An automatic atmospheric compensation algorithm for very high spatial resolution imagery

.. and its comparison to FLAASH and QUAC

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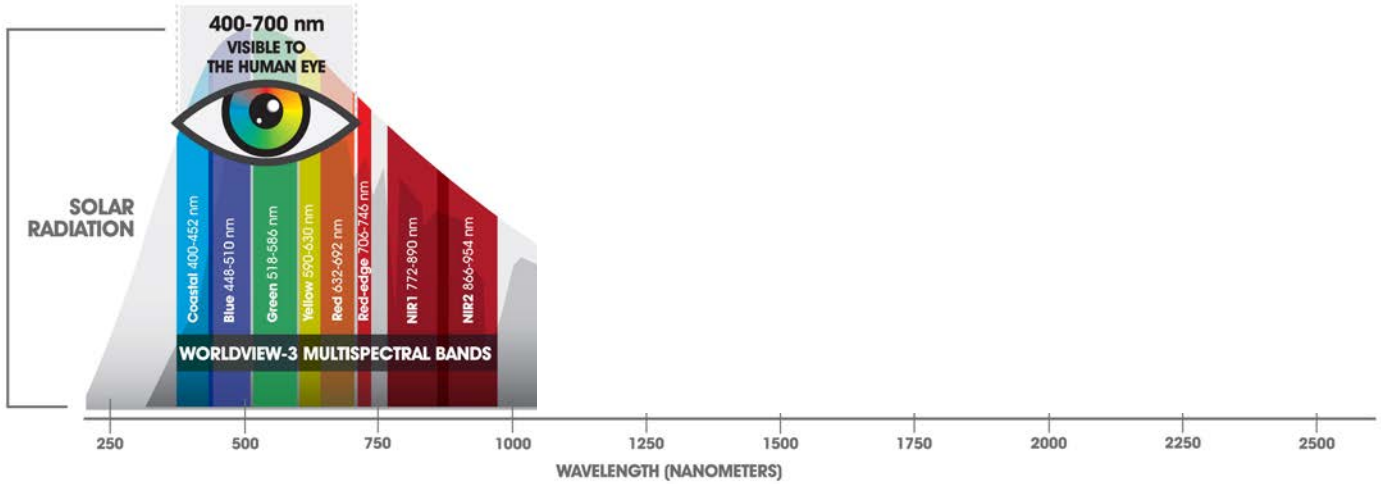
Agenda

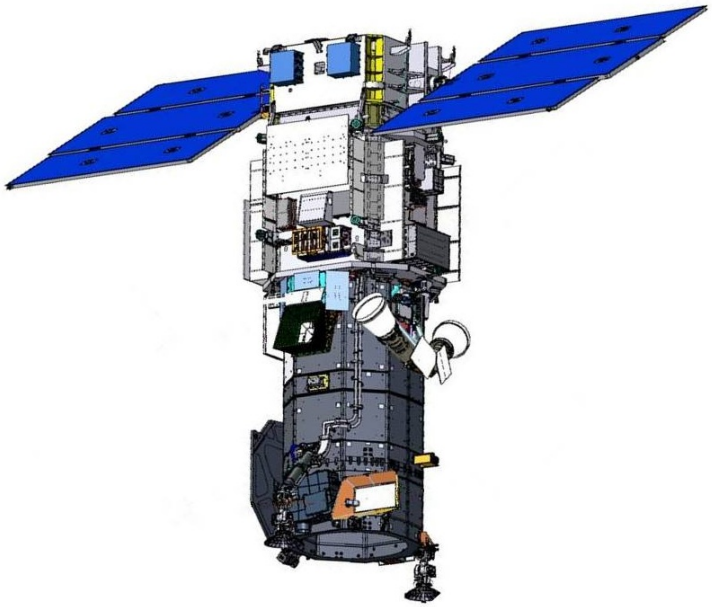
- ❑ Introduction
- ❑ Time-series over Longmont, CO (2009-2012)
- ❑ Calibrated Tarps
- ❑ Field Measurements and Coincident Satellite Acquisitions
  - Grass, Sand, Dirt, Asphalt
  - Water
  - Snow
  - CEOS Cal/Val site: Tuz Gölü
- ❑ AOD Analysis
- ❑ Conclusions
- ❑ Applications (if time is available!)

Introduction: WorldView-3



CAVIS: Cloud, Aerosol, Water Vapor, Ice & Snow

- Image simultaneous with main instrument
- 12 VNIR + SWIR Bands
- 30 m resolution
- Swath is slightly wider than main instrument



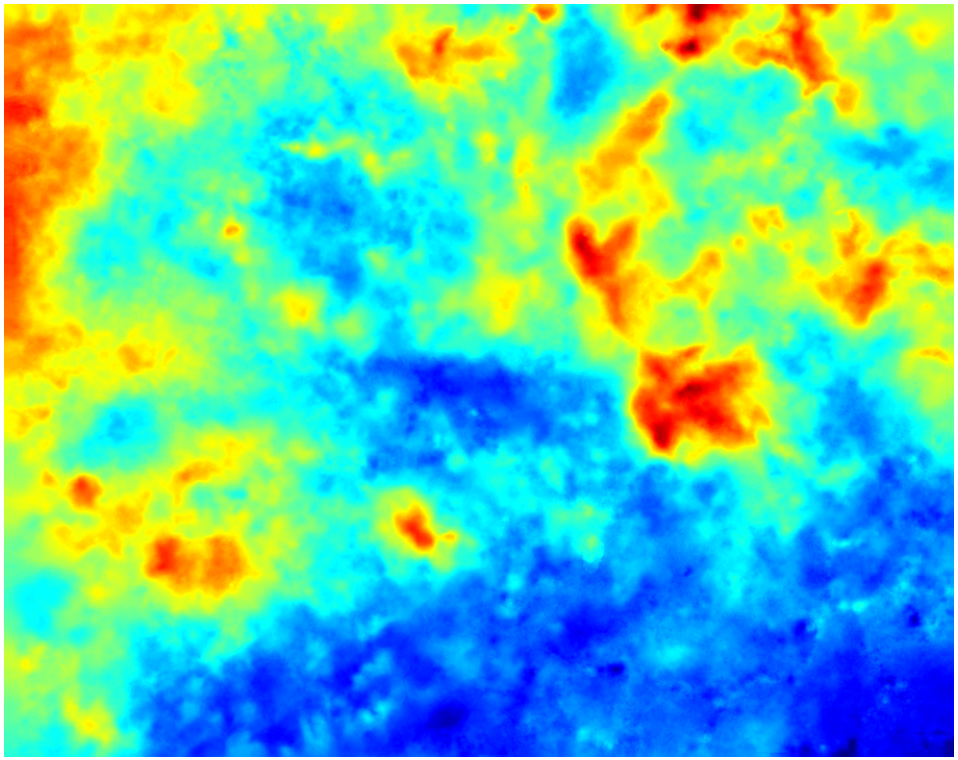
Introduction: in the meantime..

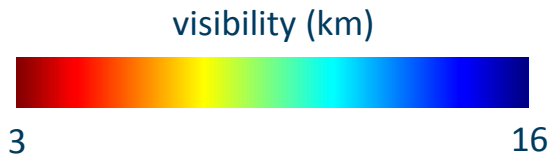
DigitalGlobe developed a fully automated framework for atmospherically compensating very high spatial resolution imagery from QB, WV1, and WV2.

This technology (DG-AComp) has several advantages:

- enables the extraction of information using physical quantities, not just scene statistics ("surface reflectance" vs. "DN counts")
- improves performance of multi-temporal data analysis
- facilitates cross-sensor processing
- fast processing via the high performance computing (HPC)

Introduction: an example from QB





Introduction: validation

DigitalGlobe

DG-AComp results are compared to in-situ measurements, and to two commercially available techniques, such as Quick Atmospheric Correction (QUAC) and Fast Line-of-sight Atmospheric Analysis of Spectral Hypercubes (FLAASH).

QUAC is a fully automated method (as DG-AComp), and this represents the baseline to compare DG-AComp with.

FLAASH requires the knowledge of atmospheric components (aerosol, water vapor, etc..), and it represents one of the most accurate method currently available. In this presentation, the atmospheric values automatically retrieved by DG-AComp are used as inputs to drive FLAASH.

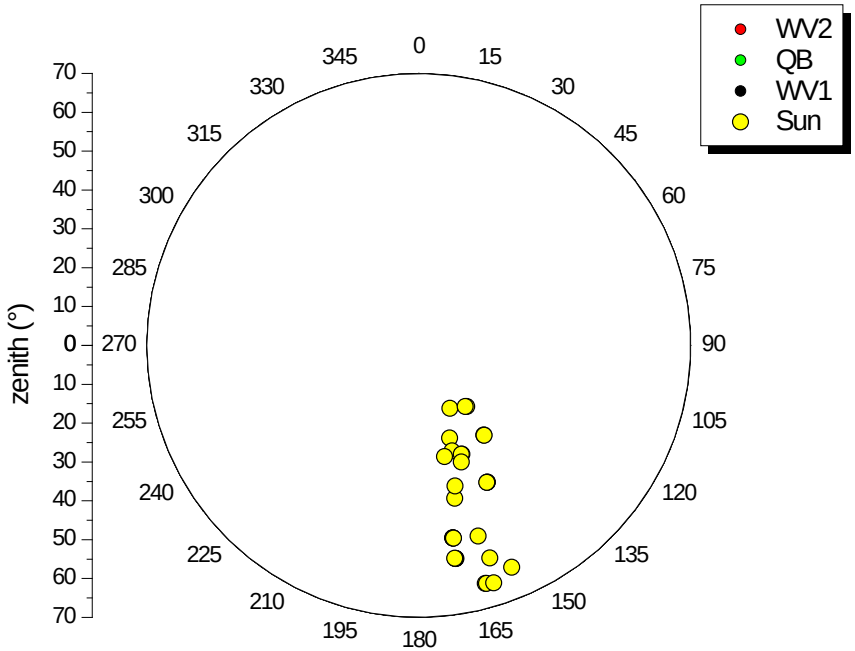
Time-series over Longmont, CO (2009-2012)

Data Set

WV2 Image	CatID	Date	meanSunAz	meanSunEl	meanSatAz	meanSatEl
1	1030010005098C00	2010-06-05T18:02:26	141.0	68.9	165.1	71.8
2	103001000582F000	2010-06-18T18:27:12	153.6	71.9	324.8	51.0
3	10300100051AFE00	2010-06-24T18:09:52	141.9	70.0	218.4	80.9
4	103001000784E200	2010-11-03T18:10:20	170.1	34.3	16.6	72.4
5	10300100079DC100	2010-11-03T18:10:30	170.2	34.3	18.0	78.0
6	103001000760B200	2010-11-03T18:10:41	170.2	34.3	21.9	83.8
7	10300100077FC700	2010-11-03T18:10:52	170.3	34.3	93.3	89.0
8	103001000701FC00	2010-11-03T18:11:12	170.4	34.4	190.0	78.5
9	103001000913F200	2011-03-29T17:59:02	153.4	50.6	77.3	62.6
10	103001000A847800	2011-03-29T17:59:10	153.4	50.6	85.7	63.8
11	103001000AA58D00	2011-03-29T17:59:21	153.5	50.6	98.1	64.7
12	103001000A655E00	2011-03-29T17:59:29	153.5	50.6	108.6	64.6
13	103001000A905200	2011-03-29T17:59:40	153.6	50.6	120.8	63.5
14	103001000B335B00	2011-06-16T18:09:27	142.7	70.2	19.2	35.6
15	103001000C1D2D00	2011-08-09T18:33:50	161.6	64.9	248.9	57.6
16	103001000CC40500	2011-08-10T17:58:24	144.1	61.5	156.5	40.8
17	103001000D763100	2011-08-10T17:58:15	144.1	61.5	153.6	43.0
18	103001000CC55900	2011-08-10T17:58:06	144.0	61.4	150.3	45.3
19	103001000D46A300	2011-08-20T18:30:05	162.5	61.5	258.4	66.5
20	103001000D824500	2011-08-23T18:19:36	158.4	59.9	339.1	82.0
21	103001000DB4AA00	2011-08-23T18:20:10	158.6	59.9	214.7	77.4
22	103001000D272200	2011-08-23T18:20:19	158.7	59.9	208.9	72.6
23	103001000D7FF200	2011-09-22T18:18:55	166.8	49.6	0.9	77.6
24	10300100111AD800	2012-01-26T17:48:00	157.3	28.1	63.0	39.9
25	10300100129FE800	2012-04-13T18:18:10	159.9	58.0	115.4	87.0
26	1030010013B5B300	2012-04-18T18:33:47	167.0	60.6	288.3	66.9

QB Image	CatID	Date	meanSunAz	meanSunEl	meanSatAz	meanSatEl
1	101001000A76CD00	2009-10-18T17:50:58	162.7	38.6	66.1	70.7
2	101001000925E300	2009-02-05T18:09:05	161.5	32.3	263.3	79.1
3	1010010009086100	2009-01-08T17:59:34	162.5	25.9	87.1	69.1

