Vicarious CalVal of airborne hyperspectral data – results from CEOS Tuz Golu campaign

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DLR-DFD German Remote Sensing Data Center
CEOS CalVal Sites

http://calvalportal.ceos.org
CEOS WGCV pilot – Comparison of techniques/instruments used for the vicarious calibration of Land surface imaging through a ground reference standard test site 2009
The Airborne HyMap Spectrometer

**Spectral Configuration**

<table>
<thead>
<tr>
<th>Module</th>
<th>Spectral range</th>
<th>Bandwidth across module</th>
<th>FWHM</th>
</tr>
</thead>
<tbody>
<tr>
<td>VIS</td>
<td>0.45 – 0.89 µm</td>
<td>15 – 16 nm</td>
<td>15 nm</td>
</tr>
<tr>
<td>NIR</td>
<td>0.89 – 1.35 µm</td>
<td>15 – 16 nm</td>
<td>15 nm</td>
</tr>
<tr>
<td>SWIR1</td>
<td>1.40 – 1.80 µm</td>
<td>15 – 16 nm</td>
<td>13 nm</td>
</tr>
<tr>
<td>SWIR2</td>
<td>1.95 – 2.48 µm</td>
<td>18 – 20 nm</td>
<td>17 nm</td>
</tr>
</tbody>
</table>

**Spatial Configurations**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>IFOV</td>
<td>2.5 mr along track</td>
</tr>
<tr>
<td></td>
<td>2.0 mr across track</td>
</tr>
<tr>
<td>FOV</td>
<td>61.3 degrees (512 pixels)</td>
</tr>
<tr>
<td>Swath</td>
<td>2.3 km at 5m IFOV (along track)</td>
</tr>
<tr>
<td></td>
<td>4.6 km at 10m IFOV (along track)</td>
</tr>
</tbody>
</table>

www.hyvista.com
Stability within HyEurope 2009 campaign

Stability within campaign of ~ 100 flightlines
Stability within a single datatake

Variability of CAL – Tuz Golu FL2

Max. absolute delta of 4 DN
Relative variability: << 5%

Mean variability within a datatake – HyEurope 2009 campaign
HyMap Data Acquisition, Sept. 1, 2009

<table>
<thead>
<tr>
<th>Line-#</th>
<th>Time (UTC)</th>
<th>Flight azimuth (0° =N, 180° =S)</th>
<th>Flight altitude (asl)</th>
<th>Solar zenith</th>
<th>Solar azimuth</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8:54</td>
<td>359°</td>
<td>3600 m</td>
<td>23.9°</td>
<td>146.4°</td>
</tr>
<tr>
<td>2</td>
<td>9:14</td>
<td>0°</td>
<td>3600 m</td>
<td>21.8°</td>
<td>158.0°</td>
</tr>
<tr>
<td>3</td>
<td>8:46</td>
<td>179°</td>
<td>3600 m</td>
<td>24.9°</td>
<td>142.3°</td>
</tr>
<tr>
<td>4</td>
<td>9:04</td>
<td>179°</td>
<td>3600 m</td>
<td>22.7°</td>
<td>152.0°</td>
</tr>
<tr>
<td>5</td>
<td>8:35</td>
<td>0°</td>
<td>3600 m</td>
<td>26.4°</td>
<td>137.1°</td>
</tr>
</tbody>
</table>

Overflights conducted by DLR (OpAiRS service)
http://www.opairs.aero
HyMap Data Processing

- Laboratory calibration and system correction (HyVista)
- Additional in-flight calibration for Tuz Golu data
  - Fine adjustment of spectral and radiometric calibration by DLR
  - Based on field spectra acquired by Tubitak Uzay during overflight
  - Additional check using field spectra measured during CEOS campaign by DLR
- Ortho-rectification to UTM grid using ORTHO software
- Atmospheric correction using ATCOR4 software
HyMap Imagery „Tuz Golu“

Mosaic of 5 ortho-rectified flightlines

• Calibrated at-sensor radiance, true color composit, nonlinear image stretching for visualization, no cross-track normalization

• Data drops in two flightlines (horizontal black bars)

• Dotted lines: UTM raster, 5km spacing
HyMap Imagery „Tuz Golu“

Details of FL2 (subset)

• Calibrated at-sensor radiance, true color composit, nonlinear image stretching for visualization, no cross-track normalization

