Spatial Resolution Characterization for AWiFS Multispectral Images

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MTF Analysis

- Spatial resolution of the AWiFS multispectral images was characterized by estimating the value of the system Modulation Transfer Function (MTF) at the Nyquist spatial frequency.
- The Nyquist frequency is defined as half the sampling frequency, and the sampling frequency is equal to the inverse of the ground sample distance (GSD).
- The MTF was calculated from a ratio of the Fourier transform of a profile across an AWiFS image of the Lake Pontchartrain Causeway Bridge and the Fourier transform of a profile across an idealized model of the bridge.
- Magnitude of the ratio normalized to the zero-frequency value provides the final MTF.

$$MTF = \frac{|\ \mathrm{FFT}(\ image\ )\ |}{|\ \mathrm{FFT}(\ scene\ )\ |}$$

Target Selection

- The Lake Pontchartrain Causeway was selected as a target in this characterization because:
  - it forms a long double bar target on a background of relatively dark and uniform water surface, and
  - a model profile of this target can be constructed.
- Direction of the bridge is also conveniently tilted from the pixel lines in the AWiFS images, and this tilt creates sub-sampling in the image of the bridge profile that allows for sub-pixel reconstruction of the spatial response.

“Pulse” Target

Lake Pontchartrain Causeway Bridge on the AWiFS image acquired on January 16, 2005.

Product GSD: 56 m
Digitization: 10 bits
Resampling: CC

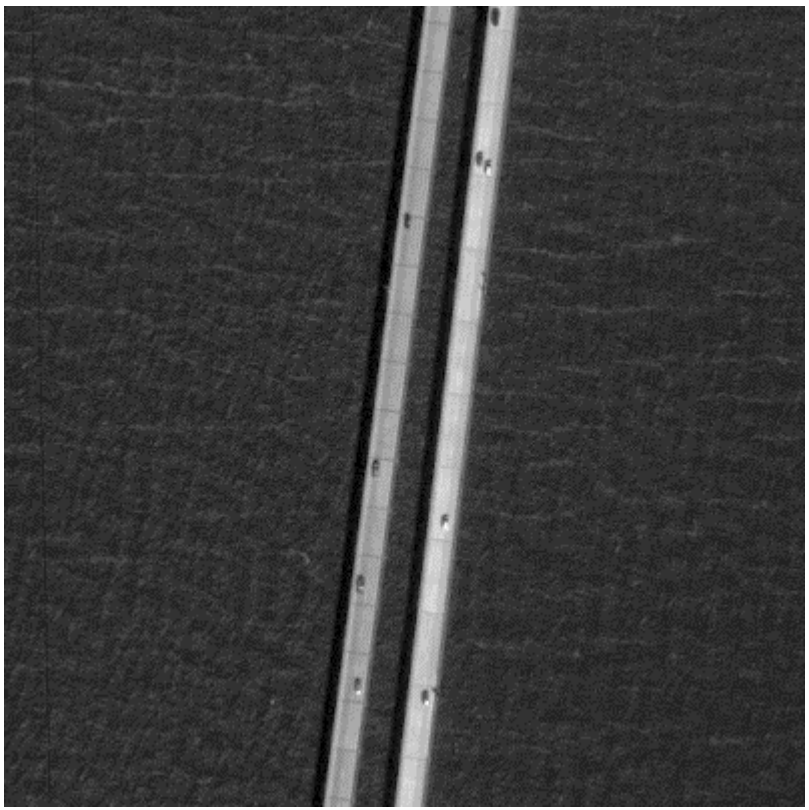
Spectral bands 4 Near Infrared (NIR), 3 (Red), and 2 (Green) are shown as the Red, Green, Blue (RGB) colors, respectively.

Because of the presence of suspended matter in Lake Pontchartrain at the time of the image acquisitions, the water background was not as uniform as expected. Analysis was performed on only uniform sections.

“Pulse” Method

AWiFS image is formed by convolution of the scene (bridges and shadows over water) with the point spread function (PSF).

