Diffuser BRDF Analysis
Modelling from On-Orbit Measurements

Final Presentation

Matthijs Krijger
Ewa Kwiatkowska, Ludovic Bourg,
Ralph Snel, Xiong (Jack) Xiaoxiong

EARTH SPACE SOLUTIONS

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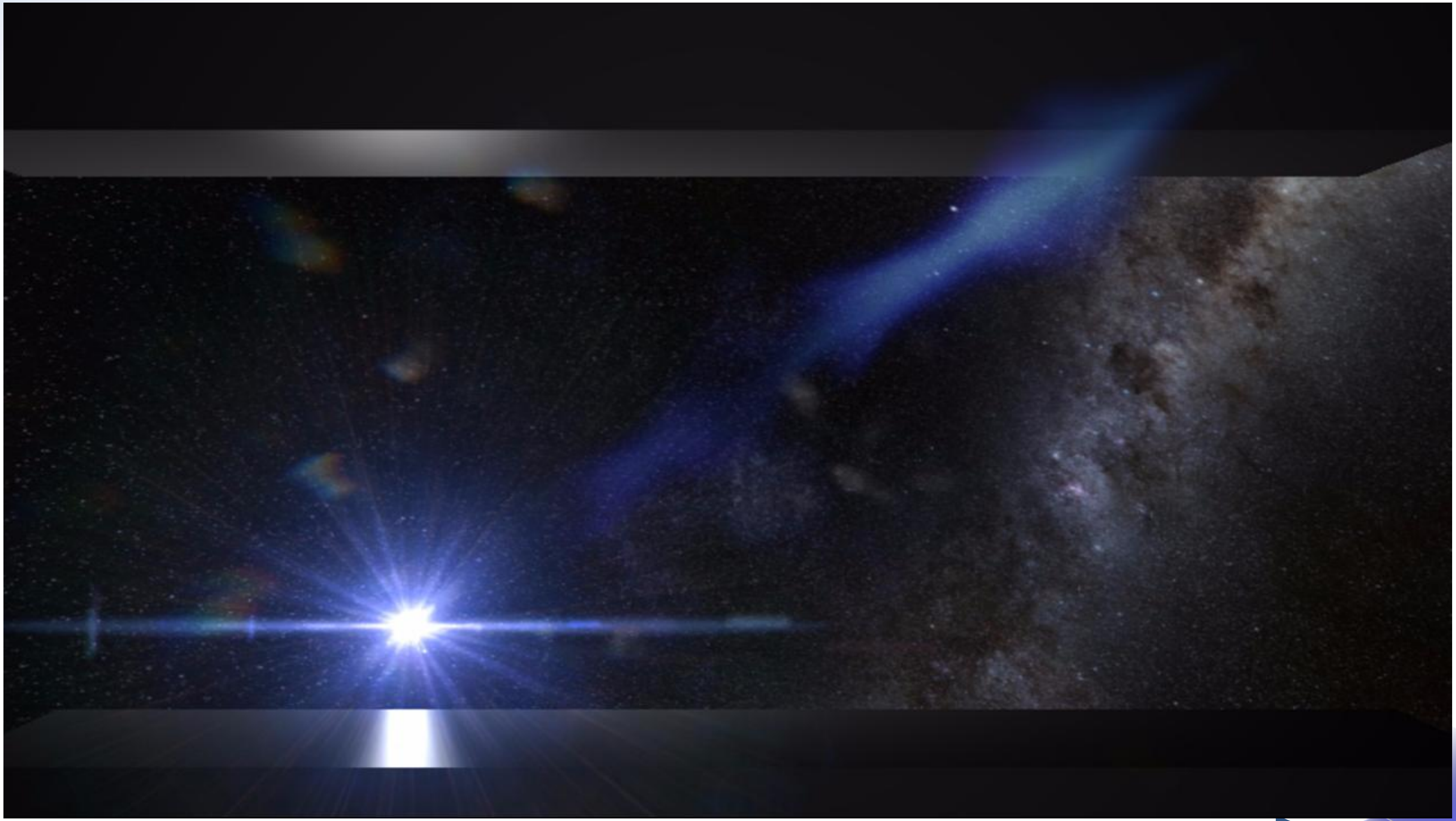
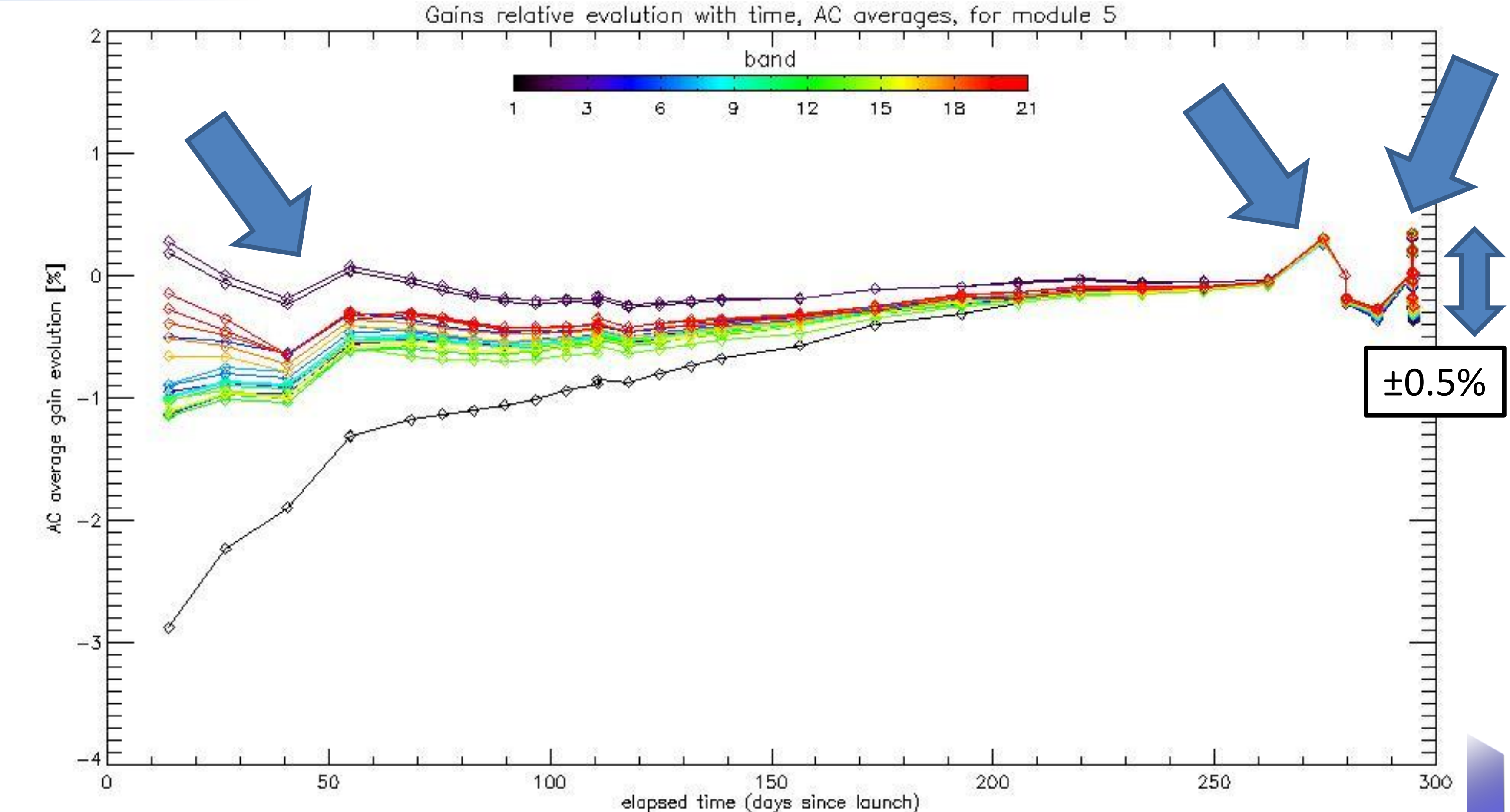
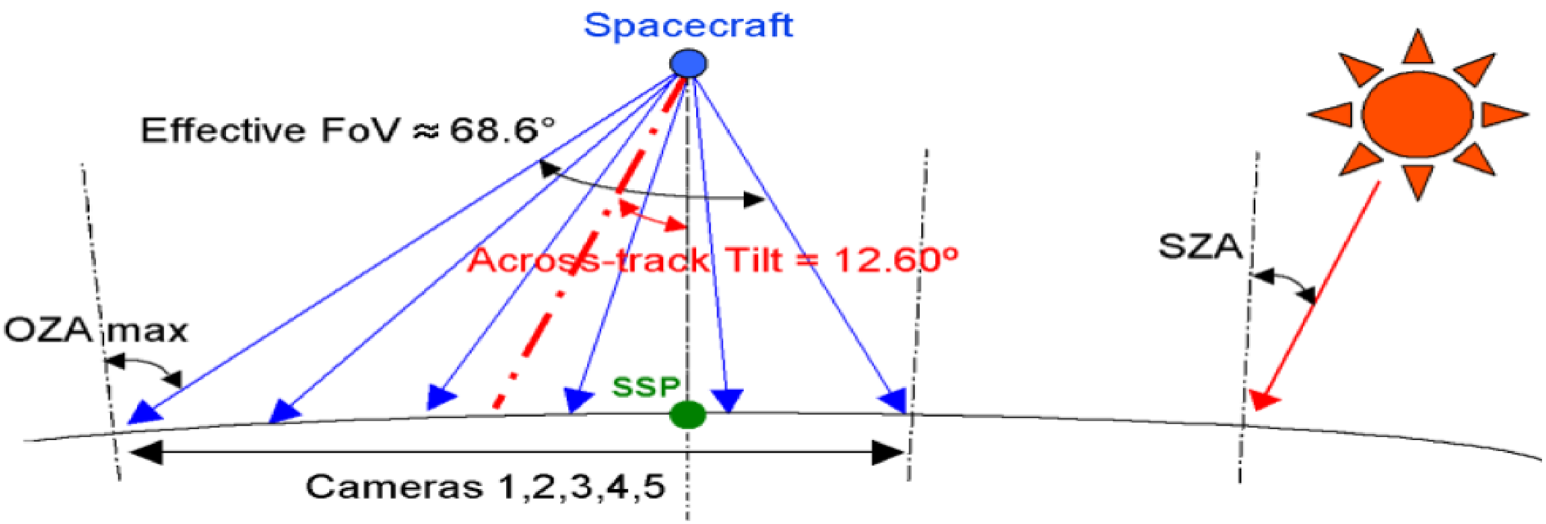
Issue

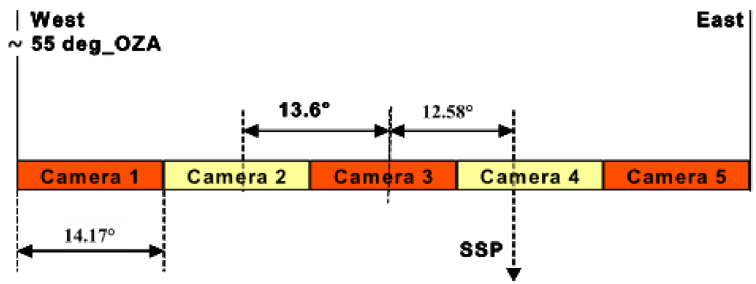


Degradation



OLCI Optical





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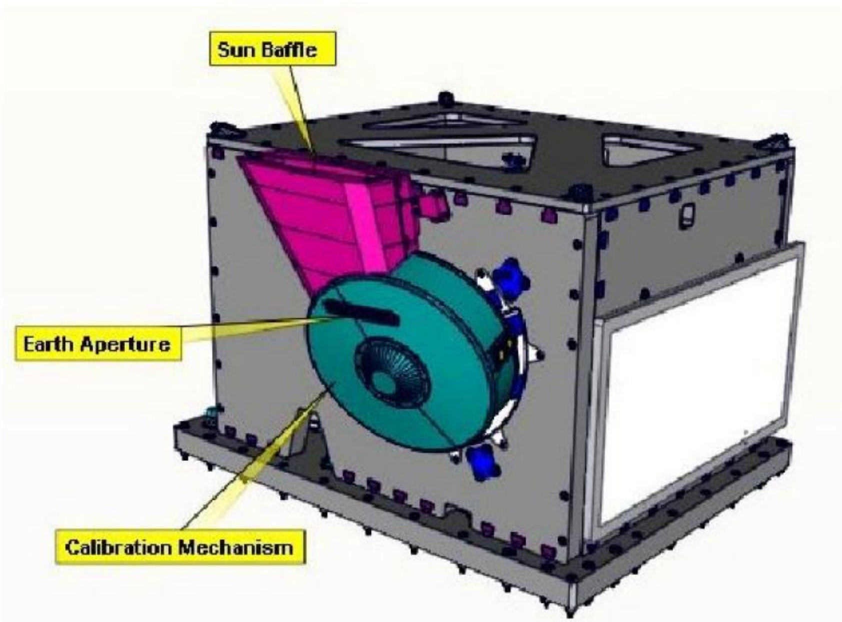

