Validation of the DigitalGlobe Surface Reflectance product

See a better world.

Agenda

- Introduction
- The Consistency of Information
- Ag Applications
- Open Data and Commercial Satellite Platforms
  - Sentinel-2
  - Landsat-8
  - RapidEye
- Validation Methodology
- Validation Results
- Conclusions

Introduction

DigitalGlobe Constellation

IKONOS®

.82 meter resolution
9 m CE90

QuickBird®

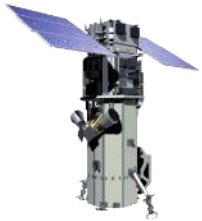
.65 meter resolution
23 m CE90

WorldView-1®

.50 meter resolution
<4 m CE90

GeoEye-1®

.46 meter resolution
<3.5 m CE90

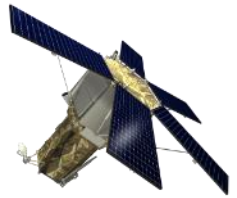


WorldView-2®

.46 meter resolution
<3.5 m CE90

WorldView-3®

.30 meter resolution
<3.0 m CE90



WorldView-4®

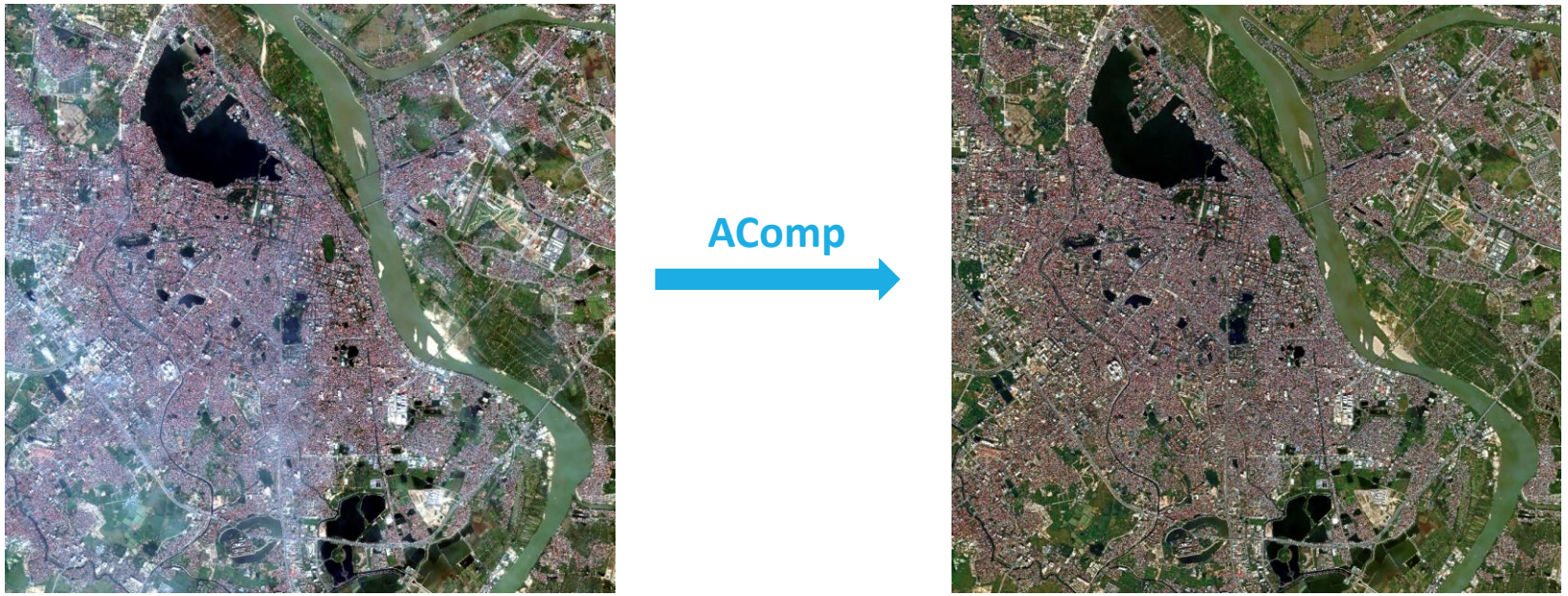
Launch scheduled:
Fall 2016

CURRENTLY IMAGING IN ORBIT

AVAILABLE VIA DIGITALGLOBE ARCHIVE

Introducing AComp (1/2)

- We collect ~100 terabytes of imagery per day, some of which is unusable because of atmospheric effects
- **AComp** is a fully automated framework for atmospherically compensating very high spatial resolution panchromatic and multi-spectral images (including SWIR bands)

