DIN 18714-8 – Requirements to Image Quality

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DLR

DLR RM-OS

Optical Information Systems

- High resolution In-Orbit-Instruments (GSD < 1m)
- **HiSpec**: Hyperspectral systems, λ = 400 nm – 14 µm (VIS…IR)
- HiTime:
- **HiProc**: real time processing, from data to information

Space Systems

- **SmartSat**: innovative, low-cost small satellites
- **CMMI**: Software-Engineering, Capability Maturity Model

Current Projects

MERTIS

- IR-Spectrometer on BepiColombo-Mission (7…14µm)
- ESA-Project

KompSat3

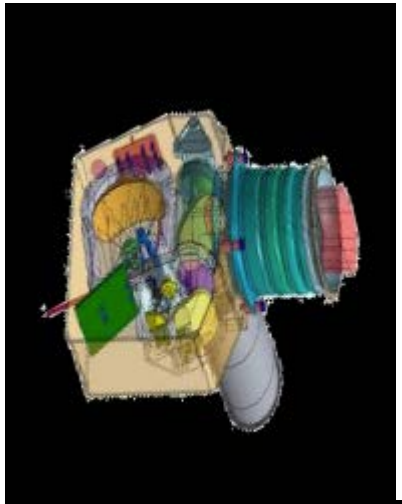
- Geometrically high resolution Sensor (0.7m)
- Project of the Korean Space Agency, Cooperation with EADS

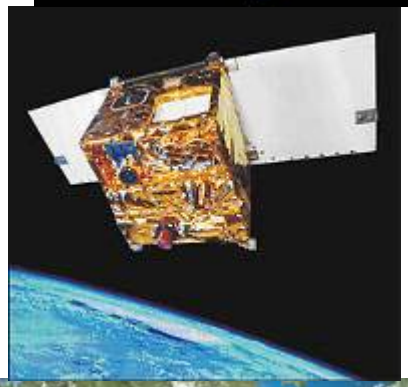
TET/ BIROS

- Small Satellite for Fire Detection and Monitoring
- Project of the German Space Agency and German Ministries

3D-Worlds

- Virtual World generated from stereo images
- Different Customers





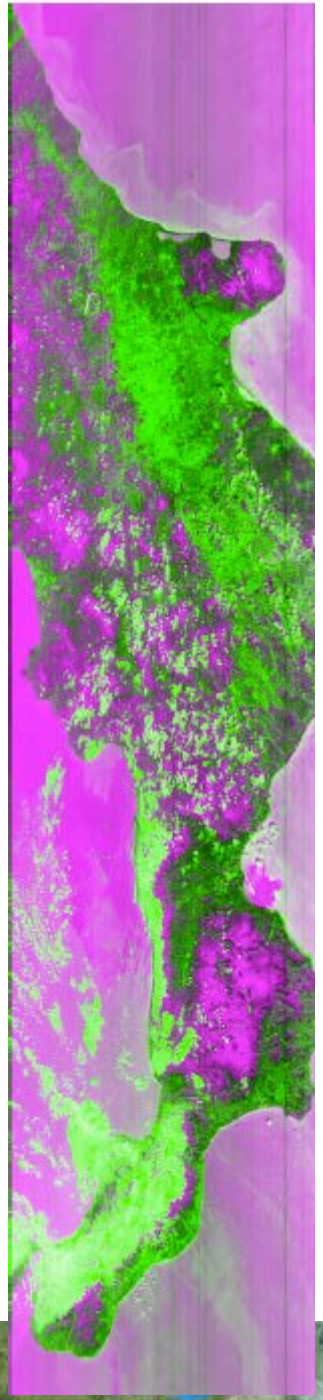
Kompsat 3

- Korean Multi-purpose Satellite 3 (KOMPSAT-3) was launched by HIIA Launch Vehicle (Mitsubishi Heavy Industries, Ltd. and JAXA) at 1:39 a.m. on May 18, 2012 (Japan Standard Time, JST) from the Tanegashima Space Center
- ASTRIUM, FPA from DLR-OS

TET (Technologie Erprobungs-Träger)

- TET-1 successfully launched July 22, 2012!

	VNIR	MIR	TIR
wavelength	460-560 nm 570-730 nm 750-920 nm	3.4-4.2 µm	8.5-9.3 µm
focal length	90.9 mm	46.39 mm	46.39 mm
detector	CCD	MCT	MCT
IFOV	43 m	360 m /180 m	360 m /180 m
swath width	223 km	184 km	184 km



Motivation

- Instrument in-orbit behavior / traceability based on image quality
- What is (spectral) image “quality”?
- There is no objective definition, which is why there is no current standard

Image quality must be related to

- signal to noise
- PSF & spatial resolution
- Contrast, linearity & dynamic range
- Influence of pre-processing, image restoration
- Geometric accuracy / direct geo-referencing
- Radiometric accuracy (including atmospheric correction)
- Other factors
- Artifacts (color bleeding, oversaturation, PRNU correction)

Image Quality - Calibration & Validation

Why is it so important?

