Landsat 8 Radiometry Overview

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Slides from various sources, i.e., don’t formally reference this presentation
Overview

- **Landsat-7 vs Landsat-8 Radiometric Requirements/Performance Comparison**
  - Bands (shortened)
  - SNR/Radiometric Resolution (shortened)
  - Saturation Radiances
  - Absolute Calibration

- **Instrument Architecture**
  - On-board Calibration Devices/function
  - Pushbroom vs. whiskbroom: Radiometric Implications
    - Processing Differences
    - Banding and Striping Differences

- **Data Product Considerations**
  - Scaling

- **Summary**
Radiometric Precision

- **Detector-by-Detector Radiometric Precision**
  - Analog system noise
    - Optical Throughput
    - Integration Time
    - Detector Sensitivity
    - Detector/Electronics Noise
  - Data quantization
    - OLI/TIRS 12 bits transmitted; TM/ETM+ 8 bits
      - 4096 levels vs 256 levels for TM/ETM+ (16 x)
    - Background/Offset levels
      - ~275 for OLI; 1000-1500 for TIRS; 3 for TM; 10-15 for ETM+
  - Radiance Scaling Range/Saturation Radiances
    - Range/quantization levels = radiometric step size \( \rightarrow \) quantization noise
    - OLI ~ 2x ETM+ Saturation Radiance (uses 1 bit)
    - TIRS ~365 K saturation versus ETM+ ~345 K (uses < 1 bit)
  - Total noise/precision (function of signal level)
    - \( \text{NE}_\Delta L/\text{NE}_\Delta T \) (1 sigma noise expressed in radiance/temperature)
    - SNR
OLI SNR performance versus ETM+

SNR at Typical Radiance

From Ed Knight slides
Noise Equivalent Delta Temperature @ 300K (smaller is better)

<table>
<thead>
<tr>
<th>Range</th>
<th>ETM+ Band 6</th>
<th>TIRS Band 10</th>
<th>TIRS Band 11</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.5-12.5 microns</td>
<td>0.15</td>
<td>0.15</td>
<td>0.15</td>
</tr>
<tr>
<td>10.3-11.3 microns</td>
<td>0.25</td>
<td>0.25</td>
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<tr>
<td>11.5-12.5 microns</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
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</tbody>
</table>
LDCM Saturation Radiances

♦ Reflective
  ➢ OLI at or above 100% reflectance at minimum solar zenith angle observed
  ➢ ETM+ at 35-51% (high gain); 52-77% (low gain)
  ➢ Saturated pixels should be rare, except for specular reflections

♦ Emissive
  ➢ ETM+ ~345K; TIRS ~365K
  ➢ Saturated pixels should be rarer
Absolute Radiometric Calibration

**OLI**
- **Requirements**
  - TOA Radiance (5% 1 sigma)—same at ETM+
  - TOA Reflectance (3% 1 sigma)
- **Predicted Performance**
  - TOA Radiance (3.5% 1 sigma)—similar to ETM+
  - TOA Reflectance (2.5% 1 sigma)
  - Calibrations independent (at launch)
    - Separate scaling coefficients provided in metadata
- Plan in place to cross calibrate during LDCM commissioning

**TIRS**
- **Requirements**
  - TOA Radiance
    - 2% 260K-330K; 4% 240-260K; 330K-360K – ETM+ was 5%
- **Predicted Performance**
  - TOA Radiance
    - ~1% 260K-330K; ETM+ similar
Instrument Architecture: On-board Calibration

**OLI**

- **Shutter**
  - Exercised before and after each acquisition interval (~2 orbit) to provide pre-dark and post dark versus every scan line for ETM+
- **Two solar diffusers**
  - Spectralon vs Paint for ETM+
    - Extensive attention to contamination control in manufacturing/I&T
    - Better illumination geometry (~45°) vs ~70° for ETM+ diffuser
    - Achieved by pointing diffuser port at sun (maneuver)
  - NIST traceable reflectance calibration (out into SWIR region)
    - New capability at NIST utilized
    - Flight parts directly characterized (did not rely on witness samples)
  - Different usage frequencies to track degradation
    - Working ~ weekly; Pristine ~semi-annually
  - Illuminated/Calibrated in-Situ with Heliostat
    - First part of transfer to orbit experiment