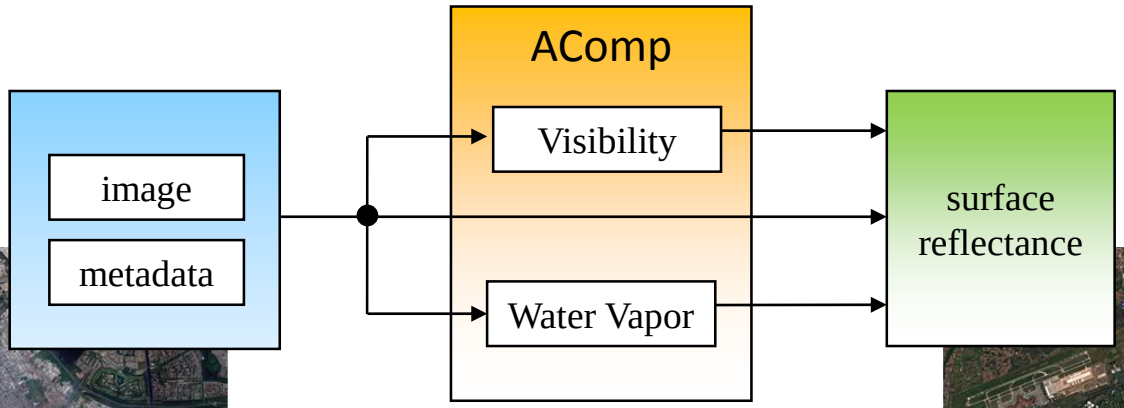


Introducing AComp (2/2)

- AComp has several advantages:
  - facilitates cross-sensor processing
  - improves performance of multi-temporal data analysis
  - enables the extraction of information using physical quantities, not just image statistics

- Results indicated that AComp is more accurate than COTS software like FLAASH or QUAC and requires no *human-in-the-loop*, making it suitable for large-scale production

