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Relative Comparison of the Spectral Resolution of RapidEye Products

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Content

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- **Background (RapidEye System, Why do we need to think about MTF?)**
- **Method (brief discription of the method used for spatial resolution estimation)**
- **Data (Resampling Kernels, Test Areas, Images)**
- **Results (differences between the different resampling kernels, over time and between the SC)**

Background (System)

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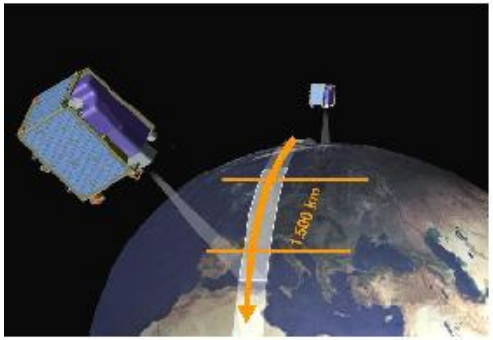

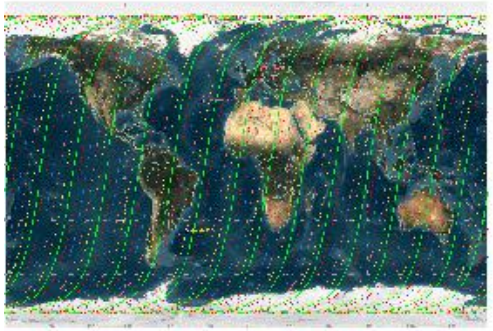

Launch Date	29 August 2008
Operational Date	01 February 2009
Sun synchronous orbit	11:00 AM eq. crossing (descending node)
Altitude	630 km
GSD	6.5 m at nadir
Swath width	77 km
Image take length	~1,500 km(max)
Standard ortho-image tile	25 x 25 km^2
No. of orbits per day/SC	14.8
Image capture capacity	~4.4 Mkm^2/day(max)

Background (Camera)

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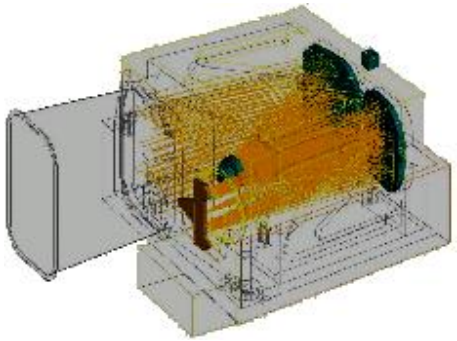

Design	**TMA** (Al mirror)
Eff. focal length	**633 mm**
Entrance Pupil Dia.	**147 mm**
f-number	**4.3**
CCD	**Atmel (AT71544)**
Pixel Size	**6.5 µm**
Pixels per line	**12,000**
Radiometric resolution	**12 bit**

Background (Camera)

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Band	Description	Specified Spectral Range at 50% transmission points (nm)	Tolerance (nm)	Measured Spectral Range at 50% transmission points (nm) – *constellation average*	Specified Center Wavelength (nm)
1	Blue	440-510	3	438.8-510.9	475.0
2	Green	520-590	3	518.6-590.7	555.0
3	Red	630-685	3	631.5-685.3	657.5
4	Red-edge	690-730	4	689.2-730.5	710.0
5	NIR	760-850	4	760.5-849.0	805.0

Spatial Resolution

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- Resolving spatial objects is important to understand the performance of remote sensing systems.
- The spatial capabilities of an imaging system are determined by many design attributes such as optics, electronics, detectors, and the focal plane.
- There is no standard method for measuring spatial resolution of an imaging system.
- Different metrics such as Ground Sampling Distance (GSD), Point Spread Function (PSF), Edge Spread Function (ESF), Relative Edge Response (RER) or Modulation Transfer Function (MTF) are all used to measure the spatial resolution of an optical system.
- While airborne systems can be periodically re-evaluated in laboratory this approach is not possible for spaceborne systems.

Method

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- The method is based on computing an Edge Spread Function (ESF) from edges found in the image.