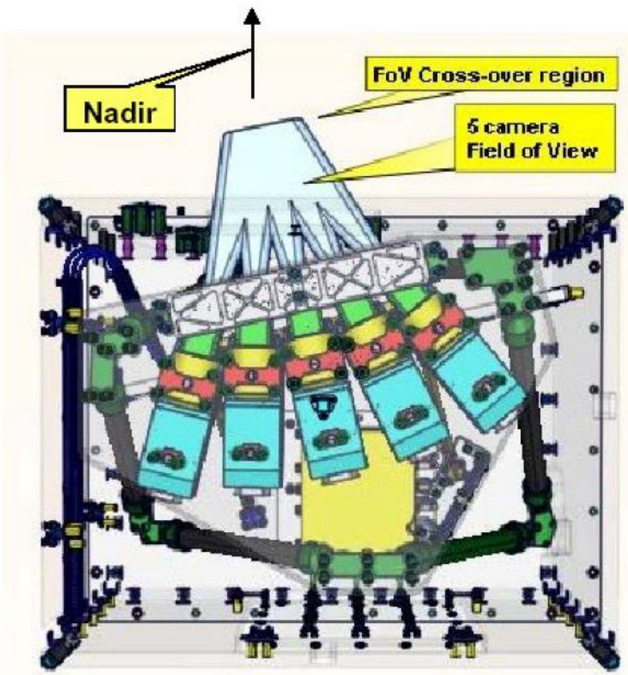

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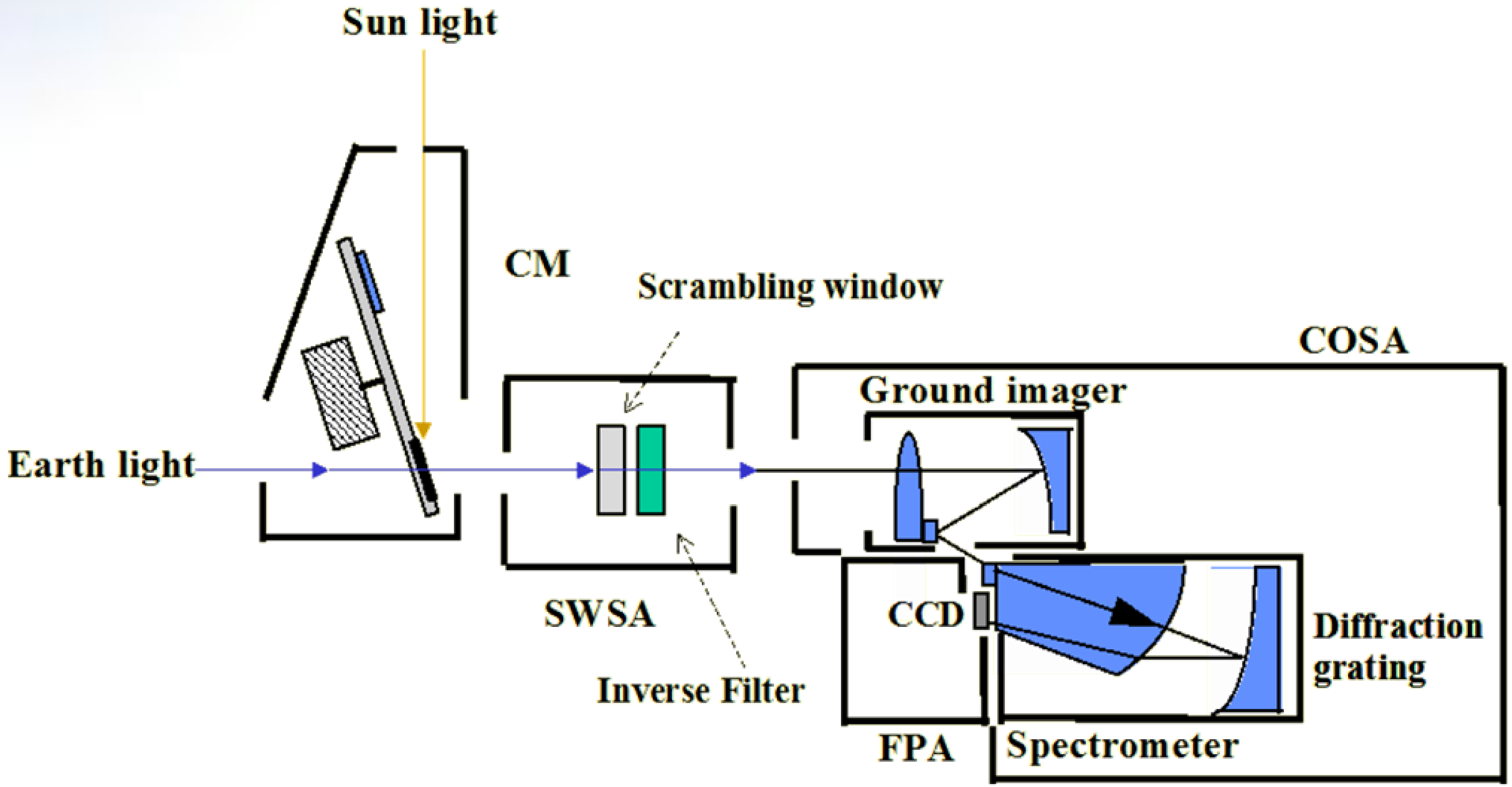
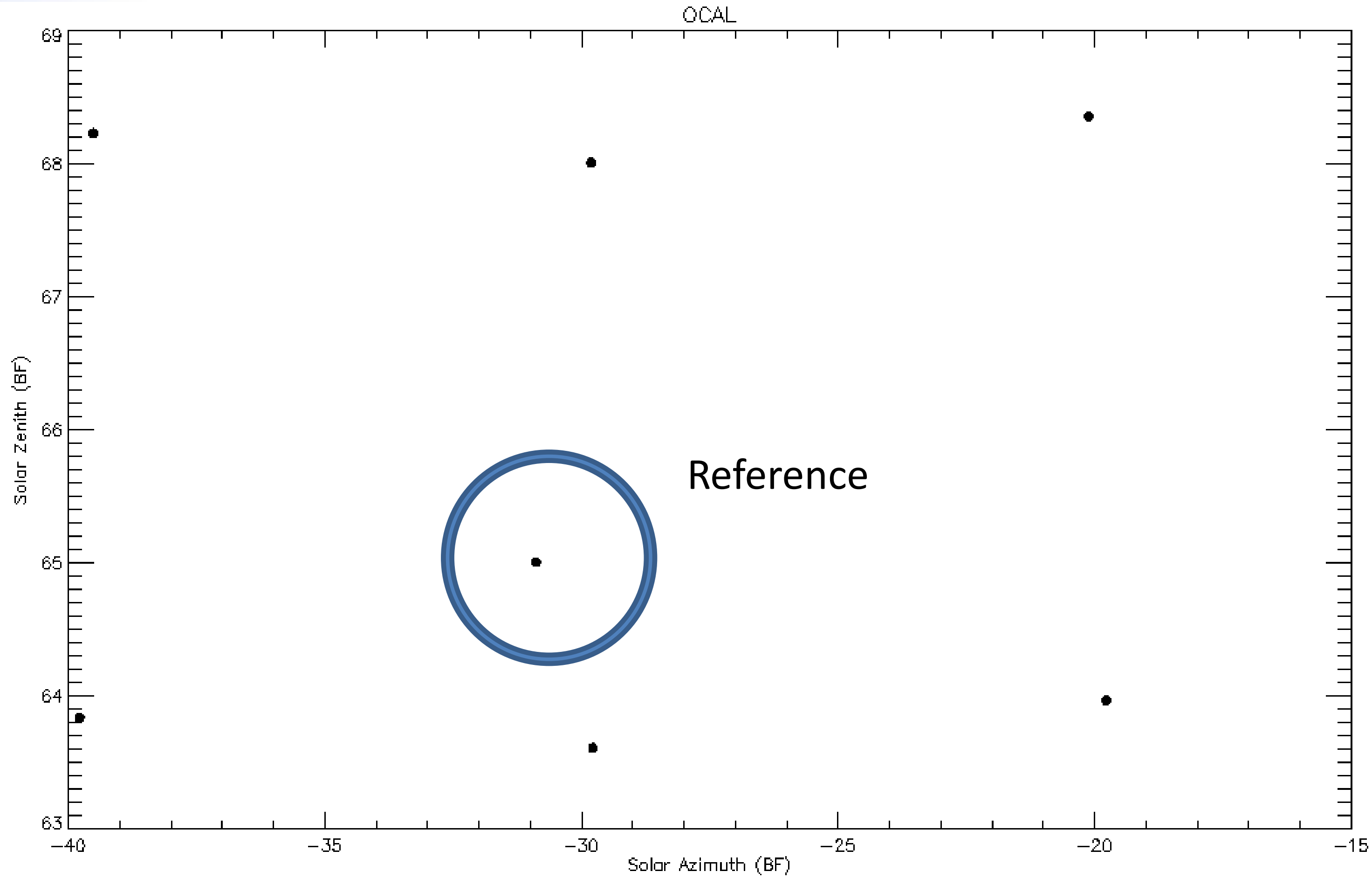
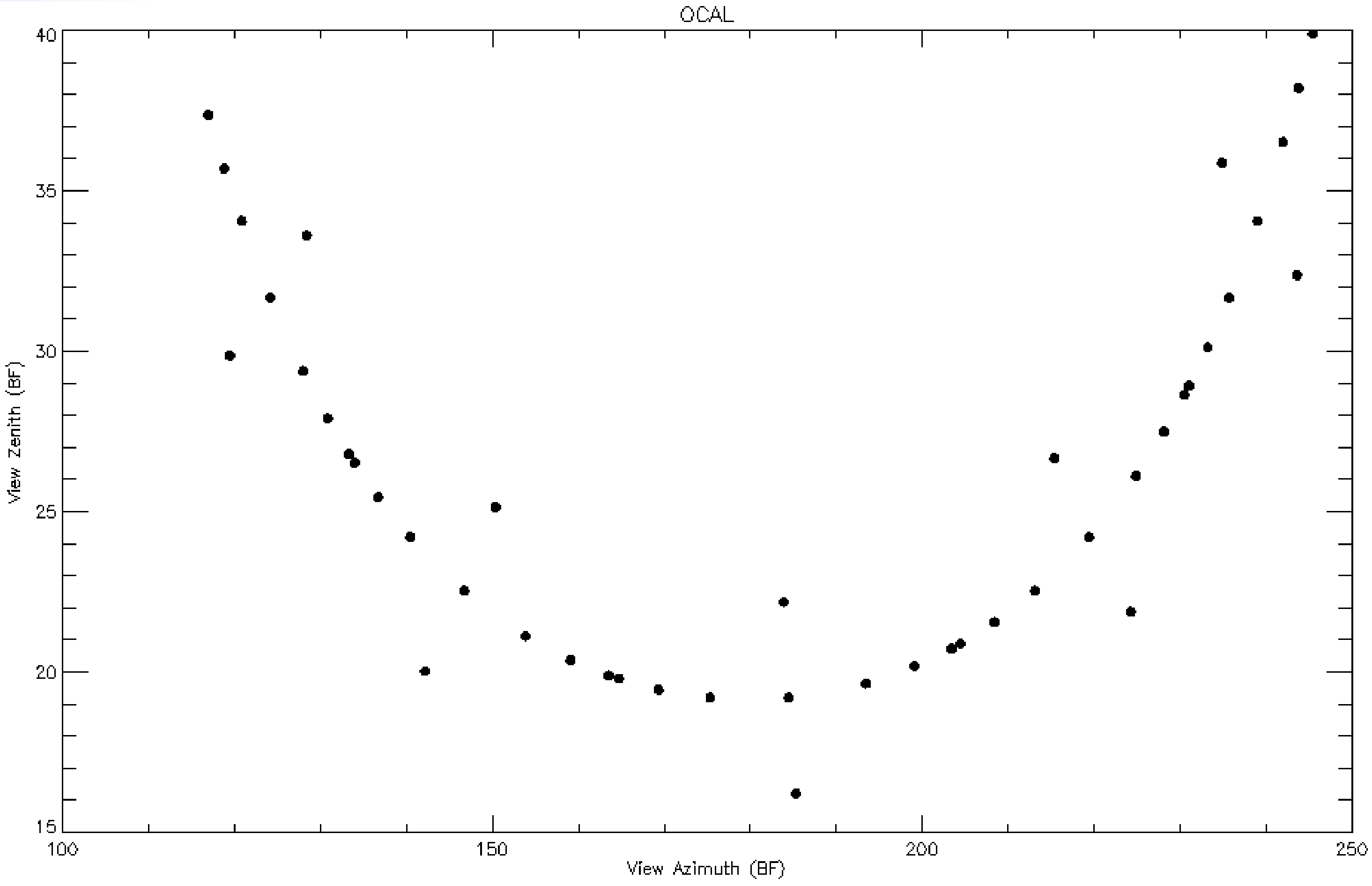


