Extending DLR's operational data quality control (DataQC) to a new sensor

Results from the HySpex 2012 campaign

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Objectives

Introduce a new approach for DataQC within DLR‘s PAF
- Characterization of sensor *in-flight* performance
e.g., spectral smile
- Identification of „anomalous“ pixels and data sets
e.g., striping
- Provide scene-dependent DataQC
e.g., on saturation

Show DataQC examples from HySpex 2012 campaign

Brief update on DLR‘s PAF related to pre-processing of two camera pushbroom scanners
DataQC Approach

Assumption:
- If scene is large enough for sound statistics, mean bandwise radiance is approximately equal for all cross-track detector elements
- For L1 data, derivations from mean radiance matrix are related to de-calibrated detector elements (striping, bad pixels, …)

Prerequisite:
- Approximately equal distribution of surfaces within columns
  \( \Rightarrow \) can be tested by column variance
Baseline of the Approach

HySpex SWIR 320m-e Image Cube
(13.5°) / 27° FOV
320 cross-track pixels
256 spectral bands (0.9 - 2.5µm)
6.25 nm spectral sampling interval
Array of DNs

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### Array of DNs

<table>
<thead>
<tr>
<th>Mean DN per column</th>
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<td>20</td>
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<td>22</td>
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<td>...</td>
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<tr>
<td>20</td>
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</tbody>
</table>
“Detector Map”

- **Mean DN per column, band 40**
  - Cross-track detector element
  - Mean DN
  - Band 40

- **Mean DN per column, band 200**
  - Cross-track detector element
  - Mean DN
  - Band 200

- Spatial dimension:
  - Band nr.
  - Column nr.
  - 1
  - 256
“Detector Map”

"Detector map": mean DN for every band and cross-track detector element
Detecting Striping Artefacts in L1 Data

Anomalous pix. at band 31, pixel 237

Normalized detector map of scene “Lehrforst”
Detecting Striping Artefacts in L1 Data

Normalized detector map of scene “Lehrforst”

Anomalous pix. at band 31, pixel 237

Difference of ~30% (in radiance) to spatially & spectrally neighboring detector elements

4x Zoom
Detecting Striping Artefacts

Anomalous pix. at band 31, pixel 237

Normalized detector map of scene “Lehrforst”
DataQC Approach

Objectives for operational DataQC

(1) Characterize nominal sensor performance

(2) Provide scene-specific information
- Consistency in striping & bad pixels
- Unstable („flickering“) pixels
- Anomalous datasets / saturation
- Indication for drifts in sensor radiometric calibration
- Indication for changes in spectral calibration / spectral smile (e.g., as a function of temperature and pressure)

Location of the 82 flightlines used in the following
DataQC Approach (cont‘)

Assumptions:
- When normalized, the mean detector map should be comparable between datasets
- Differences from campaign-mean should indicate
  - Unstable („flickering“) pixels
  - Anomalous datasets
  - Spectral / radiometric drifts
- Also valid for all housekeeping data (DC = „background matrix“)

Prerequisites:
- Normalization of integration time, incoming radiance level, …
- Exclusion of all scenes where scene homogeneity is not given
Analysis of 82 L1 Datasets

1. Calculation of column mean & stdev per band & dataset
2. Normalization by bandwise mean of each dataset
3. Exclusion of spatially heterogeneous datasets
4. Aggregation: mean of means per campaign

Mean normalized radiance over 82 datasets,
linear stretch,
all pix with >20% derivation from mean in red

4x Zoom
Mean normalized radiance over 82 datasets, linear stretch, all pix with >20% derivation from mean in red

Anomalous detector element at band 31, pixel 237 is consistent over campaign i.e., decalibrated
Analysis of 82 L1 Datasets: Other Artefacts

Mean normalized radiance over 82 datasets, non-linear stretch
Analysis of 82 L1 Datasets: Other Artefacts

Mean normalized radiance over 82 datasets, non-linear stretch

Bands / Wavelength

~30 / 1.1 µm
62-90 / 1.3 – 1.5 µm
140-167 / 1.8 – 1.9µm
175 / 2.01 µm
241… / 2.4… µm
Analysis of 82 L1 Datasets: Other Artefacts

Mean normalized radiance over 82 datasets, non-linear stretch

Bands / Wavelength

~30 / 1.1 µm
62-90 / 1.3 – 1.5 µm
140-167 / 1.8 – 1.9 µm
175 / 2.01 µm
241… / 2.4… µm