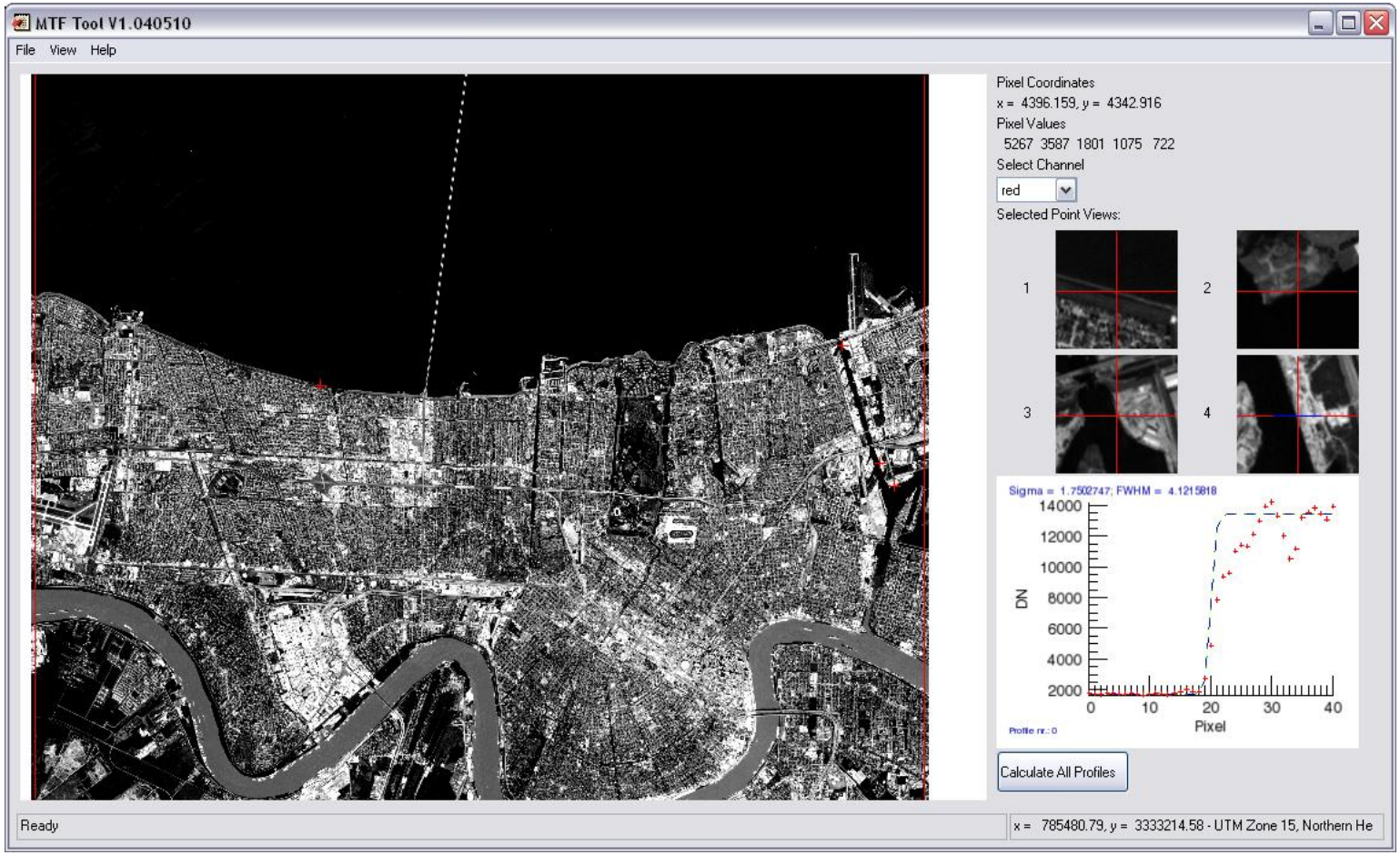
$$H_{(x)} = \frac{1}{\sigma_H \sqrt{2\pi}} \cdot e^{\frac{x^2}{2 \cdot \sigma_H^2}}$$

- The size of σ_h gives a quantitative value for the assessment of the PSF
- The ESF can then be fitted with an error function:

$$y = a_0 \cdot \Phi\left(\frac{x - a_1}{a_2 \sqrt{2}}\right) + a_3 + a_4 \cdot t$$

- a_2 is equal to σ_h and is measured in arbitrary units. In the presented study it is measured in number of pixels.

