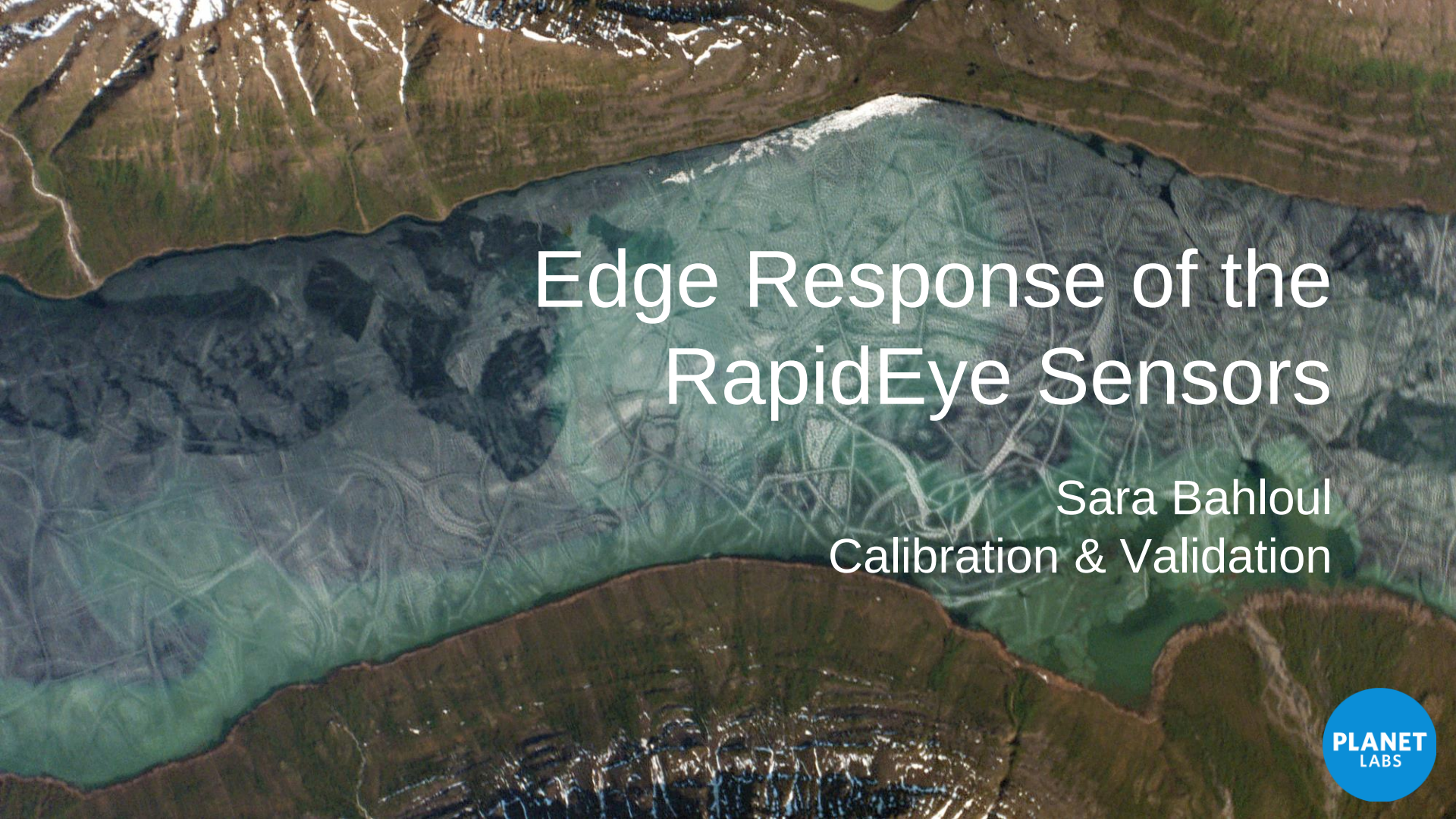


Edge Response of the RapidEye Sensors

Sara Bahloul
Calibration & Validation

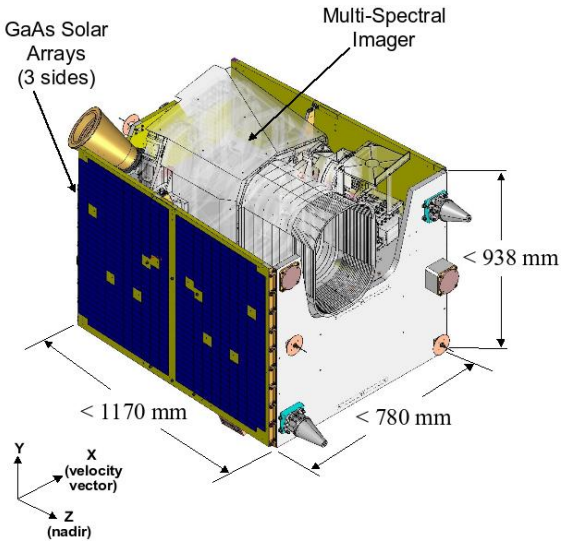
PLANET LABS

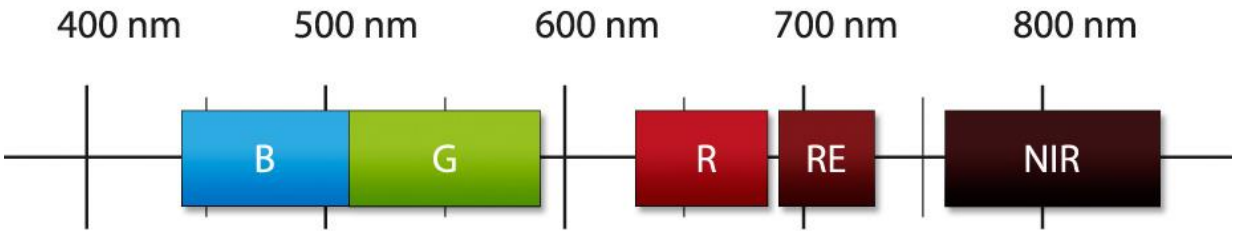
- Introduction and Motivation
- Method
  - Edge Selection and Refinement
  - RER and ERS
- Practical Implementation
  - Edge Response Trending
- Results and Outlook

Introduction to RapidEye and Motivation

The RapidEye Constellation

- Constellation of five identical satellites
- Equally phased in sun-synchronous orbit
- Approximately 630 km altitude
- Up to 5 meter pixel size
- Daily revisit time