Note: radiance not normalized
Analysis of 82 L1 Datasets: Spectral Smile

Mean normalized radiance over 82 datasets, non-linear stretch

175 / 2.01 µm
Analysis of 82 L1 Datasets: Spectral Smile

Mean normalized radiance over 82 datasets, non-linear stretch
Analysis of 82 L1 Datasets: Spectral Smile

3-band ratio related to 1267nm oxygen absorption feature

Shape of cross-track illumination related to spectral smile is consistent over campaign

3-band ratio in wavelength region without abs. features as reference
Additional Data QC – Saturation

Increased importance for flagging & monitoring saturation due to HySpex variable gain
Additional DataQC – Saturation

Analysis of 92 SWIR datasets indicates no real problem with saturation
Summary – Methodological Approach

- Approach based on bandwise column means („detector map“)
  ⇒ suitable for operational processing chains

- Normalization of mean radiance per detector element
  ⇒ reduced influence of integration time & scene radiance
  ⇒ mean radiance data now comparable between flights

- Calculation of mean of normalized means for full campaign
  ⇒ measure for average system performance

- Calculation of relative difference between single flightline and average
  ⇒ indicator for „abnormal“ system performance
Findings – First HySpex Campaign

- Relative calibration of detector elements in relation to spatial / spectral neighbours consistent within campaign
  ⇒ striping can thus be reduced by improved lab. (or in-flight) calibration

- No large derivation of normalized radiance to normalized campaign mean

- Shape of smile is consistent within campaign
  - Magnitude of smile within campaign yet to be analysed

- No indication for larger spectral shifts
  - Interactive analysis yet to be performed

- Saturation is no major issue in SWIR
Summary and Outlook

- Summary:
  - DLR’s pre-processing chain adjusted to HySpex two-camera system
  - DataQC as presented
  - For ATCOR & ORTHO feel free to ask!
  - In-flight QC shows that HySpex SWIR is stable related to calibration artefacts, bad pixels & shape of smile

- Next steps:
  - Update of system correction using CHB lab. measurements
  - Full analysis of campaign data incl. VNIR
  - Test on variety of pushbroom sensors (incl. simulated EnMAP)
Summary and Outlook

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Thank you for your attention!
Backup slides…
ATCOR – what’s new related to HySpex?

- Automatic inclusion of HySpex variable gain
- Bands @ 820nm for WV estimation
- Multiple exo-atmospheric spectral irradiances standards (E0)
- Hitran release (database 2011 & 2012)

Relative difference Kurucz Vs. Fontenla

Influence of Hitran versions depicted for a vegetation spectrum
ORTHO – what’s new related to HySpex?

Munich 2012

University LMU  English Garden

Georeferencing
GSD: 1 m
RMSEx ~0.4 m
RMSEy ~0.8 m

Co-Registration
VNIR (green)
SWIR (red)

<table>
<thead>
<tr>
<th></th>
<th>Spectral Range [nm]</th>
<th>Sampling Distance [nm]</th>
<th>Channels [#]</th>
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</thead>
<tbody>
<tr>
<td>VNIR</td>
<td>400-1000</td>
<td>3.7</td>
<td>160</td>
</tr>
<tr>
<td>SWIR</td>
<td>1000-2500</td>
<td>6.0</td>
<td>256</td>
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</tbody>
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R. Müller, J. Avbeli – DLR-IMF
Spectral Smile
CHB Measurements & In-Flight Estimates

Laboratory measurement in CHB (A. Baumgartner et al.)

In-flight estimation using ATCOR

For band in oxygen feature region at ~760nm:
- magnitude of smile @ 2x binning: ~0.7 nm
- magnitude of smile @ 4x binning: ~0.3 nm
Statistics on Atm. Correction

- Consistency in WV estimation VNIR-SWIR (excl. Water scenes)
  - Mean abs. diff in WV column: 0.20 cm
  - SWIR (line with boxes) consistently by ~10% lower WV than VNIR

- Reasons:
  - Linear interpolation Vs. non-linear spectral shape of materials
  - WV feature selection (820nm Vs. 970nm)
  - Calibration accuracy

- Influence on overlapping spectral region between VNIR & SWIR
Analysis of HK data

Mean DC of 82 SWIR datasets

Profile of scanline (no bad pix)

Spread of DC is one factor contributing to overall system noise
Excluding unsuited scenes (i.e., scene content largely differs cross-track)

Norm. Mean

norm. var.