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

Results from the HySpex 2012 campaign

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DLR-DFD-LAX

DLR

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:

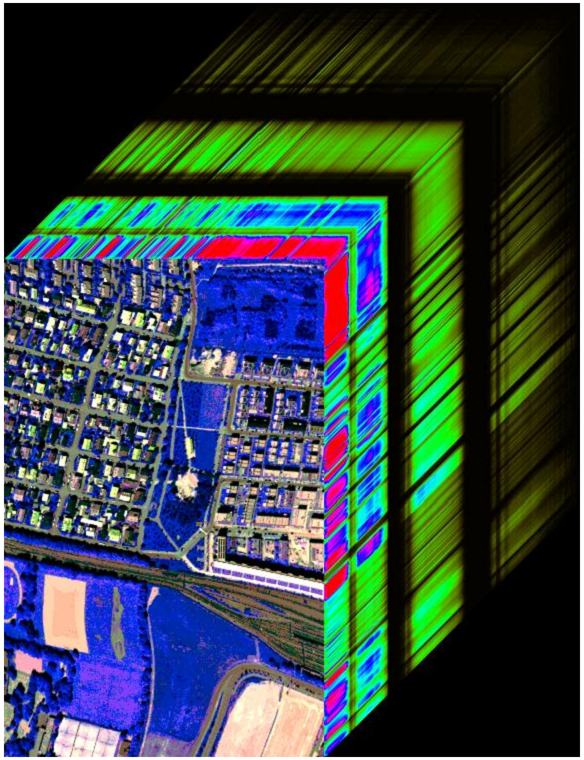
- If scene is large enough for sound statistics, mean bandwise radiance is approximately equal for all cross-track detector elements
- For L1 data, derivations from mean radiance matrix are related to de-calibrated detector elements (striping, bad pxiels, …)

Prerequesite:

- Approximately equal distribution of surfaces within columns

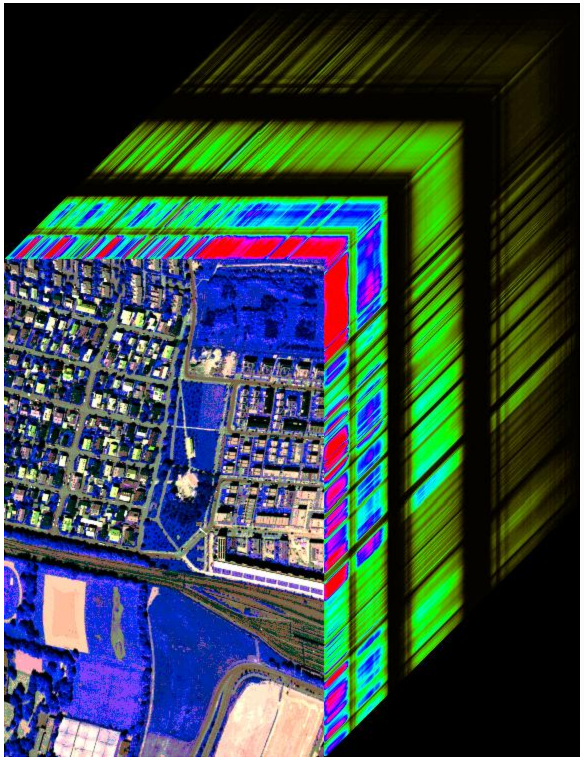
    $\Rightarrow$ can be tested by column variance

Baseline of the Approach

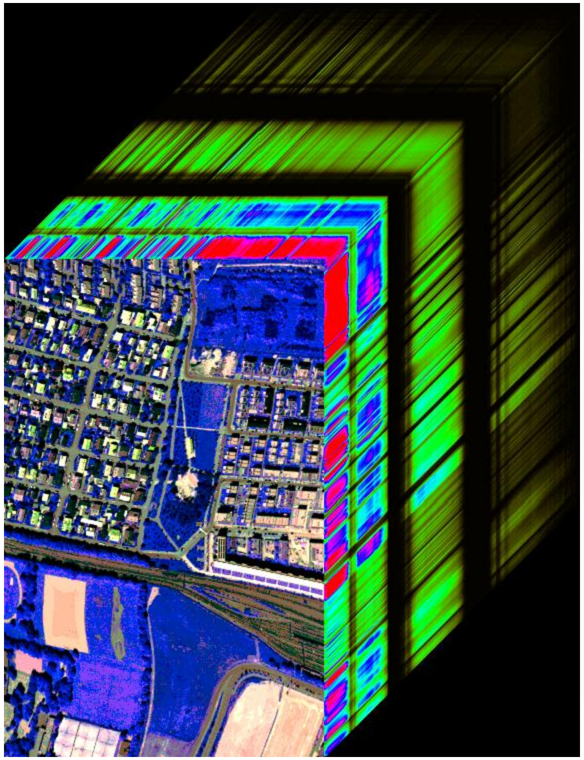


HySpex SWIR 320m-e Image Cube

(13.5°) / 27° FOV
320 cross-track pixels
256 spectral bands (0.9 - 2.5µm)
6.25 nm spectral sampling interval

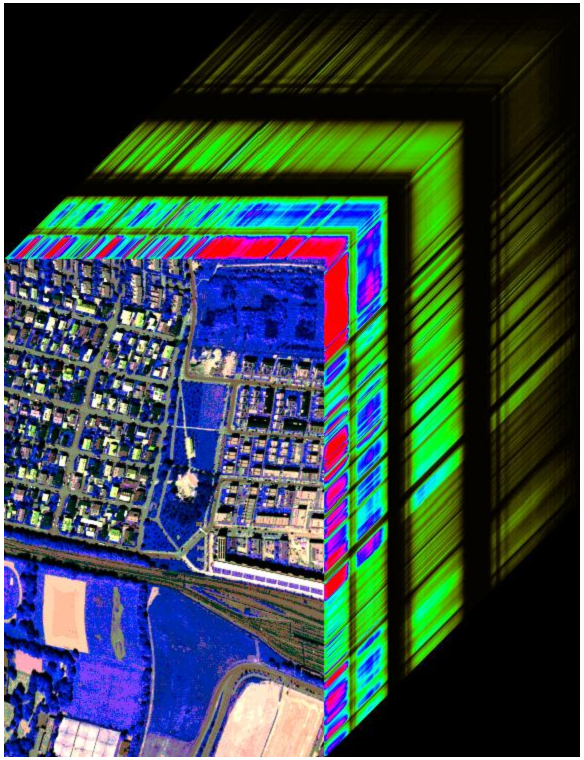


Band 40



Array
of DNs

20	22	81	…
22	23	78	…
18	21	78	…
…	…	…	…

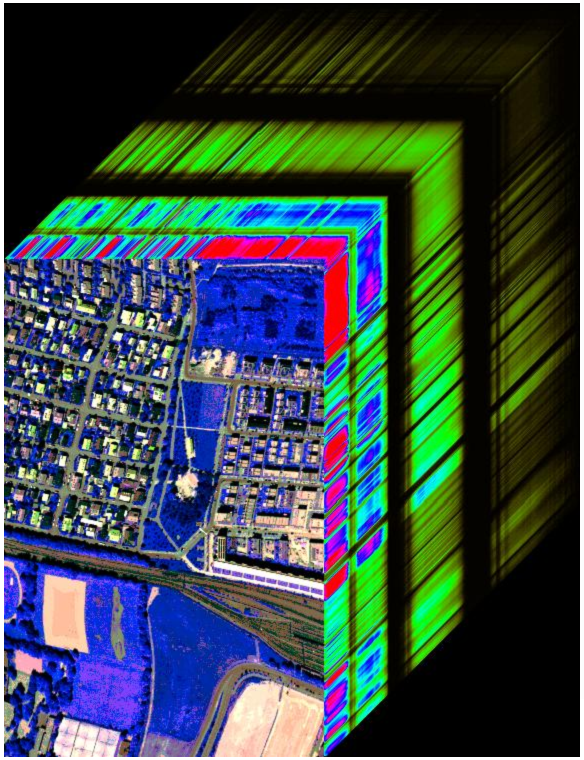


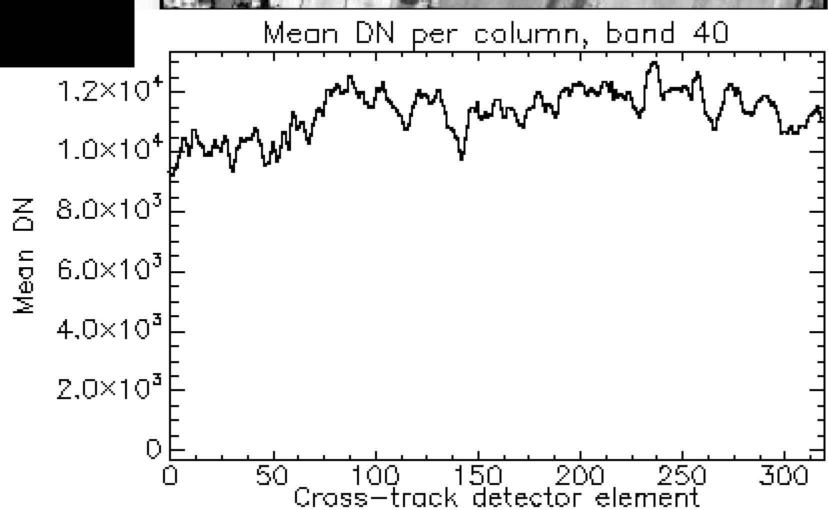
Array of DNs

20	22	81	...
22	23	78	...
18	21	78	...
...	...	...	...

