Calibration Analysis of the Maxar (Digital Globe) Constellation

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Lunch & Learn, NASA GSFC
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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)

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

Normalized \( R_n \)

Original \( R_n \)

Lyapustin et al., 2012, RSE

Developed calibration has been a standard part of MODIS Land Discipline Processing in C6 and C6.1.
Maxar Calibration Trend Characterization

- Use Libya4 CEOS cal-val site; follow general methodology developed for MODIS:


- Problems
  - High resolution images are acquired for variable view geometry (SZA~10-54°, VZA~0-37°);
  - Due to small frame size (17km), low spatial overlap among VHR images;

- Solution (100×100km² total area, each point is 5×5km² average):
  - Use MAIAC MODIS ancillary data (aerosol, column water vapor, spectral BRDF @ 1km resolution) to perform atmospheric correction of high resolution images;
  - Normalization to the common view geometry (nadir view, SZA=30°);
  - “Spatial transfer” to the common reference calibration point;
WV2 Calibration Trend Analysis

Final Result: Normalized (Blue). A direct (un-normalized) approach produces large errors.
RSR: Spectral Conversion Factor

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

• Spectral convolution of surface reflectance
  \[ \rho_{\text{simulated}} = \frac{\sum E_i R_i \Delta \lambda}{\sum E_i R_i \Delta \lambda} \]
  \( E_i \): solar irradiance
  \( R_i \): DESIS surface reflectance with high spectral resolution

• BRDF normalization factor
  \[ c(\lambda) = \frac{\text{BRF from fixed view geometry}}{\text{BRF from various DESIS view geometries}} \]
  \( \text{BRF from MODIS MAIAC} \)
  \( \rho_{\text{simulated}}(\lambda) = \rho_{\text{simulated}}(\lambda) \cdot c(\lambda) \)

• Spectral conversion factor (SCF)
  \[ \text{SCF} = \frac{\rho_{\text{simulated (DG sensors)}}}{\rho_{\text{simulated (MODIS/Aqua)}}} \]
Cross-Calibration of De-trended DG to Aqua

- Using MAIAC MODIS ancillary data (CM, aerosol, column water vapor @ 1km) perform AC of de-trended DG;

- Perform normalization to the common view geometry (nadir, SZA=20°) and “spatial transfer” to the common reference calibration (5x5km²) point;

- Apply Spectral Conversion Factor (effectively brings DG reflectance to the reference Aqua band) → $\rho^{*\text{DG}}$. Compute scale to MODIS Aqua BRDF, $\alpha=\rho^{*\text{DG}}/\text{BRDF}_n$;

- Using scaled BRDF, $\text{RTLS}^{*\text{DG}}=\alpha\text{RTLS}$, compute $\text{TOA}^{*\text{DG}}$ at normalized geometry (for reference Aqua band). Compute X-cal:

$$\frac{\text{TOA}^{*\text{DG}}}{\text{TOA}_{\text{Aqua}}}$$

Example for GeoEye

TOAₙ Aqua
TOAₙ GeoEye
TOAₙ GeoEye at Aqua band
## De-Trending & X-Calibration Coefficients (DG/Aqua)

### De-trending

<table>
<thead>
<tr>
<th>Satellite</th>
<th>Bands</th>
<th>Trend/Year/Unit Refl. (MODIS CS)</th>
<th>Trend/Year/Unit Surface Reflectance (reference spot)</th>
<th>Statistically Significant</th>
</tr>
</thead>
<tbody>
<tr>
<td>World View II</td>
<td>Blue</td>
<td>-1.39E-03</td>
<td>-8.90E-04</td>
<td>N</td>
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<td>Green</td>
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<td></td>
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<td></td>
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<tr>
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<td>-8.90E-04</td>
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<td>-5.70E-04</td>
<td>N</td>
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<tr>
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<td>Red</td>
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<td>N</td>
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<tr>
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<td>NIR</td>
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<tr>
<td>GeoEye I</td>
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<td></td>
<td>Green</td>
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<td>QuickBird II</td>
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<td>3.54E-03</td>
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<td></td>
<td>Red</td>
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<td></td>
<td>NIR</td>
<td>9.23E-05</td>
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### Cross-Calibration

<table>
<thead>
<tr>
<th>Band</th>
<th>GeoEye</th>
<th>QuickBird</th>
<th>WV02</th>
<th>WV03</th>
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<tbody>
<tr>
<td>Blue</td>
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<td>1.0194</td>
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### Summary

1. Results for QuickBird are not reliable (low stats)
2. DG sensors are within ~2-3% of each other
3. DG are systematically higher than Aqua:
   - Blue: 0-3.5% (0-1.6%)
   - Green: 2.9-4.2% (3.4-4.2%)
   - Red: 6.9-8.4% (6.9-8%)
   - NIR: 1.9-3.2% (1.9-3.2%)

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Atmospheric Correction of VHR Data

1. Quality of MAIAC MODIS Ancillary Data:
   - **CM**: MAIAC C6 has 5-25% more high-quality SR data than MOD09 annually (Lyapustin et al., FRSen, 2021);
   - **CWV**: validated against AERONET within 10% accuracy (Martins et al., 2018; 2019);
   - **AOD**: 1km resolution, 10% accuracy (Lyapustin et al., 2018, ...) + significant improvement from C6 to C6.1;

   21x21 km$^2$ (50% coverage), 0.47µm

   A single 1km pixel

<table>
<thead>
<tr>
<th></th>
<th>MAIAC C6</th>
<th>C6.1</th>
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<tbody>
<tr>
<td>N</td>
<td>304553</td>
<td>409960</td>
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<tr>
<td>%EE</td>
<td>66%</td>
<td>69.8%</td>
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<tr>
<td>R</td>
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<td>0.903</td>
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<td>RMSE</td>
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<td>MBE</td>
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<td>0.012</td>
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</table>


2. MAIAC CM and AOD are successfully used to screen “good quality” VHR data with low cloud/cloud shadow fraction and aerosol;

3. Atmospheric Correction with BRDF normalization.
Atmospheric Correction of VW2 Data

201410030717, TOA

BRF

... somewhere in Madagascar

TOA

201510010718, BRF