

Spatial Quality of Landsat-8 OLI Lunar data (Edge Slope, RER, FWHM, MTF)

(with 89 Lunar data) (Spline fitting)

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Purpose

- **Measuring the Spatial Characteristics from Landsat-8 OLI Lunar data (Level 1R)**
 - ✓ Edge Slope, RER, FWHM, MTF
- **Major Initial Considerations**
 1. Not Geometric Corrected
 - a. CCD Geometry
 2. Not Circle (Level 1R)
 3. Not Uniform Brightness
 4. Shadow area

LO800U0006422013175LGN00
Level 1R, Band_8, PAN, SCA_8

I'm not a DOG~!
A lonely Wolf...*^^*



Assumption & Uncertainty

1. Minor initial effects

- a. Almost circle of Lunar data after Geometric corrected (Level 1R)
- b. Symmetric LSF each direction of Landsat-8 OLI
- c. Outer line of Lunar data is almost circle line at the Landsat 8 resolution (30m)
- d. Brightness variation in one Step angle (Pie)
- e. Inflection point on LSF may be the starting point of Bright & Dark area
- f. 0.5 on ESF is the center of RER by Fermi-Dirac fitting

2. Geometric Correction with CCD Geometry (Minor initial effect)

- a. Scanning rate on Pitch for imaging the Moon may be Constant.

3. Drop out the low reliable angle's values

- a. Big Brightness variation in one Step angle (StdDev_B_Y) (> 0.065)
- b. Angle: 0, 90, 180, 270, 330deg
- c. etc.

Step to Calculate (1/6)

4.c

1. Decide Initial value

- Step angle (Pie): '5 deg'
- Fitting method: Spline & Fermi-Dirac (Symmetric LSF)
- Width of Bright/Dark area from Starting point: '1 pixel'

2. Read CPF & Get the CCD Geometric data

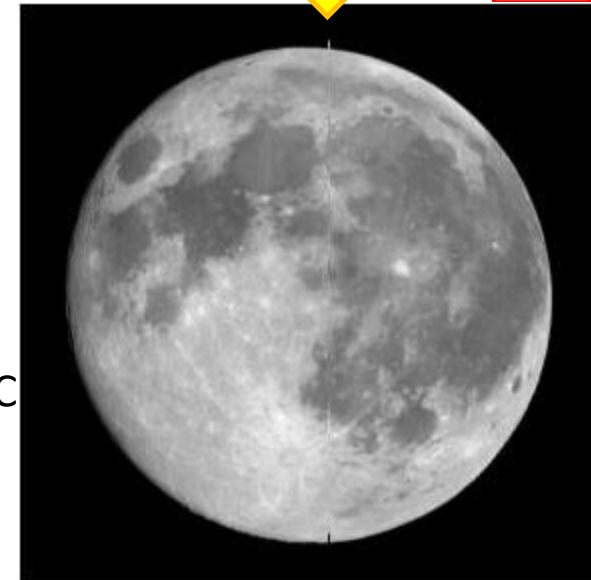
- Get 'OLI_FOCAL_PLANE' & 'OLI_DETECTOR_OFFSETS' in C
- Band: 9, SCA: 14
- Save them into 'MAT' file for Matlab

3. Read L8 Lunar data (Level 1R), HDF5 & temp Mapping XY

- Search the Number of SCA that has Lunar data
- Read Legendre & Offset with Band & SCA from (2.c)
- temp Mapping XY(Along & Across) from Legendre & Offset

4. Search, Subset & Display the only Lunar data

- Search & subset the area of the Lunar data on the whole image
- Make temporarily circle(?) Lunar data by applying with nearly offset '2' & nearly '8'
(2 x 8 = 16)
- Display it



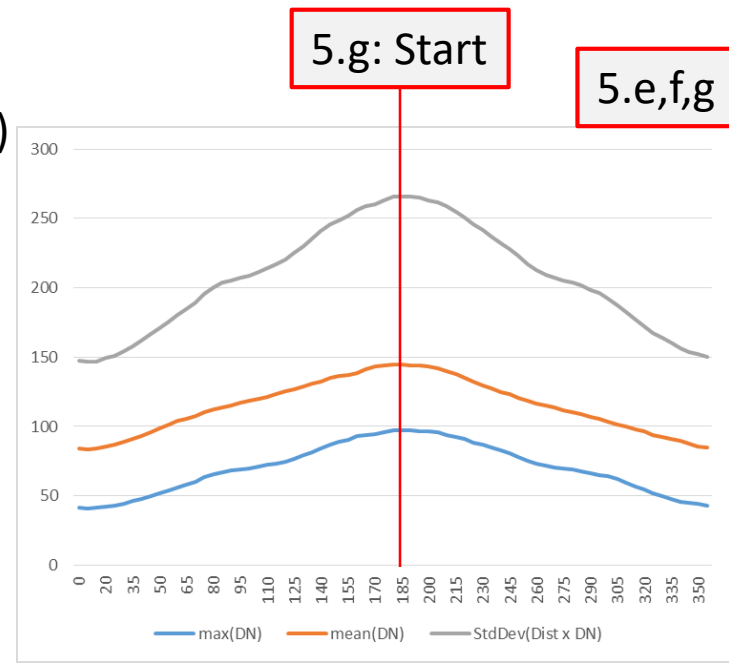
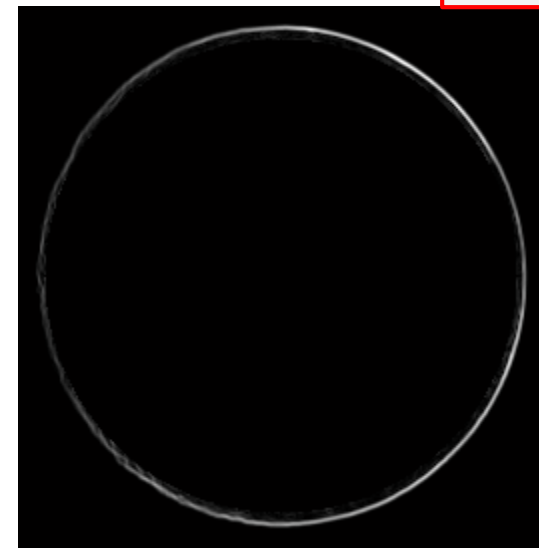
LO800U1631352013145LGN00
Level 1R, Band_7, SCA_10

Step to Calculate (2/6)

5.b

5. Find the Shadow angle range with the subset Lunar data (4.b)

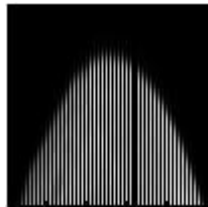
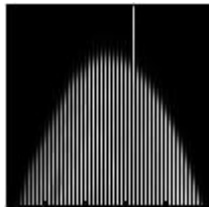
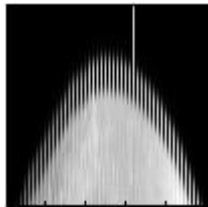
- a. 'imgradient(4.b)' in Matlab
- b. Remain the only Edge area from (5.a)
- c. Calculate the next value for every pixel in Edge area (5.b);
 - 1) Angle from temp center
 - 2) Distance from temp center
 - 3) DN
 - 4) Y, X (row, column)
- d. Calculate the next value for Step angle (1.a);
 - 1) StdDev(Distance * DN)
 - 2) Mean(DN)
 - 3) Max(DN)
- e. Calculate the next value for Step angle from (5.d)
 - a. Ang = 0 : (Step angle, 5 deg) : 355
 - b. Mean[(5.d)(Ang : Ang+180)]
- f. Shadow angle range is
 - 1) (Start) Min(5.e) ~ (End) Max(5.e)
- g. Edge angle range is
 - 1) (Start) Max(5.e) ~ (End) Min(5.e)



Step to Calculate (3/6)

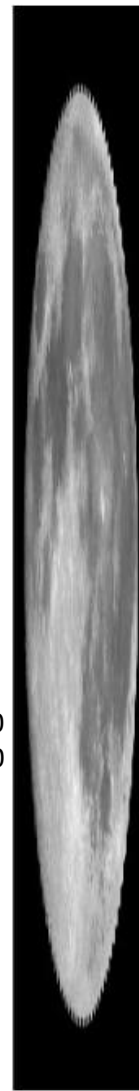
6. Get 'Alpha, deltaY(along) / deltaX(across)'

- Apply 'imgradient' in Matlab to the Lunar data
- Remove Odd or Even detector data
- Remove Peculiar detector data
- Remove the Shadow angle range by (5.f)
- Ellipse fitting
- Get the next;
 - Center (x0, y0)
 - a (deltaY, along), b (deltaX, across)
 - Alpha = a / b



6.b,c

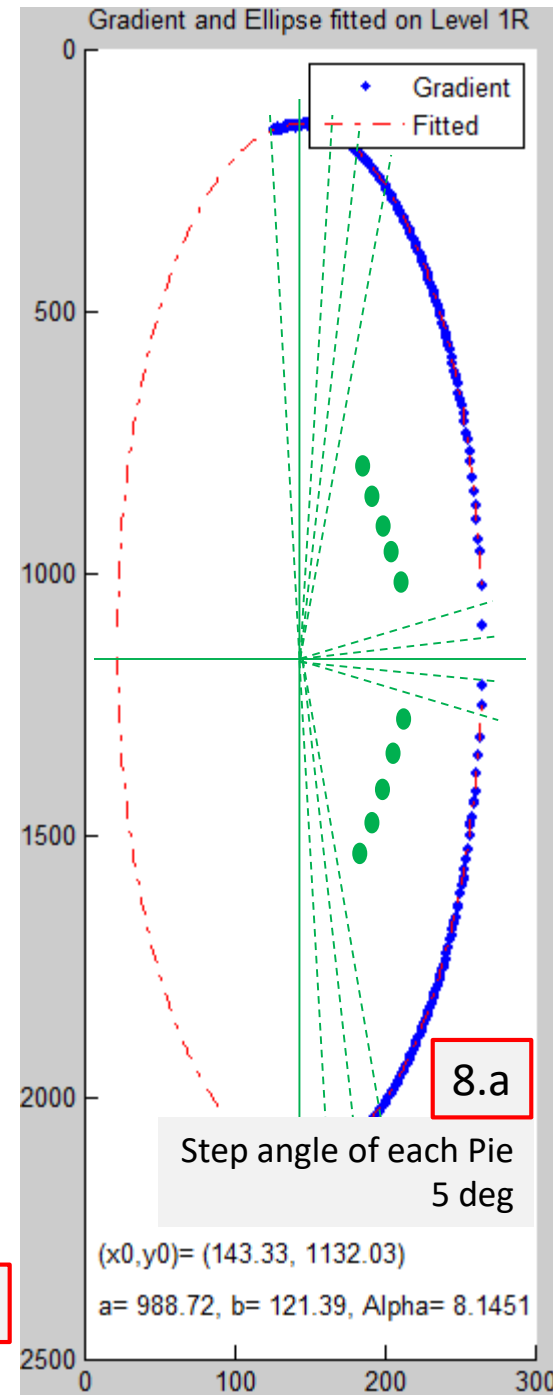
LO800U1631352013145LGN00
Level 1R, Band_7, SCA_10



7. Get the Final Map XY

- Multiply 'Alpha' to MapXY with the number of Row(Y) & Column(X) (integer) by the size of the subset Lunar data (4.a)
- Apply temp Mapping XY (3.c) to MapXY (7.a)

6.a,d,e,f

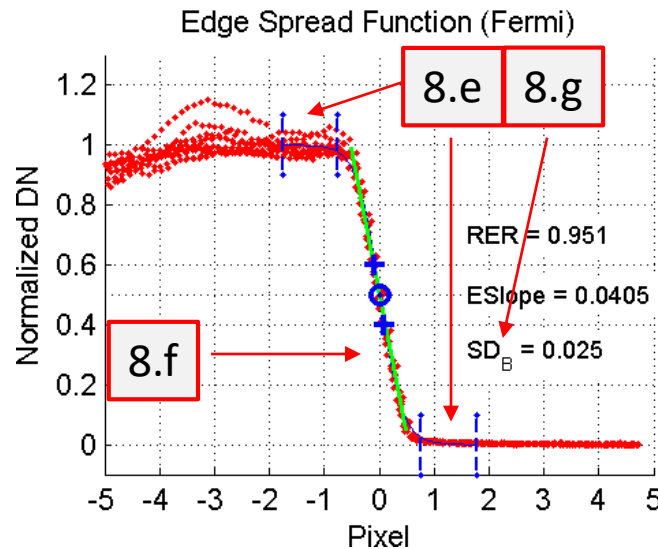
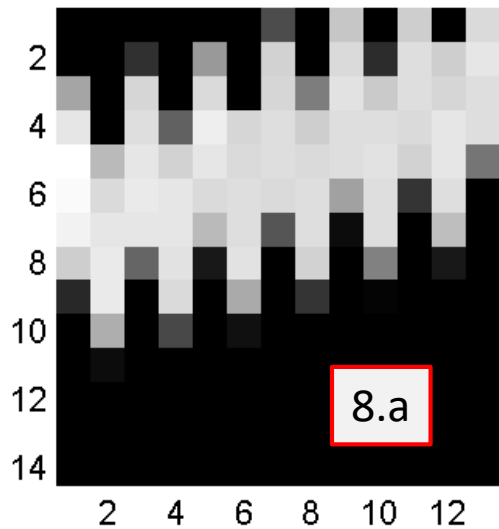


Step to Calculate (4/6)

8. Get ESF (Edge Spread Function)

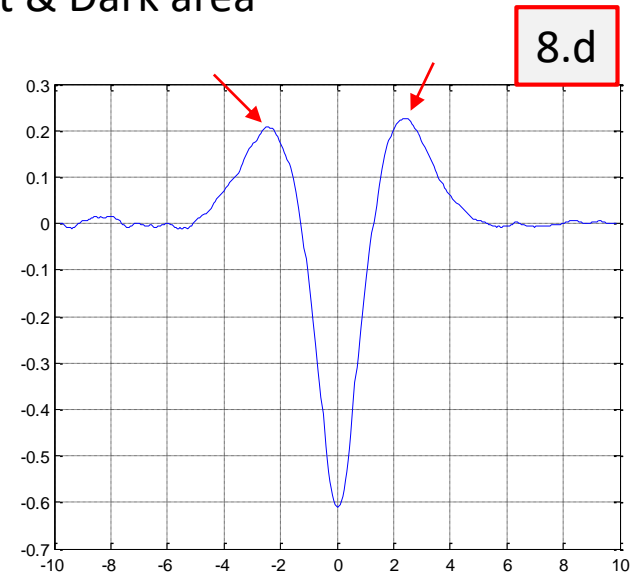
- Divide Pies by Step angle (5 deg) on L1R Lunar data
- (X-axis) Every pixel's distance from the center (6.d.1) of the L1R Lunar data to MapXY (7.b)
- (Y-axis) Every pixel's DN
- Getting the Inflection points in LSF by 'CSAPS' in Matlab fitting (TBR)
- Trim the Bright & Dark area with 1 pixel (TBR) width from the inflection points
- Fitting ESF by Spline (CSAPS in Matlab) Fermi-Dirac function (L8 OLI symmetric LSF)
- Calculating the Standard Deviation of X & Y at Bright & Dark area

Edge in each Angle (195 deg)



(8.b)

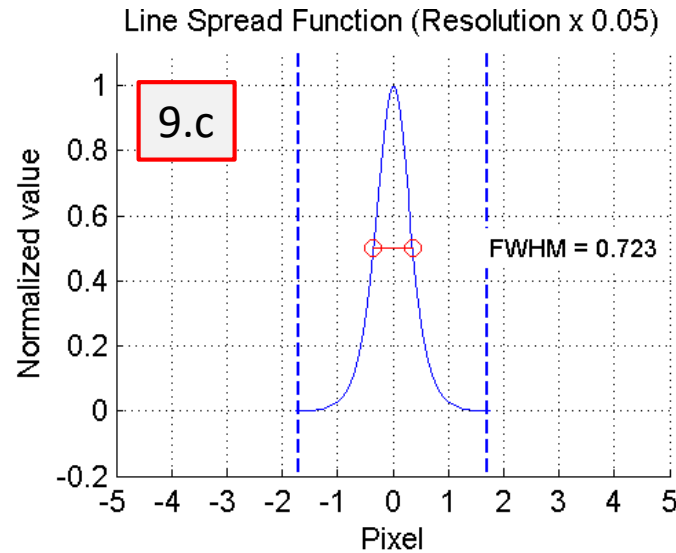
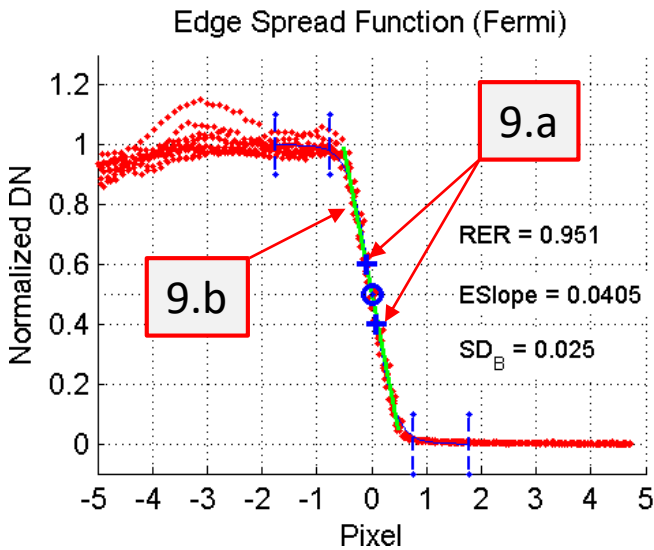
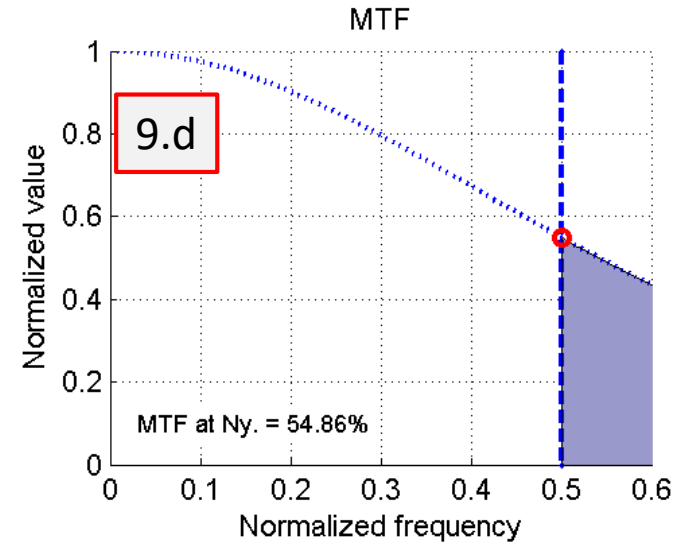
X-axis: Distance from Center to a Pixel



Step to Calculate (5/6)

9. Getting Edge Slope, RER, FWHM, MTF at Nyquist fr.

- Edge Slope between 0.4 and 0.6
- RER at 0.5 on ESF
- FWHM
- MTF value at Nyquist fr.