On-ground Calibration



On-ground Calibration



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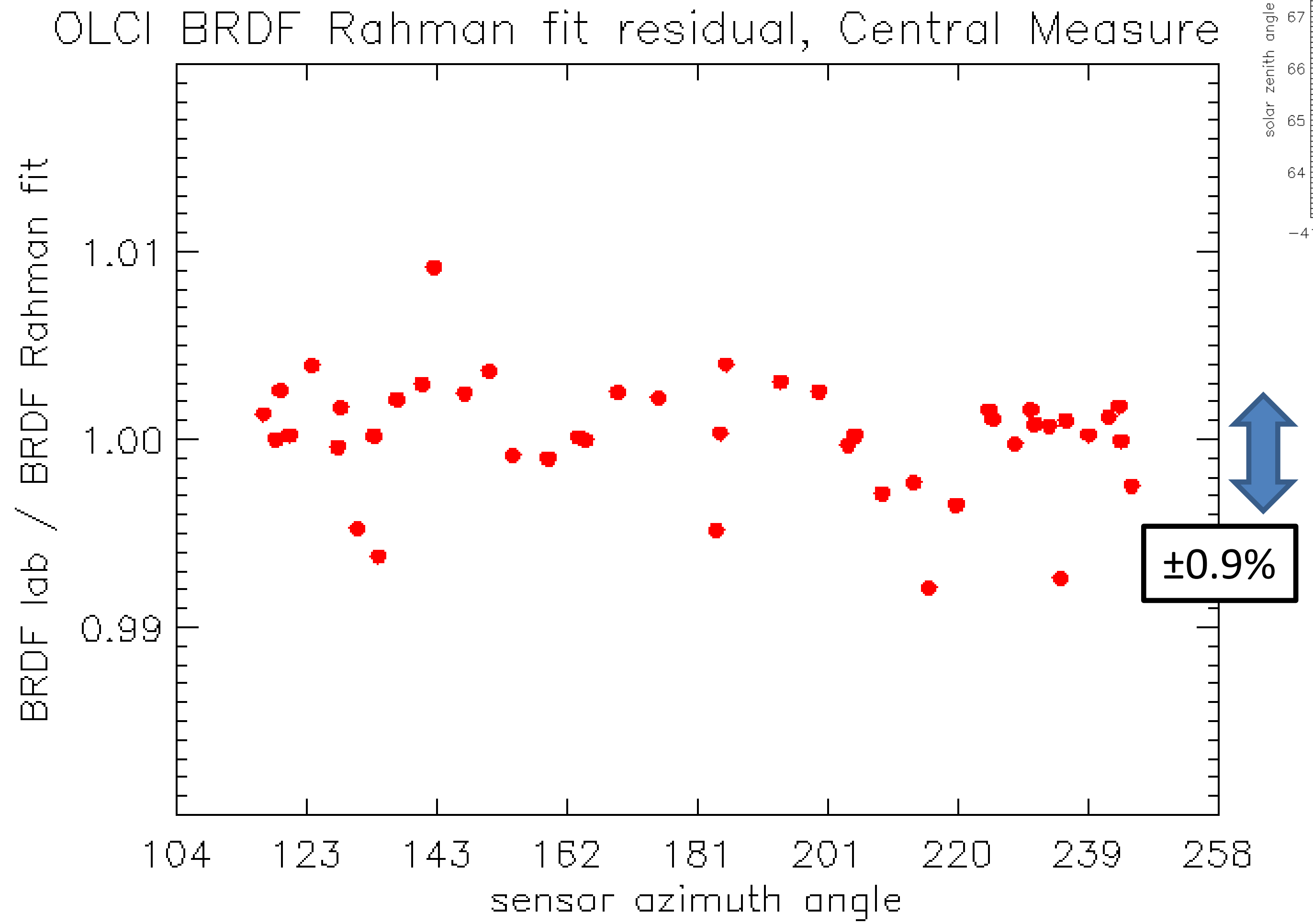
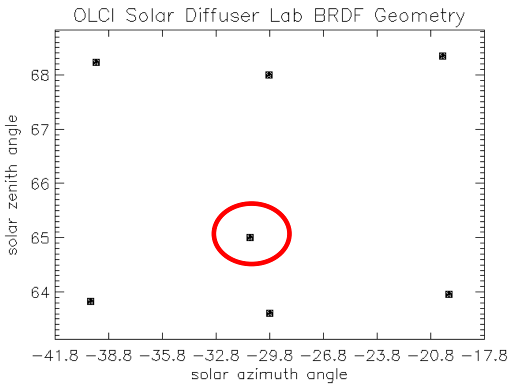
On-ground Calibration





BRDF Rahman model residual for the central lab measurement

Diffuser Model: Rahman2

Parameters: ρ_0 Θ $k-1$ ρ_1

$$\rho(\theta_i,\varphi_i;\theta_r,\varphi_r;\lambda) = \rho_0 \cdot M(\theta_i,\theta_r,k) \cdot F(g) \cdot [1+R(G)]$$

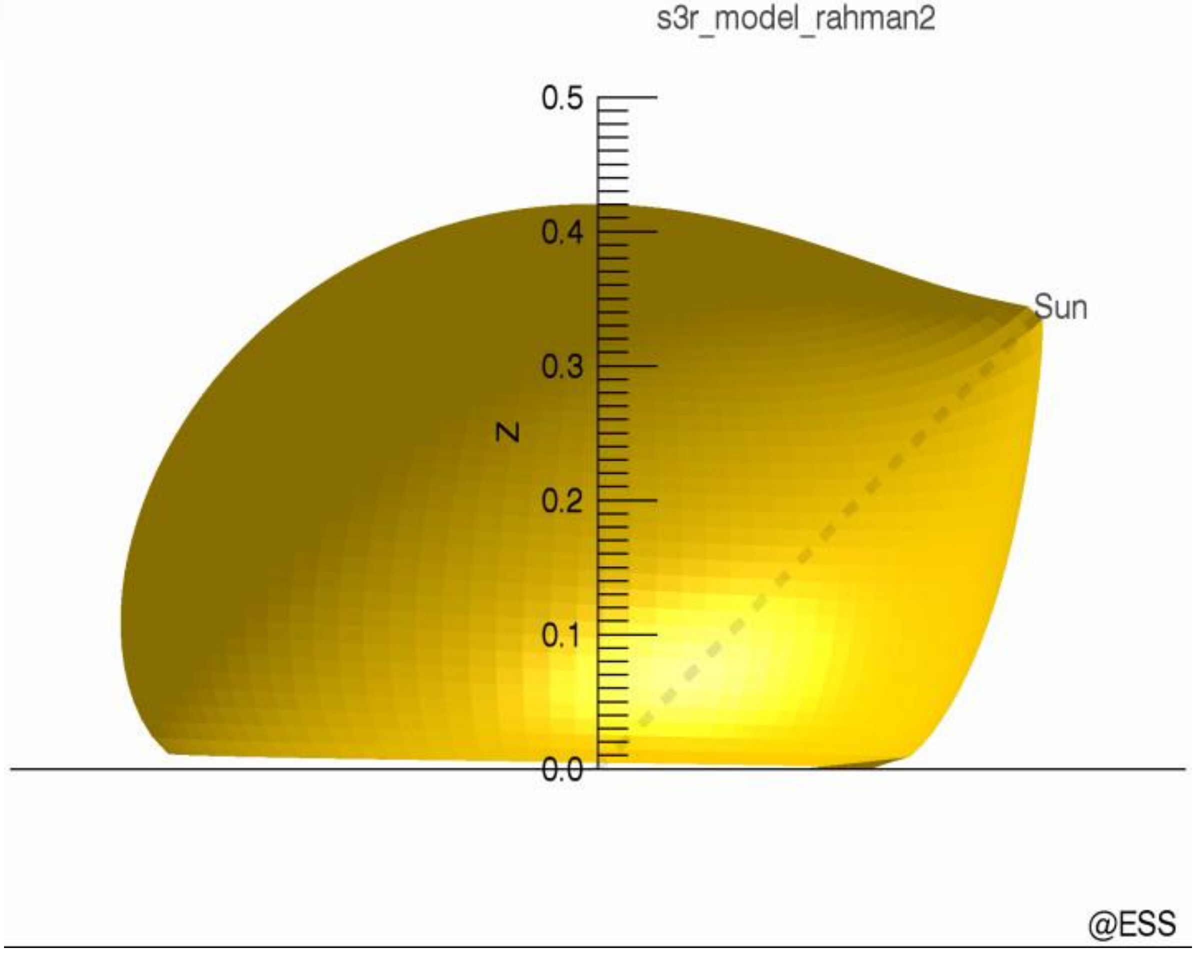
$$M(\theta_i,\theta_r,k) = (\cos\theta_i \cdot \cos\theta_r)^{k-1} \cdot (\cos\theta_i + \cos\theta_r)^{k-1}$$ Minnaert

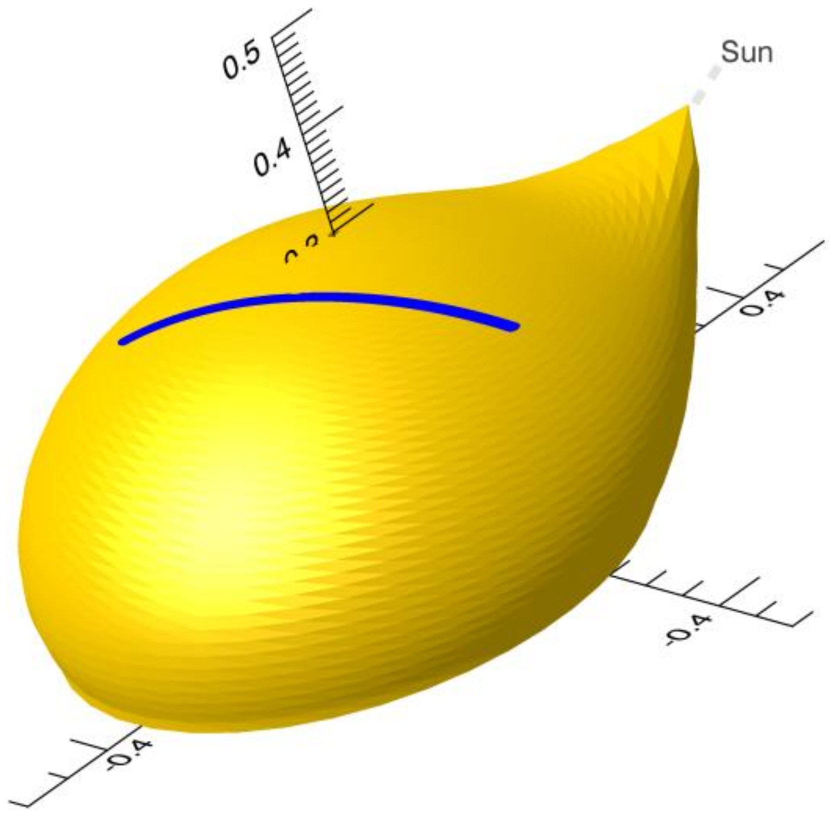
$$F(g) = \frac{1-\Theta^2}{\left[1+\Theta^2+2\cdot\Theta\cdot\cos(g)\right]^{1.5}}$$ Scattering

$$\cos g = \cos\theta_i \cdot \cos\theta_r + \sin\theta_i \cdot \sin\theta_r \cdot \cos(\varphi_i - \varphi_r)$$ Phase Angle

$$1+R(G) = 1 + \frac{1-\rho_1}{1+G}$$ Hot-Spot

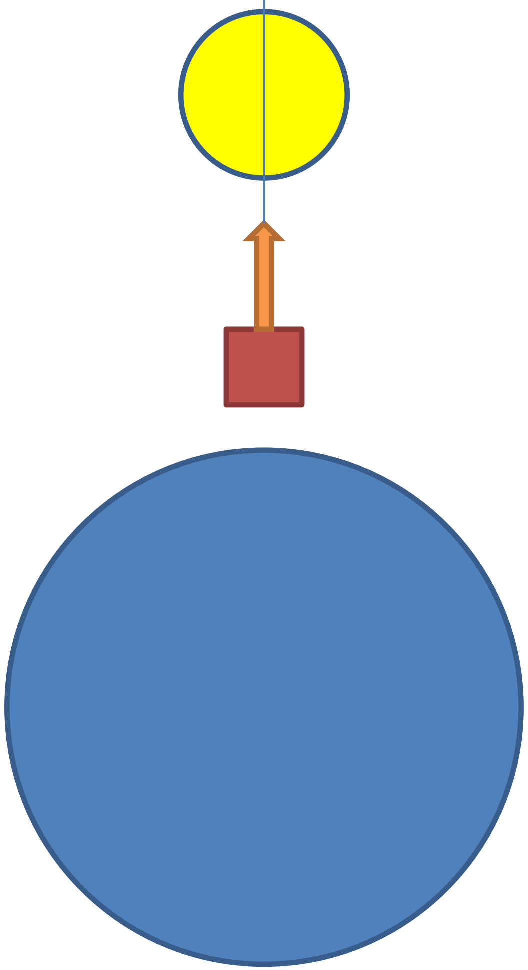
$$G = \left[\tan^2\theta_i + \tan^2\theta_r - 2\cdot\tan\theta_i\cdot\tan\theta_r\cdot\cos(\varphi_i-\varphi_r)\right]^{0.5}$$ Geometric Factor