Method (Tool)



Tool was developed by Dr. Reulke (HU Berlin / DLR)
Details will be given by Dr. Reulke in a later presentation.

Method (Application)

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- Difficult to define the right spots for the evaluation
- Direct comparison between the same spots on different images from:
  - different spacecraft
  - different times
  - different resampling kernels
  - different bands
- Currently no distinction between across track and along track is made
- Therefore no claim on an absolute and general spatial resolution measurement yet

Data (Locations)

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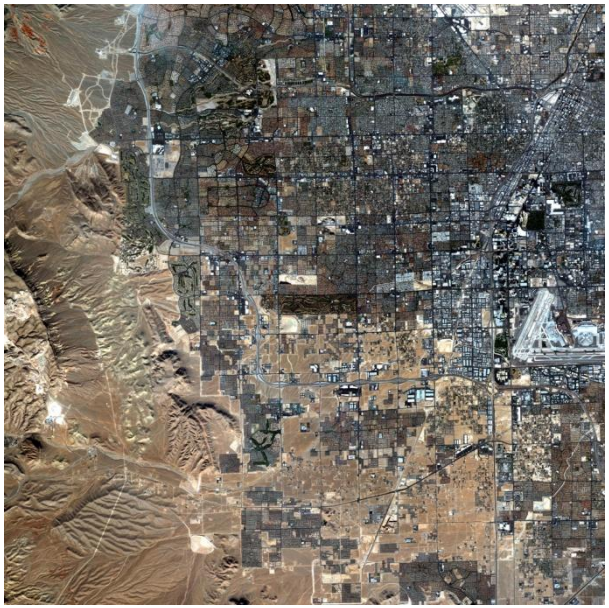
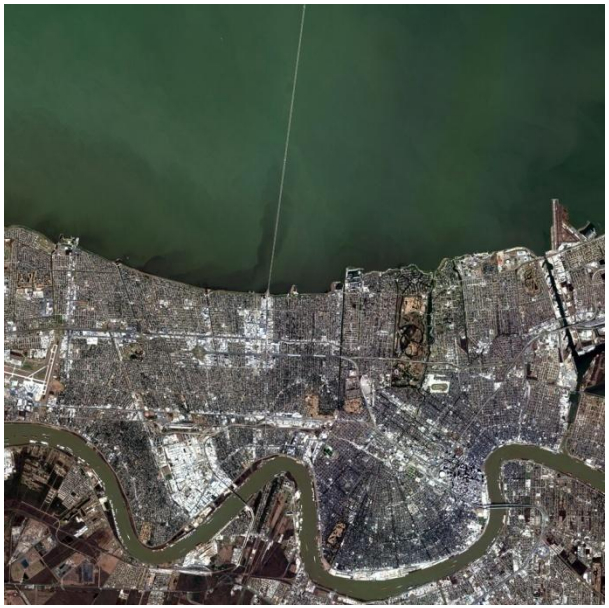
Three different locations have been used for the evaluation



Las Vegas
TID: 11 557 21

Nellis Air Force Base
TID: 11 558 22



New Orleans /
Lake Ponchartrain Bridge
TID: 15 529 26

Data (Resampling Kernels)

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Three different resampling kernels have been compared

Nearest Neighbor

This kernel moves the original image pixel to the right position in the new grid and maintains the original value.

Cubic Convolution

Cubic Convolution over 16 (4*4) pixels.
Smoothing and edge sharpening effect.
Standard RapidEye resampling kernel.

MTF Kernel

Sensor specific weighted average of (min.) 64 pixels applied in a similar fashion as CC to determine the new grid cell pixel value.
Function is based on the spatial frequency response curve of the camera.
Strong sharpening effect but more pronounced noise.

Data (Resampling Kernels)