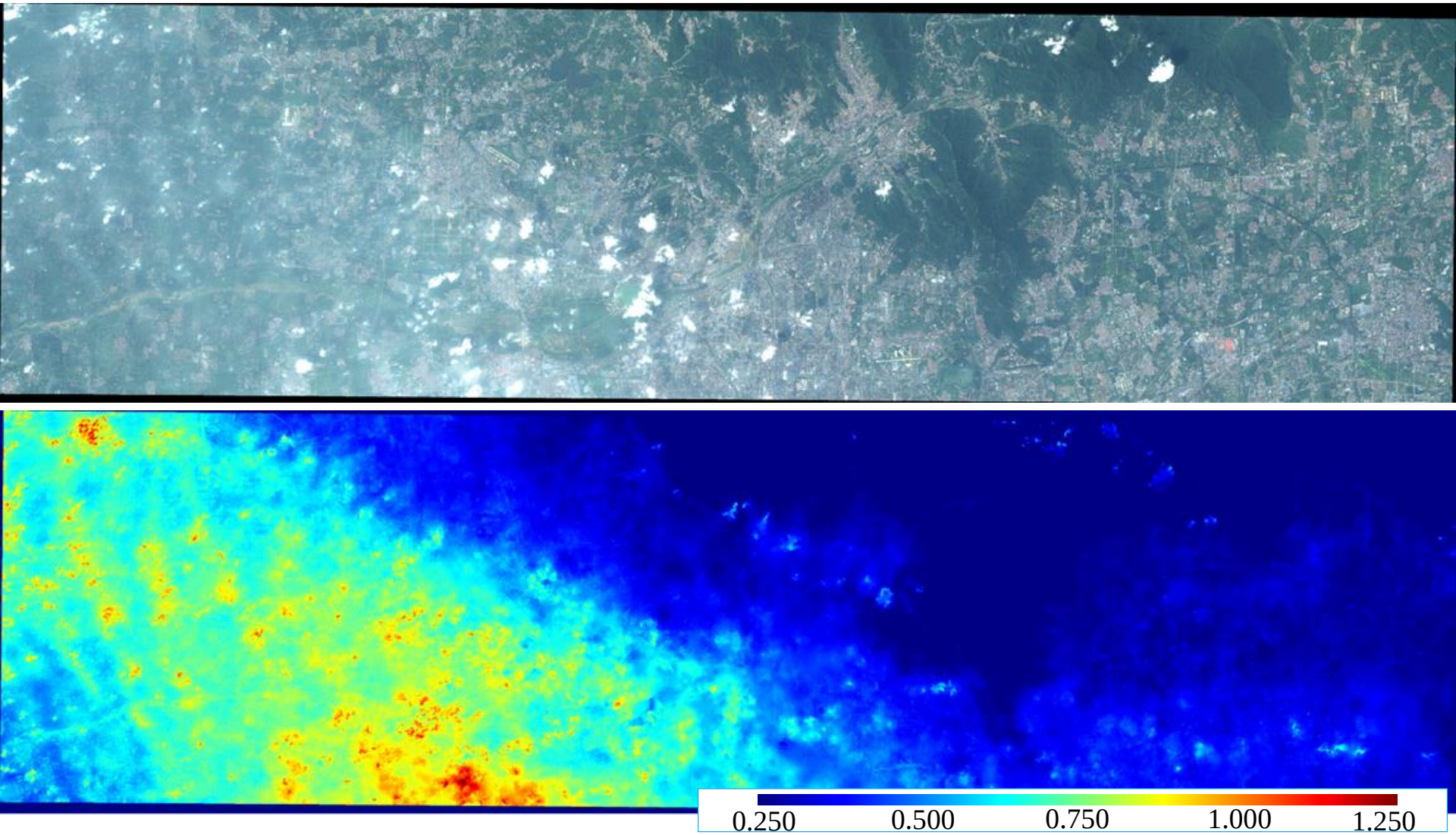
AComp Overview



Atmospheric visibility and water vapor values are derived from the image based on specific spectral properties.

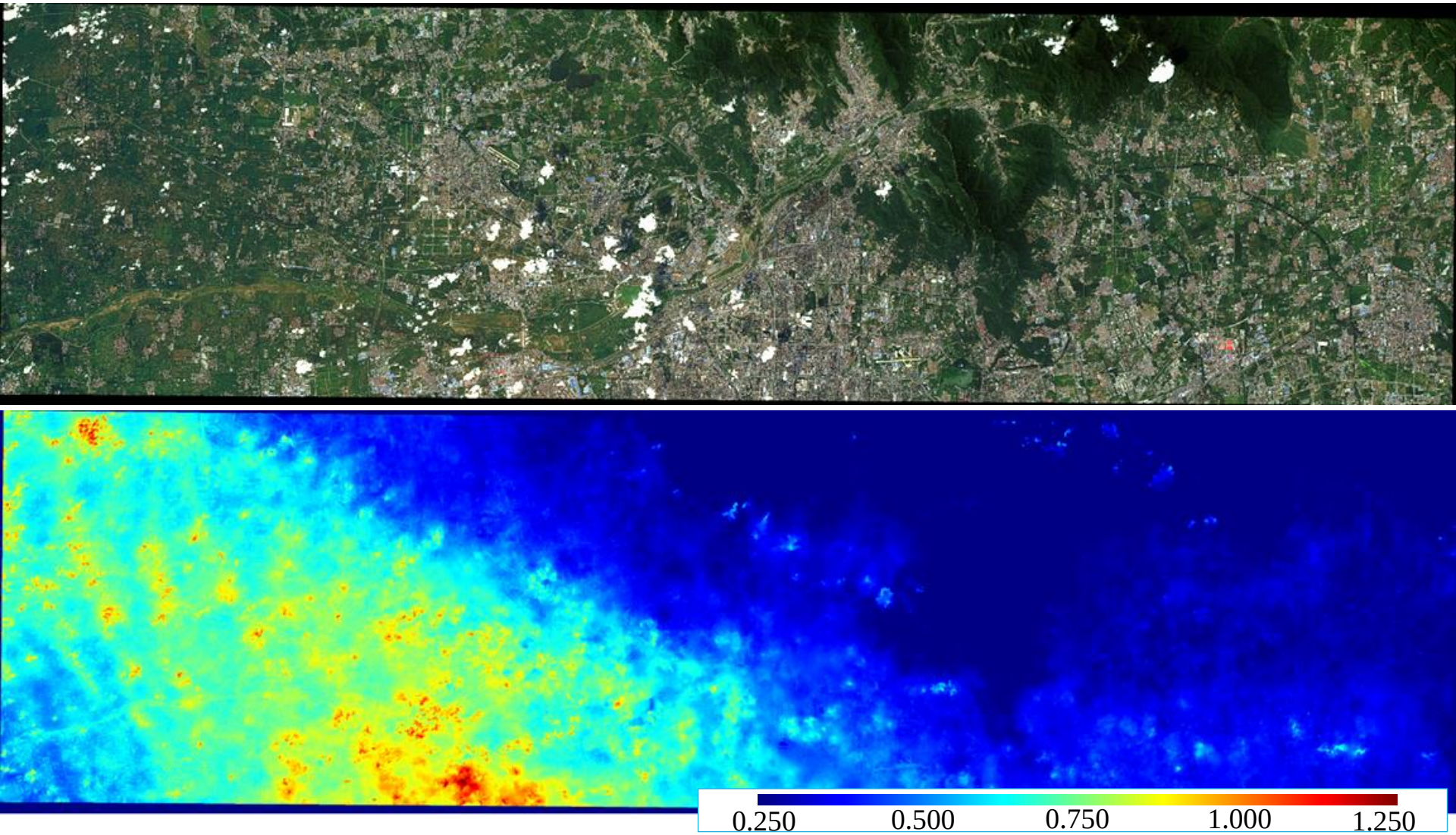
Pixel-based Approach!

