Absolute Radiometric Calibration of the DigitalGlobe Fleet and updates on the new WorldView-3 Sensor Suite

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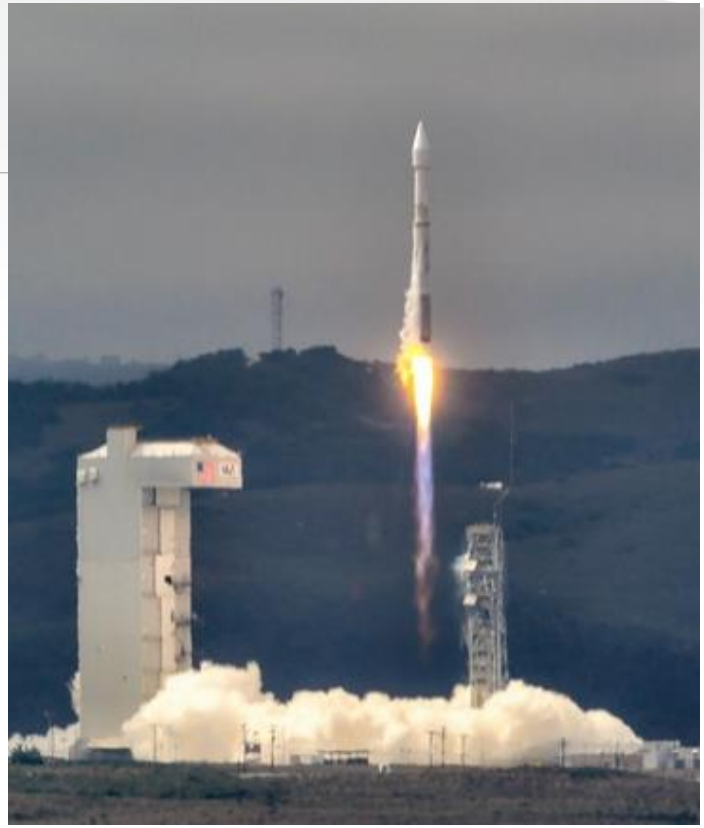
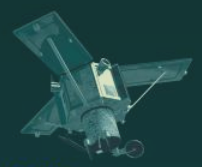
Overview

- DigitalGlobe Constellation
- Vicarious Calibration Approach
- DigitalGlobe adjustment factors to the absolute radiometric calibration
- Validation
- Ongoing Improvements



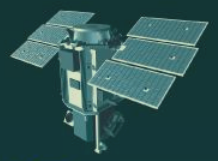
DigitalGlobe Constellation



IKONOS®

.82 meter
15 m CE90

.80 meter resolution	
PAN	723.0
BLUE	483.1
GREEN	550.6
RED	663.3
NIR	794.4



QuickBird®

.65 meter
23 m CE90

.50 meter resolution	
PAN	674.6
BLUE	478.4
GREEN	542.9
RED	650.4
NIR	803.4

ARCHIVE ONLY

WorldView-1®

.5 meter
< 4 m CE90

.50 meter resolution	
PAN	670.2

GeoEye-1®

.41 meter
5 m CE90

.40 meter resolution	
PAN	631.8
BLUE	484.5
GREEN	547.9
RED	675.2
NIR	836.5

WorldView-2®

.46 meter
< 3.5 m CE90

.40 meter resolution	
PAN	651.0
COASTAL	428.6
BLUE	479.3
GREEN	548.1
YELLOW	607.8
RED	658.9
RED EDGE	723.3
NIR	825.1
NIR2	914.5