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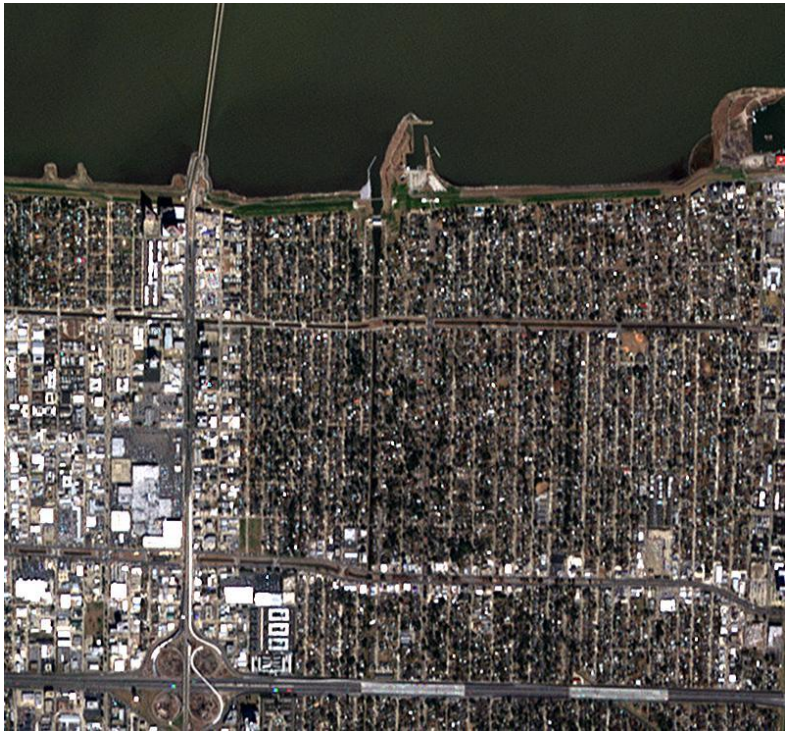
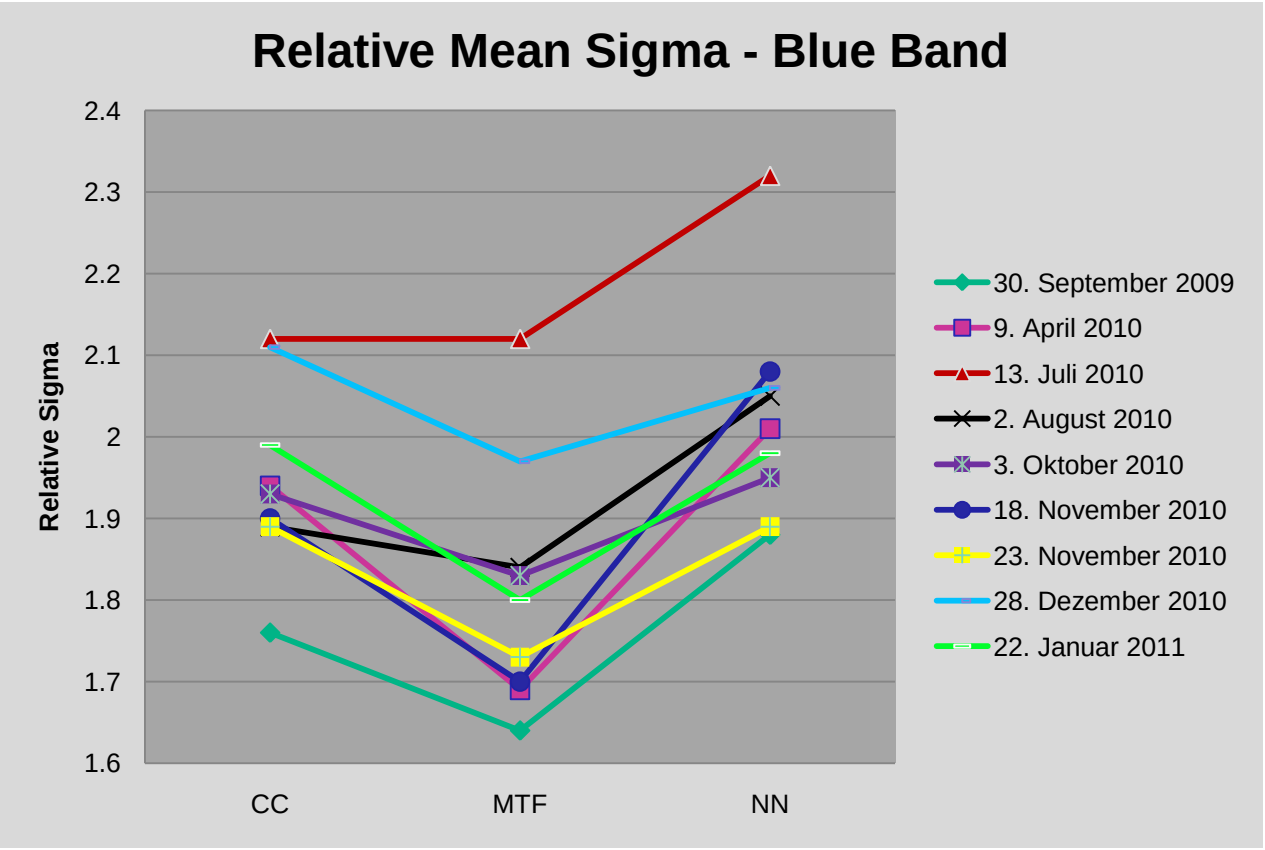
NN Kernel
Softer image impression
Less noise visibility in the water area



