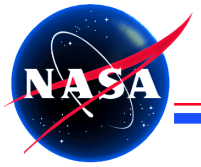



# Initial IKONOS Modulation Transfer Function Compensation (MTFC) Evaluation

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**Lockheed Martin Space Operations**
**Commercial Remote Sensing Program**
**NASA Stennis Space Center**

**March 19-21, 2001**

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**e-mail: robert.ryan@ssc.nasa.gov**

# Contributors



| | |
|---|---|
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| **Michelle Kelly** | **LMSO Stennis** |
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| **Bill Smith** | **Datastar Stennis** |
| **Tom Stanley** | **NASA Stennis** |

# Introduction



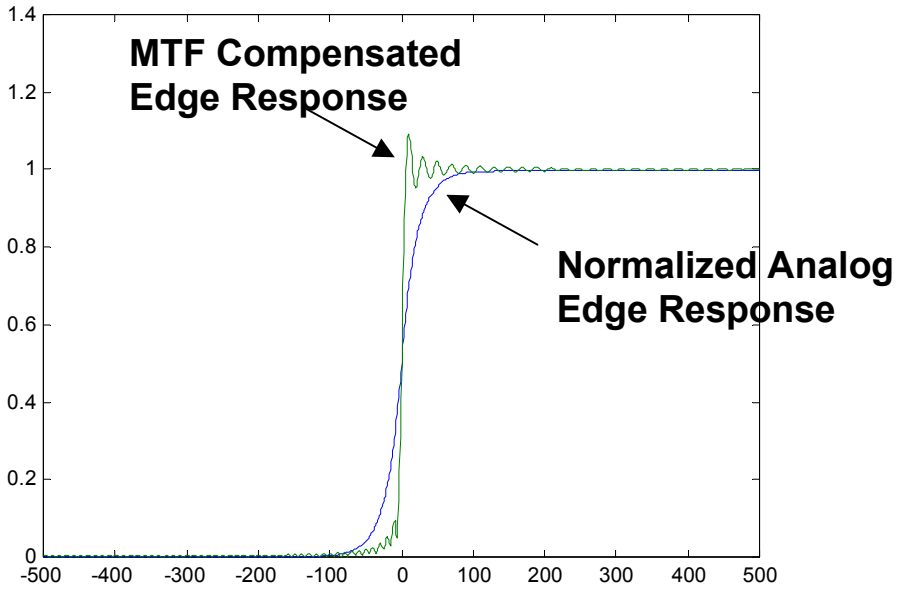
- **NASA Scientific Data Purchase (SDP) orders imagery with MTFC ON to stay consistent with commercial product offerings**
- **SDP IKONOS data specifications were developed before SI products were fully defined**
  - MTFC is not mentioned in SDP contract
  - NASA discovered products were MTFC through examination of metafiles
- **Objectives**
  - Examine radiometric differences between MTFC ON and MTF OFF for panchromatic and multispectral imagery (MS)
  - Understand impact on various work such as vicarious radiometric calibrations and sensor inter-comparison (L7)
  - Examine MTFC effects on SNR

# Background



- **MTFC is an edge sharpening technique used to partially restore image degradation to imperfections in the imaging process**
  - Historically used in CRT displays and by the intelligence community
  - Implemented in analog electronics or digitally

**Simulated Edge Response**




**MTFC sharpening edges but can produce overshoot and ringing**

# Approach



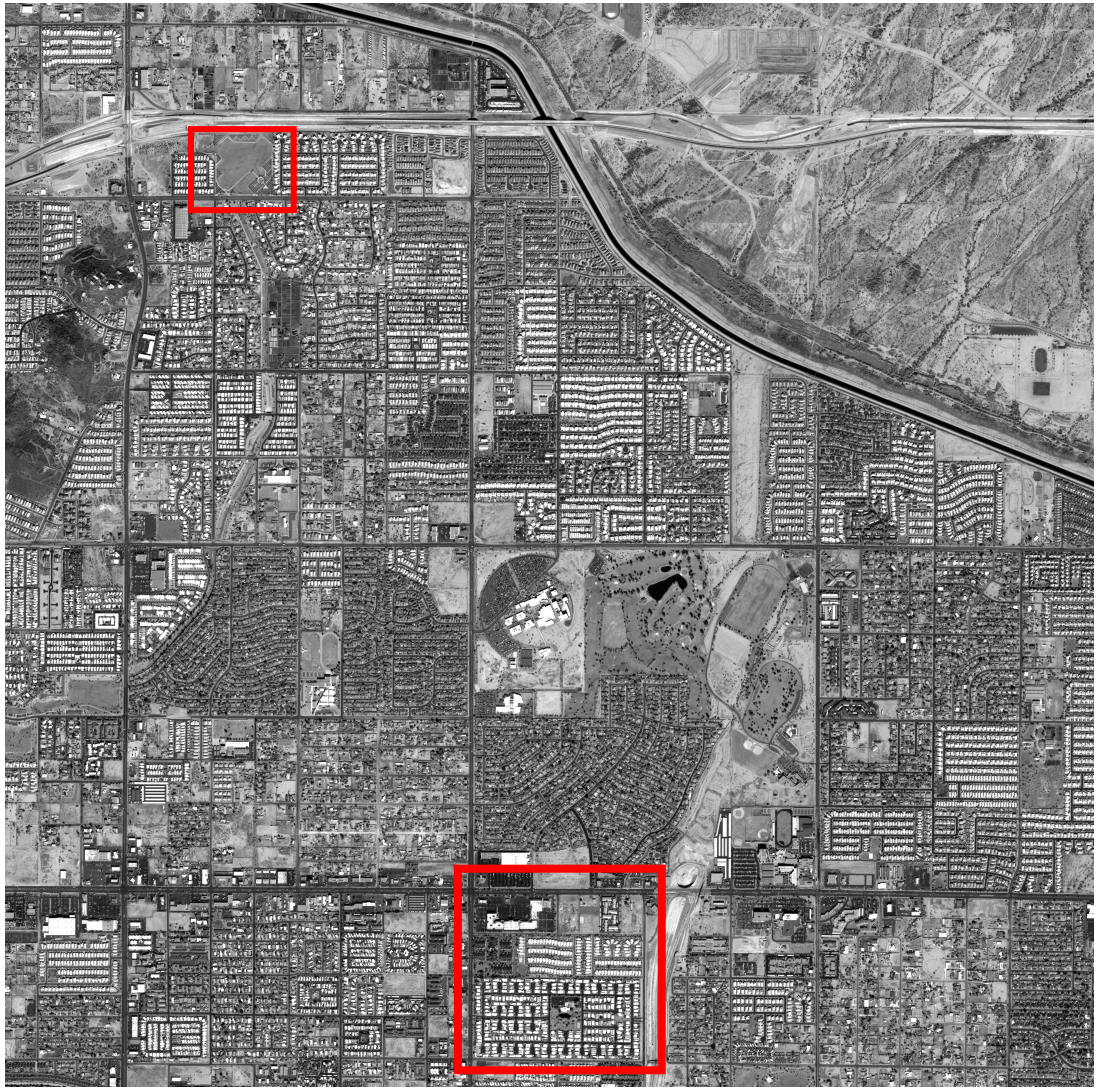
- **Perform Visual Inspection on MTFC ON and MTFC OFF Imagery**
  - Panchromatic and MS
  - Difference Imagery
- **Examine the effects of Space Imaging MTFC kernel on simulated images**
  - Examine Edge Response
  - Examine Aliasing Effects
- **Perform quantitative analysis on MTFC ON and MTFC OFF Imagery**
  - Histograms
  - Scatter plots
  - RMS and peak differences
  - Estimate MTFC

# Visual Inspection

# Phoenix PO ID# 33667



- 1 Meter Panchromatic
- October 12, 1999
- MTFC ON
- Satellite Elevation Angle 60.7°