Double pulse target: Lake Pontchartrain Causeway Bridge



QuickBird panchromatic image, GSD 0.7 m

AWiFS image of the Causeway acquired on January 16, 2005

Band 3 (Red), GSD 56 m

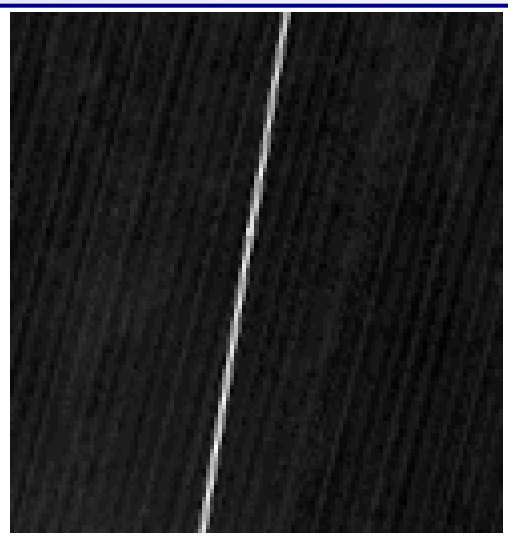
Target Images

AWiFS images of the Lake Pontchartrain Causeway Bridge used in the MTF analysis

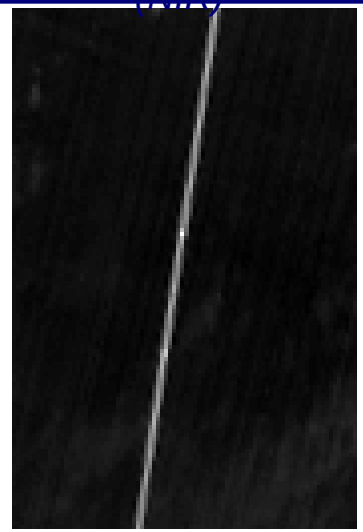
Product GSD: 56 m
Digitization: 10 bits
Resampling: CC

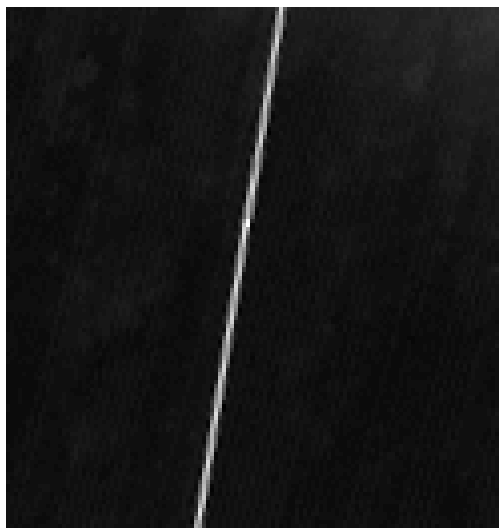
Because of the background non-uniformity created by the lake's suspended matter, the MTF analysis was conducted only for the infrared bands 4 and 5 (NIR & Short Wave Infrared (SWIR)).

January 16, 2005; Band 4 (NIR)

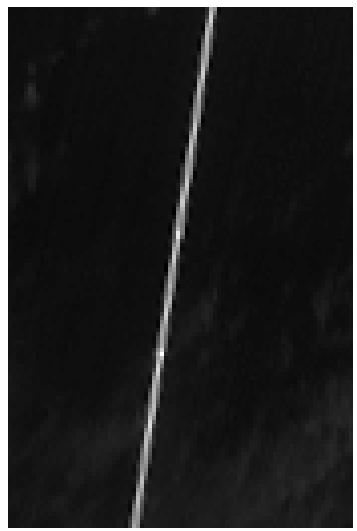


June 19, 2005; Band 4 (NIR)