Detection and quantification of objects and environmental trends requires high quality and long term stability of observations

Scientific users need to know:
- Which part of the EM spectrum they are looking at (**Spectral**)
- How much energy the instrument is receiving (**Radiometric**)
- Where the energy is coming from
    - Center of pixel location (**Geometric**)
    - Bounds of the area from which the energy is coming (**Spatial**)
- Extraneous sources of variation must be eliminated
- Calibration and validation of image products are vital pre-requisites

Image Quality - Calibration & Validation

-**Why do we need to spend this effort?**

- **Traceability**: Through high-accuracy measurements performed (and tested) in-orbit and pinned to given international standards.
- **Reproducibility**: Through overlapping time series of independent instruments. Time-dependent biases are tested by frequent intercomparison and the measurement of stable pseudo-references (e.g., the moon or Earth reference sites).
- **Accuracy** is a measure of how close a measured result is to the “true” value => Quality of a measurement
    - is estimated by a measure of uncertainty
    - includes the uncertainty associated with the calibration of the instrument
    - correctable systematic bias (an error)
    - non correctable system based noise

Image Quality

- Instrument in-orbit behaviour / traceability based on image quality
- What is (spectral) image “quality”?
- There is no objective definition, which is why there is no current standard

Image quality must be related to

- Performance measures
- Accuracy measures
- Other factors

Image Quality

Accuracy measure
- Geometric accuracy / direct geo-referencing
- Radiometric accuracy (including atmospheric correction)
- (color accuracy, co-registration, etc.)

Performance measures
- Signal to noise
- PSF & spatial resolution

Other factors
- Artifacts (color bleeding, oversaturation, PRNU correction, contrast, linearity, etc.)
- Influence of pre-processing (compression, image restoration, etc.)

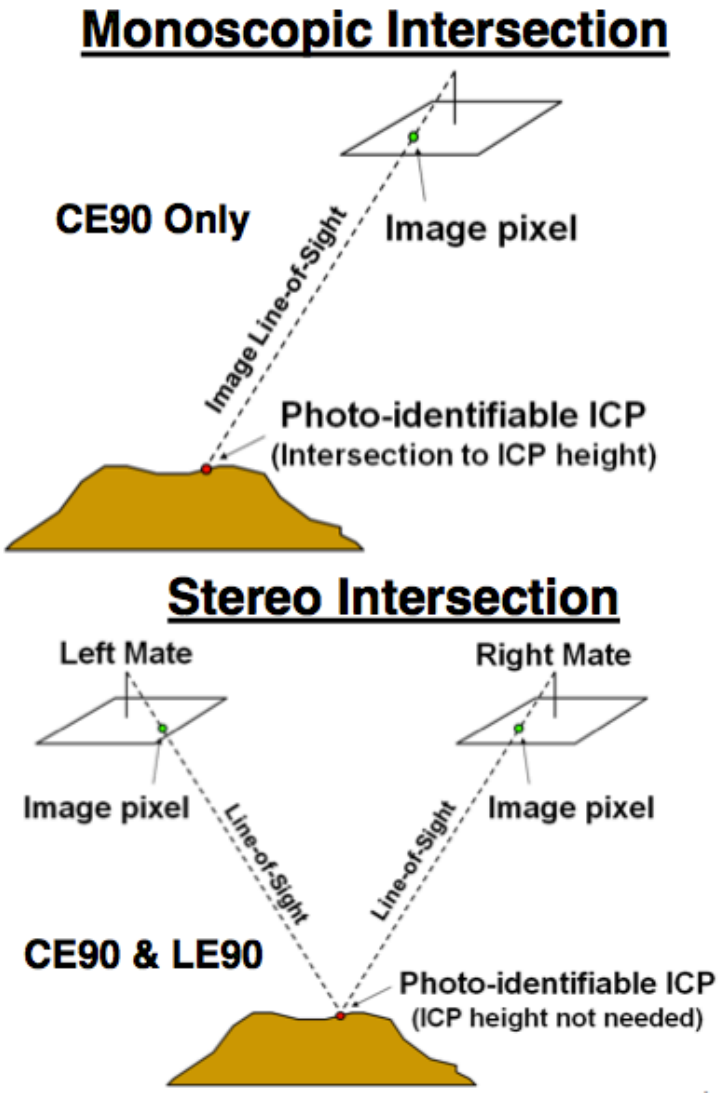
Image Quality – (spatial) Accuracy Measure

- Sample Circular Error 90% (CE90)
  - In horizontal plane
  - Radial error distance centred at zero containing 90% of the data points
- Sample Linear Error 90% (LE90)
  - In vertical dimension
  - Absolute value error distance from zero within which 90% of the vertical data points fall