MTF Kernel
Sharper image impression
More noise visibile in the water area

Results (I)

Measured spatial resolution versus Resampling Kernel - blue band example



Conclusion

Relative sigma means show a common trend for most images

MTF kernel always improves spatial resolution when compared to the other kernels significantly

CC kernel improves spatial resolution when compared to NN in most cases

Results (II)

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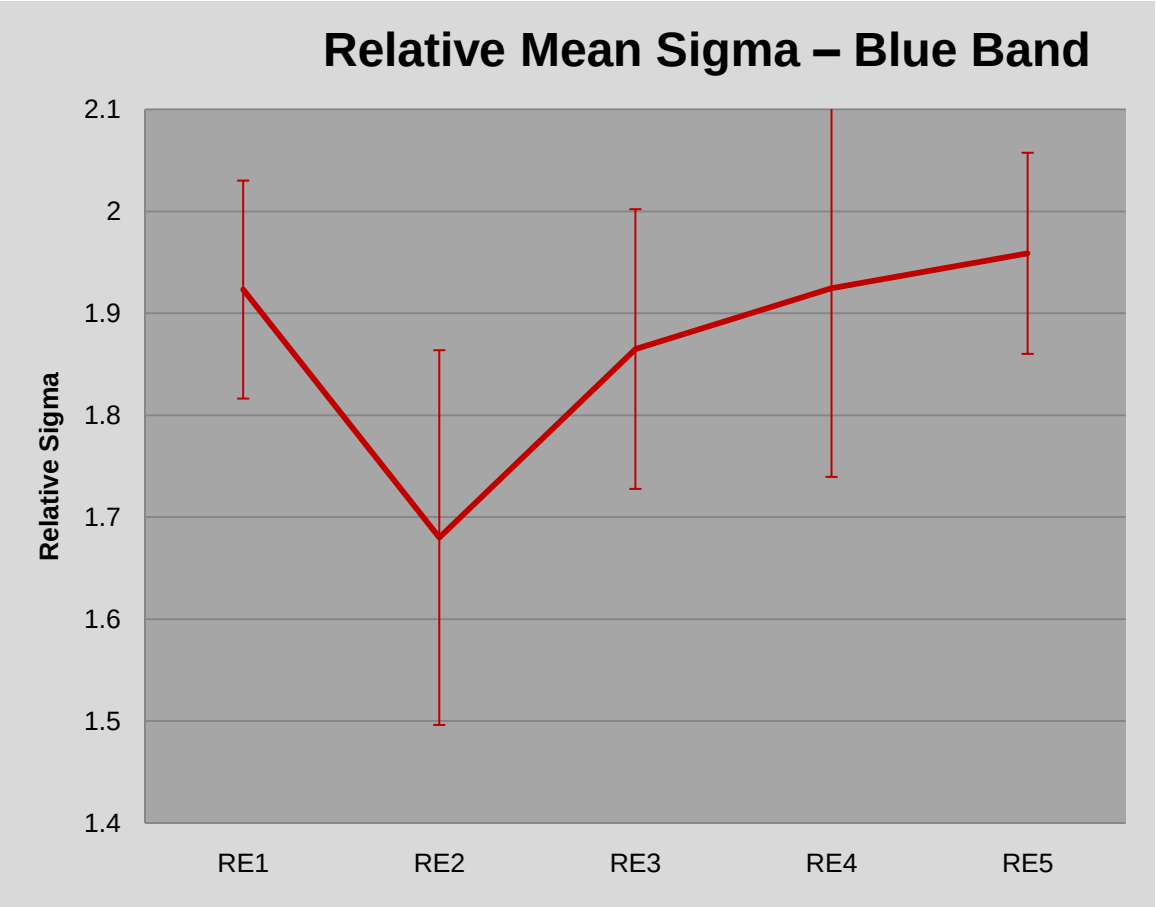
Measured relative Sigma versus Spacecraft – blue band example



Conclusion

All spacecraft relative sigma are on a similar level.