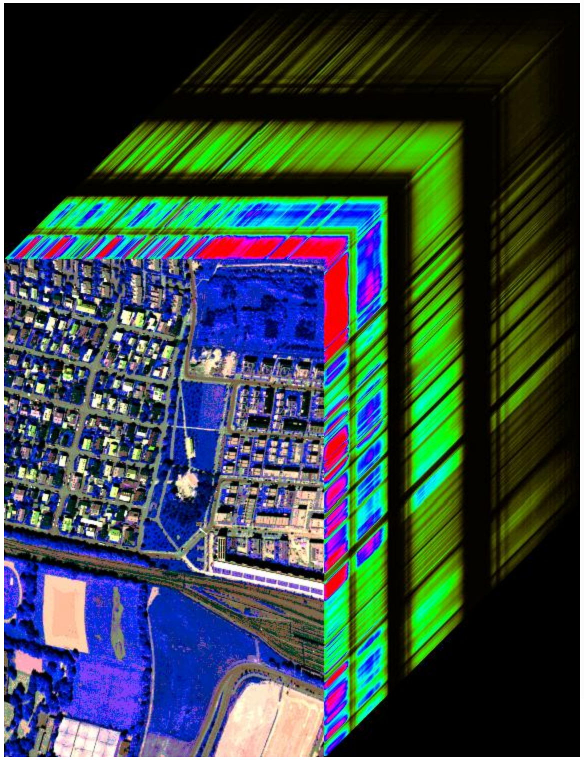
Mean DN per column

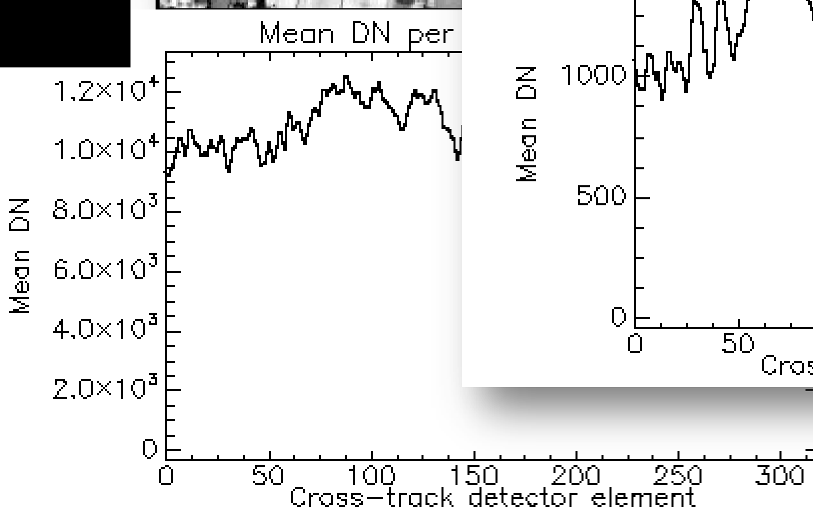
20	22	79	...

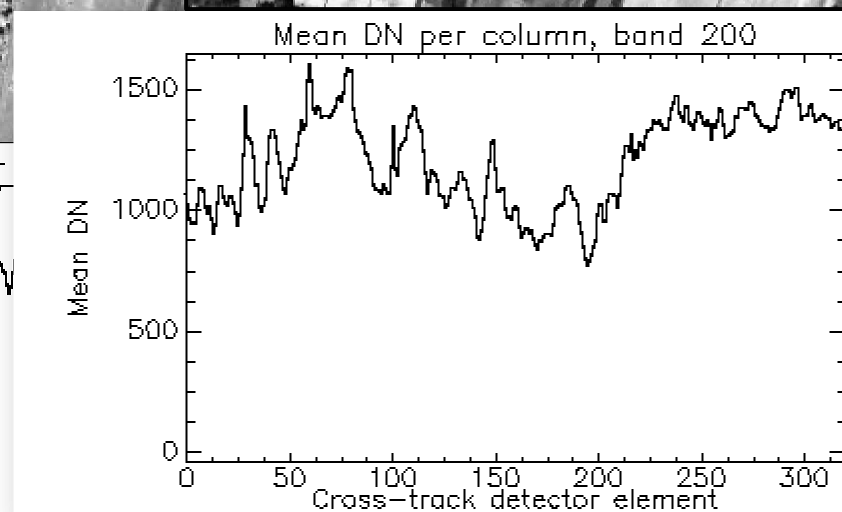




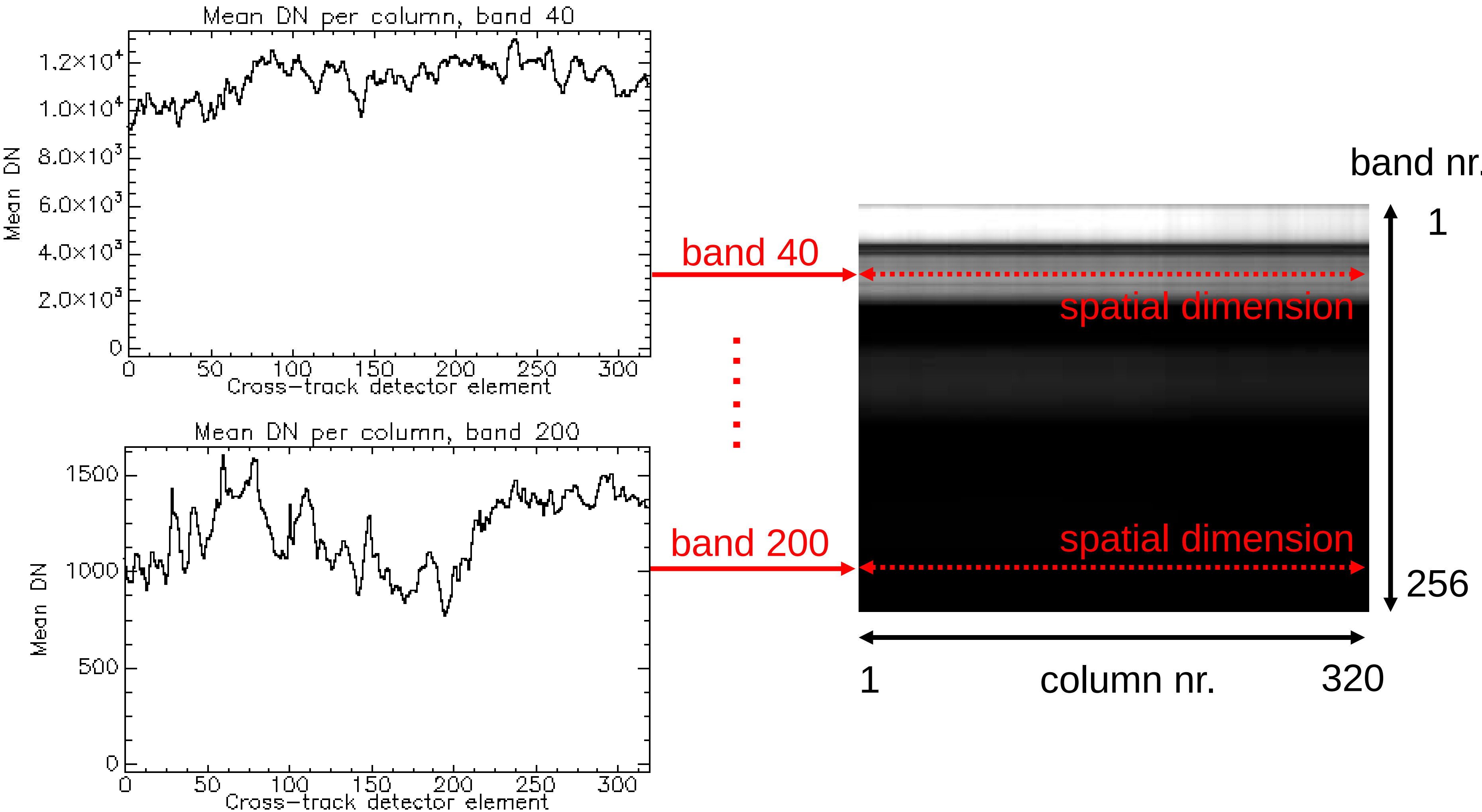
Mean DN per column, band 40
Mean DN
1.2×10^4
1.0×10^4
8.0×10^3
6.0×10^3
4.0×10^3
2.0×10^3
0
0
50
100
150
200
250
300
Cross-track detector element




Mean DN per
Mean DN
1.2×10^4
1.0×10^4
8.0×10^3
6.0×10^3
4.0×10^3
2.0×10^3
0
0
50
100
150
200
250
300
Cross-track detector element

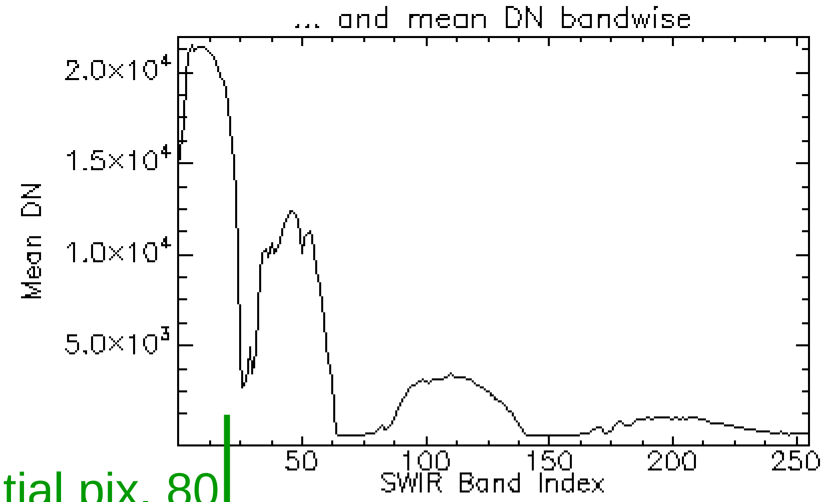

Mean DN per column, band 200
Mean DN
1500
1000
500
0
0
50
100
150
200
250
300
Cross-track detector element

