NASA IKONOS Radiometric Characterization

Mary Pagnutti

Lockheed Martin Space Operations
NASA Stennis Space Center

March 25-27, 2002

phone: (228) 688-2135
e-mail: mary.pagnutti@ssc.nasa.gov
## Co-Contributors

<table>
<thead>
<tr>
<th>Name</th>
<th>Affiliation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Troy Frisbee</td>
<td>NASA, Stennis Space Center</td>
</tr>
<tr>
<td>Vicki Zanoni</td>
<td>NASA, Stennis Space Center</td>
</tr>
<tr>
<td>Slawek Blonski</td>
<td>LMSO, Stennis Space Center</td>
</tr>
<tr>
<td>Erik Daehler</td>
<td>LMSO, Stennis Space Center</td>
</tr>
<tr>
<td>Brennan Grant</td>
<td>LMSO, Stennis Space Center</td>
</tr>
<tr>
<td>Kara Holekamp</td>
<td>LMSO, Stennis Space Center</td>
</tr>
<tr>
<td>Robert Ryan</td>
<td>LMSO, Stennis Space Center</td>
</tr>
<tr>
<td>Richard Sellers</td>
<td>LMSO, Stennis Space Center</td>
</tr>
<tr>
<td>Charles Smith</td>
<td>LMSO, Stennis Space Center</td>
</tr>
<tr>
<td>Steve Tate</td>
<td>LMSO, Stennis Space Center</td>
</tr>
<tr>
<td>Bill Smith</td>
<td>DATASTAR, Stennis Space Center</td>
</tr>
<tr>
<td>Debbie Fendley</td>
<td>DATASTAR, Stennis Space Center</td>
</tr>
<tr>
<td>Braxton Baldridge</td>
<td>NIMA</td>
</tr>
<tr>
<td>Robert Clitone</td>
<td>NIMA</td>
</tr>
</tbody>
</table>
Characterization Overview

- **Objective**
  - Perform radiometric vicarious calibrations of IKONOS imagery and compare with Space Imaging calibration coefficients

- **Approach**
  - Utilize multiple well-characterized sites
    - Widely used by the NASA science community for radiometric characterization of airborne and spaceborne sensors
  - Perform independent characterizations with independent teams.
    - Each team has slightly different measurement techniques and data processing methods
      - NASA Stennis Space Center
      - University of Arizona Remote Sensing Group
      - South Dakota State University
      - US Department of Agriculture SWRC / USWCL
  - Leverage characterization activities with other field measurement programs
Reflectance-based Approach

- Characterize target reflectance at time of satellite overpass
  Measurements taken of target area and a 99% reflectance spectralon panel (Jackson BRDF model)

- Characterize atmosphere at time of satellite overpass
  - Radiosonde data used to determine Rayleigh scattering and water molecule extinction
  - Least squares fit of sun photometer data to determine model atmosphere parameters

- Use MODTRAN radiative transport code to predict at-sensor radiance

- Compare predicted at-sensor radiance to actual radiance acquired by sensor
**Site:** Dry lake bed in central Nevada, predominantly clay surface, no vegetation, surface is hard and nearly impermeable to water. Elevation approx. 1800 m. Center point 38.4° N, 116.0° W.

**In-Situ Instrumentation:** ASD FieldSpec FR spectroradiometers, Yankee MFRSR, Airsonde radiosonde, Full sky imager, 99% spectralon panels

**Other Coincident Collects:** Landsat 7, Terra ASTER/MODIS, ATLAS
## Data Acquisitions

<table>
<thead>
<tr>
<th>Date</th>
<th>Over Pass Time (UTC)</th>
<th>Satellite Elevation</th>
<th>Satellite Azimuth</th>
</tr>
</thead>
<tbody>
<tr>
<td>July 13, 2001</td>
<td>18:39</td>
<td>75.56 deg</td>
<td>207.43 deg</td>
</tr>
<tr>
<td>July 16, 2001</td>
<td>18:48</td>
<td>69.10 deg</td>
<td>275.94 deg</td>
</tr>
</tbody>
</table>