WV1 Image	CatID	Date	meanSunAz	meanSunEl	meanSatAz	meanSatEl
1	1020010009353000	2009-10-18T18:14:10	170.0	39.7	238.0	70.9
2	10200100094A3700	2009-10-18T18:14:05	169.9	39.7	250.5	73.9
3	10200100098B0A00	2009-10-18T18:13:55	169.9	39.6	283.8	76.4
4	102001000A08B800	2009-10-18T18:13:44	169.8	39.6	316.9	73.8
5	102001000A68D900	2009-10-18T18:13:39	169.8	39.6	327.9	71.2
6	102001001109C500	2011-03-29T18:30:23	165.6	52.6	281.2	49.2
7	10200100180FDD00	2012-01-09T18:07:03	164.4	26.4	185.0	52.2
8	1020010018D32200	2012-01-09T18:06:09	164.1	26.3	64.9	83.4



BRDF Measurements of Asphalt and Concrete (1/3)

Acquisition Date: June 22, 2011
(17:15z to 18:45z)

Sun Elevation: 62° to 75°
Sun Azimuth: 120° to 170°

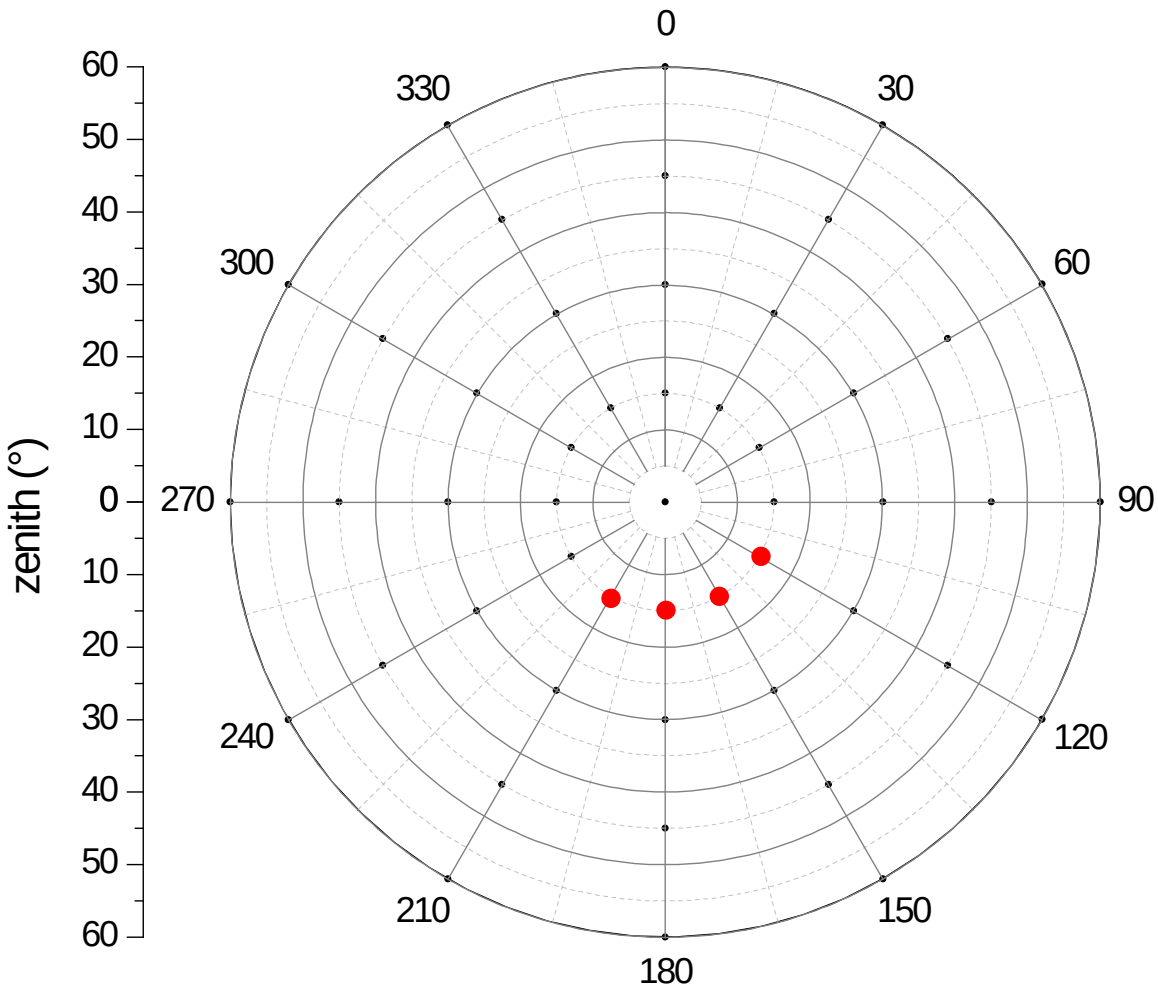
Acquisition Date: August 12-26, 2011
(17:15z to 18:45z)

Sun Elevation: 55° to 65°
Sun Azimuth: 130° to 170°

BRDF Measurements of Asphalt and Concrete (2/3)

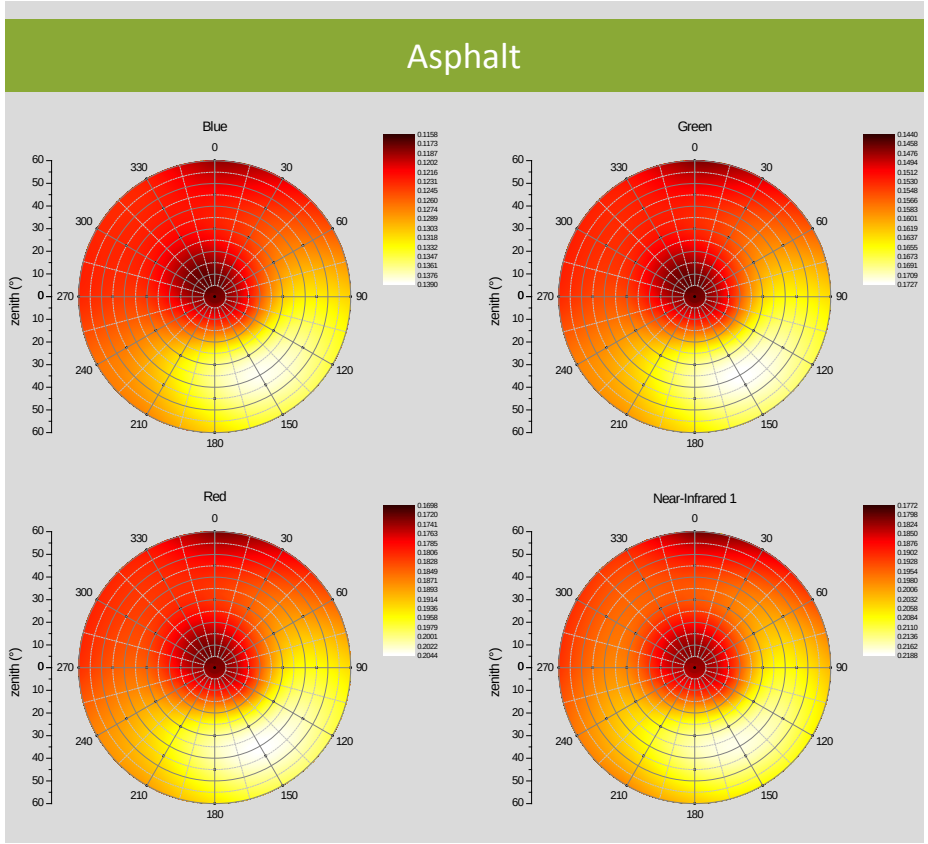
Azimuth Angles
0
30
60
90
120
150
180
210
240
270
300
330

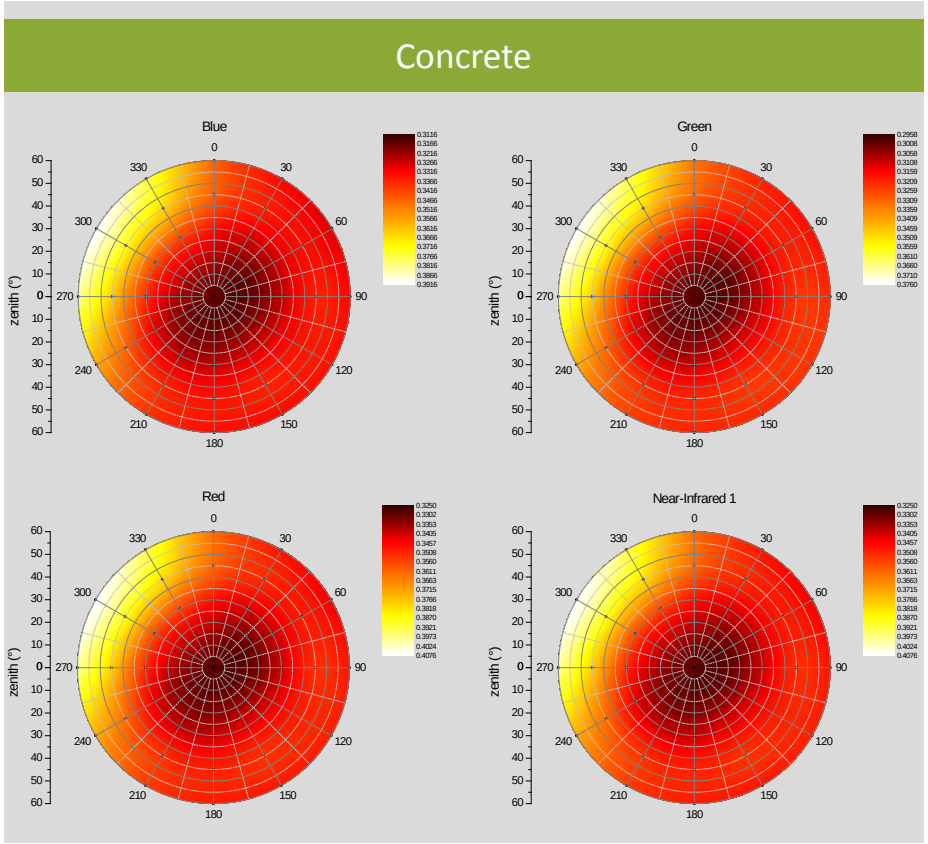
Zenith Angles
0
15
30
45
60



● Missing measurements due to the presence of shadow on the target

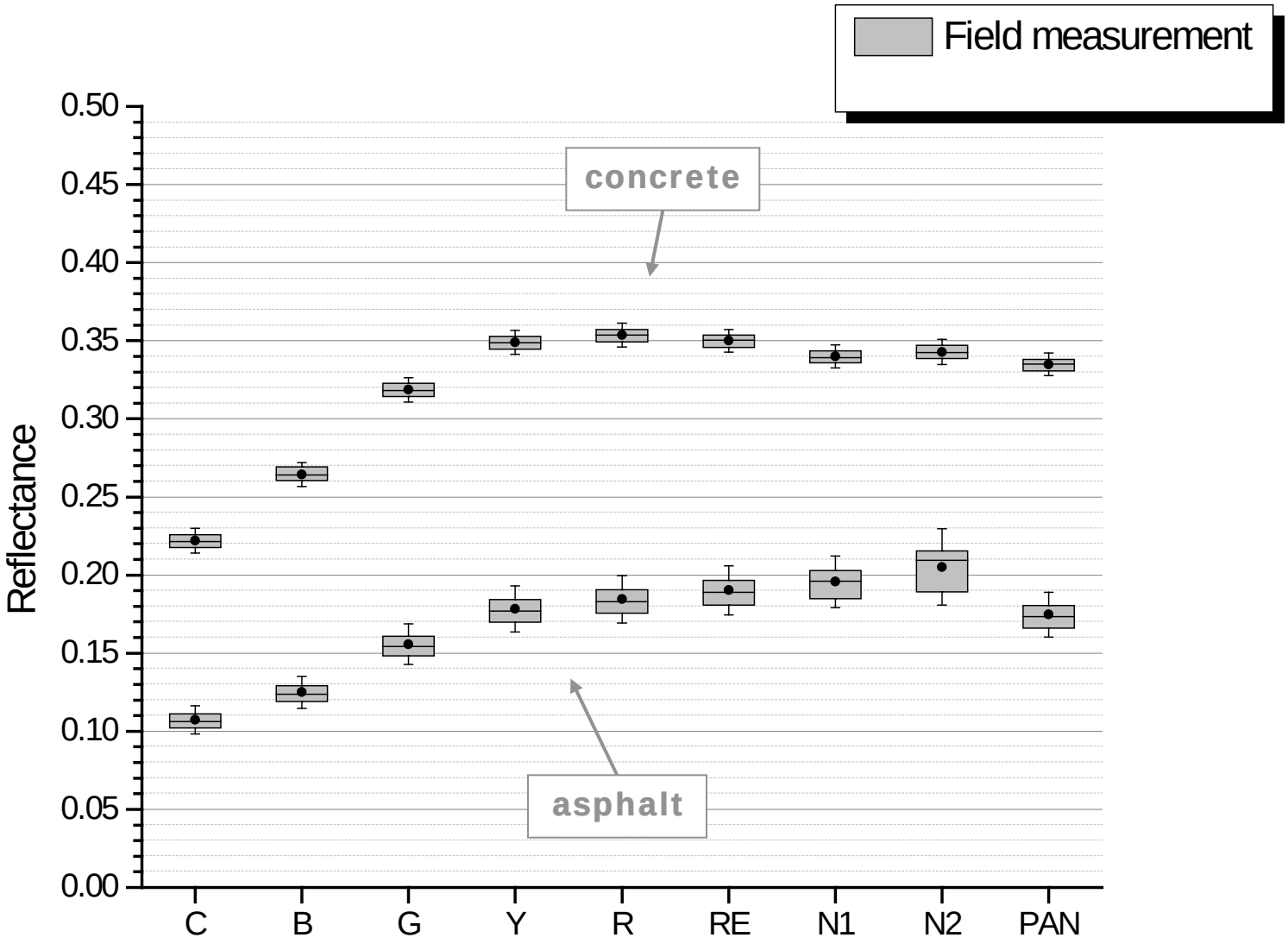
BRDF Measurements of Asphalt and Concrete (3/3)



