NEW RESAMPLING KERNEL AND ITS EFFECT ON RAPIDEYE IMAGERY

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CONTENT

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- 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.

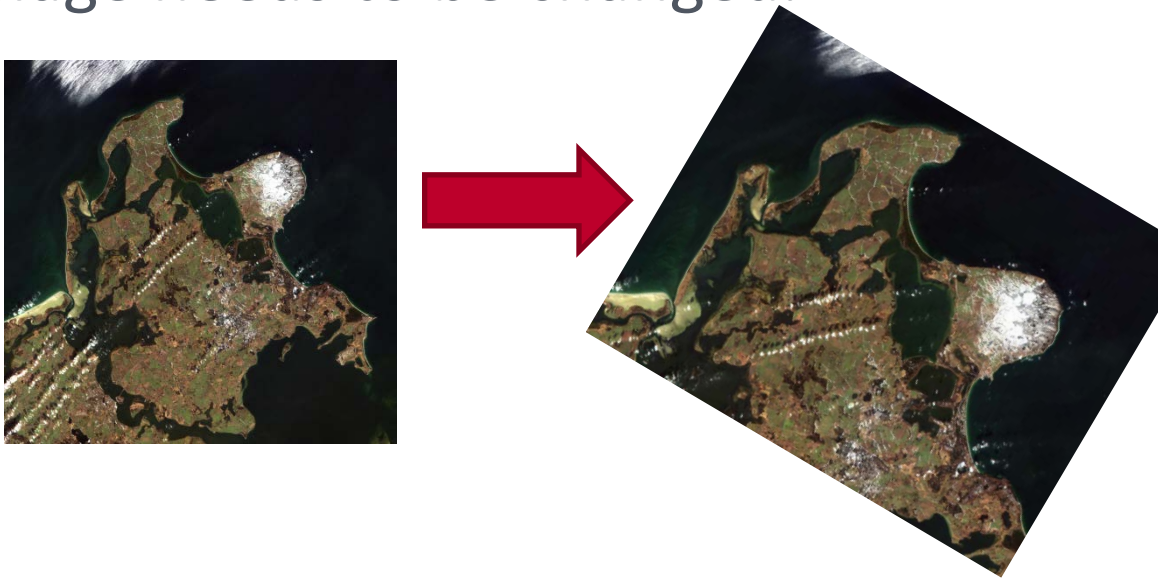

IMAGE RESAMPLER IN GENERAL

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- 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

