NEW RESAMPLING KERNEL AND ITS EFFECT ON RAPIDEYE IMAGERY

Andreas Brunn, Ellis Freedman and Dr. Robert Fleming

CONTENT

RapidEye
Delivering the World

- Image Resampler in General
- The Serious Science CMTF Resampler
- Comparison Constant MTF (CMTF) – Standard Cubic Convolution (CC)
- Conclusion

IMAGE RESAMPLER IN GENERAL

- Images are resampled everywhere where the shape or size of an Image needs to be changed. E.G.:
  - Zoom, Rotate
  - Map Projection,
  - Geometric Correction
  - Coregistration
  - etc.

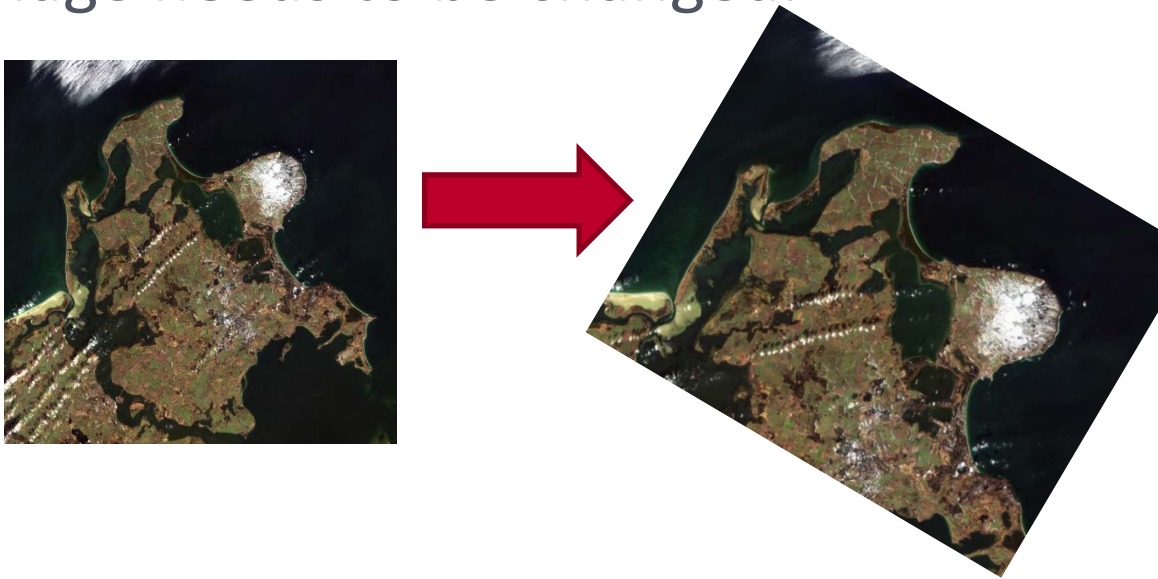


IMAGE RESAMPLER IN GENERAL

RapidEye
Delivering the World

- Resamplers go back more than 20 years (e.g. Wolberg, 1990).
- Resamplers are algorithms used to represent an a priori grid to new points in a different grid that does not necessarily correspond to the pixel location of the original map.
- This often requires an interpolation of values to locations in between the originally spaced pixels

IMAGE RESAMPLER IN GENERAL

- Several standard resamplers are known
  - Nearest Neighbor & Cubic Convolution are the best known
- Interpolators are normally represented as a convolution kernel that is a function of interpolation distance.
- No interpolator is perfect
  - The desired pixel shift is never fully achieved
  - Different blur introduced for each pixel shift distance

Pixel Shift	Cubic Convolution Coefficients			
1/32	-0.0147	0.9976	0.0175	-0.0005
3/32	-0.0385	0.9793	0.0632	-0.0040
5/32	-0.0556	0.9447	0.1212	-0.0103
7/32	-0.0668	0.8961	0.1894	-0.018
9/32	-0.0726	0.8356	0.2655	-0.0284
11/32	-0.0740	0.7655	0.3473	-0.0388
13/32	-0.0716	0.6880	0.4326	-0.0490
15/32	-0.0661	0.6052	0.5193	-0.0584