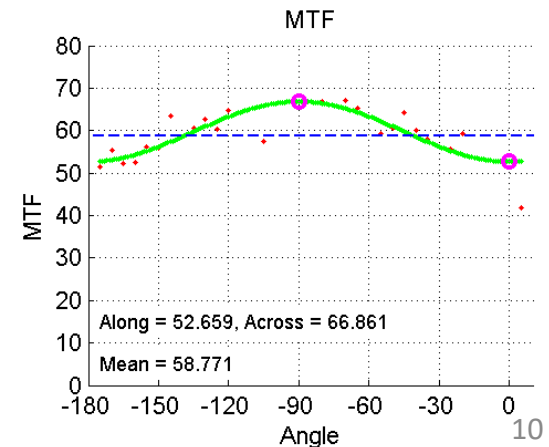
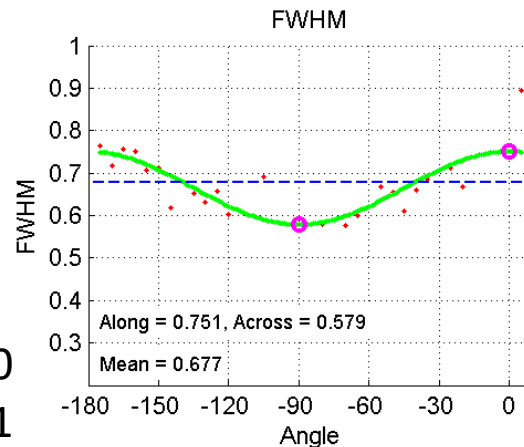
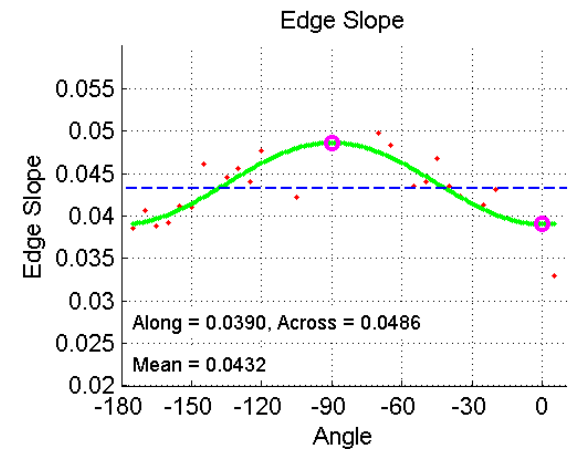
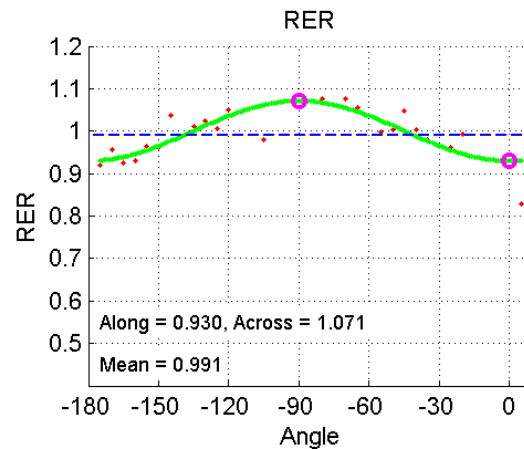
Step to Calculate (6/6)

10. Get the plot of RER, FWHM, MTF by each Step angle(pie)

- Plot by 0~360deg except the Shadow area by 5deg
- Drop out the low reliable results with the bad conditions

11. Get Mean, Along & Across

- (Mean) Average
- (Along) Value at angle 0, 180
- (Across) Value at angle 90, 270



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Level 1R, Band_1

Drop out the low reliable angle results (1/4)

1. StdDev

- $\text{StdDev_Y_min} < 0.02$
- $\text{StdDev_Y_max} > 0.065$ (Big Brightness variation in one Step angle)
- $\text{StdDev_X_min} < 0.2$

2. Biggest RER & Lowest RER

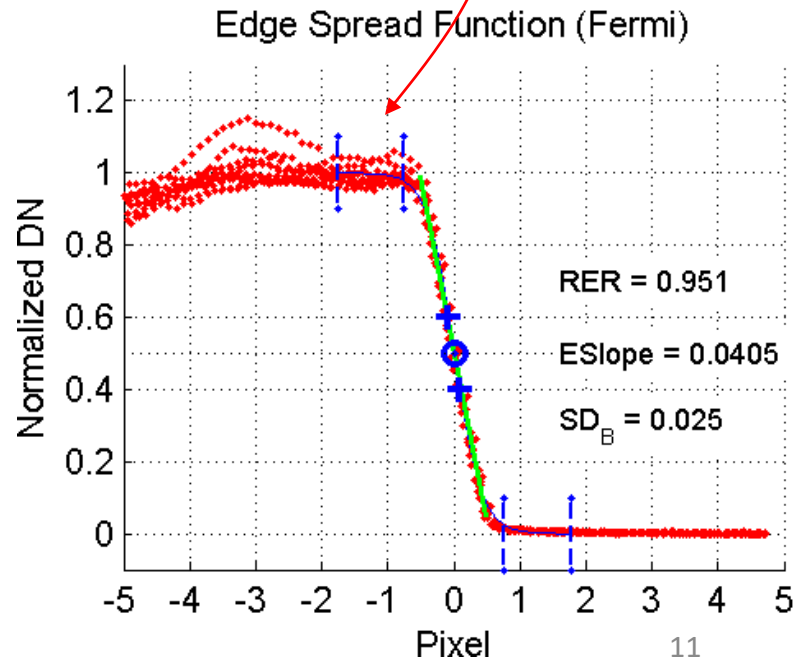
3. Angle

- 0, 90, 180, 270

4. Peculiar angle

- (Difference with adjacent angle > 0.15) & ($\text{StdDev_Bright_Y} > 0.065$)
- Difference with adjacent angle > 0.2

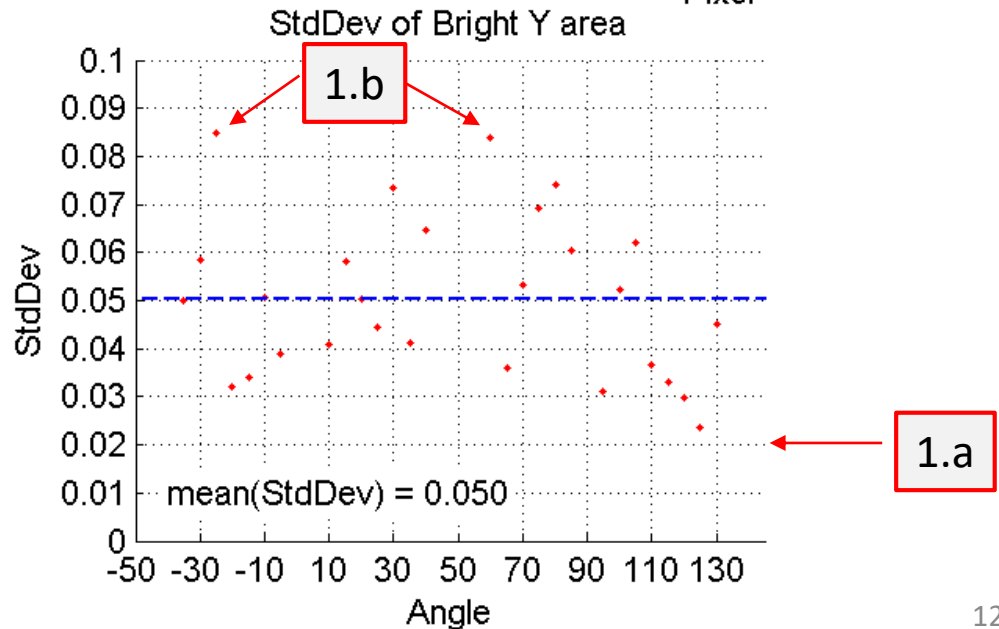
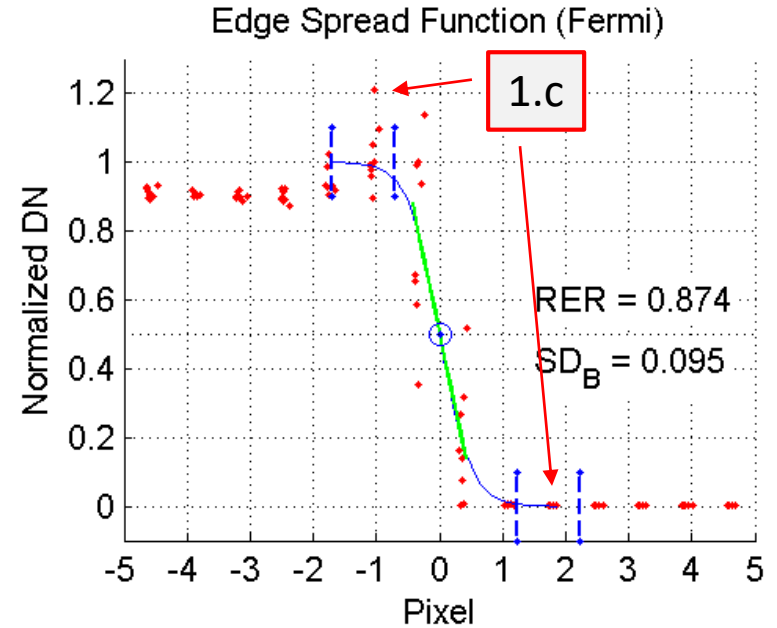
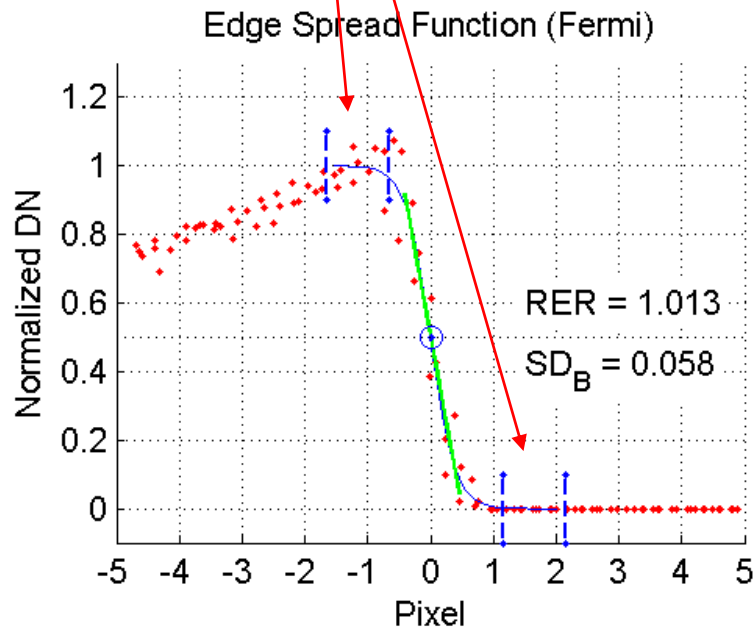
1.b



Drop out the low reliable angle results (2/4)

1. StdDev

- a. StdDev_Y_min < 0.02
- b. StdDev_Y_max > 0.07
- c. StdDev_X_min < 0.2
- d. StdDev_X_max < ?? (TBD)



Drop out the low reliable angle results (3/4)

1. StdDev

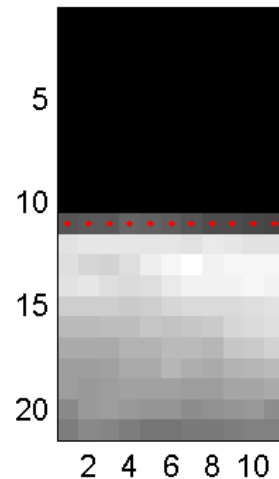
2. Biggest RER & Lowest RER

3. Angle

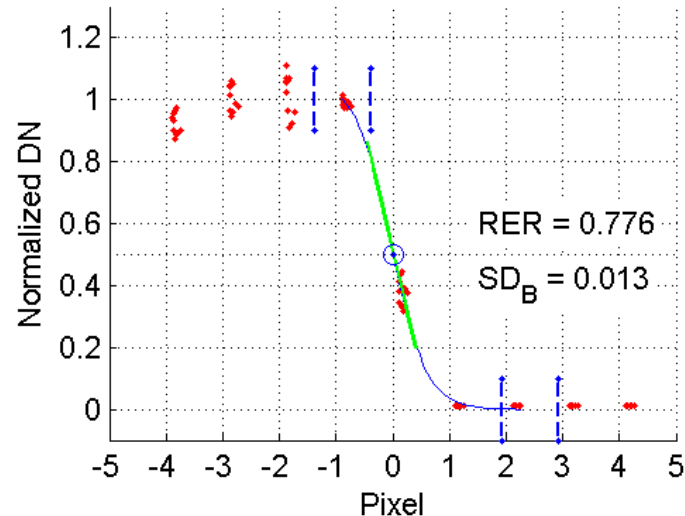
a. 0, 90, 180, 270

b. 330

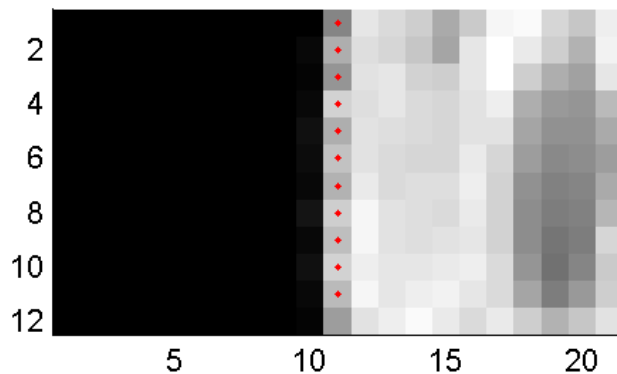
Edge in each Angle (0 deg)



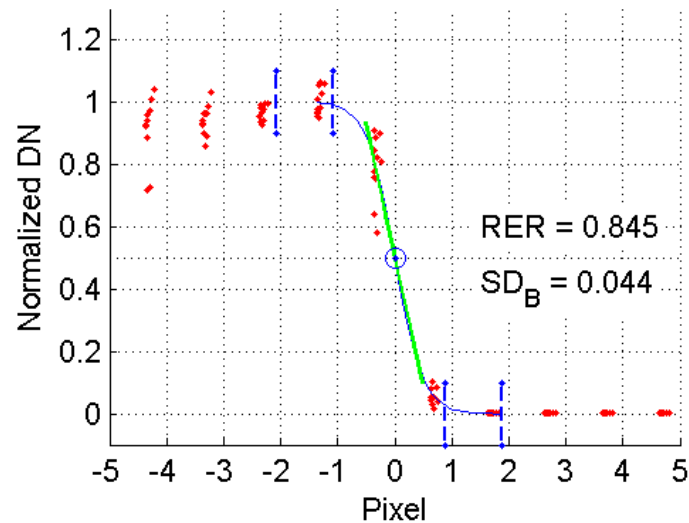
Edge Spread Function (Fermi)



Edge in each Angle (90 deg)