- **Lamps**
  - Through Full System versus at Focal plane for ETM+
  - Constant Current control
  - Built in radiance monitor (visible wavelengths)
  - Three pairs of lamps with different frequencies of usage to track degradation
  - Collects generally once/day for working lamps (vs every scan line for ETM+)
Instrument Architecture: On-board Calibration

TIRS

- Scene Select Mechanism (SSM)
  - Used to point to Earth, Black Body or Deep Space to provide cal data before and after every interval (~2/orbit) versus every scan line for ETM+

- On-Board Black Body Calibration Source
  - Full aperture full system versus internal for ETM+
    - Temperature settable from ~260K to ~330K, versus T1, T2, T3
    - Similar to MODIS OBC
    - Ops Con is to set at ~300K, but cycle through temperature range regularly
  - NIST traceable radiance calibration (via SDL)

- Deep Space Port
Implications of Push-Broom Design

**Processing**
- No line-by-line shutter, background, black-body, lamp data
- Calibration generally only available before and after science data intervals, i.e., every ~ 40 minutes
  - Blind detectors, video reference pixels can provide some data on drift between calibrations (not currently planned to be used for processing)
- OLI: Shutter data before and after each interval
  - Will be used to provide bias levels via BPF; interval specific BPF to be used for data processing
- TIRS: Deep space and OBC data before and after each interval
  - Deep Space data provides background levels; stored in BPF

Check with Ron on this slide
OLI Radiometric Processing Flow (simplified)

1. Bias Removal (BPF)
2. Response Linearization
3. Gain Application (CPF)
4. Residual Striping Correction
5. Radiance Rescaling
7. Rescaling Gain/Bias
8. SCA-SCA Ratio
9. SCA Discontinuity Correction

Flow Diagram:
- L0R → Bias Removal
- Bias Removal → Response Linearization
- Response Linearization → Gain Application
- Gain Application → SCA Discontinuity Correction
- SCA Discontinuity Correction → Residual Striping Correction
- Residual Striping Correction → Radiance Rescaling
- Radiance Rescaling → Refl. to Rad. Coeff.
- Refl. to Rad. Coeff. → Rescaling Gain/Bias
- Rescaling Gain/Bias → L1R
- L1R → Geometric Processing
- Geometric Processing → L1T

Modified K. Vanderwerff slide
TIRS Radiometric Processing Flow (simplified)

Non-Linearity Correction

Background Response (CPF)

“Gains” (CPF)

SCA-SCA Ratio

Residual Striping Correction

Geometric Processing

Radiance Rescaling

L0R

L1R

L1T
Implications of Push-broom Design

-Thousands of Detectors
  - Each views unique area on the ground
  - Assumptions of scene content based destriping techniques easily violated

-Multiple Focal Plane Modules/Sensor Chip Assemblies
  - 14 for OLI; 3 for TIRS
  - Each with unique detectors, filter pieces, electronics
    - Generally matched very well
  - Within and between spectral, linearity differences
    - Will produce between-module discontinuities/banding
    - Even if matched as well as whisk broom instruments, artifacts will be visible due to higher SNR

-Instrument, Operations, Image Assessment System have multiple techniques with dealing with banding and striping (OBC’s, side slithers, bulk scene statistics, cosmetic corrections)
Before

After
Radiometric Data Scaling

- OLI Data – scaled TOA “reflectance” or radiance
  - Two sets of coefficients in metadata
  - Independent traceability to NIST reflectance and radiance
- TIRS Data – scaled TOA radiance
Backup Slides
Pre-Launch OLI Signal-to-Noise Performance

OLI Signal-to-Noise Performance at Ltypical

SNR

band

OLI SNR Requirement (median at Ltyp)  OLI SNR Performance (12-bit median at Ltyp)
Pre-Launch OLI Signal-to-Noise Performance

OLI Signal-to-Noise Performance at Lhigh

SNR

<table>
<thead>
<tr>
<th>band</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
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<td>600</td>
<td>800</td>
<td>1000</td>
<td>1200</td>
<td>1400</td>
<td>1600</td>
</tr>
</tbody>
</table>

- OLI SNR Requirement (median at Lhigh)
- OLI SNR Performance (12-bit median at Lhigh)