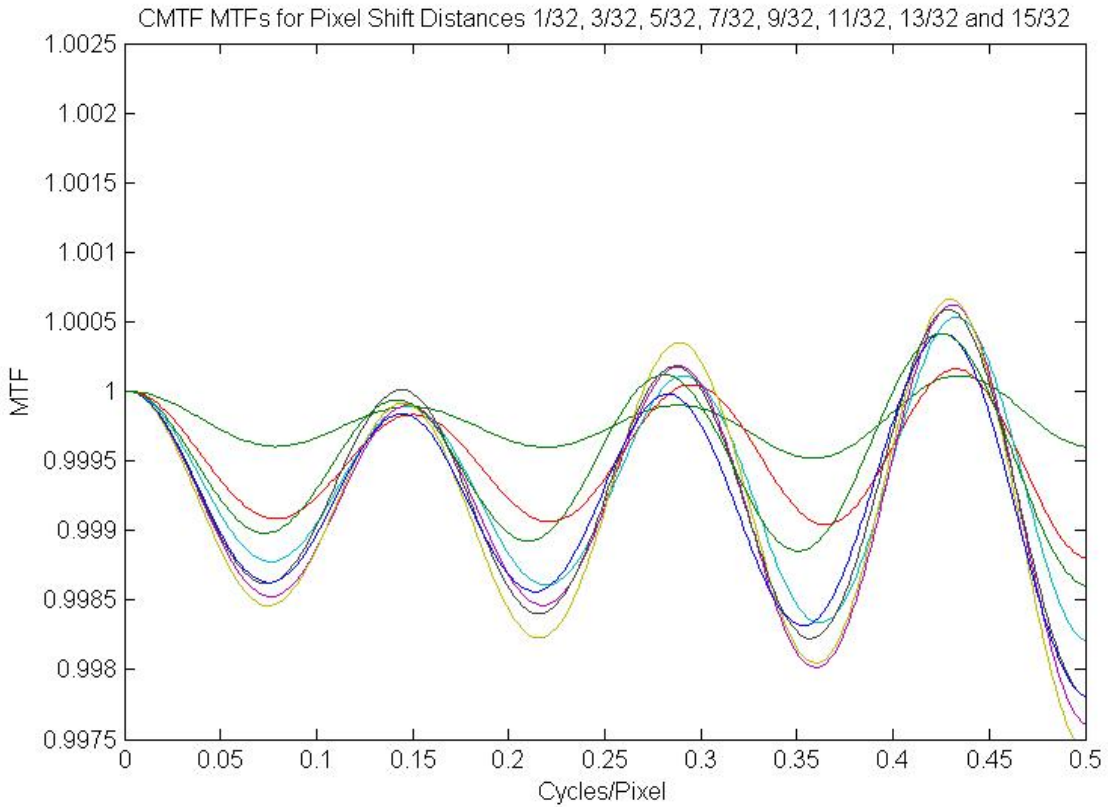
THE SERIOUS SCIENCE CMTF RESAMPLER

RapidEye
Delivering the World

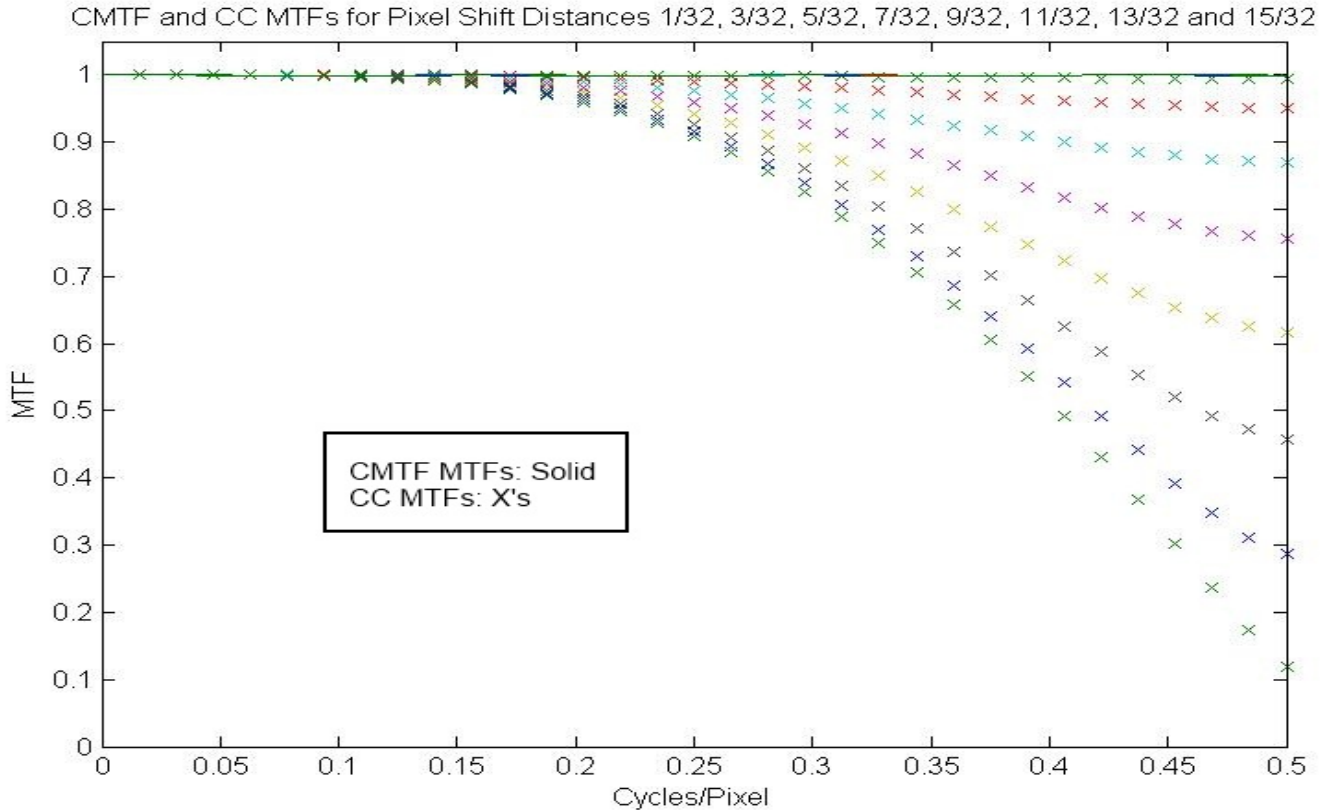
Dr. Robert Fleming and Ellis Freedman (Serious Science) developed a resampling kernel which is meant to correct the flaws in common Interpolators (Freedman, JACIE 2012)

- Virtually constant MTF across different pixel shift distances
- Allows one MTFC to be applied to interpolated images and achieve a unity MTF while correctly shifting pixels.