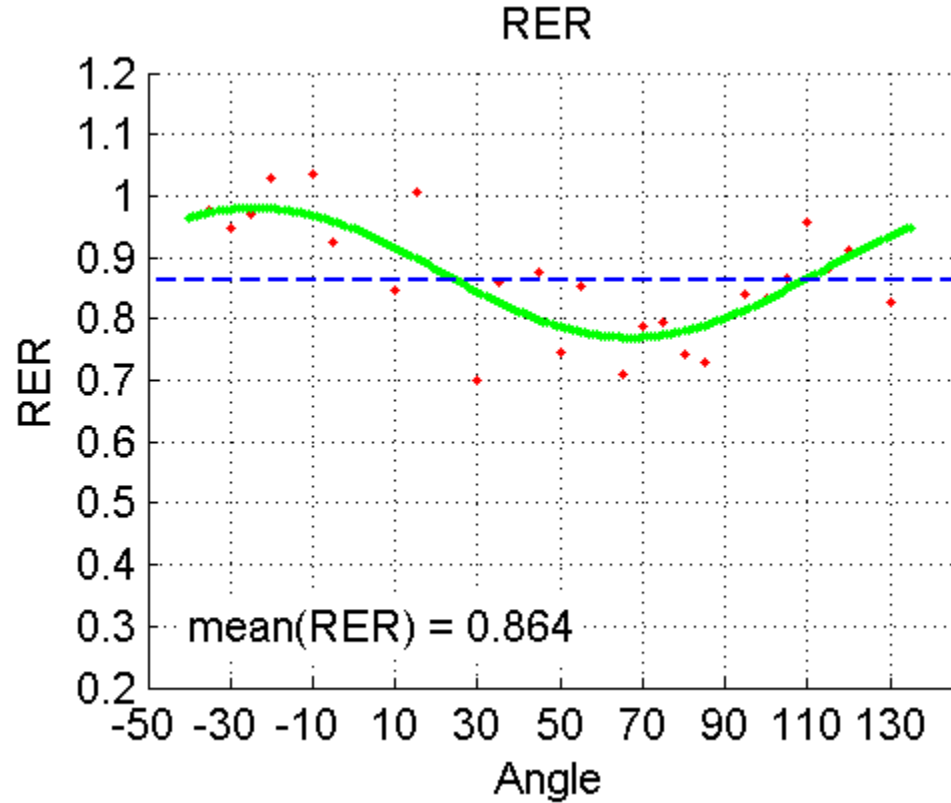
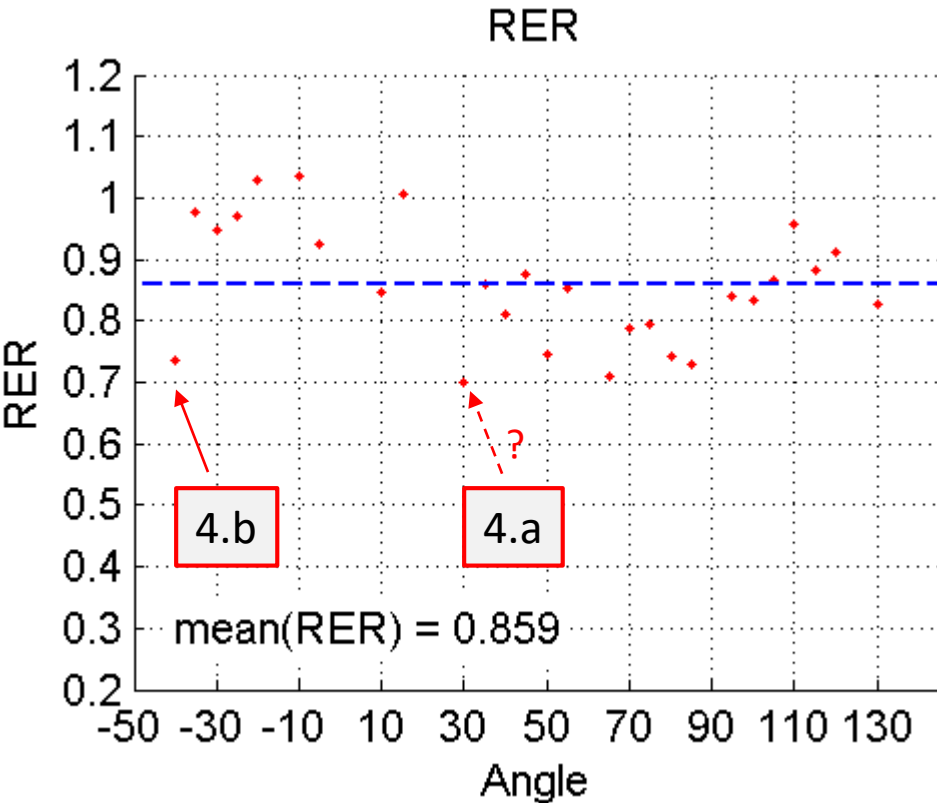


Edge Spread Function (Fermi)



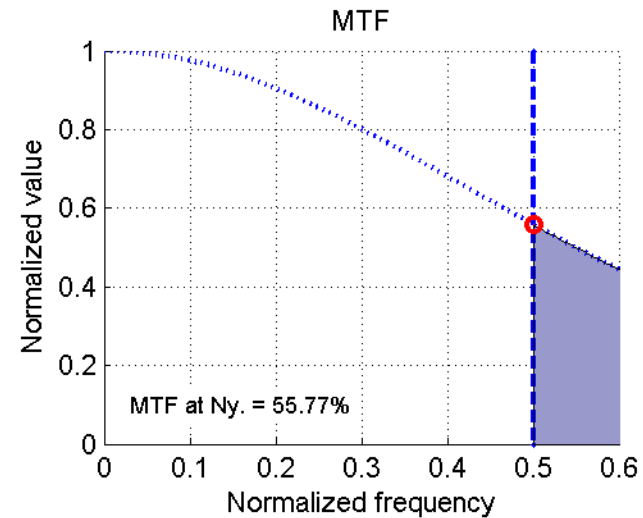
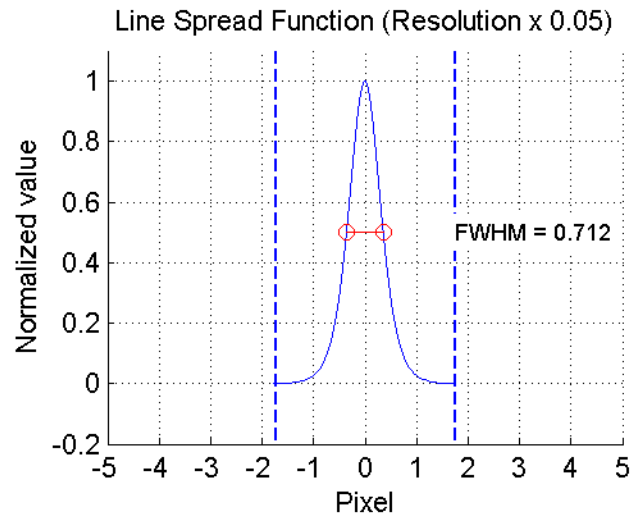
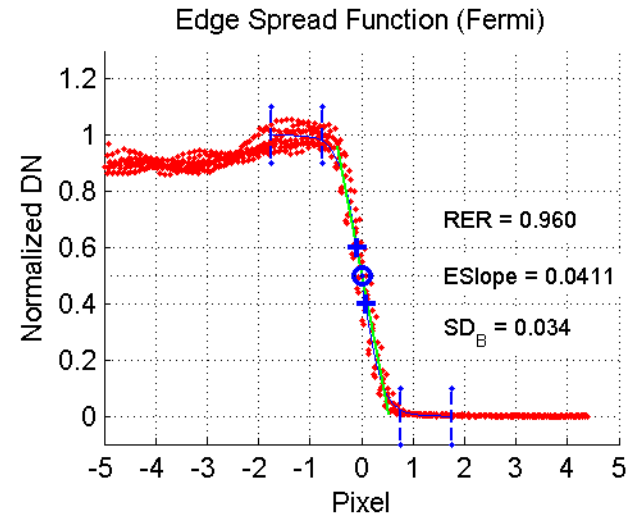
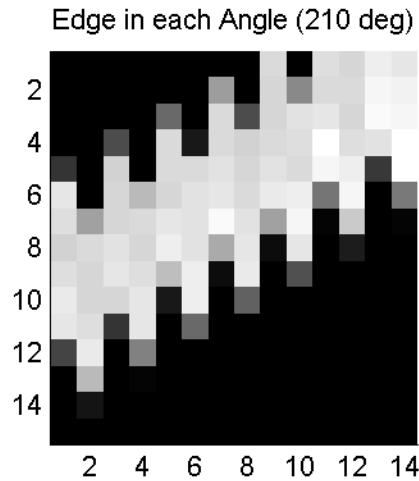
Drop out the low reliable angle results (4/4)

1. StdDev
2. Biggest RER & Lowest RER
3. Angle
4. Peculiar angle
 - a. (Difference with adjacent angle > 0.15) & (StdDev_Bright_Y > 0.065)
 - b. Difference with adjacent angle > 0.2



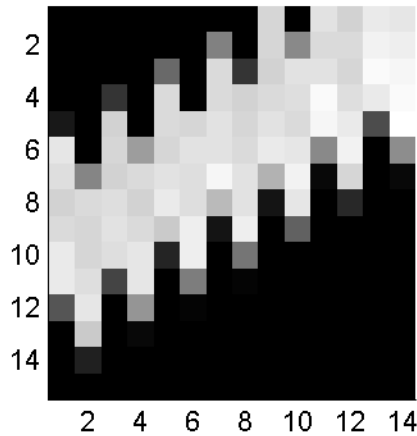
Results of L1R_LO800U0006422013175LGN00

ESF, LSF, MTF (Band_1, Angle: 210deg)

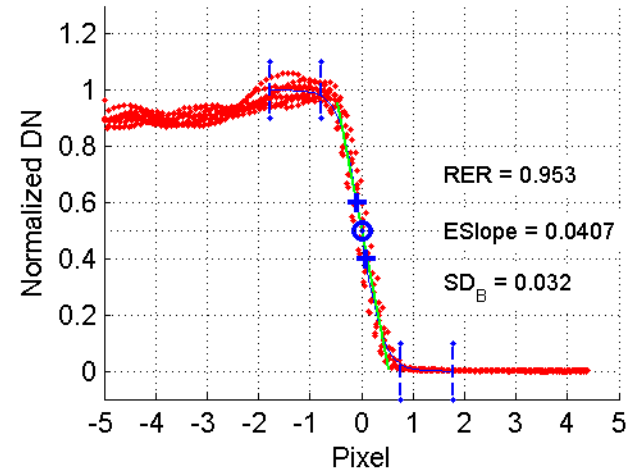


ESF, LSF, MTF (Band_2, Angle: 210deg)

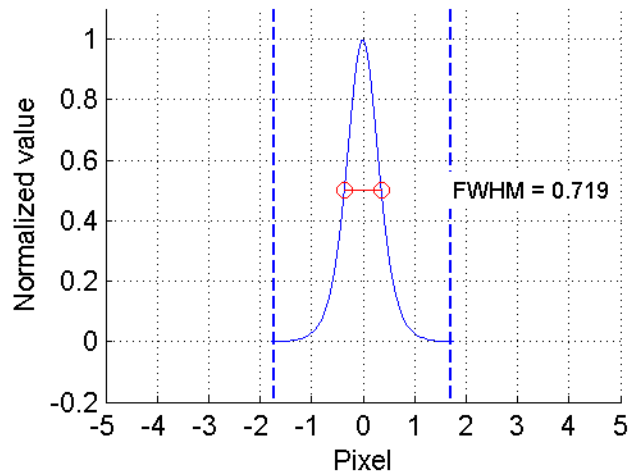
Edge in each Angle (210 deg)



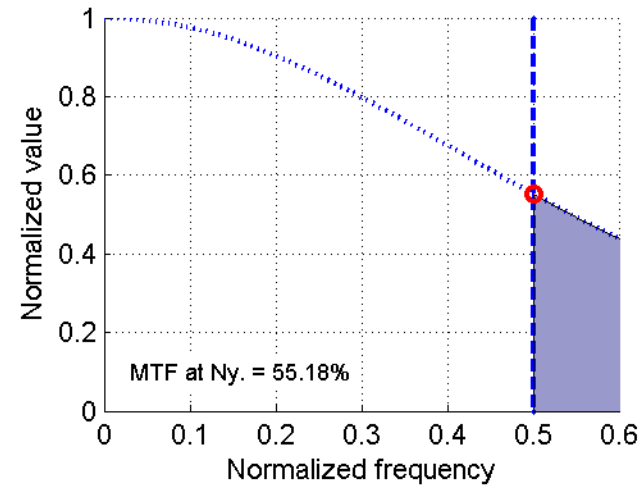
Edge Spread Function (Fermi)



Line Spread Function (Resolution x 0.05)

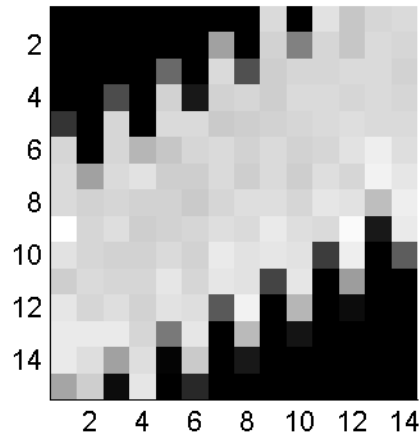


MTF

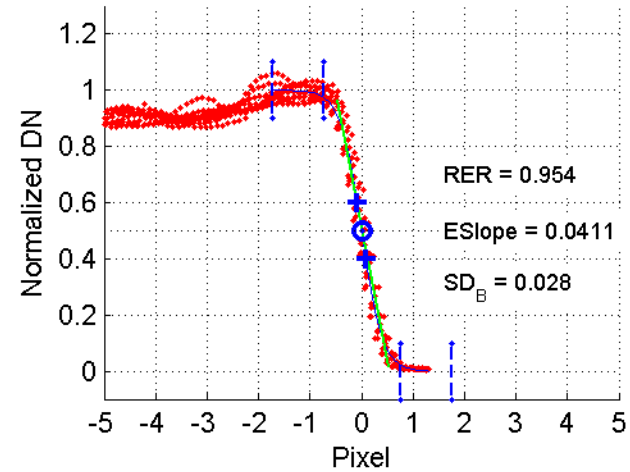


ESF, LSF, MTF (Band_3, Angle: 210deg)

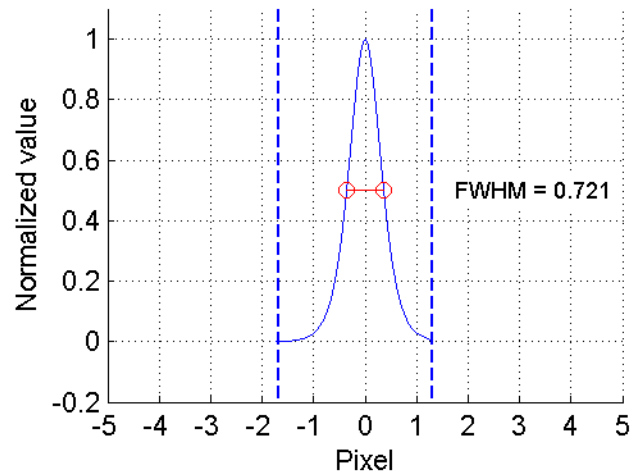
Edge in each Angle (210 deg)



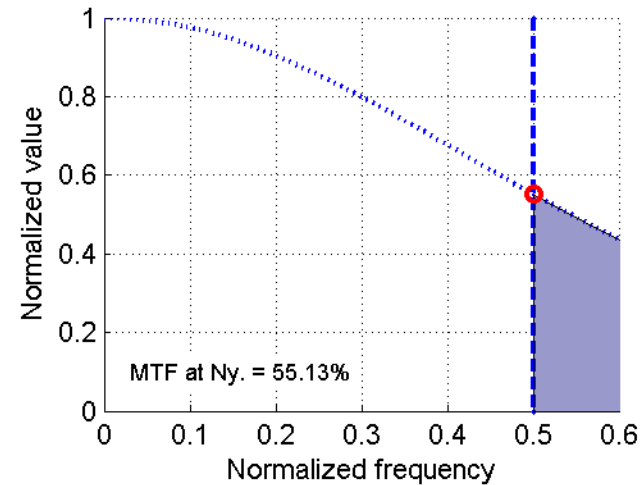
Edge Spread Function (Fermi)



Line Spread Function (Resolution x 0.05)

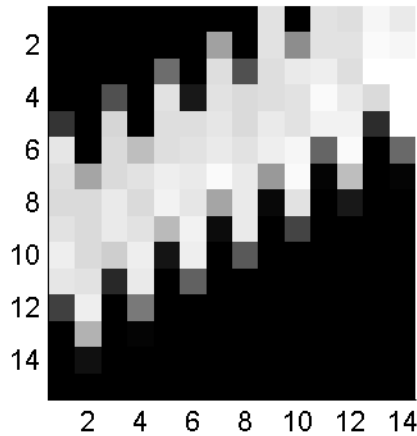


MTF

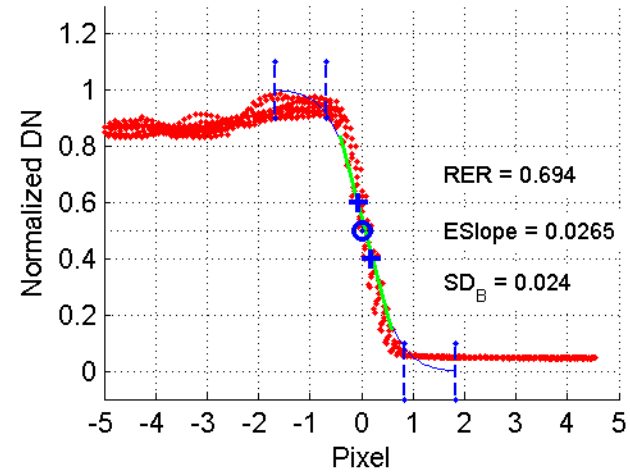


ESF, LSF, MTF (Band_4, Angle: 210deg)

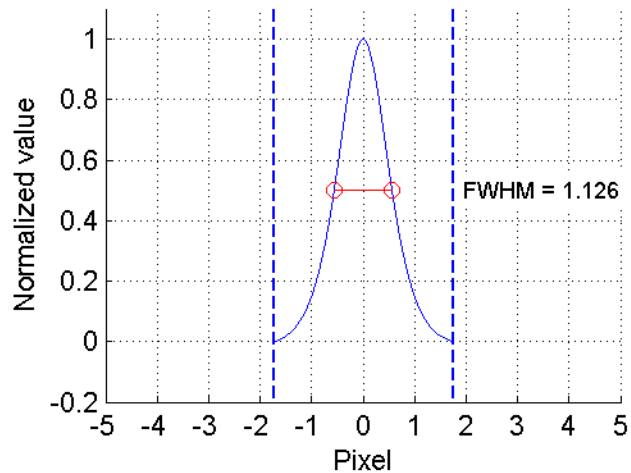
Edge in each Angle (210 deg)



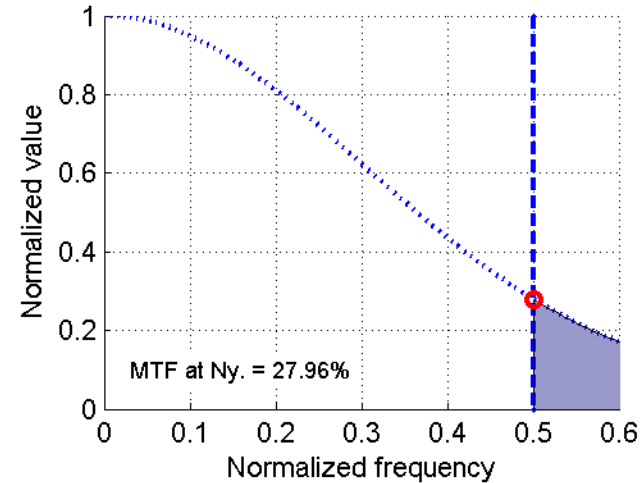
Edge Spread Function (Fermi)