# Phoenix MTFC ON/MTFC OFF Pan Comparison

*Stennis Space Center*

**1m Panchromatic Imagery Acquired October 12, 1999**

MTFC ON

MTFC OFF

# Phoenix MTFC ON/MTFC OFF RGB Comparison

*Stennis Space Center*

**4m Multispectral Imagery Acquired October 12, 1999**

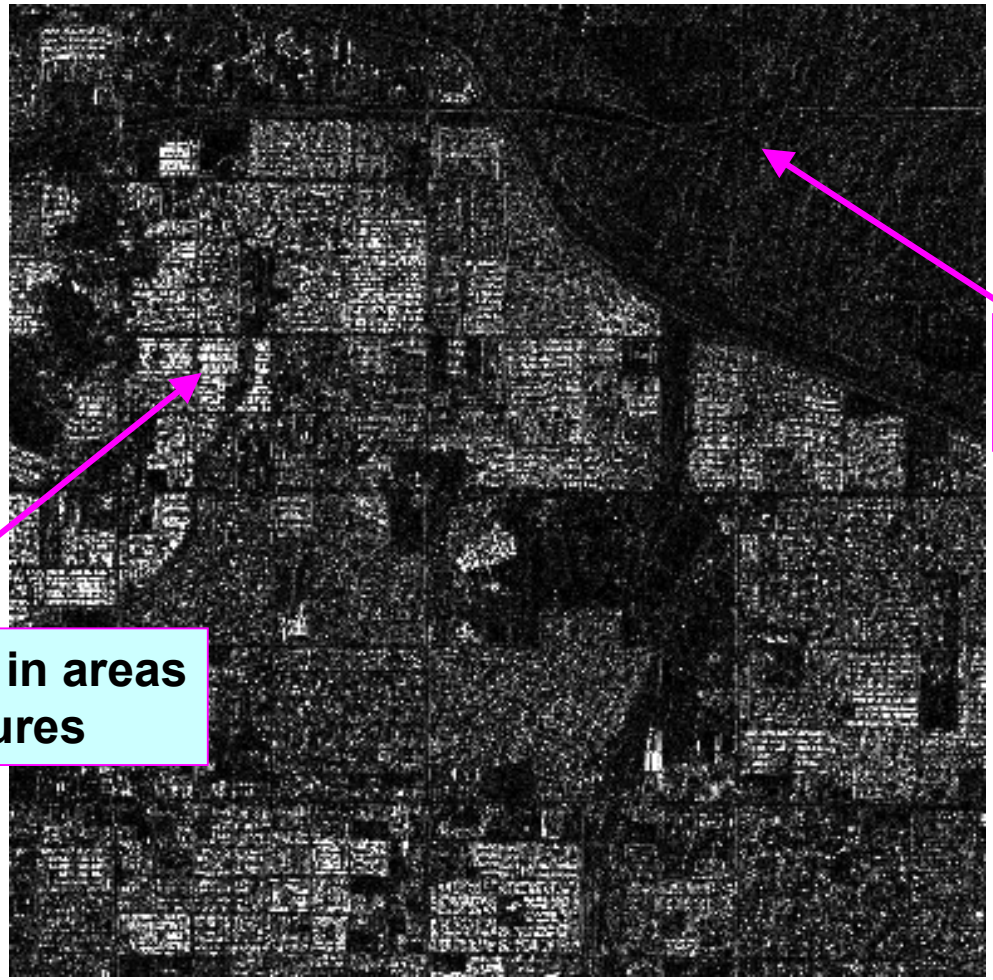
MTFC ON

MTFC OFF

# Phoenix MS Blue Band Difference Image

*Stennis Space Center*

## Abs (MTFC ON - MTFC OFF)



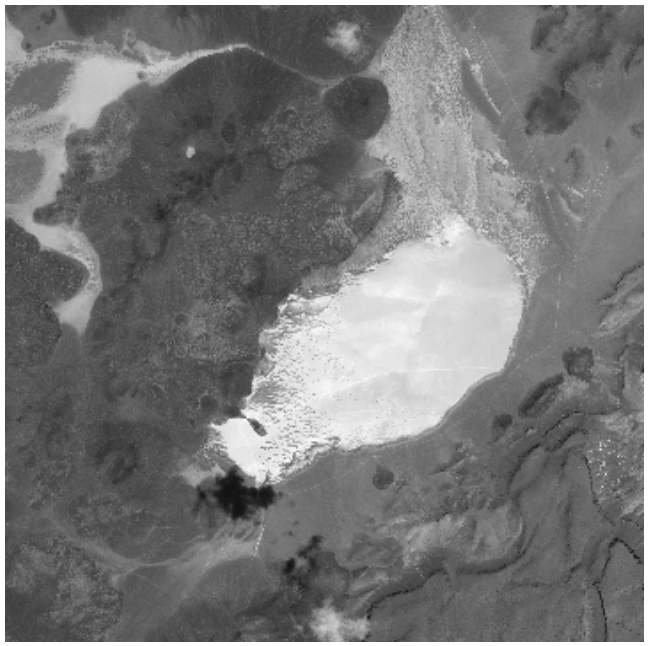
**Smallest Effects in uniform areas**

**Largest Effects in areas with sharp features**

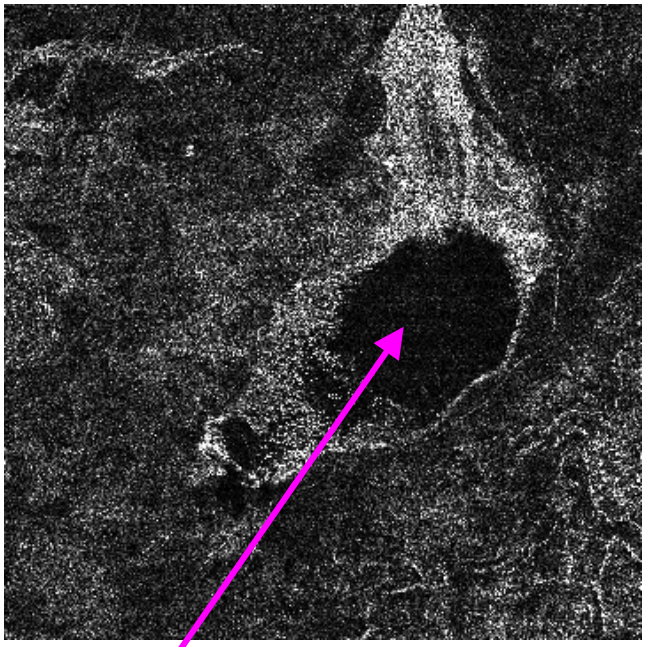
# Lunar Lake MS NIR Band Difference Image

Stennis Space Center

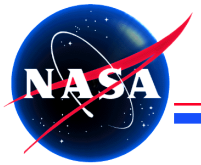
**New Lunar Lake MS Near IR MTFC On Image**



**New Lunar Lake MS Near IR Absolute Value Image of MTFC On - MTFC Off**



**There is not a noticeable difference between MTFC ON and MTFC OFF for highly uniform scenes like Lunar Lake**

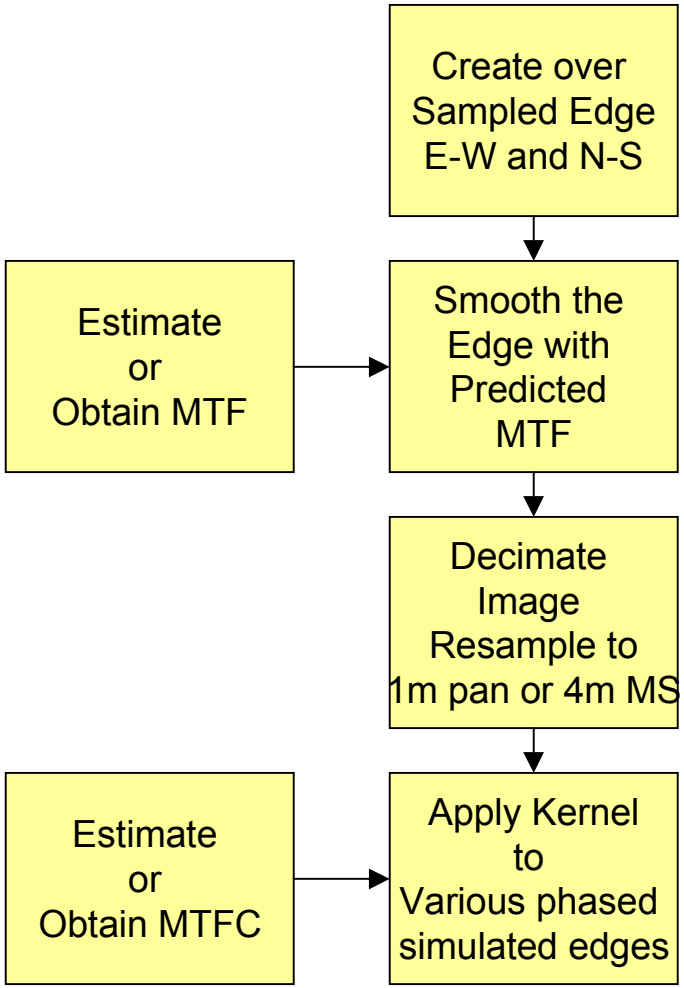




# SI MTFC Kernel Analysis

# Simulation Approach





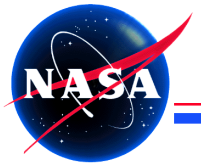

**Oversampled**
**GSD $_{pan}$ = 0.125m**
**GSD $_{MS}$ = 0.5m**

**MTF $_{pan}$ @ Nyquist = 0.1**
**MTF $_{MS}$ @ Nyquist = 0.24**

**Sensor Sampling**
**GSD $_{pan}$ = 1m**
**GSD $_{MS}$ = 4m**

**Use estimated MTFC or SI provided kernel**

# MTFC Estimation



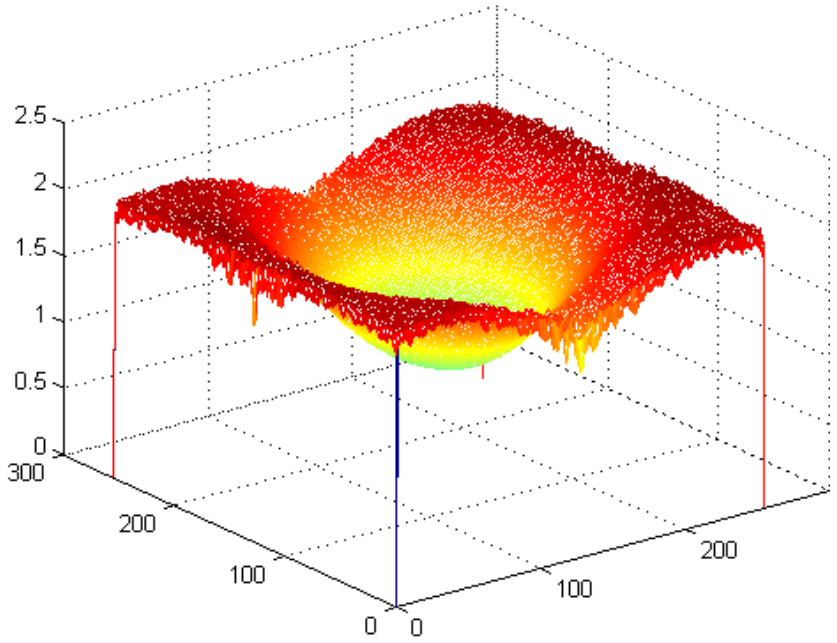
# MTFC Estimation Approach



1. Segment image into blocks
2. DFT MTFC ON image blocks
3. DFT MTFC OFF image blocks
4. Ratio MTFC ON DFT to MTFC OFF DFT
5. Smooth MTFC to provide estimate
6. Use MTFC estimate to develop inverse filter function and attempt restoration

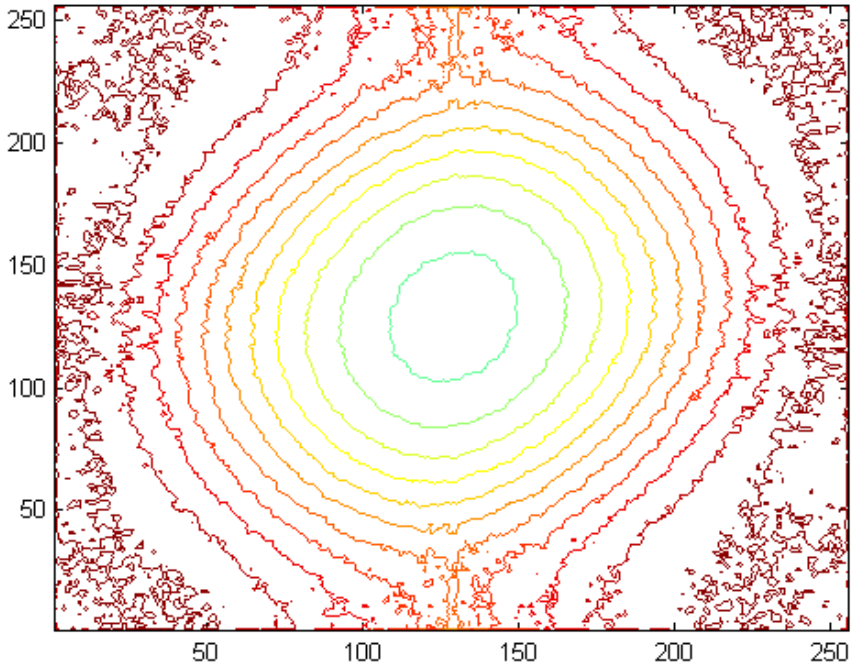
# Estimated MS NIR MTFC






**Estimated MTFC Function for the MS NIR Image**

**Stronger Compensation in Row Direction**



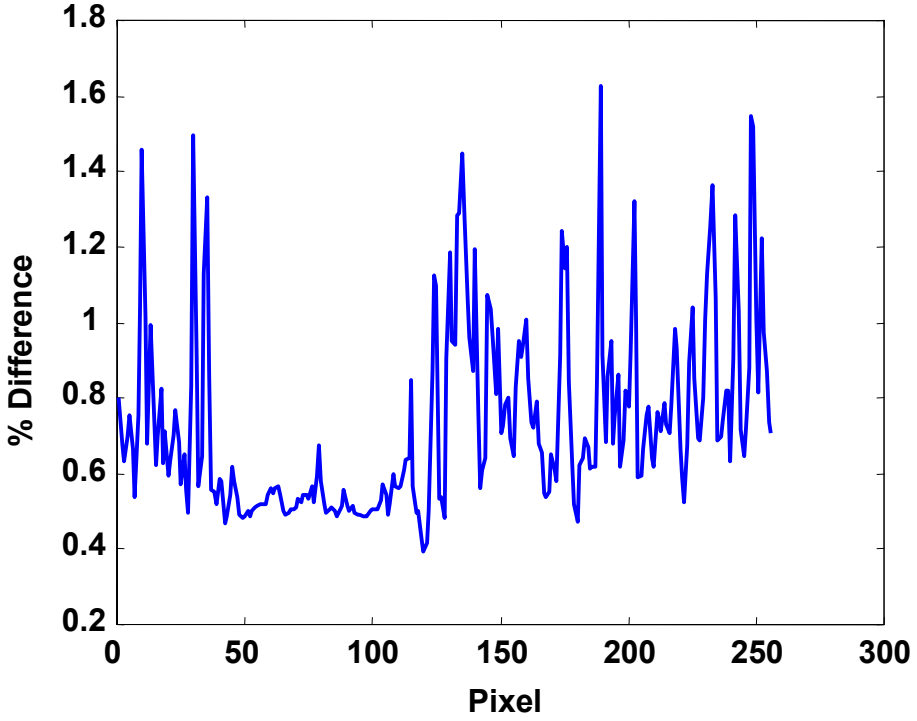

**MS NIR MTFC Contour**

**Rotation appears to be geometric correction effect**

# Difference between Restored and MTFC OFF NIR Image



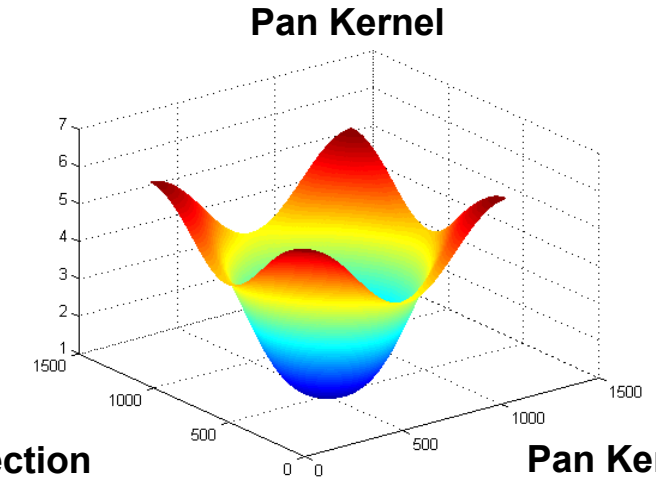
## % Difference Between Restored and Original Cross-section Image