s3r_model_rahman2
0.5
0.4
0.3
0.2
0.1
0.0
Z
Sun
@ESS

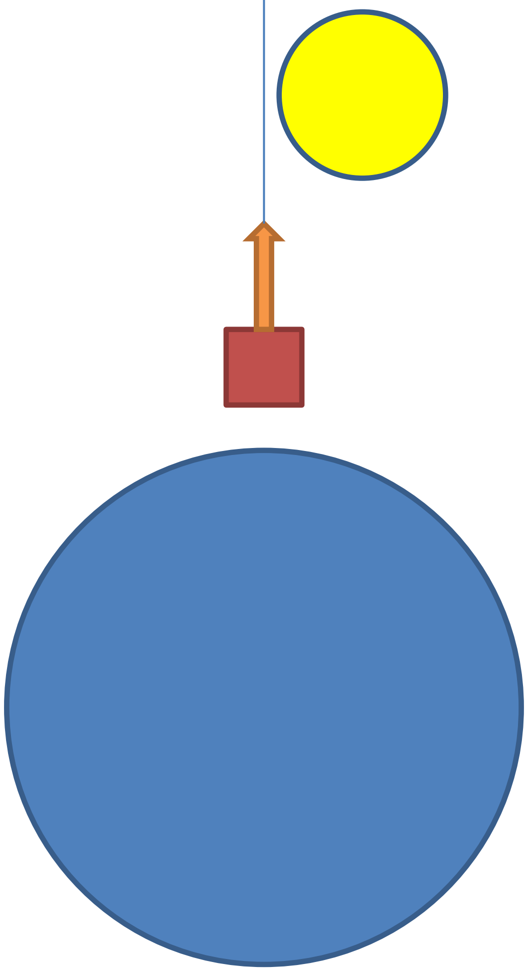


0.5
0.4
Sun
0.4
-0.4
-0.4

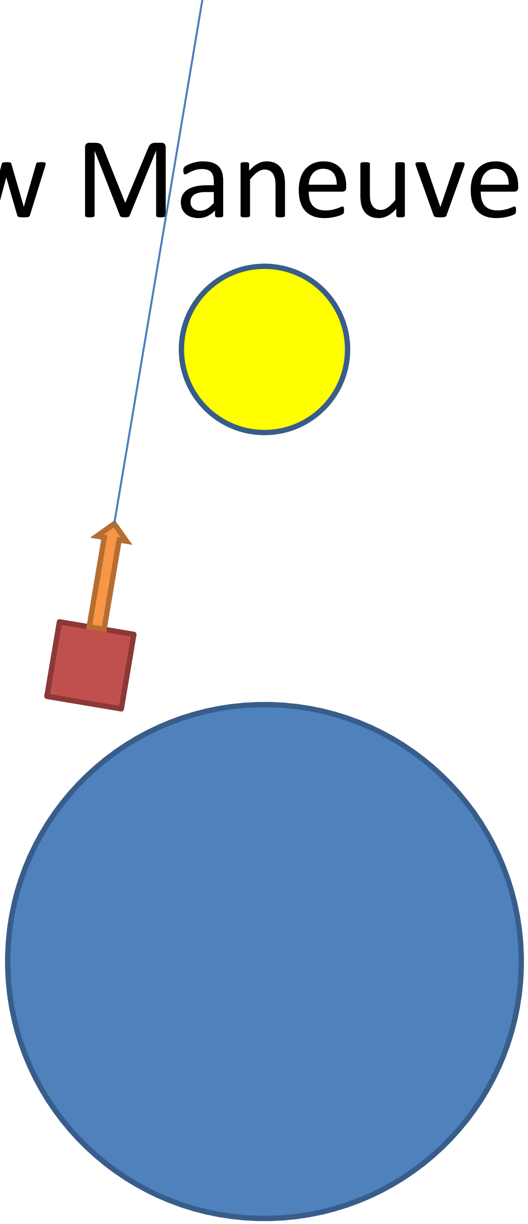
Yaw Maneuvers



Yaw Maneuvers

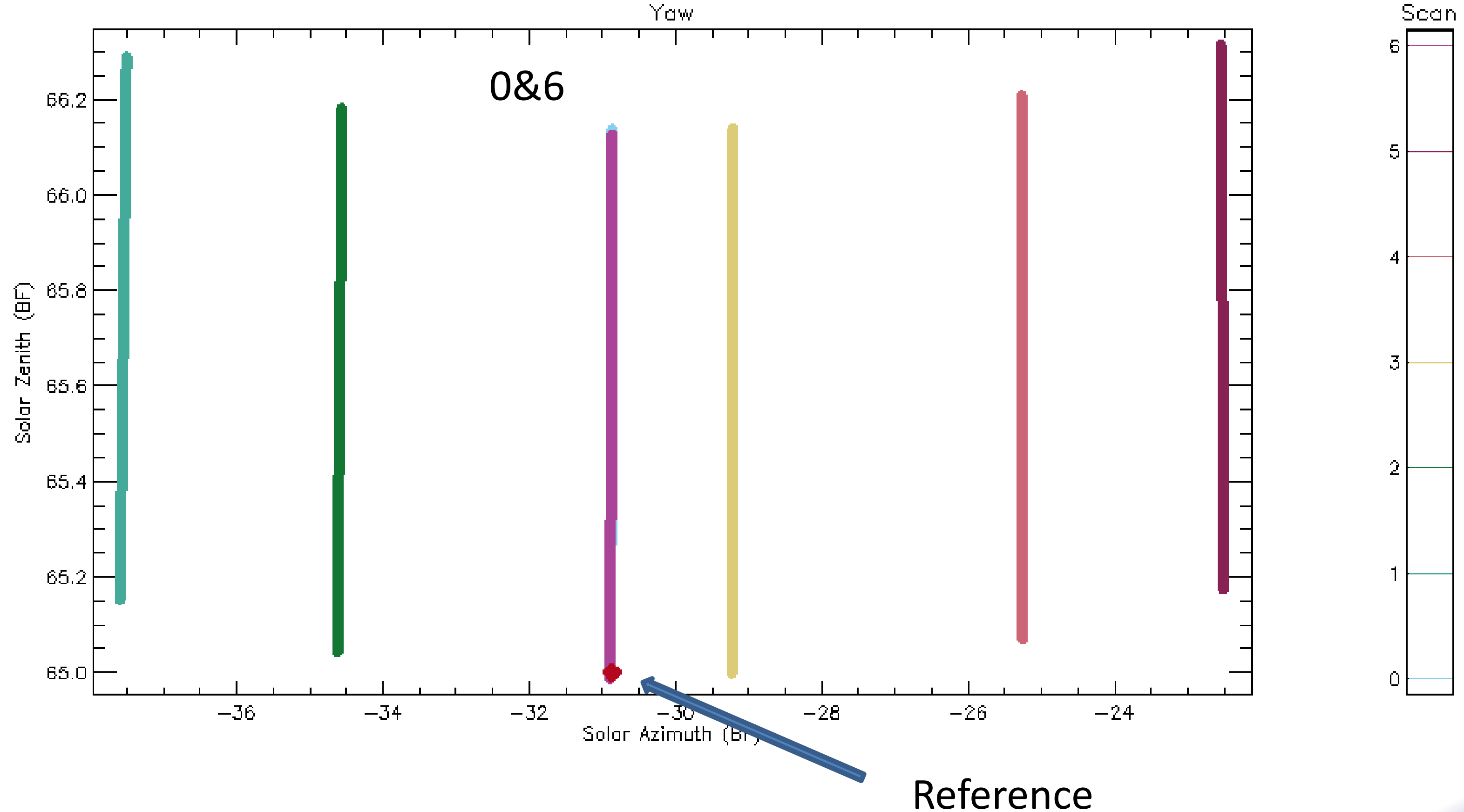


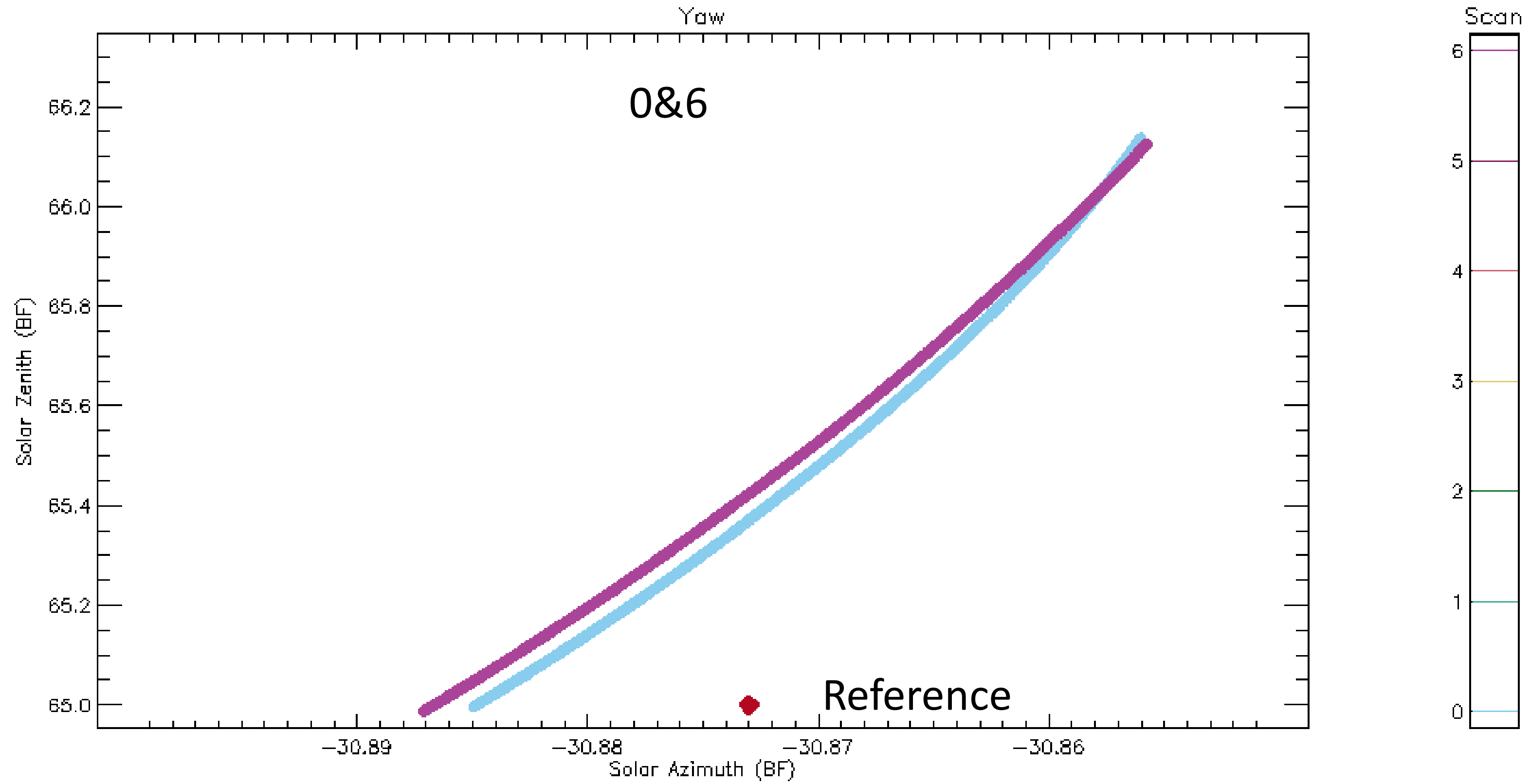
Yaw Maneuvers

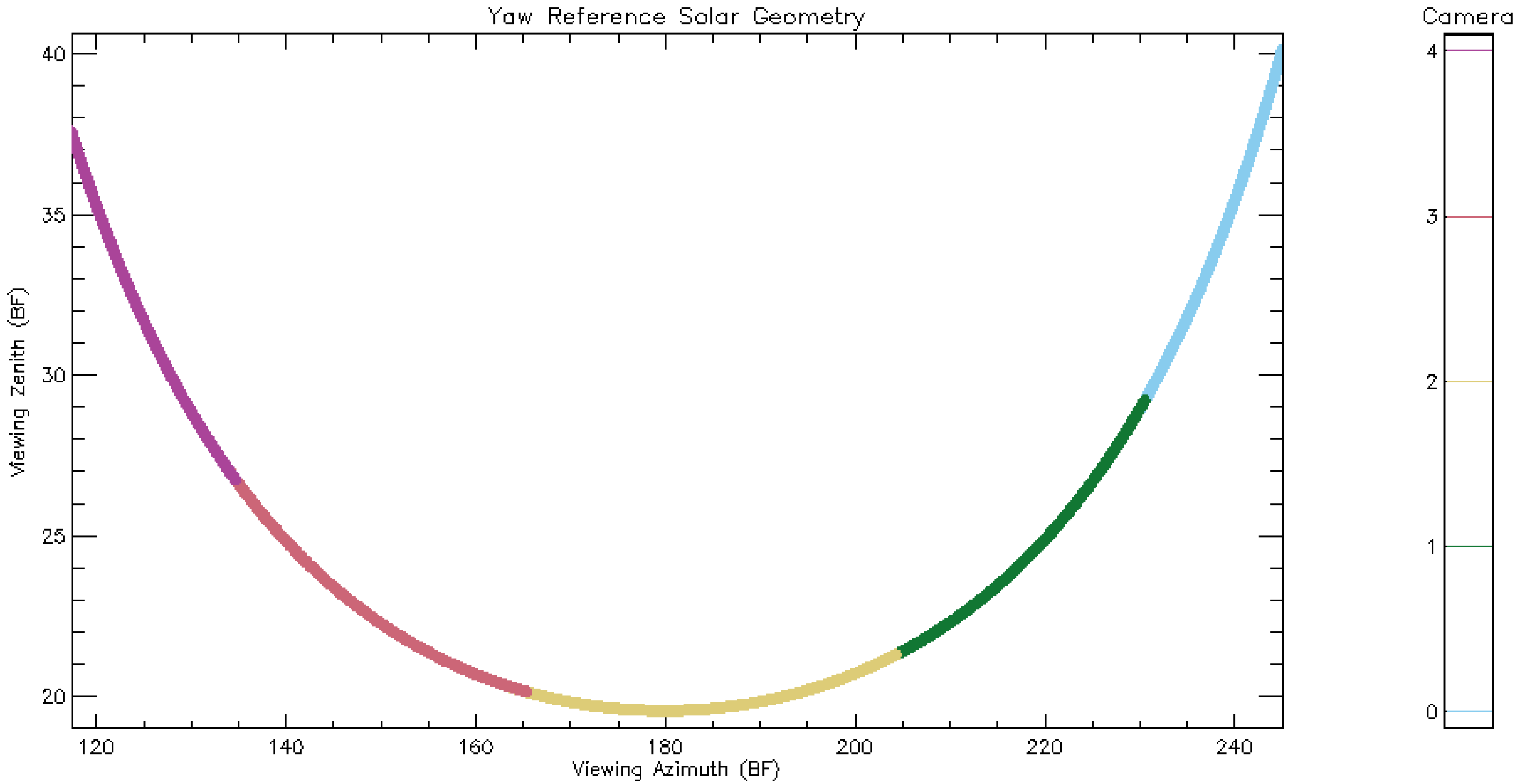


Yaw Maneuvers

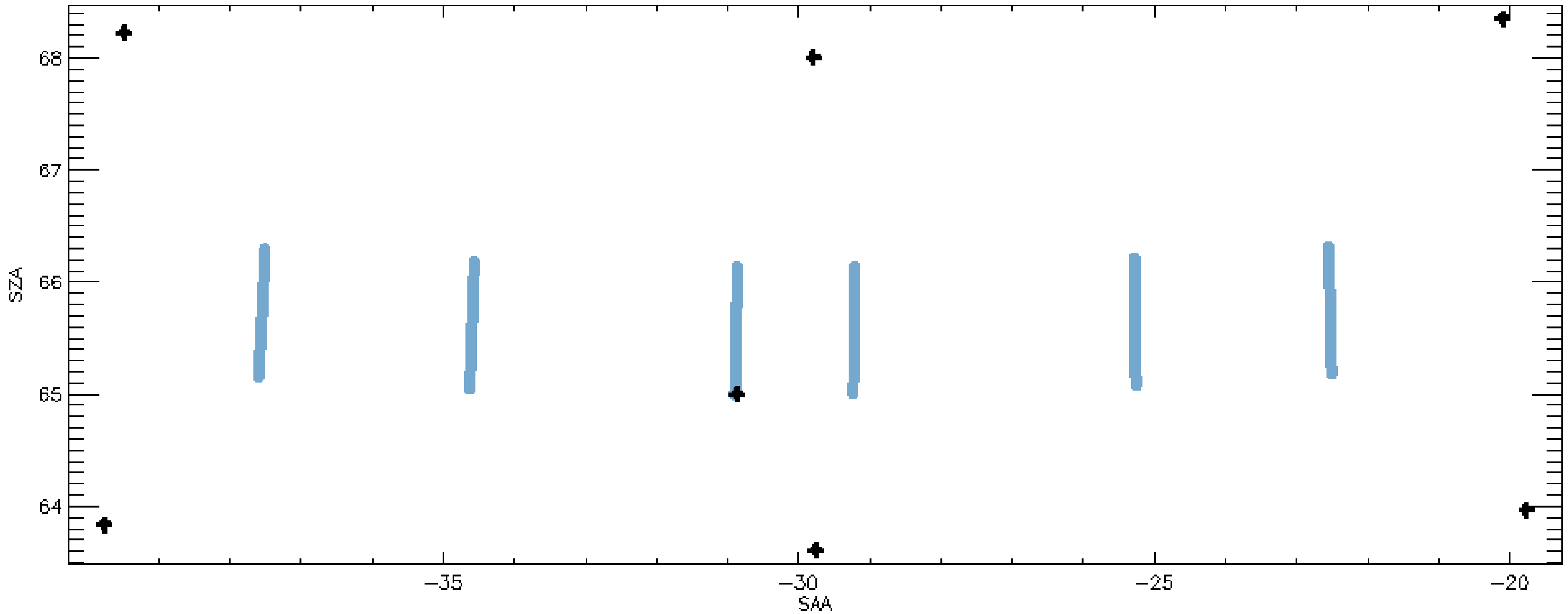
740 pixels, 5 cameras, 336 (536) solar angles, 7 scans



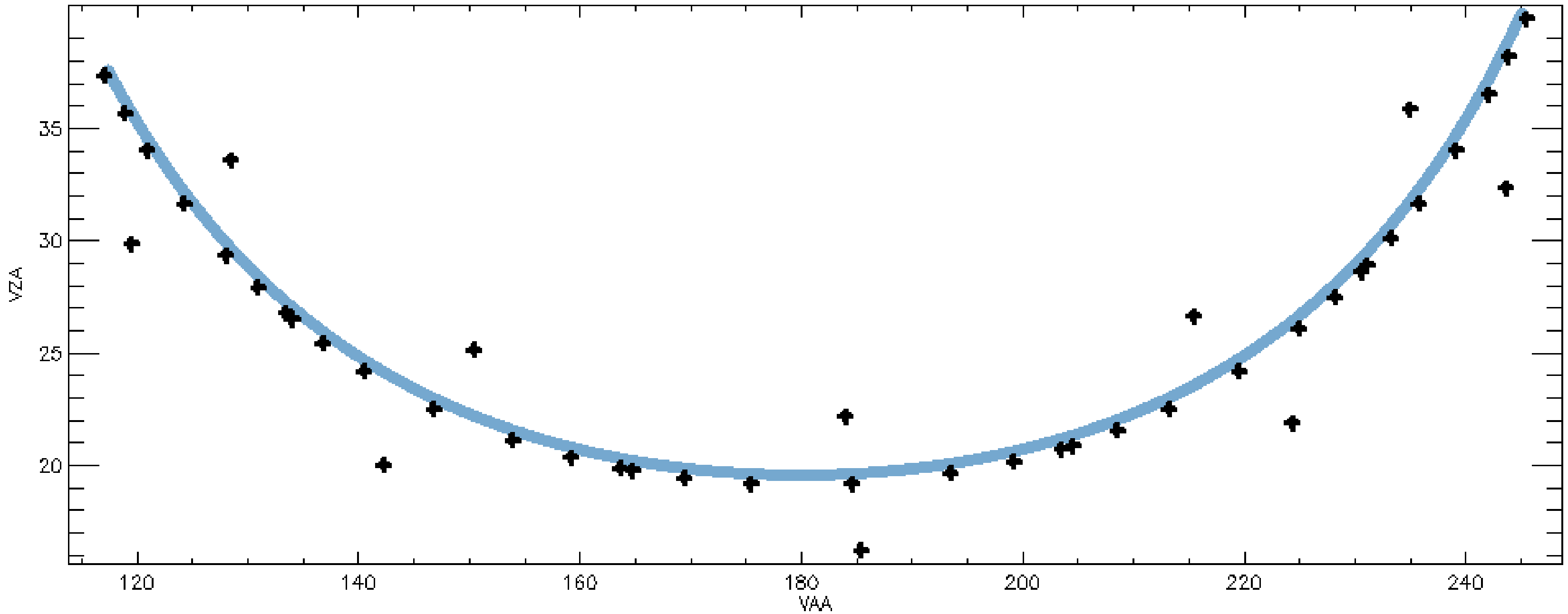

Yaw
0&6
Reference
Solar Zenith (BF)
66.2
66.0
65.8
65.6
65.4
65.2