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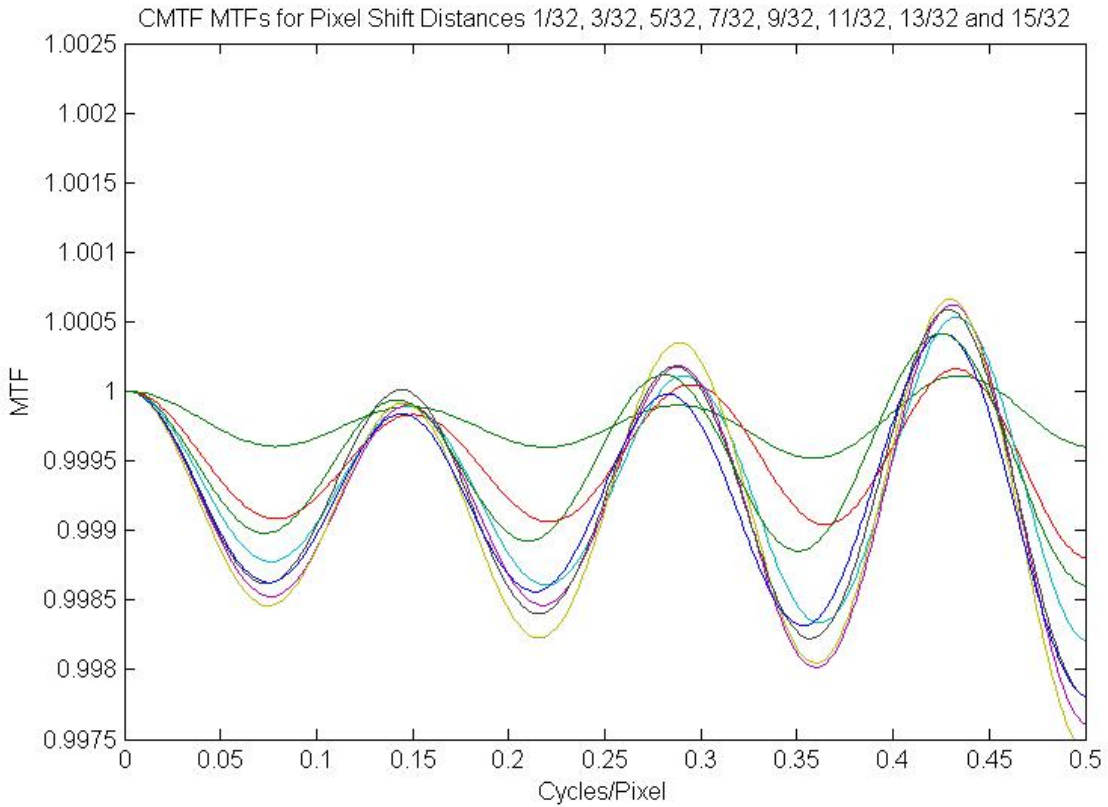
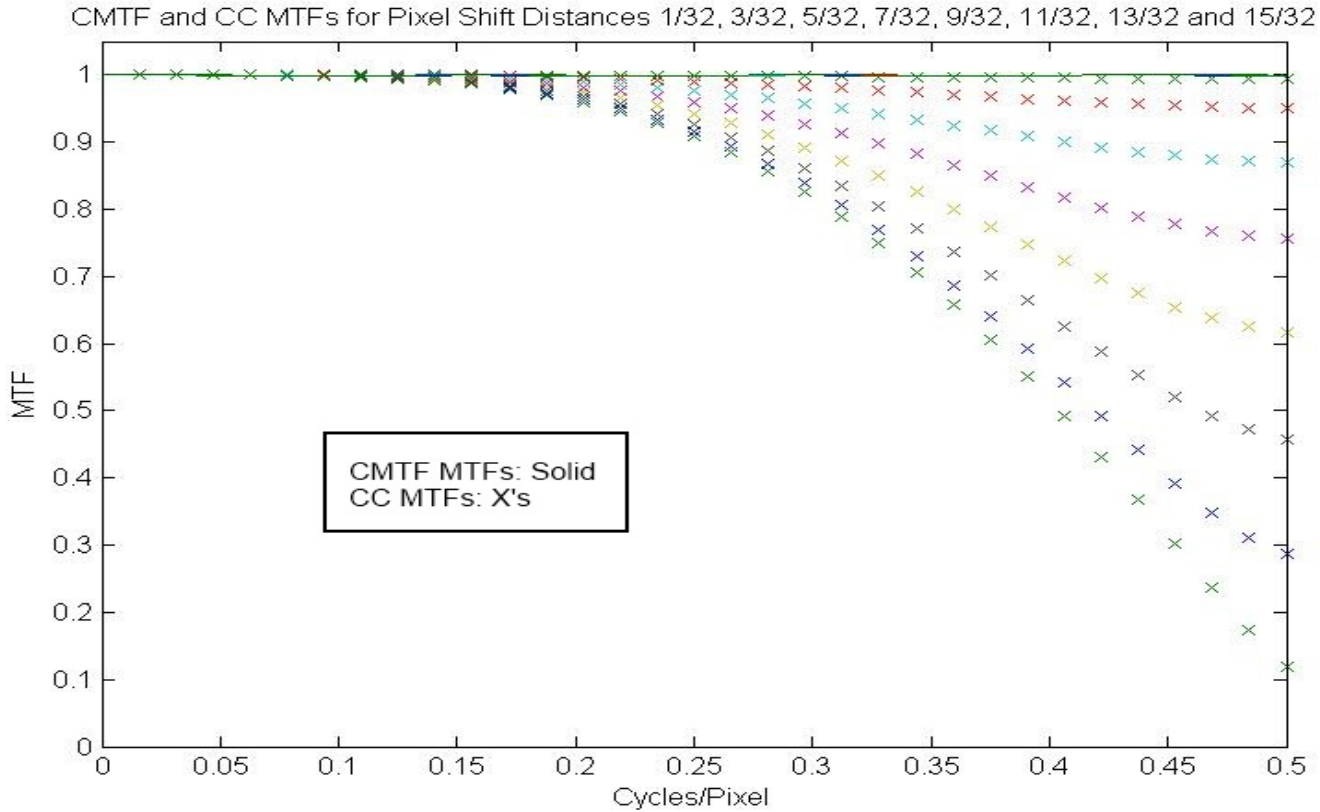
Dr. Robert Fleming and Ellis Freedman (Serious Science) developed a resampling kernel which is meant to correct the flaws in common Interpolators (Freedman, JACIE 2012)