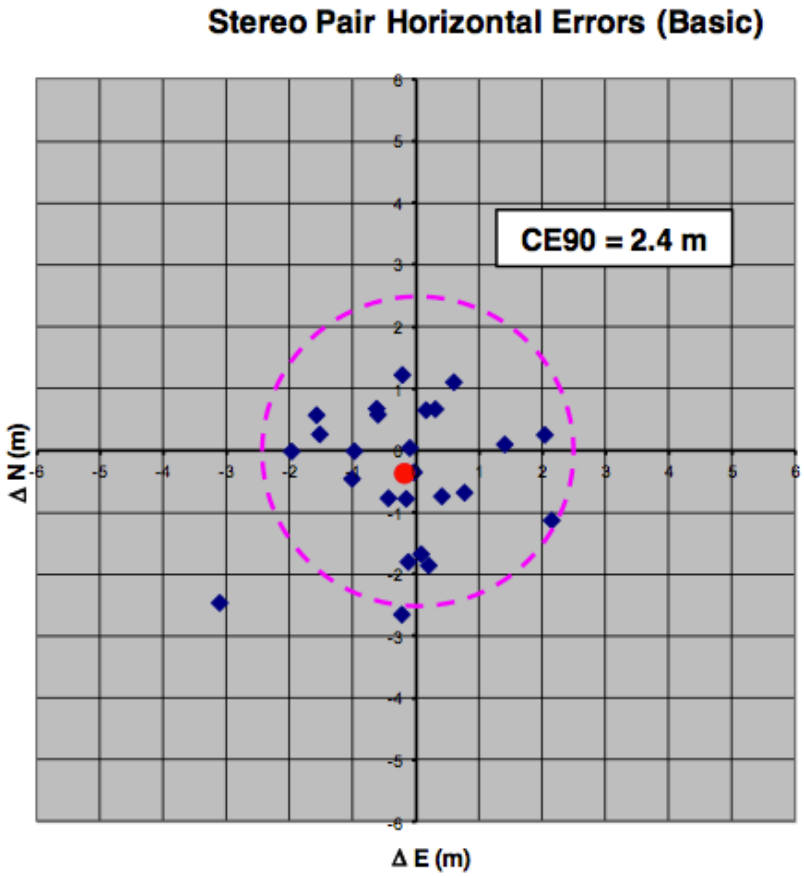
- Bresnahan, Paul (NGA), Geolocation Accuracy Re-Evaluations of GeoEye-1 and QuickBird-2 (JACIE, 2012)

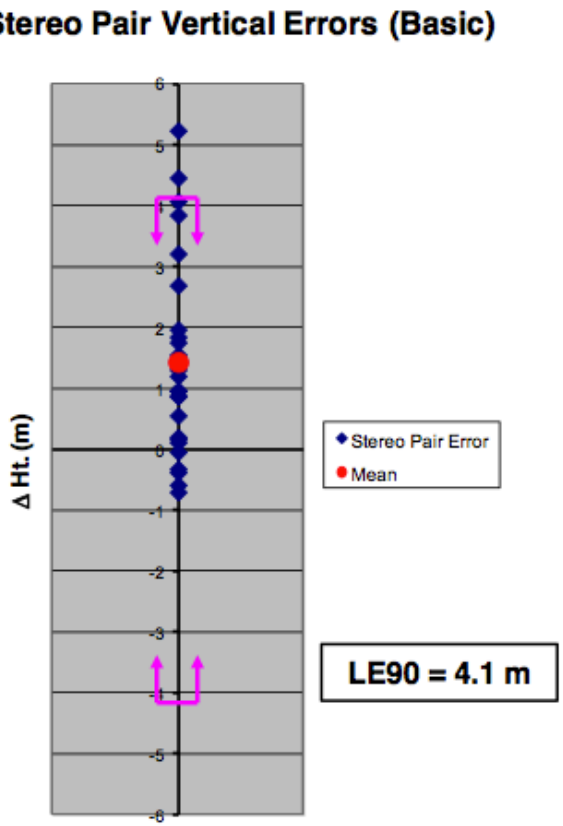
Methodology

- “Direct Geopositioning” assessment
- General Approach:
  - Mono CE90: Mono intersection of mono image or more-nadir stereo mate to checkpoint (CP) height
  - Stereo CE90 and LE90: Stereo intersection



Results (GeoEye-1)





>92.8% confidence that True CE90 < 4.0 m

Stereo Convergence Angles: 30°- 40°
>92.8% confidence that True LE90 < 5.3 m

Image Quality – (radiometric) Accuracy Measure

Image Quality - Performance Measure

- For calibration / validation purpose - Image quality assessed by artificial or natural targets
- Specially manufactured artificial targets are used
- Special arrangements (target size, orientation) are required
- Images around targets are analyzed for MTF and SNR

- Mary Pagnutti et.al., Targets, Methods, and Sites for assessing the in-flight spatial resolution of electro-optical data products, Canadian Journal of Remote Sensing, 2010, 36:(5) 583-601

Figure 12. Fort Huachuka tri-bar target (left) and Applanix painted tri-bar target pattern (right).

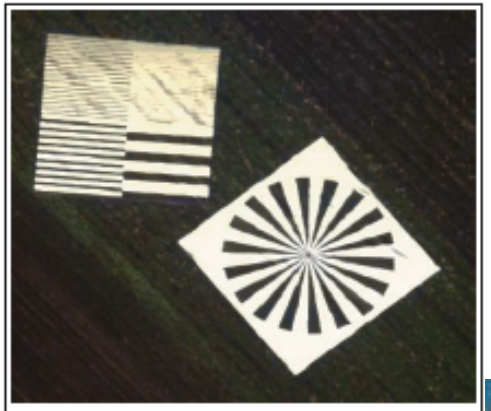


Figure 14. Leica-Geosystems bar target and Siemans star captured with an ADS40 camera.