Standard Original imagery
MTFC applied
Cubic convolution resampling algorithm
Ground Measurements

- **ASD measurements**
  - An area on the playa ~ 100 m x 100 m, visually uniform, was identified
  - All measurements were taken twice, with two different ASDs to check repeatability
  - Measurements were taken along 8 transect lines evenly dividing the target area
    - All measurements were taken while walking to increase spatial averaging
    - 8000 spectra in total were averaged to obtain the playa reflectance values
    - Spectralon panel measurements were taken between transects
    - Before any measurements were taken, the instrument was optimized and dark current measurements were made
  - All data taken within 20 minutes of satellite overpass

- **Atmospheric measurements**
  - Collect solar radiance data from early morning through post-sensor acquisition
  - Radiosonde launch near time of sensor overpass
    - Data acquired July 13 only
Spectral Albedo for Lunar Lake, NV, 7/16/01

Lunar Lake, NV
July 16, 2001
MFRSR and Tape7 Transmissions at 130Km Visibility

Lunar Lake, NV
July 16, 2001
MFRSR/Reagan: Optical Depth for Lunar Lake 2001

Wavelength of band (nm)

Optical Depth

MFRSR 07-16-01 AM

REAGAN 07-16-01
IKONOS Spectral Response
Lunar Lake IKONOS Radiometric Assessment

Lunar Lake, NV
July 13, 2001

<table>
<thead>
<tr>
<th>Band (nm)</th>
<th>NASA Estimate (W/m²sr)</th>
<th>IKONOS Measurement (W/m²sr)</th>
<th>% Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 445 - 516</td>
<td>13.574</td>
<td>13.241</td>
<td>2.45%</td>
</tr>
<tr>
<td>2 506 - 595</td>
<td>18.311</td>
<td>18.828</td>
<td>2.82%</td>
</tr>
<tr>
<td>3 632 - 698</td>
<td>14.284</td>
<td>14.561</td>
<td>1.94%</td>
</tr>
<tr>
<td>4 757 - 853</td>
<td>14.892</td>
<td>14.945</td>
<td>0.36%</td>
</tr>
</tbody>
</table>

Percent difference is calculated by: \( \text{abs}(1 - \text{IKONOS/NASA}) \)
Lunar Lake IKONOS Radiometric Assessment

Lunar Lake, NV
July 16, 2001

<table>
<thead>
<tr>
<th>Band (nm)</th>
<th>NASA Estimate (W/m²sr)</th>
<th>IKONOS Measurement (W/m²sr)</th>
<th>% Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 445 - 516</td>
<td>13.534</td>
<td>12.783</td>
<td>5.55%</td>
</tr>
<tr>
<td>2 506 - 595</td>
<td>18.380</td>
<td>18.275</td>
<td>0.57%</td>
</tr>
<tr>
<td>3 632 - 698</td>
<td>14.418</td>
<td>14.232</td>
<td>1.29%</td>
</tr>
<tr>
<td>4 757 - 853</td>
<td>15.033</td>
<td>14.683</td>
<td>2.33%</td>
</tr>
</tbody>
</table>

Percent difference is calculated by: \( \text{abs}(1 - \text{IKONOS/NASA}) \)
Site: Scattered buildings within a heavily wooded area, man-made reservoirs and canals. Elevation 5.5m - 10m. 30.388 degrees N, 89.61 degrees W.