- 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

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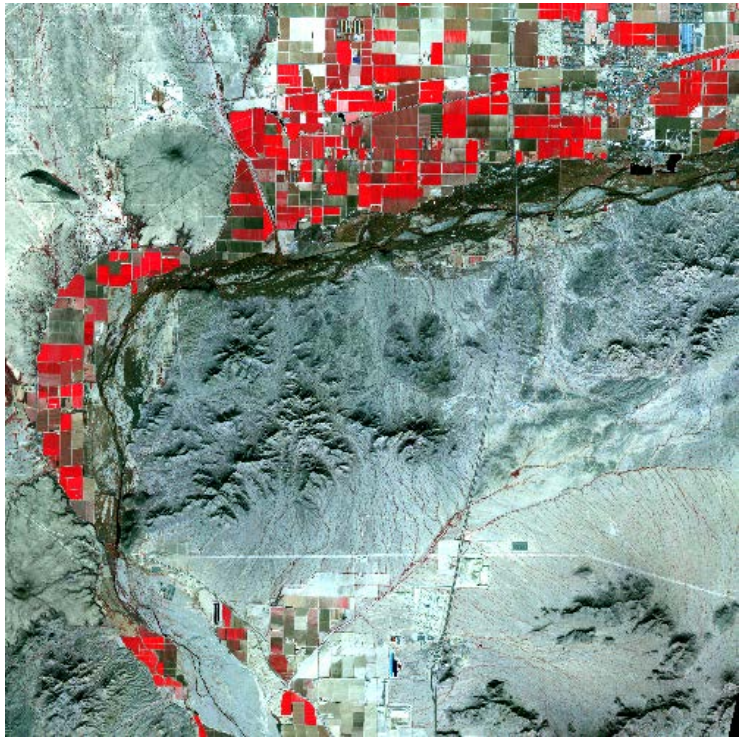
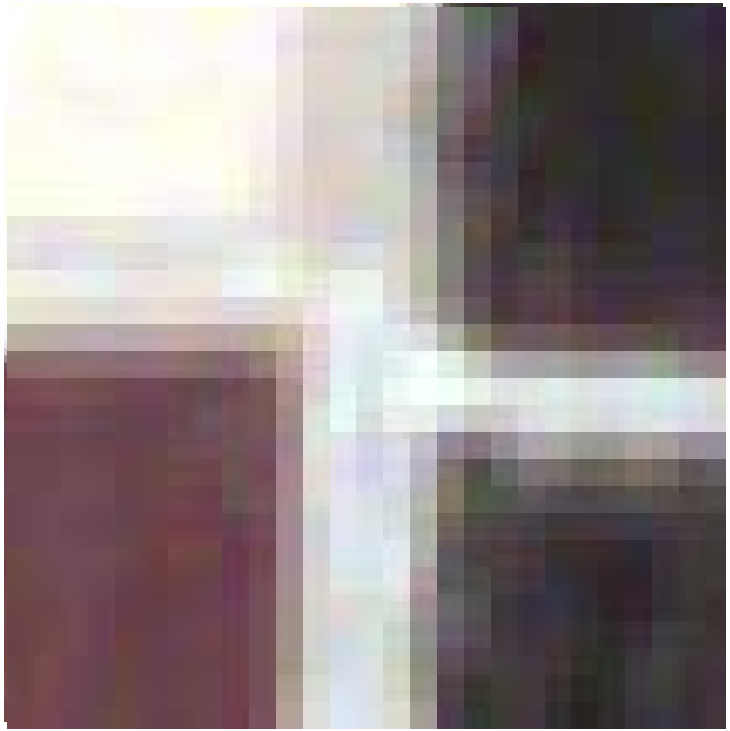
Test Site: Maricopa County, AZ