- Imaging capacity: up to 6 million km²/day





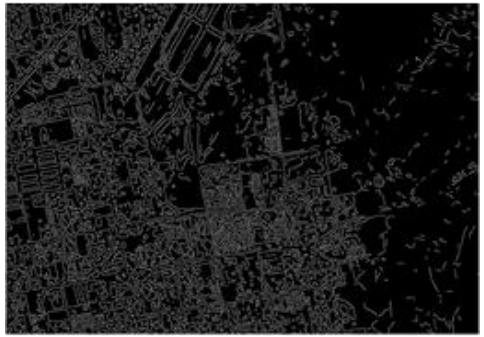
Motivation

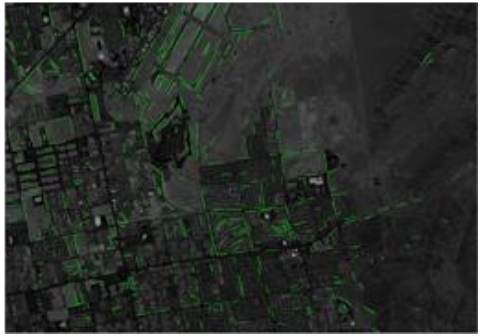
- Get a trend of the edge sharpness of the RapidEye sensors over time
- Use sharp transition between bright and dark areas in operational imagery
- No artificial targets, no dedicated acquisitions

Method

The Tool

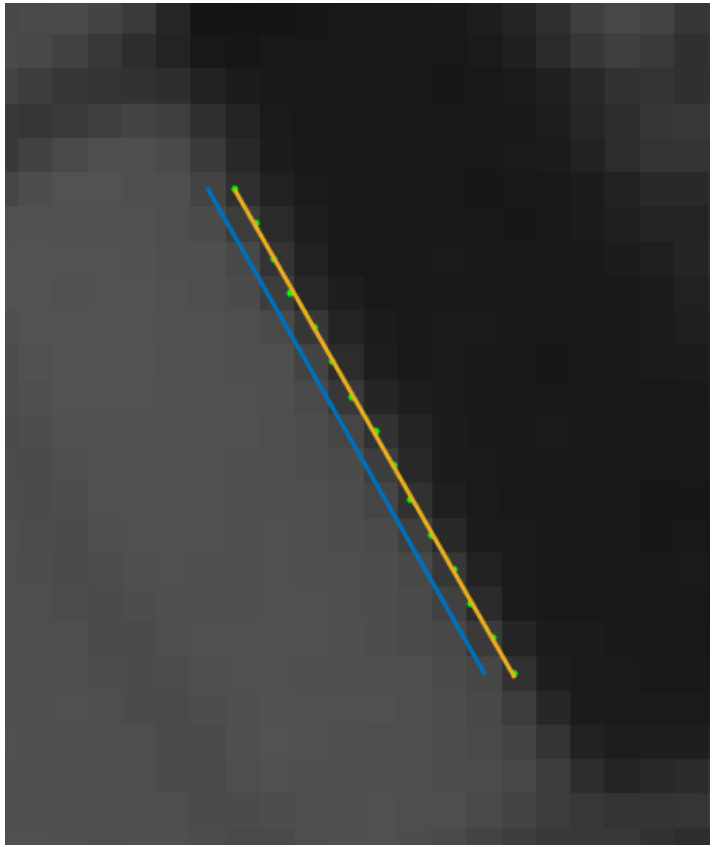
- Automated edge detection using Canny Edge Detector followed by Hough Transform
- Manual input of edge locations possible
- Edge position has to be known to sub-pixel accuracy (refinement process to achieve this)