65.0
−30.89
−30.88
−30.87
−30.86
Solar Azimuth (BF)
Scan
6
5
4
3
2
1
0

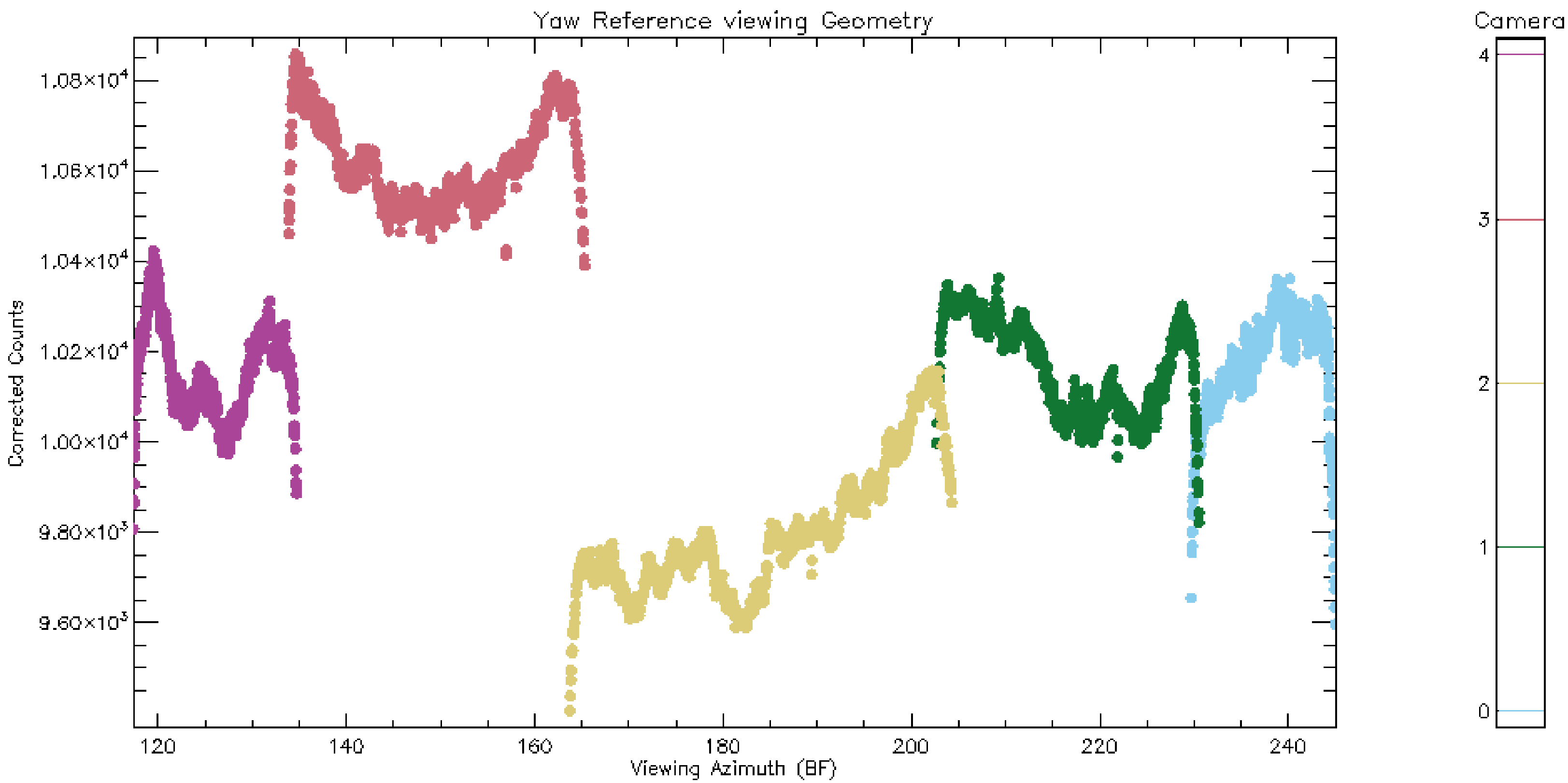


Yaw Reference Solar Geometry
Viewing Zenith (BF)
40
35
30
25
20
120
140
160
180
200
220
240
Viewing Azimuth (BF)
Camera
4
3
2
1
0

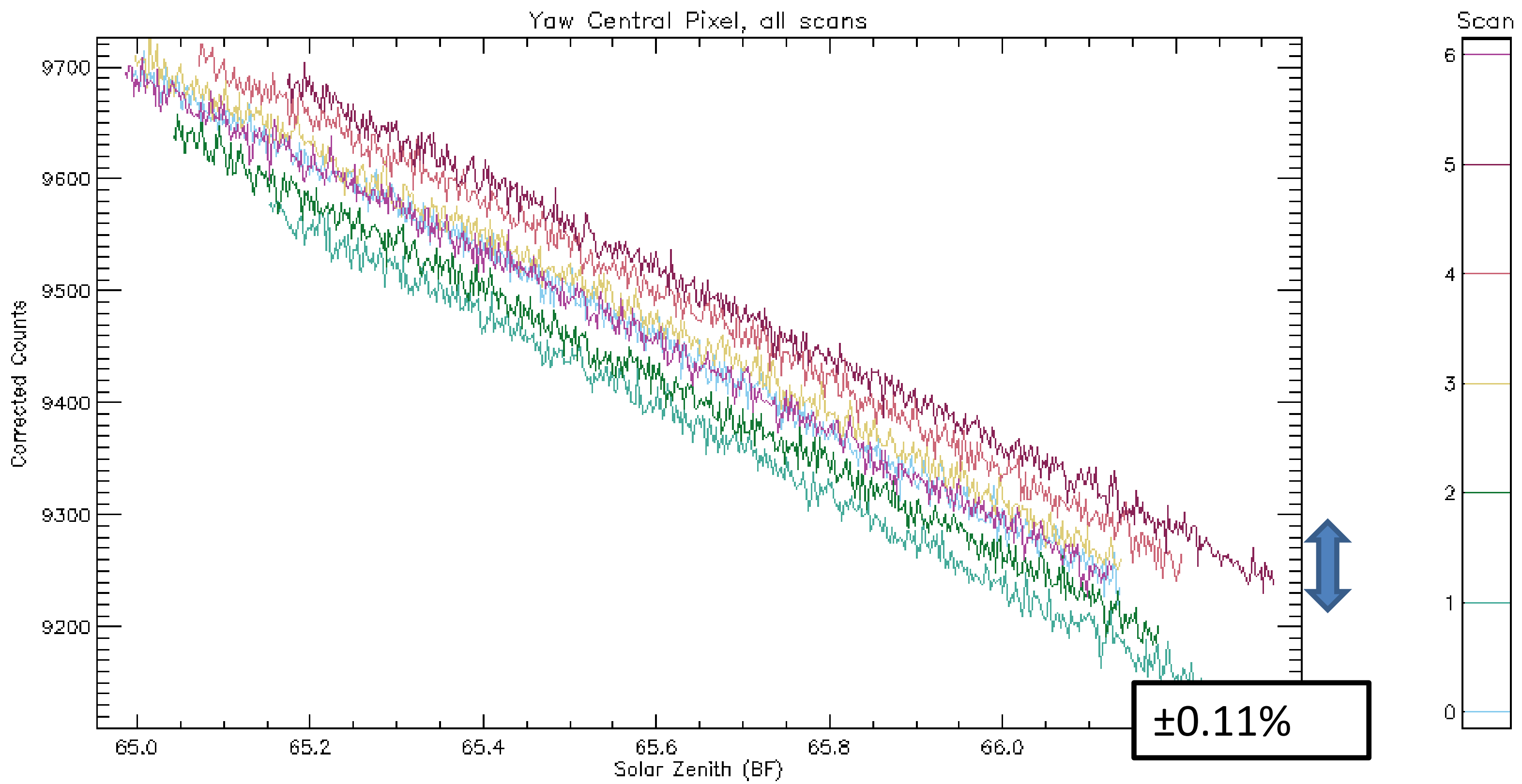


68
67
66
65
64
SZA
−35
−30
−25
−20
SAA


35
30
25
20
VZA
120
140
160
180
200
220
240
VAA



Yaw Reference viewing Geometry
Corrected Counts
1.08×10⁴
1.06×10⁴
1.04×10⁴
1.02×10⁴
1.00×10⁴
9.80×10³
9.60×10³
120
140
160
180
200
220
240
Viewing Azimuth (BF)
Camera
4
3
2
1
0