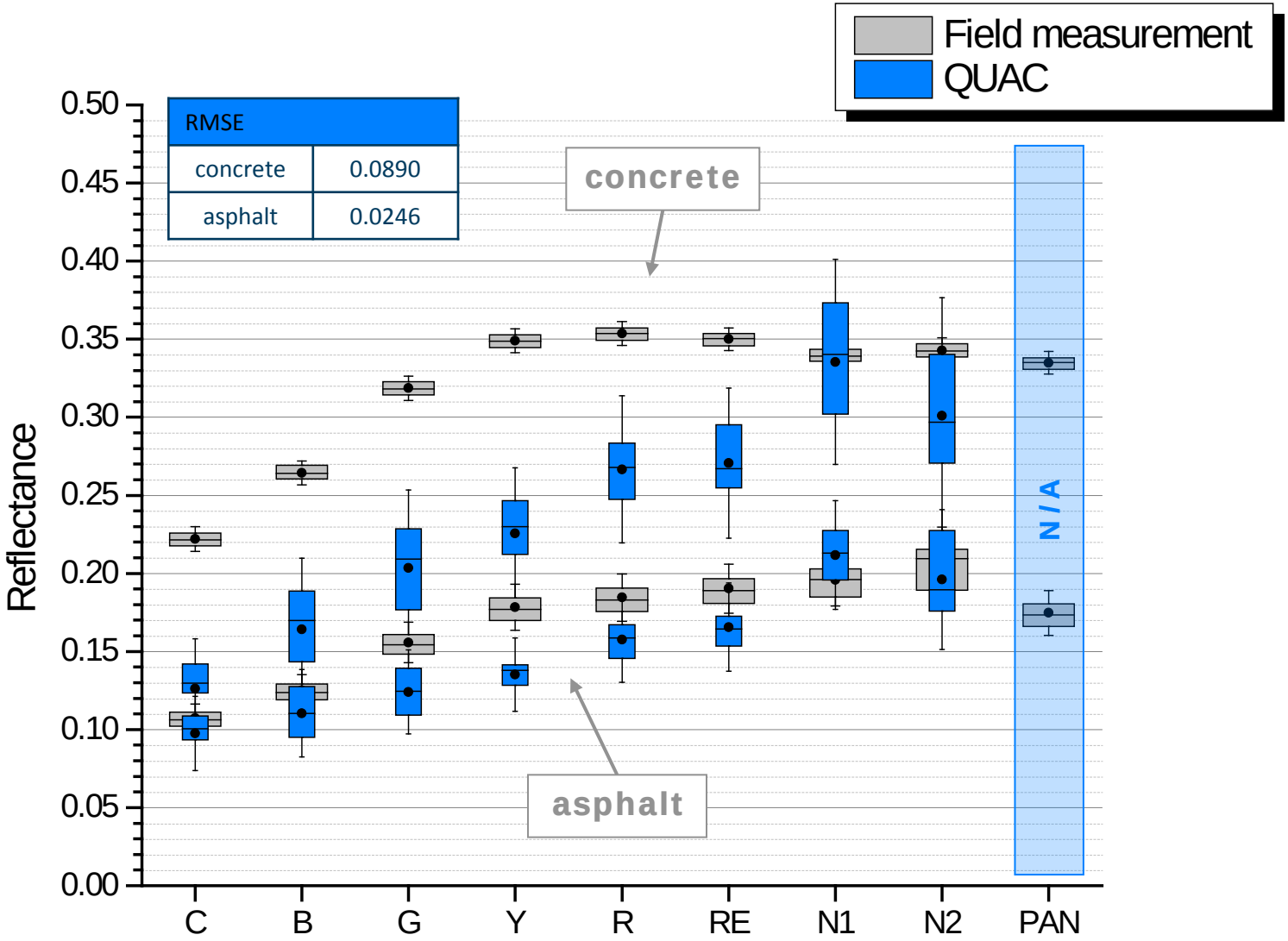


Assumption:
targets have constant (in time) spectral behavior and same illumination throughout the year

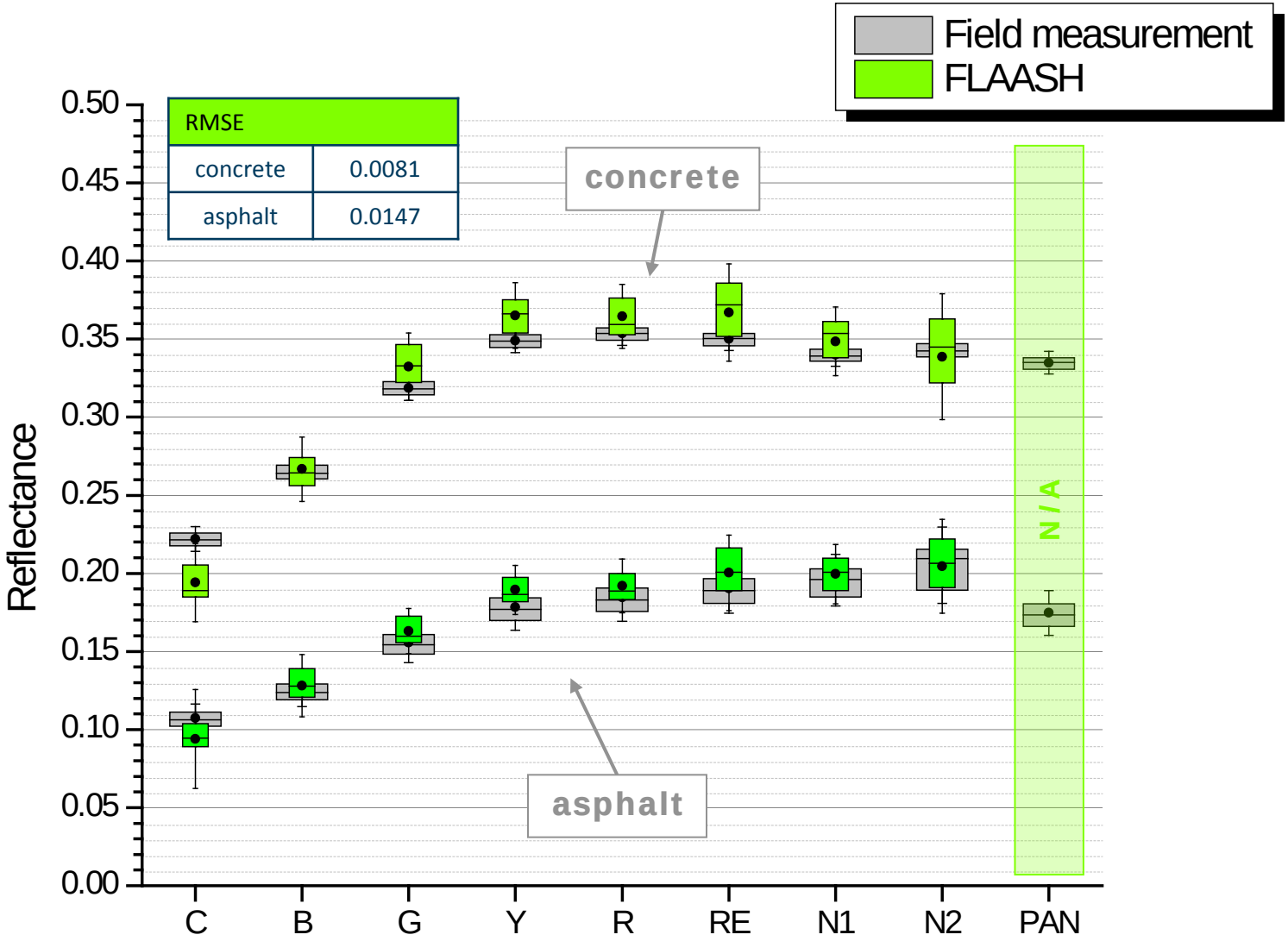
Spectral Signatures of Asphalt and Concrete



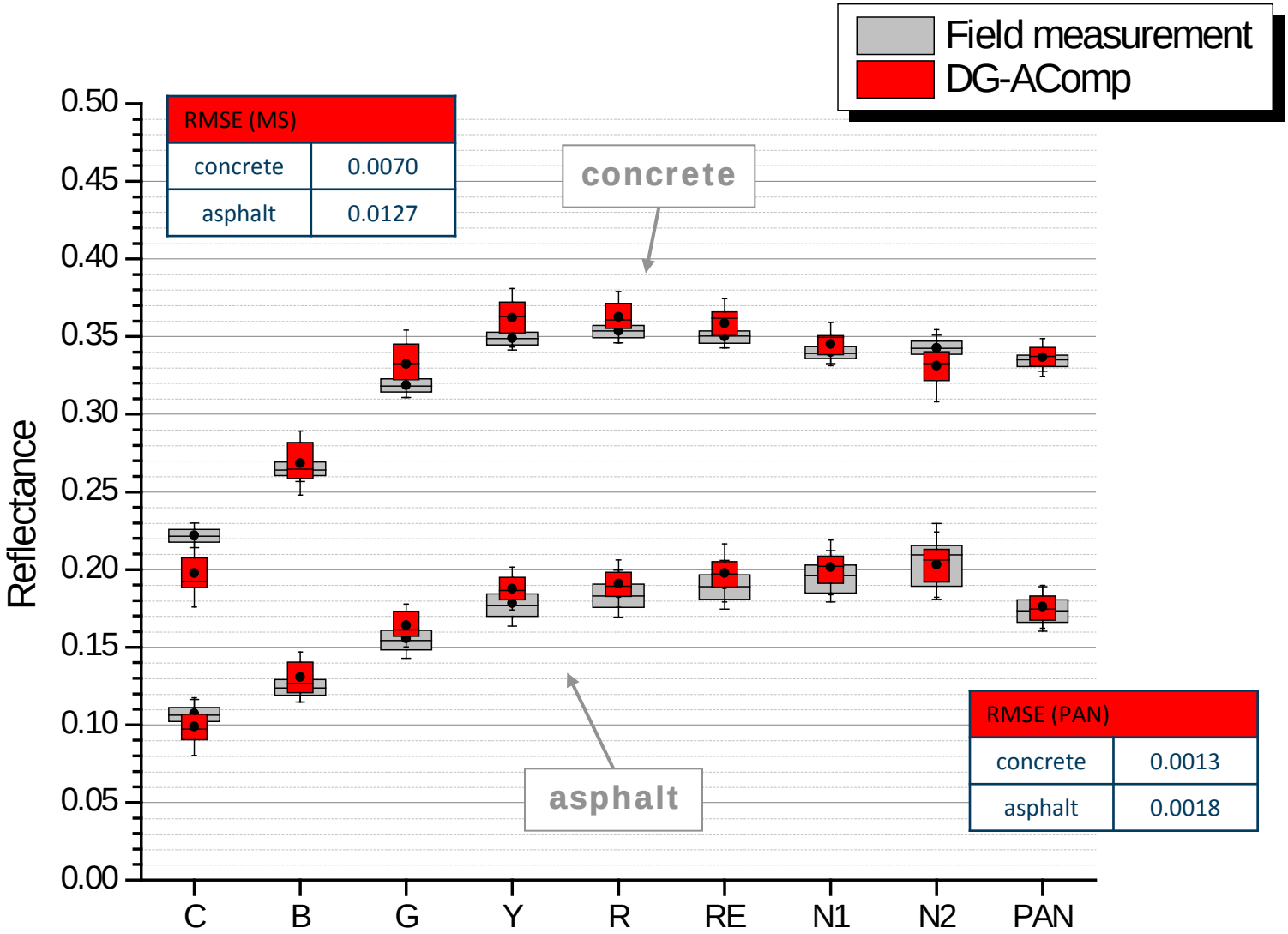
WV2: QUAC accuracy



WV2: FLAASH accuracy



WV2: DG-AComp accuracy



Calibrated Tarps

Data Set

Location	Date	Sat. Az.	Sat. El.
NASA Stennis Space Center, MS	7-Feb-06	208.2	83.2
NASA Stennis Space Center, MS	10-Jan-04	259.7	88.2
NASA Stennis Space Center, MS	14-Nov-02	274.2	79.2
NASA Stennis Space Center, MS	12-Mar-05	268.4	77.7
Brookings, SD	15-Sep-03	284.4	83.1
Brookings, SD	7-Sep-02	191.4	74.6
Brookings, SD	20-Jul-02	349.7	64.3
Brookings, SD	18-Oct-05	298.2	73.2
Wiggins, MS	15-Mar-06	319.5	76.7
Wiggins, MS	7-Jan-06	300.0	68.0
Wiggins, MS	25-Jan-06	296.6	69.3
Park Falls, WI	5-Aug-05	261.5	69.4

This set of 12 QuickBird images includes four 20 m^2 spectrally-flat tarps having nominally 3.5, 22, 34, and 52% reflectance in the visible through NIR spectral region.