- Highly linear phase (distortionless filter)

THE SERIOUS SCIENCE CMTF RESAMPLER



CMTF THEORETIC RESULTS



RESULTS ACHIEVED ON REAL IMAGES

- The original Resampler was a two step approach
  - resampling
  - image restoration

- RapidEye Ground Processor can by default only handle one step resamplers

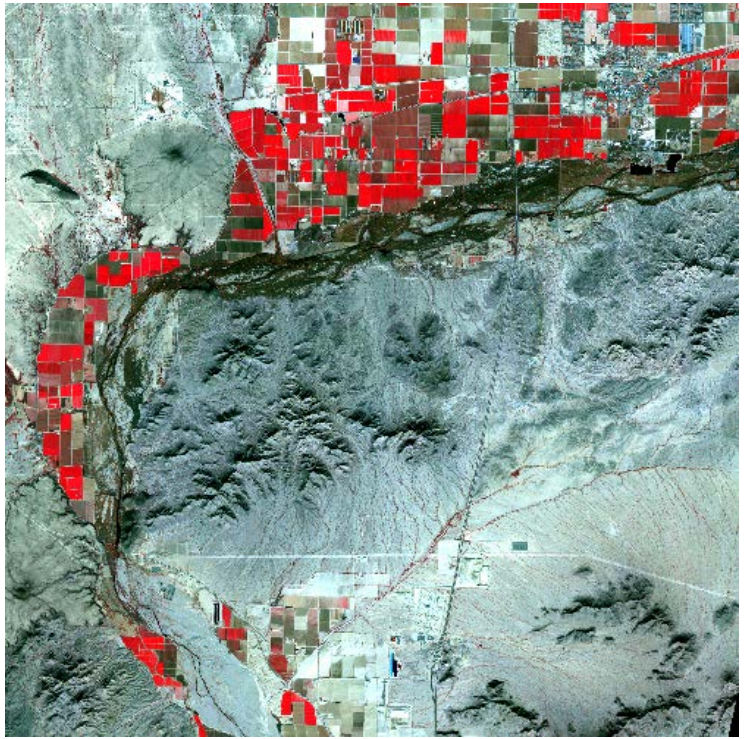
- Serious Science LLC combined the two step approach to only one set of parameters to be used in the default RapidEye processing chain.