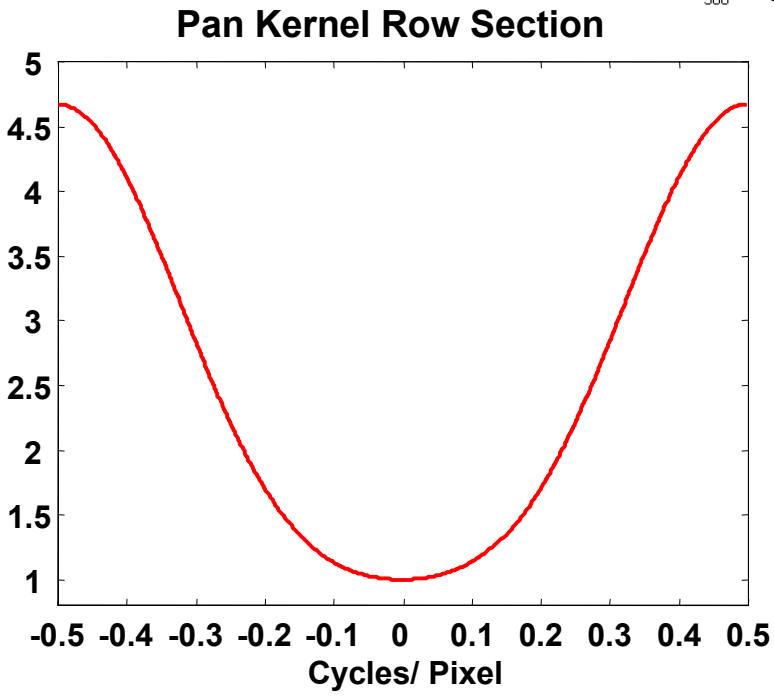


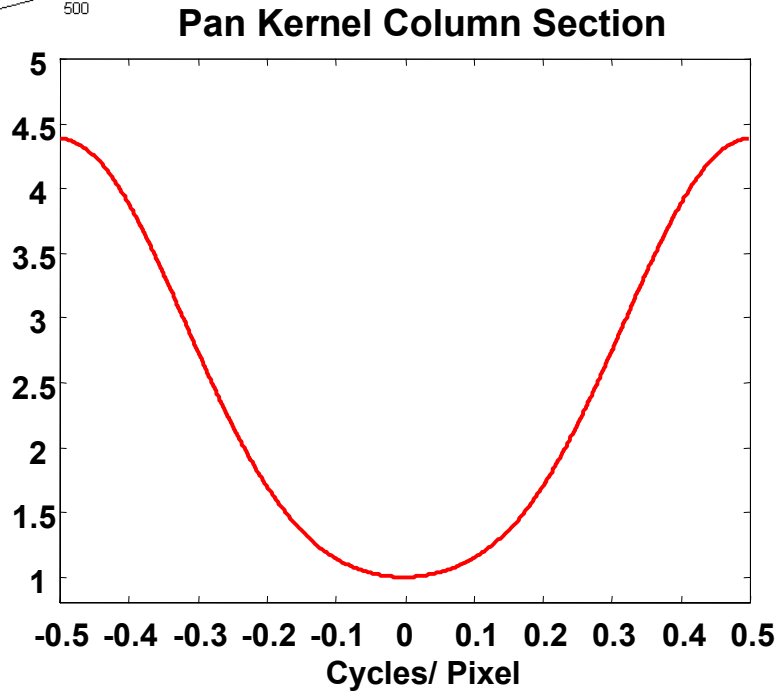

Due to noisy estimate performed analysis with SI provided kernel

# Pan Band MTFC





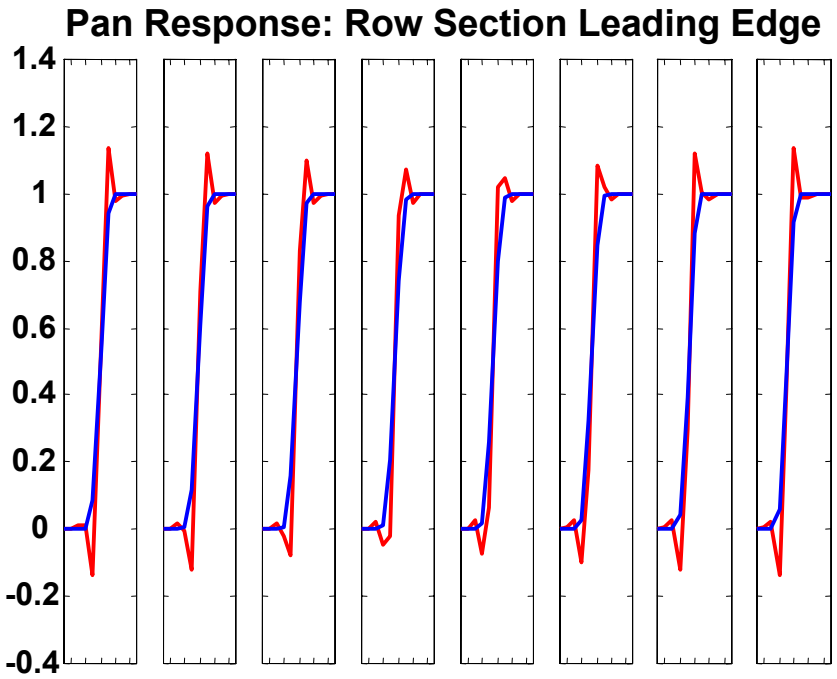



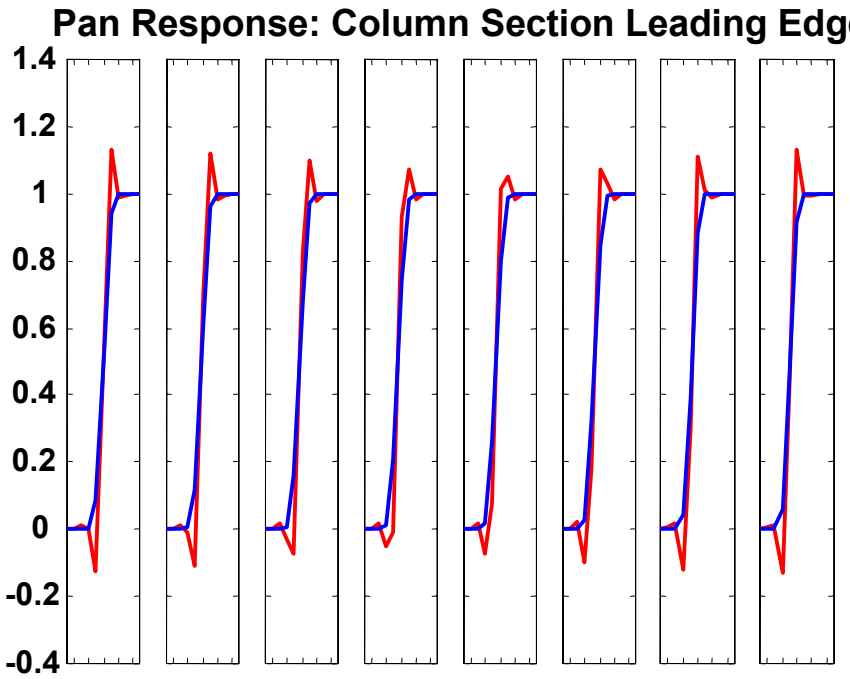




Row MTFC slightly stronger

# Pan MTFC Edge Response with Phasing Effects

*Stennis Space Center*



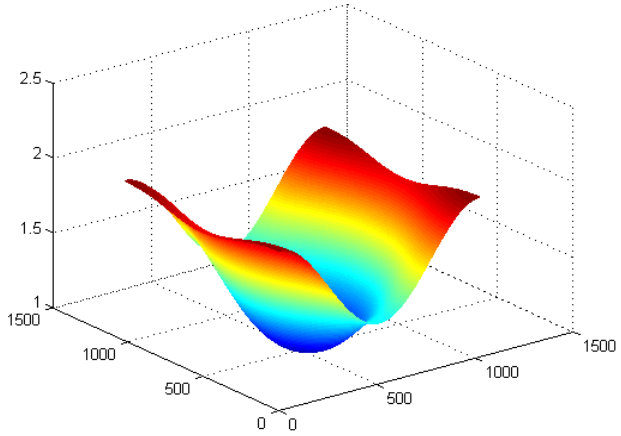




MTFC @ Nyquist assumed to be 0.1 with 1/8 pixel steps

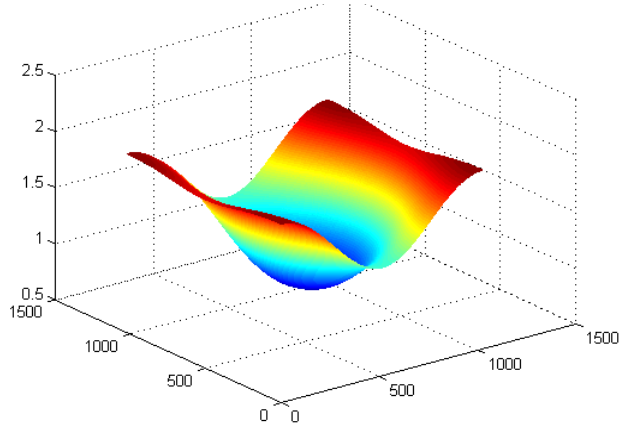
# MTFC MS Kernels



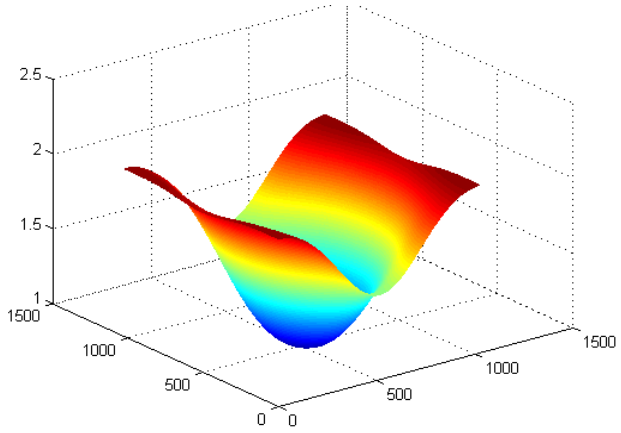
## Blue Kernel



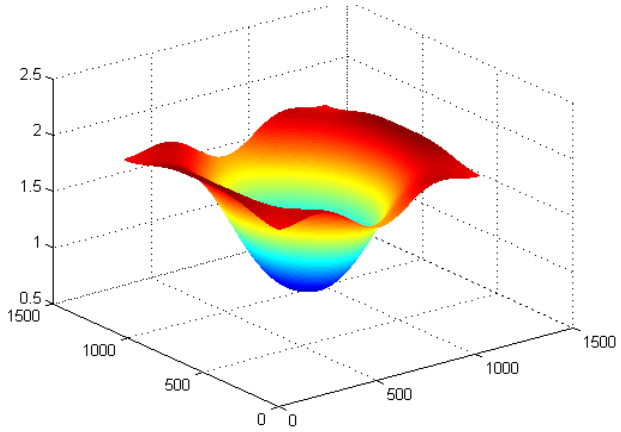