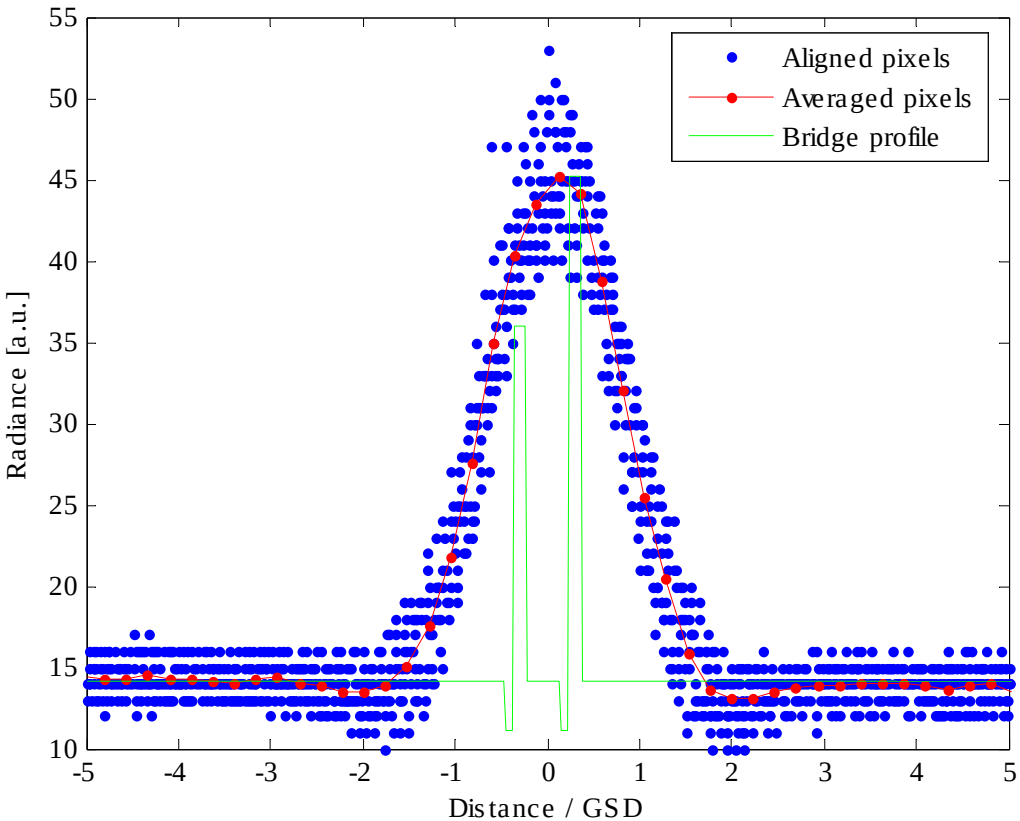
January 16, 2005; Band 5 (SWIR)



June 19, 2005; Band 5 (SWIR)

Bridge Profile

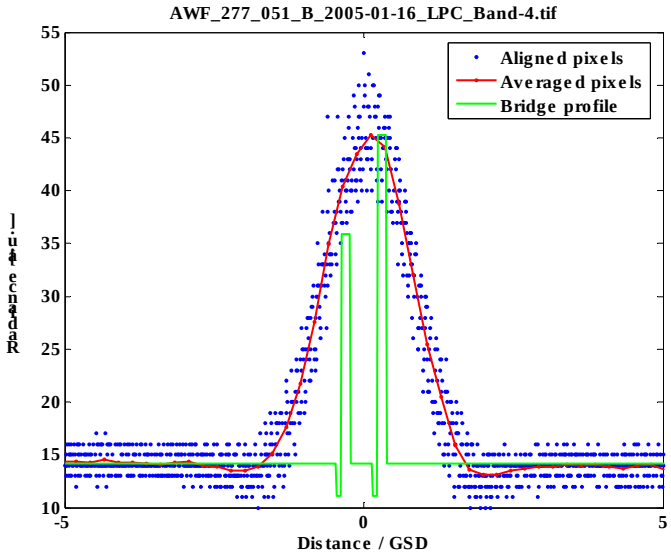
The model of the bridge profile was created based on known dimensions of the Lake Pontchartrain Causeway Bridge and on measurements from the high-resolution imagery.