Edge Refinement

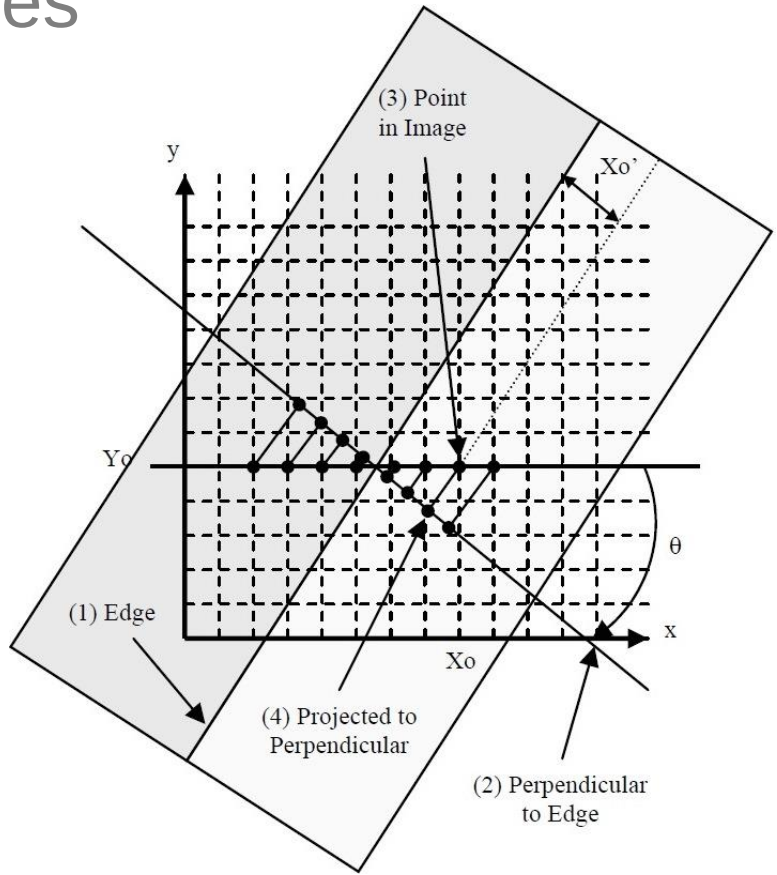
- Input edge (blue)
- In each line, the transition point (green) is determined by the half-maximum of a sigmoid through the profile
- The refined edge (yellow) is a line fit through the transition points



Oversampled Edge Profiles

- Extract profiles along the edge
- Project them on to the perpendicular to the edge
- Combine the projected profiles

➢ Oversampled edge profile



Source: Kohm. Modulation Transfer Function Measurement Method and Results for the Orbview-3 High Resolution Imaging Satellite. In Proceedings of ISPRS, 2004.

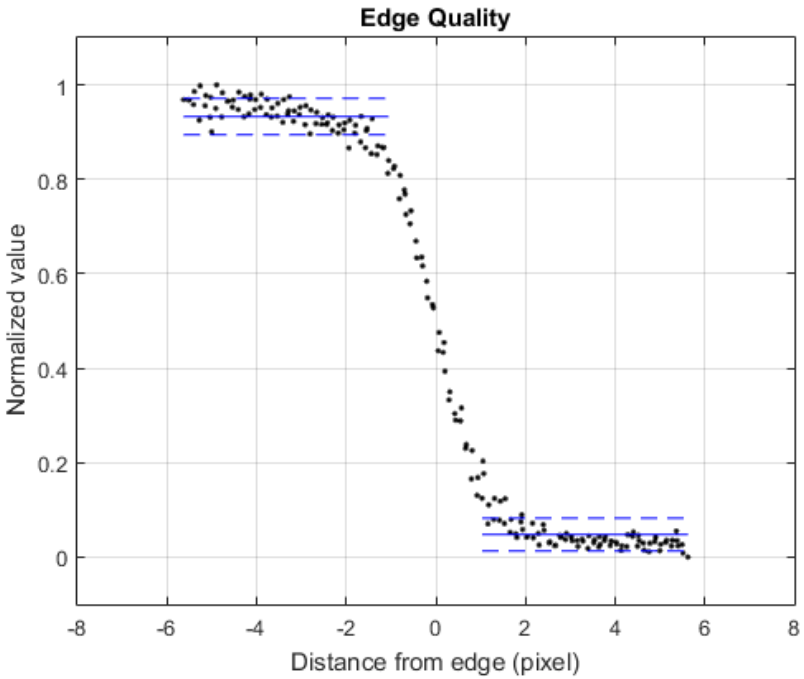
Edge Quality

Orientation

- Horizontal and vertical edges

Contrast criteria

- Difference between the mean values (before normalization) above given threshold
- Standard deviation (after normalization) below threshold