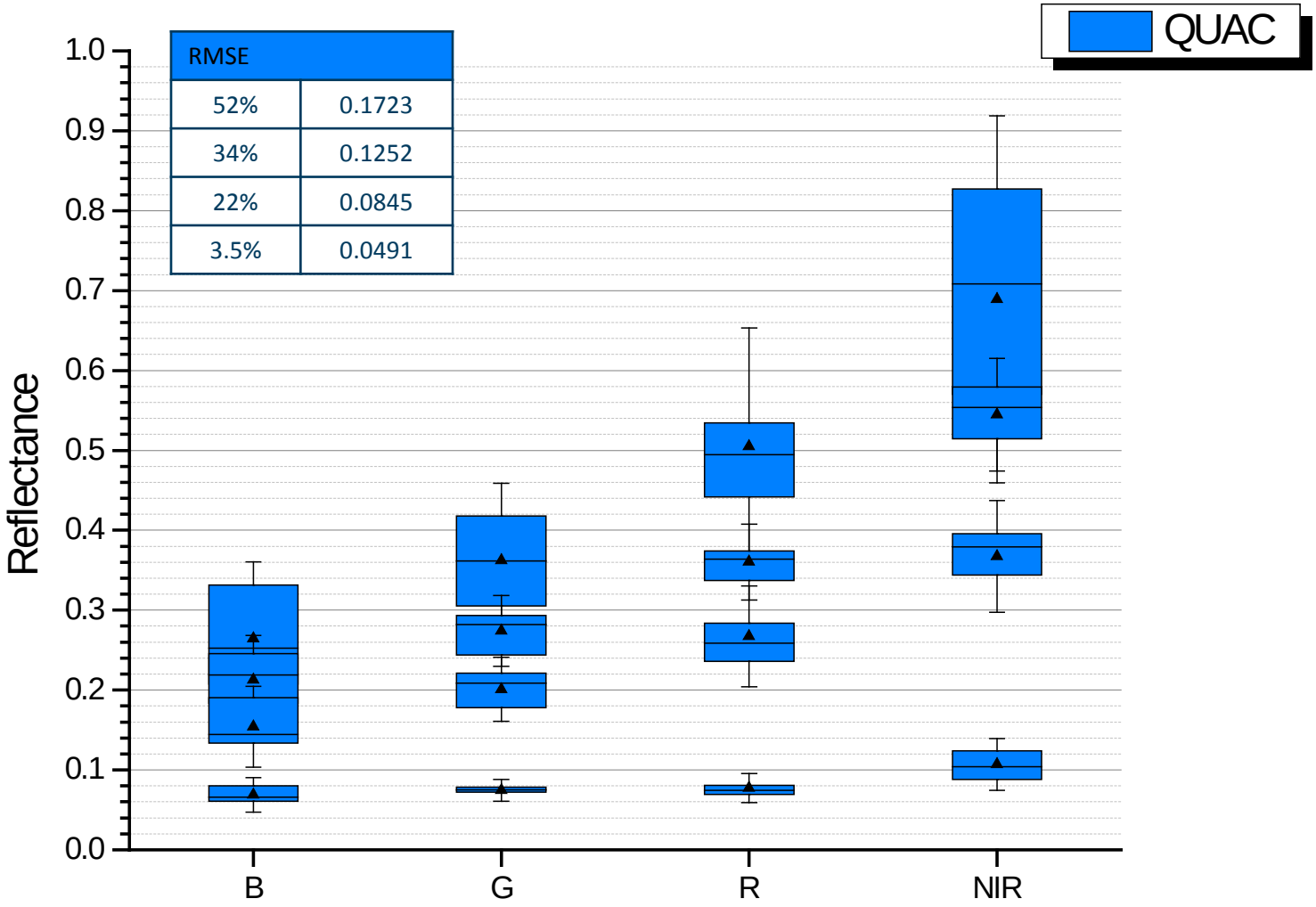
Tarps description

The tarps were manufactured to guarantee a flat spectral response between 400 nm and 1050 nm, with a peek-to-peek variation in reflectance less than 10% between 10° and 60° off-nadir.

M. Pagnutti, K. Holekamp, R.E. Ryan, R.D. Vaughan, J.A. Russell, D. Prados, and T. Stanley, "Atmospheric correction of high spatial resolution commercial satellite imagery products using modis atmospheric products", in Analysis of Multi-Temporal Remote Sensing Images, May 2005, pp. 115 – 119.

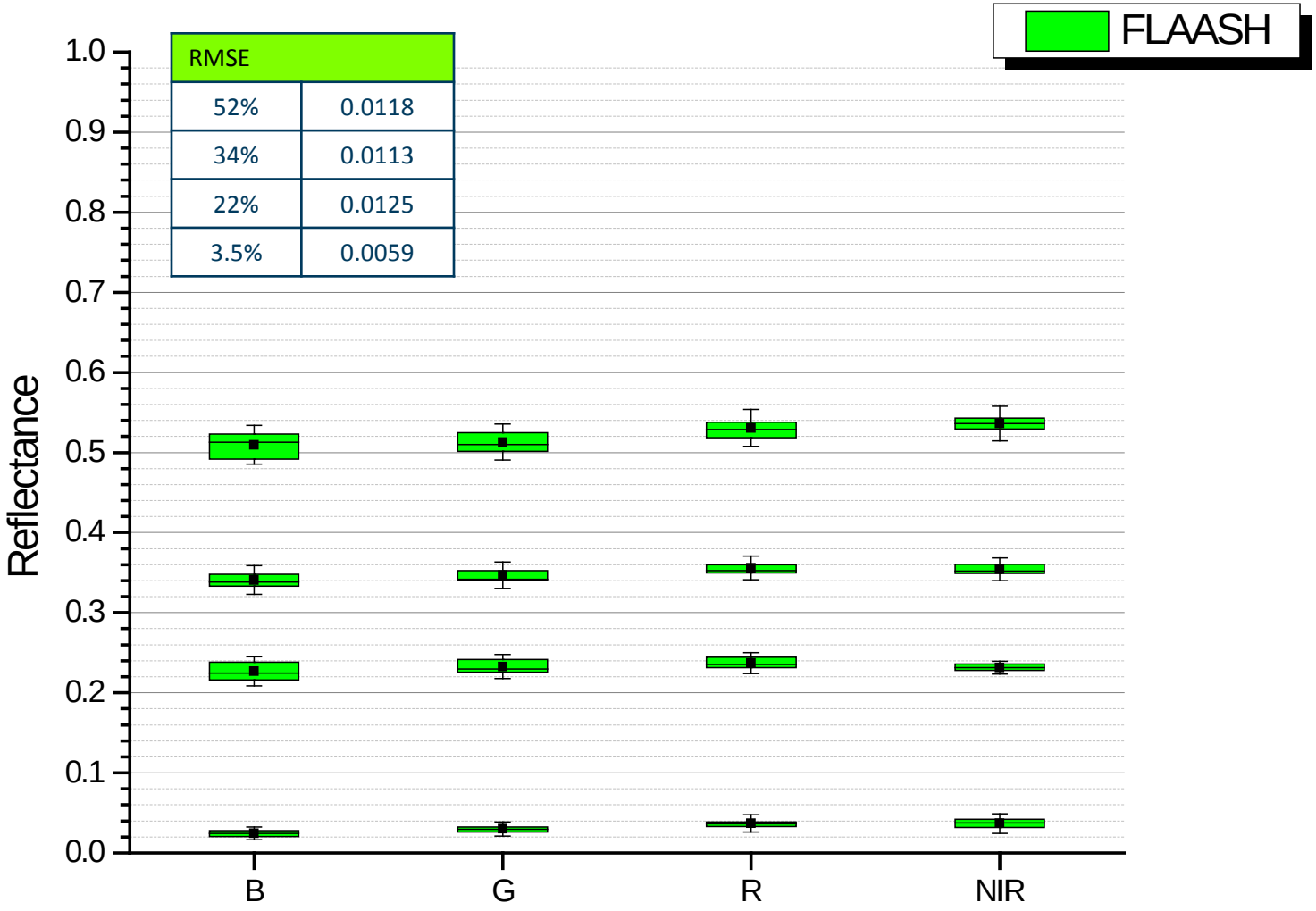
K. Holekamp, "NASA radiometric characterization", in High spatial resolution commercial imagery workshop, Reston, VA, Nov. 2004

QB: QUAC accuracy (52, 34, 22, and 3.5% reflectance)



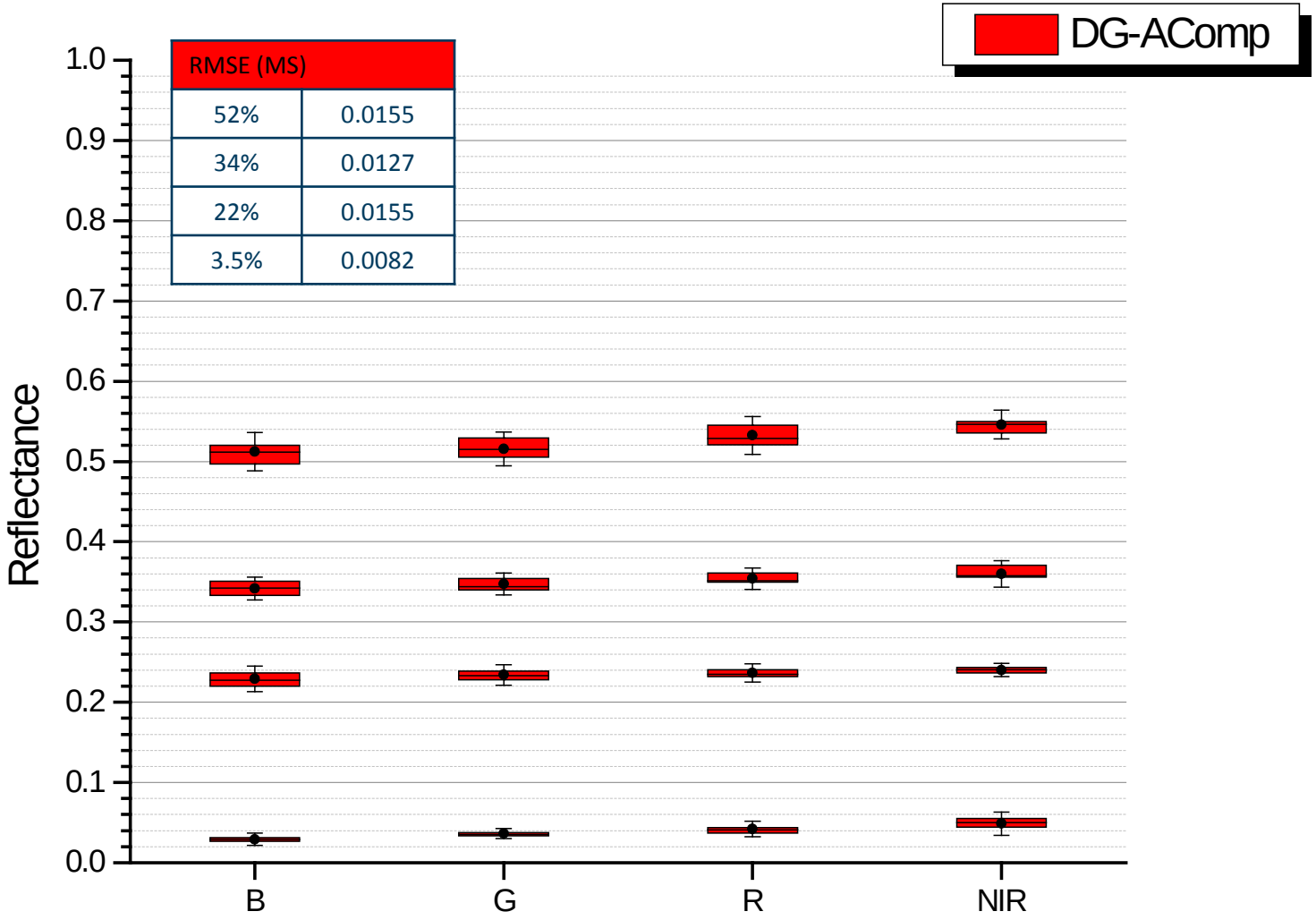
RMSE	
52%	0.1723
34%	0.1252
22%	0.0845
3.5%	0.0491