## Green Kernel




## Red Kernel



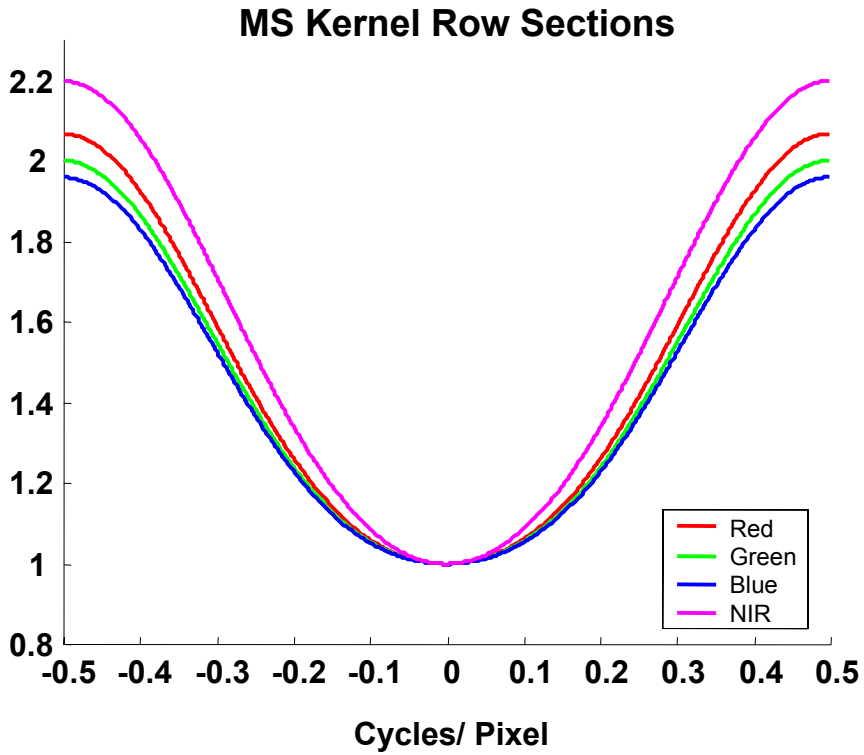

## NIR Kernel

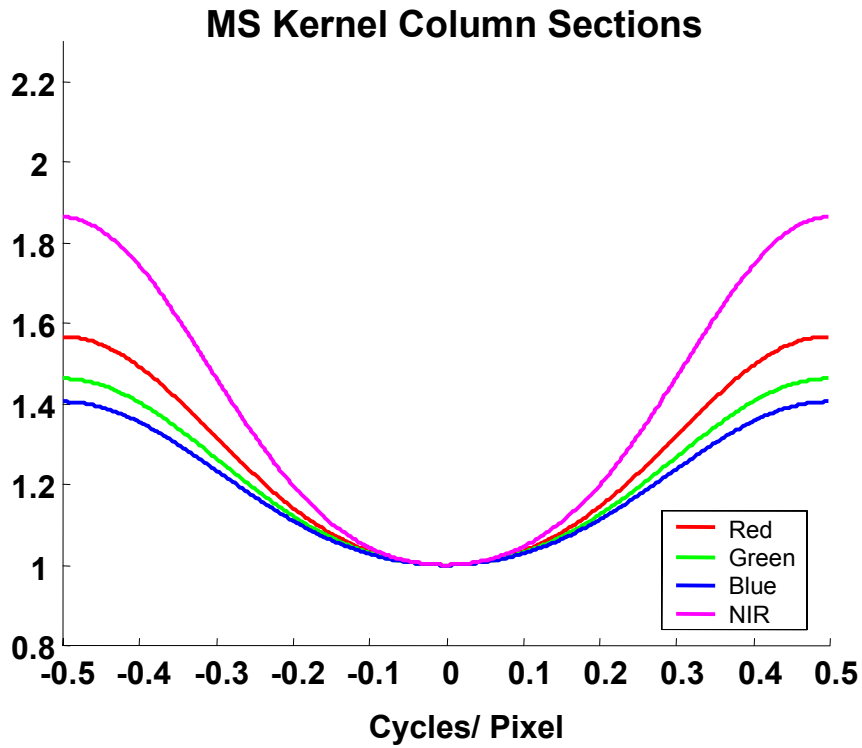



Row MTFC is stronger than column MTFC

# MTFC MS Band Comparisons





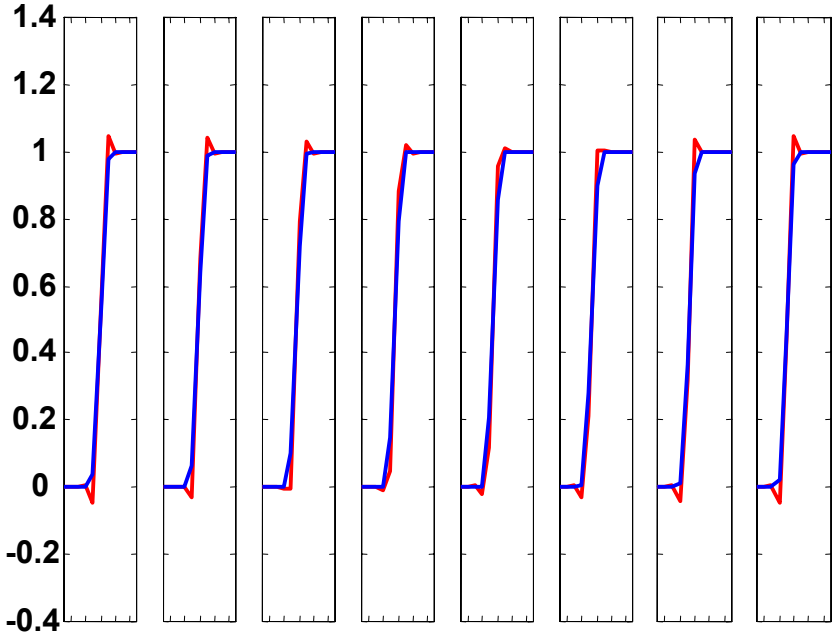




MTFC compensations increases with increasing wavelength

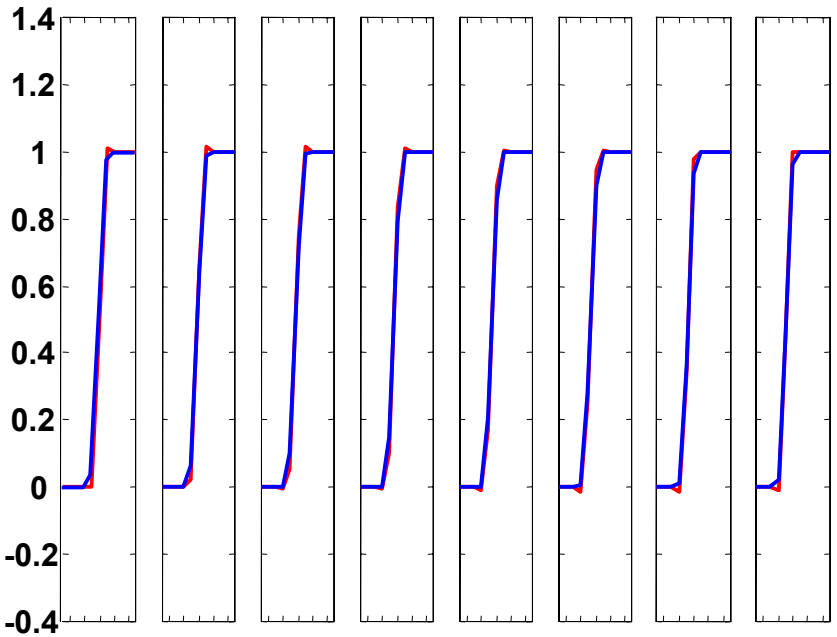
# Blue Band MTFC Edge Response with Phasing Edge

Stennis Space Center

**Blue Response: Row Section Leading Edge**




**Blue Response: Column Section Leading Edge**

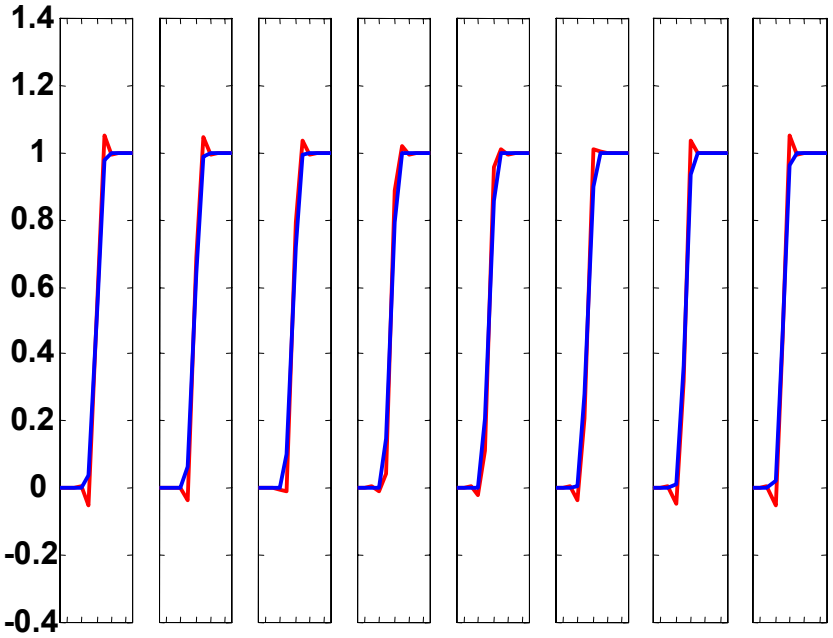



Overshoot more pronounce in row direction

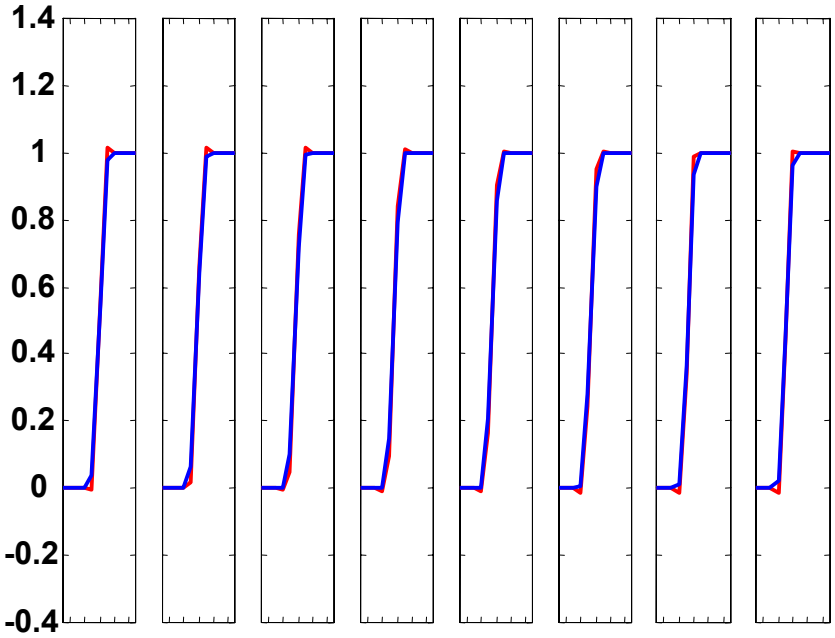
# Green Band MTFC Edge Response with Phasing

