MCST Technical Report

Date: Jul 28, 2014
From: MCST
To: MCST Library
Subject: Terra Band 5 correction and its implementation in Collection 6 L1B
Memo #: TR-005

Introduction

The MODIS Solar Diffuser (SD) Bidirectional reflectance factor (BRF) was characterized prelaunch using reference samples traceable to NIST reflectance standards. The on-orbit changes in the SD BRF are monitored using the Solar Diffuser Stability Monitor (SDSM). Currently, the SDSM is operated once every three weeks and the ratio of the SD and sun response as seen by the 9 SDSM detectors (0.41 to 0.94 μm) is used to estimate the on-orbit BRF change. The SDSM was designed to track the change in reflectance properties of the SD below 1 μm. After 14+ (Terra) and 12+ (Aqua) years on-orbit, the SD has experienced significant degradation, especially at the shorter wavelengths. The SD degradation at the MODIS RSB wavelengths is obtained via interpolation from the measured degradation at the 9 SDSM wavelengths.

MODIS SWIR bands (B5: 1.24 μm, B26: 1.375 μm, B6: 1.64 μm and B7: 2.13 μm) are used in various Land/Aerosol/Cloud products. Since the SDSM detector coverage is restricted from 0.41 to 0.94 μm, no correction of SD degradation is applied beyond 0.94 μm. The SD degradation at 0.936 μm, as measured by the detector 9 of the SDSM is 2.3% since launch for Terra MODIS. In comparison the degradation for Aqua MODIS is about 0.6%. Since mid-2003, the SD door for Terra MODIS has been set to a permanent open position which has led to solar exposure every orbit, which in turn leads to an increased rate of SD degradation. The pseudo-invariant desert targets are already used to track the long-term stability of the MODIS VIS/NIR bands. In Collection 6, the measurements from the on-board calibrators are supplemented with the Earth-View (EV) response trends at various scan-angles. A similar approach to monitor the long-term stability of the SWIR bands is discussed in this memo. Results indicate a long-term drift in the reflectance trending for band 5, likely due to the degradation of the SD, which is currently not accounted for in the SD gain (m1) computation. Also, the long-term trends from Deep Convective Clouds (DCC) trending are evaluated for further validation of the trend observed from the EV desert measurements.

Methodology

The pseudo-invariant desert targets in the North African desert are known for their radiometric stability. The MODIS C6 algorithm for the VIS/NIR bands (Terra bands 1-4,9 8 -10, and Aqua bands 8,9) use the responses observed at these targets to track the on-orbit gain change. The Libya 1 (24.42º, 13.35º), Libya 2 (25.05º, 20.48º), and Libya 4 (28.55º, 23.39º) sites are currently used in the calculation of the MODIS C6 LUT. The top-of-atmosphere (TOA) reflectance trending for the SWIR bands over these sites at various angles of incidence (AOI) are evaluated for long-term drifts. Assuming the temporal stability of these sites, any long-term drift observed in the data is attributed to the inadequacy of the on-orbit gain (derived from the solar diffuser measurements) to accurately characterize the sensor's on-orbit change.

Figure 1(a) and (b) shows the normalized TOA reflectance trending (plotted in black symbols) for mirror side 1 and mirror side 2 of Terra band 5 plotted as a function of time at the frame 1040 respectively. The TOA reflectance trending is derived from Libya 2 site and frame 1040 is the nearest representative frame to the SD (frame 978). Also, plotted on the same figure in green symbols, is the yearly averaged version of the TOA reflectance trends. A simple linear model is fitted to the data-sets, and all measurements are normalized to the first fitted model. Similar normalized trends from the DCC data-set are plotted in pink. An excellent agreement (within 0.3%) is seen between the yearly-averaged version of the normalized reflectance and the DCC trends. It is worth noting that the DCC measurements have been collected at all scan-angles (not restricted to frame 1040). Since there is no evidence to suggest a need for a time-dependent RVS for any of the SWIR bands, the DCC trends can be used as an additional source of validation to the trends observed from the North African desert.

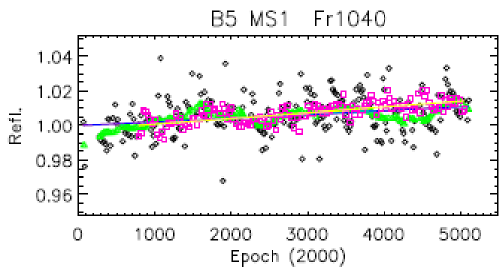

Figure 1 (a). Normalized TOA reflectance trending for Terra band 5 mirror side 1 at Frame 1040

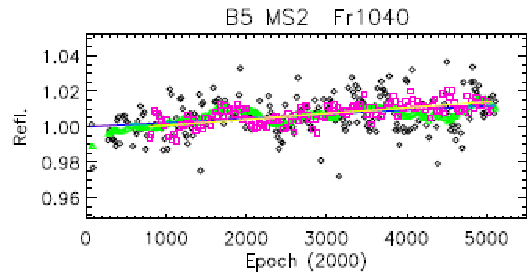

Figure 1 (b). Normalized TOA reflectance trending for Terra band 5 mirror side 1 at Frame 1040

Overall an upward trend of about 1.2% is observed over 14+ years of MODIS operation. This is an expected trend which suggests an inadequate correction of the SD degradation at the band 5 wavelength. Given the SDSM's limited wavelength coverage, the SD degradation beyond 0.94 µm has to be estimated via extrapolation, if the on-board mechanism is to be used. However, this may result in a greater uncertainty in the SD degradation estimate. Alternatively, the EV-reflectance trends shown in Figure 1 can be used to derive a long-term correction factor, assuming that the long-term drift observed is due to the inadequate correction for SD degradation at the Band 5 wavelength. Long-term drifts within 0.3% were seen at other SWIR wavelengths, and hence no correction is being considered for those bands at this time.