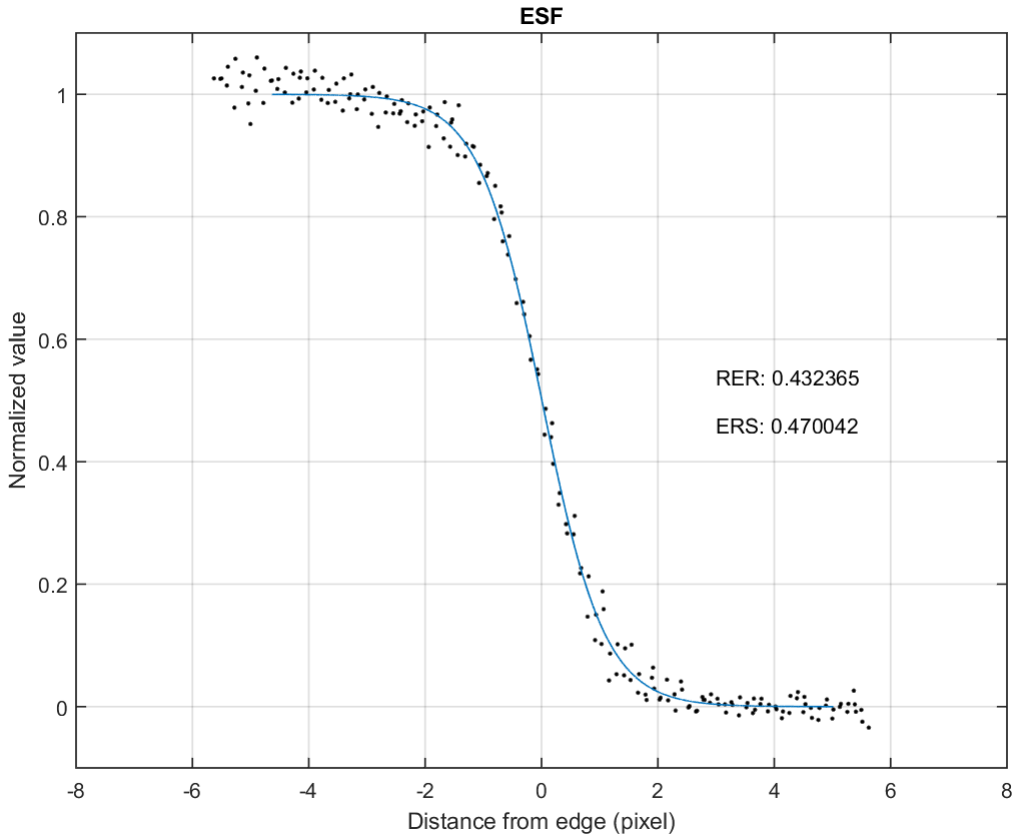
Figures of Merit

- Relative Edge Response
- $RER = |ESF(-0.5) - ESF(0.5)|$
- Slope of the ESF within -0.5 to 0.5 pixel from the edge

- Edge Response Slope
- $ERS = \left|\frac{0.6-0.4}{x_{0.6}-x_{0.4}}\right|$ with $ESF(x_{0.6}) = 0.6, ESF(x_{0.4}) = 0.4$
- Slope of the ESF between 40% and 60% of its values

RER and ERS - Example

$$f(x) = p_1 + \frac{p_2 - p_1}{1 + 10^{(p_3 - x)\cdot p_4}}$$



Practical Implementation

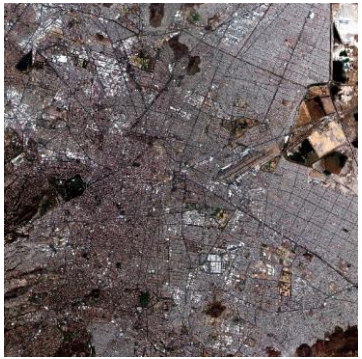
Trending

- Eight test sites equipped with 15 to 20 suitable horizontal and vertical edges each
- Analyse 316 products of those test sites covering the entire time from the start of operations in early 2009 until the end of 2015 for the entire fleet