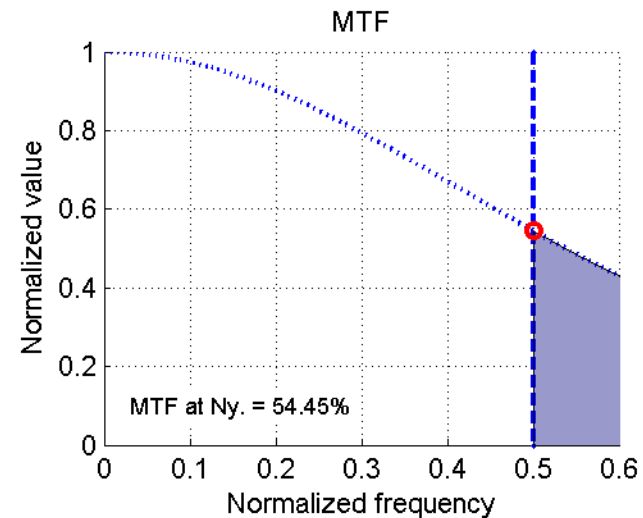
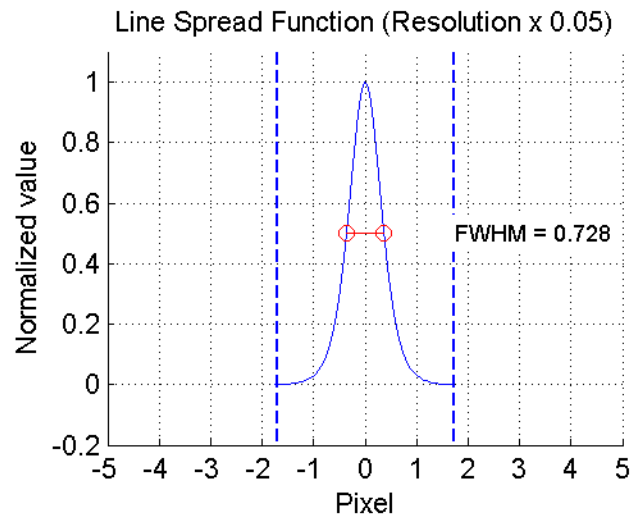
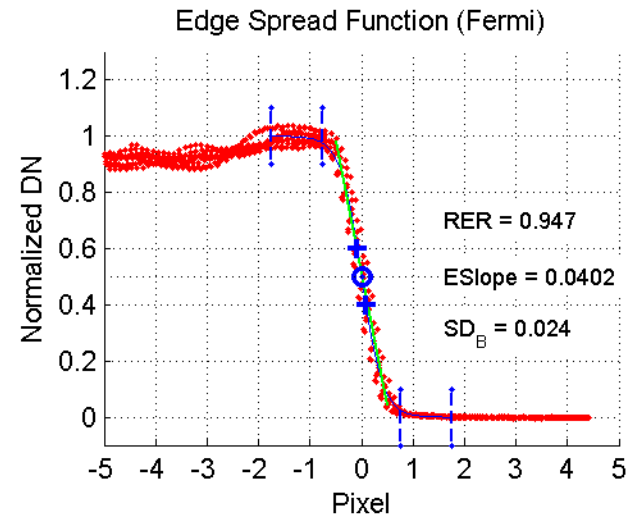
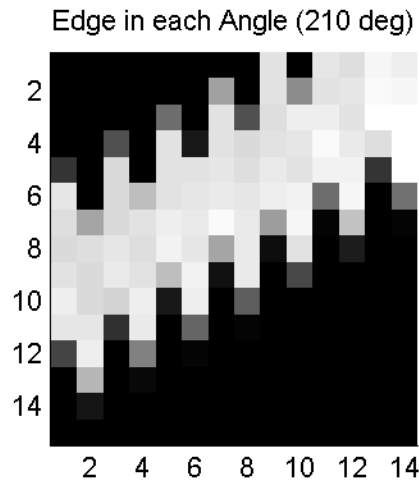
Line Spread Function (Resolution x 0.05)



MTF

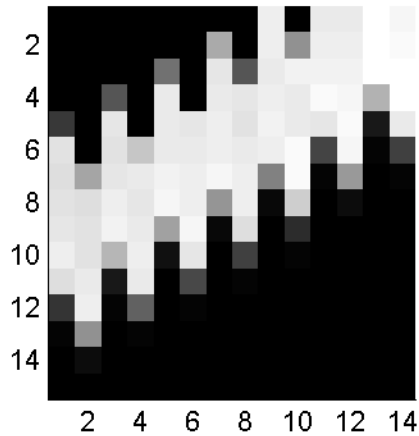


ESF, LSF, MTF (Band_5, Angle: 210deg)

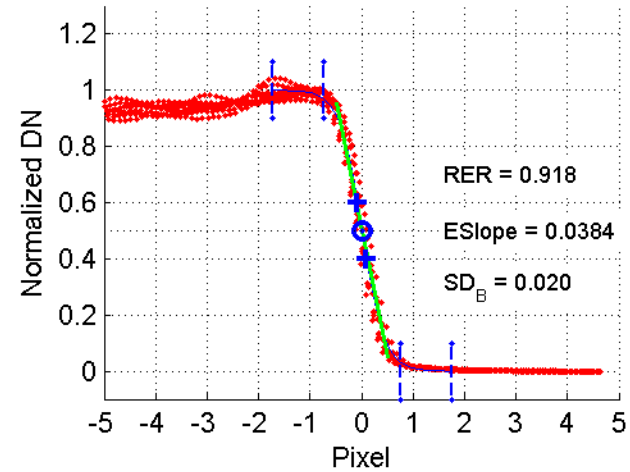


ESF, LSF, MTF (Band_6, Angle: 210deg)

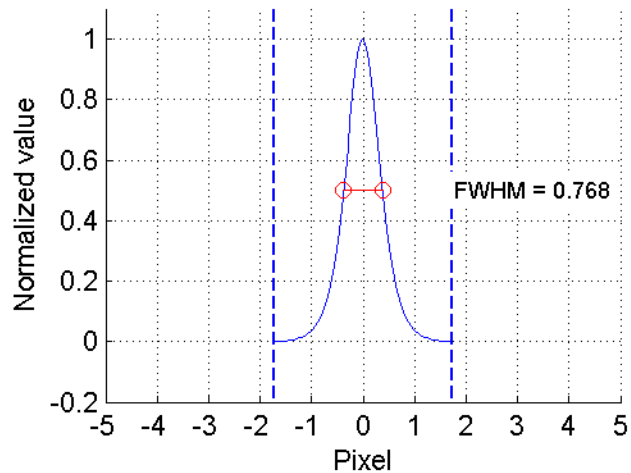
Edge in each Angle (210 deg)



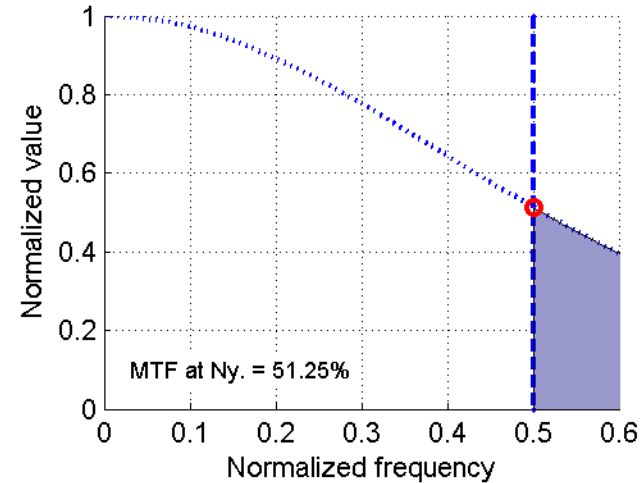
Edge Spread Function (Fermi)



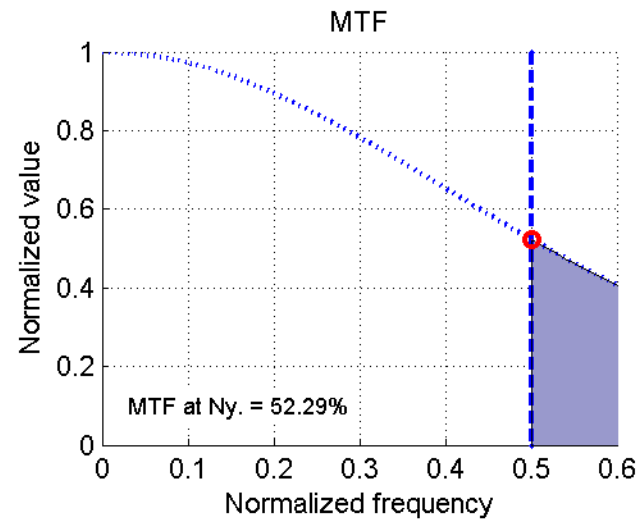
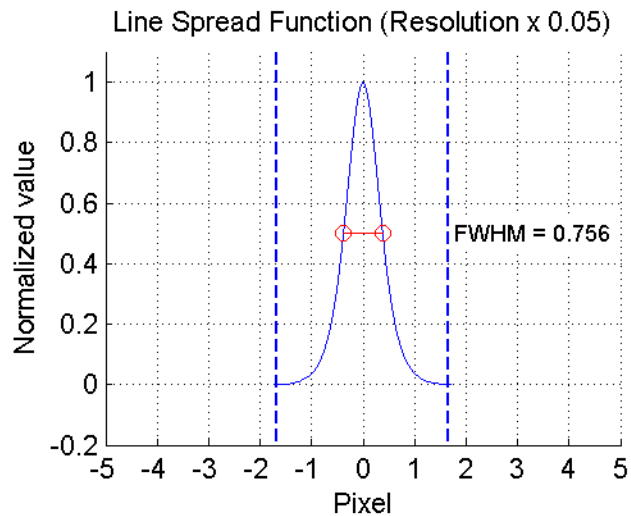
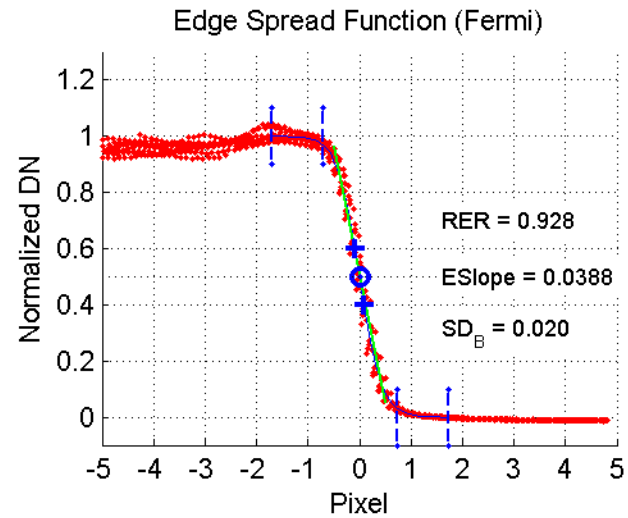
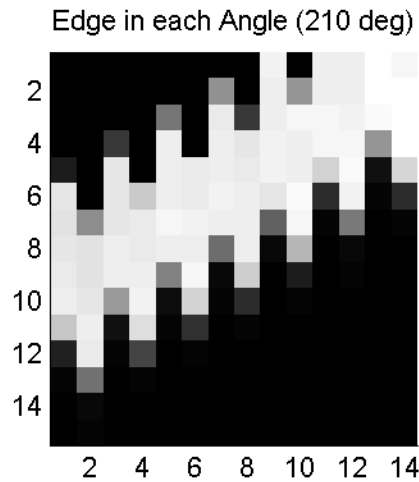
Line Spread Function (Resolution x 0.05)



MTF

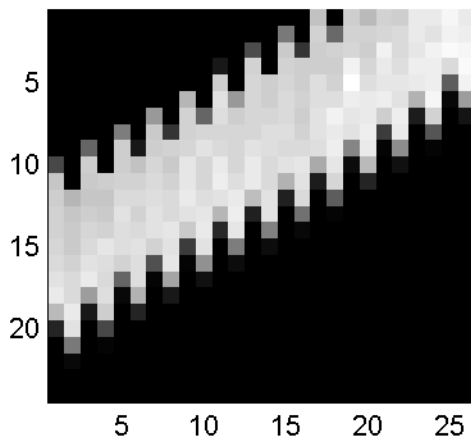


ESF, LSF, MTF (Band_7, Angle: 210deg)

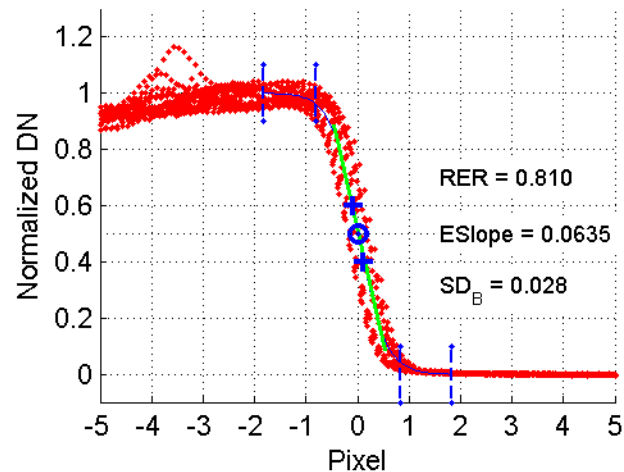


ESF, LSF, MTF (Band_8, PAN, Angle: 210deg)

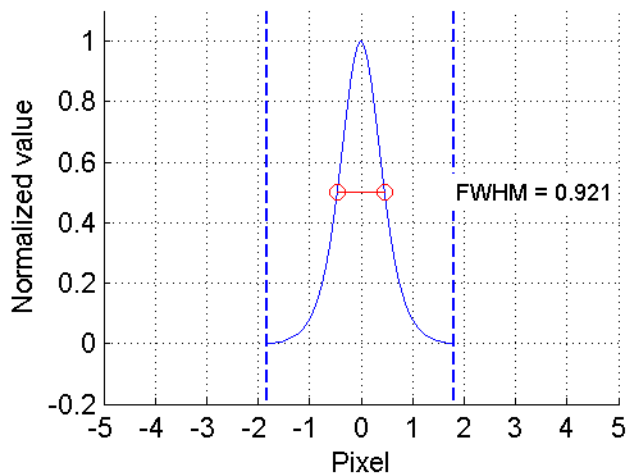
Edge in each Angle (210 deg)



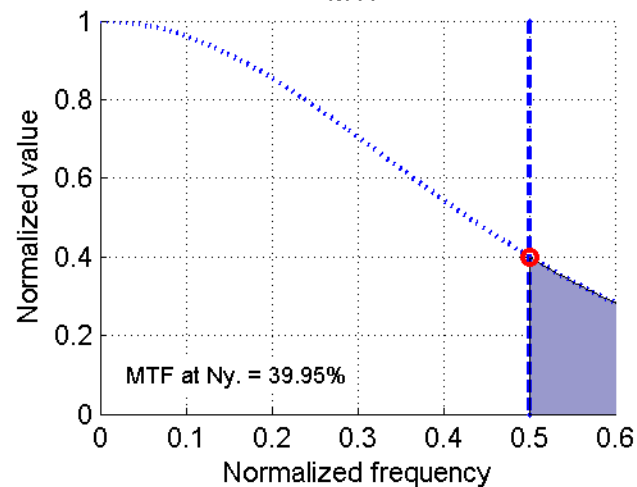
Edge Spread Function (Fermi)



Line Spread Function (Resolution x 0.05)

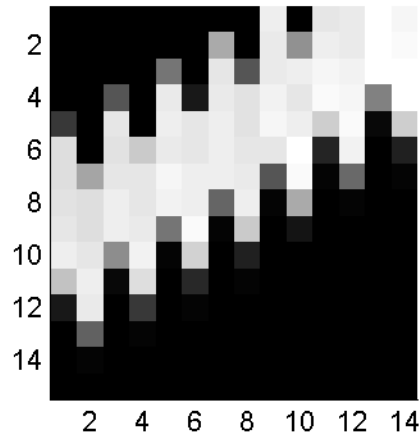


MTF

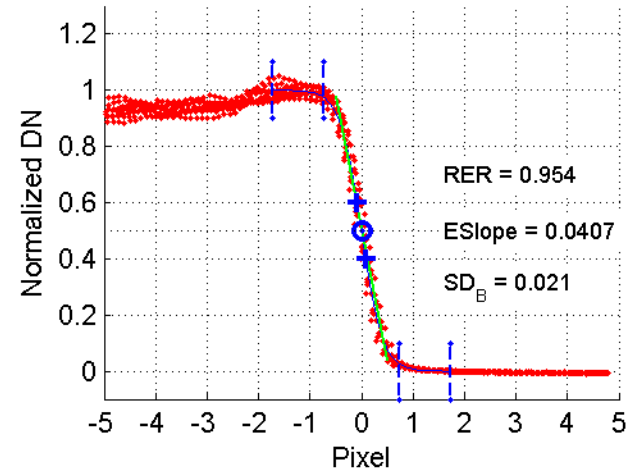


ESF, LSF, MTF (Band_9, Angle: 210deg)