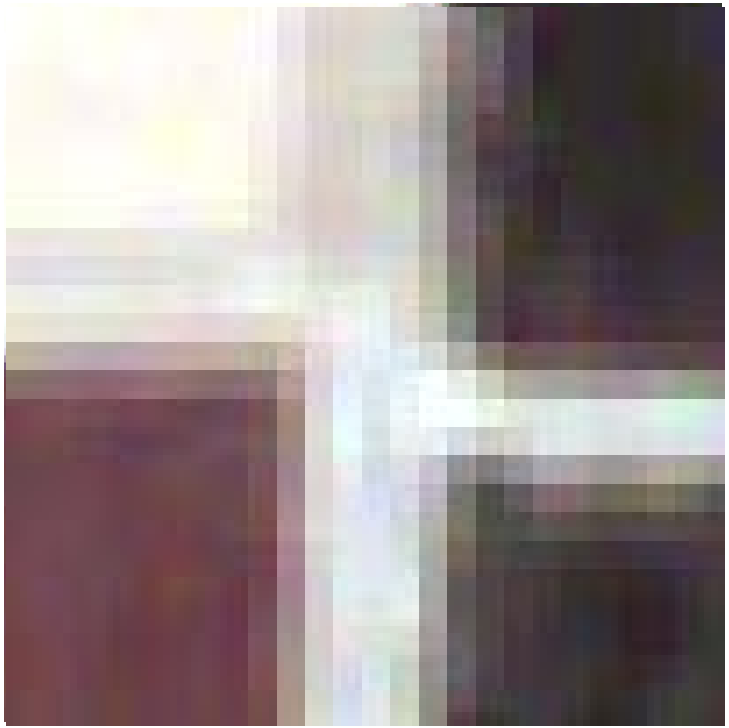
- Agricultural area 50 km West of Phoenix
- Different crop types and growing stages built up good edges