➢ 10,959 edges have been analyzed

San Francisco

Las Vegas



Mexico City

Rio de Janeiro

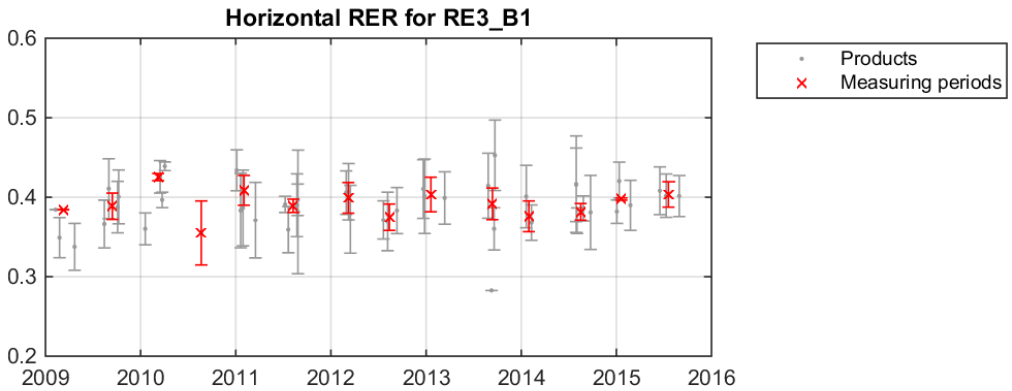
Madrid

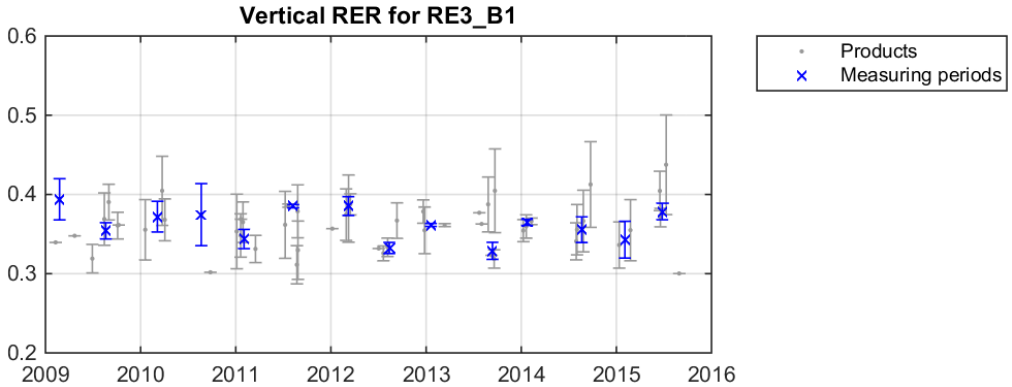
Berlin

Palm Island

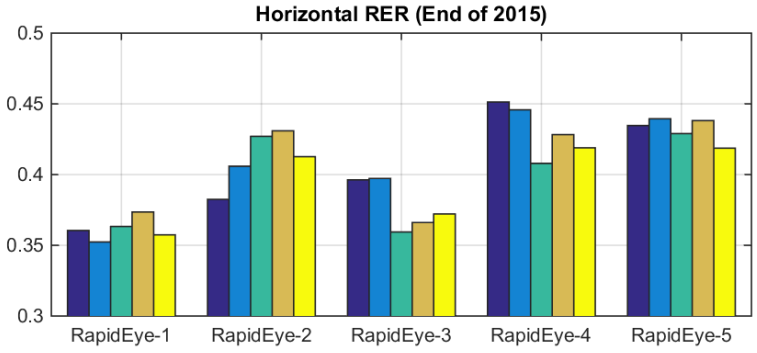
Sydney

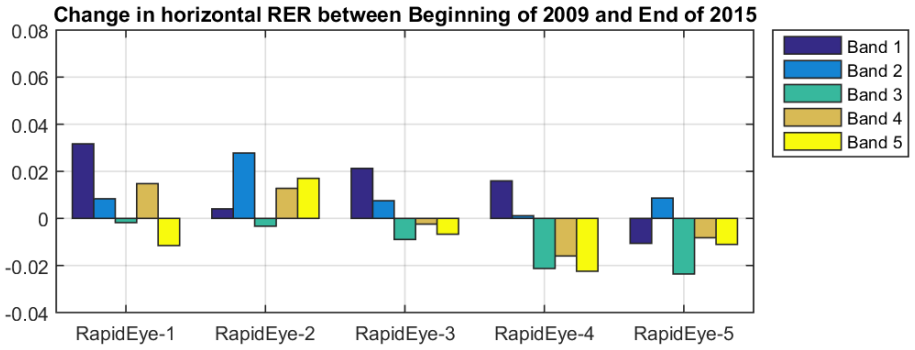
Trend for RE3 Band1

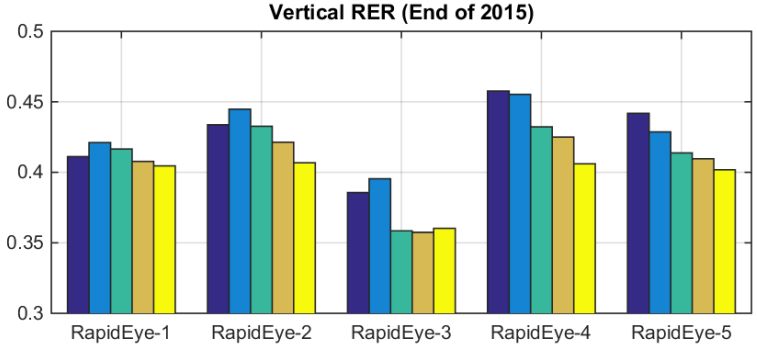




Results - RER


Horizontal RER (End of 2015)
0.5
0.45
0.4
0.35
0.3
RapidEye-1
RapidEye-2
RapidEye-3
RapidEye-4
RapidEye-5