WorldView-3®

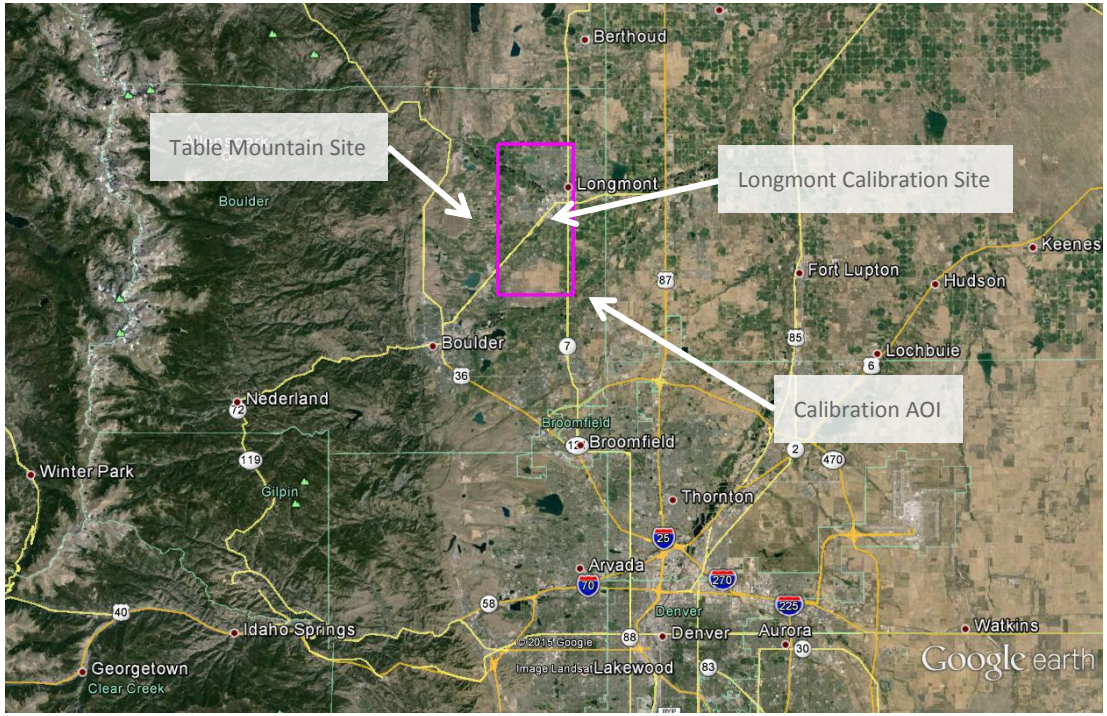
.31 meter < 3.5 m CE90

.30 meter resolution	
PAN	649.4
COASTAL	427.4
BLUE	481.9
GREEN	547.1
YELLOW	604.3
RED	660.1
RED EDGE	722.7
NIR	824.0
NIR2	913.6
SWIR1	1209.1
SWIR2	1571.6
SWIR3	1661.1
SWIR4	1729.5
SWIR5	2163.7
SWIR6	2202.2
SWIR7	2259.3
SWIR8	2329.2

Reflectance-based method employed for ground-based vicarious calibration

- In-situ measurements put into radiative transfer code (MODTRAN) to calculate top-of-atmosphere radiance to compare to sensor
- Three targets employed
  - White and black calibration tarps
  - Sampling at different parts of dynamic range
- Emphasis is put on getting correct BRDF measurements
  - In-situ measurements made w/ ASD portable spectrometer (350 – 2500 nm) and NIST-traceable reference panel
  - On-going model of targets as back-up
- Table Mountain AERONET for aerosol optical depth, water vapor and asymmetry
- On-site Yankee MFR-7 shadowband radiometer (validation) and weather station (temperature, pressure)
- Thuillier 2003 Solar Curve