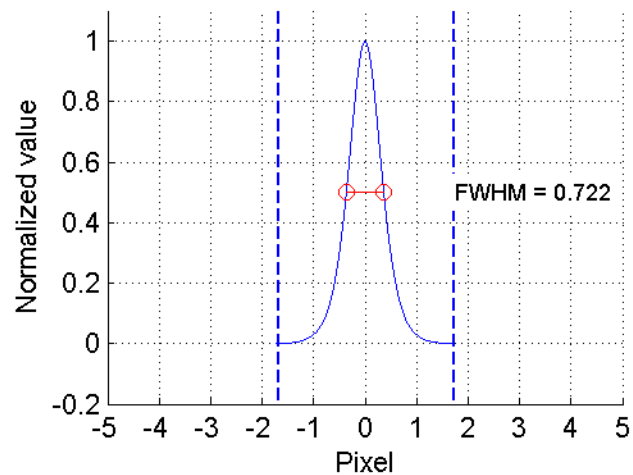
Edge in each Angle (210 deg)



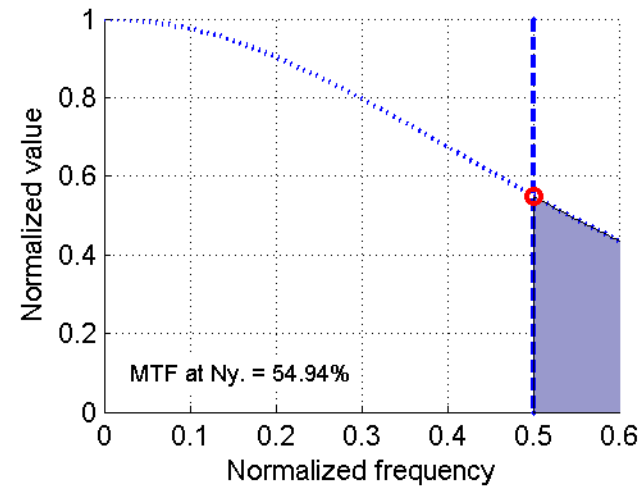
Edge Spread Function (Fermi)



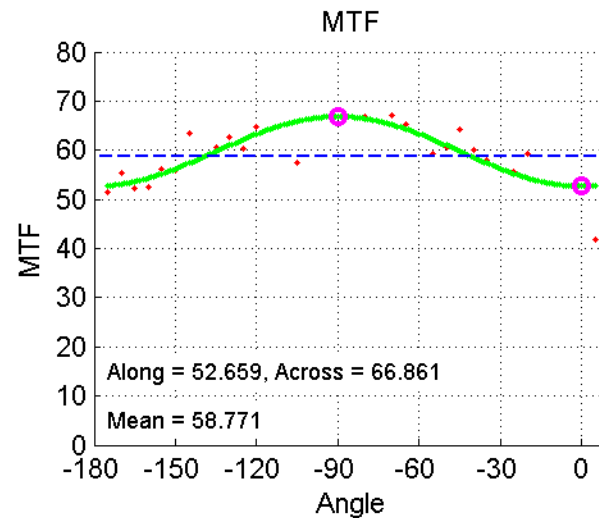
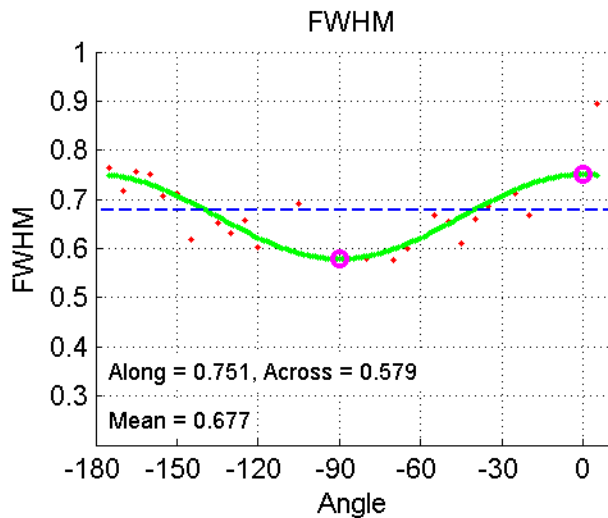
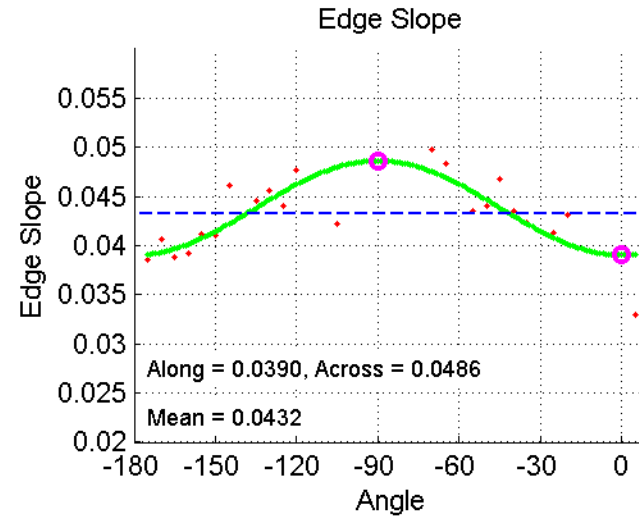
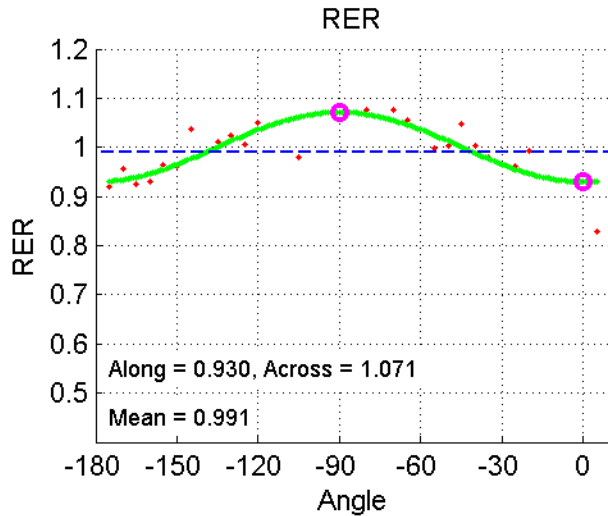
Line Spread Function (Resolution x 0.05)



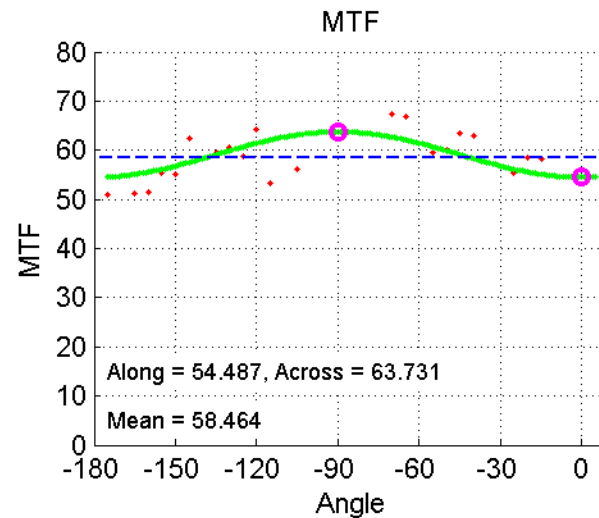
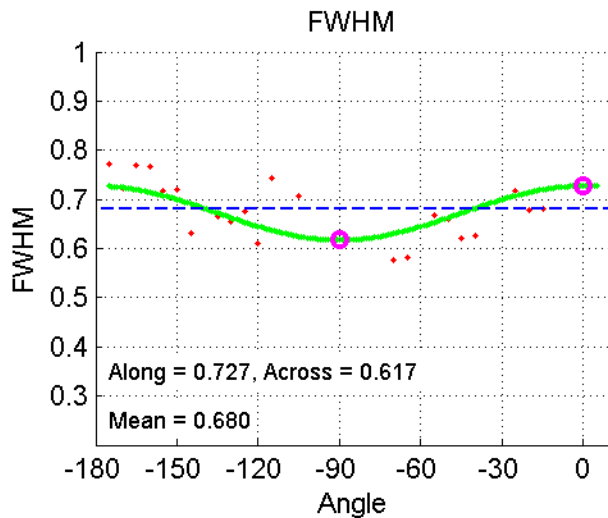
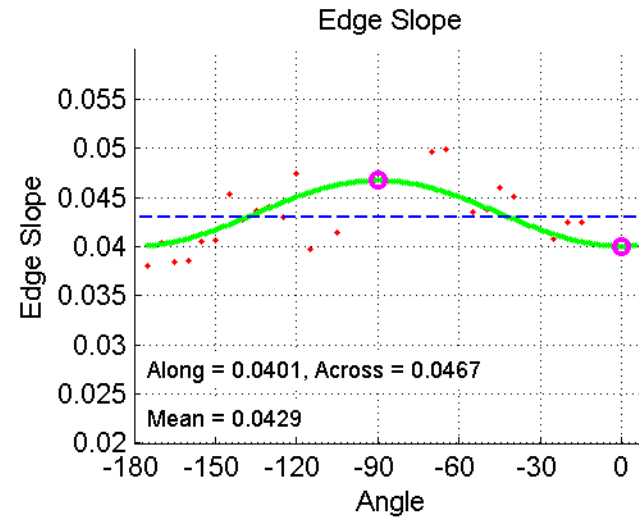
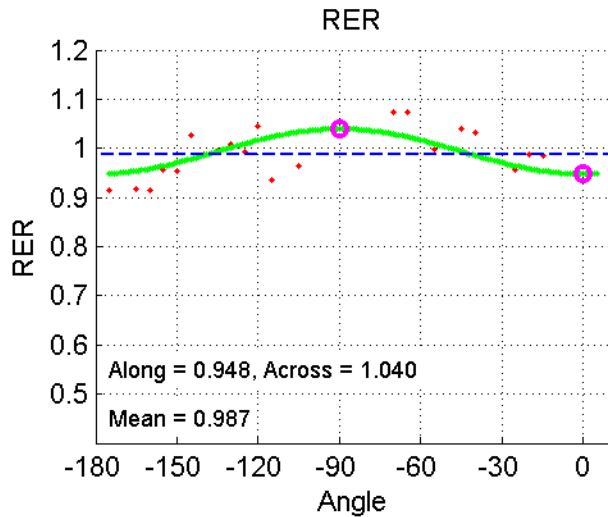
MTF



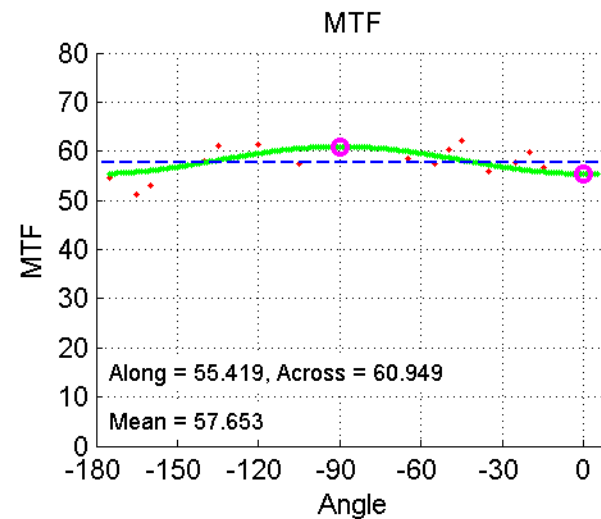
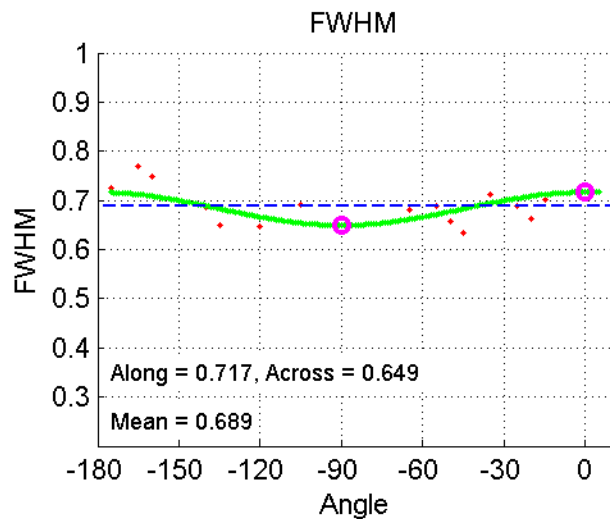
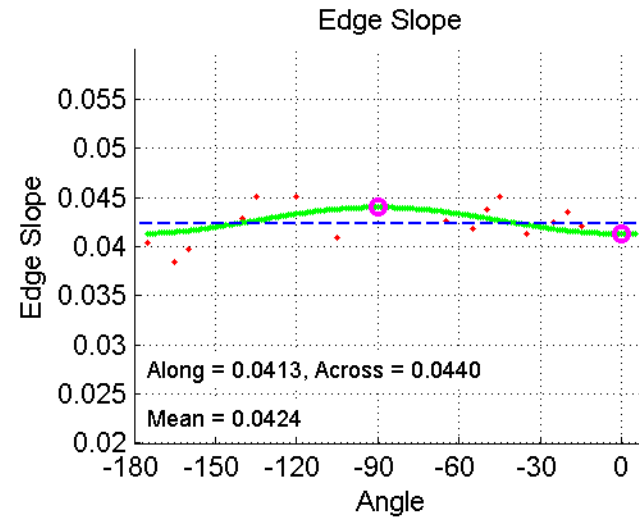
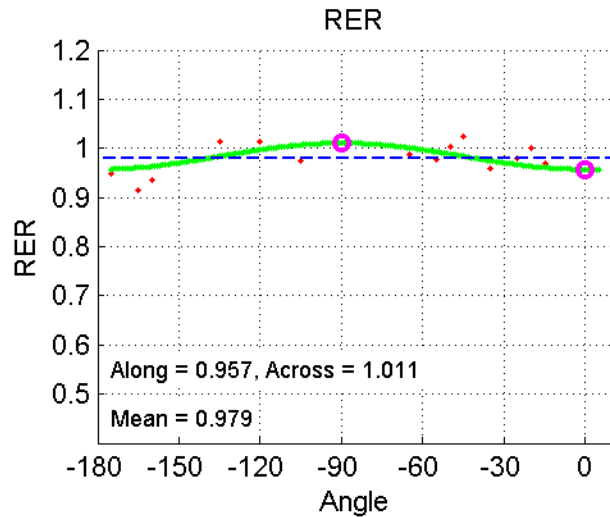
RER, Edge Slope, FWHM, MTF (Band_1)



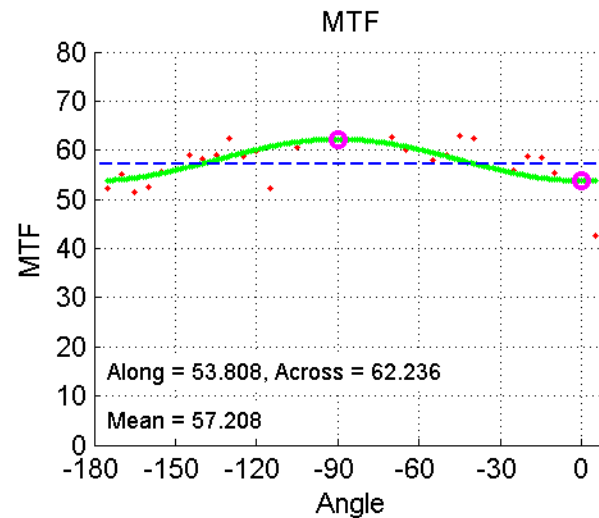
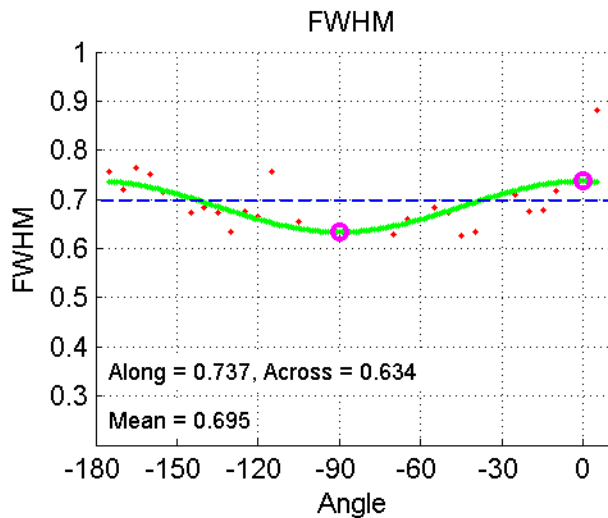
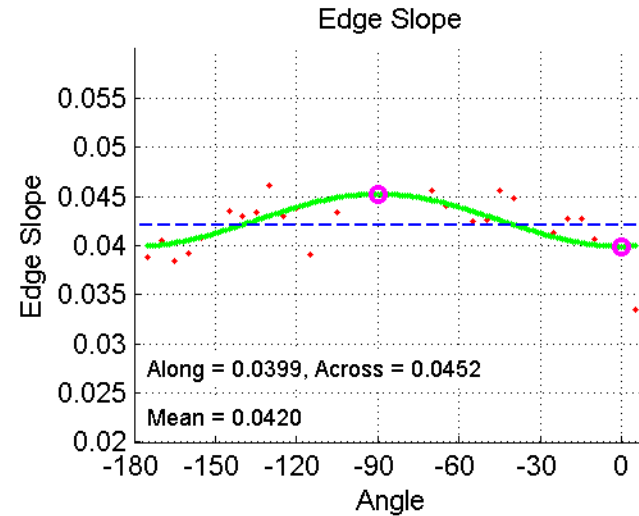
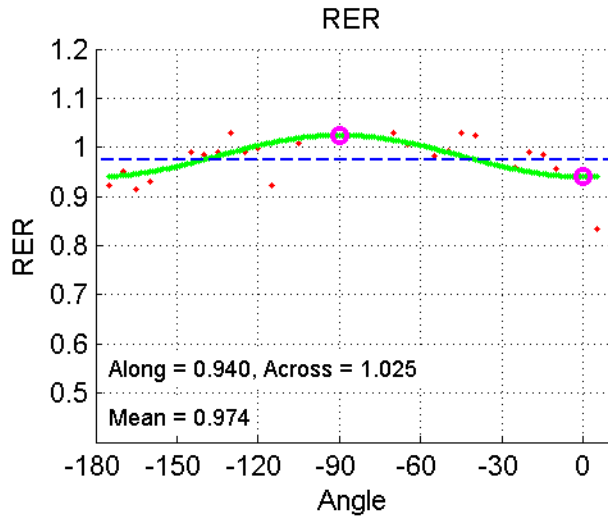
RER, Edge Slope, FWHM, MTF (Band_2)



