Complementarity of IRS–P6 AWiFS and Landsat TM/ETM+ sensors for Land Cover Change Analysis
Contributors

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Sensor Comparisons

AWiFS Geometric Assessment
- Image to image assessment
- Band to band assessment

Radiometric Assessment
- AWiFS Dual Camera Radiometric Consistency Check
- X-cal between ETM+ and AWiFS
- AWiFS swath width induced bidirectional reflectance (BRDF) effects

Sample Application Results
- Forestry

Summary and Comments
The IRS-P6 satellite was launched into a polar sun-synchronous orbit on Oct. 17, 2003, with a design life of 5 years.

**AWiFS VITAL FACTS**

- Instrument: Pushbroom
- Bands (4): 0.52–0.59, 0.62–0.68, 0.77–0.86, 1.55–1.70 µm
- Spatial Resolution: 56 m (near nadir), 70 m (near edge)
- Radiometric Resolution: 10 bit
- Swath: 740 km
- Repeat Time: 5 days
- Design Life: 5 years

<table>
<thead>
<tr>
<th>Platform</th>
<th>Landsat 7</th>
<th>IRS-P6</th>
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<tbody>
<tr>
<td>Sensor</td>
<td>ETM+</td>
<td>AWiFS</td>
</tr>
<tr>
<td>Launch Date</td>
<td>15-Apr-99</td>
<td>17-Oct-03</td>
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<tr>
<td>Number of Bands</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Spatial Resolution (m)</td>
<td>15, 30, 60</td>
<td>56 (nadir), 70</td>
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<tr>
<td>Swath (km)</td>
<td>183</td>
<td>740</td>
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<tr>
<td>Spectral Coverage (µm)</td>
<td>0.4–12.5</td>
<td>0.52–1.7</td>
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<tr>
<td>Pixel Quantization (bits)</td>
<td>8</td>
<td>10</td>
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<tr>
<td>Orbit Type</td>
<td>Sun synchronous</td>
<td>Sun synchronous</td>
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<tr>
<td>Equatorial Crossing Time</td>
<td>10:00 AM</td>
<td>10:30 AM</td>
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<tr>
<td>Altitude (km)</td>
<td>705</td>
<td>817</td>
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</table>
Landsat – AWiFS Swath Width Acquisition Differences

AWiFS (two cameras)

- 817 km altitude
- 740 km swath
- ~24° ~24°

Landsat

- 705 km altitude
- 185 km swath
- 15°

AWiFS imagery exhibits greater BRDF effects due to larger swath
Relative Spectral Response (RSR) Comparison

L7 ETM+

IRS P6 AWiFS
IRS–provided calibration coefficients used during this assessment
- Developed pre–launch and have never been updated
- Provided with imagery
- Calibration coefficients for both the A and B cameras are the same

<table>
<thead>
<tr>
<th>Band</th>
<th>Green</th>
<th>Red</th>
<th>NIR</th>
<th>SWIR</th>
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<tbody>
<tr>
<td>Calibration Coefficient</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>[W/m² sr μm DN]</td>
<td>0.512</td>
<td>0.398</td>
<td>0.278</td>
<td>0.045</td>
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</tbody>
</table>

NASA–funded vicarious calibrations performed in 2005–2006 indicate calibration differences
- Limited calibration (21 targets within 10 scenes)
Geometric Assessment
Geometric Assessment

- Completed using the Image Assessment System
  - Developed for Radiometric and Geometric Characterization and Calibration for the Landsat Program

- Image to Image registration
  - Compares the registration between two images (reference and test image)
  - Image chips selected from reference image and correlated with test image
  - Relative accuracy assessment
  - Can be used to detect any systematic bias in the test image

- Band to Band registration
  - Performed to ensure proper band alignment
  - Performed by registering each band against every other band within a test image
The characterization was performed to compare the accuracy of AWiFS against the GLS2000 dataset:

- A total of 33 AWiFS images over Railroad Valley, and 22 images over Sonoran were used.
- The AWiFS images were typically registered to within one pixel to the GLS2000 dataset.
Image to Image Assessment (Sonoran & Railroad Valley Test Sites)

Mean Error & RMSE (Sonoran)

Mean Error & RMSE (RVVPN)

<table>
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<tr>
<th></th>
<th>Pixels</th>
<th>Meters</th>
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<tbody>
<tr>
<td></td>
<td>Line</td>
<td>Sample</td>
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<tr>
<td>Sonoran Mean</td>
<td>0.46</td>
<td>0.18</td>
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<tr>
<td>Standard Deviation</td>
<td>0.34</td>
<td>0.38</td>
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<tr>
<td>RMSE</td>
<td>0.60</td>
<td>0.56</td>
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<table>
<thead>
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<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Line</td>
<td>Sample</td>
</tr>
<tr>
<td>RVVPN Mean</td>
<td>0.36</td>
<td>0.30</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>0.15</td>
<td>0.22</td>
</tr>
<tr>
<td>RMSE</td>
<td>0.41</td>
<td>0.40</td>
</tr>
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</table>
The MS bands are registered to sub-pixel accuracy.

The results show that alignment between bands 2, 3 and 4 is very good, while the alignment errors with band 5 are higher.