DigitalGlobe Calibration Site

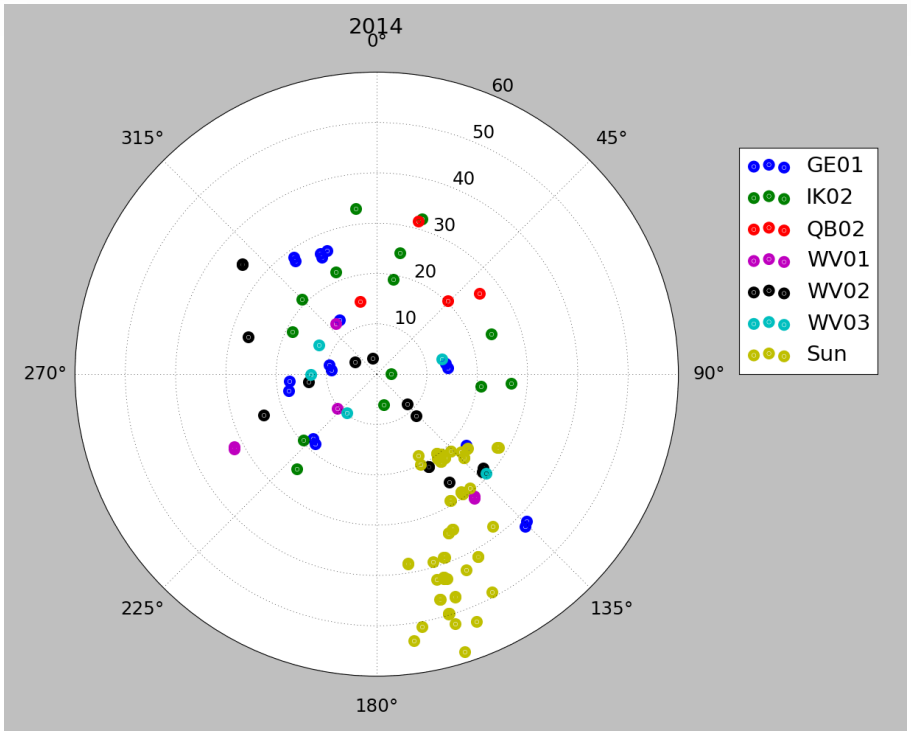


Our goal is to collect as many good days as possible over a large range of view angles

2014 SEASON COLLECTS

Sensor	Good Days
WorldView-3	4
WorldView-2	8
GeoEye-1	8
IKONOS	4
QuickBird	4
WorldView-1	6