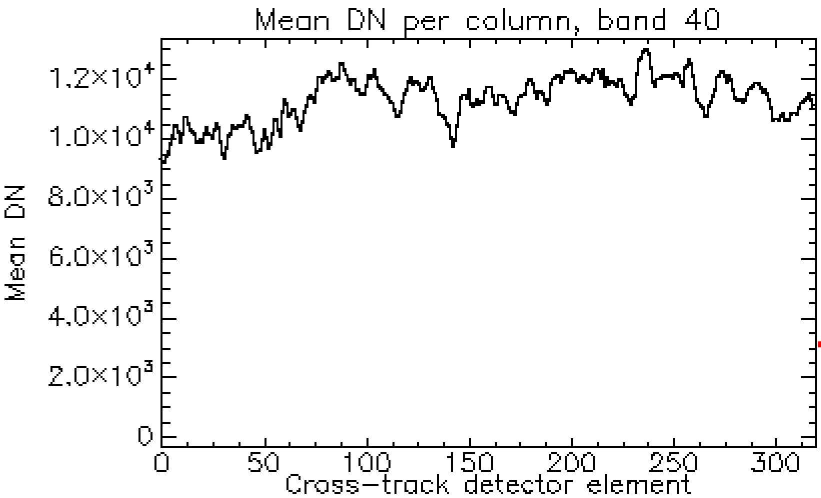
“Detector Map”

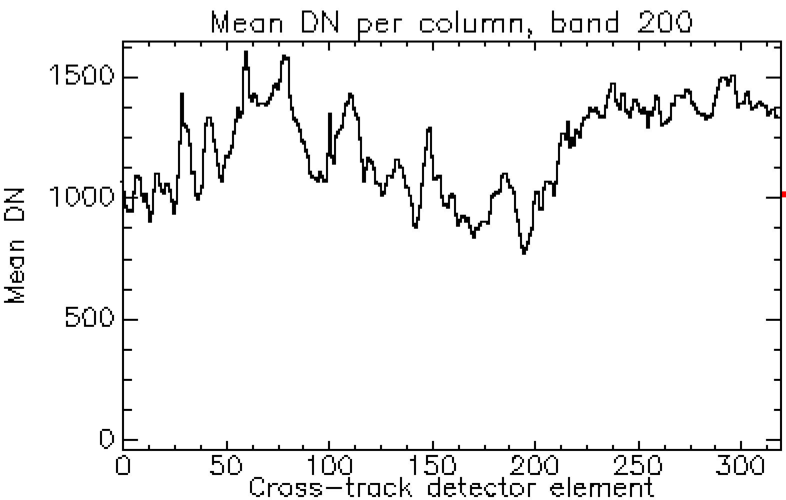


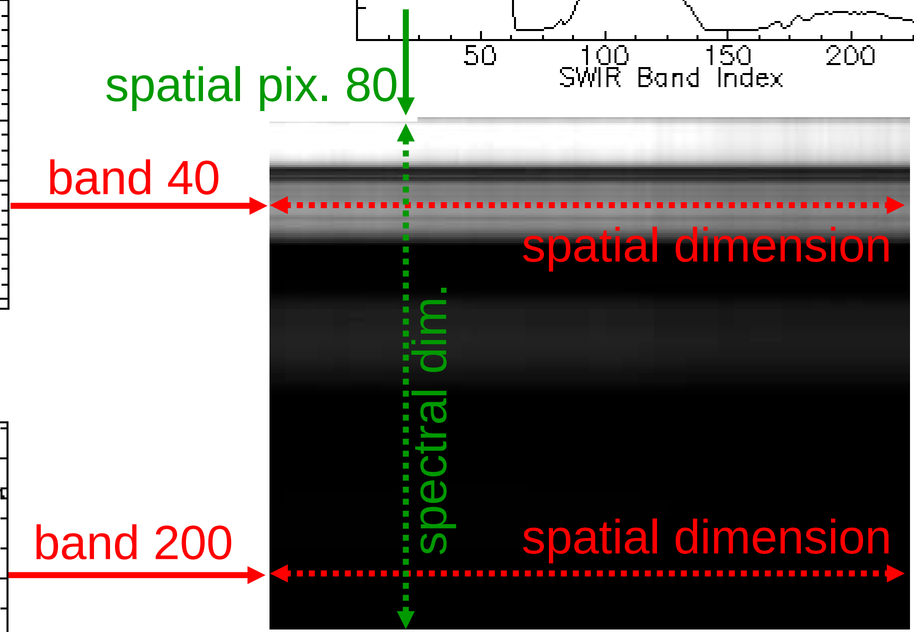
DLR

“Detector Map”





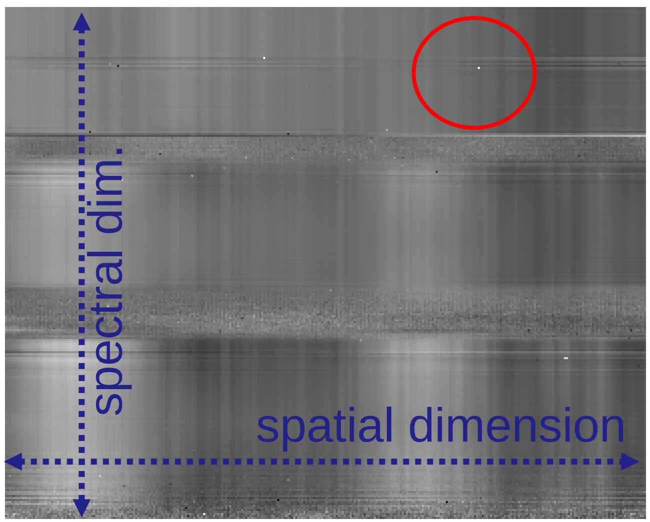




„Detector map“:
mean DN for every band and cross-track detector element

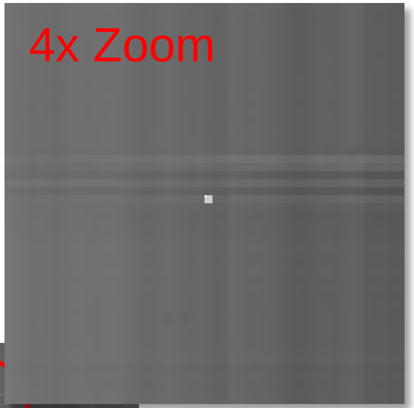
Detecting Striping Artefacts in L1 Data

Anomalous pix.
at band 31, pixel 237



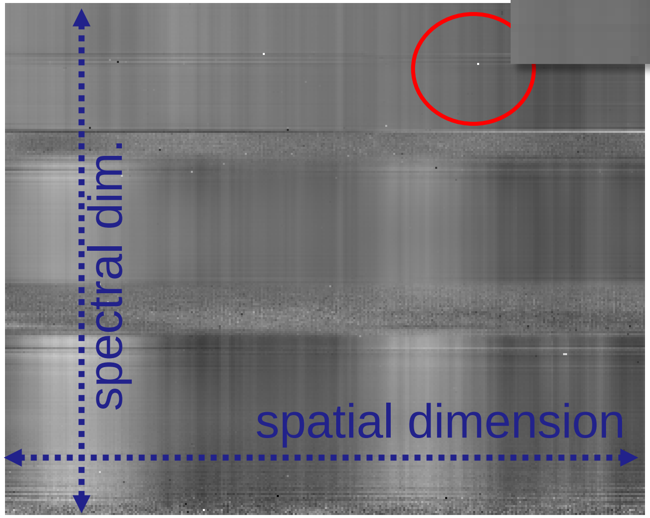
Normalized detector map of scene “Lehrforst”

Detecting Striping Artefacts in L1 Data



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

Anomalous pix.
at band 31, pixel 237



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Detecting Striping Artefacts

