Radiometric Calibration Assessment of Commercial High Spatial Resolution Multispectral Image Products

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3 Presentations:

- South Dakota State University
  
  David Aaron

- University of Arizona
  
  Kurt Thome

- SSC: Science Systems and Applications, Inc
  
  Kara Holekamp
Reflectance Based Calibration
Base Process:

1. Identify a target area that has uniform reflectance over a multi-pixel area
2. During satellite imaging overpass: ground level reflectance measurement
3. Hours preceding and subsequent to overpass: continually monitor select wavelengths for direct and diffuse downwelling solar radiance
4. From above: Calculate extinction parameters using Langley analysis
5. From extinctions and other atmospheric parameters calculate hyperspectral atmospheric model
6. Propagate Top of Canopy radiances thru atmosphere via above model
7. Band these Top of Atmosphere hyperspectral radiances
8. Use satellite image DN counts of target area to calculate gain
Independent Groups make up the JACIE Radiometric Evaluation Team

- Scheduling: Coordinated through SSC
- Diverse locations and collection seasons
  - Collections represent various times of the year
  - Collections thru different atmospheres
- Diverse target set:
  Radiance
  - ‘dark’ targets (vegetation)
  - ‘bright’ targets (playa)
  - high contrast (tarps)
  Spectral response:
  - vegetation signatures
  - high reflectance natural surfaces
  - flat response manmade targets
Collection Sites Exhibit Varied Surfaces
Note: typical Band 2 and 4 reflectances shown

**SDSU ‘3M’ site**
- $\rho_{\text{band2}} = 0.06$
- $\rho_{\text{band4}} = 0.27$

**UOA 'RRV' site**
- $\rho_{\text{band2}} = 0.35$
- $\rho_{\text{band4}} = 0.44$

**SSC 'ball field' site**
- **Tarps**: $\rho_{\text{tarps}} = 0.035$ to $0.52$
- **PVC grass**: $\rho_{\text{band2}} = 0.07$, $\rho_{\text{band4}} = 0.35$
- **Gravel pit**: $\rho_{\text{band2}} = 0.39$, $\rho_{\text{band4}} = 0.57$
Radiometry Groups (cont)

- Similar (but certainly not identical) equipment sets
  - spectroradiometers (primarily Analytic Spectral Devices Field Spec)
  - Sunphotometers, shadowband radiometers, reference panels, etc
    - some common basis but also considerable variation/replication/modification from group to group

- Data collection: Each group has developed their own protocols

- Data reduction: Each group has developed their own techniques
  - Atmospheric modeling:
    - SDSU & SSC: all MODTRAN based
    - UOA RSG: Combination of custom code and MODTRAN
SDSU Satellite Calibration

Physics Department (Satellite Calibration Group):
   David Aaron
   Larry Leigh
   Sara Landau

Electrical Engineering and Computer Science (Image Processing Lab):
   Dennis Helder
   Jason Choi
   Tim Ruggles
   Jim Dewald
(see Dennis’ slides for a complete list of graduate and undergraduate engineers)
SDSU Radiometry Goals: 2004-2005

Vegetated target collections
  IKONOS
  QuickBird
  OrbView 3
  Landsat 5
  Landsat 7
  AWiFS (2005)
  EO1 (2004)

Complete re-establishment of full SDSU processing capability
  Partial 2004
  Full 2005
  (2001-2003 atmospheric modeling courtesy of UOA and SSC)
SDSU Vicarious Calibration Process:

- ‘Simultaneous’ satellite imaging and hyperspectral measurement of upwelling radiance at grass target area (“3M” in Brookings SD).
  - ASD FS FR unit 638 with 8 degree optic
  - 18” Spectralon 99% panel, BRDF characterized

- Monitor atmospheric transmittance over time interval including overpass
  - Primary monitor: 10 Channel ASR unit 30

- Use ASR Langley analysis to determine extinction values
  - Supplement with MFR Shadowband units (global/diffuse measurement)

- Populate MODTRAN using extinctions, angles, etc; optimize thru measured ASD values
  - MODTRAN 4.3.2

- Transfer (hyperspectral) Top of Canopy (TOC) to TOA using MODTRAN model

- Band hyperspectral radiances to produce in-band TOA radiance

- Calculate gain by comparing satellite DN to in-band TOA radiance values
2005 SDSU Calibration Collection Summary:
Data collections summary (perceived useful collections only)

2005:

- May 19: L5 good +: some cumulus later in day
- June 22: QB + AWiFS okay, some clouds
- July 6: L5 good – considerable cirrus
- July 14: L7 popcorn clouds but probably okay
- July 18: OV (pan)
- **July 29: OV (MS) OV failed decompression, data not retrievable
- Aug 1: OV (MS) + IK shot thru considerable popcorn cumulus
- Aug 23: L5 okay but lots of cumulus
- Aug 29: Katrina L7 good - : cumulus just passed by
- Sept 16: L7 very good pm, okay late am
- Oct 7: OV (pan) excellent
- Oct 18: QB + L7 good
Year 2005: Added Goal
Process Capability