RE2 relative sigma seems to be slightly better than the rest of the constellation.

Sample size needs to be extended to confirm the results.

Results (III)

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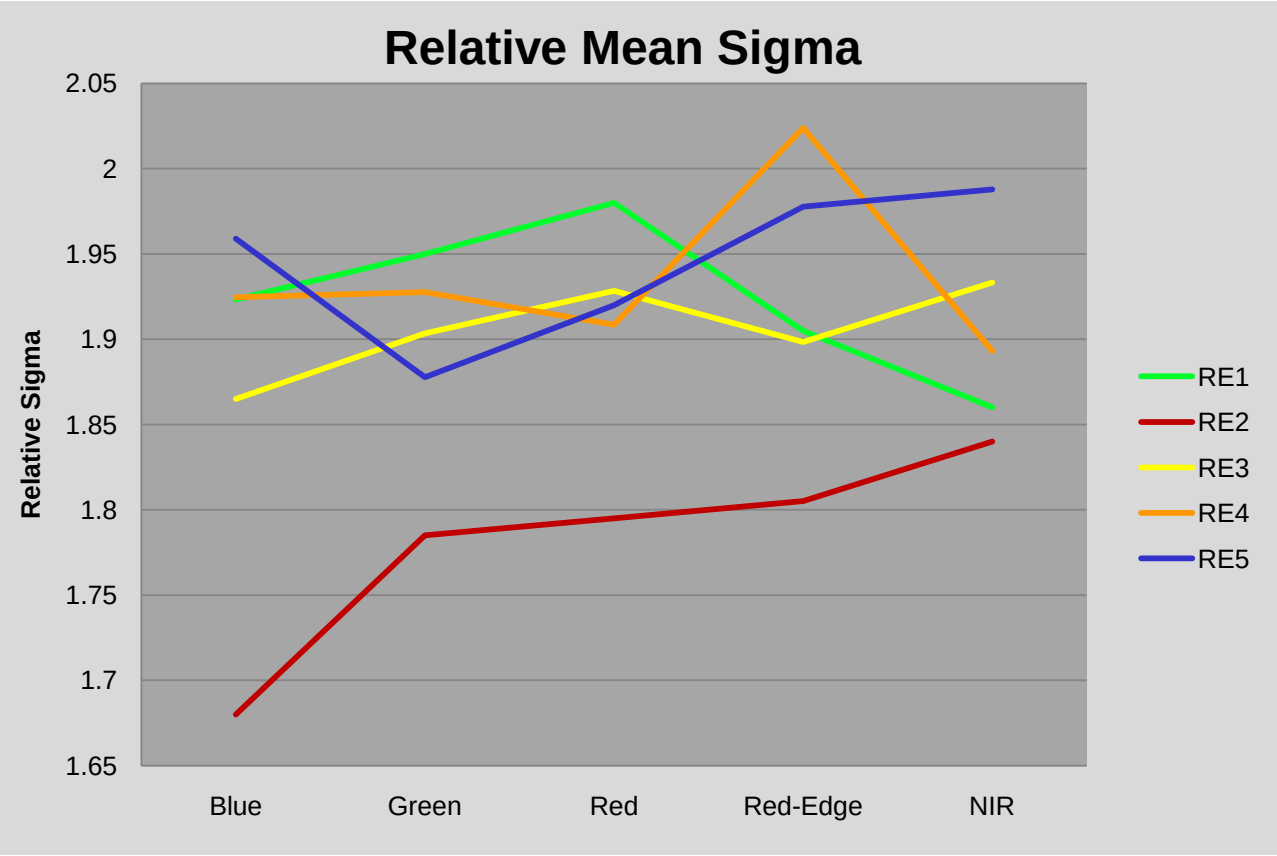
Measured relative Sigma versus spectral bands