COMPARISON BETWEEN CC AND CMTF

RapidEye
Delivering the World

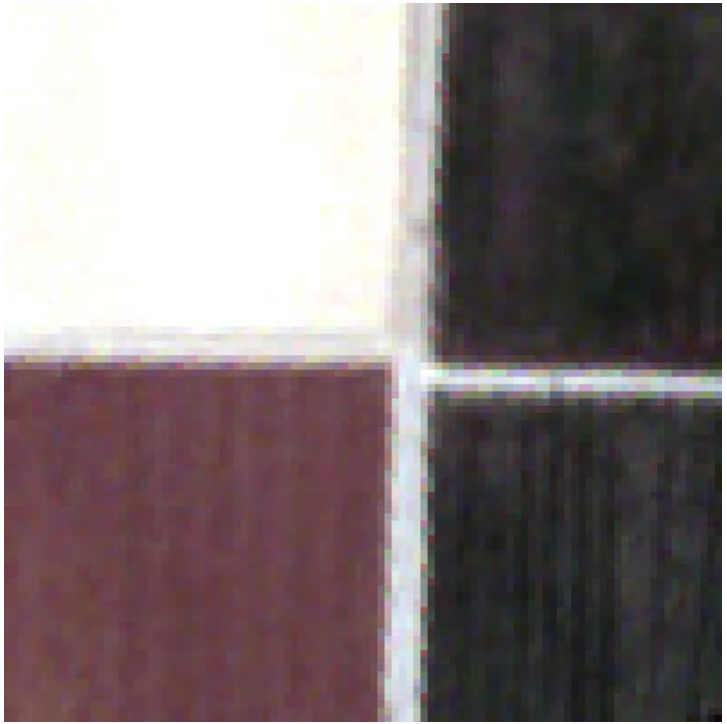
Test Site: Maricopa County, AZ

- Agricultural area 50 km West of Phoenix
- Different crop types and growing stages built up good edges