In-Situ Instrumentation: ASD FieldSpec FR spectroradiometers, Yankee MFRSRs, Reagan sunphotometer, Airsonde radiosonde, full sky imager, 20m x 20m radiometric tarps, 99% spectralon panels.
Radiometric Tarps

- 4 20m x 20m tarps with reflectance values of
  - less than 5%
  - between 20% and 25%
  - between 30% and 40%
  - between 50% and 55%
- Spectral measurement range of 400 to 1050 nm
- Standard deviation about average reflectance less than 1% spatially
- Peak to peak variation in reflectance less than 10% within any 100 nm spectral band
- Less than 10% variation in reflectance values when measuring tarps from 10 deg to 60 deg off axis
- Each side is straight to within ±6.0 centimeters over the 20 meter length
- Each tarp panel has 60 square witness samples measuring 30.5 centimeters by 30.5 centimeters.
## Data Acquisitions

<table>
<thead>
<tr>
<th>Date</th>
<th>Over Pass Time (UTC)</th>
<th>Satellite Elevation</th>
<th>Satellite Azimuth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan 15, 2002</td>
<td>16.44</td>
<td>77.19 deg</td>
<td>112.97 deg</td>
</tr>
<tr>
<td>Feb 17, 2002</td>
<td>16.47</td>
<td>81.88 deg</td>
<td>100.73 deg</td>
</tr>
</tbody>
</table>

Standard / Original imagery
MTFC applied
Cubic convolution resampling algorithm
ASD Measurements

- Measurements of several target areas were taken
  - ~35-m x 15-m area of a dried grassy field
  - ~30-m x 20-m area of a concrete parking lot
  - Three 20-m x 20-m radiometric tarps (3.5%, 52% and 22% reflectance)
- Measurements were taken along transect lines (grass and concrete) or tarp perimeter
  - All measurements were taken while walking to increase spatial averaging
  - Between 2500 and 7500 points were taken of each target
  - ASD optimization and dark current measurements were taken prior to target measurements. Periodic spectralon panel measurements were taken
- Stationary ASD measurements taken of a spectralon panel to record sun position effect on radiometry
- ASD measurements taken of a spectralon panel across measurement field to record building presence effect on radiometry
- All data taken within 20 min of satellite overpass
Atmospheric Measurements

- Solar radiance data taken from early morning through post-sensor acquisition
  - 1 MFRSR and 1 Reagan sunphotometer acquired data from the measurement field
  - 1 MFRSR acquired data from a building rooftop approx. 2 miles away
- Radiosonde was launched 30 minutes prior to satellite overpass. Data acquired over a 90-min period up to 23 km
Full Sky Imager

NASA SSC
January 15, 2002
Includes material © Space Imaging L.P.
Spectroradiometer Data

Spectral Albedo for Stennis Space Center, 1/15/03

NASA SSC
Jan 15, 2003

Reflectance

Wavelength (μm)

0.4 0.5 0.6 0.7 0.8 0.9 1

0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1

22% Tarp
52% Tarp
3.5% Tarp
Concrete
Grass
Reagan/MFRSR Optical Depth Values

SSC, MS
Jan 15, 2002

Center Band Wavelength (nm)

Optical Depth

- REAGAN #25 Stennis Field
- MFRSR #451 Stennis Roof
- MFRSR #477 Stennis Field
IKONOS Blue Band Calibration Summary

Blue Band Calibration Summary

- SSC, Lunar Lake, 7/13/01
- SSC, Lunar Lake, 7/16/01
- SSC, Maricopa, 7/26/01
- SSC, Big Spring, 8/5/01
- UofA, Brookings, 7/3/01
- UofA, Railroad Valley, 7/13/01
- UofA, Lunar Lake, 7/13/01
- UofA, Railroad Valley, 7/16/01
- UofA, Lunar Lake, 7/16/01
- UofA, Brookings, 7/17/01
- UofA, Brookings, 7/25/01
- UofA, Ivanpah Playa, 11/19/01

Space Imaging Calibration Curve, Post 2/22/01

SI Radiance = DN/72.8

Predicted Radiance [W/(m²sr)]