Yaw Central Pixel, all scans
Corrected Counts
9700
9600
9500
9400
9300
9200
65.0
65.2
65.4
65.6
65.8
66.0
Solar Zenith (BF)
±0.11%
Scan
6
5
4
3
2
1
0

Corrections

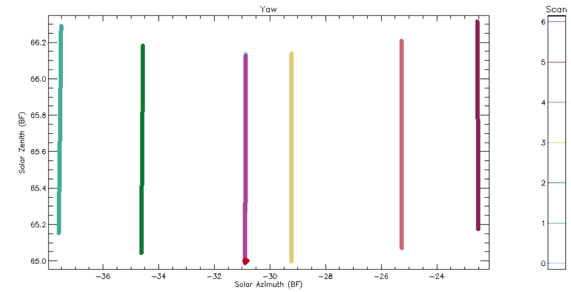
- Start with data corrected for
  - All Instrument Effects
    - except Straylight & Gain
  - Combine Microbands to Bands
  - Correct Straylight
  - Solar Distance and Illumination geometry

- 536 Measurements per Maneuver

Corrections

- Throw out solar angles where no signal (536 → 500)
- Throw out solar angles where straylight drops quickly (500 → 336)

Corrections



- Relative to In-flight reference angle
  - All measurements for given pixel are divided by inflight- **measurement**

    for that pixel, at reference angle
- Relative to On-ground reference angle
  - All measurements for given pixel are multiplied by on-ground **model**

    for that pixel, at reference angle

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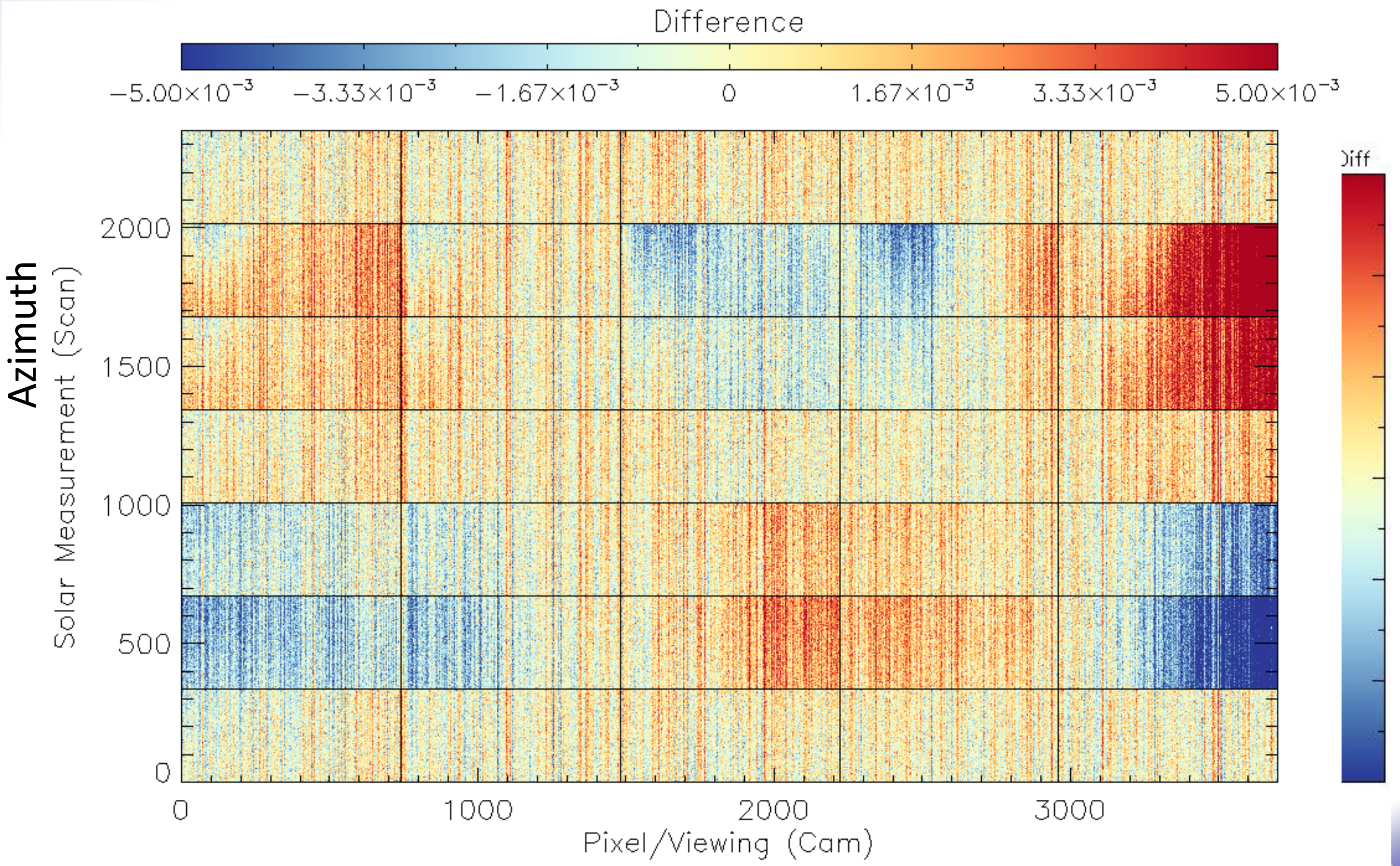
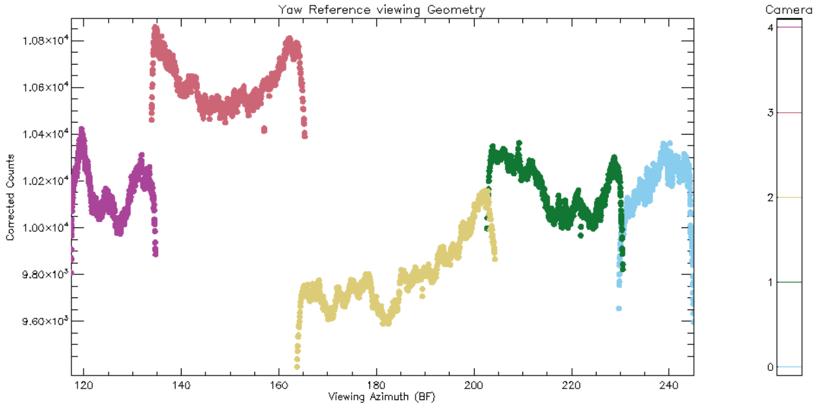
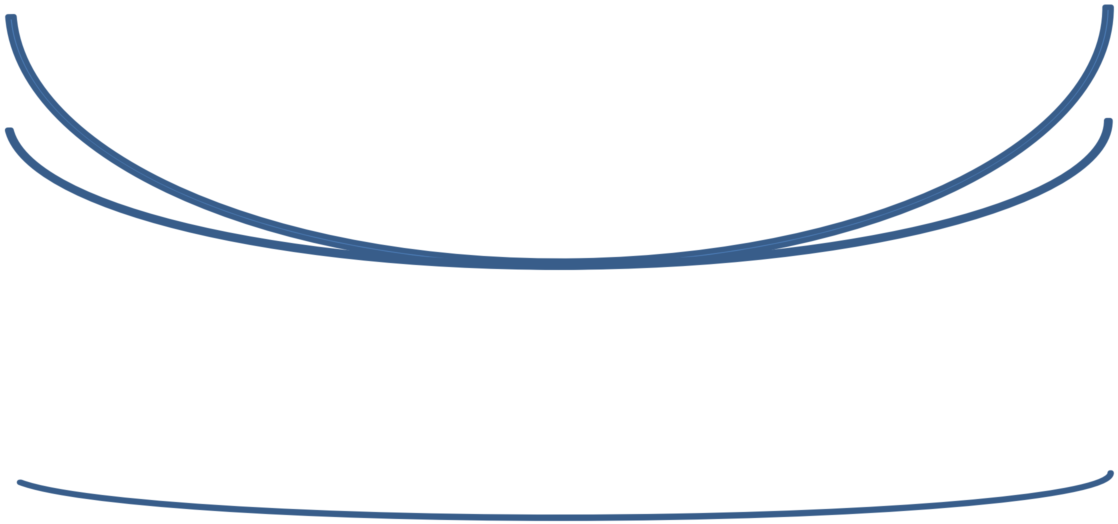
Rahman2 from Onground



Relative Response





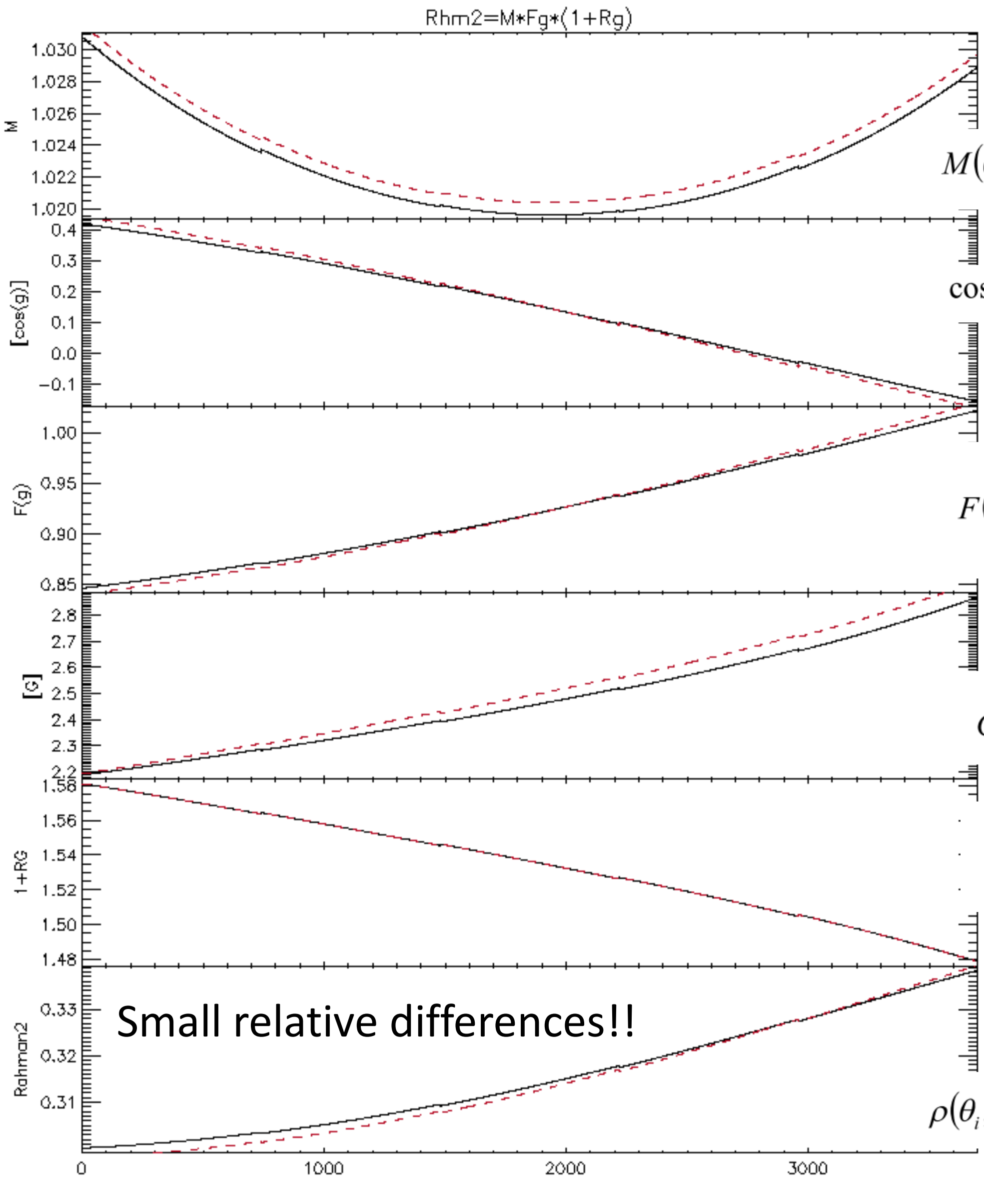
Measurement

Reference

Relative

Add noise
and little left to fit

Rahman2



$$M(\theta_i,\theta_r,k)=(\cos\theta_i\cdot\cos\theta_r)^{k-1}\cdot(\cos\theta_i+\cos\theta_r)^{k-1}$$

$$\cos g=\cos\theta_i\cdot\cos\theta_r+\sin\theta_i\cdot\sin\theta_r\cdot\cos(\varphi_i-\varphi_r)$$