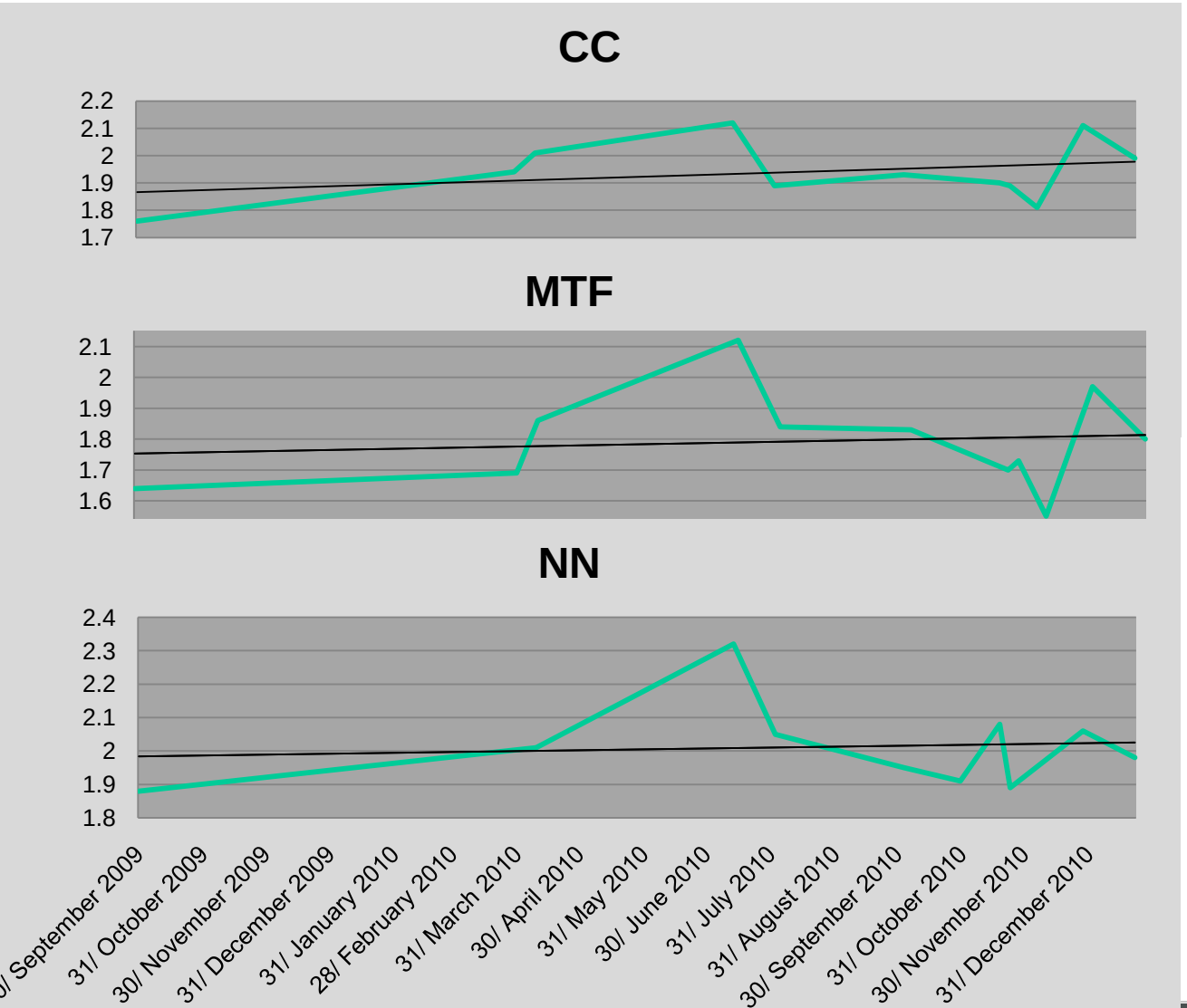


Conclusion

RE2 is slightly better in spatial resolution performance throughout all bands.

The other four spacecraft are within 0.15 pixel relative sigma throughout all bands

Results (IV)



Measured relative Sigma over time

Conclusion

18 Month development shows hardly any trend.

Seasonal effects (due to e.g. atmosphere, sun elevation or surface effects) influence the measurement results.

Thank you very much

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Change Detection Analysis from RapidEye as a contribution to support aid teams in Japan after the fatal Earthquake/Tsunami on Friday, March 11, 2011