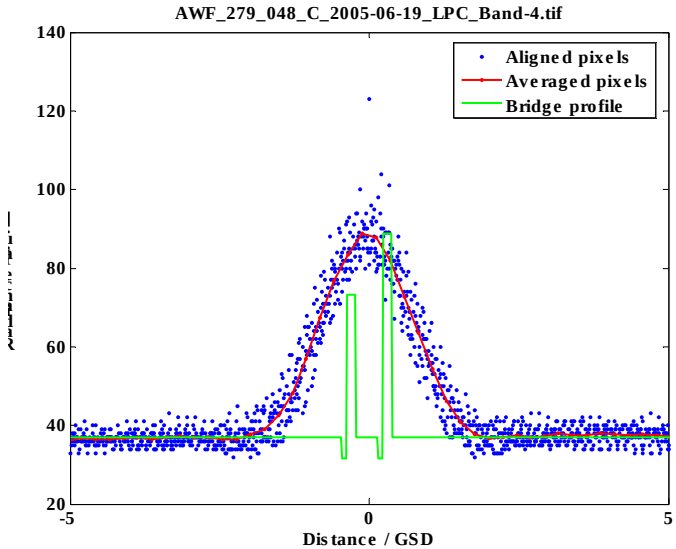


- In the first step of the analysis, the rows of image pixels were aligned to each other to remove the bridge tilt and create a bridge profile with multiple, sub-pixel sampling.
- Then, the pixels were aggregated over small, sub-pixel distance ranges to reduce noise in the measured bridge profile at a cost of decreasing spatial sampling.
- The aggregated bridge profile was subsequently Fourier transformed and divided by the transform of the model bridge profile.

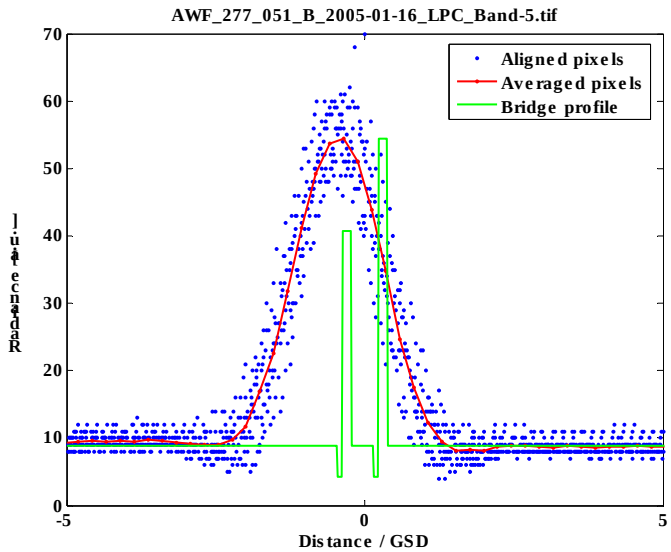
Bridge Profiles

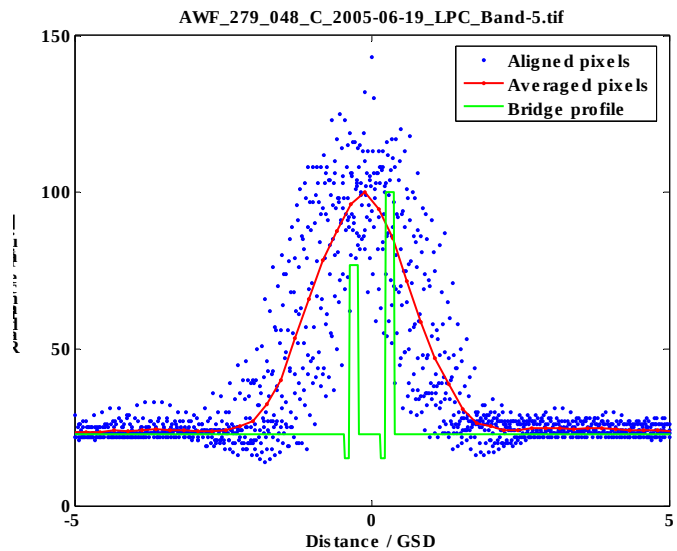
Band 4 (NIR)





Band 5 (SWIR)



