is needed to locate the sending pixel that temporally matches the receiving pixel. The amount of the frame shift is determined by the relative position between the sending and receiving bands on the focal plane assembly. The sending signal is not available if the position of the sending pixel is out of bounds after the frame shift. No crosstalk correction from this sending band is applied in the current C6.1 to the receiving pixels at edges of scans. This has been a known issue since the Terra MODIS early mission when the PC crosstalk correction was applied in Terra MODIS L1B. NASA Atmosphere group also reported the anomaly at edges of scans in the cloud product in a MsWG meeting in 2018. It is due to the same reason that not all sending bands are included in the PV LWIR crosstalk correction to the pixels at edge in the C6.1 L1B.

In C7, an average over 3 pixels at the edge of scan is used to estimate the sending signal at the edge if the position of the sending pixel is out of bounds after the frame shift. Our test results indicate noticeable improvements to Terra bands 27 and 28 at the end of scan and Terra band 30 at the beginning of scan. The edge impact to other bands is very small. Two images, each 100 frames wide and cropped from the end of scan for Terra band 27 and the beginning of scan for Terra band 30, are shown in Figures 2 and 3 to demonstrate the improvements in C7 compared to C6.1.

A penalty based on the magnitude of the correction is accounted in the uncertainty calculation for the pixels applied the crosstalk correction. The same method is applied to the edge pixels. The pixel-based uncertainty is saved in the L1B product in the form of uncertainty index (UI). Each UI value from 0 to 15 represents a range of uncertainty in percentage. And the variation of the edge pixels is typically small as well, due to the significant overlap on the ground (bowtie effect). Therefore, the edge correction will make the UI from edge pixels consistent with the rest of imagery but no significant change.

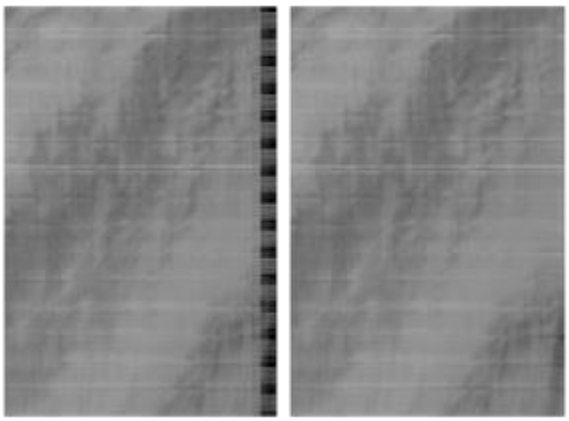

Figure 2. Comparison between C6.1 (left) and C7 (right) for Terra band 27 at the end of scan.

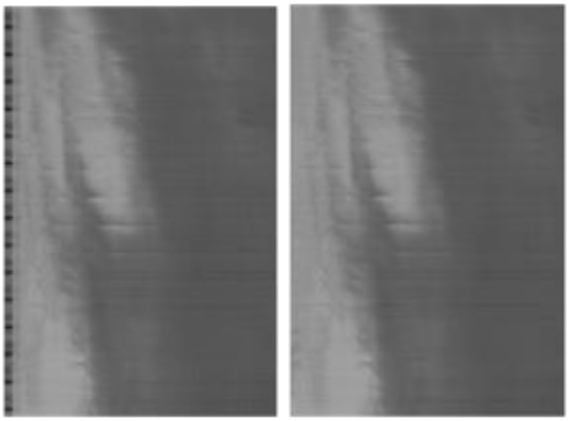

Figure 3. Comparison between C6.1 (left) and C7 (right) for Terra band 30 at the beginning of scan.

3. COLLECTION 7 LUT UPDATE

There are LUT updates for both reflective solar bands (RSB) and thermal emissive bands (TEB) in C7.

A. RSB LUTs update

All RSB LUTs updated in C7 are listed in Table 2. Most of them are reprocessed over the entire missions except for the SWIR-OOB_corr_sending_band and E_sun_over_pi LUTs. The major change is in the m1 and RVS_RefSB LUTs. They are derived with the following major calibration algorithm improvements and will be discussed in a separate memo:

1) Using Polarization corrected EV data for Terra MODIS bands 3, 8, 9 and 10
2) Use of inter-band calibration for Terra MODIS bands 11 and 12
3) Time-dependent SWIR RVS (bands 5 and 26) using DCC measurements for Terra MODIS
4) Updated vignetting function for Aqua MODIS high gain ocean bands

Table 2. RSB LUT updated in C7

LUT name	Aqua	Terra
m1	X	X
RVS_RefSB	X	X
X_OOB_1	Same as C6.1	X
SWIR_OOB_corr_sending_band	Same as C6.1	X (sending band changed to band 25 from the start of mission.)
Uncertainty LUTs (u1, u2, u3, u4)	X	X
dn_sat_ev	X	X
E_sun_over_pi	X	X

B. TEB LUT update

All TEB LUTs updated in C7 are listed in Table 3. The C7 offline calibration algorithm has been updated to improve Terra MODIS a0 in the early mission and after the 2016 safe mode event. The Aqua MODIS C7 will apply the derived mirror-side bias adjustments to the pre-launch a0 coefficients. The a2 coefficients for Terra are re-derived with the adjusted a0 coefficients using blackbody warm-up/cool-down data. In the case for Aqua, an improved fitting strategy is used to derive a2 over the entire mission. The C7 algorithm will significantly reduce the stripping at cold scenes caused by the mirror side differences in L1B TEB product for both Aqua and Terra MODIS.

Table 3. TEB LUTs updated in C7

LUT name	Aqua	Terra
a0	X	X
a2	X	X
Band21 b1	X	X
Sigma_a0	X	X
Sigma_a2	X	X
Sigma_b1_band21	X	X

mwir_xt_coeff	X	X
pvlw_xt_coeff	X	Same as C6.1

C. QA LUT update

The detector quality flag LUT is also revised for both Terra and Aqua MODIS. There are no major changes in C7, except a few timestamp adjustments to reflect the detector status more precisely in the mission.

4. SUMMARY

There are two major improvements in the C7 L1B code. First, the crosstalk correction algorithm is extended to selected detectors in Terra MWIR bands and Aqua MWIR and PV LWIR bands. Second, an edge frame correction is added to account for missing sending band data after the frame shift in the TEB crosstalk correction. The calibration algorithm improvements in RSB and TEB contribute to multiple major L1B LUT updates in C7. Please note that the polarization correction will not be applied in the C7 L1B due to the scene-dependence of the polarization impact. The polarization correction will be left to each science discipline's post L1B process as in C6.1.

REFERENCE

1. https://mcst.gsfc.nasa.gov/meetings/modis-thermal-emissive-band-crosstalk-workshop.
2. G. Keller, T. Wilson, X. Geng, A. Wu, Z. Wang, and X. Xiong "Aqua MODIS Electronic Crosstalk Survey: Mid-Wave Infrared Bands" IEEE Transactions on Geoscience and Remote Sensing, 57(3), 1684-1697, March 2019.
3. T. Wilson, A. Shrestha, and X. Xiong "Electronic crosstalk impact assessment in the Terra MODIS mid-wave infrared bands", Proc. SPIE 10423, Sensors, Systems, and Next Generation Satellites XXI, 104231Z (29 September 2017); https://doi.org/10.1117/12.2277953