QB: FLAASH accuracy (52, 34, 22, and 3.5% reflectance)



RMSE	
52%	0.0118
34%	0.0113
22%	0.0125
3.5%	0.0059

QB: DG-AComp accuracy (52, 34, 22, and 3.5% reflectance)



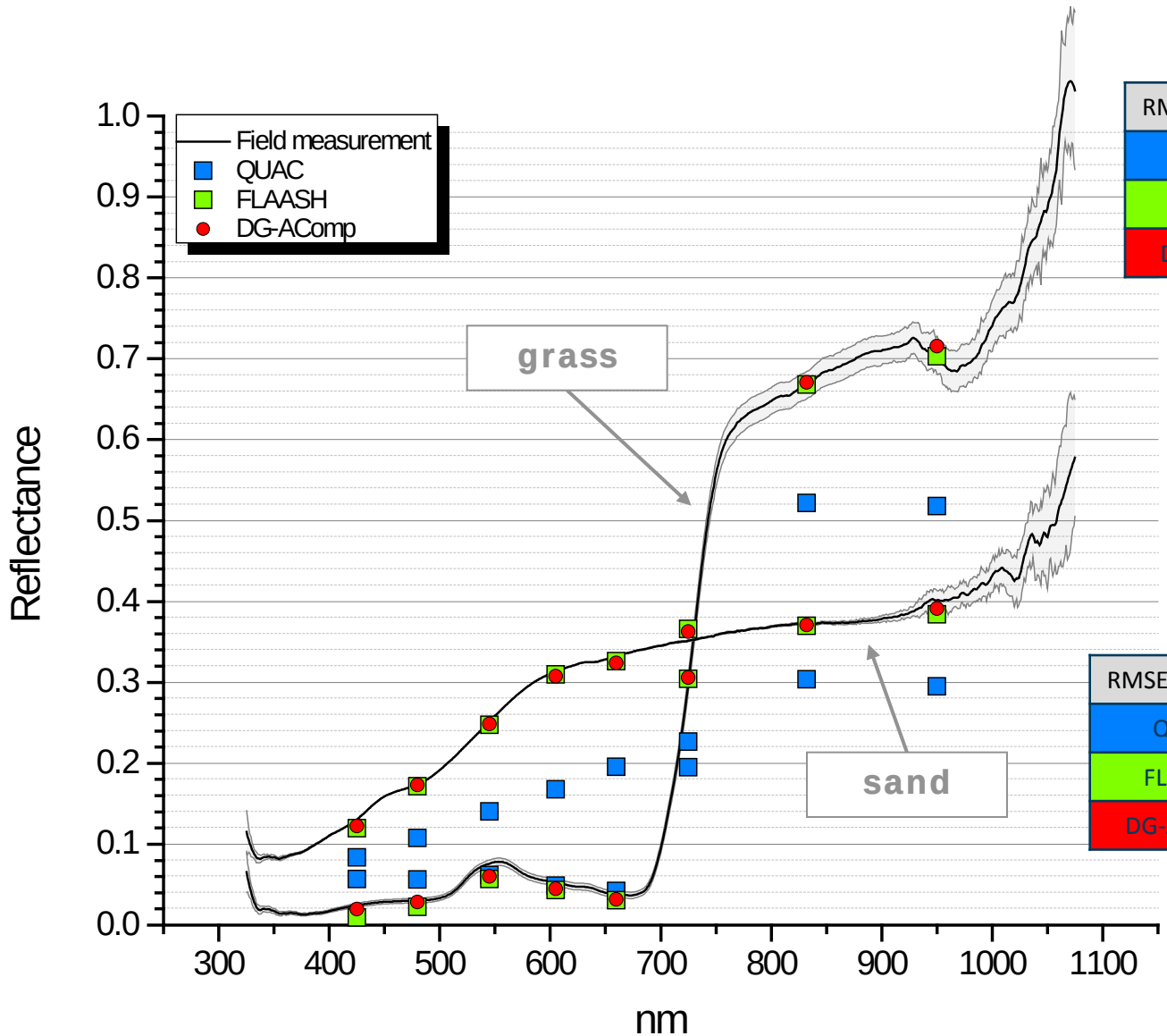
RMSE (MS)	
52%	0.0155
34%	0.0127
22%	0.0155
3.5%	0.0082

Field Measurements
and Coincident Satellite Acquisitions

Common Target Measurements

WV2 Acquisition Date:
August 7, 2011 – 18:06z
Sat. Elevation: 73.4°
Sat. Azimuth: 111.2°

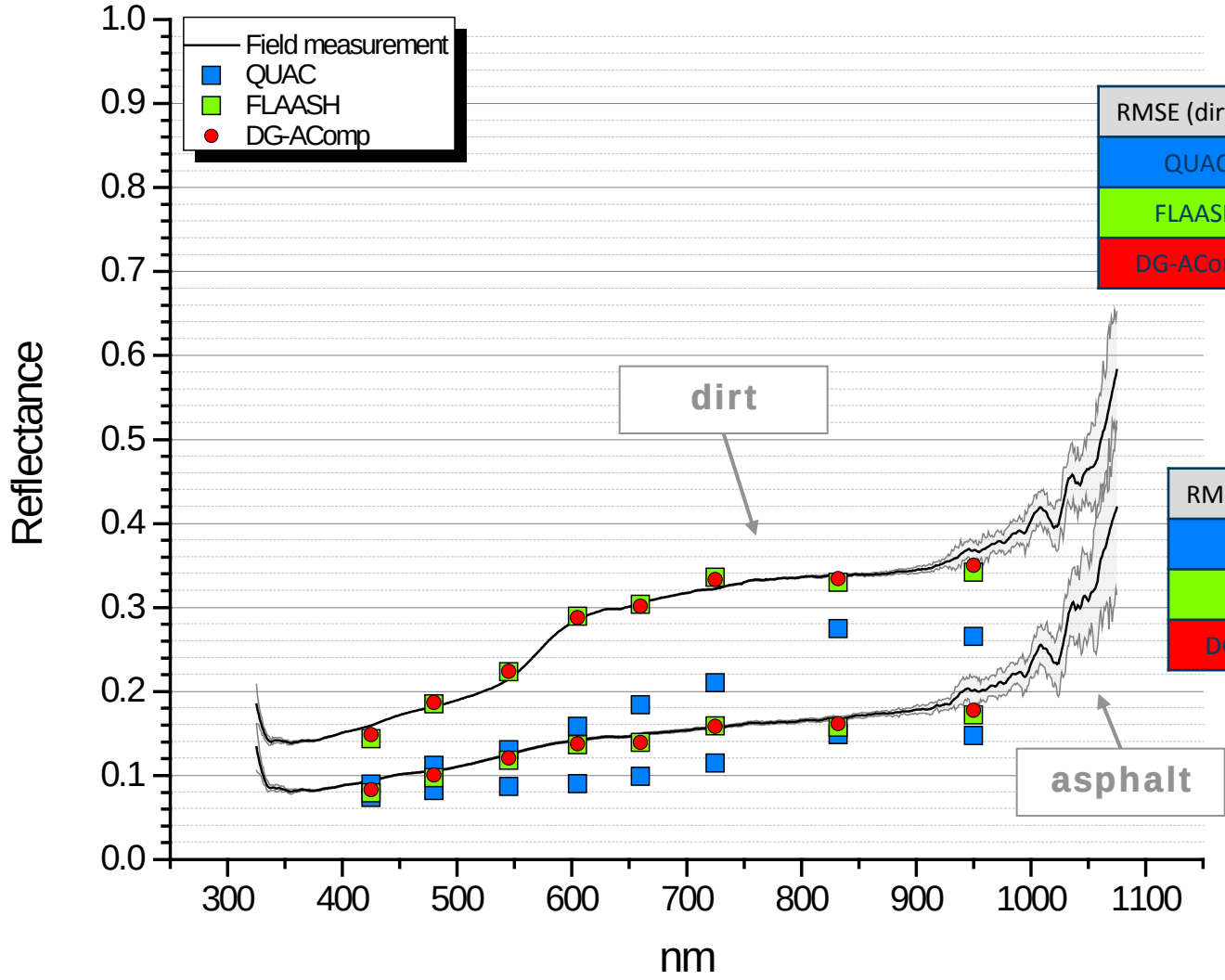
Grass and Sand



RMSE (grass)	
QUAC	0.0943
FLAASH	0.0096
DG-AComp	0.0060

RMSE (sand)	
QUAC	0.1061
FLAASH	0.0091
DG-AComp	0.0078

Dirt and Asphalt



RMSE (dirt)	
QUAC	0.0967
FLAASH	0.0103
DG-AComp	0.0071

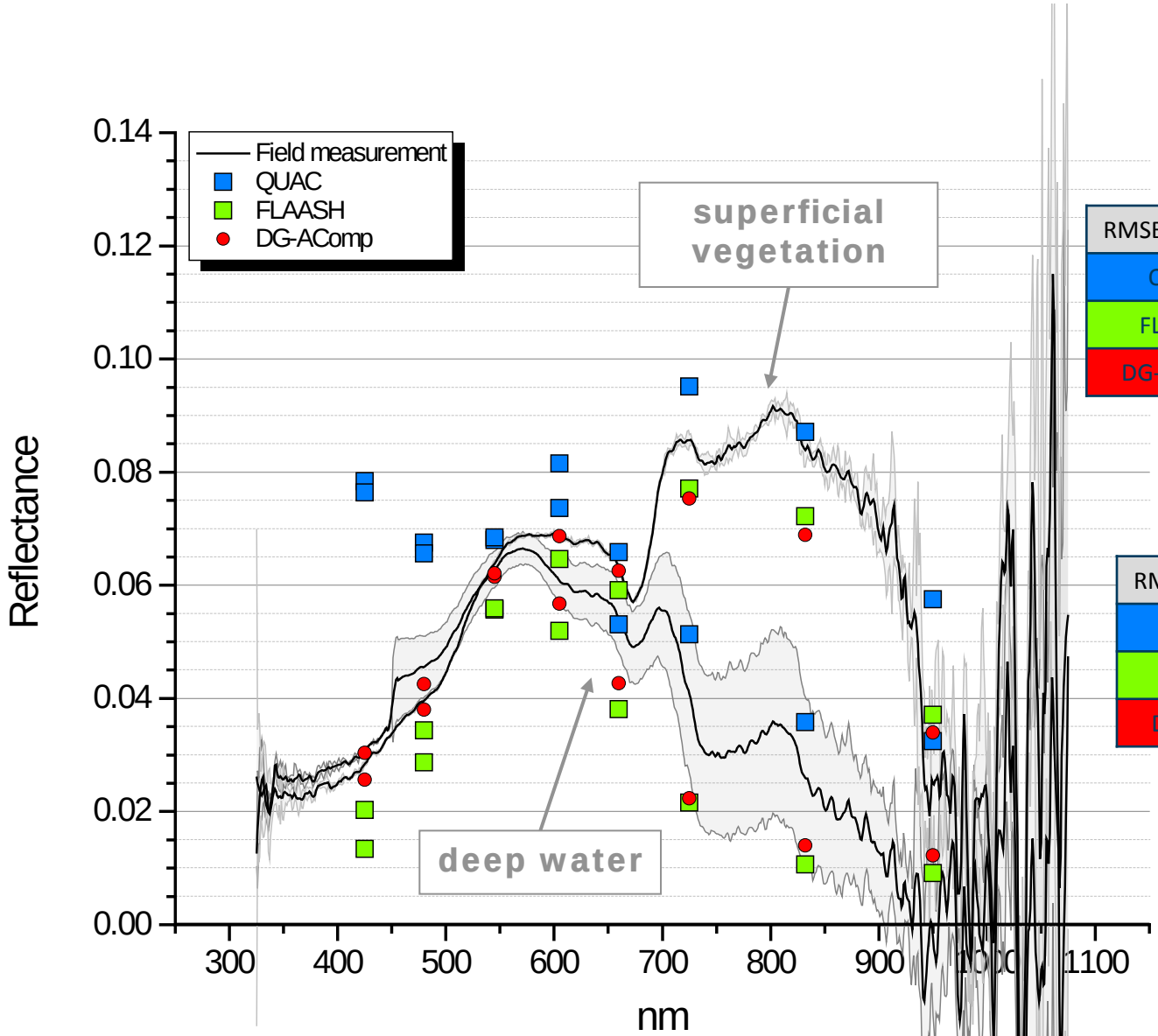
RMSE (asphalt)	
QUAC	0.0385
FLAASH	0.0114
DG-AComp	0.0085