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National Image Interpretability Rating Scales (NIIRS)

www.fas.org/irp/imint/niirs.htm, en.wikipedia.org/wiki/NIIRS

- NIIRS is a subjective scale (based on interpretability)
- NIIRS defines different levels of image quality
- **NIIRS consists of 10 levels between 0 (worst quality) and 9 (best quality).**
- Individual NIIRS has been developed for four major imaging types: Visible, Radar, Infrared, and Multispectral
- Automated Assessment of NIIRS and GRD of High Resolution Satellite Images through Edge Profile Analysis of Natural Targets, Taejung Kim, Jae-In Kim, JACIE 2011

Alternative Approaches

- Dumic, E., S. Grgic, et al. (2010). "New image-quality measure based on wavelets." Journal of Electronic Imaging 19(1)
    - Describes the difference between the original and tested images in different wavelet sub-bands
- Planinsic, P., B. Gergic, et al. (2001). "Fuzzy control of subband coded image quality using standard and fuzzy quality measure."
- Gerwe, D., R. , E. L. Carlos, et al. (2009). Information Theoretic Based Image Quality Evaluation, Optical Society of America.
    - Evaluates the Shannon mutual information between the perceived image and the original pristine object
- N.B. Nill and B.H. Bouzas, April 1992, "Objective Image Quality Measure Derived from Digital Image Power Spectra", Optical Engineering, vol.31, pp.813
    - IQM Approach: Quality from Image Power Spectrum

Other image quality measure

-Jahn, H. and R. Reulke (2012). "A Sensor-Based Approach to Image Quality. " Photogrammetrie, Fernerkundung, Geoinformation (PFG) 1: 9.

- Compares the output of the sensor with the output of an ideal sensor

Ideal image

- no disturbances from the environment, no dark current,
- Ideal quantum efficiency, optical transmission within the considered spectral range, diffraction limited optical Point Spread Function (PSF), ideal pixel PSF (box shaped function), linear and noise free electronic channel with delta - shaped impulse response, Analogue Digital Unit (ADU) with infinite small quantization step

Results

- With increasing PSF size the image quality in an area around an edge decrease
- For comparison the IQC with NIIRS we investigate an IKONOS image (green channel) from Dresden.

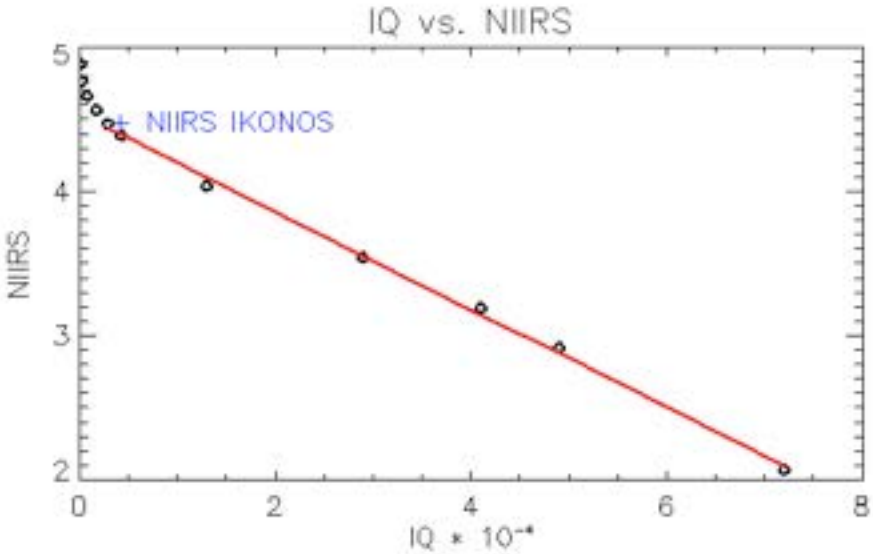


Fig. 2: Test case IKONOS image acquired at 8.7.2007 (left) and comparison with NIIRS.

NIIRS - Image Quality Equations (VIS & IR)