*Stennis Space Center*

**Green Response: Row Section Leading Edge**



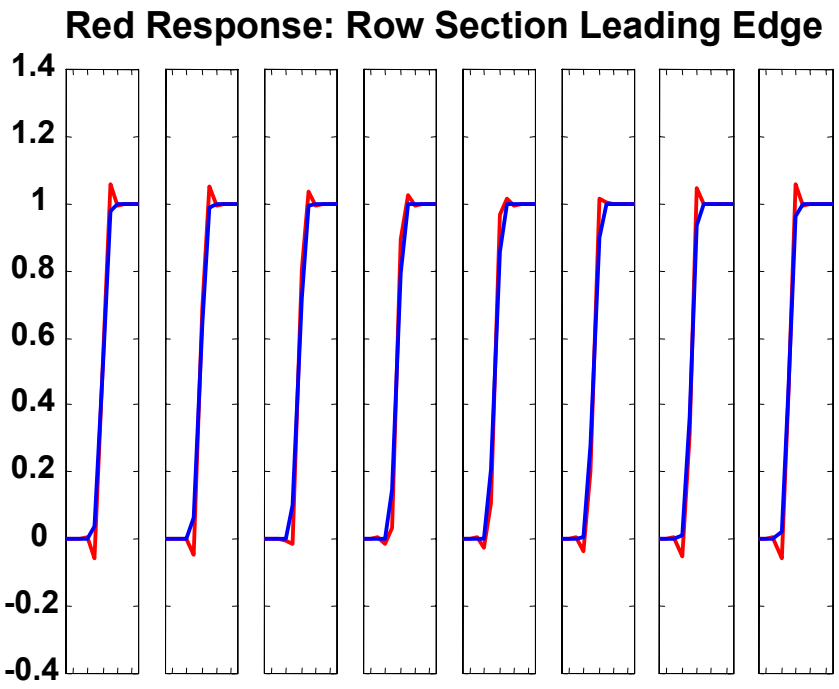

**Green Response: Column Section Leading Edge**

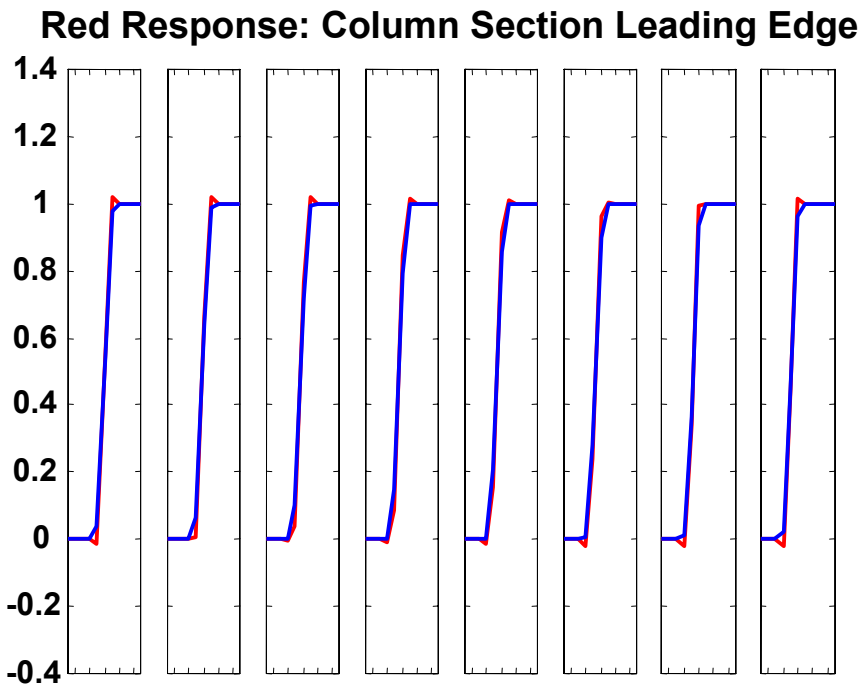



Overshoot more pronounce in row direction

# Red Band MTFC Edge Response with Phasing



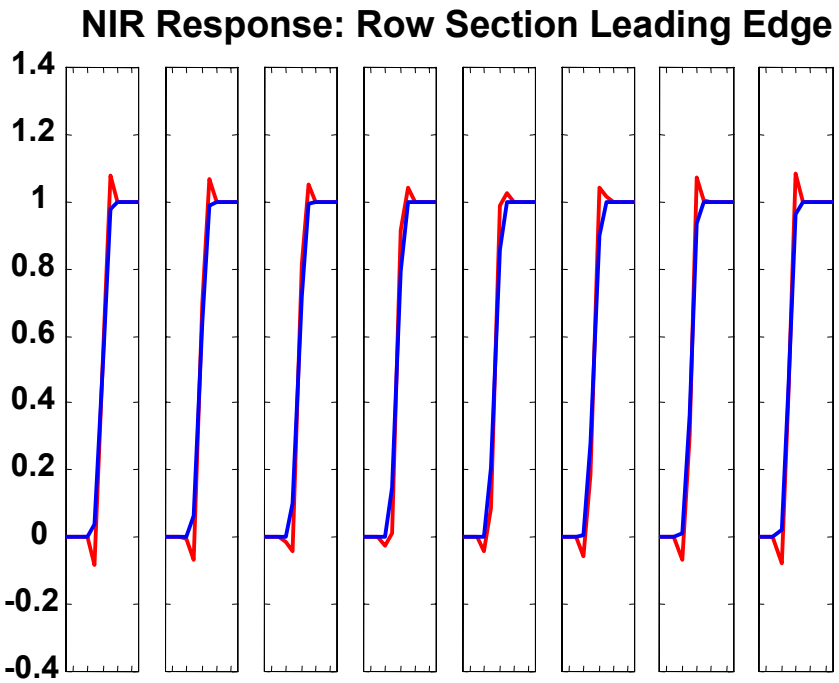


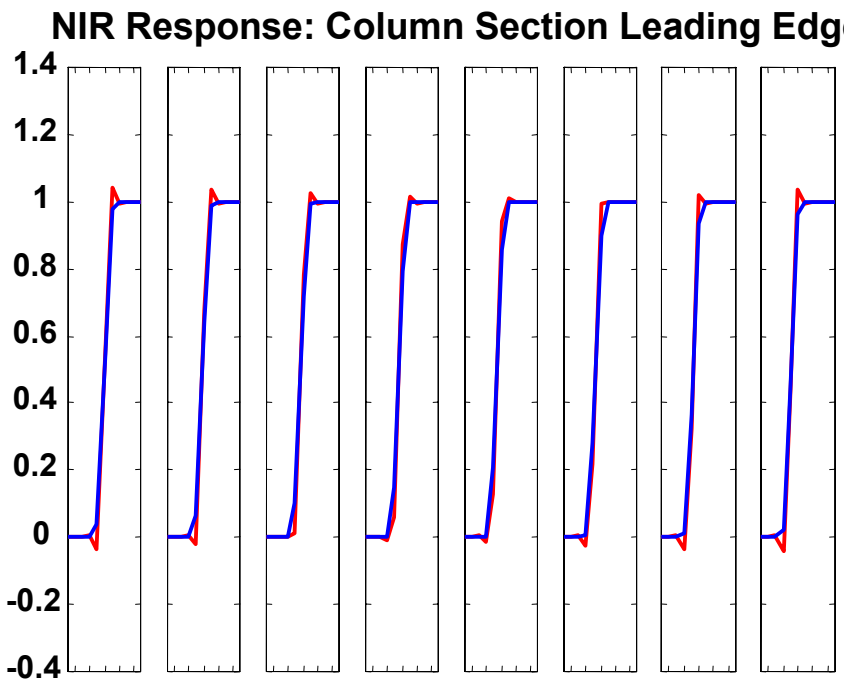




Overshoot more pronounce in row direction

# NIR Band MTFC Edge Response with Phasing

*Stennis Space Center*




NIR is more symmetrical than other bands

# Quantitative Analysis



- Intercomparisons
- Scatter plots
- Histograms

# MTFC ON/OFF Imagery Under Analysis

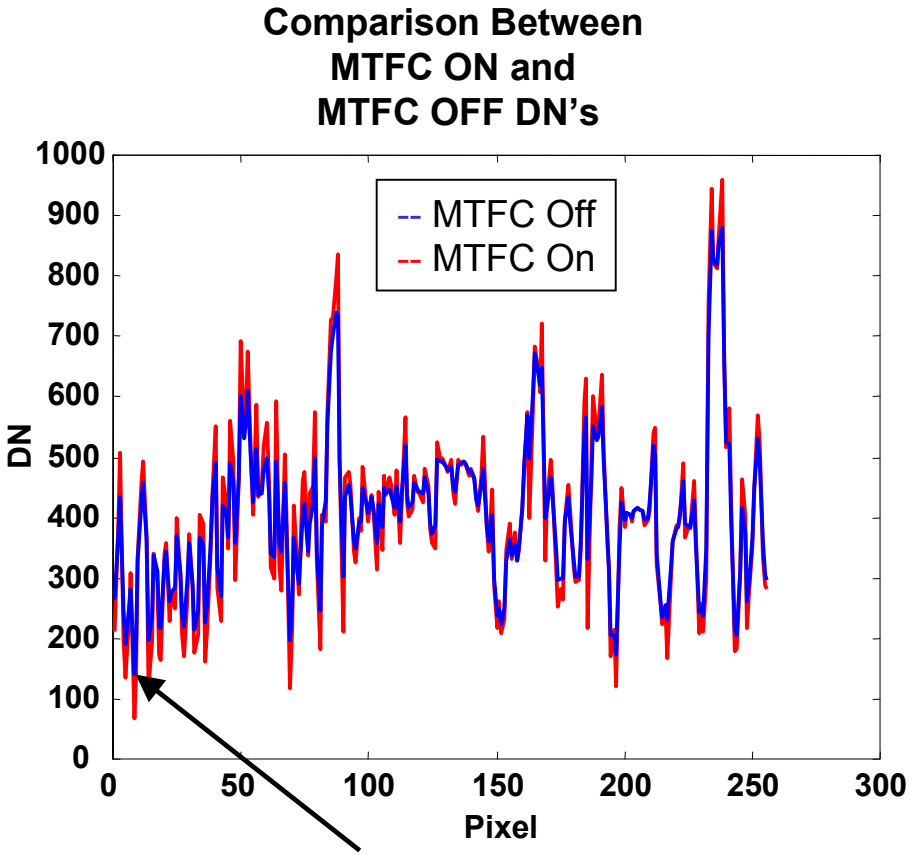


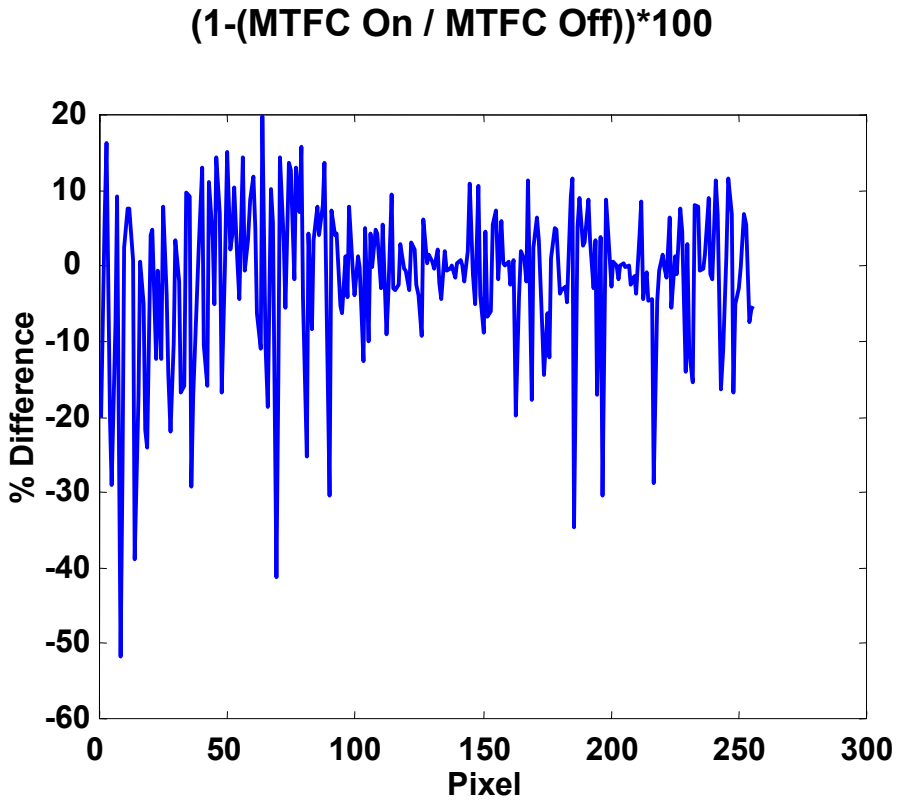
| SITE | MTFC ON PO ID # | MTFC OFF PO ID # | Purpose |
|---|---|---|---|
| Phoenix | 33667 | 33668 | Urban site with many edges |
| Tucson | 48561 | 51367 | Urban site with many edges |
| Lunar Lake | 39390 | 53143 | Radiometric site |