- Pre 2005 Mode: Data processing is primarily ‘post season’
- Agriculture applications require ‘real-time’ reflectance correction
- Pilot analysis of processing streams:
  - Image acquisition
  - Atmospheric correction
  - Image correction
  - Data archiving
- Pilot study of atmospheric correction
  - May 19 pilot run(L5): Less than 1 week for all steps
  - scattered clouds: still implementing auto filter algorithm
“3M” Site Characteristics

• 180 X 160m ‘grass’ site (approx)
  – rotated 9 degrees off N-S
  – NW corner:
    • Lat: 44°17’31.12383”N
    • Long: 96°45’59.33636”W
    • Elevation 503 m
    – Elevation change = 4.89 meters

  Differential GPS values measured by the Stennis GRIT Staff

• Maintenance mowing
  – 6 ft rotary mower (rough, not finish cut) for easternmost 2/3 of site
  – western 1/3 of site, finish cut
    (target area for high resolution MTF collection)

• To accommodate AWiFS, new markers in unmowed area
3M Site
Oct 7, 2005 (OrbView)

180m x 160m
9 deg off true N
Oct 7, 2005
Initially cloudy but clear at overpass
Ground data collection

ASD FS FR with 2 meter cable
  • 8 deg optic on pole held 1.5 to 2 m above ground
    – Nadir view (~25cm diameter sample area)

  • Collect while walking ASD along 150 m N-S rows
    – 20 spectra/file, 10 files/save
      • Results in 60 files per row so about 600 files per collection
      • ~ 20 minutes for 10 row collection

  • White reference at end of each row pair (north end)
Brookings ‘3M’ Grass Site
Shown with targets deployed

180mX160m
9 deg off true N
Standard ASD Data Acquisition Paths
(note: When SSC tarps deployed, Row 2 is skipped)
MTF Tarp collection
(SSC 3.5 and 52% tarp sets)

Generally tarps are laid out EW with 3.5% to E
Nominal collection:
• Start at N center (White ref) and sample ‘in’ ~1m from edge.

• Sample tarp edge perimeter CCW
  10 spectra/file, either 3 or 5 files per save
  4 saves per ‘side’ (each tarp set)
  a second WR when get to S center
  a third WR when return to N center

• Radiance values are BRDF corrected as part of standard analysis
MTF tarp data collection 'walk' paths and file numbers for standard 3 files/save

WR1: file numbers: 000-002
WR3: 072-075

WR3: (return to N side)

Scale: 10 m
2004 SDSU Calibration Collection Summary:
Data collections summary (useable collections only)

We weren’t at all happy in 2004
May thru Aug 20, ~5 ‘clear’ days at noon
(and none of these coincided with overpasses)

2004
• June 28: L7 + E01  Scattered clouds used Schiller trapped light model
• Aug 30: QB + OV
• Sept 29: L7 + E01
• Oct 5: QB
• Oct 8: OV
2005 SDSU Calibration Collection Summary:
Data collections summary (perceived o.k. collections only)

2005:
• May 19: L5 good +: some cumulus later in day
• June 22: QB + AWiFS okay, some clouds
• July 6: L5 good – considerable cirrus
• July 14: L7 popcorn clouds but probably okay
• July 18: OV (pan)
• Aug 1: OV (MS) + IK shot thru considerable popcorn cumulus
• Aug 23: L5 okay but lots of cumulus
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IKONOS

VICARIOUS CALIBRATION RESULTS
SDSU
2005
Aug 1, 2005
IKONOS
IKONOS Results:

Only one data collection performed at SDSU 2004-2005

- Aug 1, 2005: Site was ‘shot between the clouds’ (IKONOS + Orbview)

- Attempted a ‘light trapping’ model but results to date show too large an uncertainty to be reportable.
Note: Aug 1, 2005
also an OrbView (MS) overpass
QUICKBIRD

VICARIOUS CALIBRATION
RESULTS
SDSU
2004 AND 2005
3M Site: Oct 18, 2005
QuickBird
### QuickBird Band Gains: 2004-2005