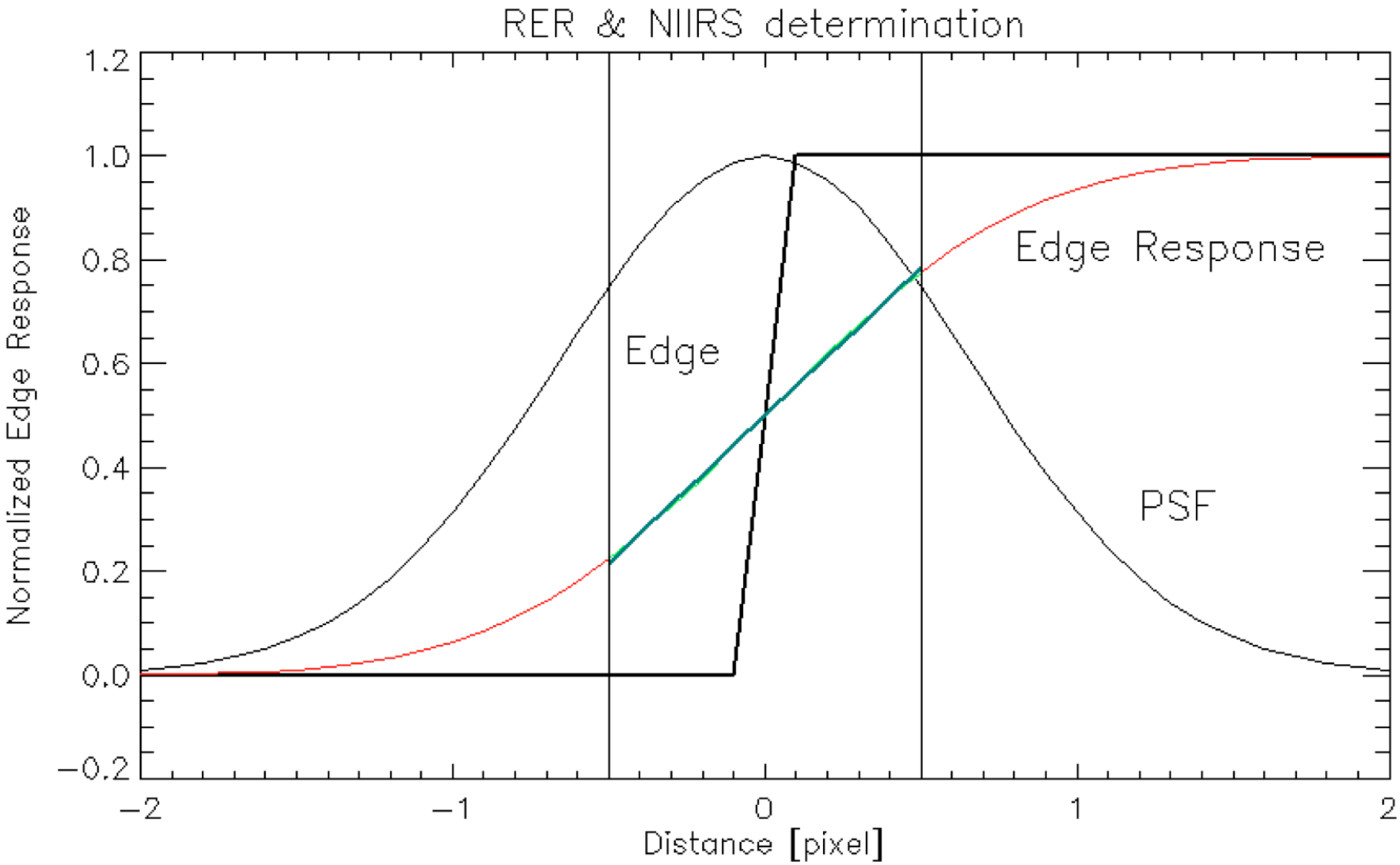
- Jon C. Leachtenauer: Image Quality Equations and NIIRS
- NIIRS is an empirical measure used to indicate the amount of information that can be extracted from the imagery. A commonly accepted form of the GIQE that accounts for the effects is:

$$NIIRS = c_0 + c_1 \cdot \log_{10} GSD + c_2 \cdot \log_{10} RER + c_3 \cdot \frac{G}{SNR} + c_4 \cdot H$$

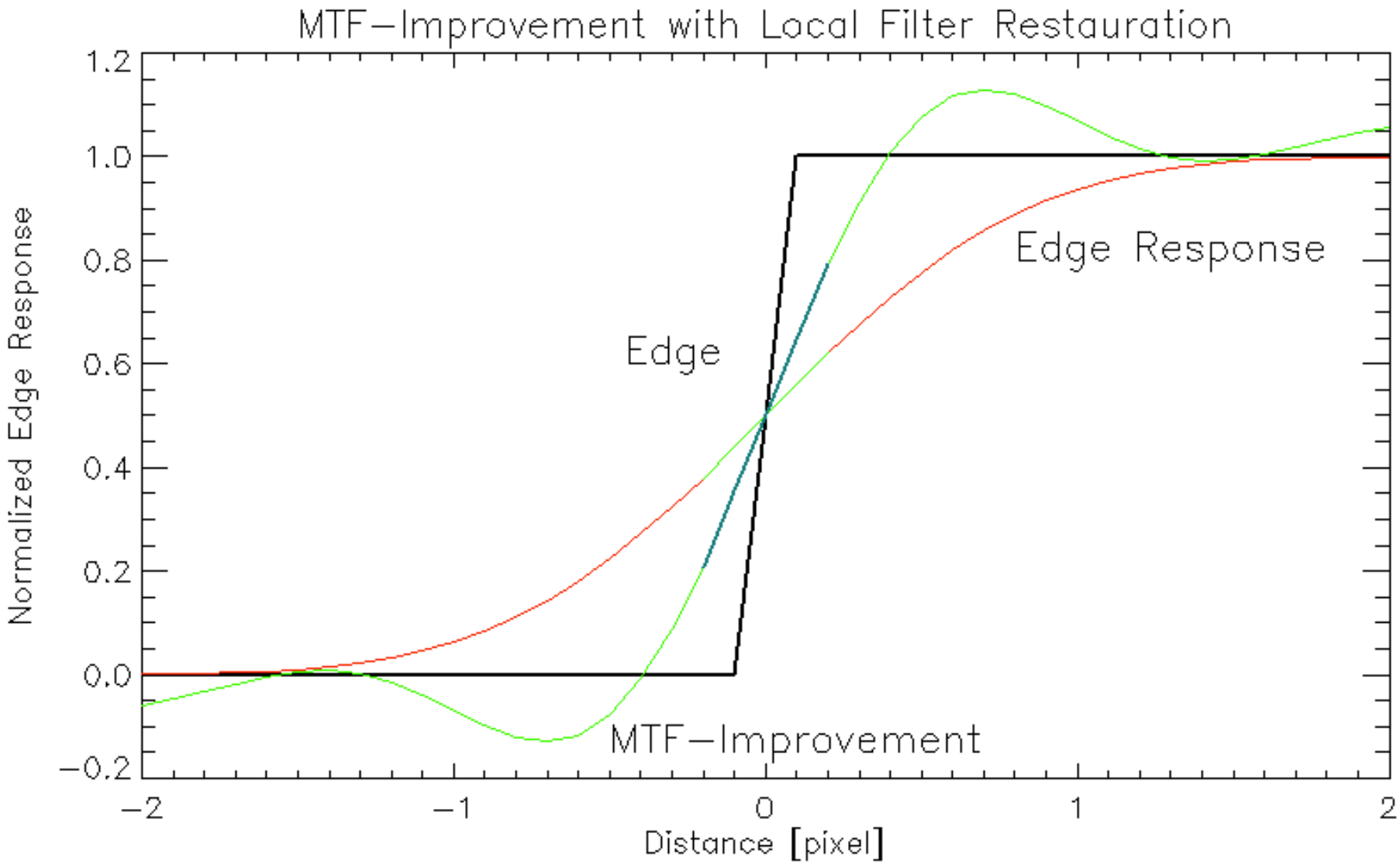
- GIQE 4.0 (for RER<0.9)