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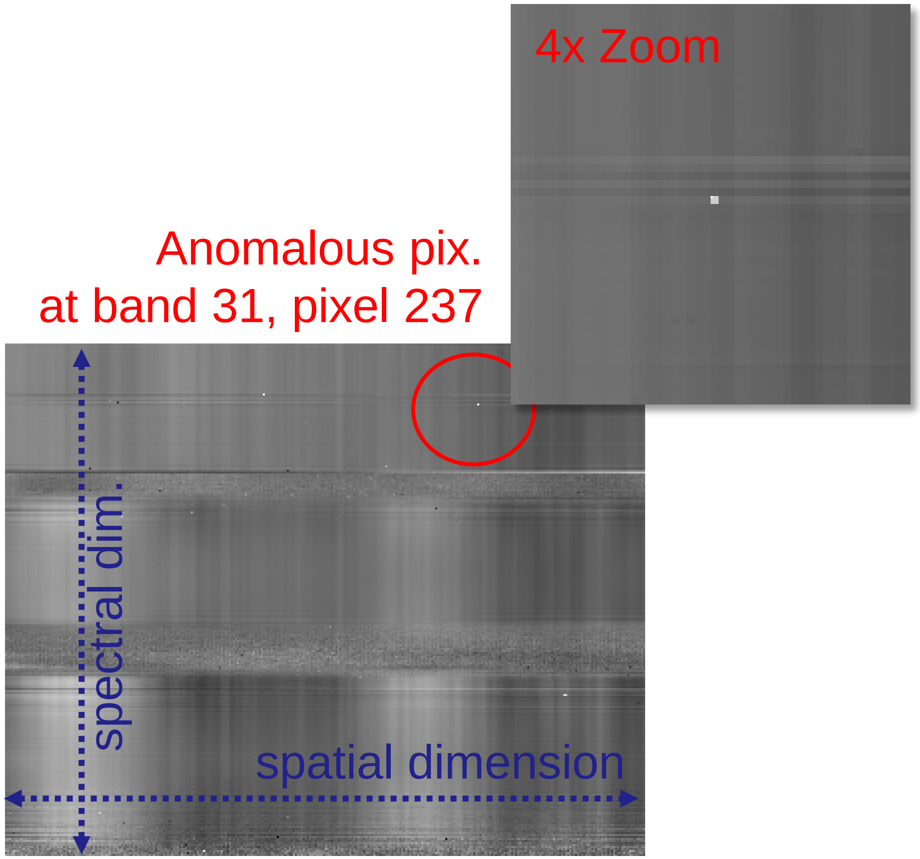

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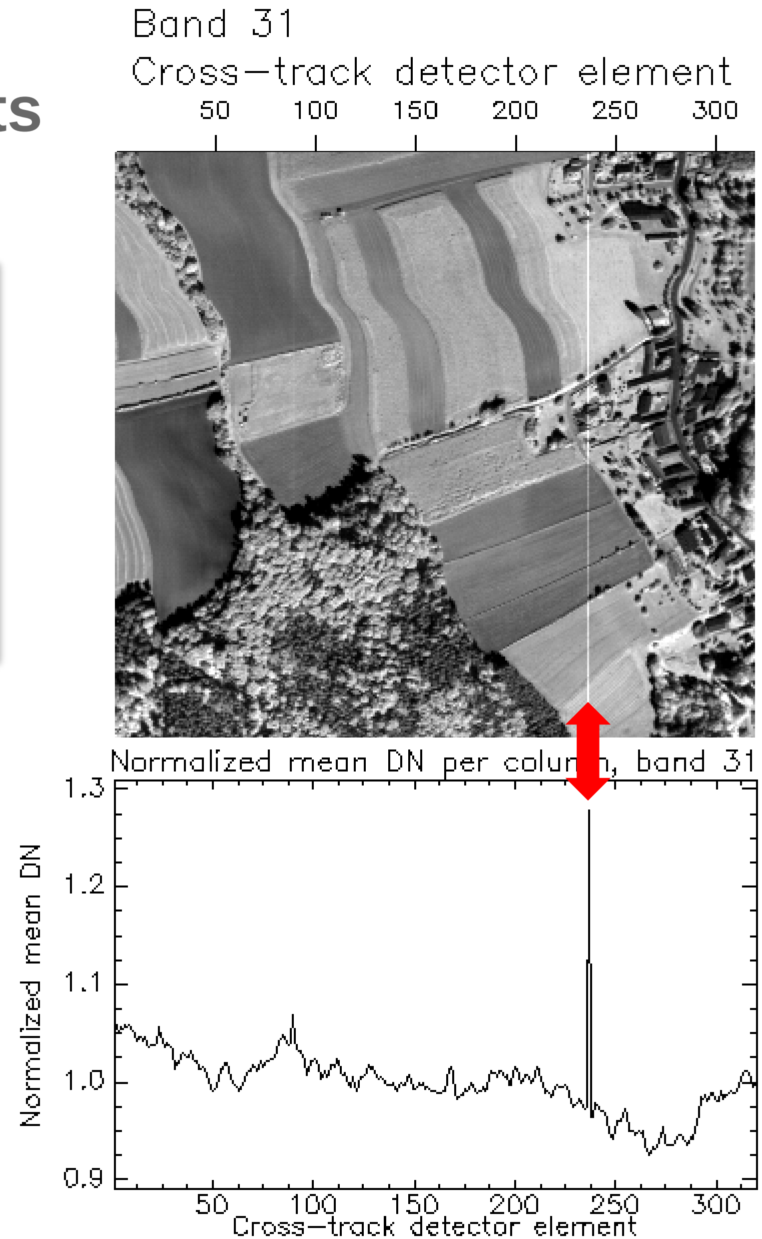


DataQC Approach

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:

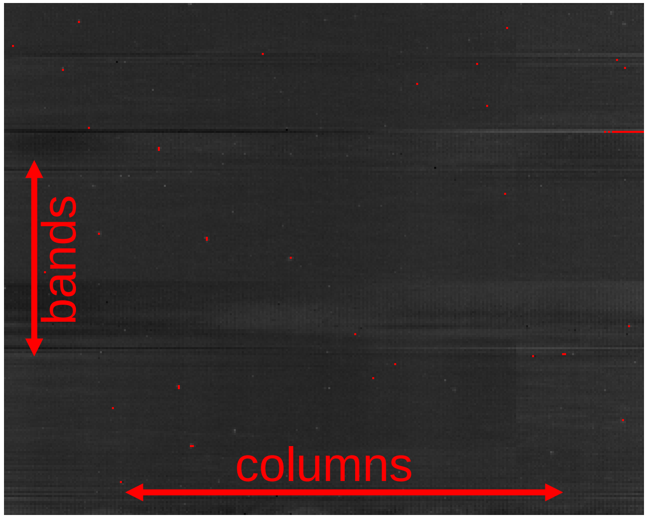
- When normalized, the mean detector map should be comparable between datasets
- Differences from campaign-mean should indicate
  - Unstable („flickering“) pixels
  - Anomalous datasets
  - Spectral / radiometric drifts
- Also valid for all housekeeping data (DC = „background matrix“)

Prerequesite:

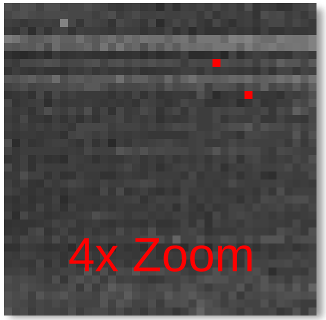
- Normalization of integration time, incoming radiance level, …
- Exclusion of all scenes where scene homogeneity is not given

Analysis of 82 L1 Datasets

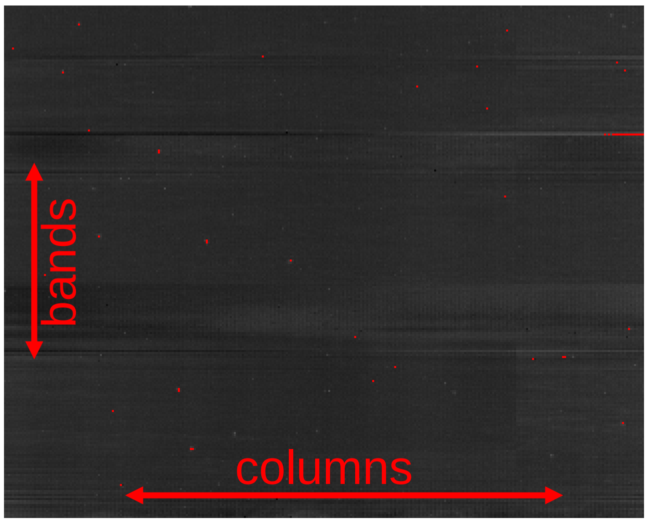
1. Calculation of column mean & stdev per band & dataset
2. Normalization by bandwise mean of each dataset
3. Exclusion of spatially heterogeneous datasets
4. Aggregation: mean of means per campaign



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



Analysis of 82 L1 Datasets: Consistency in Bad Pix



Mean normalized radiance over 82 datasets,
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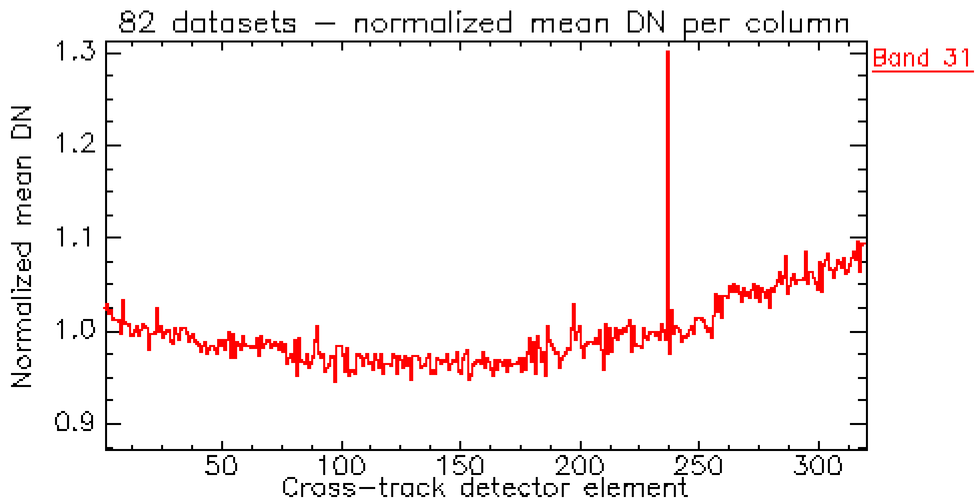
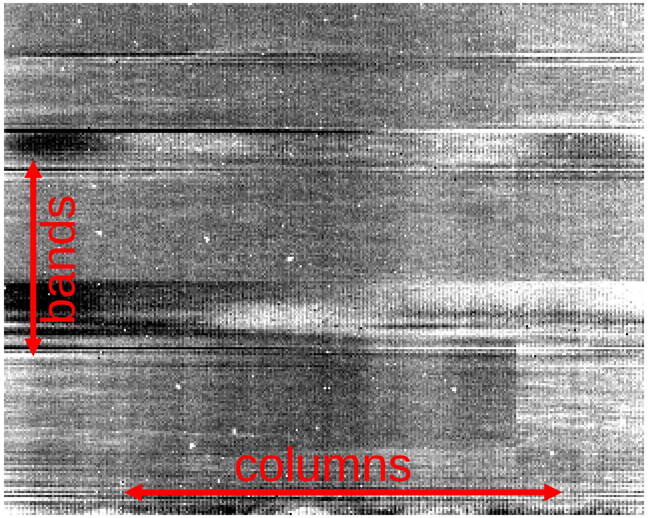