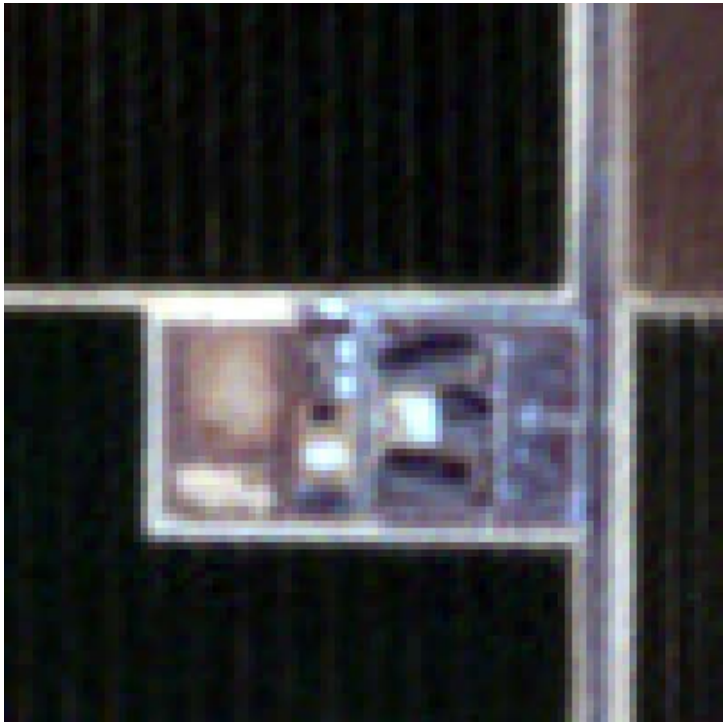
VISUAL COMPARISON

CMTF

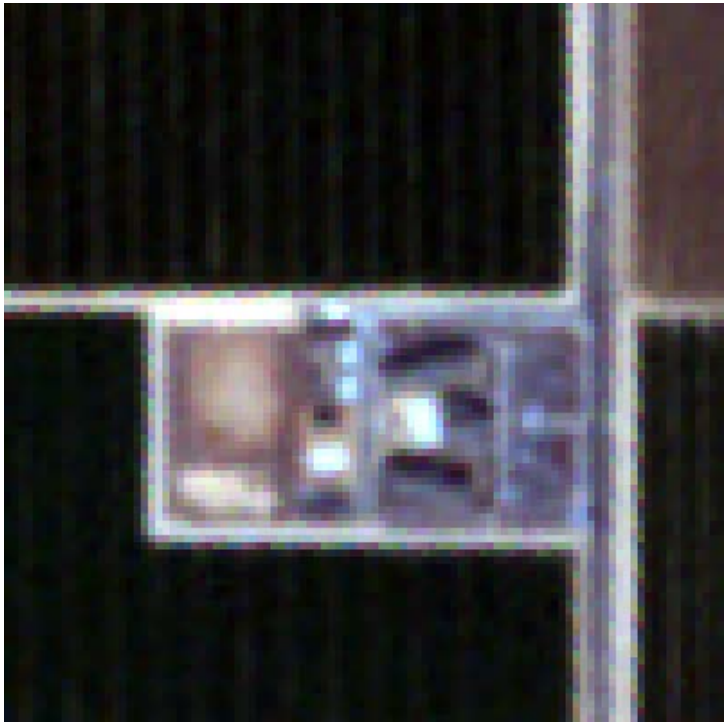


CC

VISUAL COMPARISON



CMTF



CC

VISUAL COMPARISON

RapidEye
Delivering the World

- Edges on CMTF processed images look visually sharper than those on CC processed images
- CC processed images show a colored frame (rainbow) around the edges on rgb color composites
- Automatic band to band registration is improved with CMTF Kernel compared to standard CC