c_0 = 10.251, c_1 = -3.16, c_2 = 2.817, c_3 = -0.334, c_4 = -0656

- GSD - system ground sample distance,
- RER - system post-processing relative edge response,
- G - system post-processing noise gain,
- SNR - signal-to noise ratio of the unprocessed imagery,
- H - system post-processing edge overshoot factor.


RER & NIIRS determination
Normalized Edge Response
Distance [pixel]
Edge
Edge Response
PSF
1.2
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
−2
−1
0
1
2

DLR


MTF−Improvement with Local Filter Restauration
Normalized Edge Response
Distance [pixel]
Edge
Edge Response
MTF−Improvement
1.2
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
−2
−1
0
1
2

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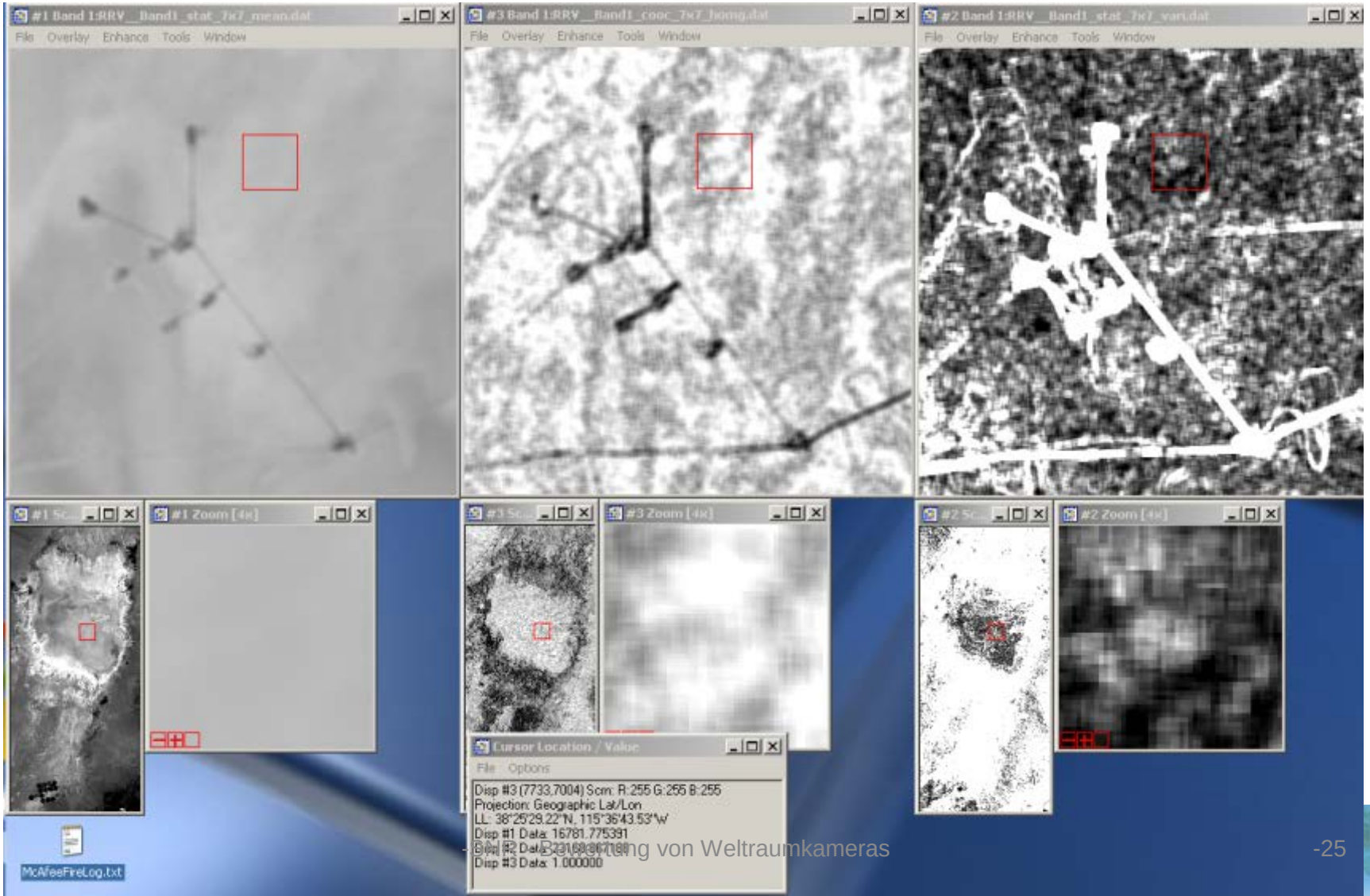
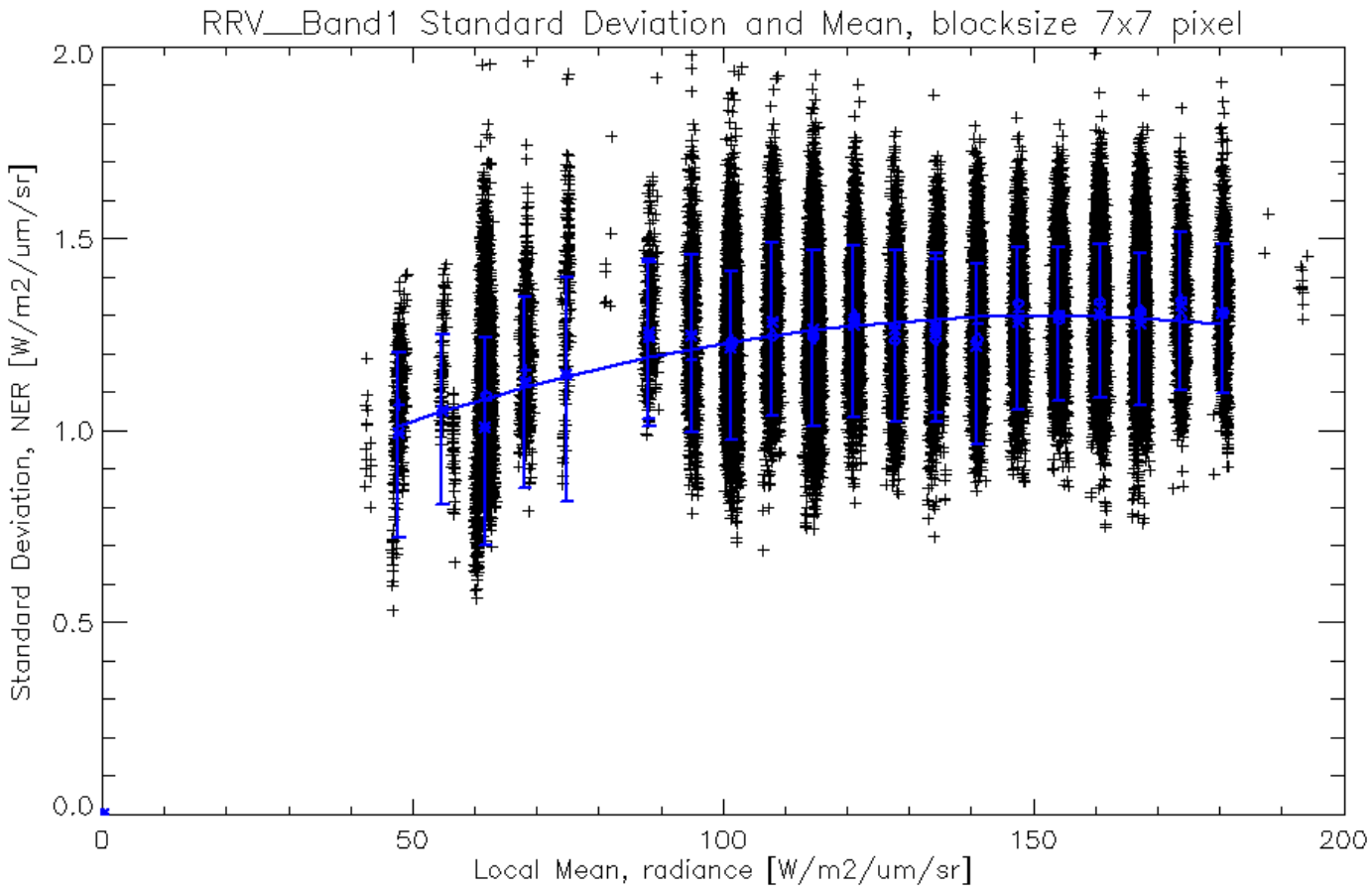
NIIRS – Image Restoration