VISUAL COMPARISON



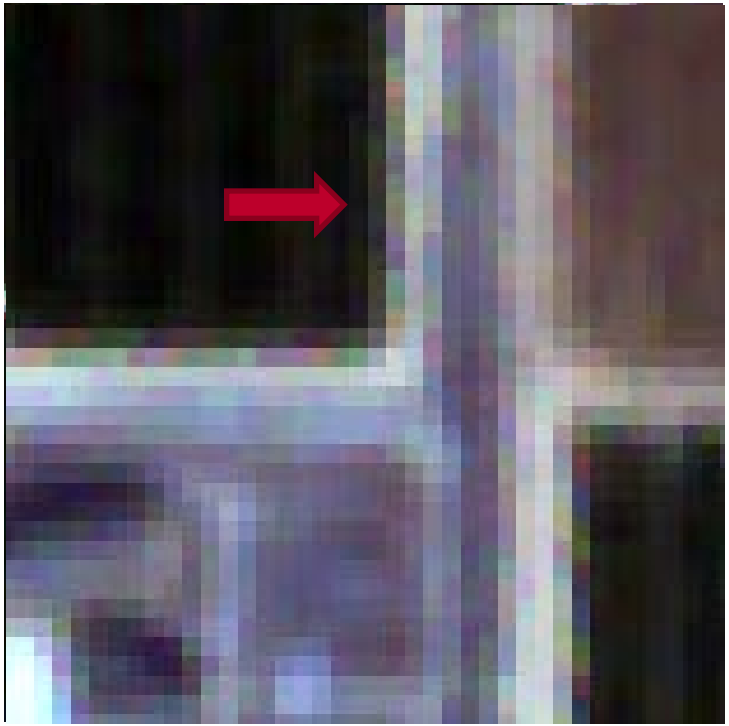
CMTF



CC

VISUAL COMPARISON

CMTF



CC

VISUAL COMPARISON

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- 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

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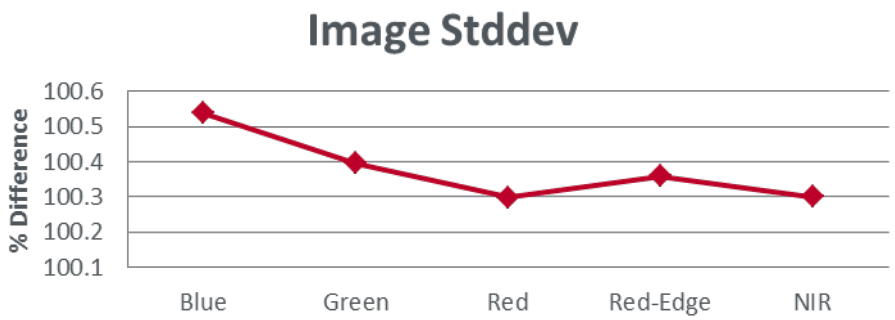
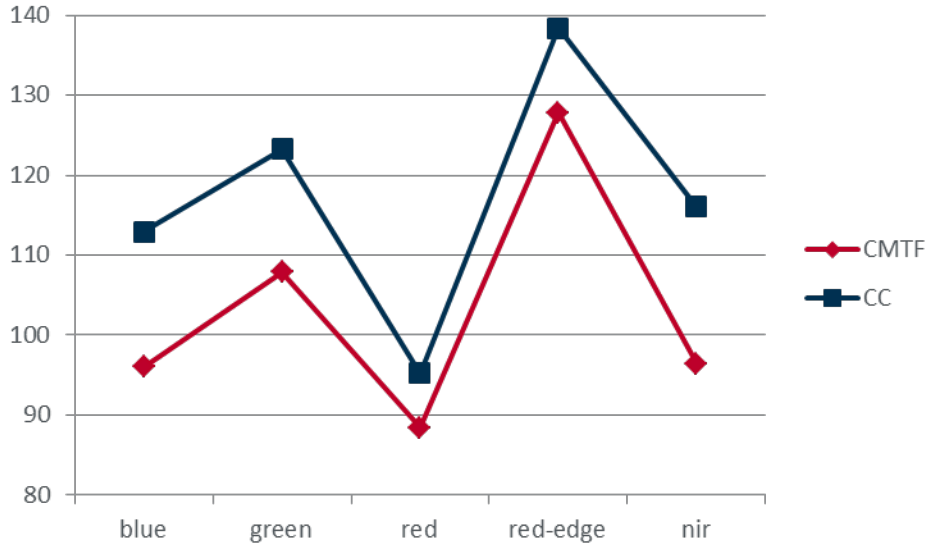
Statistical Parameters

- Statistical Parameters are very much alike
- Means match better than 1/10 of a percent
- Stddev match to better than 1%. While edges in the CC image are more noisy, the transition is smoothed compared to the CMTF image



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 appears to improve SNR compared to CMTF