Image DN

2002 JACIE WC
Reston, VA
Green Band Calibration Summary

- SSC, Lunar Lake, 7/13/01
- SSC, Lunar Lake, 7/16/01
- SSC, Maricopa, 7/26/01
- SSC, Big Spring, 8/5/01
- UofA, Brookings, 7/3/01
- UofA, Railroad Valley, 7/13/01
- UofA, Lunar Lake, 7/13/01
- UofA, Railroad Valley, 7/16/01
- UofA, Lunar Lake, 7/16/01
- UofA, Brookings, 7/25/01
- UofA, Brookings, 7/17/01
- UofA, Brookings, 11/19/01
- UofA, Ivanpah Playa, 11/19/01

Space Imaging Calibration Curve, Post 2/22/01

SI Radiance = DN/72.7

Image DN

0 200 400 600 800 1000 1200 1400 1600 1800 2000

0 5 10 15 20 25 30 35
Red Band Calibration Summary

- SSC, Lunar Lake, 7/13/01
- SSC, Lunar Lake, 7/16/01
- SSC, Maricopa, 7/26/01
- SSC, Big Spring, 8/5/01
- UofA, Brookings, 7/3/01
- UofA, Railroad Valley, 7/13/01
- UofA, Lunar Lake, 7/13/01
- UofA, Railroad Valley, 7/16/01
- UofA, Lunar Lake, 7/16/01
- UofA, Brookings, 7/17/01
- UofA, Brookings, 7/25/01
- UofA, Ivanpah Playa, 11/19/01

Space Imaging Calibration Curve, Post 2/22/01

SI Radiance = DN/94.9
IKONOS NIR Band Calibration Summary

NIR Band Calibration Summary

- SSC, Lunar Lake, 7/13/01
- SSC, Lunar Lake, 7/16/01
- SSC, Maricopa, 7/26/01
- SSC, Big Spring, 8/5/01
- UofA, Brookings, 7/3/01
- UofA, Railroad Valley, 7/13/01
- UofA, Lunar Lake, 7/13/01
- UofA, Railroad Valley, 7/16/01
- UofA, Lunar Lake, 7/16/01
- UofA, Brookings, 7/17/01
- UofA, Brookings, 7/25/01
- UofA, Ivanpah Playa, 11/19/01

Space Imaging Calibration Curve, Post 2/22/01

SI Radiance = DN/84.3

Predicted Radiance [W/(m² sr)] vs. Image DN
<table>
<thead>
<tr>
<th>Band</th>
<th>NASA Gain</th>
<th>Space Imaging Gain</th>
<th>NASA Gain SI Initial Gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>63.3</td>
<td>63.7</td>
<td>0.99</td>
</tr>
<tr>
<td>2</td>
<td>64.9</td>
<td>57.3</td>
<td>1.13</td>
</tr>
<tr>
<td>3</td>
<td>84.0</td>
<td>66.3</td>
<td>1.27</td>
</tr>
<tr>
<td>4</td>
<td>74.6</td>
<td>50.3</td>
<td>1.48</td>
</tr>
</tbody>
</table>

Units of Gain = \[ \frac{W}{(m^2 \text{ sr})}/\text{DN} \]
Summary

- The current "Post 2/22/01" calibration coefficients provided by Space Imaging agree well with the NASA team vicarious calibration
  - IKONOS sensor has been radiometrically stable over the past year
### Conference Presentation: NASA IKONOS Radiometric Characterization

**AUTHOR(S)**
- Mary Pagnutti
- Robert Ryan
- Kara Holekamp
- Vicki Zanoni

**PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)**
Lockheed Martin Space Operations - Stennis Programs

**PERFORMING ORGANIZATION REPORT NUMBER**
SE-2002-03-0002-SSC

**SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)**
SSC Earth Science Applications Directorate

**SPONSORING/MONITOR'S ACRONYM(S)**

**DISTRIBUTION/AVAILABILITY STATEMENT**
Publicly Availability STI per form 1676

**SUPPLEMENTARY NOTES**
Conference - High Spatial Resolution Commercial Imagery Workshop IKONOS Reston Virginia

**ABSTRACT**

---

[Form Approved OMB No. 0704-0188]

The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.