- Griffith, Doug (NGA), General Image Quality Equation (GIQE), JACIE, 2012

Mean - Homogeneity - Variance



Result



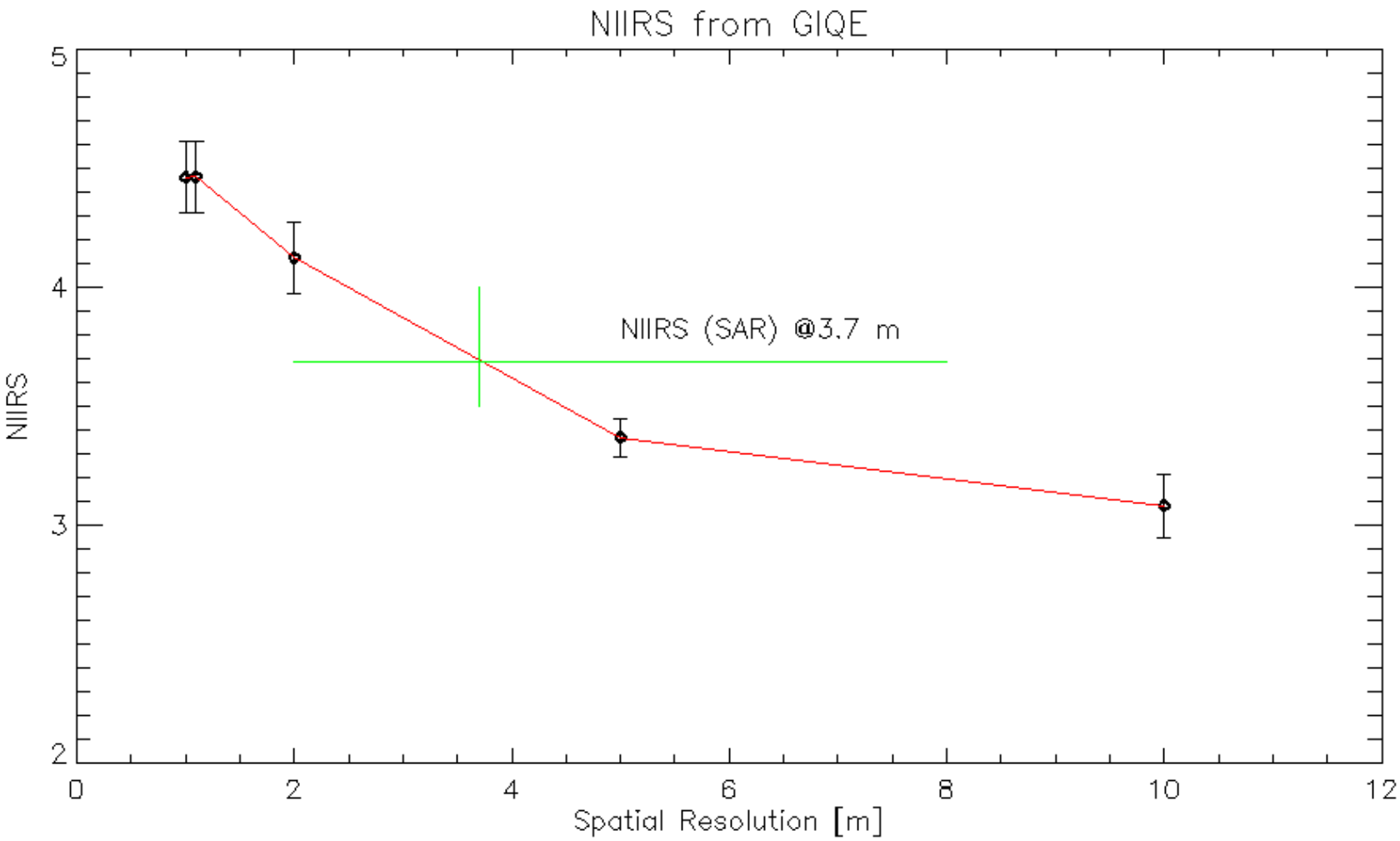
- Radiance vs. noise equivalent radiance (Band 1)
- SQRT – characteristic

Comparison of Image Quality (GIQE)

- IKONOS, 4.49+/-0.19, (4)
- QuickBird, 4.9, (1)
- WorldView-1, 5.1, (1)
- WorldView-2, > 5.0, (1)
- GeoEye-1, 5.5, (2)
- GeoEye-2, 6.0, (3)

1. https://www.digitalglobe.com/downloads/DigitalGlobe_Core_Imagery_Products_Guide.pdf
2. http://calval.cr.usgs.gov/JACIE_files/JACIE07/Files/110Schus.pdf
3. http://www.topview.cc/_d272735291.htm
4. E.C.Jones, IQ evaluation, JACIE 2004

NIIRS Calculation



Results / Outlock

- image quality (IQ) definition
- possible parameters for IQ determination
- determination of NIIRS was described more in detail
- Robust method and implementation for PSF & SNR determination are necessary
- Investigation of alternative image quality criteria

References

- Jahn, H. and R. Reulke (1995) "Systemtheoretische Grundlagen optoelektronischer Sensoren", 1995 WILEY-VCH Verlag GmbH & Co.
- Gyanesh Chander, Tim J. Hewison, Nigel Fox, Xiangqian Wu, Xiaoxiong Xiong, William J. Blackwell, Overview of Intercalibration of Satellite Instruments, IEEE Transactions on Geoscience and Remote Sensing, VOL. 51, No. 3, March 2013
- ISO 12233:2000 Photography -- Electronic still-picture cameras -- Resolution measurements, 2000