$$F(g)=\frac{1-\Theta^2}{[1+\Theta^2+2\cdot\Theta\cdot\cos(g)]^{1.5}}$$

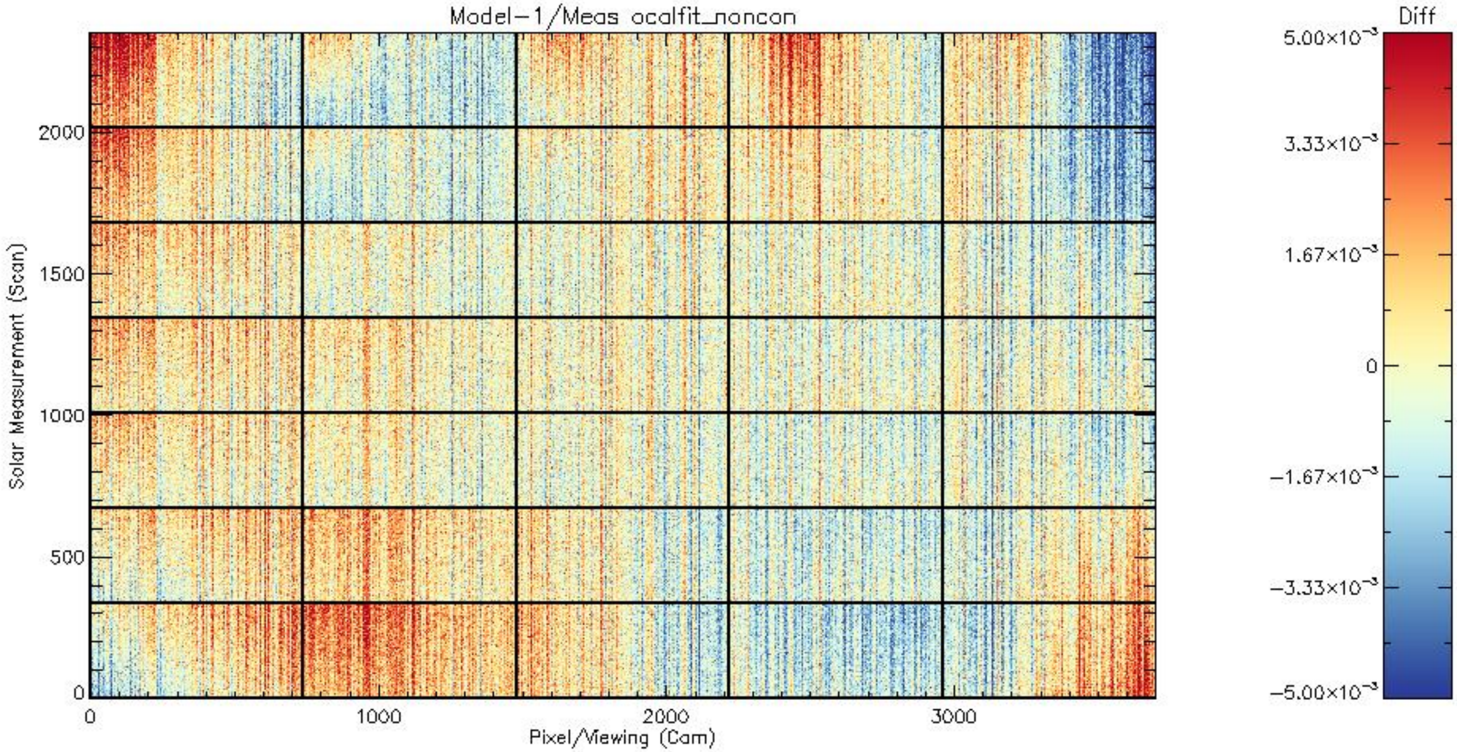
$$G=[\tan^2\theta_i+\tan^2\theta_r-2\cdot\tan\theta_i\cdot\tan\theta_r\cdot\cos(\varphi_i-\varphi_r)]^{0.5}$$

$$1+R(G)=1+\frac{1-\rho_0}{1+G}$$

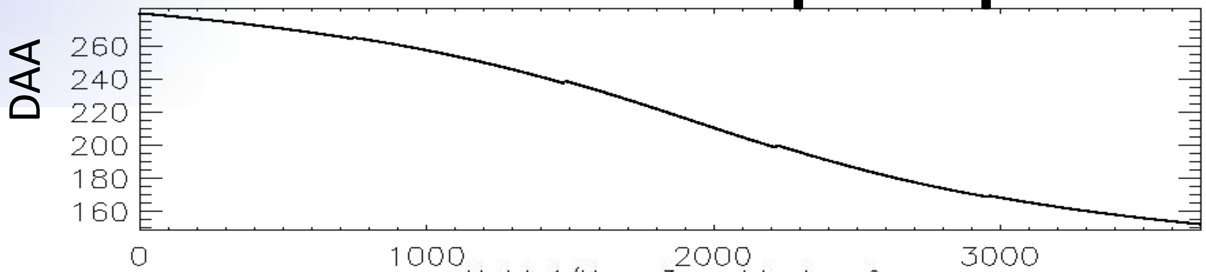
$$\rho(\theta_i,\varphi_i;\theta_r,\varphi_r;\lambda)=\rho_0\cdot M(\theta_i,\theta_r,k)\cdot F(g)\cdot[1+R(G)]$$

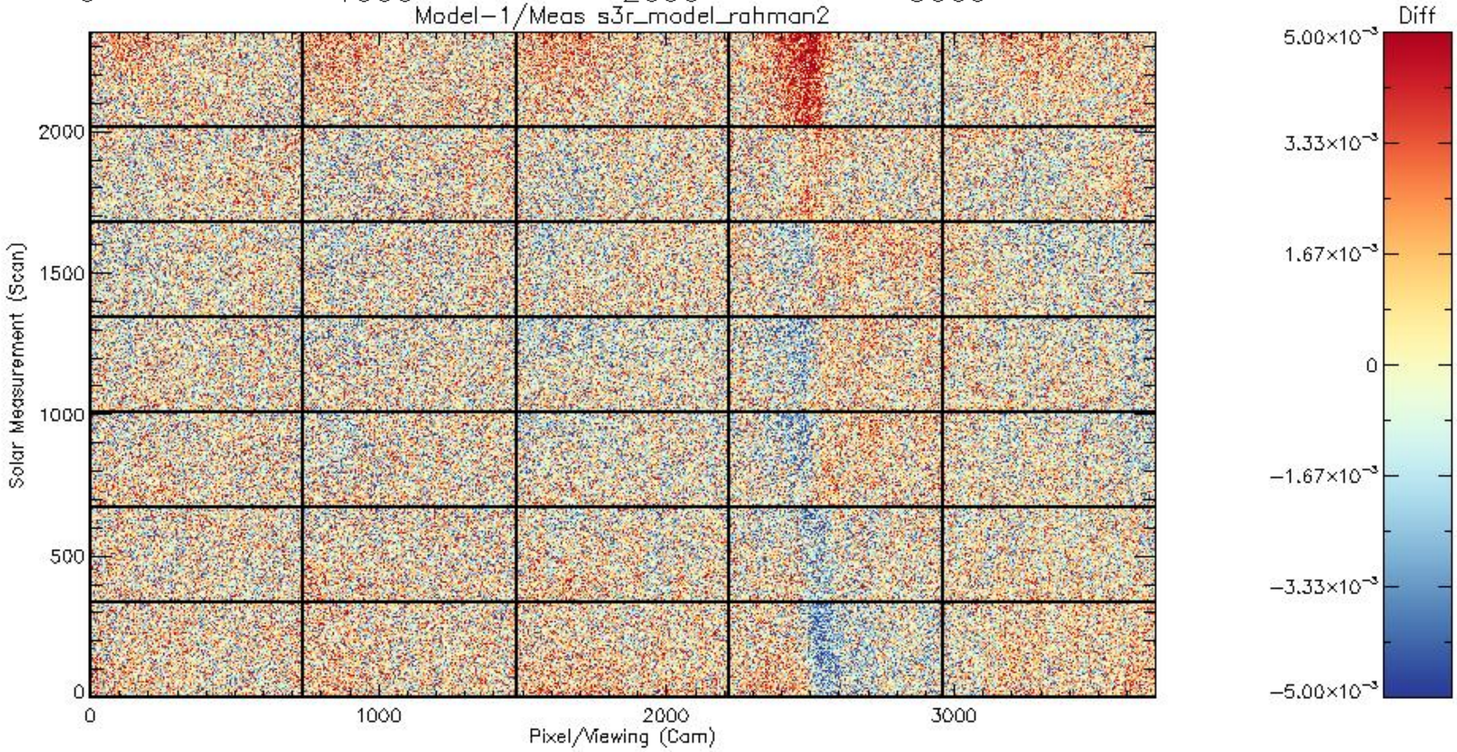
Rahman2 fit non-constrained

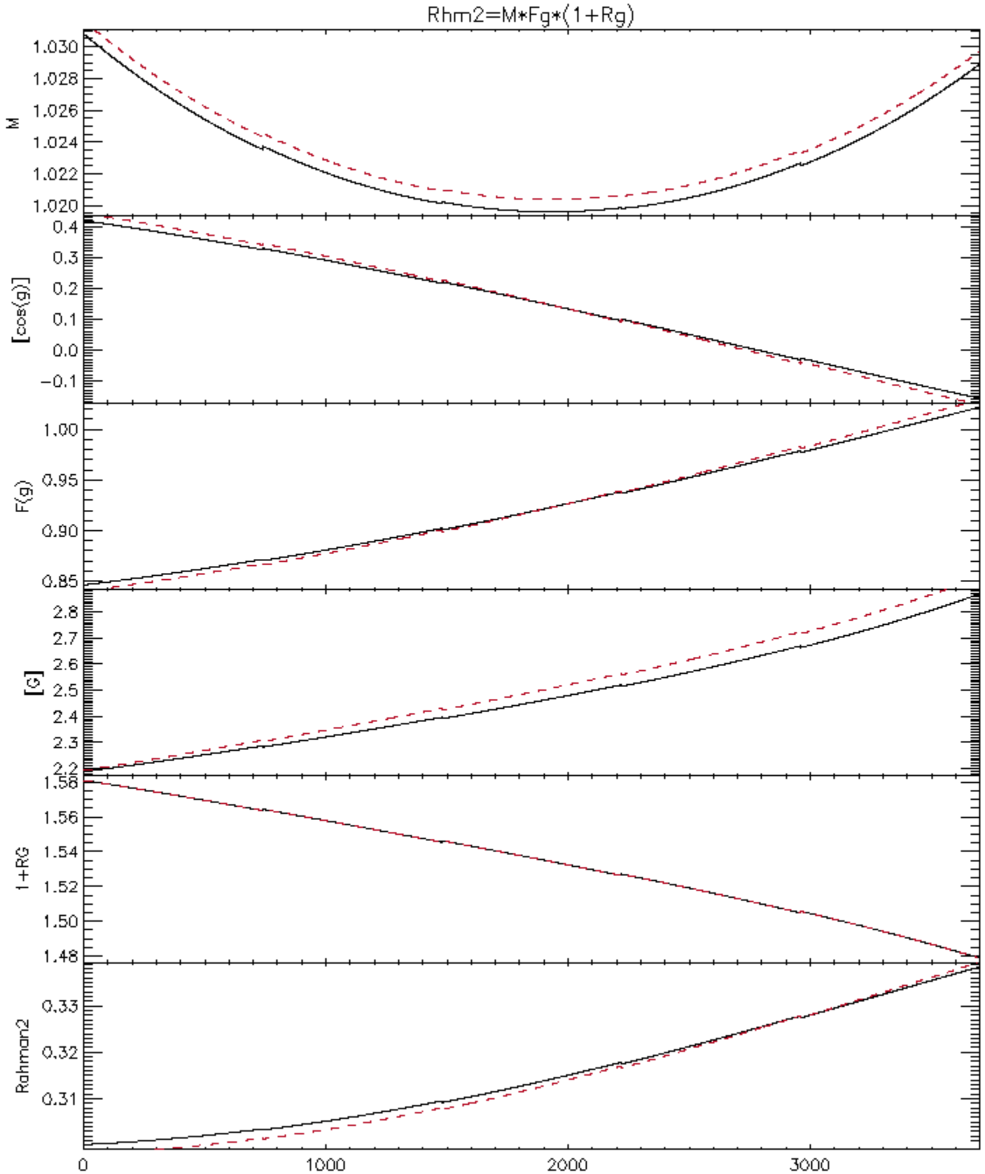
Non-physical parameters



Rahman2 per pixel







Quite 'linear' functions

And

Viewing angles 'fixed'

Polynomial per pixel

- P0* [absolute calibration]

  1+P1*SZA+P2*SAA [linear]

  1+P3*SAA*SZA [cross-term]

  1+P4*SZA^2+P5*SAA^2 [second order]

