Geometric Assessment of TopSat and BEIJING-1 Data

JACIE 2008 Workshop
March 26-28, 2008

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*Work performed under USGS contract 03CRCN0001
Outline

- Landsat 7 (L7) Image Assessment System (IAS)
  - Image to Image (I2I) registration assessment tool
  - Band to Band (B2B) registration assessment tool
- BEIJING-1 and TopSat Overview
  - Panchromatic (Pan) data
  - Multispectral (MS) data
- Conclusions

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<thead>
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<th>Sensor</th>
<th>QA</th>
<th>I2I</th>
<th>B2B</th>
</tr>
</thead>
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<tr>
<td><strong>BEIJING-1</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>MS</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Pan</td>
<td>✓</td>
<td>✓</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>TOPSAT</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>MS</td>
<td>✓</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Pan</td>
<td>✓</td>
<td>✓</td>
<td>N/A</td>
</tr>
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</table>
L7 IAS Overview

- The IAS is responsible for offline assessment of image quality to ensure compliance with the radiometric and geometric requirements of the L7 spacecraft and the ETM+ sensor throughout the mission.

- **IAS contains B2B registration assessment tool**
  - B2B is performed to ensure that the proper band alignment parameters are provided.
  - It is typically done by registering each band against every other band.
  - A reference band is selected and all other bands are adjusted (offset determined) by least square adjustment of the registration solution.

- **IAS contains I2I registration assessment tool**
  - I2I is usually performed to compare the relative accuracy between two images.
  - One image is selected as reference and another as the search image.
  - Image chips are selected from reference image and are correlated with search image.
  - The co-registration results provide an insight to the relative accuracy of the search image with respect to the reference image.
  - When the correlated points are plotted in the image, it also helps to detect any systematic bias in the image.
Ground Control using Digital Orthophoto Quadrangles (DOQs)

- **DOQs are mosaicked to create a dataset equal to one WRS-2 nominal swath**
  - Resampled to match Landsat resolution - 1 m DOQs reduced in resolution to match Pan band (15 m for ETM+ and 10 m for ALI)
  - USGS 1-arc-second DEMs used for ground control height
- **Supersites built from DOQs**
  - DOQs are designed to meet national mapping accuracy standards of 1:24 k maps, or ~6 m (Inspection with highly accurate GPS surveyed locations showed most DOQs exceeded 6 m)
- **Supersites are georeferenced images derived from high-resolution source**
Ground Control using High Resolution Digital Imagery

- Digital Aerial imagery available over Minnehaha county, SD
- Red, green, blue bands acquired
- Data projected to UTM, zone 14, WGS84, with 2 feet pixel size
- Accuracy of dataset is 4.0 m
BEIJING-1 Overview

- **Launch date**: October 27th 2005
- **Imaging Camera**:
  - Pan images – 1 band, 4 m GSD with 24 km swath
  - MS images – 3 bands (NIR, red, green), 32 m GSD and 640 km swath
- **Mass**: ~ 166.4 kg
- **Altitude**: 686 km
- **Storage Units**: HDDR (240Giga Bytes) + SSDR (4 Giga Bytes)
- **Downlink Data Rate**:
  - X-Band: 40Mbps/20Mbps
  - S-Band: 8Mbps
- **Lifetime**: 5 Years
- **Off-Pointing Capability**: ±30°
BEIJING-1 Data: Sioux Falls area

BEIJING-1 MS
Imaging date: 2007-11-19
Product Level: L1T
DC000760p_L1T_qi.jpg

BEIJING-1 PAN
Imaging date: 2007-12-19
Product Level – Systematic Correction
dc000794hp_l3.jpg
One of the best metadata files!
BEIJING-1 (MS)

- Appears to be a missing detector
- The data is missing in all three bands, but at different locations

Images:

- NIR
- Red
- Green
- RGB

DC000760p_L1T_MS
BEIJING-1 (MS)

- There is some residual striping, about 2 DN in magnitude, which is visible only with harsh stretches over homogenous regions
- The MTF is better in green and red compared to NIR
- No other artifacts were found, overall, the data is pretty clean!
BEIJING-1 (MS): I2I

- MS band assessed against DOQ imagery
- Data looked somewhat blurry and grainy against DOQ
BEIJING-1 (MS): I2I

- Compared against DOQ imagery with an accuracy of ~6 meters, a mean offset of 10.65 and 12.35 m was observed in the line and sample direction.
- Quick visual inspection through ENVI supported results produced from I2I process.
- BEIJING-1 MS imagery registered to DOQ imagery to sub-pixel accuracy.

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<thead>
<tr>
<th></th>
<th>Pixels</th>
<th>Meters</th>
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<tbody>
<tr>
<td></td>
<td>Line</td>
<td>Sample</td>
</tr>
<tr>
<td>Mean</td>
<td>0.33</td>
<td>0.39</td>
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<tr>
<td>Standard Deviation</td>
<td>0.36</td>
<td>0.40</td>
</tr>
<tr>
<td>RMSE</td>
<td>0.49</td>
<td>0.55</td>
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</table>

57 points were used to calculate statistics.
BEIJING-1 (MS): |2| Vector Residual Plot

Vectors scaled to indicate pattern not magnitude
BEIJING-1 (MS): B2B

- Band alignment assessment gave the following statistics in line and sample direction
- BEIJING-1 MS B2B registration assessment on MS imagery showed bands registered to a sub-pixel level