• 100% zoom, pixel size: 6m
HyMap Imagery „Tuz Golu“

Subset including the test area

- Calibrated at-sensor radiance, true color composit, nonlinear image stretching for visualization, no cross-track normalization

- 100% zoom, pixel size: 6m
Spectral In-Flight Calibration using ATCOR

**Approach:** carry out multiple atmospheric corrections, thereby shift channel center wavelengths until reflectance spectrum shows minimum deviations with respect to smoothed spectrum.

\[ \chi^2 = \sum_{i=1}^{N} \left[ \rho_i(\delta) - \rho_i^{\text{smooth}} \right]^2 = 0 \]

thin: before spectral calibration
thick: after calibration

AVIRIS spectrum

Spectral Calibration – Approach

**Approach:**
carry out **multiple** atmospheric corrections, thereby shift center wavelengths until reflectance spectrum shows minimum deviations with respect to smoothed spectrum

Spectral Calibration – Approach

Approach: carry out **multiple** atmospheric corrections, thereby shift channel center wavelengths until reflectance spectrum shows minimum deviations with respect to smoothed spectrum

Spectral In-Flight Calibration: Results

For Tuz Golu:

<table>
<thead>
<tr>
<th>HyMap detector array</th>
<th>Estimated shift in [nm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.81</td>
</tr>
<tr>
<td>2</td>
<td>-0.49</td>
</tr>
<tr>
<td>3</td>
<td>-1.07</td>
</tr>
<tr>
<td>4</td>
<td>-0.90</td>
</tr>
</tbody>
</table>

For comparison: HyMap FWHM: ~17 nm

Typical uncertainties related to the approach:

0.25 nm – 0.50 nm

(estimated using a Monte-Carlo study, see EUFAR DJ2.1.2)
Radiometric In-Flight Calibration using ATCOR

\[ L(i) = c_0(i) + c_1(i) \cdot DN(i) \]

Calculated Radiance \( L_T(i) \)

\[ L_T(i) = \int R_i(\lambda) \cdot L_T(\lambda) \, d\lambda / \int R_i(\lambda) \, d\lambda \]

RT Code \( L_T(\lambda, \rho, \theta_S, \theta_V, \phi) \)

Measurement of Atm.

Ground Spectrometer \( \rho(\lambda) \)

Sensor

Ref. Targets

Spatial Model

Target \( DN_T^{image} \Rightarrow true \, DN_T \)

Background adjacency effect

PSF

Measurement

Radiative Transfer Model

Spatial Model
Radiometric In-Flight Calibration: Results

Bandwise gain factors based on laboratory calibration and in-flight calibration conducted for Tuz Gölü.

Relative changes in bandwise gain factors between laboratory and in-flight calibration.

Typical uncertainties related the approach: ~ 5-10% in ground reflectance  (EUFAR DJ2.1.2)

=> implicitly includes other sources of uncertainty such as field measurements, atmospheric correction, …
Radiometric In-Flight Calibration: Results

Comparison of atmospheric corrected image spectra to field spectra acquired during overflight by Tubitak Uzay

Note: this is not to be mistaken for “accuracy”!
Radiometric In-Flight Calibration: Results

**Comparison** of atmospheric corrected image spectra to field spectra acquired during overflight by Tubitak Uzay

Note: this is not to be mistaken for “accuracy”!
Site Characterization – overall – based on HyMap

Spectral Variability – Average Reflectance per HyMap Flightline

ρ = 10%
Site Characterization – M2 – based on HyMap

Absolute spectral variability of M2

Relative spectral variability of M2

Area of M2: 300m x 100m
Summary

- Within pilot comparison HyMap data supporting ongoing field measurements & sat.-based CalVal activities
  - See upcoming NPL REPORT DQL OR (RES) 042
- Reflectance values derived by HyMap in good agreement with ground measurements (but no independent validation…)
- Site characteristics: bright in VNIR ($\rho > 50\%$), low reflectance in SWIR ($\rho \sim 10\%$)
- Changing water content in the salt layer affecting reflectance behavior
  - Variability during day (evaporation)
  - Homogeneity in reflectance of smaller areas (300m x 100m) within 5% relative
  - Overall spatially “heterogeneous” – scale to be analyzed
- CEOS Key Comparison 2010 without airborne data acquisition
  - See calvalportal.ceos.org
Thank you for your attention!

Acknowledgements:
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