Most analysis has been done on Phoenix Imagery

# Example NIR Band Phoenix Cross Section



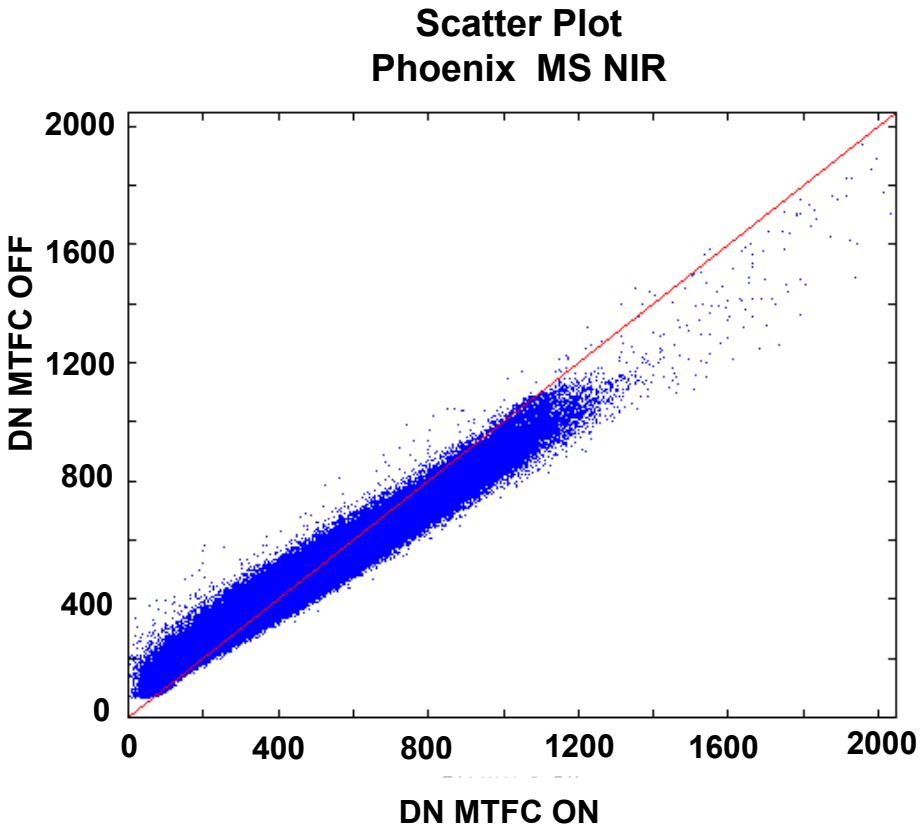


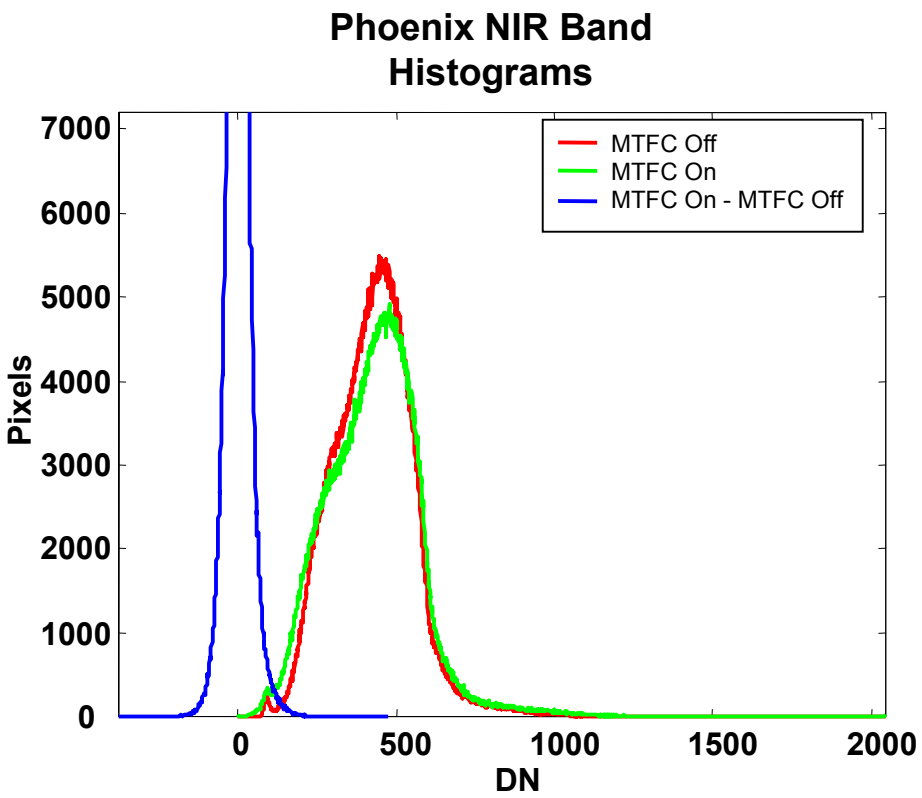




Regions with both large positive and negative swings can produce significant changes

# Phoenix Near IR Band






Some outliners are produced but mean of image is unchanged

# Phoenix Multispectral Statistics Summary

*Stennis Space Center*

| | Blue | | Green | | Red | | NIR | |
|---|---|---|---|---|---|---|---|---|
| | MTFC OFF | MTFC ON | MTFC OFF | MTFC ON | MTFC OFF | MTFC ON | MTFC OFF | MTFC ON |
| **Mean** | 328.3 | 328.3 | 412.5 | 412.5 | 397.8 | 397.8 | 426.9 | 426.8 |
| **Standard Dev** | 89.46 | 97.89 | 133.45 | 147.29 | 146.0 | 161.5 | 126.2 | 145.84 |
| **Min** | 153 | 0 | 135 | 0 | 83 | 0 | 65 | 0 |
| **Max** | 2047 | 2047 | 2047 | 2047 | 2047 | 2047 | 2047 | 2047 |
| **Max Diff** | 425 | | 444 | | 454 | | 427 | |
| **Min Diff** | -327 | | -307 | | -327 | | -378 | |
| **RMS Difference %** | 4.7 | | 5.9 | | 7.0 | | 7.6 | |

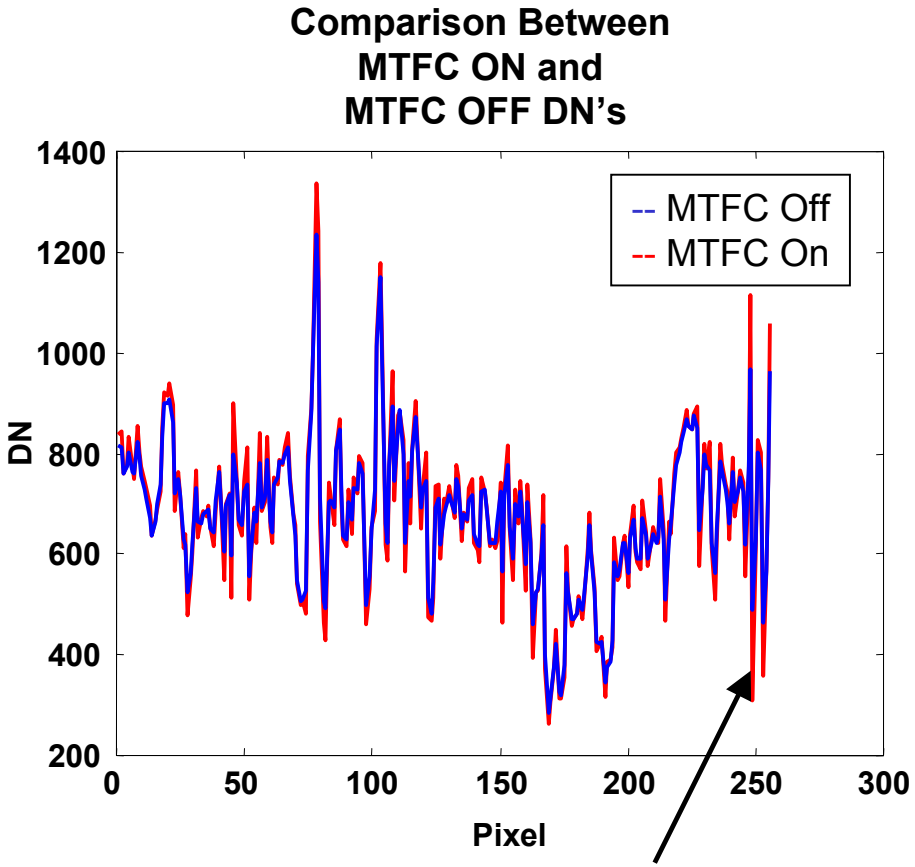
# Phoenix Panchromatic Statistics

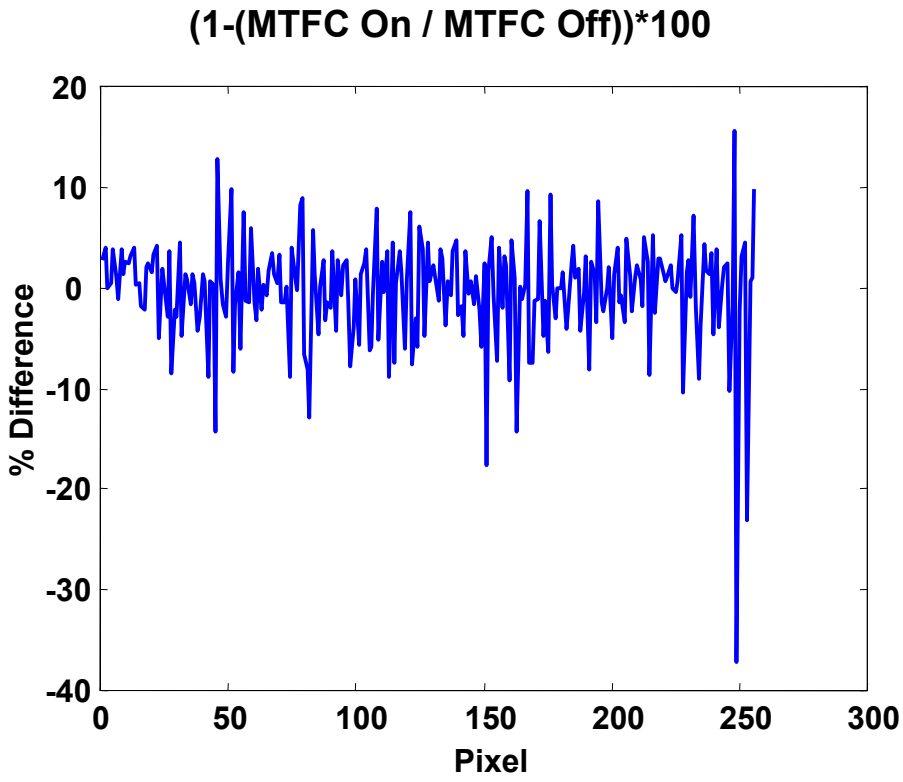


| Statistic | Panchromatic MTFC OFF | Panchromatic MTFC ON |
|---|---|---|
| **Mean** | 598.2 | 598.2 |
| **Standard Dev** | 183.6 | 205.2 |
| **Min** | 149 | 0 |
| **Max** | 1983 | 2047 |
| **Max Diff** | 844 | |
| **Min Diff** | -781 | |
| **RMS Difference %** | 8.5 | |