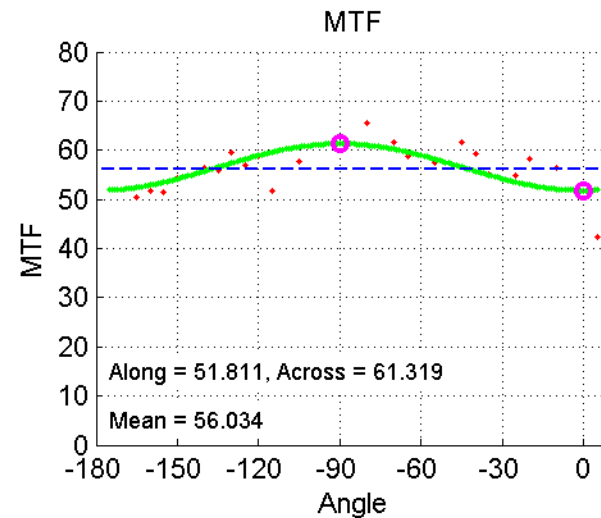
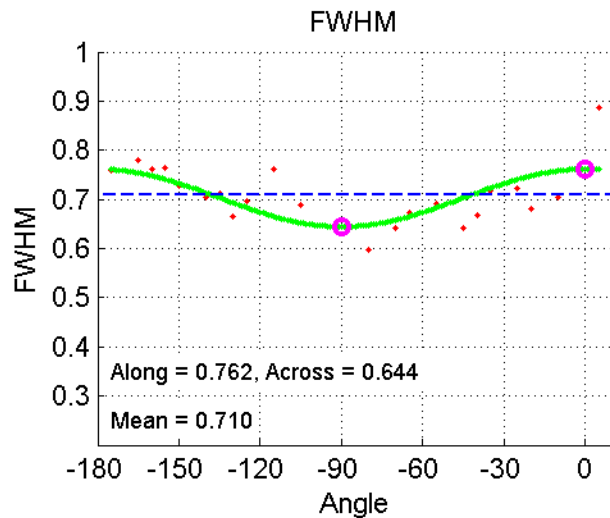
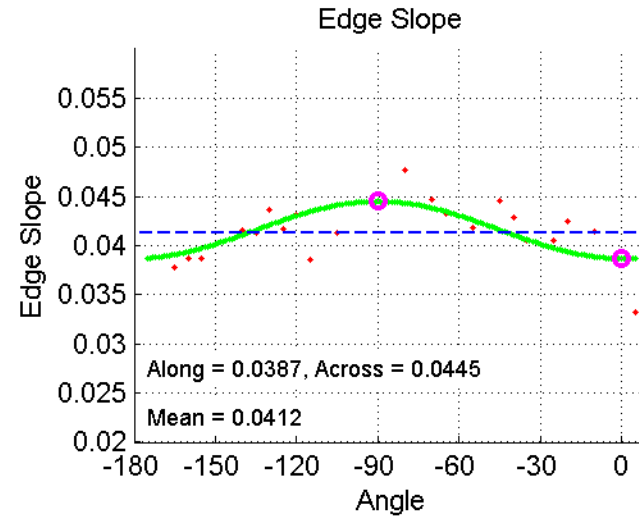
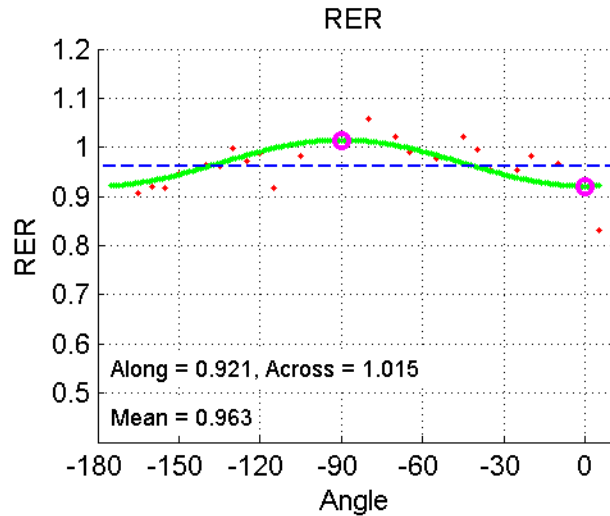
RER, Edge Slope, FWHM, MTF (Band_3)



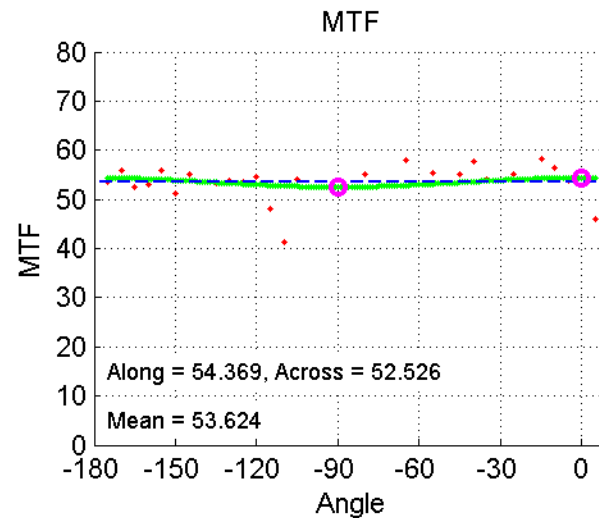
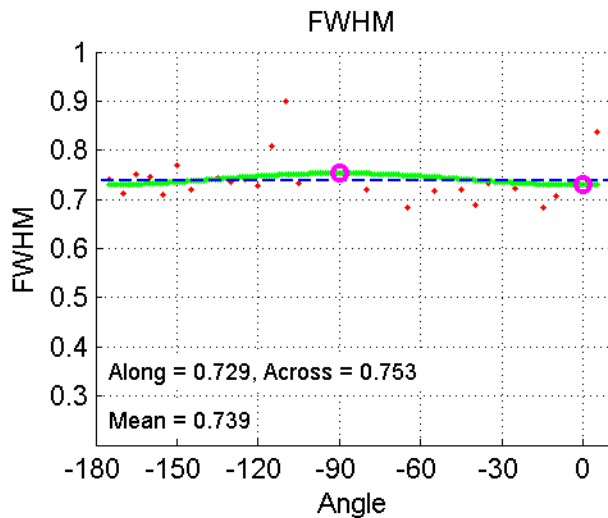
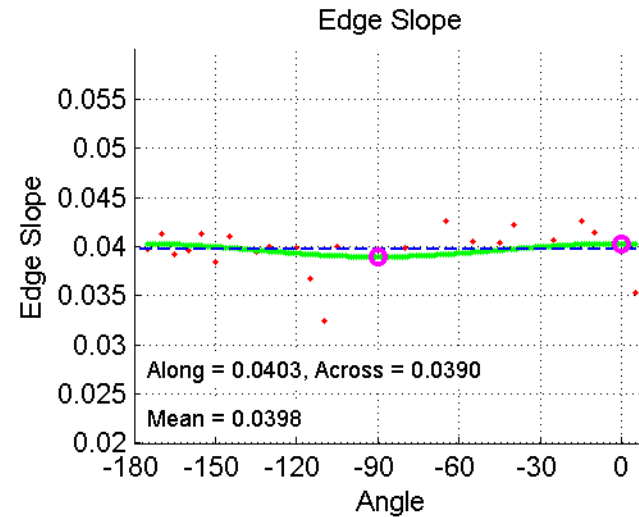
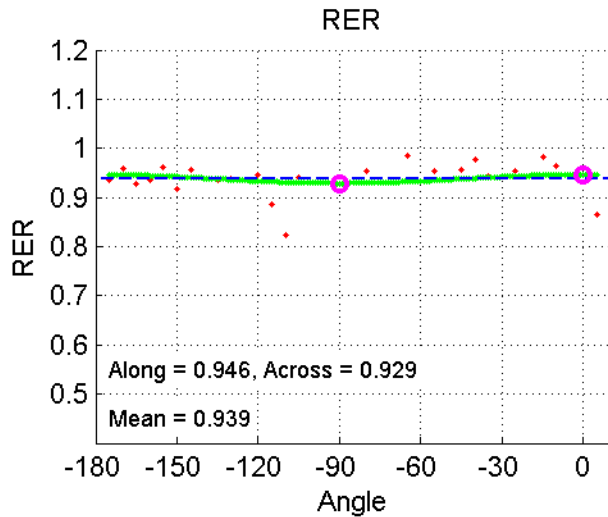
RER, Edge Slope, FWHM, MTF (Band_4)



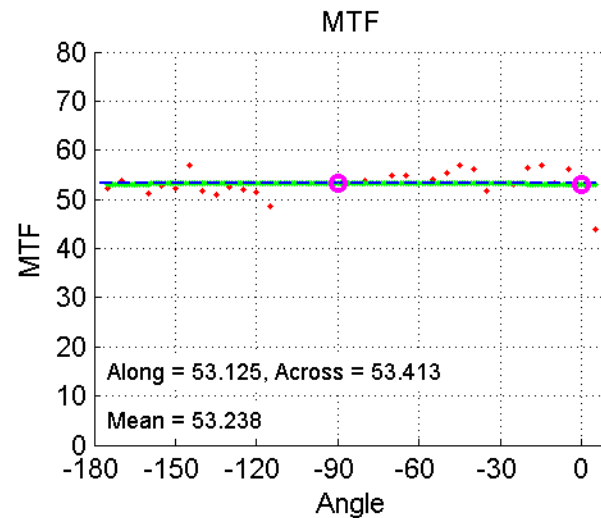
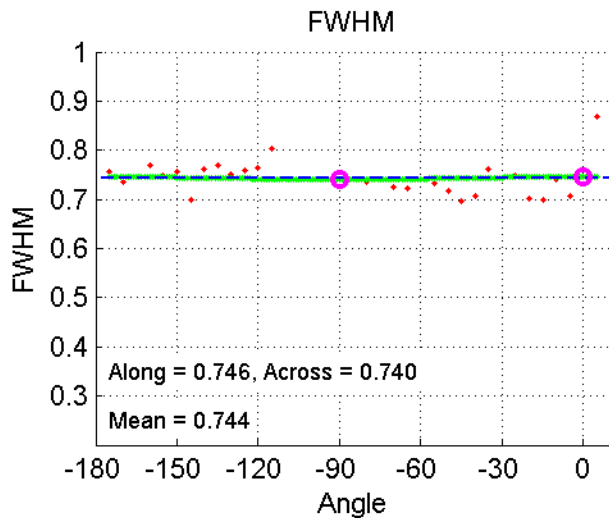
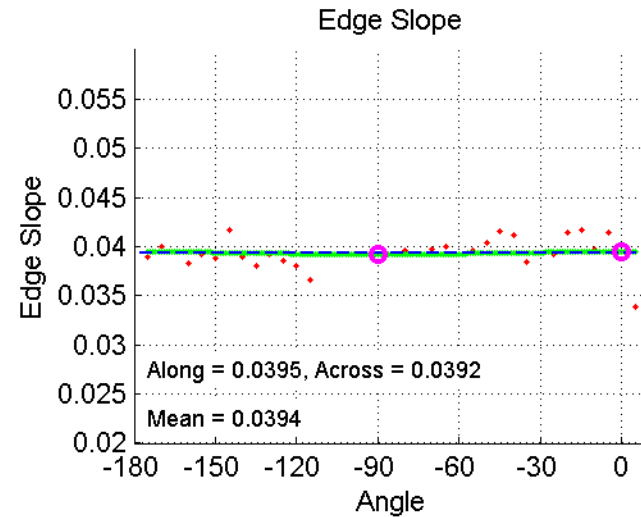
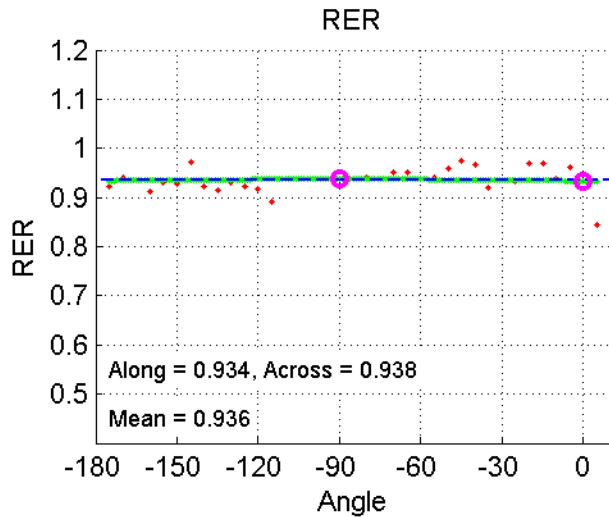
RER, Edge Slope, FWHM, MTF (Band_5)



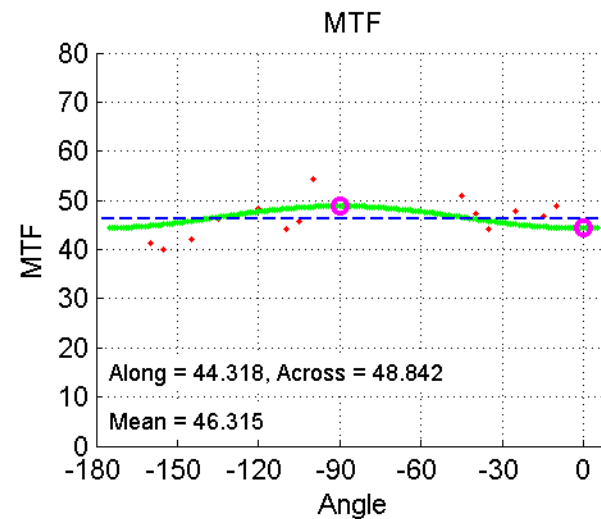
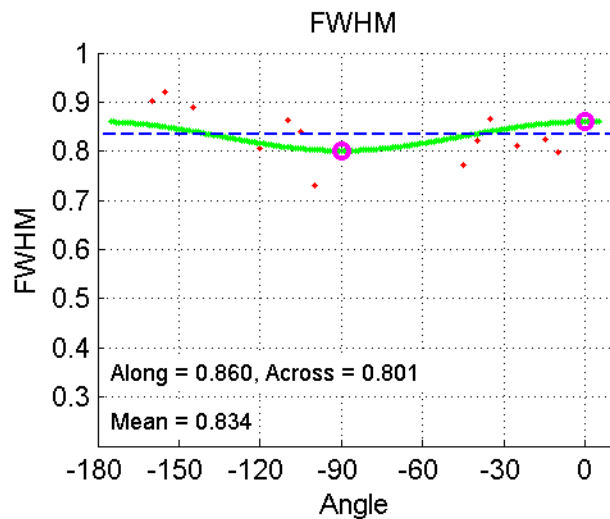
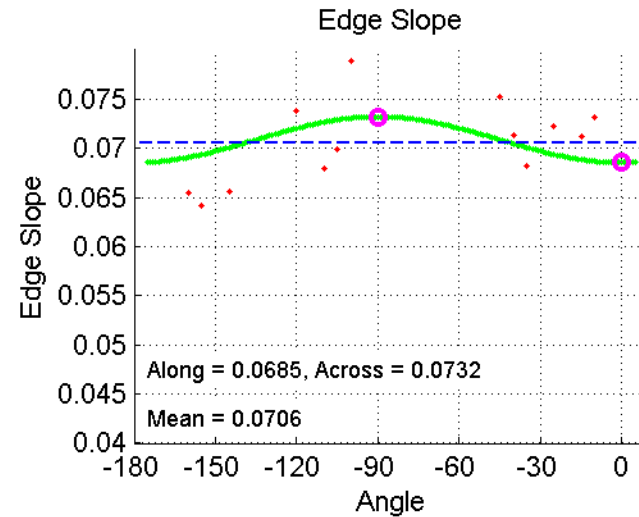
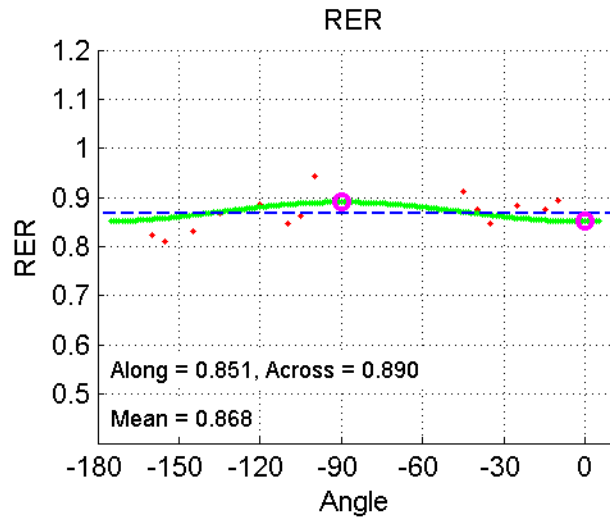
RER, Edge Slope, FWHM, MTF (Band_6)