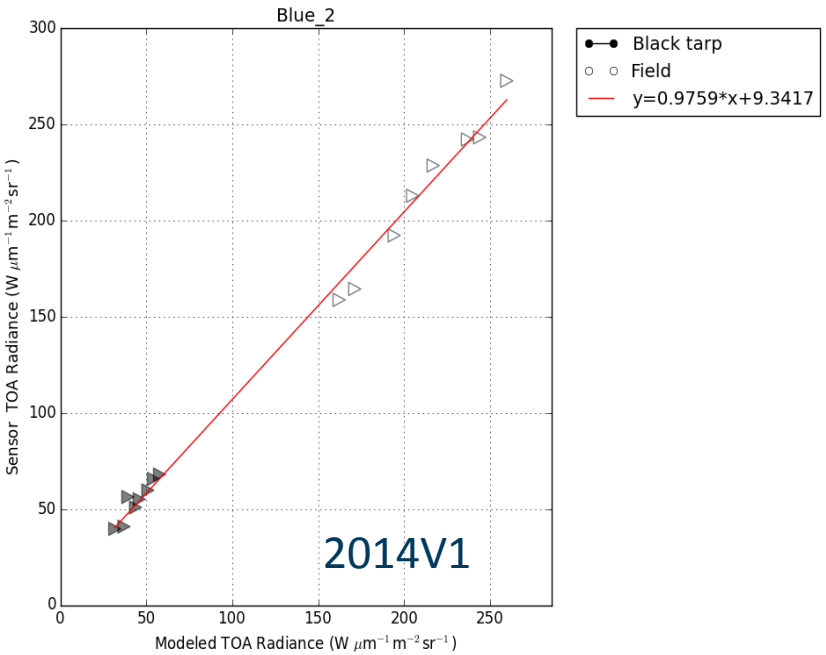
VIEW ANGLE SAMPLING



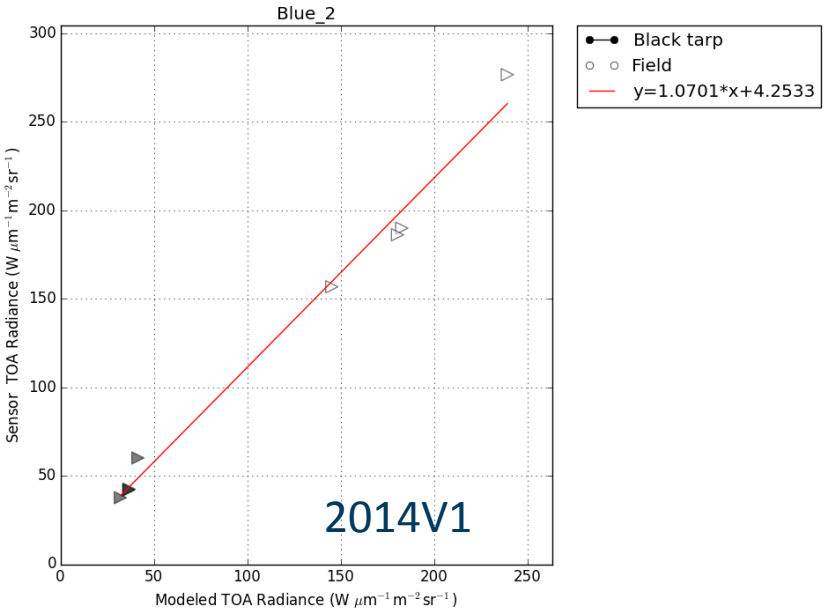
Weather is a big impactor always

Regression of data gives the final calibration

WORLDVIEW-2



WORLDVIEW-3



Calibration Coefficient Adjustment Factors: Season 2014 V1

WorldView-2		
	2014 Season V1	
BAND	GAIN	OFFSET
PAN	1.041	3.157
COASTAL	0.889	11.558
BLUE	1.004	9.809
GREEN	1.063	4.455
YELLOW	1.049	3.408
RED	1.042	1.752
REDEDGE	0.953	2.671
NIR1	0.955	2.558
NIR2	0.941	2.444

WorldView-1		
	2014 Season V1	
BAND	GAIN	OFFSET
PAN	0.965	4.632

QuickBird-2		
	2014 Season V1	
BAND	GAIN	OFFSET
PAN	1.158	1.646
BLUE	0.904	3.331
GREEN	0.941	3.245
RED	0.958	2.484
NIR	0.984	4.525

GeoEye-1		
	2014 Season V1	
BAND	GAIN	OFFSET
PAN	1.005	3.919
BLUE	0.937	8.309
GREEN	0.993	5.814
RED	0.988	4.571
NIR	0.967	4.919

KONOS		
	2014 Season V1	
BAND	GAIN	OFFSET
PAN	1.081	5.838
BLUE	0.911	9.035
GREEN	0.995	8.485
RED	1.049	5.921
NIR	0.935	9.792

WorldView-3 VNIR		
	2014 Season V1	
BAND	GAIN	OFFSET
PAN	1.045	2.220
COASTAL	1.157	7.070
BLUE	1.070	4.253
GREEN	1.082	2.633
YELLOW	1.048	2.074
RED	1.028	1.807
REDEDGE	0.979	2.633
NIR1	1.006	3.406
NIR2	0.975	2.258

WorldView-3 SWIR		
	2014 Season V1	
BAND	GAIN	OFFSET
1	0.844	3.295
2	0.835	1.496
3	0.848	1.385
4	0.834	1.009
5	0.780	0.356
6	0.750	0.353
7	0.749	0.252
8	0.729	0.167

Note: Gain and Offsets are shown as a correction to the current abscalfactor found in the IMD metadata file delivered with product

Coefficients derived from 2014 Calibration Season Version 1. Released 3/6/2015

How to utilize the on-orbit calibration

$$L = DN \frac{ACF}{EBW} * (2 - Gain) - Offset$$

- *Where "Gain" and "Offset" are taken from the previous slide*
- *DN is per pixel*
- *ACF is abscalfactor from IMD file*
- *EBW is effective bandwidth from IMD file*