Water Measurements

superficial vegetation

"deep" water

Deep Water and Superficial Vegetation



RMSE (superf. veg.)	
QUAC	0.0209
FLAASH	0.0096
DG-AComp	0.0099

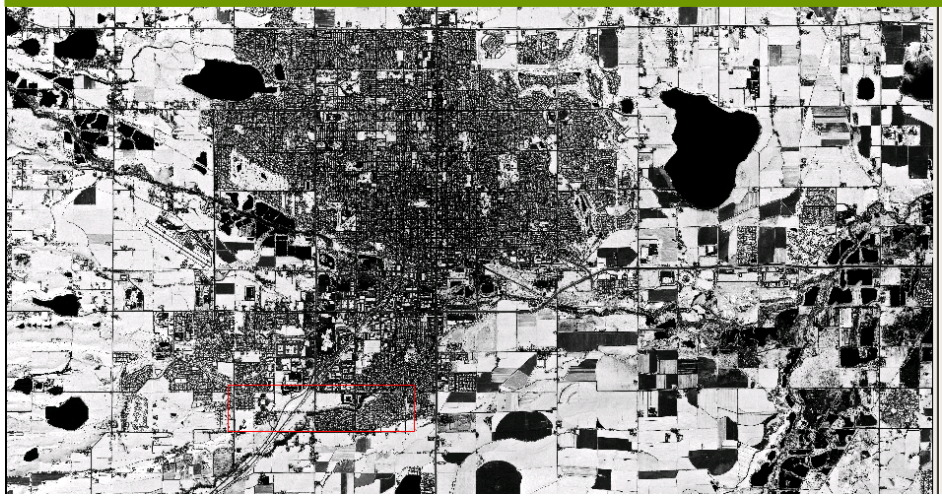
RMSE (deep water)	
QUAC	0.0231
FLAASH	0.0104
DG-AComp	0.0054

Snow Measurements

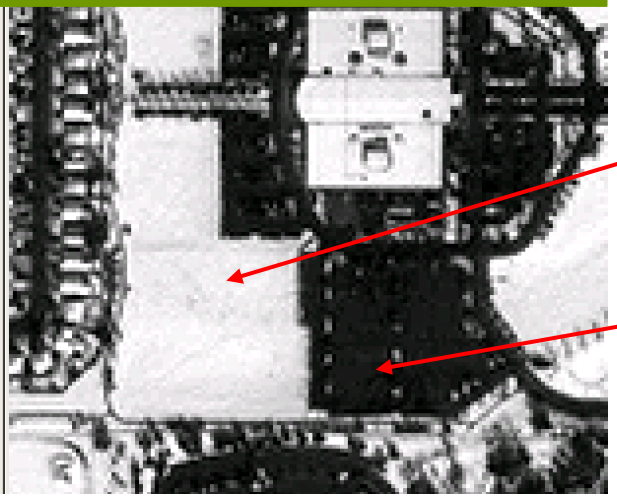
QB Acquisition Date:
October 28, 2011 – 17:16z
Sat. Elevation: 77.2°
Sat. Azimuth: 86.4°

Detail

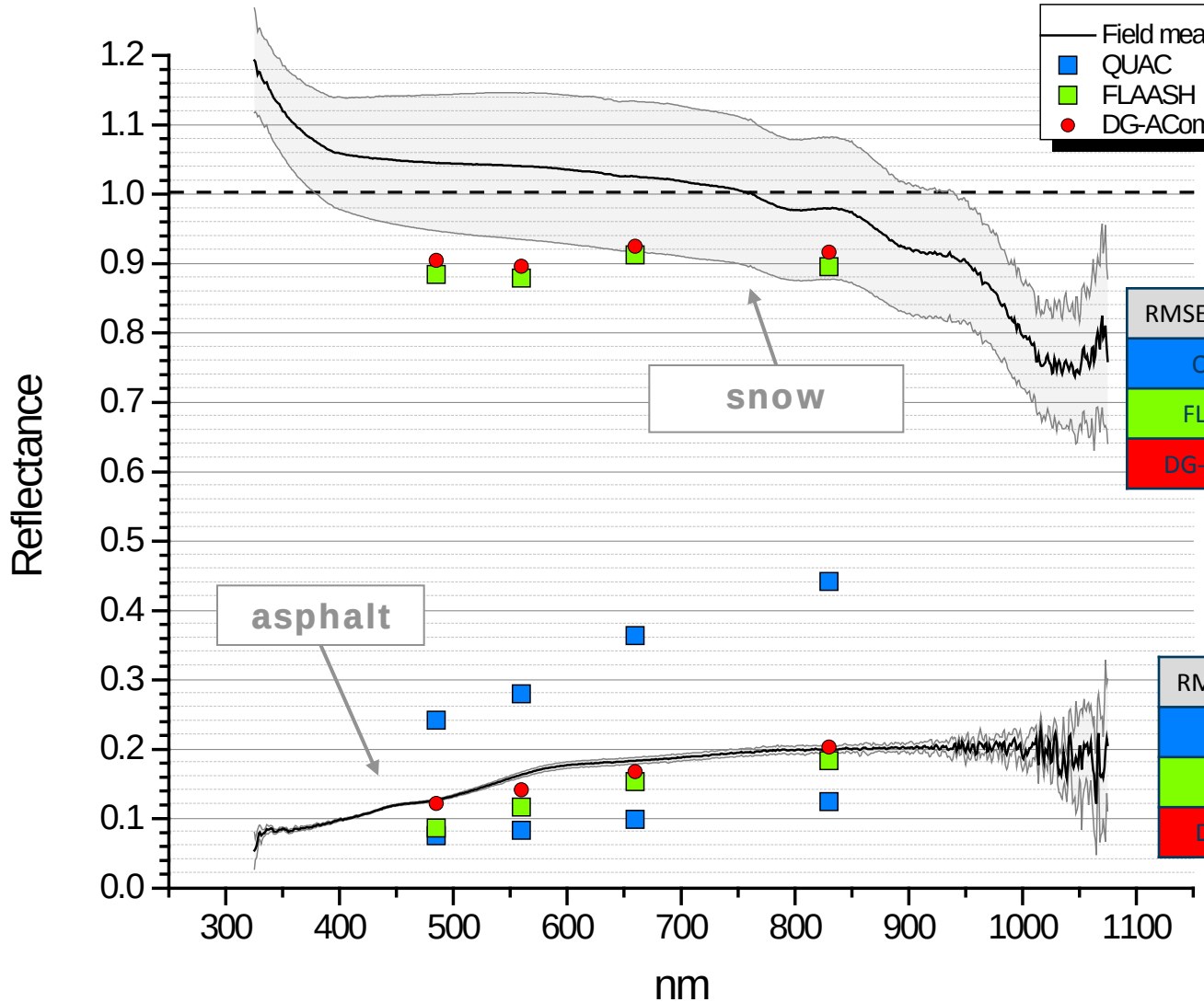
Full Scene



Zoom



Snow and Asphalt



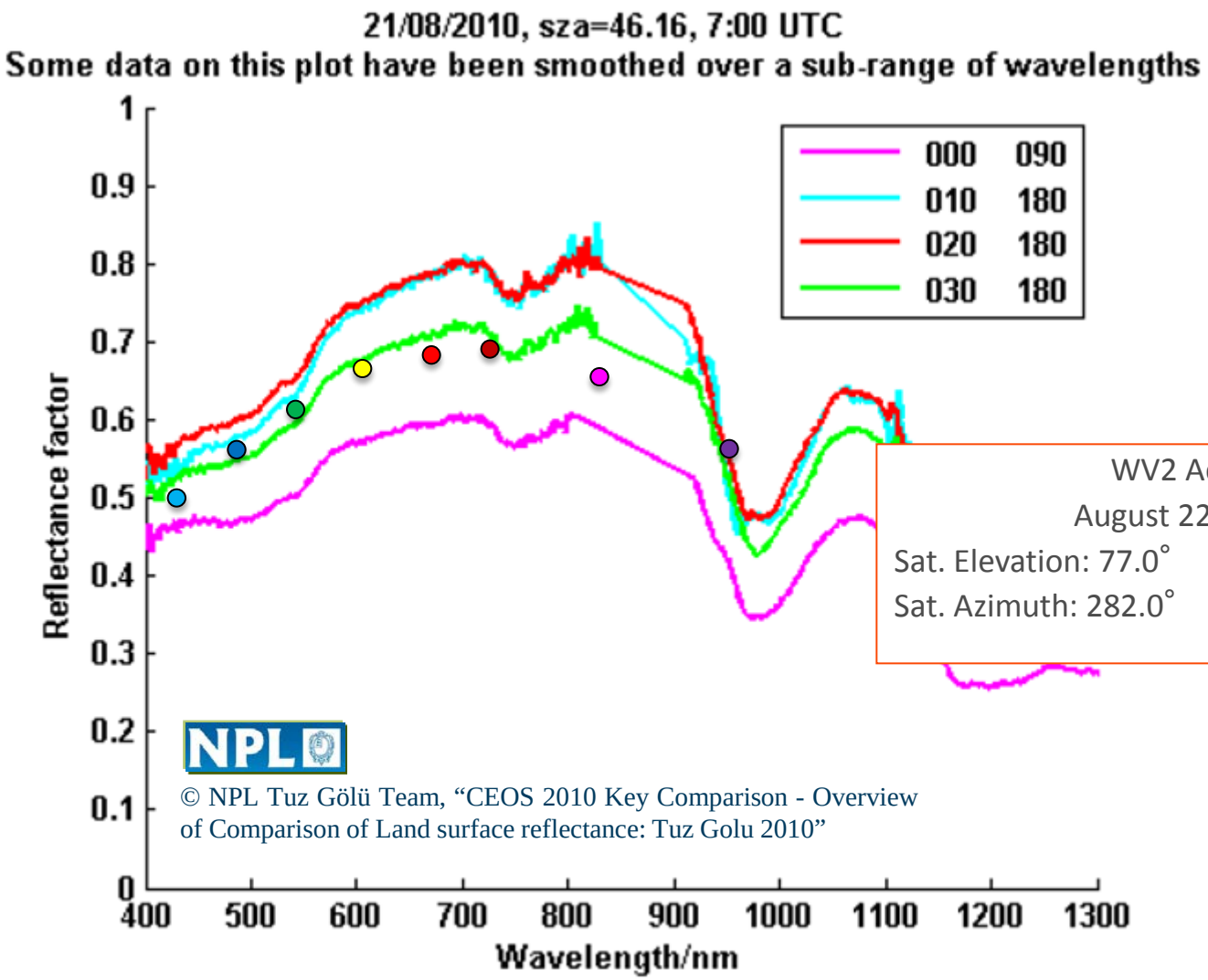
RMSE (snow)	
QUAC	0.6977
FLAASH	0.1334
DG-AComp	0.1163

RMSE (asphalt)	
QUAC	0.0762
FLAASH	0.0371
DG-AComp	0.0145

Tuz Gölü

During the summer of 2010, a large field campaign was conducted in Tuz Gölü, involving a total of 13 different teams from around the world.

Tuz Gölü: BRDF measurements using GRASS



WV2 Acquisition Date:
August 22, 2010 – 09:01z
Sat. Elevation: 77.0°
Sat. Azimuth: 282.0°