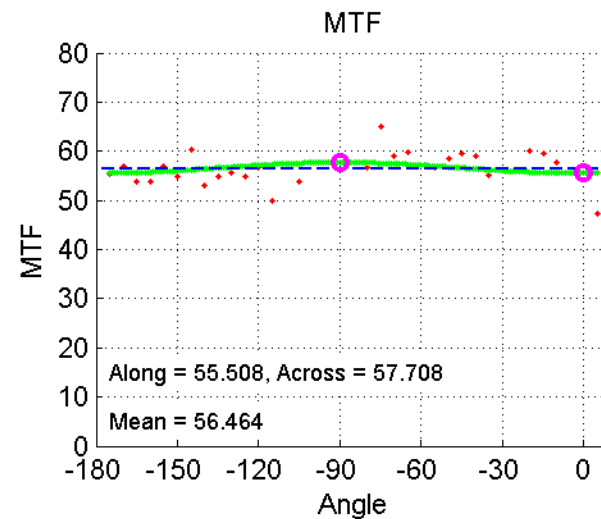
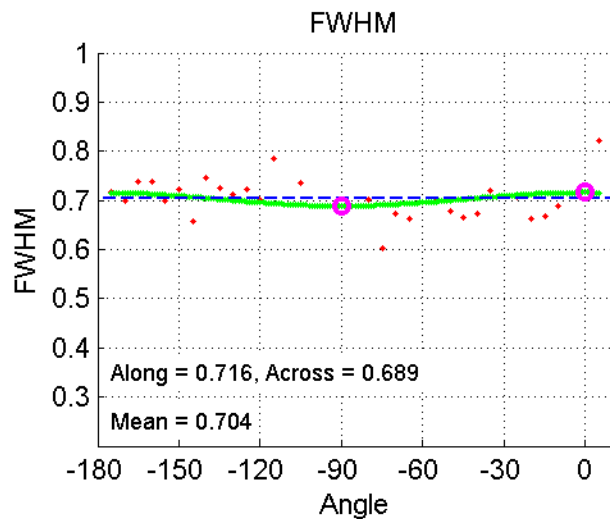
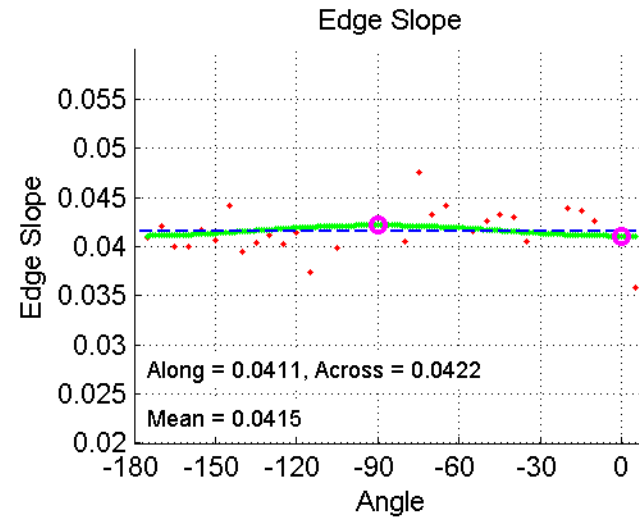
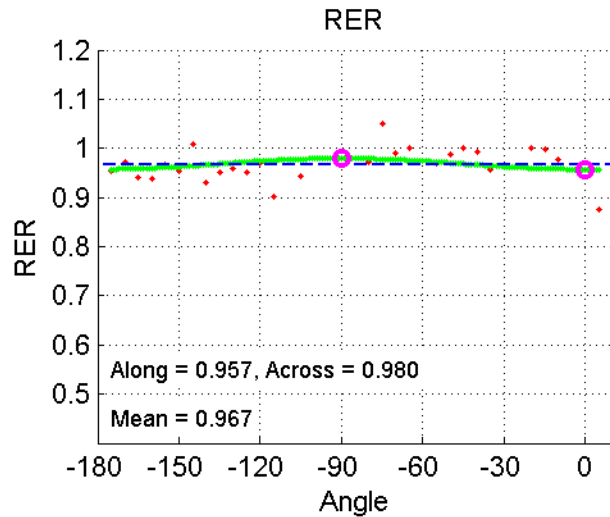
RER, Edge Slope, FWHM, MTF (Band_7)



RER, Edge Slope, FWHM, MTF (Band_8, PAN)



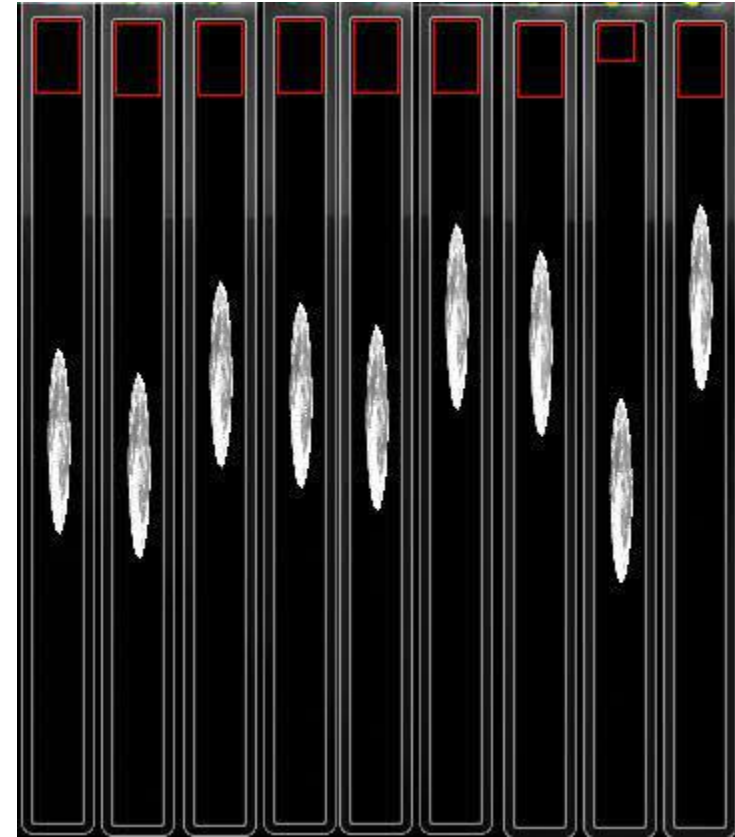
RER, Edge Slope, FWHM, MTF (Band_9)



Dataset of Level 1R Lunar data (89 set)

Date	No.
2013.085	15
2013.086	15
2013.115	15
2013.116	15
2013.145	6
2013.175	1
2013.351	15
2014.076	1
2014.164	1
2014.193	5

SCA	No.
1	5
2	5
3	5
4	5
5	5
6	5
7	10
8	13
9	6
10	7
11	7
12	6
13	5
14	5



LO800U1631352013145LGN00, Level 1R
Band 1, 2, 3, 4, 5, 6, 7, 8, 9

Compare and Result of Edge Slope, RER, FHWM, MTF

OLI	Edge Slope	GSD		RER	
		MS	PAN	MS	PAN
Specification	0.027	30	15	0.81	0.405
Measured (Jim Storey at TIM, 2013.12)	0.03054	29.934	14.932	0.914184	0.456023
Measured (Jim Storey at TIM, 2014.04)	0.02966	29.934	14.932	0.887842	0.442883

Band	Edge Slope		RER		FWHM		MTF	
	Spline	Fermi	Spline	Fermi	Spline	Fermi	Spline	Fermi
1	0.0329	0.0404	0.868	0.950	0.985	0.726	49.25	54.70
2	0.0326	0.0399	0.863	0.943	0.991	0.735	48.61	53.96
3	0.0326	0.0399	0.862	0.942	0.988	0.737	48.33	53.84
4	0.0324	0.0393	0.857	0.933	0.994	0.749	47.70	52.90
5	0.0321	0.0386	0.849	0.923	0.998	0.761	46.62	51.85
6	0.0317	0.0374	0.837	0.904	0.998	0.787	45.03	49.89
7	0.0311	0.0363	0.821	0.886	1.003	0.811	43.27	48.04
8 (PAN)	0.0593	0.0657	0.793	0.825	1.046	0.902	40.30	41.51
9	0.0320	0.0381	0.845	0.914	0.991	0.773	45.85	50.98

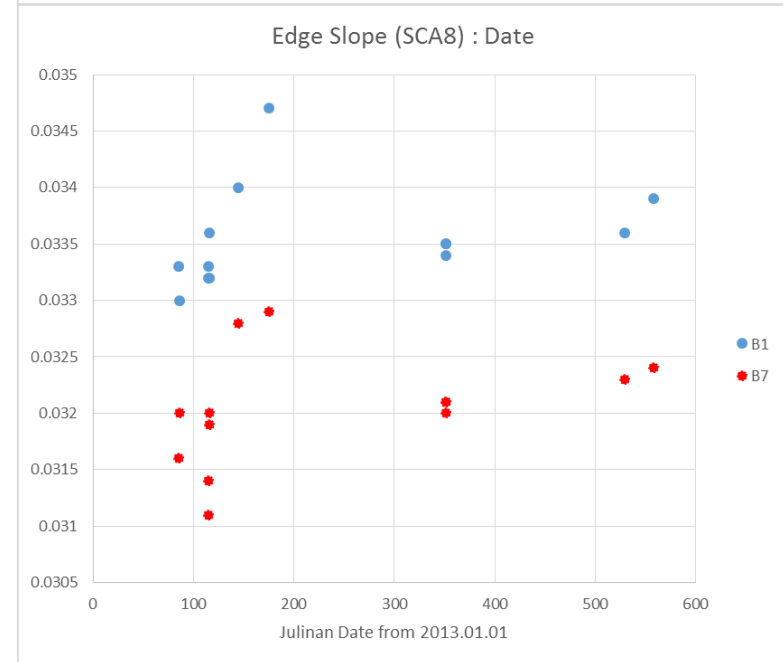
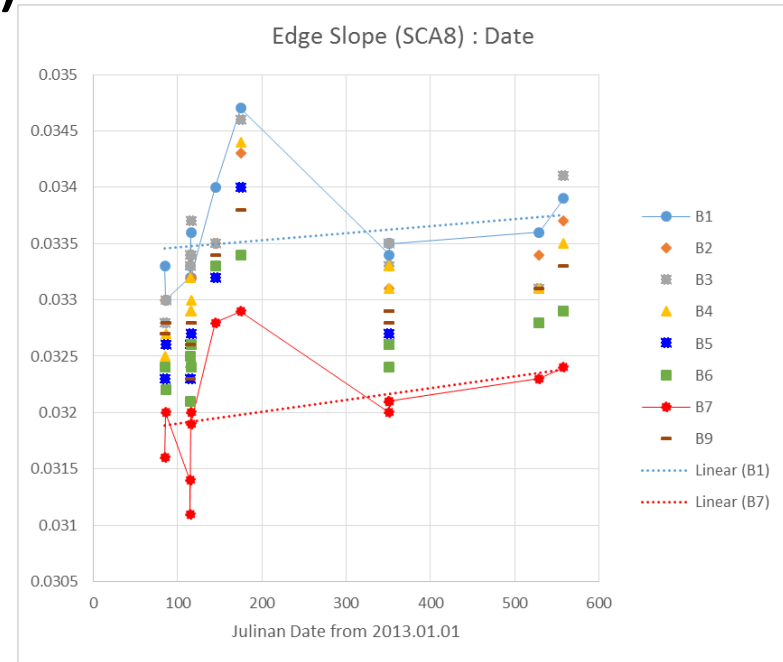
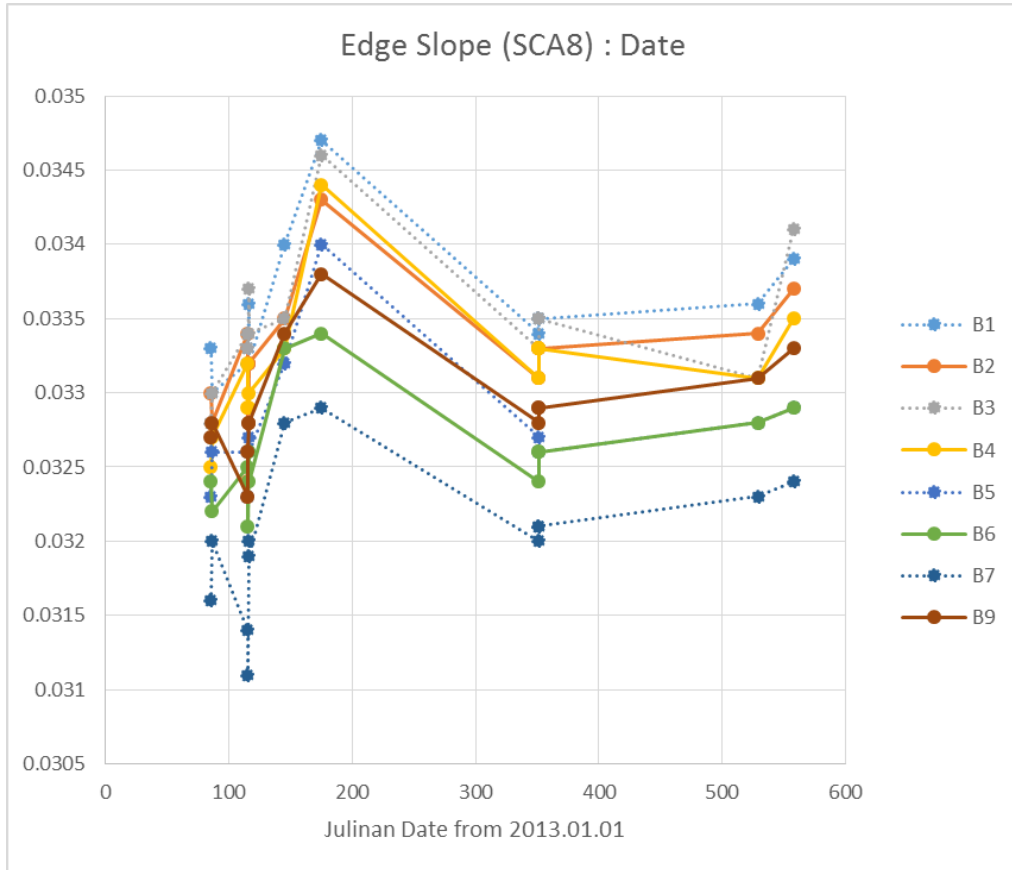
Issues & Concerns from the Result

1. **This Edge Slope is a little more than Jim's**
 - a. Atmosphere or Not
 - b. Fermi-Dirac fitting on ESF may make the bigger values.
 - ✓ The result of Spline (CSAPS in Matlab) is a little bigger than Jim's; '0.002'
 - ✓ What is Optimal fitting method on ESF?

2. **Edge Slope of B8 (PAN) is almost double than MS, but RER of B8 (PAN) is not double.**
 - a. FWHM & MTF is same with RER
 - b. Edge Slope is more stable and reliable for Landsat 8 OLI that has the very high spatial quality.

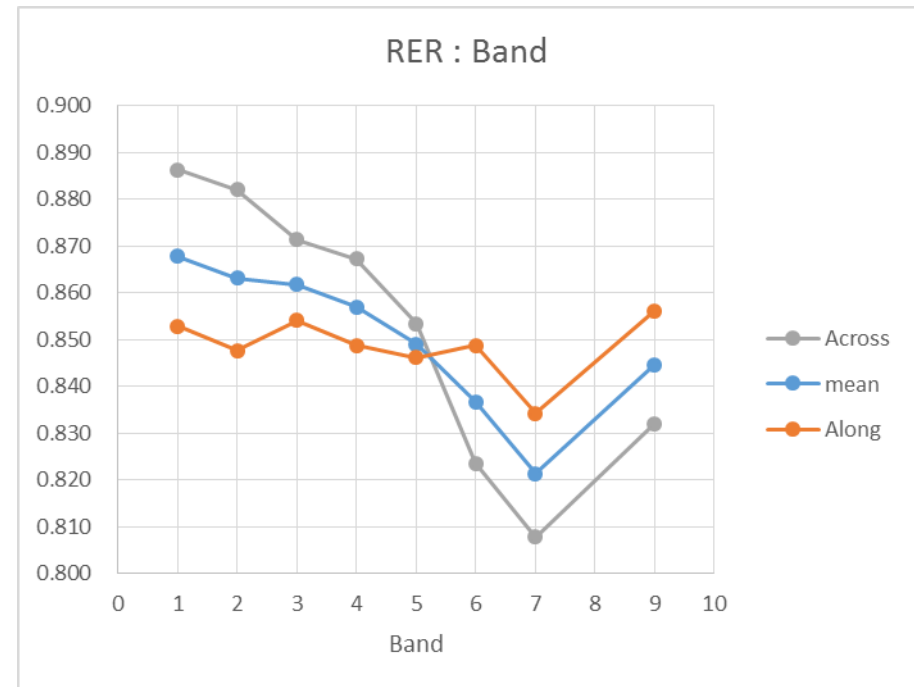
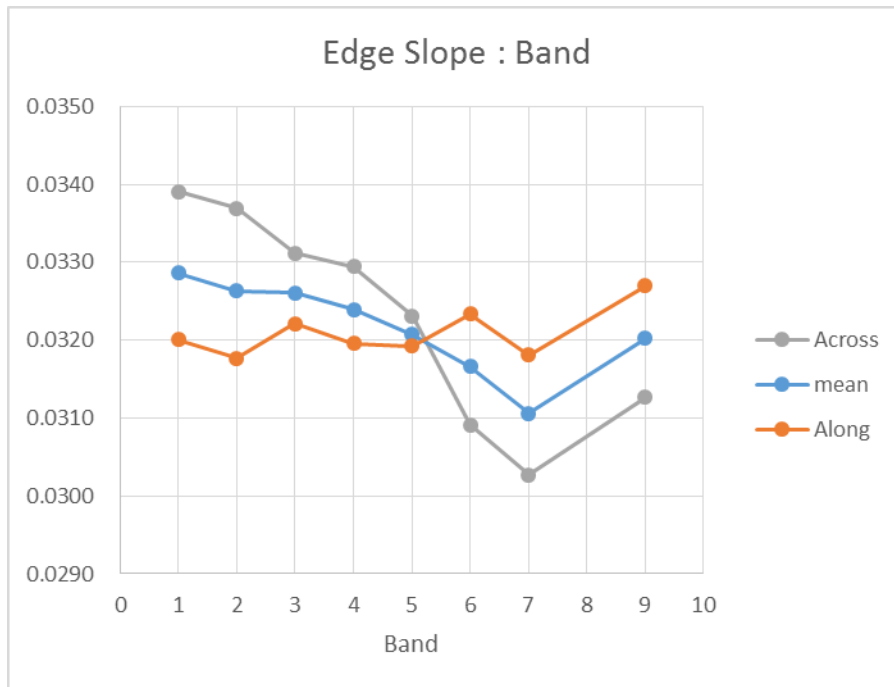
Edge Slope (SCA8) vs. Date

