Cross-Calibration of the Landsat-7 ETM+ and EO-1 ALI sensors

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Outline

• Physical Specifications
• Spectral Bands
• Cross-Calibration Results
  – Calibration of near simultaneous surface observations
  – Vicarious Calibration
• Conclusion
Physical Specifications & Key ALI Performance

- Meet or exceed ETM+ performance (w/o thermal band) at minimum size, weight, schedule, and cost
  - Push broom imaging
  - 10 m panchromatic GSD
  - On-orbit internal calibration and stability monitoring system

- SNR four to ten times ETM+ values, depending on band

- Demonstrate spatial, spectral, and radiometric calibration for large detector arrays

<table>
<thead>
<tr>
<th>E0-1/L7 Instrument Comparison</th>
<th>L7 (ETM+)</th>
<th>E0-1 (ALI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Unit</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass (Kg)</td>
<td>425</td>
<td>100</td>
</tr>
<tr>
<td>Power (W)</td>
<td>545</td>
<td>100</td>
</tr>
<tr>
<td>Size (m²)</td>
<td>1.4</td>
<td>0.2</td>
</tr>
<tr>
<td>Bands</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>Detectors per band</td>
<td>16</td>
<td>6200</td>
</tr>
<tr>
<td>Thermal band</td>
<td>1</td>
<td>None</td>
</tr>
<tr>
<td>Data rate (Mbps)</td>
<td>150</td>
<td>300</td>
</tr>
<tr>
<td>Pan Resolution (m)</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>Relative SNR</td>
<td>1x</td>
<td>4x</td>
</tr>
</tbody>
</table>
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Noordwijk, The Netherlands Oct 12-14, 2004

EO-1, L7 Descending Tracks

- Landsat-7 ETM+ 187 Km
- EO-1 Atmospheric Corrector 187 Km
- E0-1 Hyperion 7.5 Km
- E0-1 ALI 37 Km

Satellite Track

SCA - 4
SCA - 3
SCA - 2
SCA - 1
**ETM+ Heritage Bands**
- ETM+ panchromatic band extends into NIR
- ALI panchromatic band cuts off in the red
- ETM+ NIR band 4 split into ALI bands 4/4p

**ALI “Prime” Bands**
- Band 1p “deep” blue (atmospheric correction, oceanography)
- Band 4/4p Modified NIR (avoid water vapor absorption feature)
- Band 5p SWIR 1 (vegetation mapping applications)

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**Relative Spectral Response (RSR) Profiles**

- **ETM+ Heritage Bands**
  - ETM+ panchromatic band extends into NIR
  - ALI panchromatic band cuts off in the red
  - ETM+ NIR band 4 split into ALI bands 4/4p

- **ALI “Prime” Bands**
  - Band 1p “deep” blue (atmospheric correction, oceanography)
  - Band 4/4p Modified NIR (avoid water vapor absorption feature)
  - Band 5p SWIR 1 (vegetation mapping applications)
Cross-Calibration

• Image Pairs from ALI and ETM+
  – Image statistics based on large common areas between the image pairs from near simultaneous surface observations
  – Compared Predicted TOA radiance to measured radiance

<table>
<thead>
<tr>
<th>Location</th>
<th>Date</th>
<th>DOY</th>
<th>Path/Row</th>
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<tbody>
<tr>
<td>Brookings</td>
<td>Sept. 05, 2001.</td>
<td>248</td>
<td>029/029</td>
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<tr>
<td>Railroad Valley</td>
<td>June. 30, 2001.</td>
<td>181</td>
<td>040/033</td>
</tr>
<tr>
<td>White Sands</td>
<td>Mar. 25, 2001.</td>
<td>84</td>
<td>033/037</td>
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</table>
ETM+ / ALI Scenes from Brookings (DOY 248)
Common Ground Regions

White Sands (084)  Railroad Valley (181)
Hypothesis Test

• Cross-Calibration results were tested for slope=1 and intercept=0:
  – Fitting a regression line to each SCA data common to ALI /ETM+
    • \( L_{(ALI)} = \beta_1 L_{(ETM+)} + \beta_0 \)
  – Applying a slope/intercept hypothesis test to the regression lines

\( SLOPE \)

\( H_0: \beta_1 = 1 \)
\( H_1: \beta_1 \neq 1 \)

\( \text{Intercept} \)

\( H_0: \beta_0 = 0 \)
\( H_1: \beta_0 \neq 0 \)
Anomalous detectors in Band-5

Band:5 (SCA-4)  Band:5 (SCA-3)
Slopes

- The slopes from all the regression lines for data points within each SCA and the combined results for all the data in a band

<table>
<thead>
<tr>
<th>Band</th>
<th>SCA4</th>
<th>SCA3</th>
<th>SCA2</th>
<th>SCA1</th>
<th>ALL</th>
<th>ALL</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>1.02</td>
<td>1.01</td>
<td>1.01</td>
<td>1.02</td>
<td>1.02</td>
<td>1.94</td>
</tr>
<tr>
<td>2</td>
<td>1.00</td>
<td>1.00</td>
<td>1.01</td>
<td>1.00</td>
<td>1.00</td>
<td>0.36</td>
</tr>
<tr>
<td>3</td>
<td>0.98</td>
<td>0.98</td>
<td>0.98</td>
<td>0.97</td>
<td>0.98</td>
<td>-1.81</td>
</tr>
<tr>
<td>5</td>
<td>0.97</td>
<td>1.00</td>
<td>0.98</td>
<td>0.98</td>
<td>0.98</td>
<td>-2.28</td>
</tr>
<tr>
<td>7</td>
<td>0.96</td>
<td>0.97</td>
<td>0.95</td>
<td>0.94</td>
<td>0.96</td>
<td>-3.84</td>
</tr>
</tbody>
</table>

Slope vs. Spectral Band
Vicarious Calibration Approach

- **Instrumentation**
  - Blue Tarps
  - ASD-FR Spectroradiometer
  - Regan Sun Radiometer
  - MFRSR Shadowband Radiometers
Vicarious Calibration

Blue Tarps serve as ground reference pixels

ALI

ETM+
Predicted (TOA) Radiance vs Measured ETM+ Radiance
Sept 05th/2001 Day (248)

\[ L_{\text{TOA}} = 0.9755L_{\text{ETM+}} + 0.4829 \]
\[ R^2 = 0.9993 \]

TOA Radiance
Courtesy: Dr. Kurt Thome (U of Az)

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Predicted (TOA) Radiance vs Measured ALI Radiance
Sept 05th/2001 Day (248)

\[ L_{\text{TOA}} = 0.9692L_{\text{ALI}} + 0.8069 \]
\[ R^2 = 0.9984 \]

TOA Radiance
Courtesy: Dr. Kurt Thome (U of Az)
Measured ALI vs. Measured ETM+ Radiance
Sept 05th/2001 Day (248)

L_{(ALI)} = 1.01L_{(ETM)} - 0.1848
R^2 = 0.9996

Band: 1
Band: 2
Band: 3
Band: 5
Band: 7
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Conclusion

• All SCA gains agree with ETM+ reflective bands within ~2% and the SWIR bands within ~4%
• Agreement between SCA gains is greatest among reflective bands, potentially indicating a radiometric calibration problem for SWIR bands
• Vicarious calibration methods indicate differences of 5.3% for all bands for ETM+ and 7.5% for ALI
• TOA estimations appear to be
  – ~0-4% lower for reflective bands
  – ~3-7% higher for SWIR bands