Aerosol Optical Depth Analysis

AOD (@550nm) Analysis

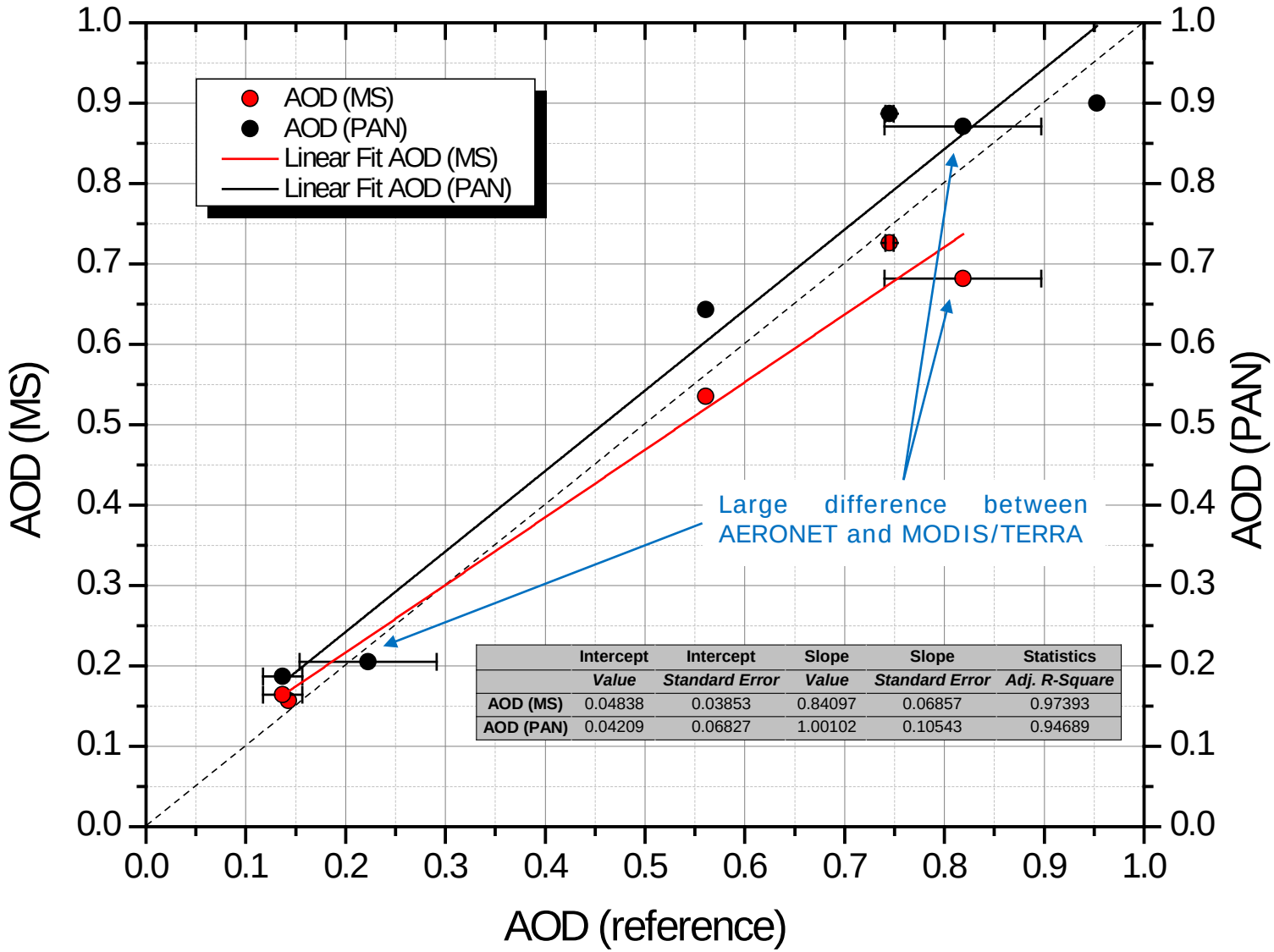
Location	Environment	Sensor	Date	AERONET	MODIS/Terra	DG-AComp
Osaka Japan	urban	QB MS	17-May-08	0.748	0.742	0.726
		QB PAN				0.887
		WV1	11-Aug-08	0.271	0.174	0.205
Dakar Senegal (*)	desert	QB MS	11-May-08	0.561	-	0.535
		QB PAN				0.643
Kanpur India (**)	rural	QB MS	24-Jun-08	0.874	0.763	0.682
		QB PAN				0.871
Beijing China	urban	WV1	21-Jun-08	-	0.953	0.900
Great Guana Cay The Bahamas	oceanic	WV2	26-Dec-09	-	0.143	0.157
Rafah Gaza Strip (***)	desert	QB MS	24-Jan-08	0.123	0.151	0.164
		QB PAN				0.187

(*) AERONET station is 60 km from the target.

(**) AERONET station is 90 km from the target. The data was collected the day after the QB acquisition.

(***) AERONET station is 70 km from the target. The data was collected 4 hours after the QB acquisition.

AOD (@550nm) Analysis



	Intercept	Intercept	Slope	Slope	Statistics
	Value	*Standard Error*	*Value*	*Standard Error*	*Adj. R-Square*
AOD (MS)	0.04838	0.03853	0.84097	0.06857	0.97393
AOD (PAN)	0.04209	0.06827	1.00102	0.10543	0.94689

Conclusions

DigitalGlobe

The applications of surface reflectance data are countless, including:

- land cover and change detection
- bathymetry
- target detection
- environmental studies (LAI, biomass)

The accuracy of DG-AComp depends on several factors:

- the absolute radiometric calibration of the sensor
- the radiative transfer model
- the correct choice of atmospheric input parameters

We are looking for alpha-customers!!!

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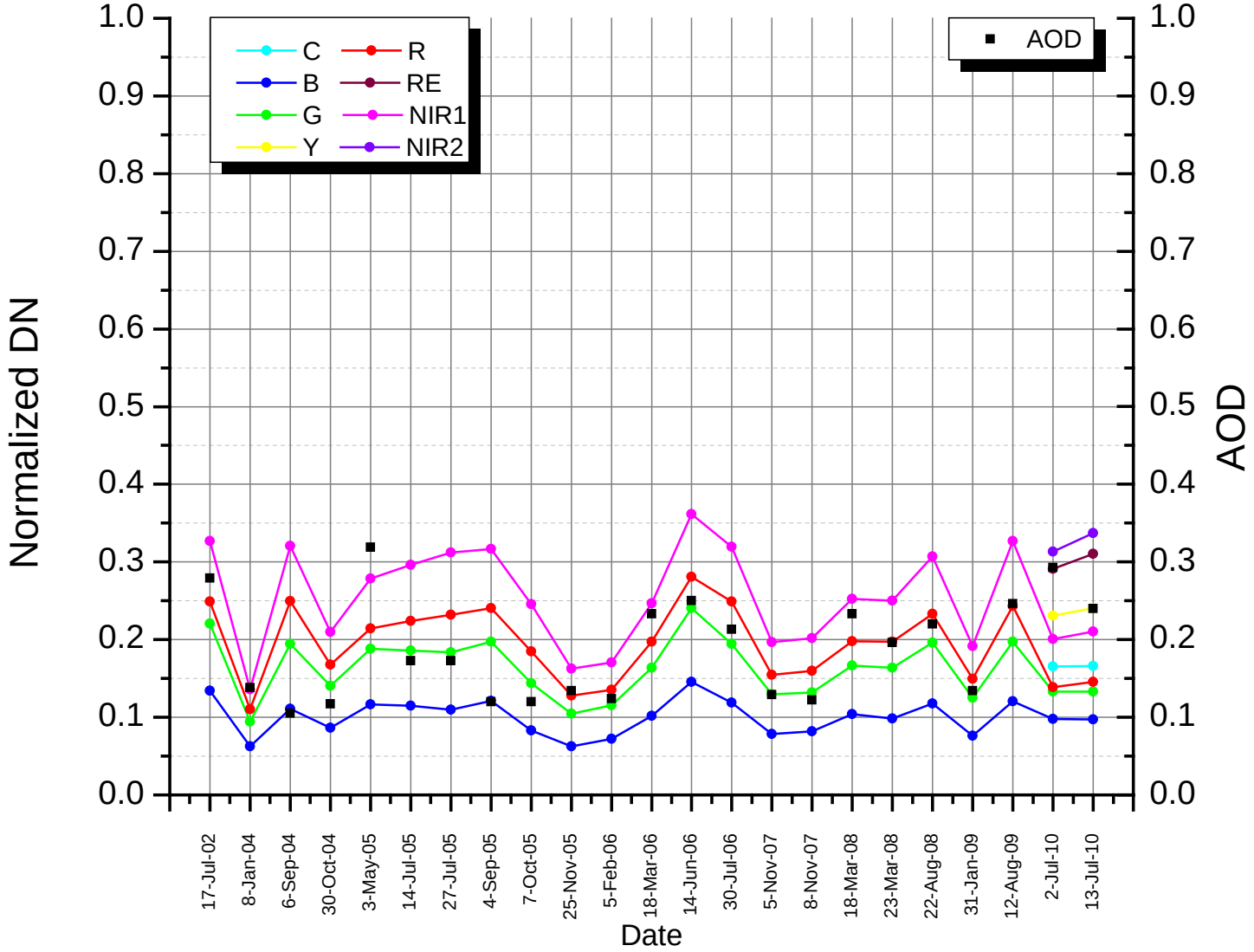
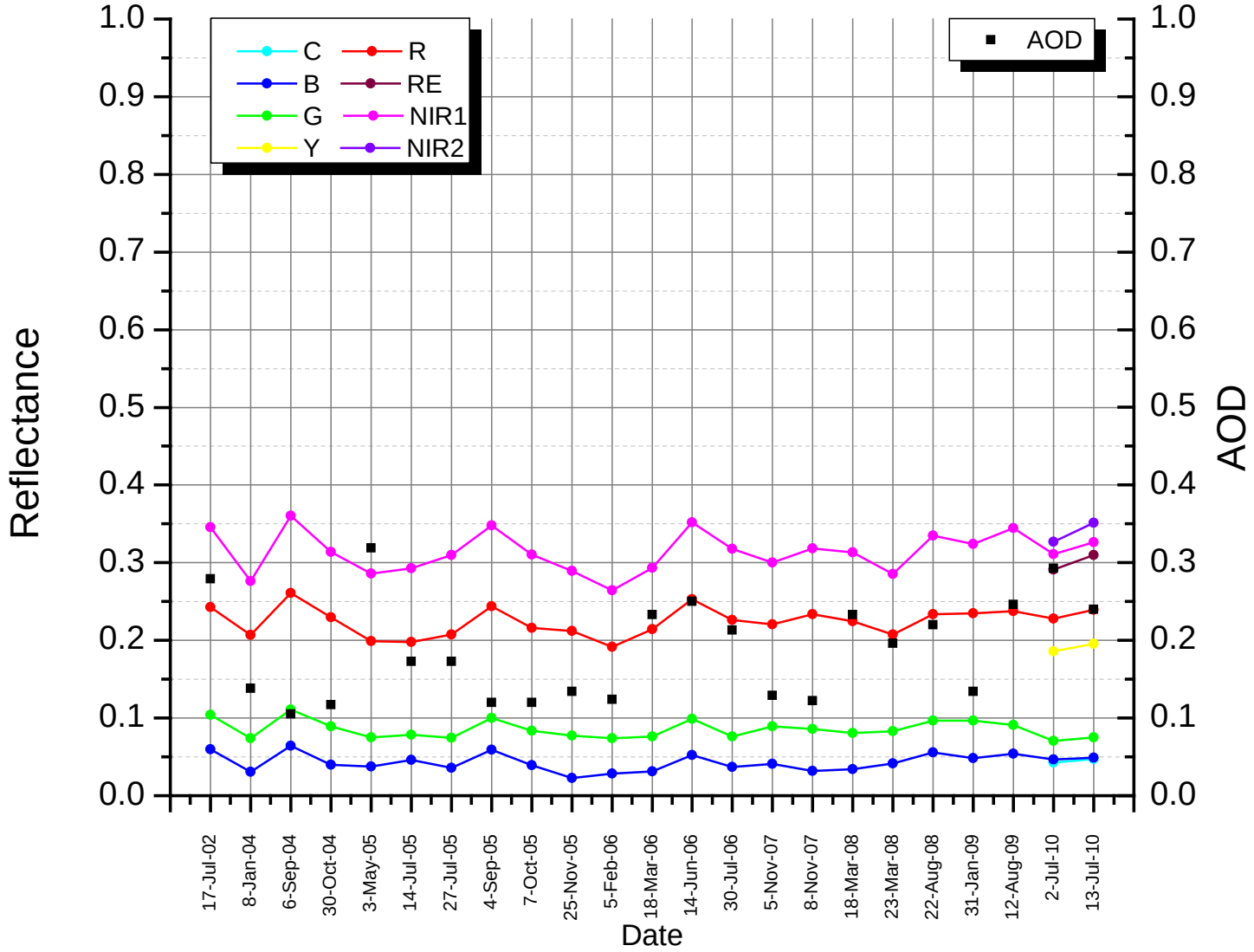
Back-up Slides

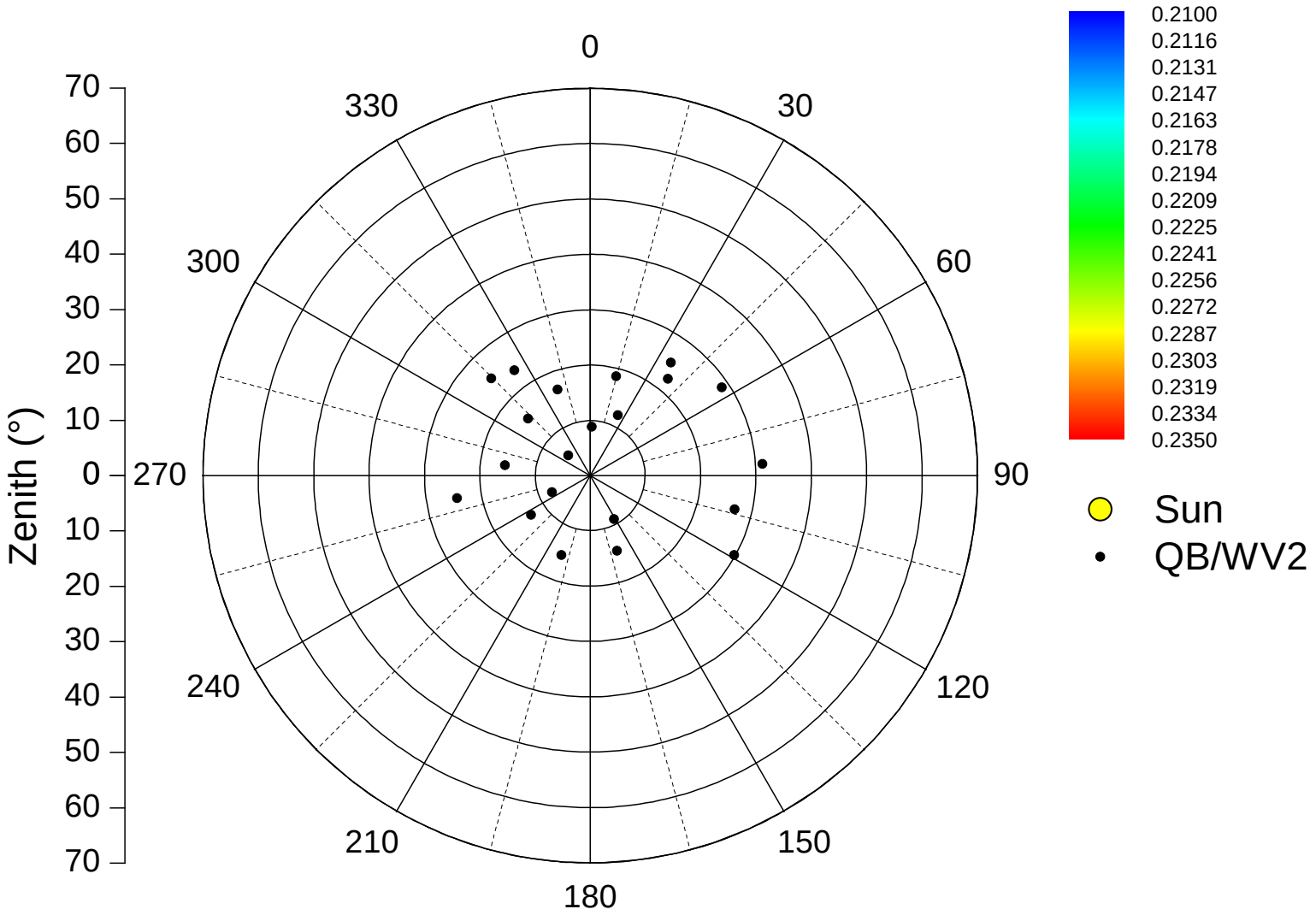
Quiz… What are we looking at? (1/3)