STATISTICAL COMPARISON

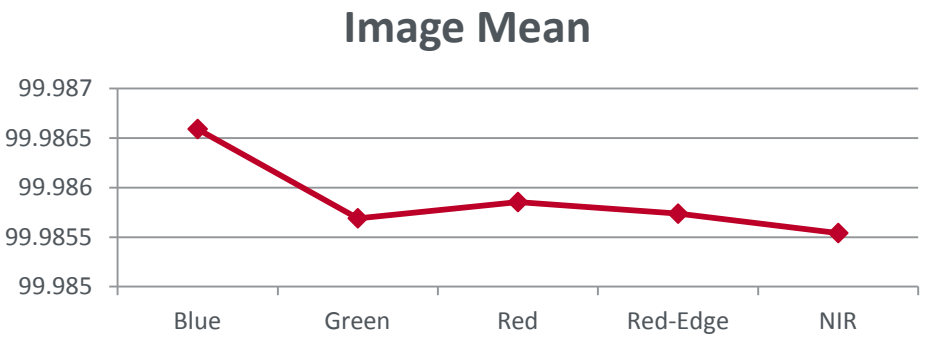
RapidEye
Delivering the World

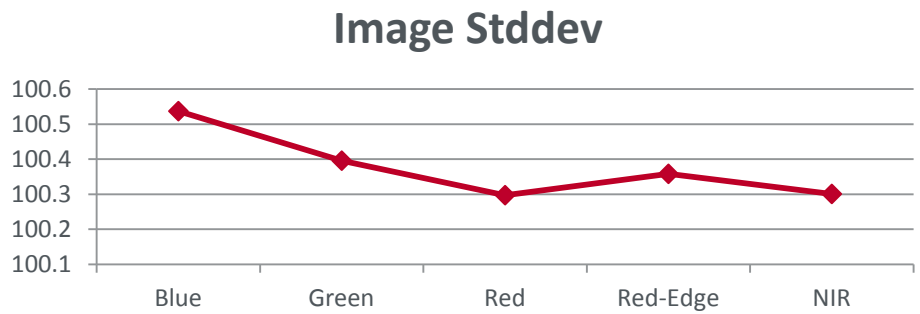
Statistical Parameters

Statistical Parameters are very much alike

Means match better than 1/10 of a percent

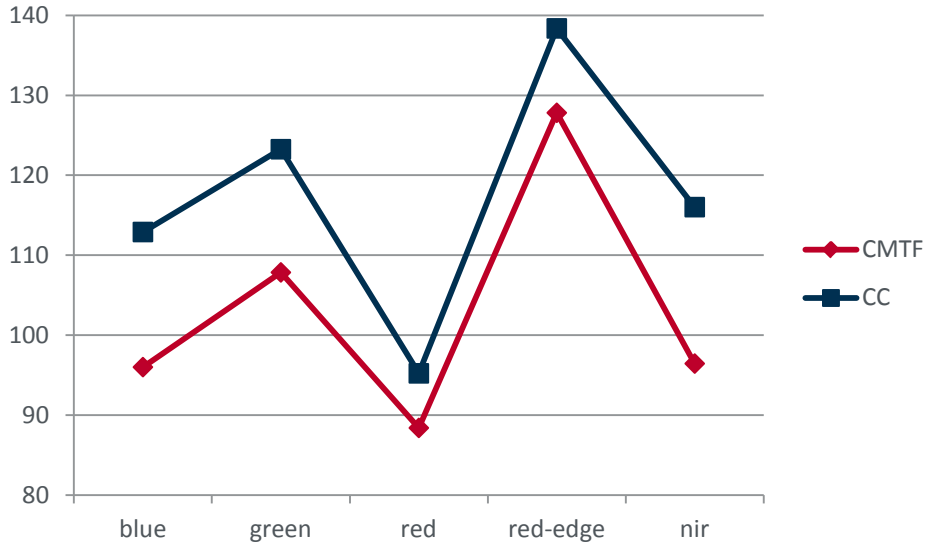
Stddev match to better than 1%. Reason is probably that the CC Kernel usually smooths the results





SIGNAL TO NOISE RATIO (SNR)

- Signal to Noise Ratio in percent of the un-resampled image subset
- No surprise that the smoothing effect of CC improves SNR compared to CMTF



SPATIAL RESOLUTION ANALYSIS

- It is assumed that the Point Spread Function is a normal distribution (Gaussian)

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

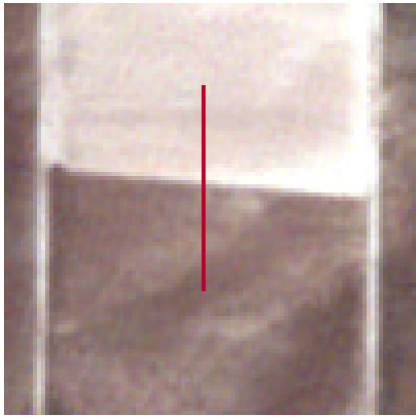
- The size of σ_H gives a quantitative value for the assessment of the PSF

- σ_H is used as a description of the change by the application of the different resampling kernels
  - A smaller σ indicates a sharper image with a better RER and MTF