# Example NIR Band Tucson Cross Section





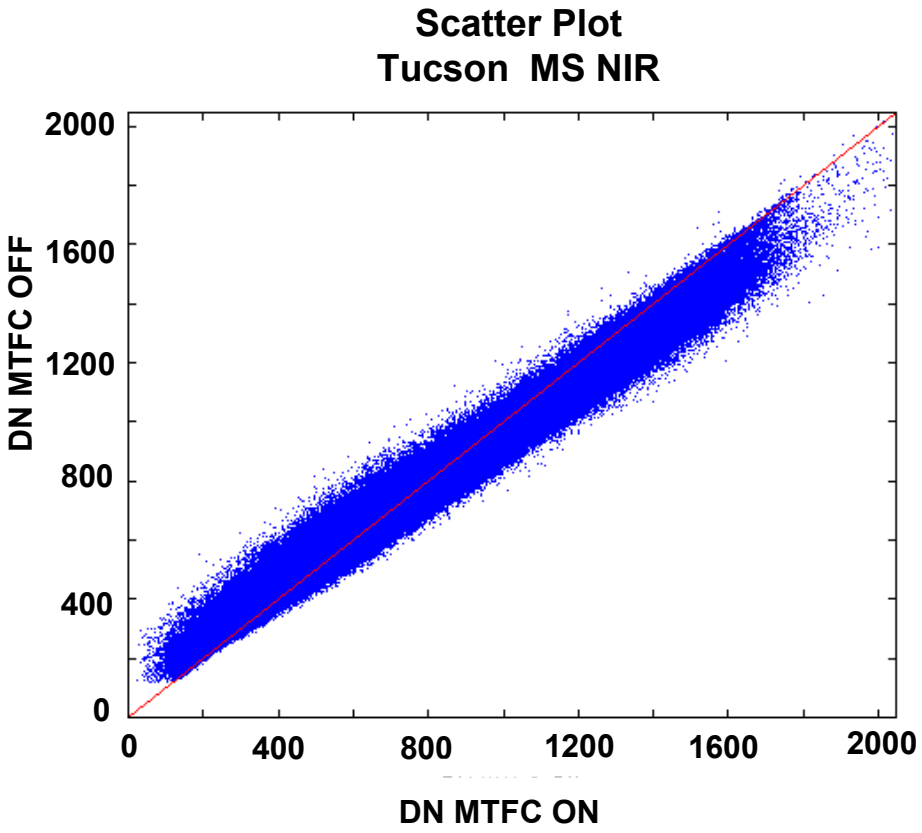



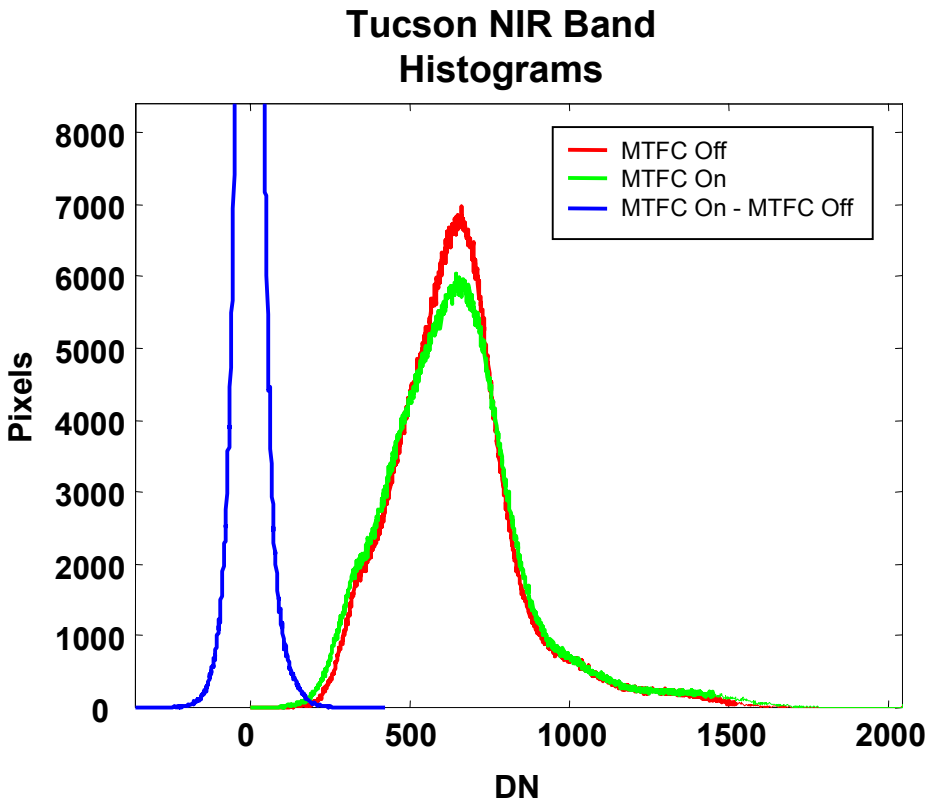

Regions with both large positive and negative swings can produce significant changes