In order to have further confirmation of the observed result, normalized TOA reflectance trends as well as the DCC trends have been plotted for Aqua MODIS, also at the SD frame. Figure 2 (a) and (b) show the results for Aqua MODIS.

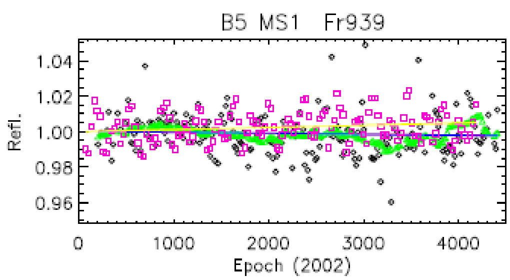

Figure 2 (a). Normalized TOA reflectance trending for Aqua band 5 mirror side 1 at Frame 1040

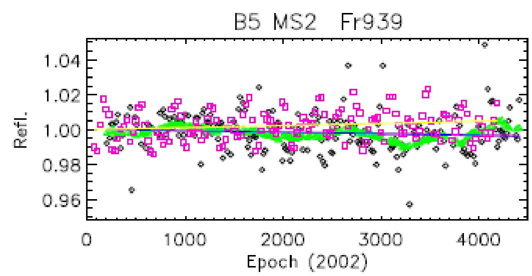

Figure 2 (b). Normalized TOA reflectance trending for Aqua band 5 mirror side 1 at Frame 1040

In comparison with Terra MODIS, the long-term trend for Aqua MODIS exhibits a smaller change, within 0.2%. The SD degradation at 0.94 µm for Aqua MODIS is 0.6%, and hence a minimal degradation is expected at the SWIR wavelengths. Hence no correction is currently considered for Aqua MODIS.

Implementation

A simple linear model is estimated from the TOA reflectance trends for Terra MODIS as shown in Figure 1. The MODIS land and atmosphere products primarily use band 5 TOA reflectance and it is desired to have the above correction incorporated in the L1B before any downstream products are generated. Since the C6 reprocessing of the land and atmosphere products has not been started for Terra MODIS (as of the date of this memo), implementation of this correction is being planned for the entire time-series of MODIS C6 L1B. MCST delivered a tool to the data-production team (SDST) to update the existing archive of Terra C6 L1B product with the band 5 correction applied.

The tool will change the following data in the archived L1B product,

1. The SDS attributes "reflectance scales" and "radiance scales" for band 5. Since those scale factors are linearly proportional to the m1, the correction can be simply expressed as
   Scales_new = Scales_old/(1. + b*(t-t0))

where b is the correction coefficient, t is the Julian day since year 2000, and t0 = 55, the first day the Terra MODIS Nadir door opened;

2. There is a cross-talk impact to band 26 from band 5, so the change in band 5 will be considered accordingly to make the correction to band 26 SI;
3. Any metadata with the Process Generation Executive (PGE) version 6.1.14 (the current official Terra C6) will be changed to 6.1.16, and the LUT version will be changed to 6.1.16.2.

The L1B LUT 6.1.16.3, with the band 5 correction through the entire mission, is prepared for the forward update. This new L1B LUT will be effective on 2014218.1200. The tool developed by MCST should be applied for band 5 correction to all Terra C6 L1B before this time-stamp. The tool is designed to check the PGE version at the beginning. If the L1B granule is generated with the PGE version 6.1.16 (with the band 5 correction applied to the C6 LUT), and not using version 6.1.14, the L1B granule won't be processed. This also serves as a QA check to avoid duplicate application of the band 5 correction.

FAQ for science users:

1) Where do I find the PGE version related information?

A: Process Generation Executive – Run by MODAPS, contains one or more processes generating the data products stored by MODAPS. PGE01 contains MOD_PR01 and MOD_PR03. PGE02 contains MOD_PR02 and MOD_PR02QA. More information can be found here: http://modaps.nascom.nasa.gov/services/production/pge_all.html

2) How do I identify an L1B granule processed with the new PGE version which has the band 5 correction?

A: Each MODIS L1B granule has a code and LUT version meta data fields. More information regarding the format and meta data names can be found here:
http://mcst.gsfc.nasa.gov/sites/mcst.gsfc/files/file_attachments/M1054_RevC_PUG_022709_Update.pdf
The information provided in the document above can help identify the latest PGE version.

3) If I had previously downloaded a Terra C6 L1B granule (which did not have band 5 correction), do I have to reorder the same L1B with the latest PGE version?

A: MCST recommends ordering and downloading the new L1B granule (which includes the band 5 correction) as it will eliminate any observable long-term drift using previous versions.

4) Is this correction planned for other SWIR bands? Will there be a reprocess if this correction is extended to other SWIR bands

A: MCST continually monitors the long-term calibration performance of all bands. At this time, the existing calibration is seen to be accurate in characterizing the long-term changes for other SWIR bands. However, if any trends suggest a need for extending this correction to other SWIR bands, MCST will gradually incorporate this via a LUT (conditional to science team approval) and no reprocess, such as above, will be required.

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