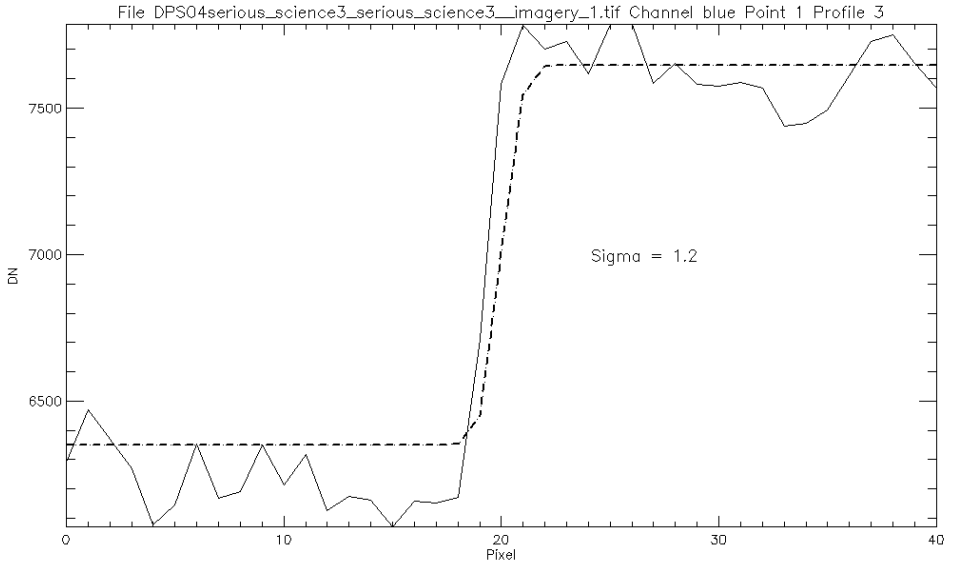
Reulke, JACIE 2011

SPATIAL RESOLUTION ANALYSIS

- Edge response of dark/bright transitions is used to model the PSF



Horizontal Edge



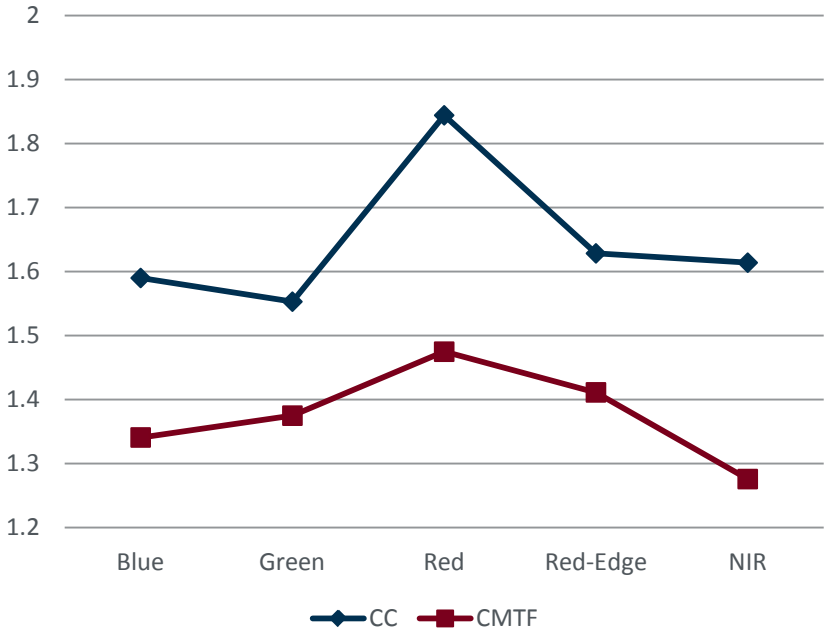
solid line: read image DN along the profile
dashed line: least square fit of the profile