Anomalous detector element at band 31, pixel 237 is consistent over campaign i.e., decalibrated

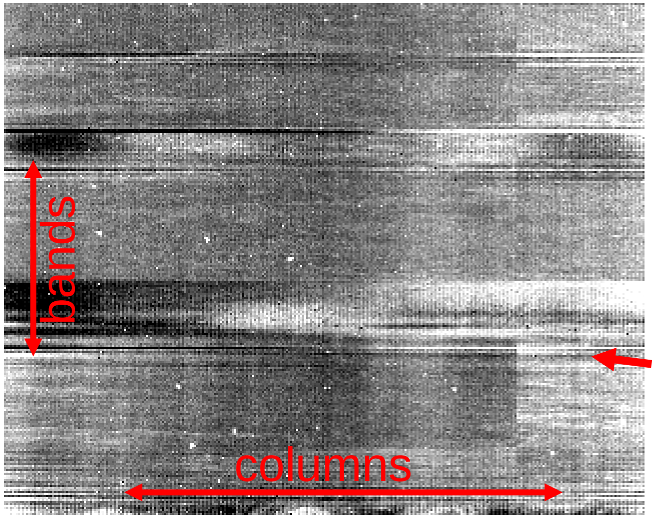
Analysis of 82 L1 Datasets: Other Artefacts



Mean normalized radiance over 82 datasets, non-linear stretch

Analysis of 82 L1 Datasets: Other Artefacts

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

Mean normalized radiance over 82 datasets, non-linear stretch

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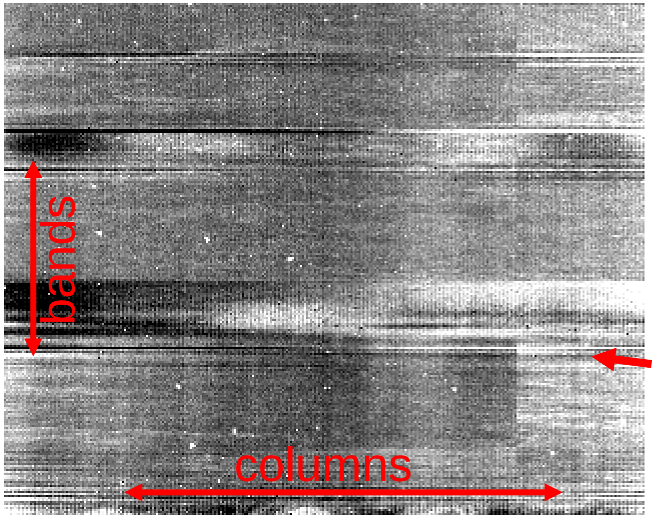

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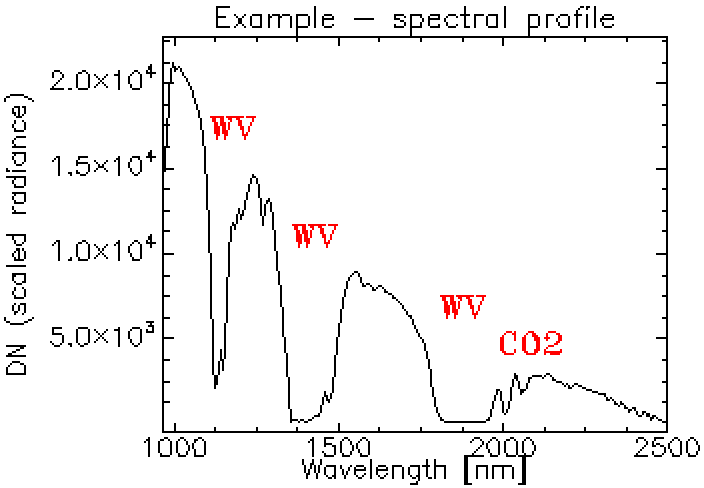
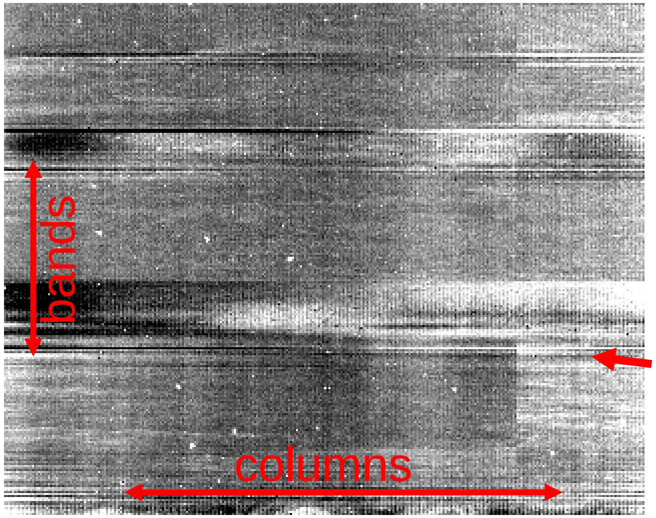


Note: radiance not normalized

Analysis of 82 L1 Datasets: Spectral Smile



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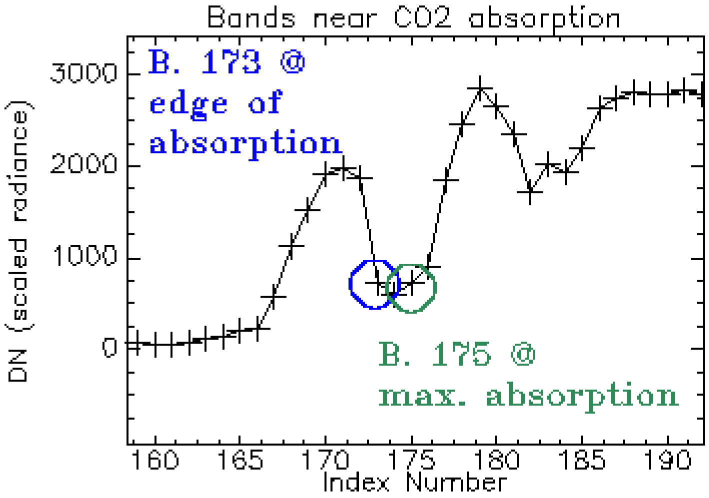
Mean normalized radiance over
82 datasets,
non-linear stretch



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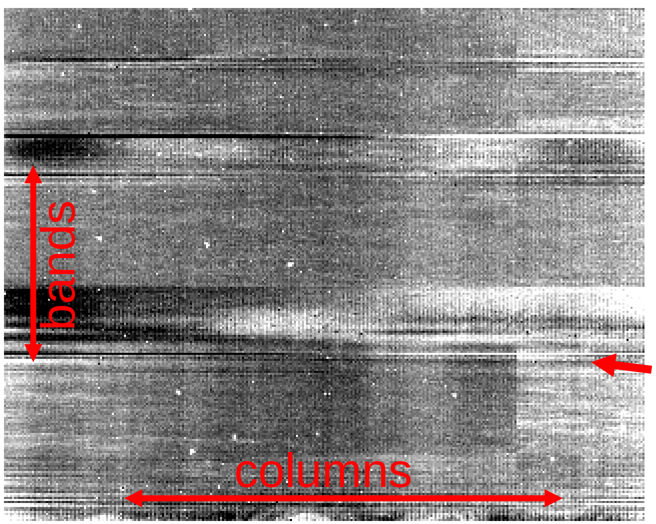

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Mean normalized radiance over
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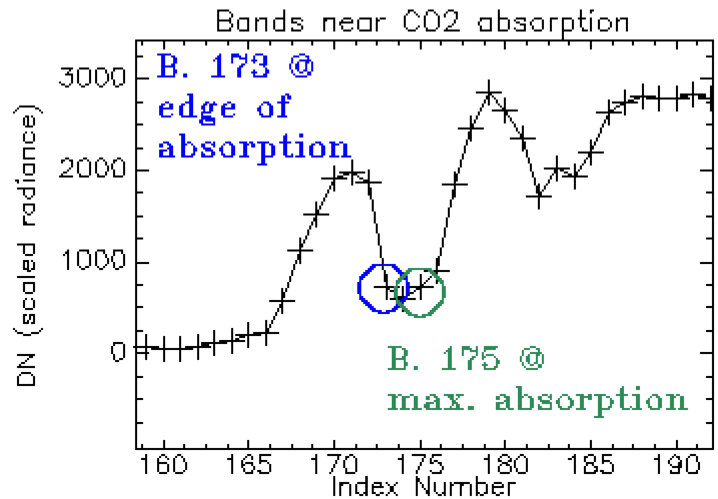