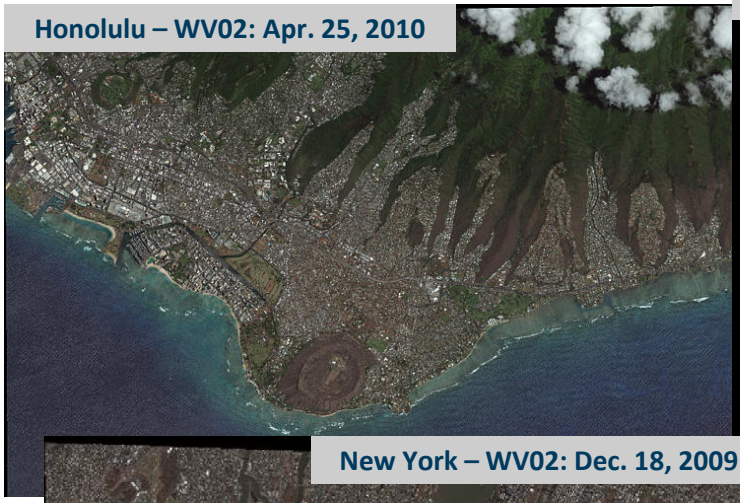
Quiz… What are we looking at? (2/3)

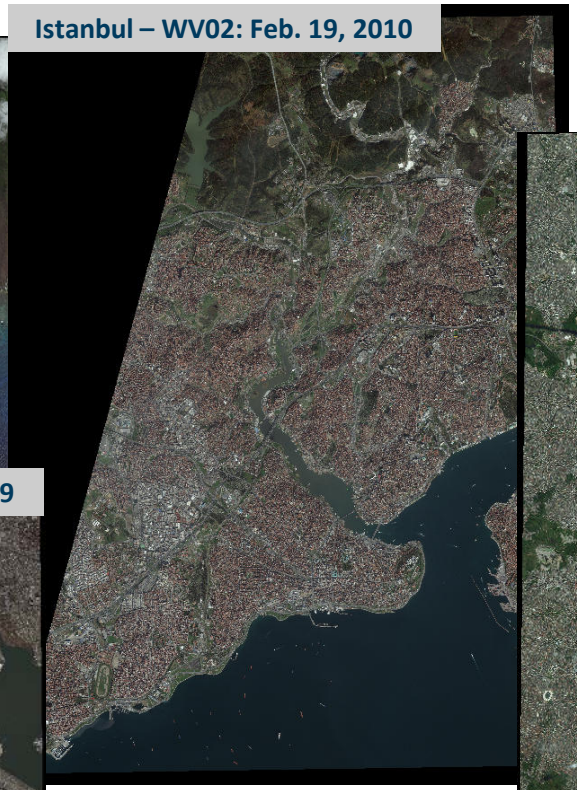


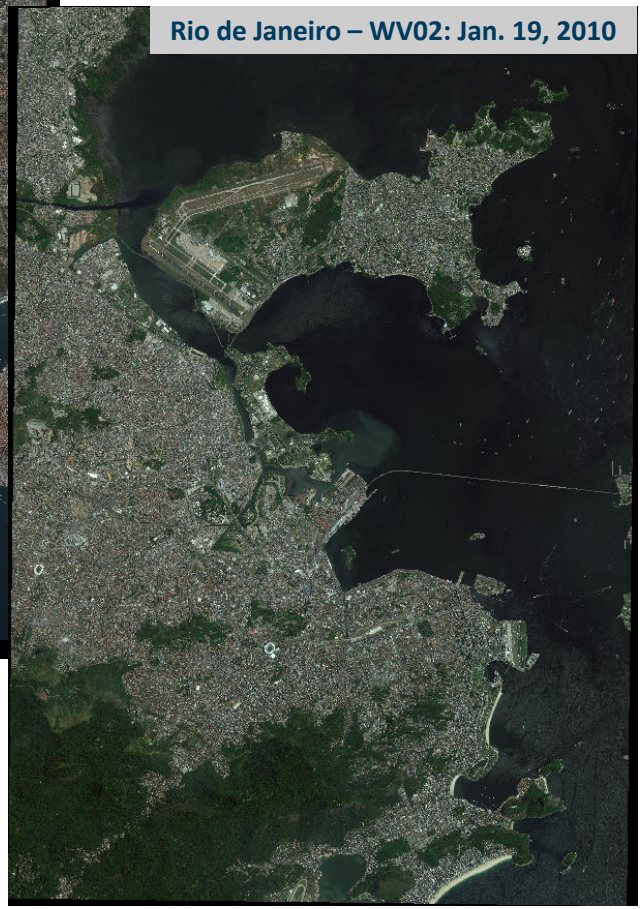
Quiz… What are we looking at? (3/3)



Model Portability (1/2)



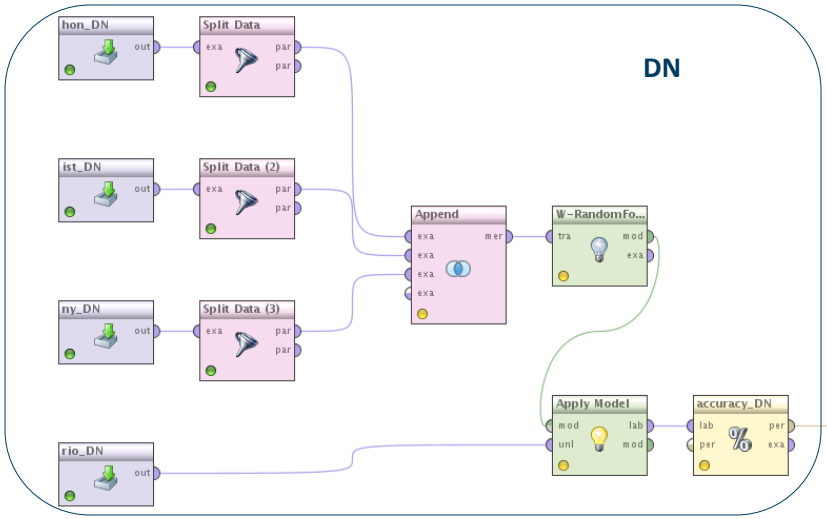


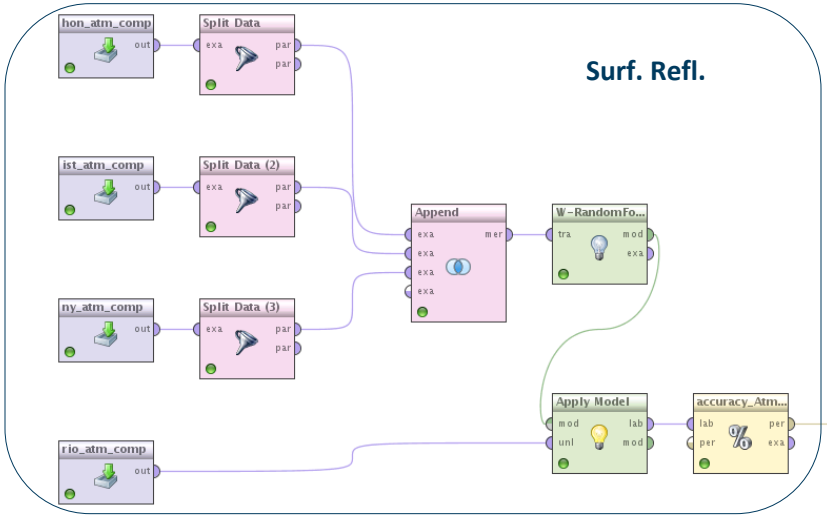


Six classes of interest:

1. **Grass**
2. **Tree**
3. **Water**
4. **Soil**
5. **Built-up**
6. **Shadow**

Model Portability (2/2)

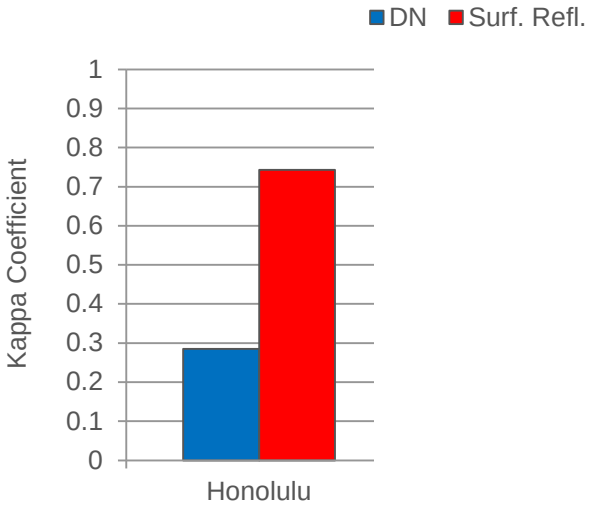




Three different experiments using training pixels from:

1. Honolulu
2. Honolulu and Istanbul
3. Honolulu, Istanbul, and New York

In all cases, the image of Rio de Janeiro has been used ONLY for validation.



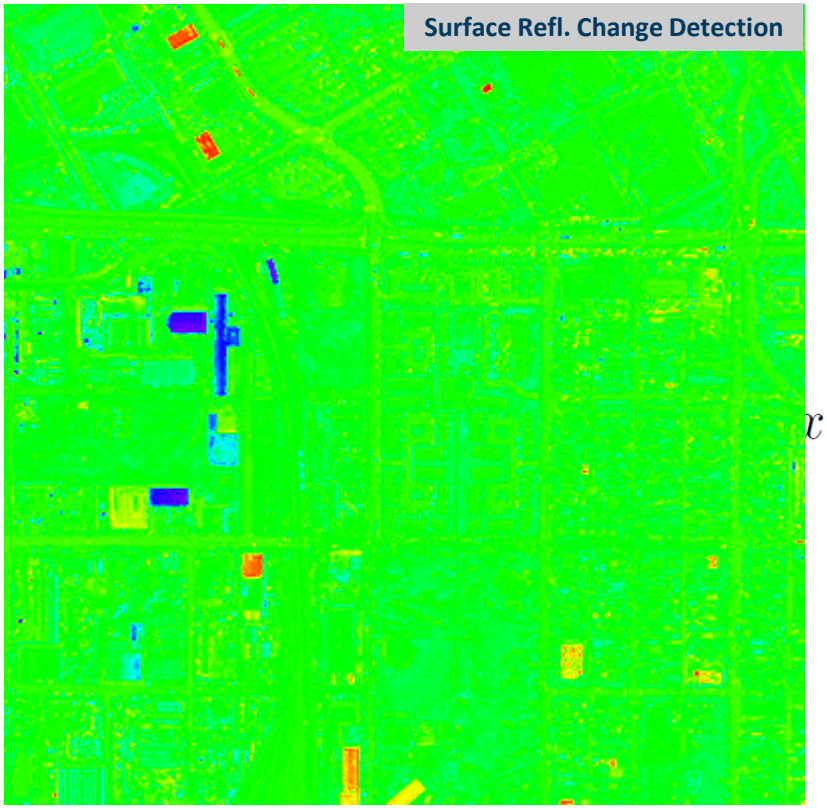
Automated Change Detection

Denver – QB: July 17, 2002

Denver – QB: August 22, 2008

$I(x, y)$

Surface Refl. Change Detection



$x, y)]\}$

Negative Change | No-Change | Positive Change