<table>
<thead>
<tr>
<th>Bans-2-Band Assessment</th>
<th>Band 1 to Band 2</th>
<th>Band 1 to Band 3</th>
<th>Band 2 to Band 3</th>
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</thead>
<tbody>
<tr>
<td>113 points used to calculate statistics</td>
<td>Pixels</td>
<td>Meters</td>
<td>Pixels</td>
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<tr>
<td>Mean</td>
<td>Line</td>
<td>Sample</td>
<td>Line</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>0.19</td>
<td>0.18</td>
<td>5.95</td>
</tr>
<tr>
<td>RMSE</td>
<td>0.19</td>
<td>0.18</td>
<td>5.95</td>
</tr>
<tr>
<td>140 points used to calculate statistics</td>
<td>Pixels</td>
<td>Meters</td>
<td>Pixels</td>
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<td>Mean</td>
<td>Line</td>
<td>Sample</td>
<td>Line</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>0.24</td>
<td>0.28</td>
<td>7.62</td>
</tr>
<tr>
<td>RMSE</td>
<td>0.25</td>
<td>0.28</td>
<td>7.94</td>
</tr>
<tr>
<td>260 points used to calculate statistics</td>
<td>Pixels</td>
<td>Meters</td>
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</tr>
<tr>
<td>Mean</td>
<td>Line</td>
<td>Sample</td>
<td>Line</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>0.09</td>
<td>0.09</td>
<td>2.75</td>
</tr>
<tr>
<td>RMSE</td>
<td>0.10</td>
<td>0.09</td>
<td>3.10</td>
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</table>
BEIJING-1 (Pan): I2I

- Pan band assessed against aerial imagery
- BEIJING-1 dataset covers much larger area than control

BEIJING-1 (Pan)  
High resolution control reprojected to BEIJING image frame
• BEIJING-1 and control were not spectrally well matched
  ◦ This creates issues with the correlation
BEIJING-1 (Pan): I2I

- BEIJING-1 I2I was compared against aerial imagery with an accuracy of 4.0 m a mean offset of 8.11, -6.05 m was observed in the line and sample direction.
- Quick visual inspection through ENVI supported results produced from I2I process.
- Several items affected assessment:
  - Limited extent of control
  - Spectral differences between datasets

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<td>Line</td>
<td>Sample</td>
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<tr>
<td>Mean</td>
<td>2.03</td>
<td>-1.51</td>
<td>8.11</td>
<td>-6.05</td>
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<tr>
<td>Standard Deviation</td>
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<td>1.26</td>
<td>4.81</td>
<td>5.03</td>
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<tr>
<td>RMSE</td>
<td>2.35</td>
<td>1.96</td>
<td>9.40</td>
<td>7.83</td>
</tr>
</tbody>
</table>

49 points were used to calculate statistics.
BEIJING-1(Pan): I2I Vector Residual Plot

Vectors scaled to indicate pattern not magnitude
TopSat Overview

- TopSat was launched successfully on 27th October 2005
- Carries an optical camera capable of delivering
  - Pan images – 1 band, 2.8 m GSD with 16 km swath
  - MS images – 3 bands (red, green, blue), 5.6 m GSD with 16 km swath
- The sensor used is a 6,000-pixel linear array device from Kodak
- TopSat weighs just 120 kg
TopSat Data: Sioux Falls area
Image Date: 2007-11-25

TopSat PAN
Product Level 1 G
WF26110701-2158-ax0_ortho_ql.jpg

TopSat MS (L1R)
image-2158-ms.jpg
TopSat (MS)

- The TopSat MS data is not geometrically corrected
  - Therefore the aspect ratio seems off in the TopSat MS “L1R” imagery
  - Example 1 is canaries baseball stadium, which should be square
  - Example 2 is the rural sections, where there are parcels of land that should be exactly one mile square
- In both cases, the aspect ratio appears to be about 13:11
TopSat (MS)

- There are strange noise artifacts in water regions - they are very minor (maximum of about 3 DN) and only appear in very harsh stretches.
- But their appearance looks algorithmic.
- It seems like a sharpening filter applied to this data?
TopSat (Pan)

- There appears to be a series of flat or dead detectors
- There is a striping artifact in the PAN image
- There are odd artifacts around very bright objects (edge filter effect?)
TopSat (Pan): I2I

- Minnehaha data resampled to 2.5 meters and grey scale correlation performed between datasets
- TopSat I2I was compared against aerial imagery with an accuracy of 4.0 m a mean offset of -3.38, 11.18 m was observed in the line and sample direction with a small time varying component in the vector residuals

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<tbody>
<tr>
<td></td>
<td>Line</td>
<td>Sample</td>
</tr>
<tr>
<td>Mean</td>
<td>-1.35</td>
<td>4.47</td>
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<tr>
<td>Standard Deviation</td>
<td>2.56</td>
<td>5.59</td>
</tr>
<tr>
<td>RMSE</td>
<td>2.89</td>
<td>7.15</td>
</tr>
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</table>
TopSat (Pan): I2I Vector Residual Plot

Vectors scaled to indicate pattern not magnitude
Conclusion

- L7 IAS can be expanded for use beyond that of the ETM+
- BEIJING-1
  - MS “L1T” imagery when compared to DOQ achieved sub-pixel accuracy
  - MS “L1T” B2B assessment showed bands registered to very high accuracy
  - Pan imagery “L1G” was difficult to assess geolocation accuracy as only systematic correction applied
- TopSat
  - MS “L1R” data had several artifacts that needs further examination
  - Pan “L1G” was analyzed for geolocation accuracy and there seemed to be a small time varying component in the vector residuals
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