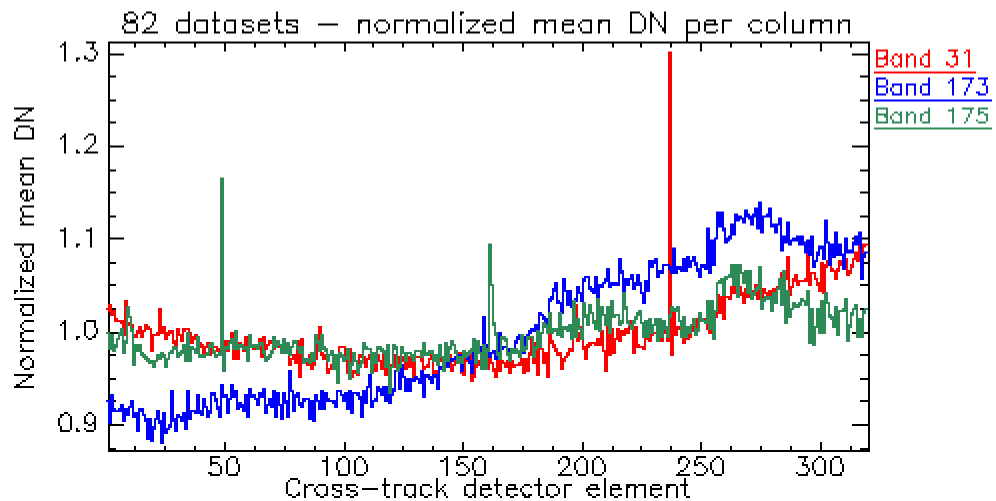

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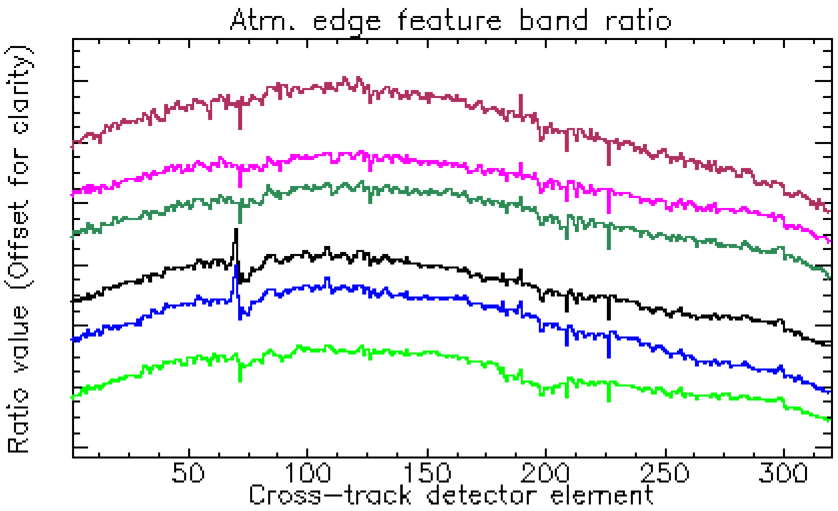
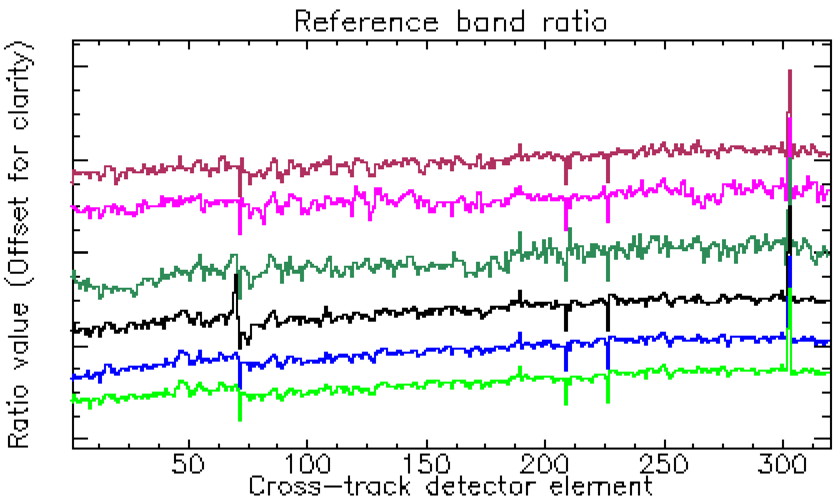


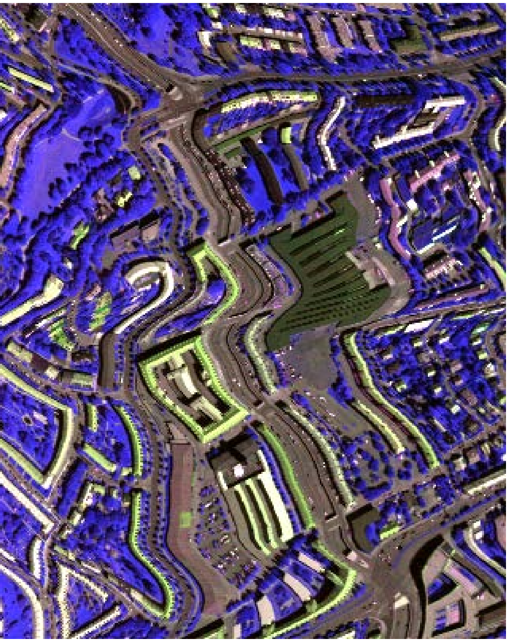
3-band ratio related to 1267nm oxygen absorption feature



3-band ratio in wavelength region without abs. features as reference

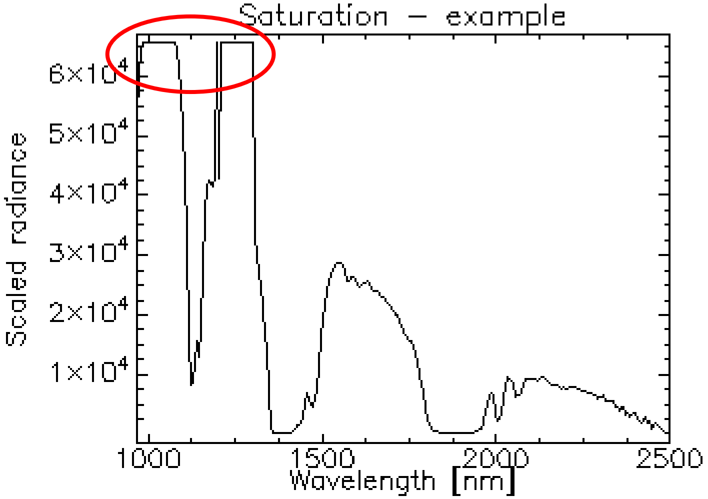
Shape of cross-track illumination related to spectral smile is consistent over campaign

Additional DataQC – Saturation



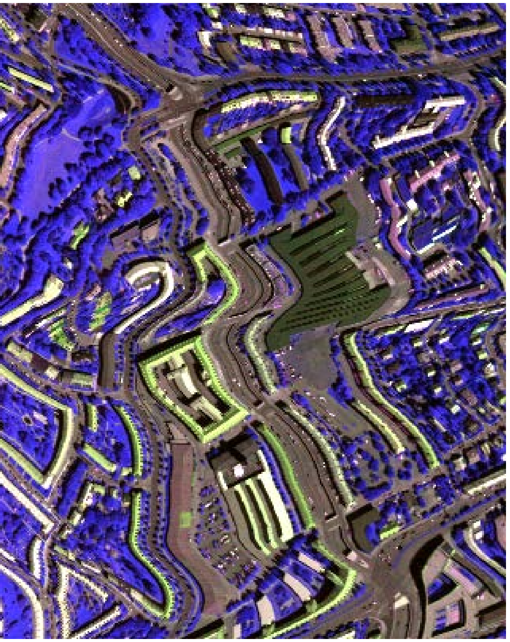
SWIR dataset Munich

QC flags „Saturation“



Increased importance for flagging & monitoring saturation due to HySpex variable gain

Additional DataQC – Saturation



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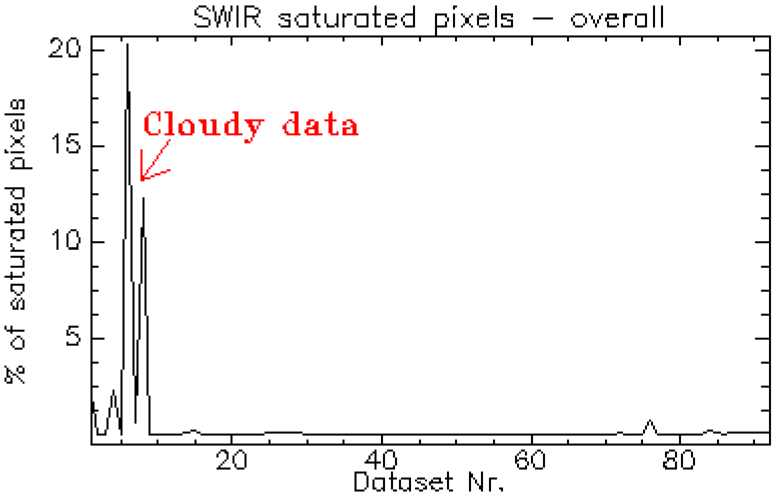