# Tucson Near IR Band



New Tucson MS Near IR Histograms

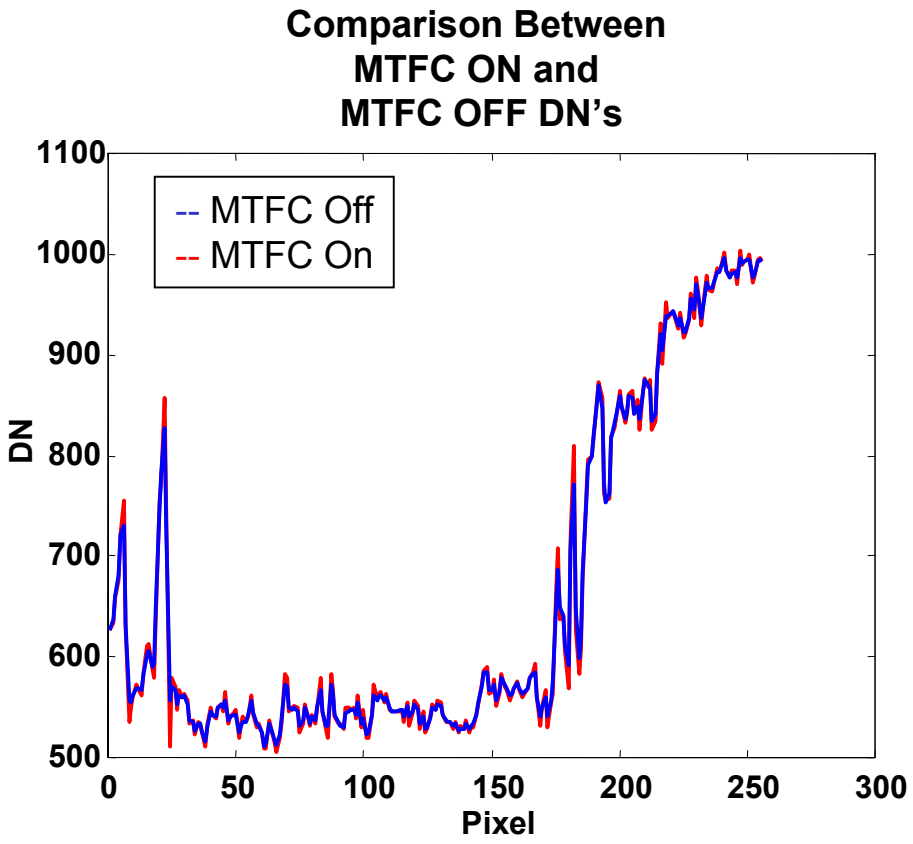


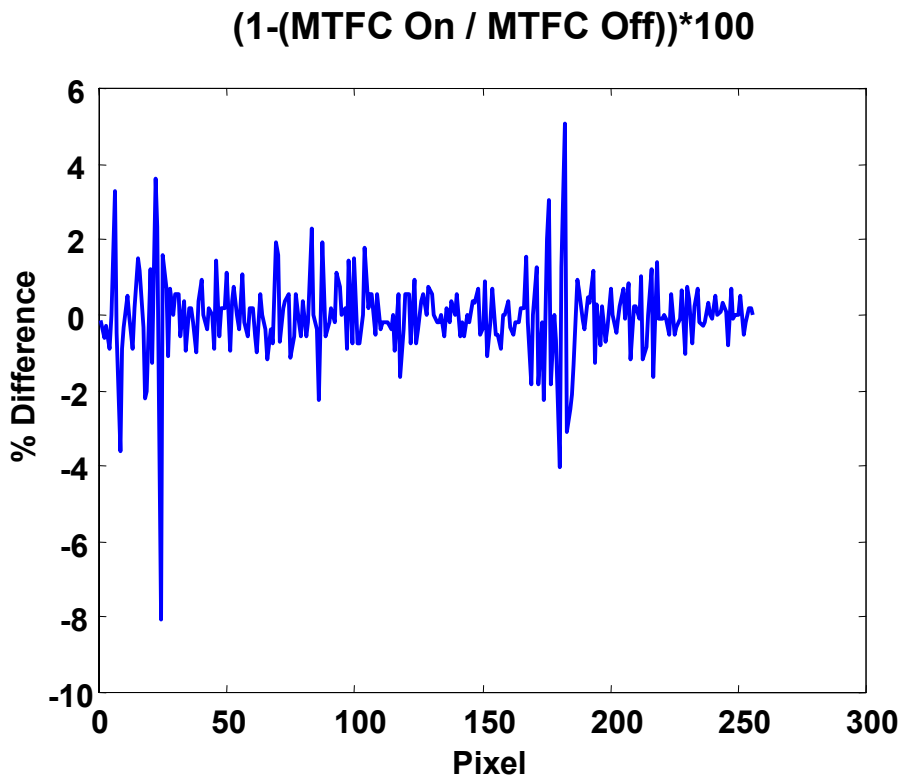




Some outliners are produced but mean of image is unchanged

# Example NIR Band Lunar Lake Cross Section

Stennis Space Center

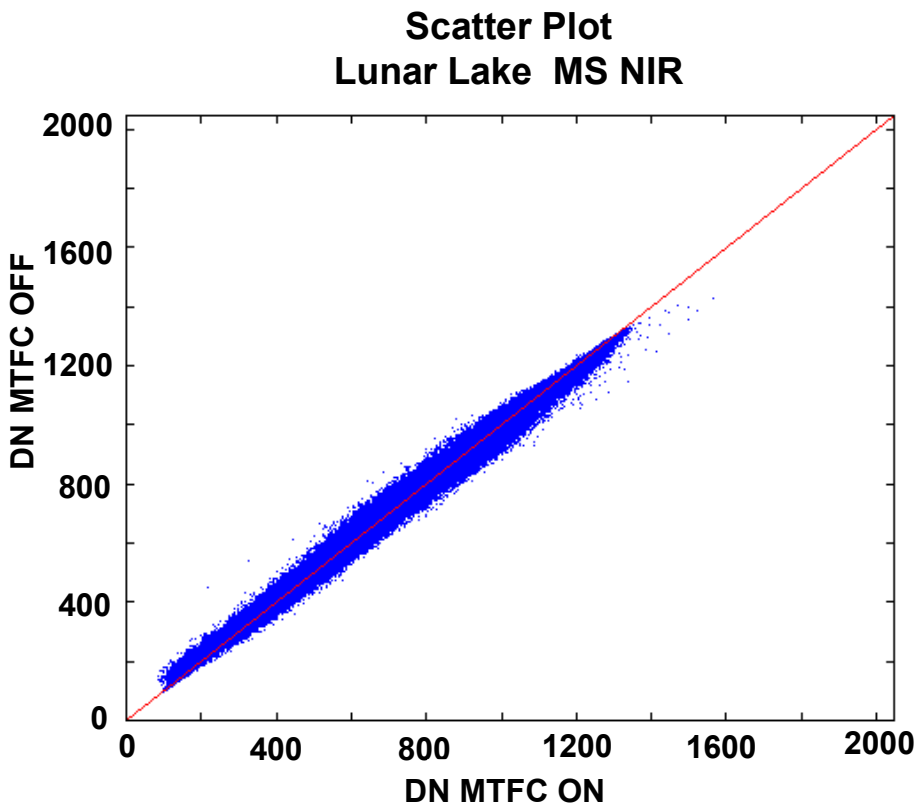


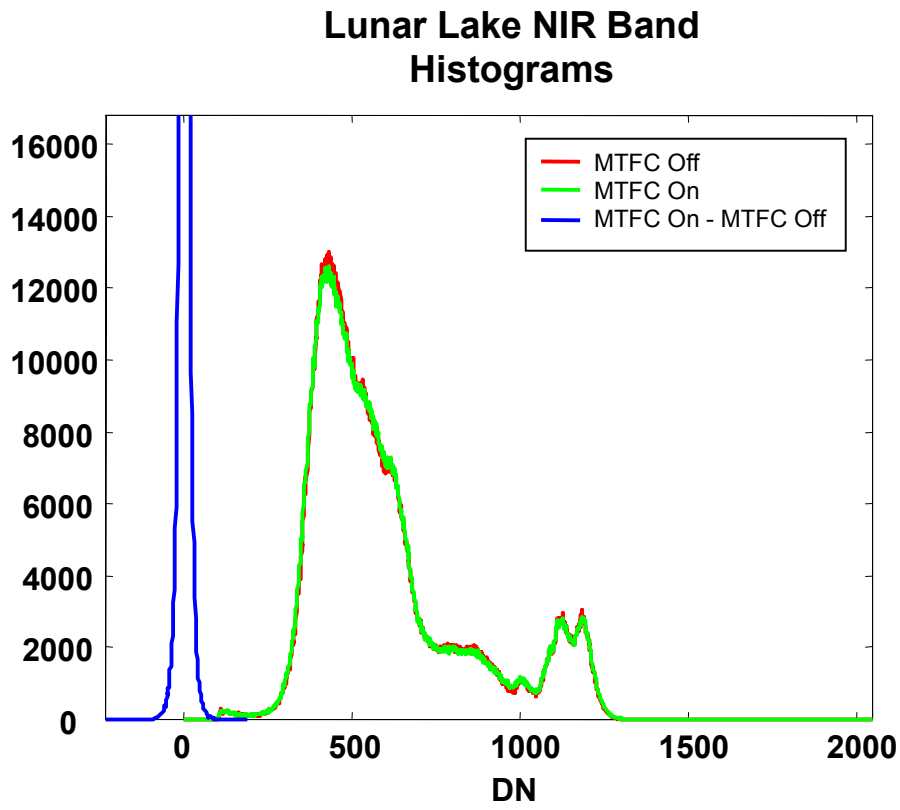




Highly uniform scenes do not show significant change between MTFC ON and MTFC OFF

# Lunar Lake MS NIR Band Histograms

*Stennis Space Center*




The histograms for MTFC ON and MTFC OFF do not show significant change

# Lunar Lake Multispectral Statistics Summary

*Stennis Space Center*

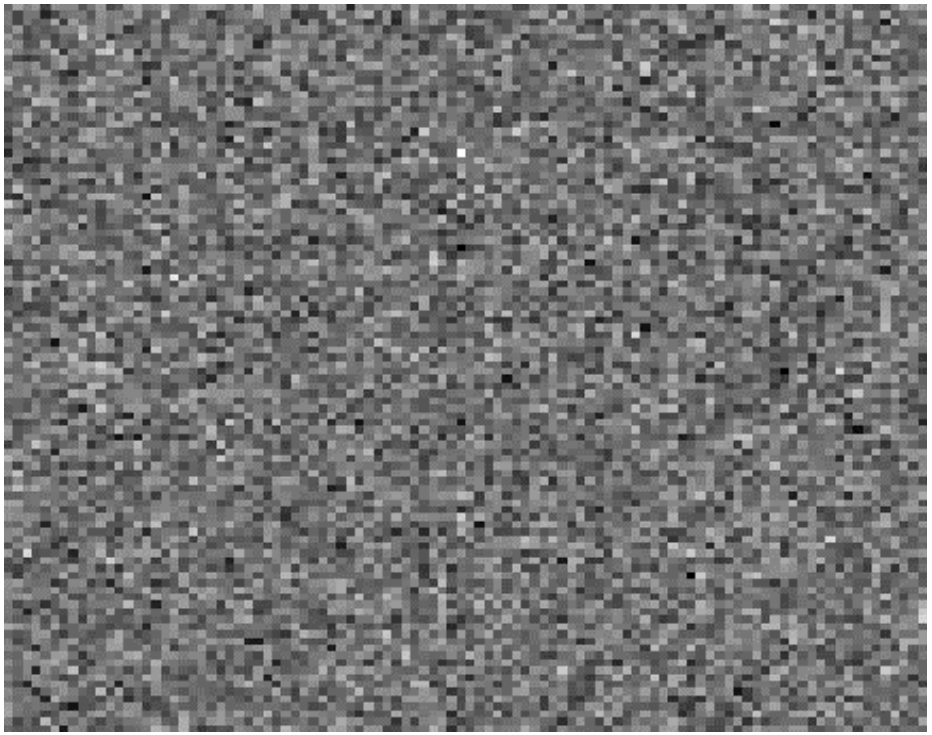
| | Blue | | Green | | Red | | NIR | |
|---|---|---|---|---|---|---|---|---|
| | **MTFC OFF** | **MTFC ON** | **MTFC OFF** | **MTFC ON** | **MTFC OFF** | **MTFC ON** | **MTFC OFF** | **MTFC ON** |
| **Mean** | 762.8 | 764.4 | 1089.3 | 1090.7 | 1104.4 | 1105.4 | 1020.7 | 1021.6 |
| **Standard Dev** | 8.13 | 11.37 | 12.76 | 17.71 | 13.12 | 17.64 | 13.14 | 17.91 |
| **Min** | 741 | 739 | 1058 | 1051 | 1070 | 1067 | 990 | 984 |
| **Max** | 782 | 800 | 1118 | 1138 | 1140 | 1157 | 1051 | 1067 |
| **Max Diff** | 31 | | 60 | | 49 | | 56 | |
| **Min Diff** | -26 | | -42 | | -38 | | -42 | |
| **RMS Difference %** | 1.5 | | 1.6 | | 1.7 | | 1.8 | |

Vicarious calibrations are not significantly impacted by MTFC ON or MTFC OFF

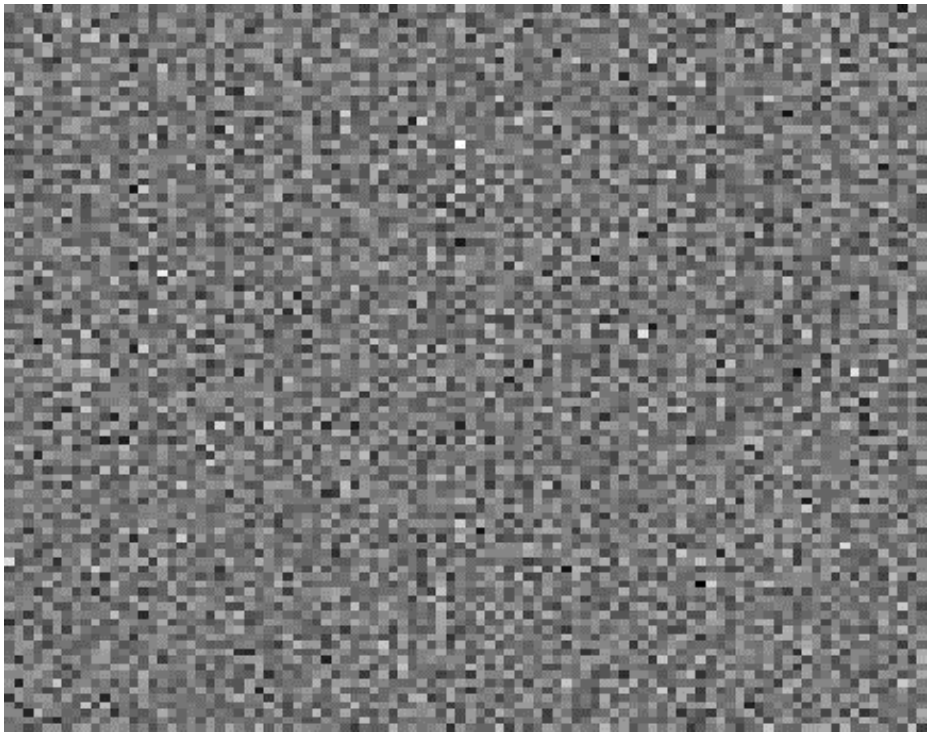
# SNR MTFC ON/MTFC OFF Imagery



NIR Kernel Applied to Simulated Imagery



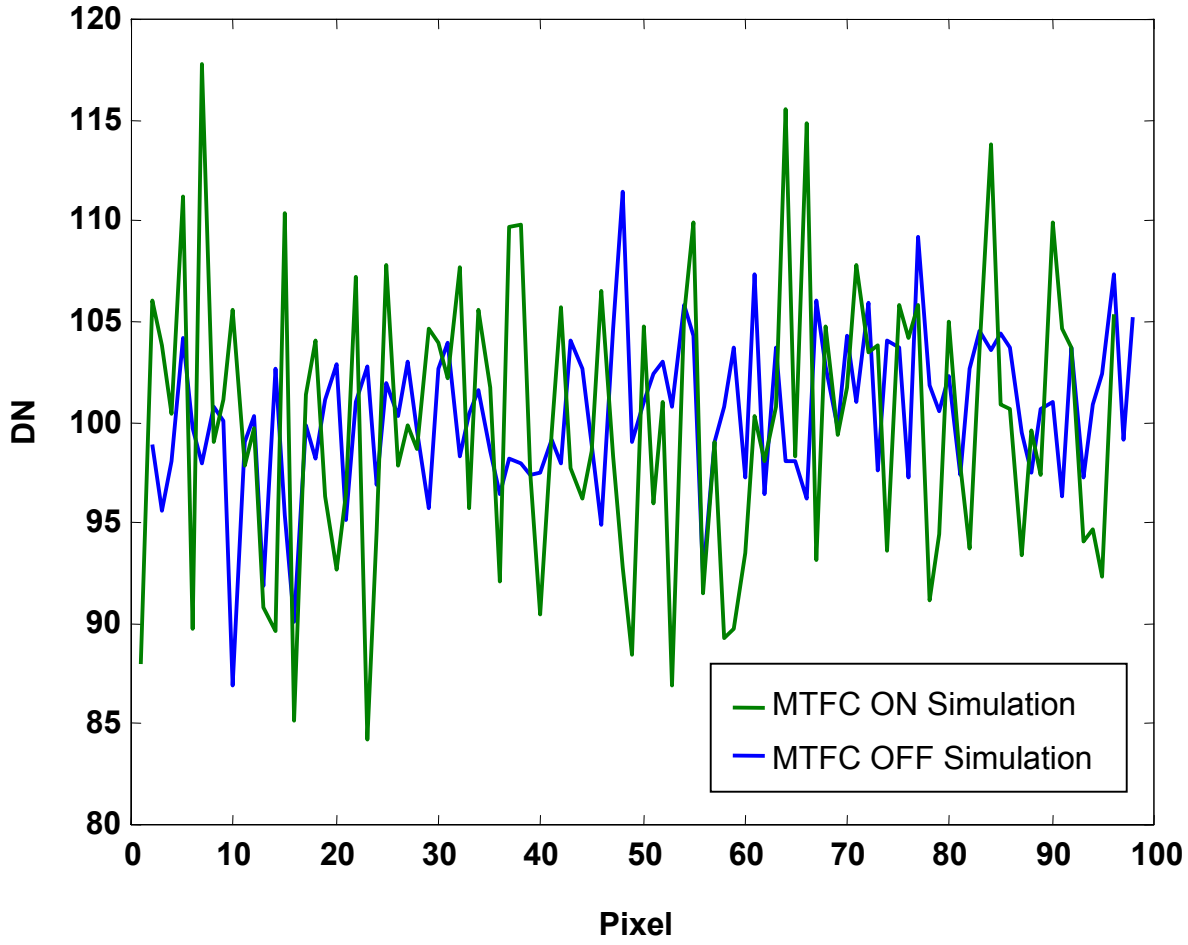
MTFC OFF SNR 25



MTFC ON SNR 13

# Intercomparison





# Summary



- **Significant radiometric differences between MTFC ON and MTF OFF imagery occur for some pixels**
- **Panchromatic MTFC much stronger than MS**
- **MS MTFC increases with increasing wavelength**
- **MS MTFC stronger in row direction then in column direction**
- **Radiometry comparisons involving averaging of many pixels (L7, MODIS) will not be effected**
- **Simulations indicate SNR for MTFC ON is less than MTFC OFF imagery (~50% for NIR Band)**