SPATIAL RESOLUTION ANALYSIS

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

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

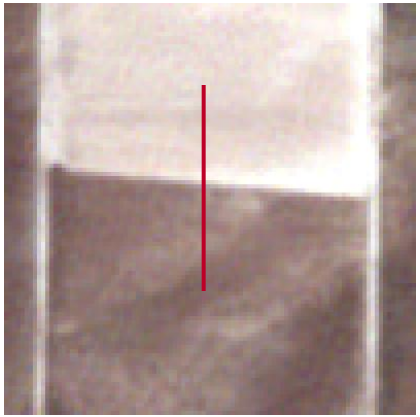
- The magnitude of σ_H gives a quantitative value for the assessment of the PSF

- 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 Relative Edge Response (RER) and Modulation Transfer Function (MTF)

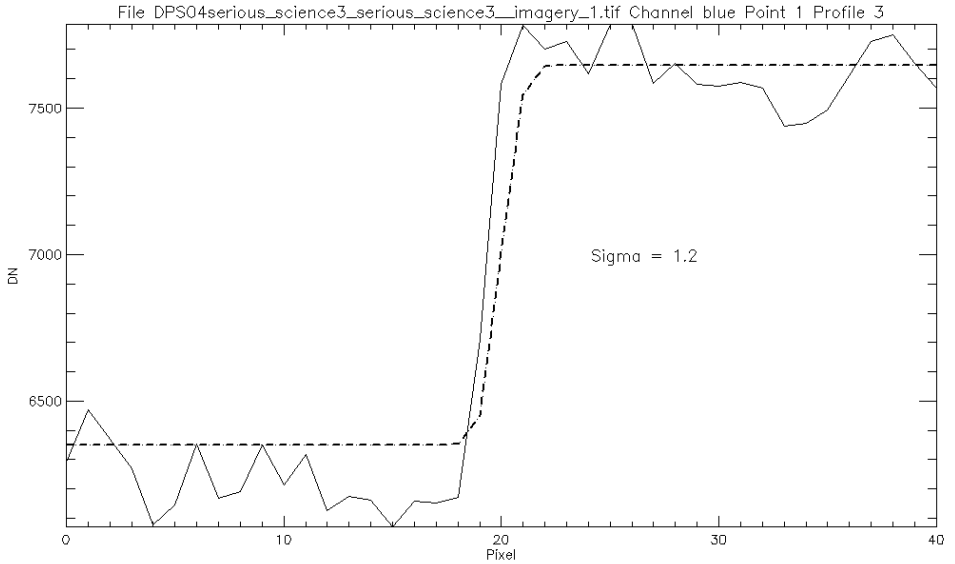
Reulke, JACIE 2011

SPATIAL RESOLUTION ANALYSIS

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



Horizontal Edge



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

SPATIAL RESOLUTION ANALYSIS