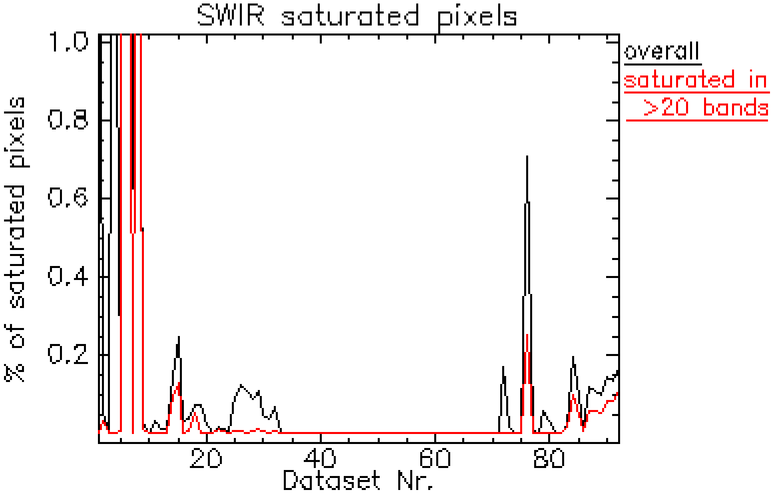

Analysis of 92 SWIR datasets
indicates no real problem with saturation

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
  - $\Rightarrow$ 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)

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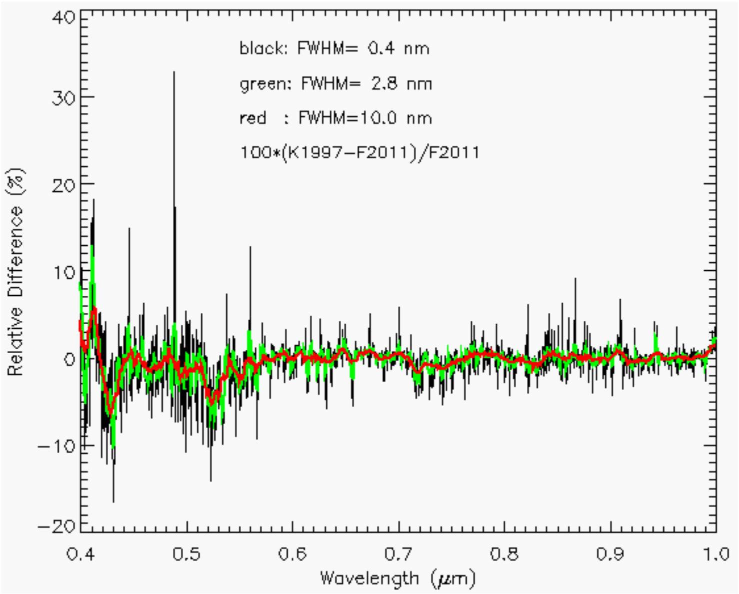
Thank you for your attention!

DLR

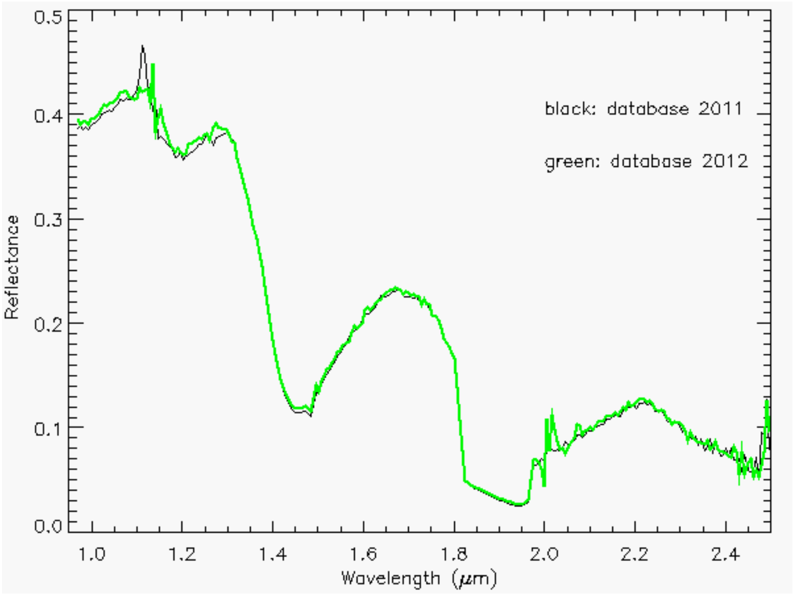
Backup slides…

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 (databse 2011 & 2012)



Relative difference Kurucz Vs. Fontenla



Influence of Hitran versions
depicted for a vegetation spectrum

ORTHO – what‘s new related to HySpex?

SWIR VNIR

Munich 2012

University LMU English Garden

	Spectral Range [nm]	Sampling Distance [nm]	Channels [#]
VNIR	400-1000	3.7	160
SWIR	1000-2500	6.0	256

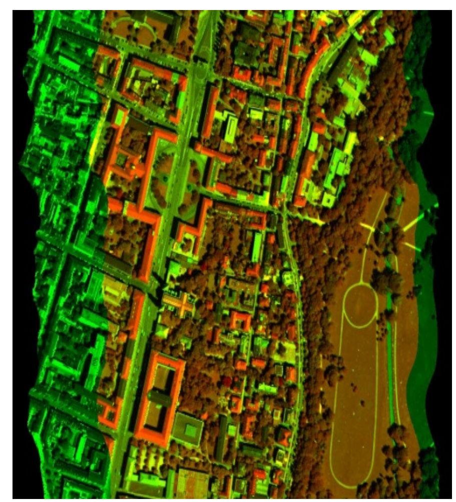
+ 3K DEM

Georeferencing

GSD: 1 m

RMSEx ~0.4 m

RMSEy ~0.8 m

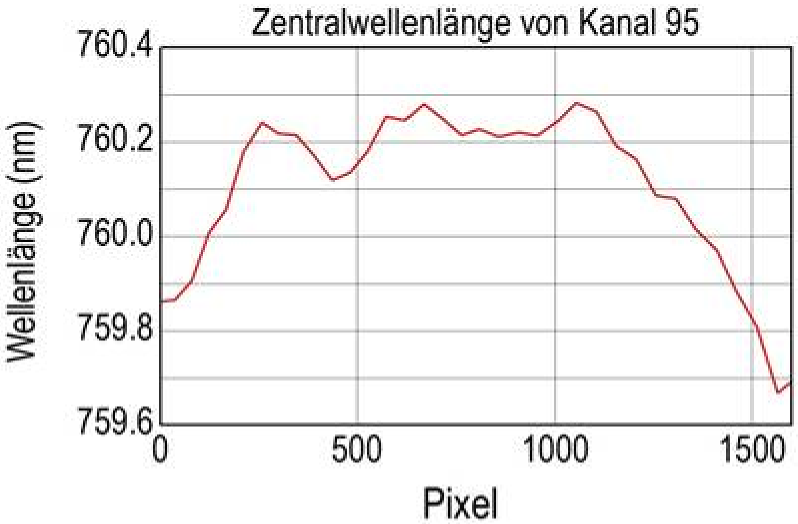


Co-Registration

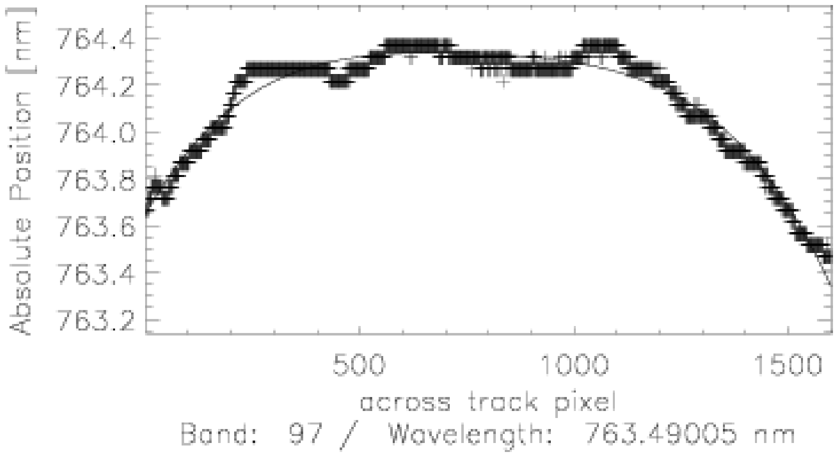
VNIR (green)

SWIR (red)