Change in horizontal RER between Beginning of 2009 and End of 2015
0.08
0.06
0.04
0.02
0
-0.02
-0.04
RapidEye-1
RapidEye-2
RapidEye-3
RapidEye-4
RapidEye-5
Band 1
Band 2
Band 3
Band 4
Band 5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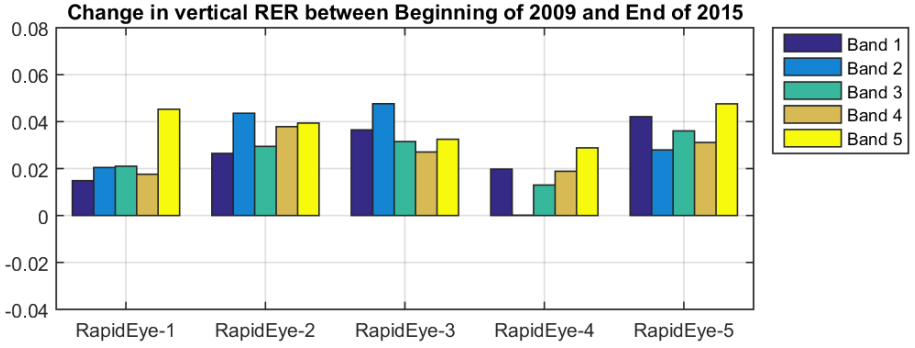
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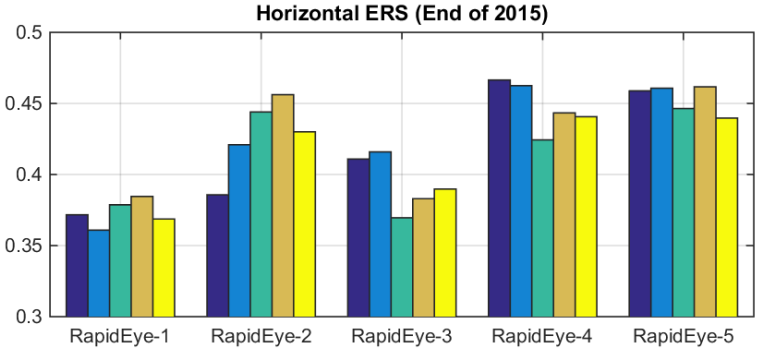
RapidEye-4
RapidEye-5
Band 1
Band 2
Band 3
Band 4
Band 5

Results - ERS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0.4
0.35
0.3
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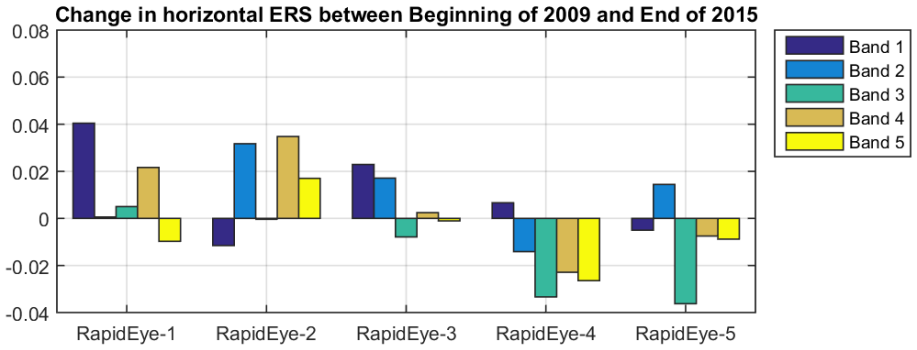
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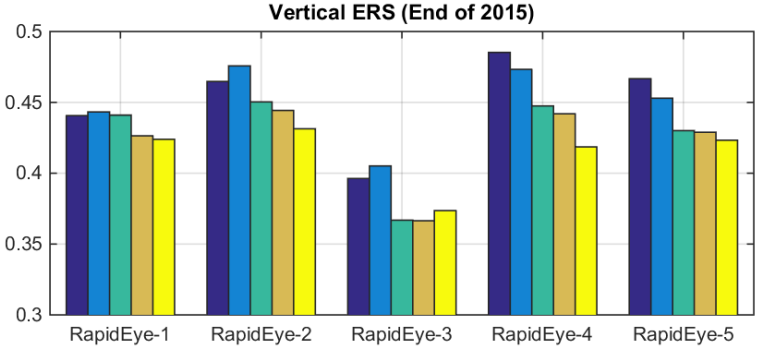
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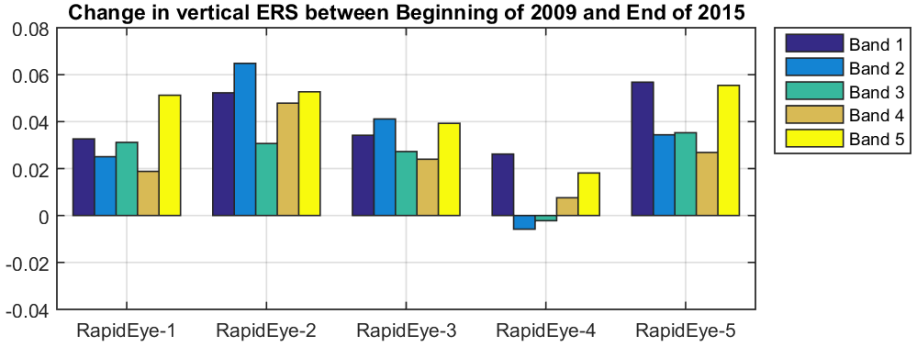
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Discussion of Results