Units of Radiance: $W\mu m^{-1}\ m^{-2}\ sr^{-1}$

```
BEGIN_GROUP = BAND_Y
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      ULLat =   40.21060059;
      ULHAE =  1585.08;
      URLon = -105.06230115;
      URLat =   40.21212011;
      URHAE =  1519.85;
      LRLon = -105.06273057;
      LRLat =   40.05884448;
      LRHAE =  1515.95;
      LLLon = -105.22400699;
      LLLat =   40.05747572;
      LLHAE =  1581.97;
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      effectiveBandwidth = 3.810000e-02;
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      URLon = -105.06230115;
      URLat =   40.21212011;
      URHAE =  1519.85;
      LRLon = -105.06273057;
      LRLat =   40.05884448;
      LRHAE =  1515.95;
      LLLon = -105.22400699;
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      LLHAE =  1581.97;
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BEGIN_GROUP = BAND_RE
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      ULLat =   40.21060059;
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Solar exoatmospheric irradiance for reference (@1 AU)

$$\rho_{\lambda_{\text{Pixel,Band}}} = \frac{L_{\lambda_{\text{Pixel,Band}}} \cdot d_{ES}^{\,2} \cdot \pi}{Esun_{\lambda_{\text{Band}}} \cdot \cos(\theta_S)}$$

	Worldview-2		
	Thuillier 2003	ChKur	WRC
PAN	1571.36	1575.38	1580.76
COASTAL	1773.81	1759.24	1757.77
BLUE	2007.27	1977.4	1974.29
GREEN	1829.62	1857.89	1856.03
YELLOW	1701.85	1738.11	1738.59
RED	1538.85	1554.95	1559.35
REDEDGE	1346.09	1302.19	1342.05
NIR1	1053.21	1061.4	1069.59
NIR2	856.599	856.816	861.201

	Worldview-1		
	Thuillier 2003	ChKur	WRC
PAN	1478.62	1481.48	1487.92

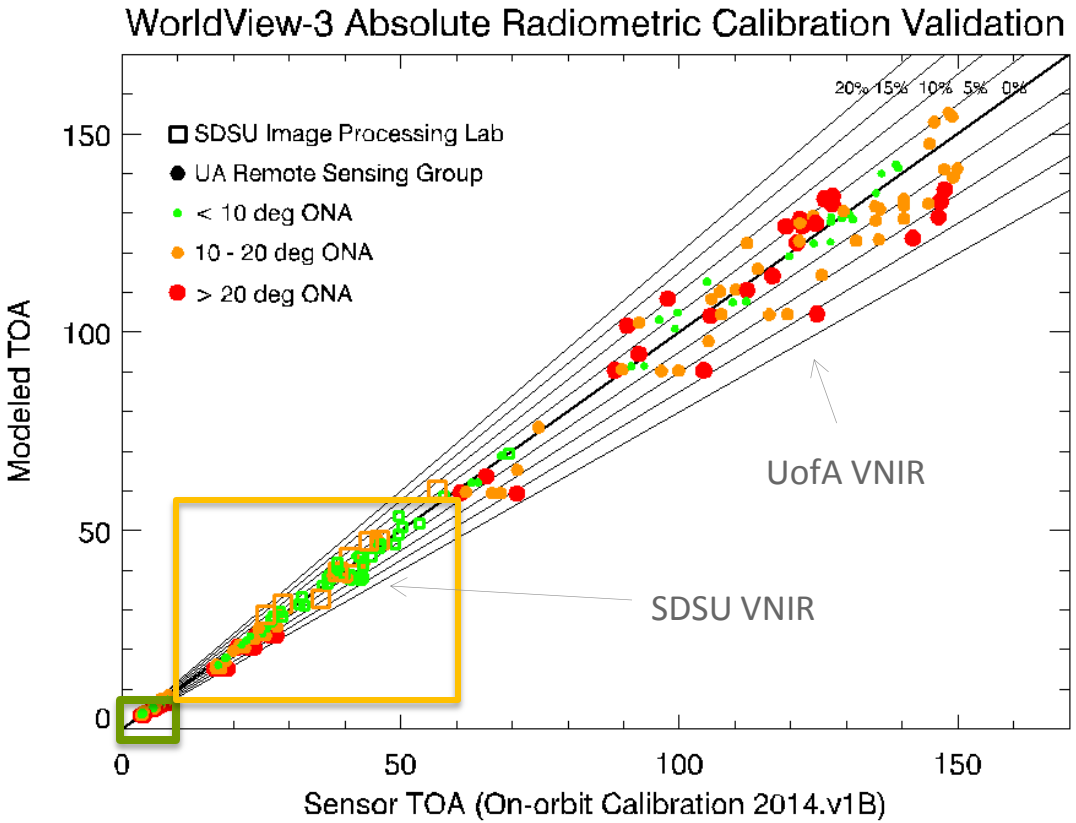
	QuickBird		
	Thuillier 2003	ChKur	WRC
PAN	1370.92	1376.3	1381.72
BLUE	1949.59	1926.55	1924.62
GREEN	1823.64	1844.26	1842.81
RED	1553.78	1571.58	1574.65
NIR	1102.85	1107.47	1113.72

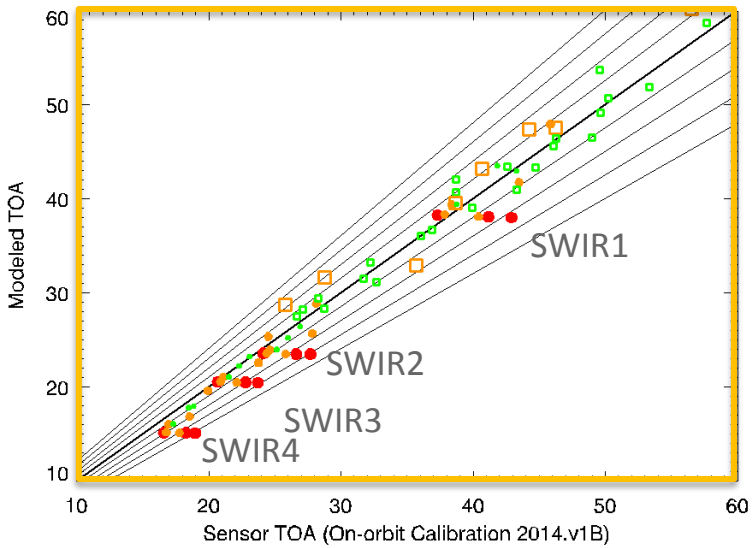
	GeoEye-1		
	Thuillier 2003	ChKur	WRC
PAN	1610.73	1614.88	1619.49
BLUE	1993.18	1966.03	1963.53
GREEN	1828.83	1857.12	1855.25
RED	1491.49	1500.38	1506.29
NIR	1022.58	1029.61	1037.7

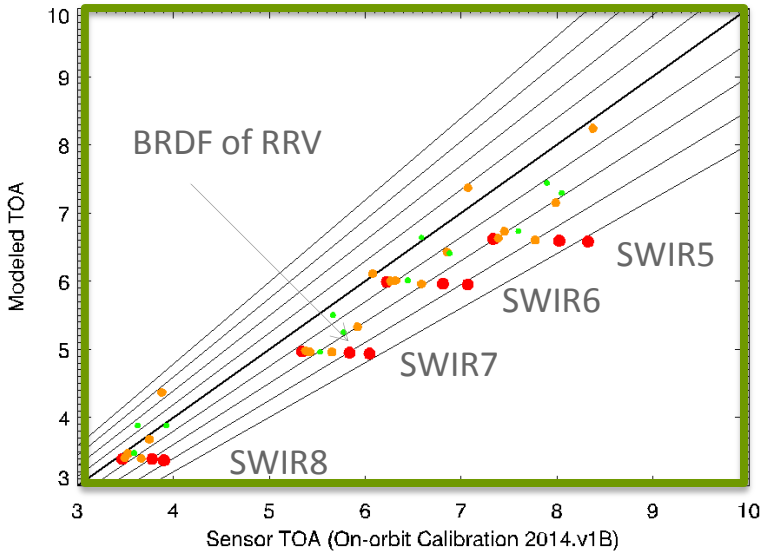
	IKONOS		
	Thuillier 2003	ChKur	WRC
PAN	1353.25	1358.59	1364.06
BLUE	1921.26	1902.54	1901.19
GREEN	1803.28	1827.32	1826.04
RED	1517.76	1526.48	1532.48
NIR	1145.8	1150.51	1155.37

	Worldview-3		