Vector scale: 1:2800
Radiometric Assessment
Evaluated the 7.8 km overlap area between the A & B cameras
  - A and B Quads
  - Mesa, AZ scene provided by USGS (GeoEye archive)
    - Path/row 257/47, acquired 06/29/05
Overlapping Area Scatter Plots – Individual Pixel Comparison

Excellent agreement between camera modules
Evaluated the 7.8 km overlap area between the A & B cameras

- 2004-08-04 (P268/R036); 2004-08-24 (P272/R046), 2005-04-27 (P278/R047); 2005-08-18 (P267/R040),
- 2006-07-15 (P266/R039); 2006-07-31 (P274/R039), 2007-04-15 (P268/R040); 2007-06-20 (P262/R035);

Excellent agreement between camera modules

Band 2 was observed to have the largest difference (2%) between camera AC/BD

In all other bands, the difference is within 1% in most cases
Reflectance Map Generation

- Planetary Reflectance / Top of Atmosphere
  - First-order approximation – no knowledge of atmosphere
  - Corrects for solar zenith and Earth–Sun distance

\[ \rho_{TOA} = \frac{\pi d^2 L_{TOA}}{E_{sun} \cos \theta} \]

- Surface Reflectance
  - Atmospheric correction is the process of converting satellite signals (at–sensor radiance) to surface reflectance
  - In general, surface reflectance yields more accurate results than planetary reflectance
  - Spherical albedo formulation (Tanre et. al, 1979)

\[ \rho_T = \left( \rho_{TOA} - \rho_0 - \frac{B \rho_{bg}}{1 - s \rho_{bg}} \right) \left( 1 - s \rho_{bg} \right) \]
RGB using NIR, green, and red

Path 247, Row 36, Quad D, Acquired June, 22 2006.
L7 ETM+ and AWiFS–BD Quads (ROI)
BRDF Model Approach

- 11 AWiFS scenes
- June 2006–Sept 2008
- Clear days: AOT <0.11
- Vary geometries
  - Solar and viewing elevation angles (θ)
  - Solar and viewing azimuth angles (φ)
- 4 classes determined using supervised maximum likelihood and USDA NASS CDL
  - Woody
  - Non-woody
  - Bare
  - Water

Radiometrically Calibrated AWiFS Scenes with Varying θs

Reflectance Map Generation (Planetary or Surface)

Cloud Mask /Classification

Sort by (θs, θv, φ)

Class I Regression \( f_1(\theta_s, \theta_v, \phi) \)

Class II Regression \( f_{II}(\theta_s, \theta_v, \phi) \)

Class … Regression \( f_{\ldots}(\theta_s, \theta_v, \phi) \)

Class N Regression \( f_N(\theta_s, \theta_v, \phi) \)
Example Reflectance Variation as a Function of View ANgle
Statistical BRDF Model

- Modified Walthall model
  \[ \rho(\theta_s, \theta_v, \phi) = a_0 + a_1 \theta_s + a_2 \theta_v \cos(\phi) \]
  - Each camera treated separately
  - Determined \( a_0, a_1 \) and \( a_2 \) for each land cover class

  *Example modified Walthall fit results at \( \theta_s = 37^\circ \) and \( \phi = 108^\circ \) for Camera A and \( \phi = -49^\circ \) for Camera B*

Forestry Application
Assess Applicability of using AWiFS data to generate LCLUC products

- North American Forest Dynamics (NAFD)
  - Vegetation Change Tracker (VCT) exploits time series stacks of Landsat imagery (1984 – 2008) to detect forest disturbance
  - Test substitution of a single date of AWiFS imagery into the Landsat Time Series Stack at 3 locations

Kennedy et al., submitted
VCT Test: Minnesota Site (p27r27)
Application Results

- How does AWiFS substitution affect map accuracy?
  - Visual inspection shows close match using AWiFS for all 3 test sites
  - Stand-clearing disturbances are captured successfully with both data stacks

- Next Steps
  - Quantify accuracy results of both AWiFS and non-AWiFS maps (standard error matrix form)
  - Quantify affects of IFOV, BRDF, and radiometric calibration
AWiFS–Landsat Comparison Summary

- **Geometric Assessment**
  - Image to Image Assessment
    Registered to within one pixel
  - Band to Band Assessment
    Registered to within sub-pixel

- **AWiFS Dual Camera Radiometric Consistency Check**
  - Within 1% in most cases

- **X-cal between ETM+ and AWiFS**
  - B2=14.69%; B3=16.93%; B4=13.04%; B5=3.11%

- **BRDF Effects (Non-principle plane geometries)**
  - Linear dependence on viewing angle
  - Can expect BRDF affect to be ~3x greater than Landsat
Summary Comments

- Scientific research and application assessments can often benefit by more frequent high temporal data
  - Weather/clouds
  - Quickly changing phenomena
- Increased data frequency can be accomplished with
  - Multiple same sensors (constellations)
  - Multiple sources with potentially different spectral band passes and spatial resolution
- **All Source Solutions** are only possible when data sets are well understood
  - Separate phenomena differences from sensor differences
- The assessments and cross calibrations performed herein represent the types of analyses that are required to interchange and combine data streams