- Average RER is 0.398151 ± 0.02648 (std dev ~6.65%)
- Average ERS is 0.415249 ± 0.03425 (std dev ~8.25%)

➢ No significant differences over time
➢ <u>No significant trend, no degradation</u>

Outlook

- Expand analysis to Modulation Transfer Function (at Nyquist)
  - Differentiate the ESF
  - Keep uncertainties under control

Thank you for your Attention!

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Backup slides

Combination of separate images

$$\mu_{weighted} = \frac{\sum_i \frac{\mu_i}{\sigma_i^2}}{\sum_i \frac{1}{\sigma_i^2}} \qquad \text{for } i = 1, \ldots, K \text{ and} \tag{13}$$

$$\sigma_{weighted} = \frac{1}{\sqrt{\sum_i \frac{1}{\sigma_i^2}}} \qquad \text{for } i = 1, \ldots, K, \tag{14}$$

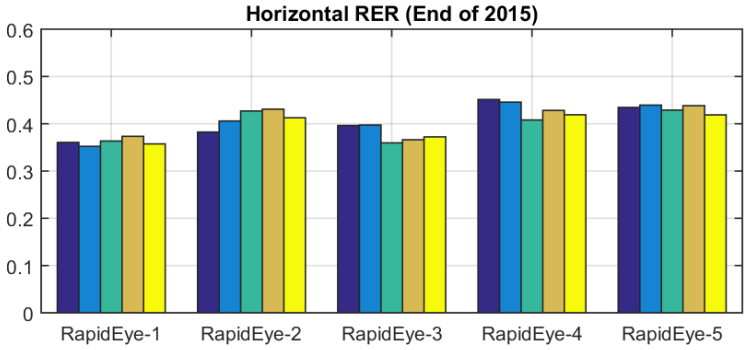
where K is the number of images within the measuring period, μ_i is the actual value (RER, ERS, FWHM or MTF at Nyquist) and σ_i is the corresponding standard deviation, both of which are given in the Excel sheet.

Why use Level 3A products?

- Radiometric, sensor and geometric corrected
- 5 meter pixel size (resampled from 6.5 meter GSD)
- Orthorectified as 25x25 km tiles

- Measure properties of the processing rather than properties of the sensor
- For trending (comparability) this is acceptable
- Easier to handle as they are precisely defined by the geographic location