Spectral Smile
CHB Measurements & In-Flight Estimates



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

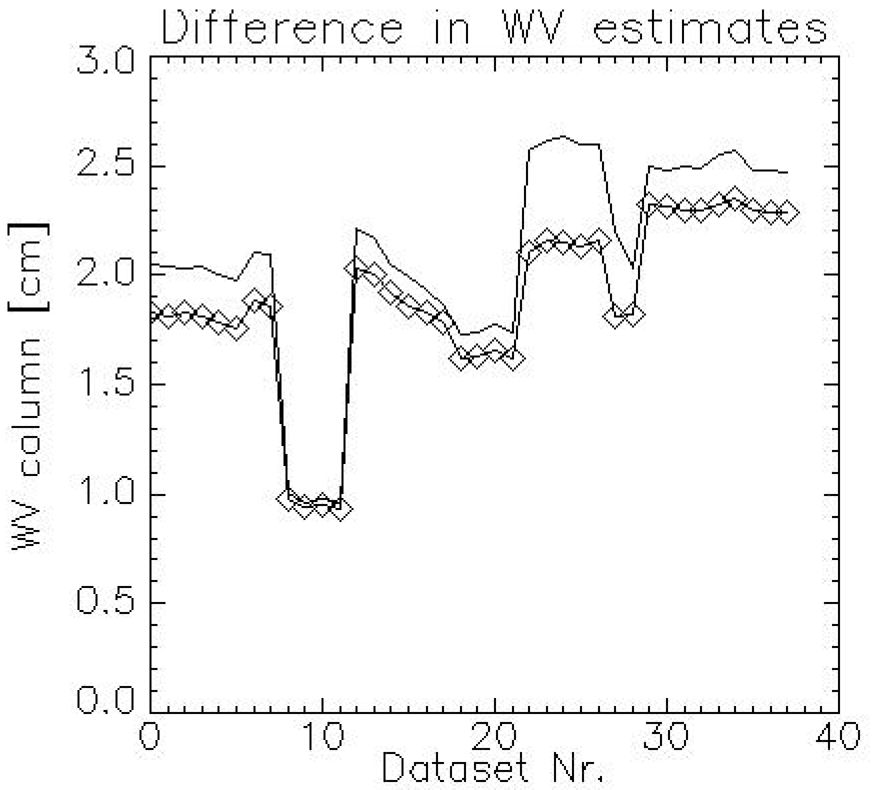


In-flight estimation using ATCOR

For band in oxygen feature reagion at ~760nm:
- magnitude of smile @ 2x binning: ~0.7 nm
- magnitude of smile @ 4x binning: ~0.3 nm

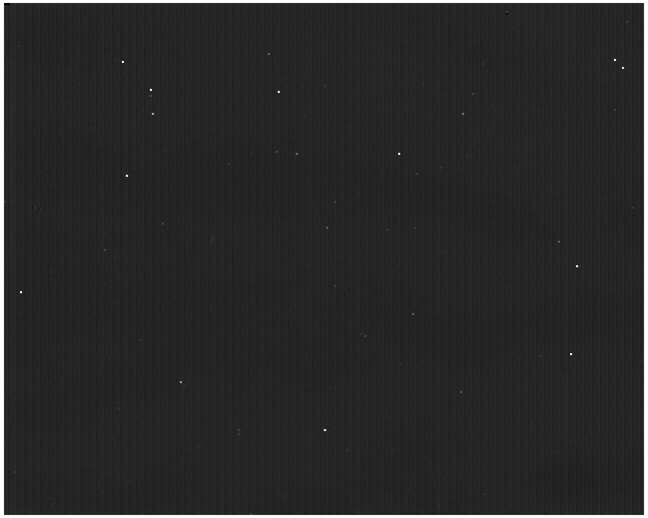
Statistics on Atm. Correction

- 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

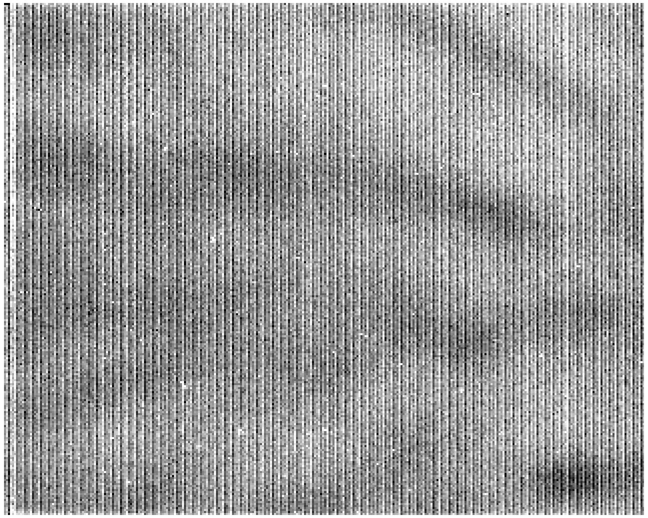


- Influence on overlapping spectral region between VNIR & SWIR

Analyisis of HK data

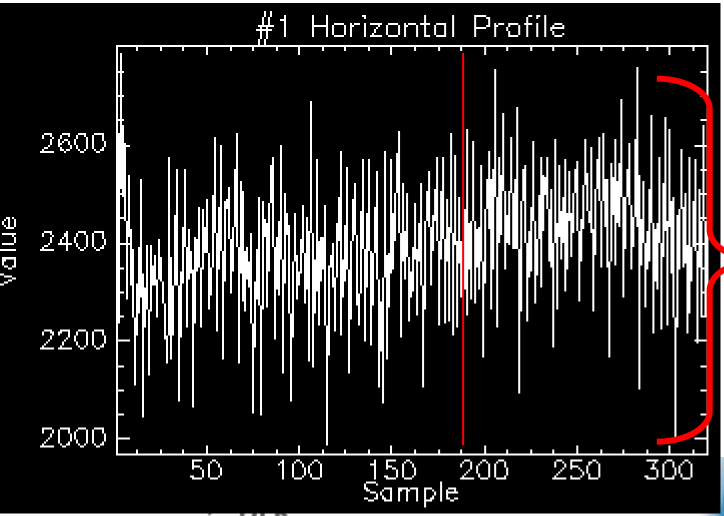


Linear stretch



Nonlinear stretch

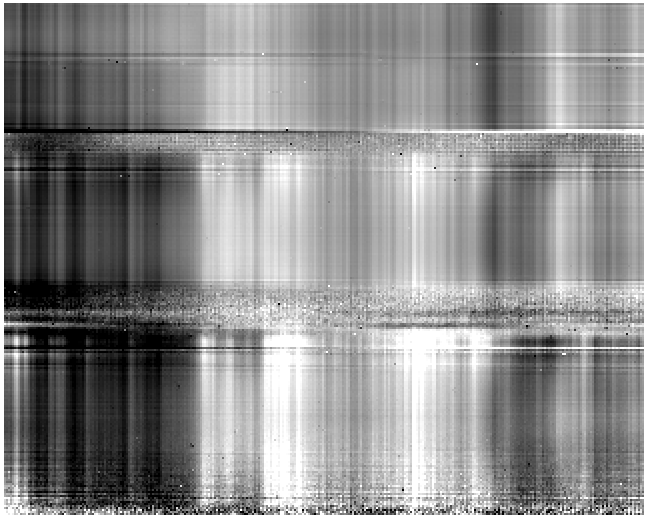
Mean DC of 82 SWIR datasets



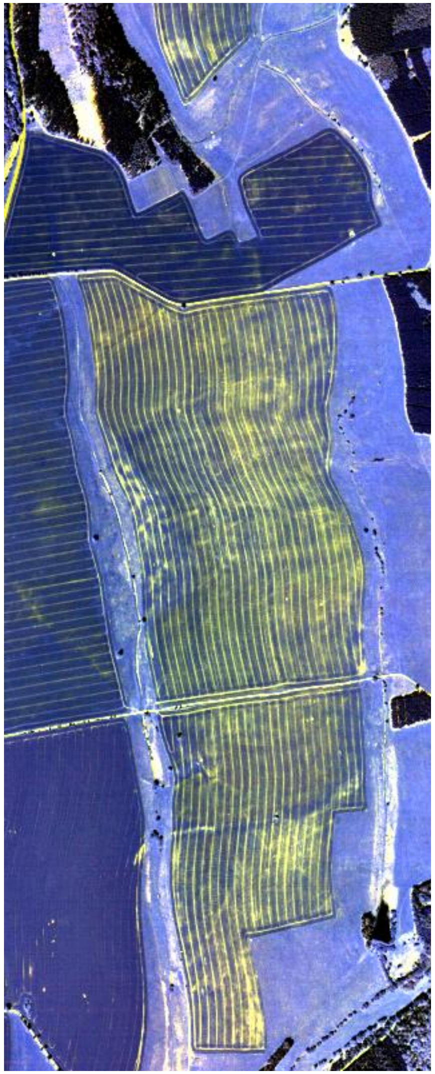
Profile of scanline (no bad pix)

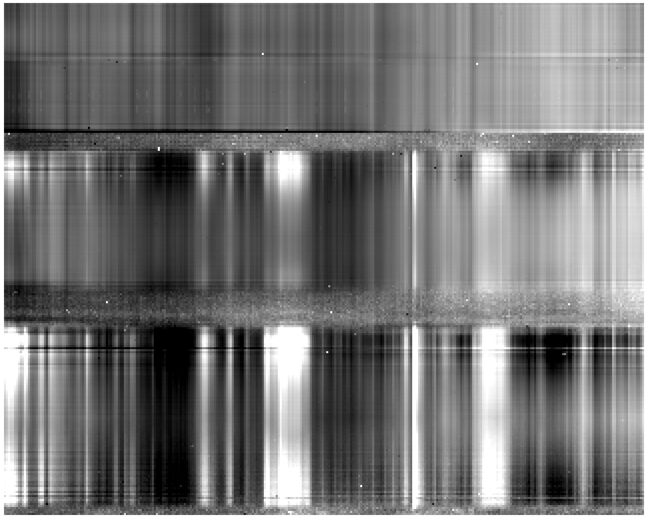
Spread of DC is one factor contributing to overall system noise

Excluding unsuited scenes
(i.e., scene content largely differes cross-track)



Norm. Mean





norm. var.