Reducing the uncertainty in radiometric cross-calibration over the Libya 4 site – Measurement and Modelling

Laura Brindle, Dr Stephen Mackin, Paul Stephens DMCii
Overview

- Introduction to 22m satellites
- Outline calibration method
- Expand on Libya 4 Cross-Calibration and it's limitations
- Future Developments
- Results
Introduction to 22m Satellites

- 3 in constellation – UK-DMC2, Deimos-1 and Nigeriasat-X
- SSTL-100 platform
- 22m GSD
- ~3 Day repeat
- Pushbroom
- 640km Swath
- Landsat compatible Red, Green and Near Infra-red bands
- Drifting ground tracks
- 2 imaging banks

<table>
<thead>
<tr>
<th>Spectral Band</th>
<th>Spectral Bandwidth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green</td>
<td>0.52 – 0.60 μm</td>
</tr>
<tr>
<td>Red</td>
<td>0.63 – 0.69 μm</td>
</tr>
<tr>
<td>NIR</td>
<td>0.63 – 0.69 μm</td>
</tr>
</tbody>
</table>
Introduction to 22m Satellites

• Working together in imaging campaigns they must be very closely calibrated to ensure accuracy for our customers.

• Figure shows UK-DMC2 in blue, Deimos-1 in green and Nigeriasat-X in pink.

• Nigeriasat-X is descending while the others are ascending.
Calibration Method

- **Dark Images**
  - Pacific Ocean at Night
  - Determine calibration bias
  - Remove artefacts

- **White Images**
  - Dome C
  - Equalisation
  - Determine calibration gain
  - Cross-Calibration

- **Libya 4 Cross-Calibration**
Libya 4 Cross Calibration

- Absolute calibration
- Dune field, homogenous and stable
- Used to validate and refine the calibration result
- Collect images most available opportunities
- Monitor trends and changes in patterns
Libya 4 limitations

- Atmospheric components - Ozone, water vapour and aerosols. Exacerbated by different pass times.
- Seasonal Solar Zenith Angle BRDF effects
- View Angle BRDF effects
- Geometry of the dunes
Methodology

- Cross calibrate against any well calibrated reference sensor
- Currently using Landsat-7 as the data is widely distributed
- Planning to use Landsat-8 when available
- Landsat views at ~Nadir whilst DMC satellites have a drifting ground track and hence variable view angle to the surface per image. This must be corrected in order to directly compare to Landsat
Scatter shown in the UK-DMC2 data (blue) is greater than in Landsat-7 data (pink) primarily due to different view angle.
At first with limited data points the only fit we were able to establish was a linear relationship.
As we collected more data with time, a distinct shape emerged that showed a separate linear relationship per bank.
Now we have over 100 data points the shape has changed again and the best result is given when using a second order polynomial.
Alternatives to our empirical fit?

- Polynomial equation is an improvement on our first attempts at an empirical solution to remove view angle effects

- Looking into Snyder BRDF model provided by CNES and to cross compare against empirical model results

- Full physical model of the surface including
  - Geometric modelling of the dune facets
  - Modelling of BRDF of the sand
Basic geometric model

- Initial steps were to treat the dune field of Libya 4 as a set of facets, with no BRDF component (surface or atmosphere)
- Secondly we included BRDF of the sand based on measurements made by CNES in Libya
Comparison against our data

- Only images with >60 degrees elevation used as lower angles cause scatter, this is being investigated
Further Developments

Modelling especially useful for newer satellites when we only have a small amount of data points e.g. Nigeriasat-X
Using the UKDMC-2 polynomial equation as an empirical model we were able to improve upon the initial calibration results generated using the linear relationship of the NX results
Further Developments

• An improved model would reduce the uncertainty when cross comparing different sensors over the site given their different overpass times and view angles.

• Additionally, we can include atmospheric information derived from other sensors/meteorological models to account for the atmospheric component.
Calibration Results Summary

<table>
<thead>
<tr>
<th>Mean TOA Reflectance Vs Landsat</th>
<th>Green</th>
<th>Red</th>
<th>NIR</th>
</tr>
</thead>
<tbody>
<tr>
<td>UKDMC-2</td>
<td>-0.62274</td>
<td>-0.78877</td>
<td>0.28753</td>
</tr>
<tr>
<td></td>
<td>+/- 0.44</td>
<td>+/- 0.89</td>
<td>+/- 1.21</td>
</tr>
<tr>
<td>Nigeriasat-X</td>
<td>-0.95864</td>
<td>-0.32346</td>
<td>-0.11269</td>
</tr>
<tr>
<td></td>
<td>+/- 0.45</td>
<td>+/- 1.13</td>
<td>+/- 1.72</td>
</tr>
<tr>
<td>Deimos-1</td>
<td>-0.62399</td>
<td>-0.35624</td>
<td>0.915778112</td>
</tr>
<tr>
<td></td>
<td>+/- 0.52</td>
<td>+/- 0.58</td>
<td>+/- 0.72</td>
</tr>
</tbody>
</table>

- The overall results suggest that the sensors are very stable with absolute calibrations that are 5% or better in all bands
- NIR shows the largest spread for all sensors
Before Model Correction

Trends in Green TOA Reflectance in Landsat and UK-DMC2

TOA Reflectance

Date

22/02/2008 06/07/2009 18/11/2010 01/04/2012 14/08/2013
Scatter in the UK-DMC2 data (blue) has been reduced by applying our empirical model. This can be further reduced by correcting for atmospheric effects.