- Landsat 8 OLI may be stable on time (?)
 - ✓ Need more Lunar data



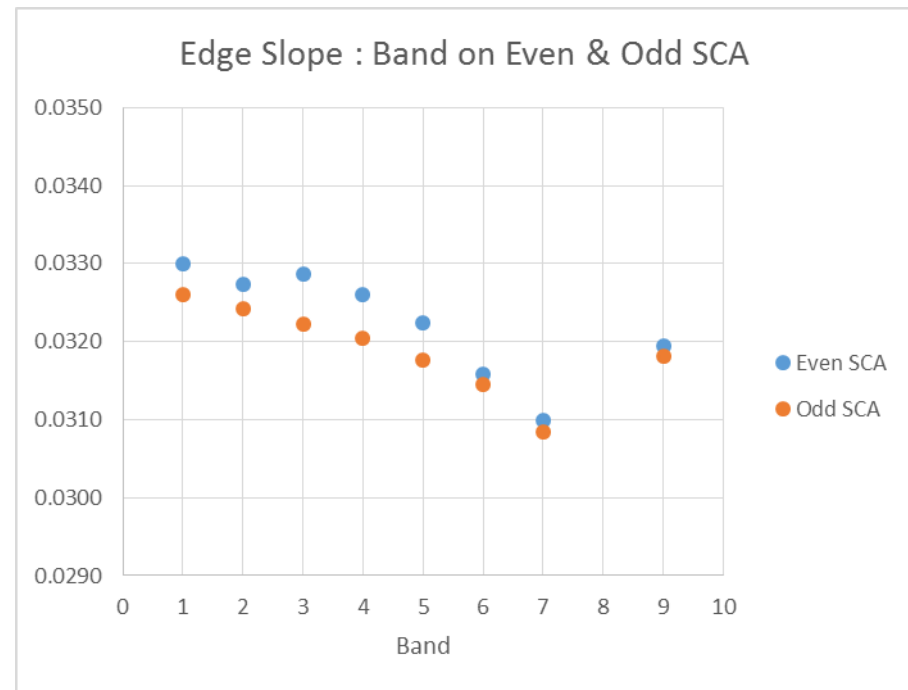
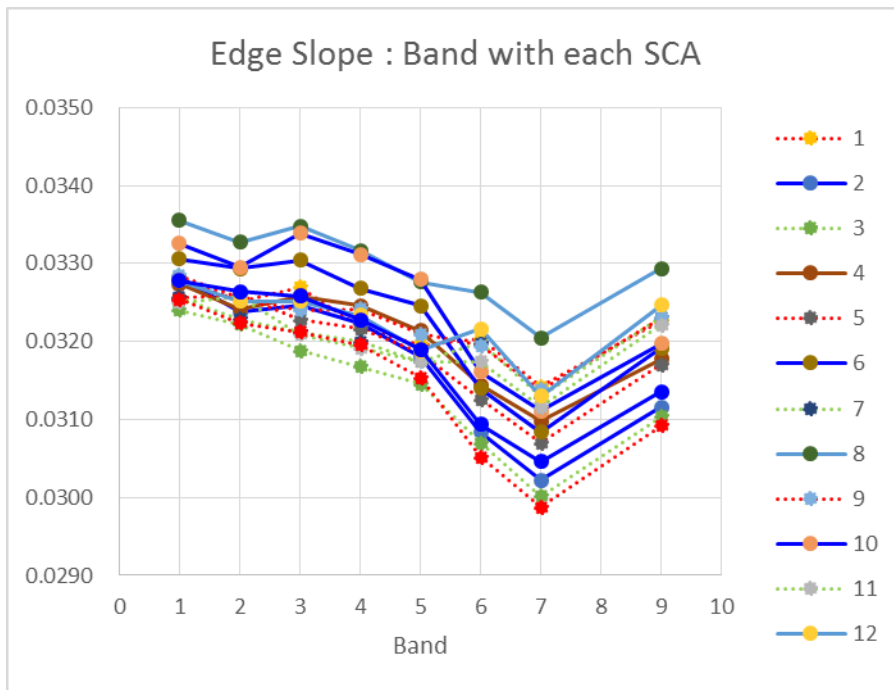
Edge Slope & RER vs. Band

- The trend of Edge Slope and RER is same.
- Along Edge Slope is not depended on the Bands.
 - ✓ (Issues) Along Edge Slope may be affected from any scanning work of Landsat 8.



Edge Slope vs. SCA

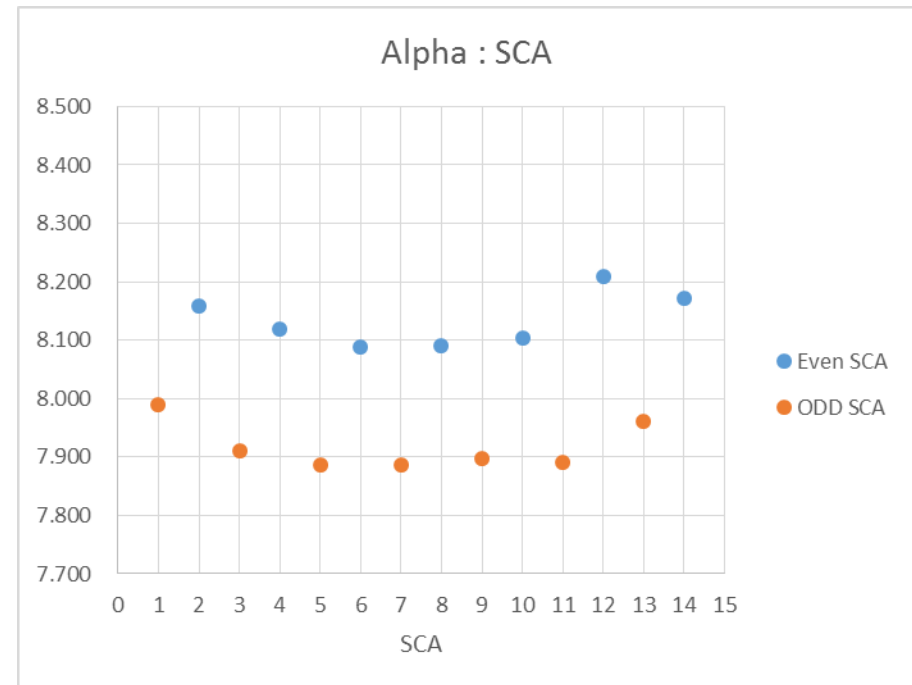
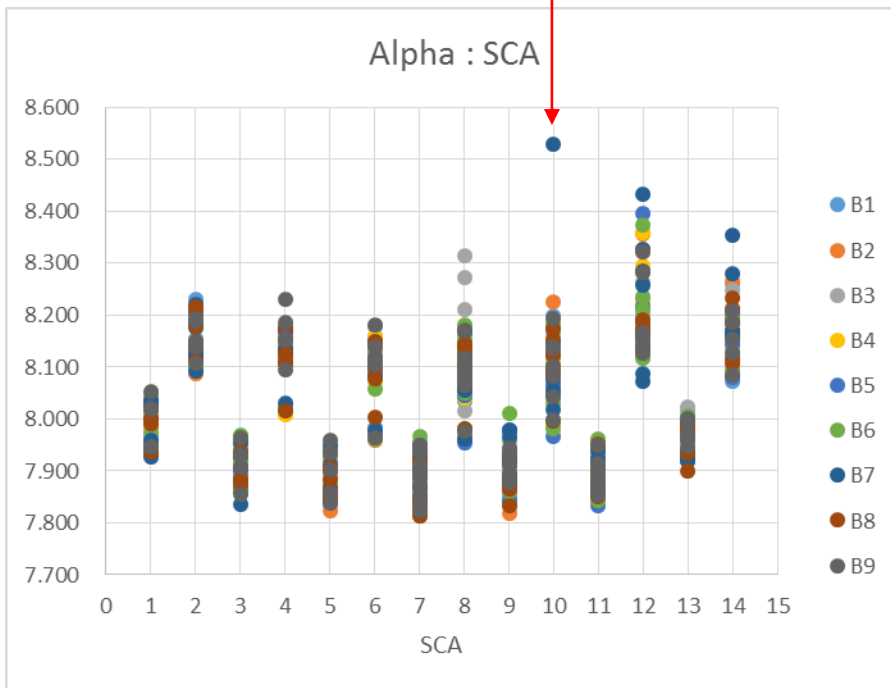
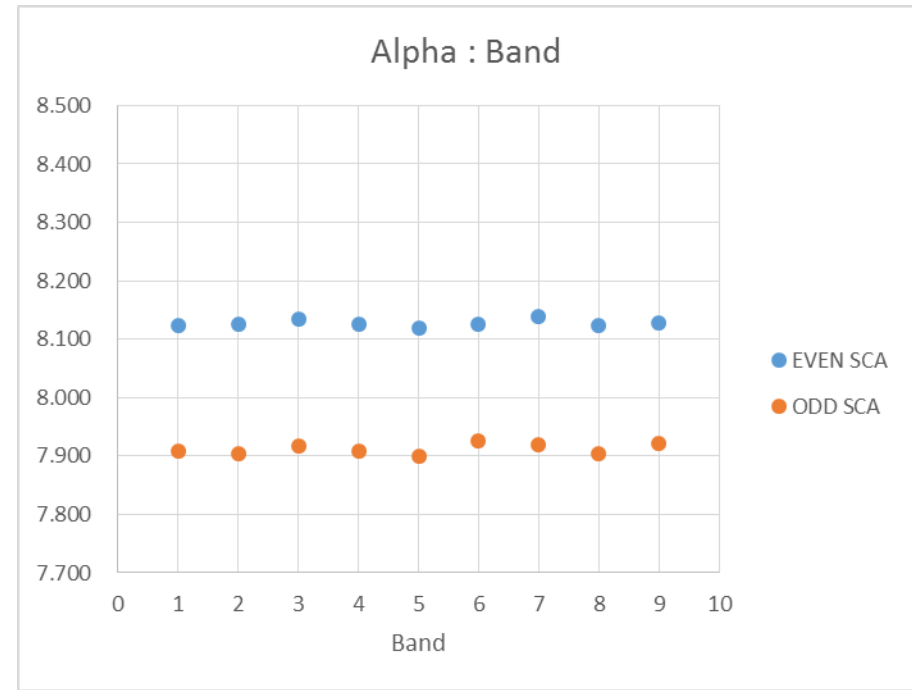
- Edge Slope of each SCA may be a little different.
- Edge Slope of Even SCA is more than Odd's.



Alpha vs. SCA & Band

- Alpha (a/b from Ellipse fitting) depends on SCA.
- Even SCA is bigger than Odd's.
- Band7, SCA10, 2013 116
 - ✓ Alpha: 8.530
 - ✓ Need more checking

Band7, SCA10, 2013 116 (8.530)



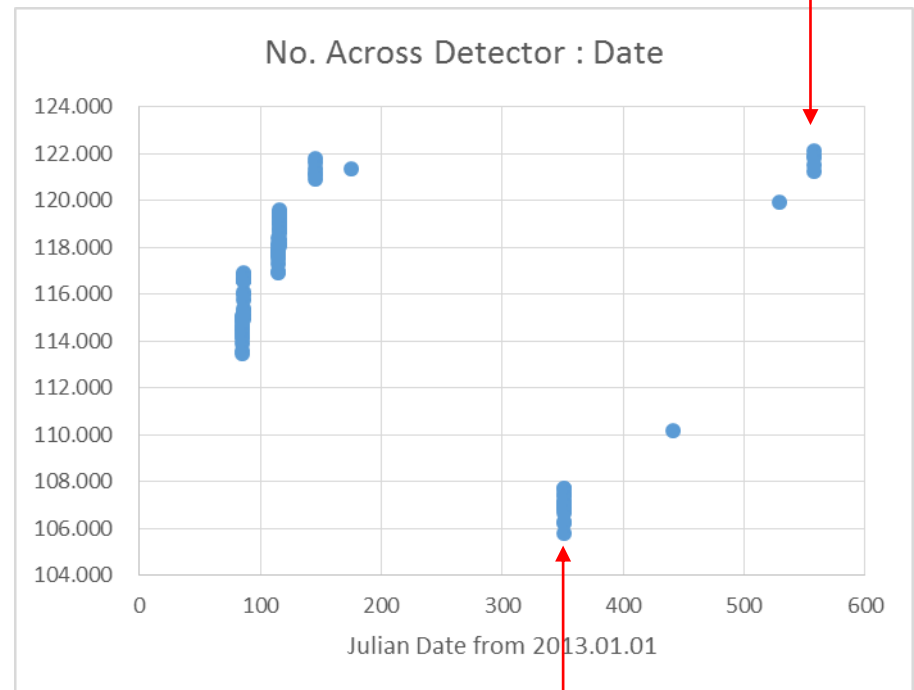
No. Across Detector (b) vs. Date

- No. Across Detector (b from Ellipse fitting).



Date	No.
2013.351 (Dec. 17, 2013)	214.24
2014.193 (Jul. 12, 2014)	242.70

Super Moon (July 12, 2014)



Small Moon (Dec 17, 2013)

Issues & Concerns

1. **This Edge Slope is a little more than Jim's**
 - a. Atmosphere or Not
 - b. Fermi-Dirac fitting on ESF may make the bigger values.
 - ✓ The result of Spline (CSAPS in Matlab) is a little bigger than Jim's; '0.002'
 - ✓ What is Optimal fitting method on ESF?
2. **Edge Slope of B8 (PAN) is almost double than MS, but RER of B8 (PAN) is not double.**
 - a. FWHM & MTF is same with RER
 - b. Edge Slope is more stable and reliable for Landsat 8 OLI that has the very high spatial quality.
3. **Landsat 8 OLI may be stable on time (?)**
 - a. Need more Lunar data
4. **Along Edge Slope is not depended on the Bands.**
 - a. Along Edge Slope may be affected from any scanning work of Landsat 8
5. **Edge Slope of each SCA may be a little different.**
 - a. Edge Slope of Even SCA is more than Odd's.
6. **Alpha (a/b from Ellipse fitting) depends on SCA.**
 - a. Even SCA is more than Odd's.
 - b. Band7, SCA10, 2013 116
 - ✓ Alpha: 8.530
 - ✓ Need more checking

Future Work

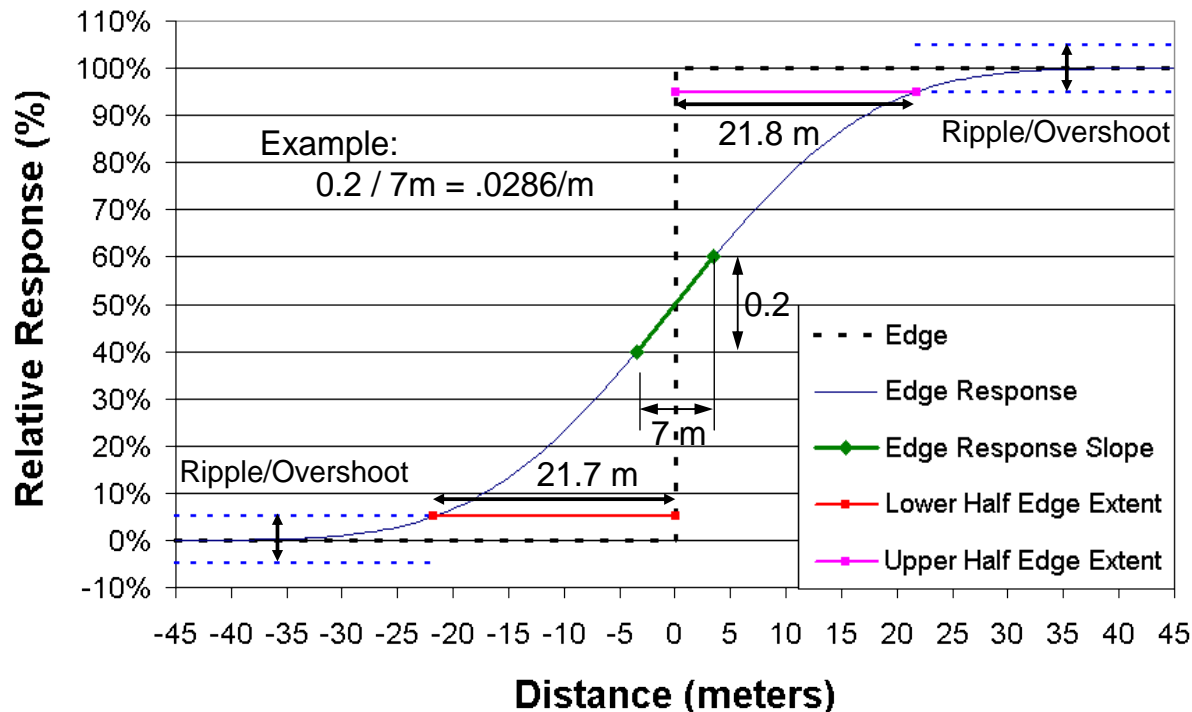
- 1. Debugging & Stabilizing with more Landsat 8 Lunar data**
- 2. Interface with the regular format of L8 Lunar data**
- 3. Some Lunar data of Band 7 on SCA 10 may have a little different shadow area (angle).**
 - a. Need more checking of it.

Definition of Edge Slope

1. Edge response Slope

- The relative edge response slope is defined as the slope between the 40% and 60% response points as depicted in Figure
- In Landsat 8 OLI Specification
- for Calculating the Edge slope, the real GSD needs on image data.

Edge Response Slope



RER & Edge Slope in Landsat 8 OLI

1. In Landsat 8 with the very~ very~ high spatial quality

- a. RER cannot be gotten accurately.
- b. In Landsat 8, Edge Slope is more stable and reliable than RER.