	Thuillier 2003	ChKur	WRC
PAN	1574.41	1578.28	1583.58
COASTAL	1757.89	1743.9	1743.81
BLUE	2004.61	1974.53	1971.48
GREEN	1830.18	1858.1	1856.26
YELLOW	1712.07	1748.87	1749.4
RED	1535.33	1550.58	1555.11
REDEDGE	1348.08	1303.4	1343.95
NIR1	1055.94	1063.92	1071.98
NIR2	858.77	858.632	863.296
SWIR 1	479.019	478.873	494.595
SWIR 2	263.797	257.55	261.494
SWIR 3	225.283	221.448	230.518
SWIR 4	197.552	191.583	196.766
SWIR 5	90.4178	86.5651	80.365
SWIR 6	85.0642	82.0035	74.7211
SWIR 7	76.9507	74.7411	69.043
SWIR 8	68.0988	66.3906	59.8224

External validation from SDSU and UofA



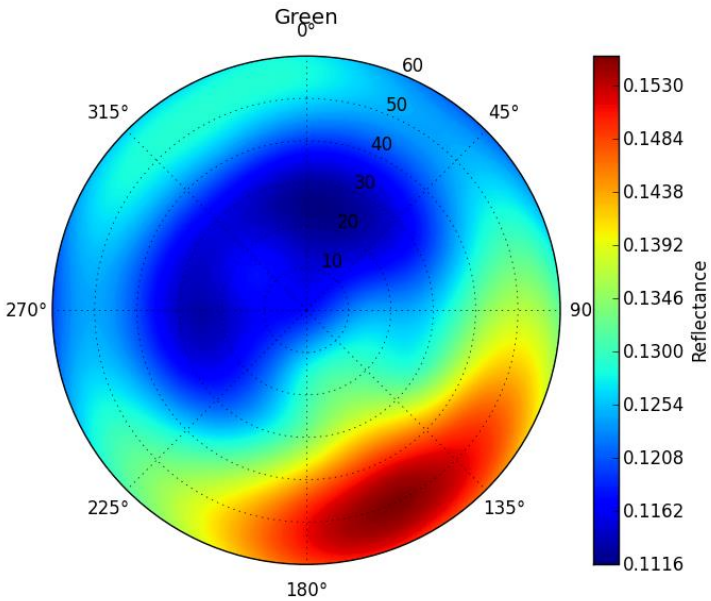




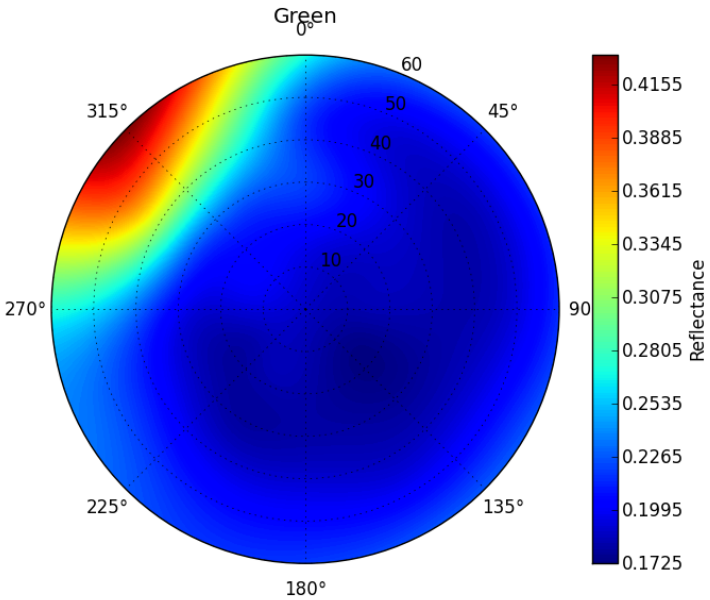
- *Data taken at greater ONA gives greater uncertainty*
  - *BRDF*
  - *Increased atmospheric path length*
- < 10 ONA data gives < 5 % difference between validation and DG corrected imagery for VNIR
- <20 ONA data gives < 10% difference for SWIR
- Independent samplings only look at small portion of the instrument dynamic range

All materials have their own bidirectional fingerprint

- The nimbleness of the DigitalGlobe constellation allows for highly varying view angles
- Solar angles are also a part of the equation