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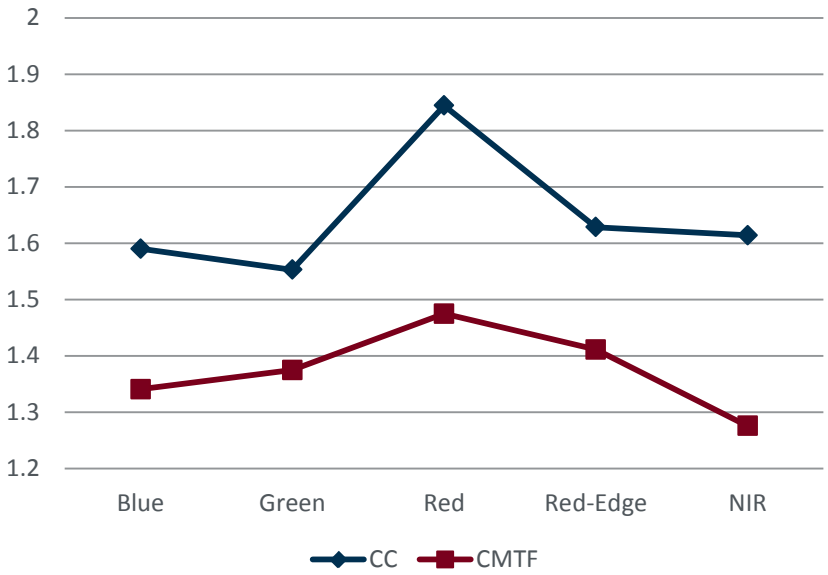
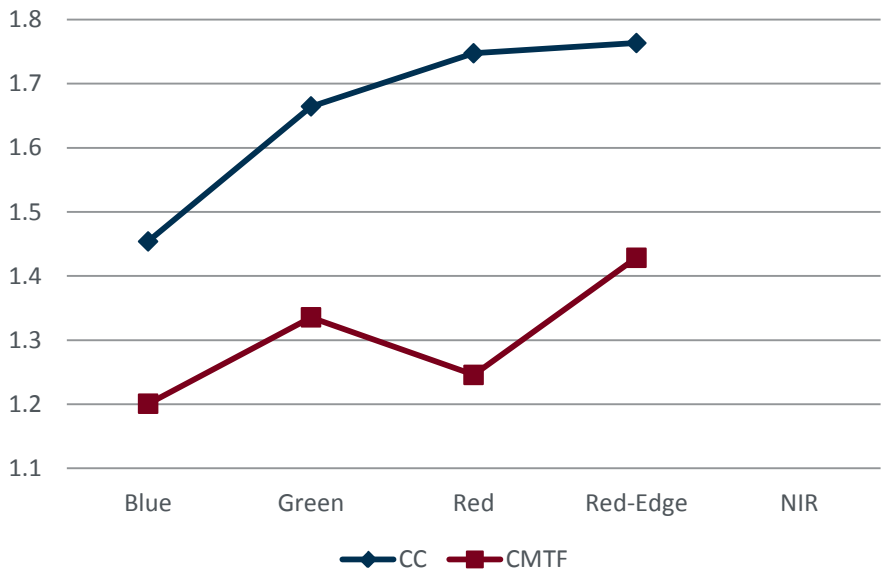
Lower values are better

Mean Transition of Vertical ESF (σ)

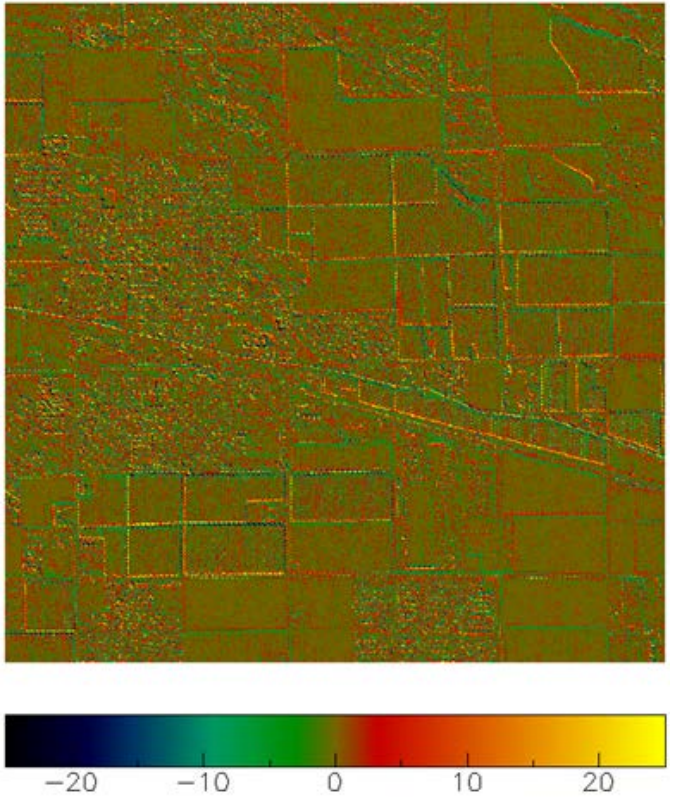


Mean Transition of Horizontal ESF (σ)



DIFFERENCE IMAGE (CMTF – CC)

- 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

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- CMTF resampler doesn’t change the image statistics
- Due to image smoothing the CC Kernel appears to improve 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

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