Basic Radiance (W/m² sr μm) to DN ratio

<table>
<thead>
<tr>
<th>3M Grass</th>
<th>Band 1</th>
<th>Band 2</th>
<th>Band 3</th>
<th>Band 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aug 30 2004</td>
<td>0.234</td>
<td>0.156</td>
<td>0.174</td>
<td>0.122</td>
</tr>
<tr>
<td>Oct 5 2004</td>
<td>0.232</td>
<td>0.146</td>
<td>0.174</td>
<td>0.135</td>
</tr>
<tr>
<td>Jun 22 2005</td>
<td>0.236</td>
<td>0.149</td>
<td>0.183</td>
<td>0.123</td>
</tr>
<tr>
<td>Oct18 2005</td>
<td>0.227</td>
<td>0.146</td>
<td>0.179</td>
<td>0.130</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>52% Tarps</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Jun 22 2005</td>
<td>0.256</td>
<td>0.165</td>
<td>0.193</td>
<td>0.141</td>
</tr>
<tr>
<td>Oct18 2005</td>
<td>0.263</td>
<td>0.165</td>
<td>0.196</td>
<td>0.143</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3.5% tarps</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Jun 22 2005</td>
<td>0.230</td>
<td>0.146</td>
<td>0.174</td>
<td>0.116</td>
</tr>
<tr>
<td>Oct18 2005</td>
<td>0.220</td>
<td>0.131</td>
<td>0.150</td>
<td>0.083</td>
</tr>
</tbody>
</table>

| average       | 0.237  | 0.151  | 0.178  | 0.124  |
| standard deviation (1 sigma) | 0.015  | 0.011  | 0.014  | 0.019  |
QuickBird Band 1 Gain: Forced Zero Intercept
SDSU 2004-05 data

y1 = 0.25x

'Standard' gain is 7.5% lower than SDSU gain
QuickBird Band 2 Gain: Forced Zero Intercept
SDSU 2004-05 data

\[ y_2 = 0.16x \]

'Standard' gain is 11% lower than SDSU gain
QuickBird Band 3 Gain: Forced Zero Intercept
SDSU 2004-05 data

\[ y_3 = 0.19x \]

'Standard' gain is 8.0% lower than SDSU gain
QuickBird Band 4 Gain: Forced Zero Intercept
SDSU 2004-05 data

\[ y_4 = 0.13x \]

Radiance (W/m\(^2\) sr micron)

‘Standard’ gain is 0.2% higher than SDSU gain
QuickBird Band Gains
SDSU 2004-05 data

\[ y_1 = 0.254x \]
\[ y_2 = 0.163x \]
\[ y_3 = 0.192x \]
\[ y_4 = 0.135x \]

Band 1 Factory
Band 2 Factory
Band 3 Factory
Band 4 Factory

Radiance (W/m^2 sr micron)

DN
ORBVIEW-3

VICARIOUS CALIBRATION
RESULTS
SDSU
2004 AND 2005
OrbView Band Gains: 2004
Basic Radiance (W/m² sr μm) to DN ratio

<table>
<thead>
<tr>
<th>3M Grass</th>
<th>Band 1</th>
<th>Band 2</th>
<th>Band 3</th>
<th>Band 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aug 30 2004</td>
<td>0.317</td>
<td>0.304</td>
<td>0.269</td>
<td>0.172</td>
</tr>
<tr>
<td>Oct 8 2004</td>
<td>0.310</td>
<td>0.295</td>
<td>0.256</td>
<td>0.183</td>
</tr>
<tr>
<td>average</td>
<td>0.314</td>
<td>0.300</td>
<td>0.263</td>
<td>0.177</td>
</tr>
<tr>
<td>standard deviation (1 sigma)</td>
<td>0.014</td>
<td>0.014</td>
<td>0.015</td>
<td>0.009</td>
</tr>
</tbody>
</table>
OrbView Band 1 Gain: Forced Zero Intercept
SDSU 2004 data

\[ y_1 = 0.31x \]

‘Standard’ gain is 15% lower than SDSU gain
OrbView Band 2 Gain: Forced Zero Intercept
SDSU 2004 data

\[ y_2 = 0.30x \]

‘Standard’ gain is 21% lower than SDSU gain

Radiance (W/m² sr micron)

DN

<table>
<thead>
<tr>
<th>Radiance</th>
<th>DN</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.25</td>
<td>0</td>
</tr>
<tr>
<td>0.30</td>
<td>100</td>
</tr>
<tr>
<td>0.35</td>
<td>200</td>
</tr>
<tr>
<td>0.40</td>
<td>300</td>
</tr>
<tr>
<td>0.45</td>
<td>400</td>
</tr>
</tbody>
</table>

- band 2
- B2 Factory
- Linear (band 2)
OrbView Band 3 Gain: Forced Zero Intercept
SDSU 2004 data

\[ y_3 = 0.26x \]

'Standard' gain is 21% lower than SDSU gain
OrbView Band 4 Gain: Forced Zero Intercept
SDSU 2004 data

\[ y_4 = 0.18x \]

'Standard' gain is 20% lower than SDSU gain.
OrbView  Band Gains: Forced Zero Intercepts
SDSU 2004 data

\[ y_1 = 0.315x \]
\[ y_2 = 0.301x \]
\[ y_3 = 0.265x \]
\[ y_4 = 0.177x \]
Acknowledgements:

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- NASA EPSCoR NCC5-588