Results - RER


Horizontal RER (End of 2015)
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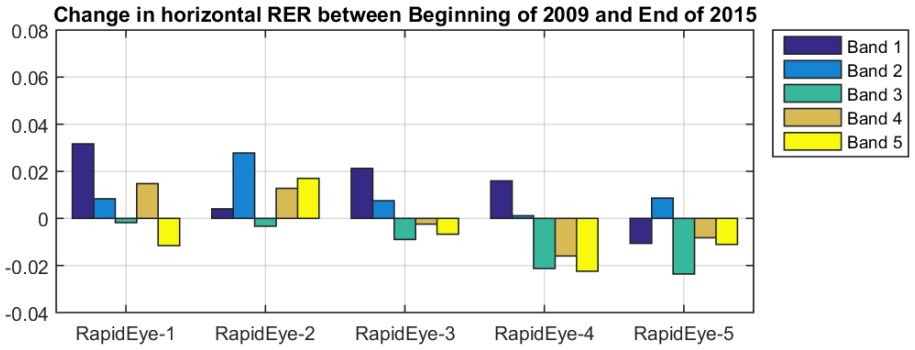
0.5
0.4
0.3
0.2
0.1
0
RapidEye-1
RapidEye-2
RapidEye-3
RapidEye-4
RapidEye-5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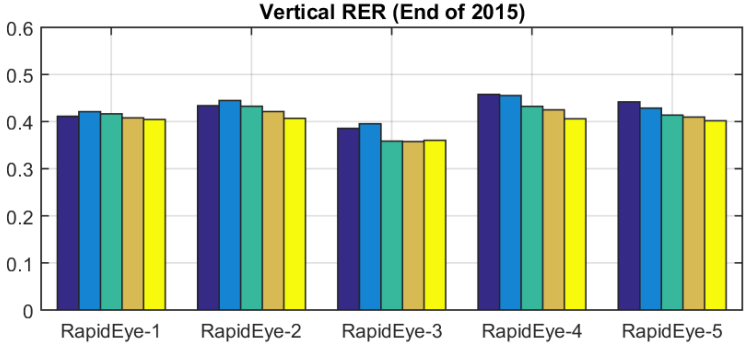
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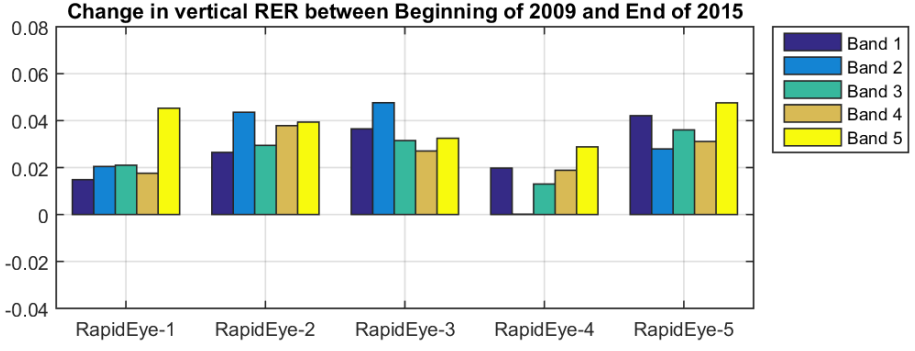
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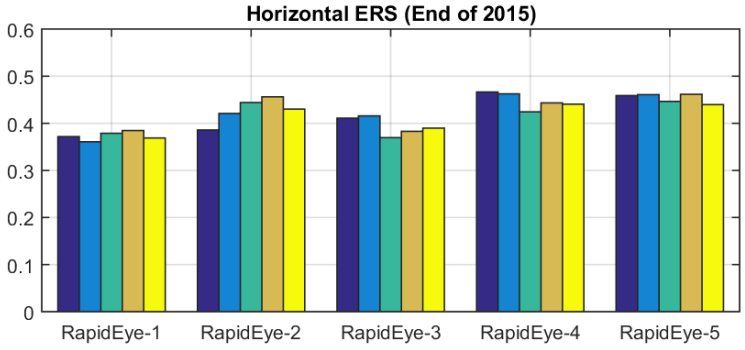
Results - ERS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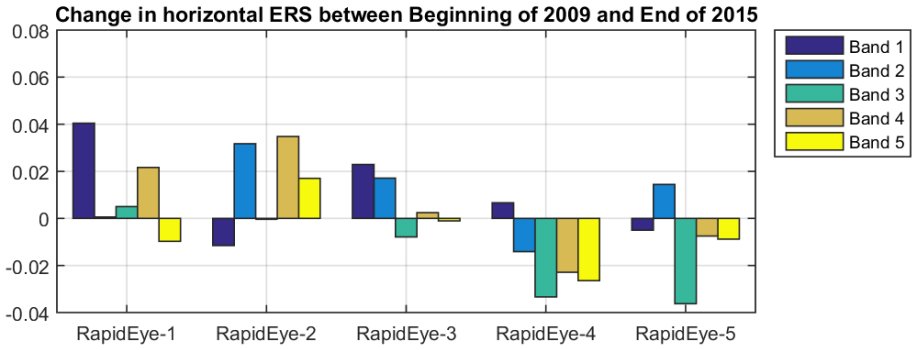
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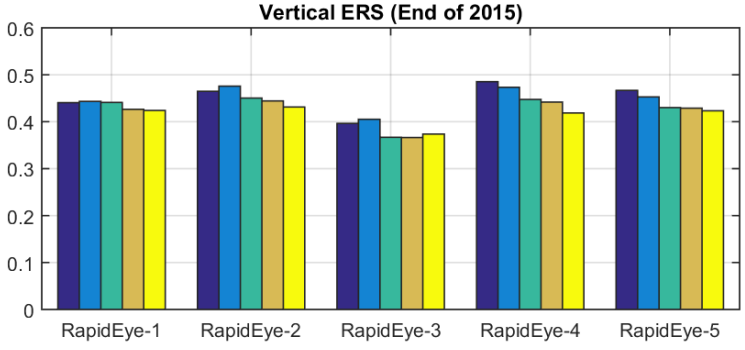
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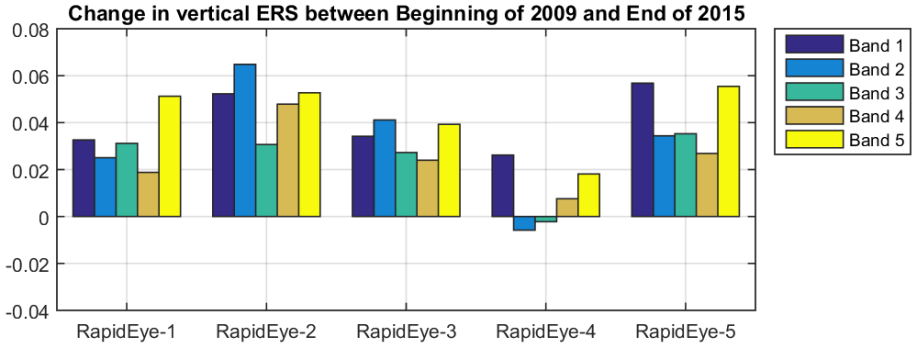
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