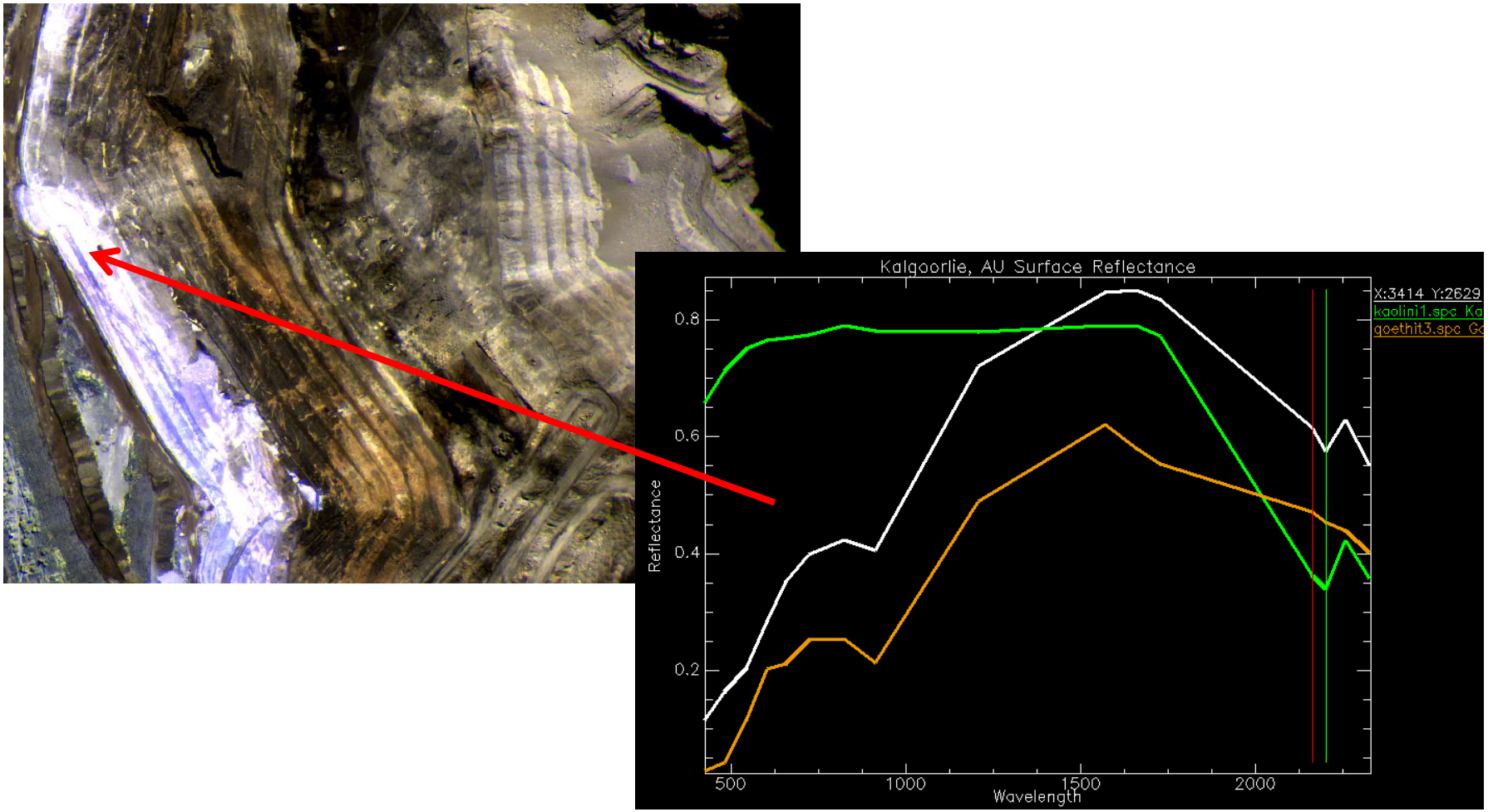


Asphalt



Concrete

Spectral material validation of calibration



Ready for the start of a new season

- On-site Shadowband ready for aerosol measurements 2015 season
  - Validation of instrument at AERONET Table Mountain site this winter
  - In-house algorithm removes bad points (due to clouds) and follows AERONET scheme
  - Plan to iterate between MODTRAN output and Shadowband measurements for more accurate depiction of atmospherics
- Upcoming is our third season (so we can *start* looking at season-to-season stats)!
- Future work
  - On-going updates to BRDF model of our calibration targets
  - Collect more data for cross-calibration of fleet
  - Including a request in for Hyperion & catching Landsat 8 for comparison

Special thanks

- Patrick Disterhoff, NOAA for the Table Mountain space and for maintaining the AERONET site that we utilize for our work
- Lex Berk, Spectral Sciences Inc. for the MODTRAN assistance
- Brent Holben, NASA Goddard Space Flight Center and AERONET for the data processed at the Table Mountain Research Station

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