SPATIAL RESOLUTION ANALYSIS

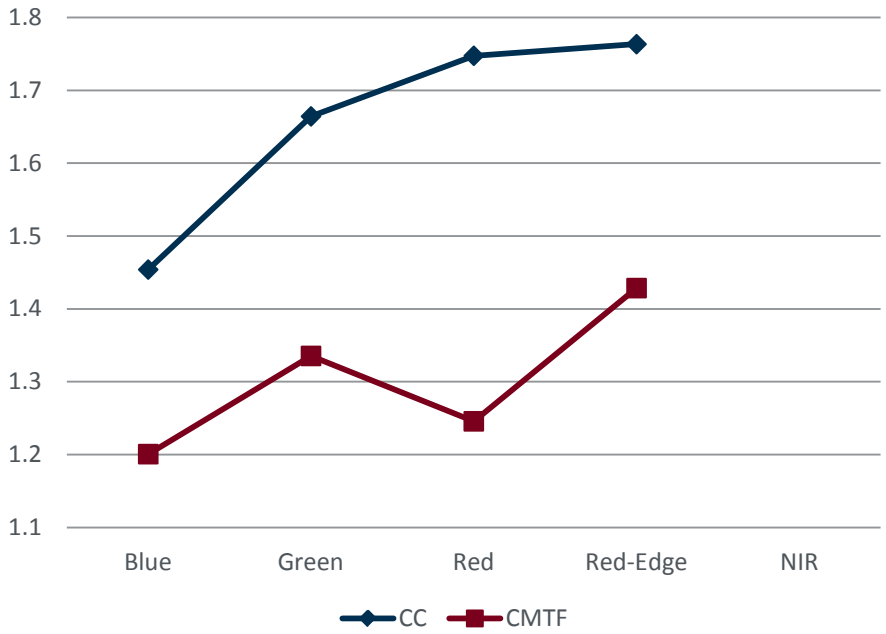
RapidEye
Delivering the World

Lower values are better

Mean Width of Vertical ESF

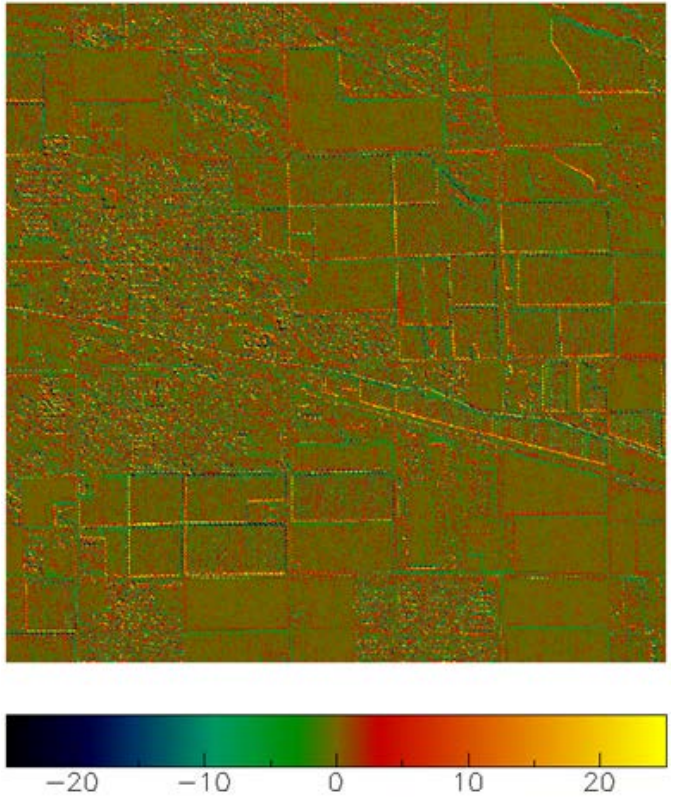


Mean Width of Horizontal ESF



DIFFERENCE IMAGE

- It is not possible to compare the different resampling kernels against the unresampled image (coregistration needs resampling)
- The assumption is that the CMTF Kernel keeps the EDGE sharpness constant
- Difference Image shows especially large differences of more than 20 % of the image DN at the field boundaries



CONCLUSION

RapidEye
Delivering the World

- CMTF resampler doesn’t change the image statistics
- Due to image smoothing the CC Kernel improves the Signal to Noise Ratio (lowpass filter)
- CMTF resampling kernel does not degrade image MTF and leads to improved RER and visual sharpness impression

=> The interpretability of the images is improved when resampled using the CMTF resampler

Andreas Brunn,
Head of Calibration and Validation
brunn@rapideye.com

Ellis Freedman,
Owner, Serious Science LLC
seriousscienceellc@gmail.com

Dr. Robert Fleming,

RapidEye :: Delivering the World

Germany | USA | Canada | Luxembourg

info@rapideye.com
www.rapideye.com