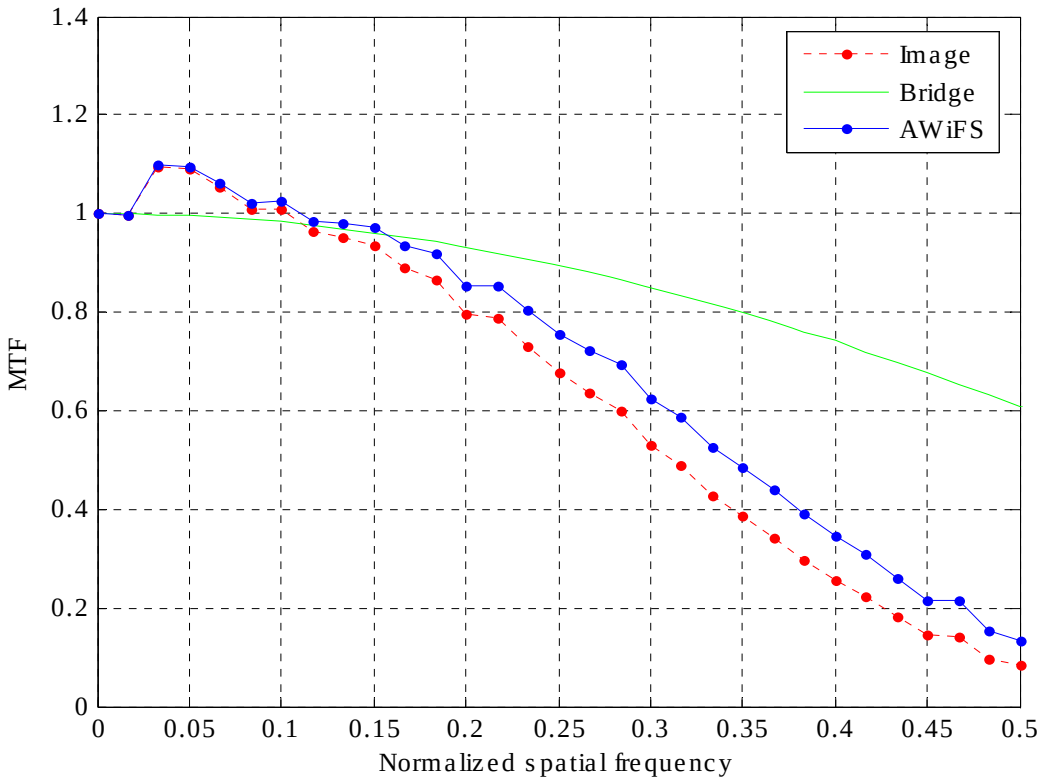


AWiFS-B Camera

AWiFS-A Camera

MTF Calculation

As the image is formed by convolution of the scene with the system spatial response, and convolution is replaced with the product of Fourier transforms in the spatial frequency domain, MTF is calculated as a ratio of the transforms:

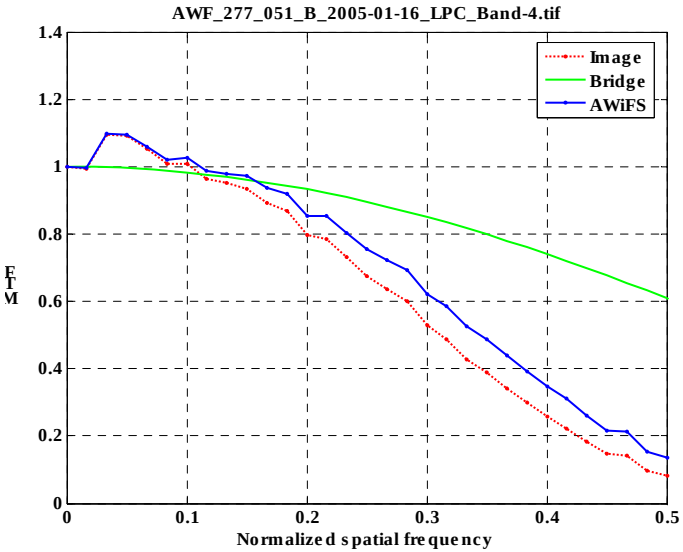


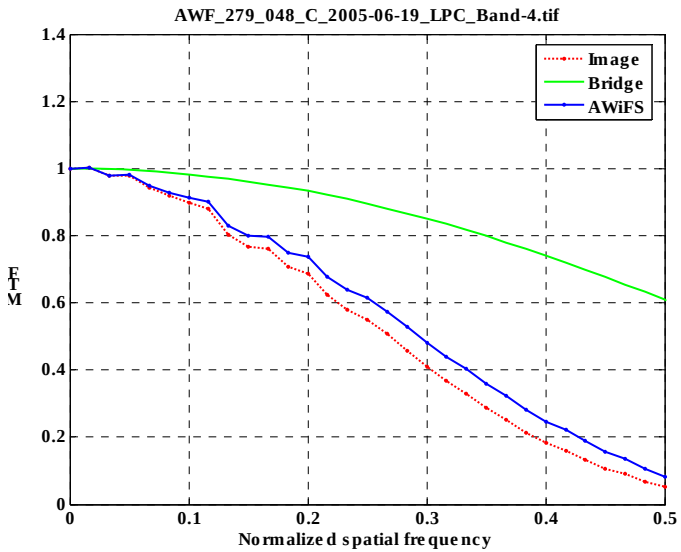
$$MTF = \frac{|\ FFT(\ image\ )\ |}{|\ FFT(\ scene\ )\ |}$$

MTF ≈ 0.15 at Nyquist frequency

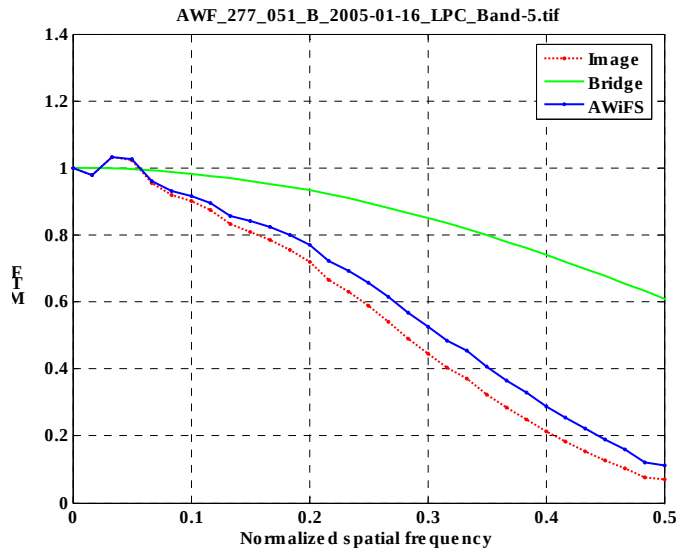
MTF Results

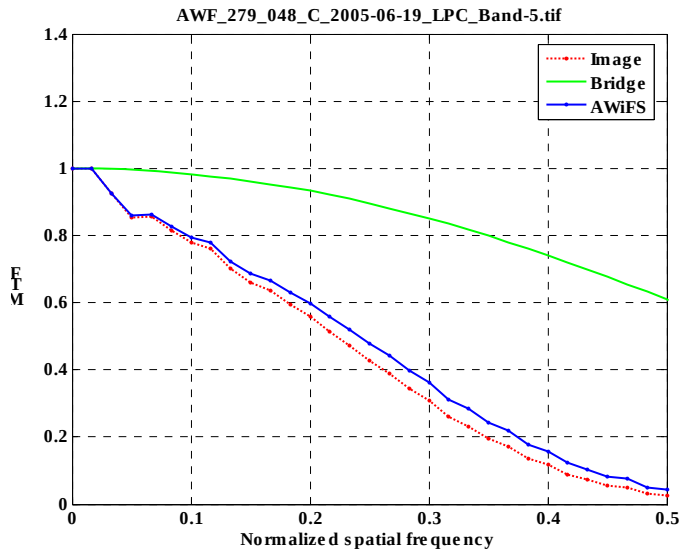
Band 4 (NIR)





Band 5 (SWIR)





AWiFS-B Camera

AWiFS-A Camera

Results Summary

- Estimates of MTF at Nyquist frequency:
  - AWiFS-A Camera
    - Band 4 (NIR): 0.10
    - Band 5 (SWIR): 0.05
  - AWiFS-B Camera
    - Band 4 (NIR): 0.15
    - Band 5 (SWIR): 0.10
- These values are for resampled images (using Cubic Convolution)
- Results only preliminary (single images)
  - More images need to be analyzed
  - Future plans: at least five images for each camera (across the field of view, too)
  - Improve bridge model (spectral reflectance, shadows)
  - Develop error budget (Monte Carlo simulations)