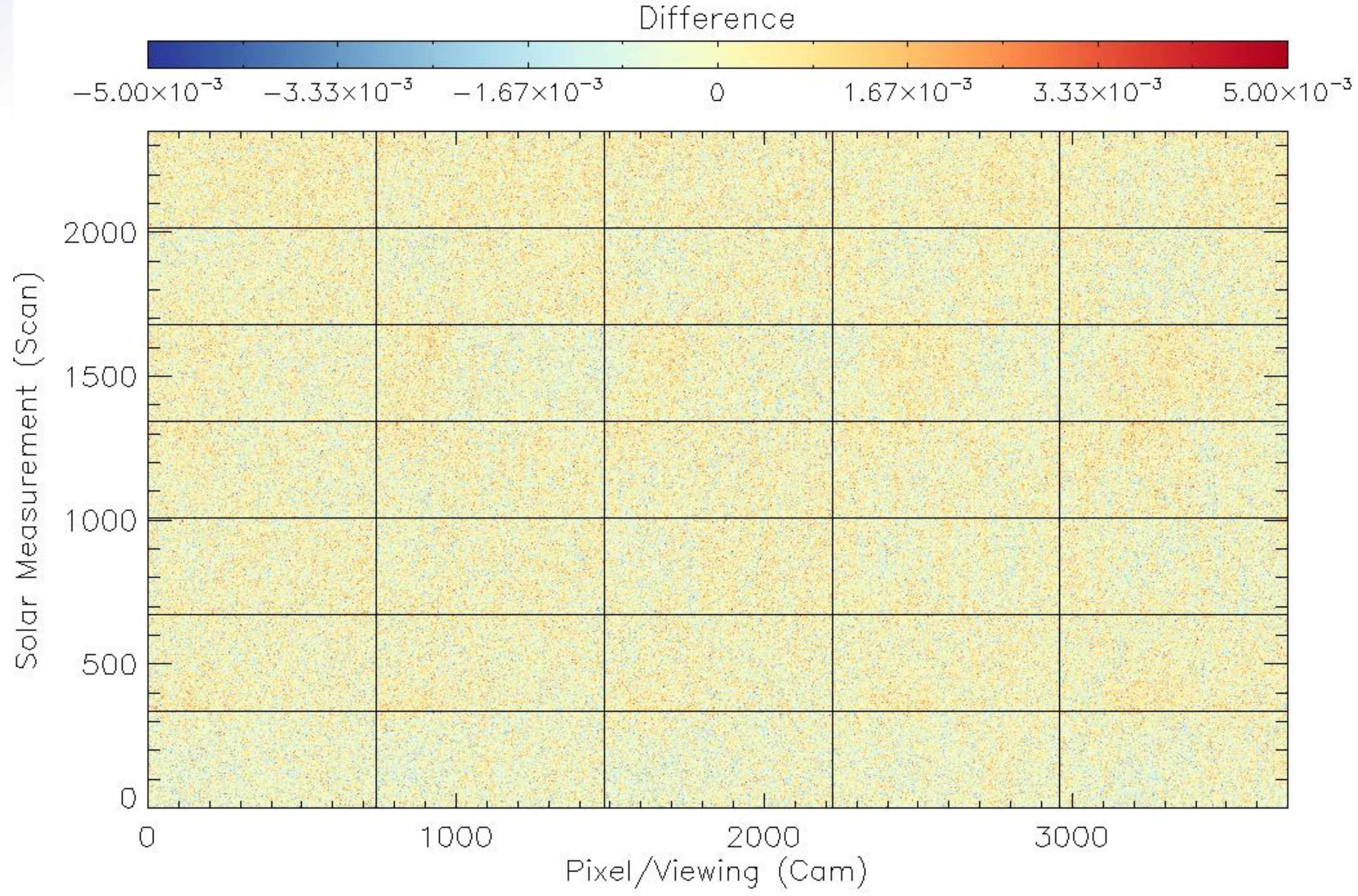
  →

  P0*(1+P1*SZA+P2*SAA+P3*SAA*SZA+P4*SZA^2+P5*SAA^2)

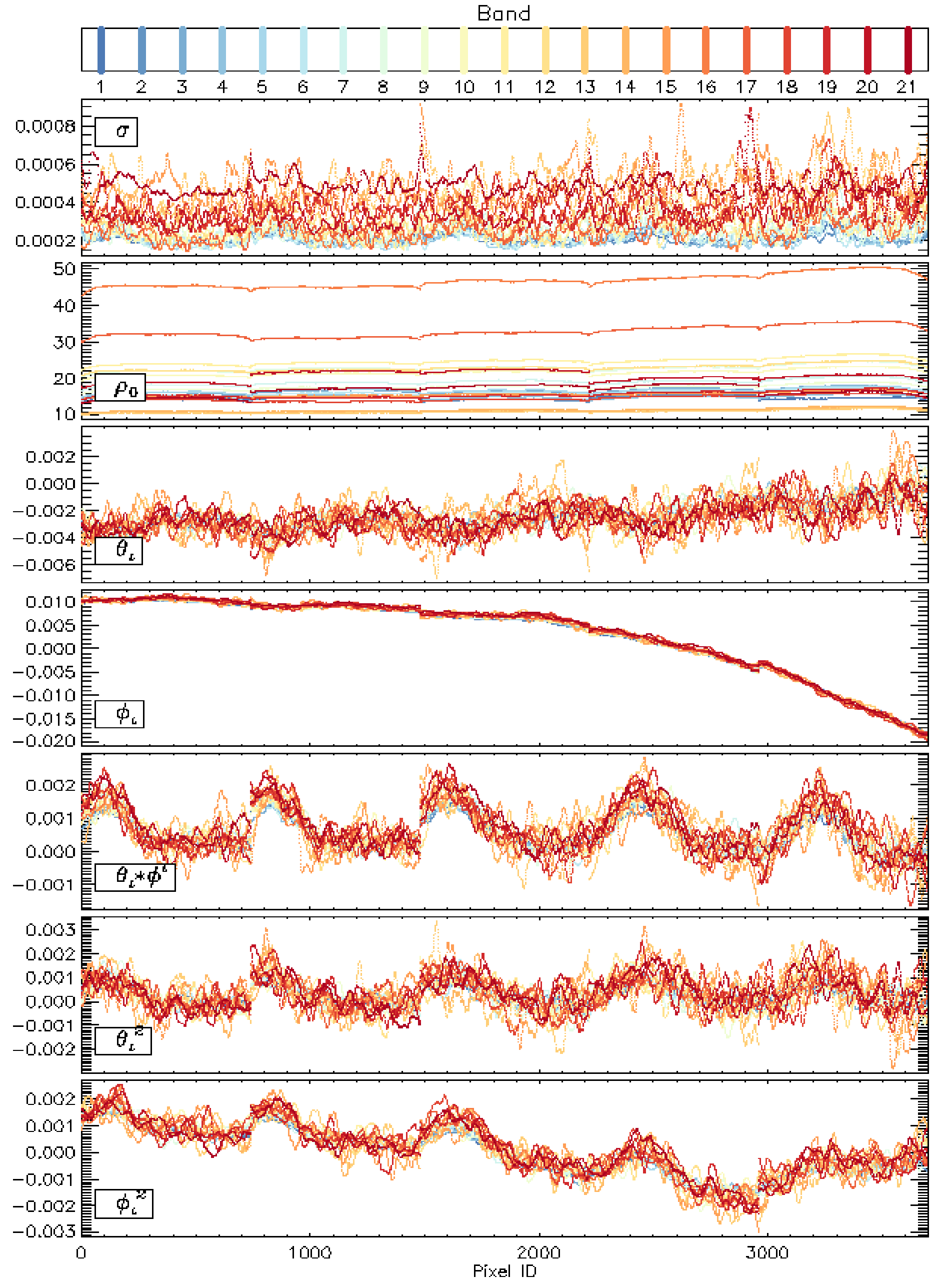
  With P0-P5 free fitting parameters (for each band)

Polynomial per pixel

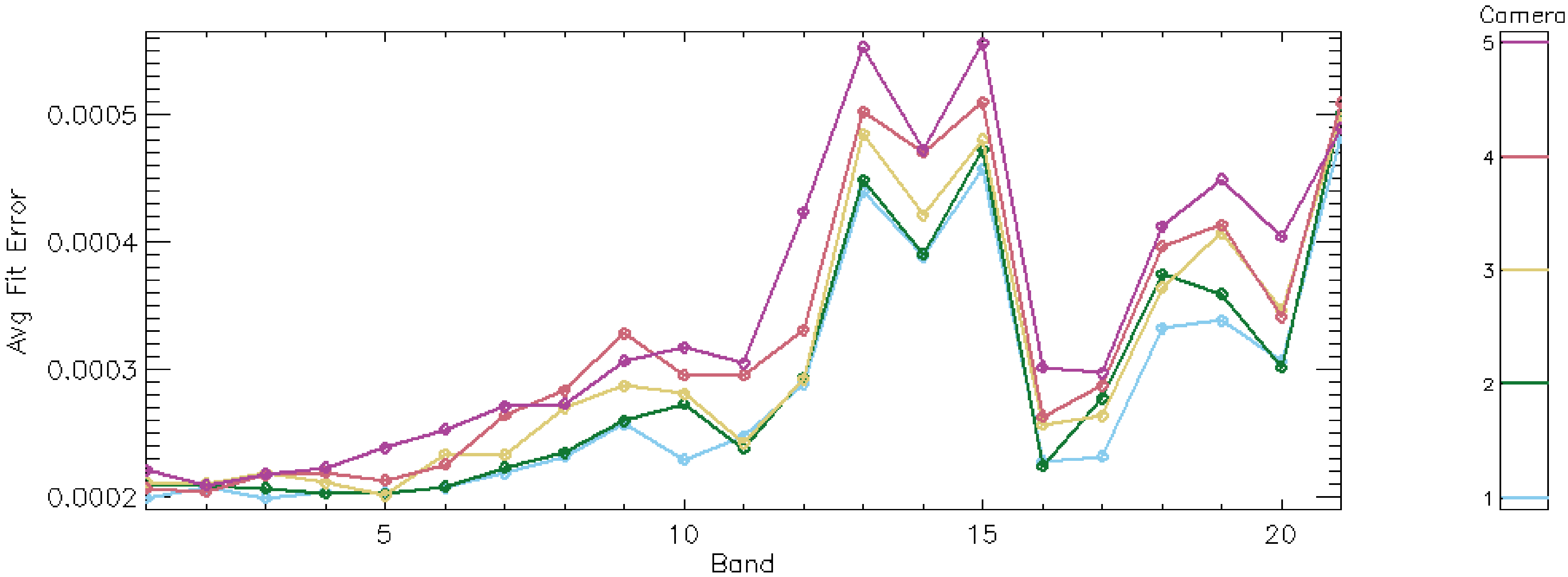
P0*(1+P1*SZA+P2*SAA+P3*SAA*SZA+P4*SZA^2+P5*SAA^2)



EARTH SPACE SOLUTIONS

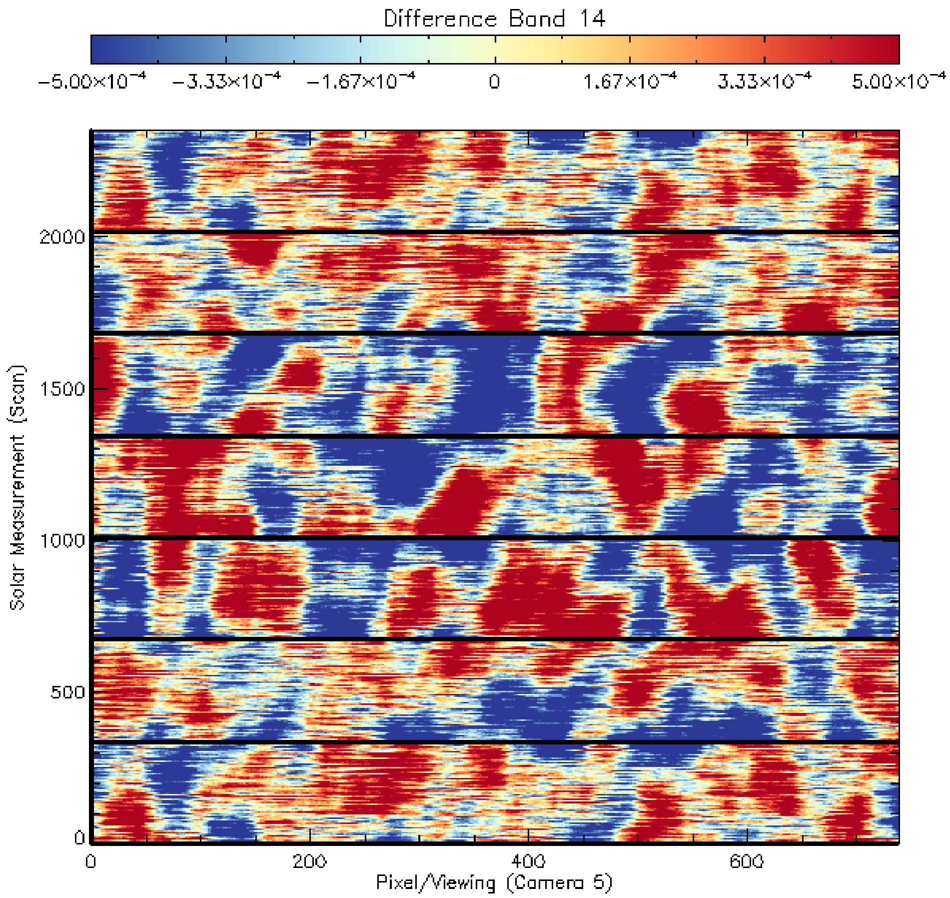

Band
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
σ
0.0008
0.0006
0.0004
0.0002
ρ0
50
40
30
20
10
θι
0.002
0.000
−0.002
−0.004
−0.006
φι
0.010
0.005
0.000
−0.005
−0.010
−0.015
−0.020
θι*φι
0.002
0.001
0.000
−0.001
θι²
0.003
0.002
0.001
0.000
−0.001
−0.002
φι²
0.002
0.001
0.000
−0.001
−0.002
−0.003
0
1000
2000
3000
Pixel ID

Band Error



Camera
5
4
3
2
1
0.0005
0.0004
0.0003
0.0002
Avg Fit Error
5
10
15
20
Band

Speckles


Difference Band 14
−5.00×10⁻⁴ −3.33×10⁻⁴ −1.67×10⁻⁴ 0 1.67×10⁻⁴ 3.33×10⁻⁴ 5.00×10⁻⁴
Solar Measurement (Scan)
2000
1500
1000
500
0
0
200
400
600
Pixel/Viewing (Camera 5)

Conclusion

New OLCI Diffuser BRDF Model

- Relative accuracy to < 0.05%
  - Derived from yaw maneuvers
- Absolute accuracy < 1%
  - Derived from on-ground calibration

Lessons Learned

- On-ground reference measurement dominates absolute calibration accuracy
  - So repeat several times
- Yaw maneuvers provide accurate BRDF model
- More Yaw angles allow even more accurate model by speckle characterization

Thank you

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