Beijing (China) - August 12, 2012: original image



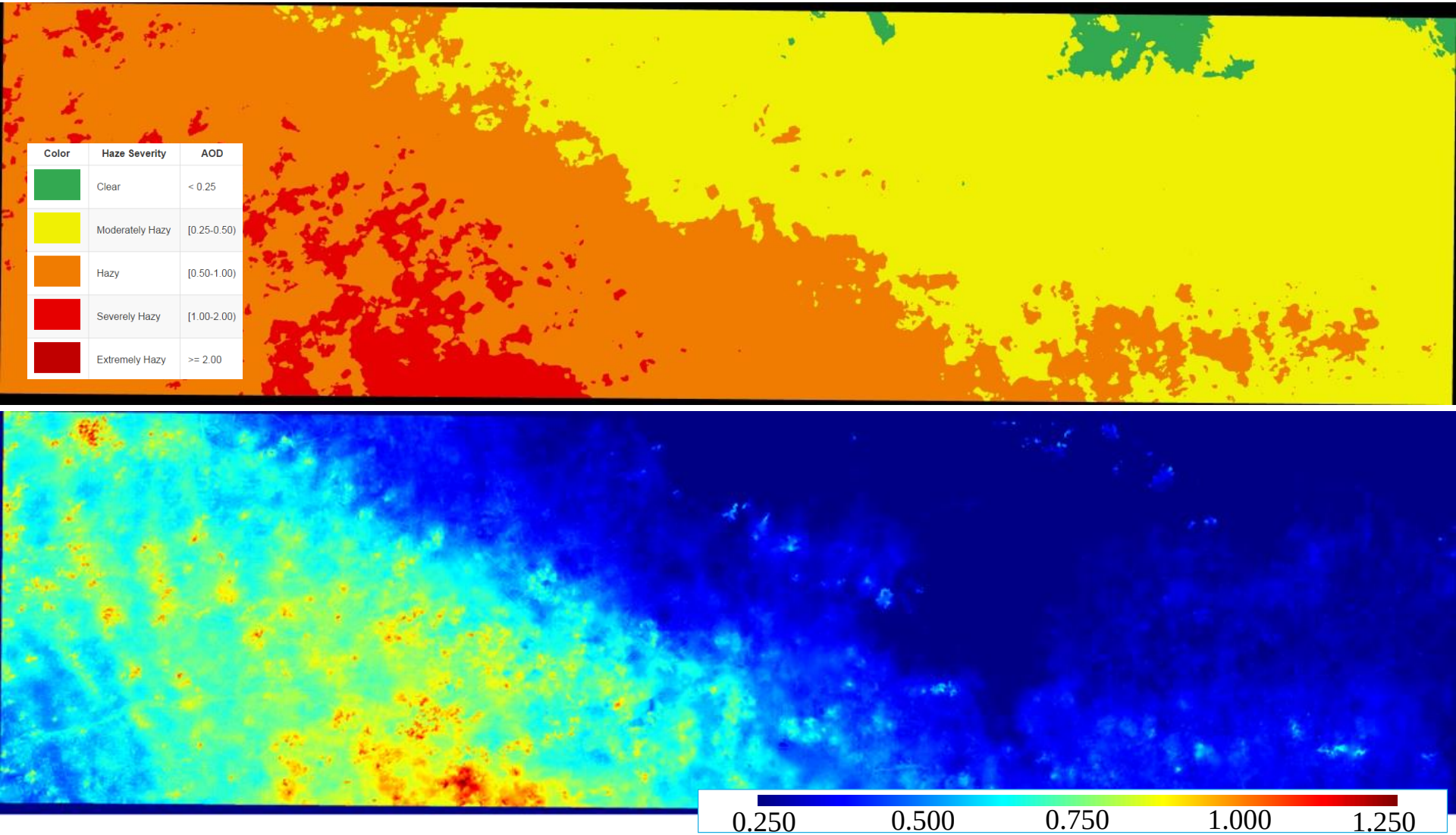
Pixel-based Approach!

Beijing (China) - August 12, 2012: AComp



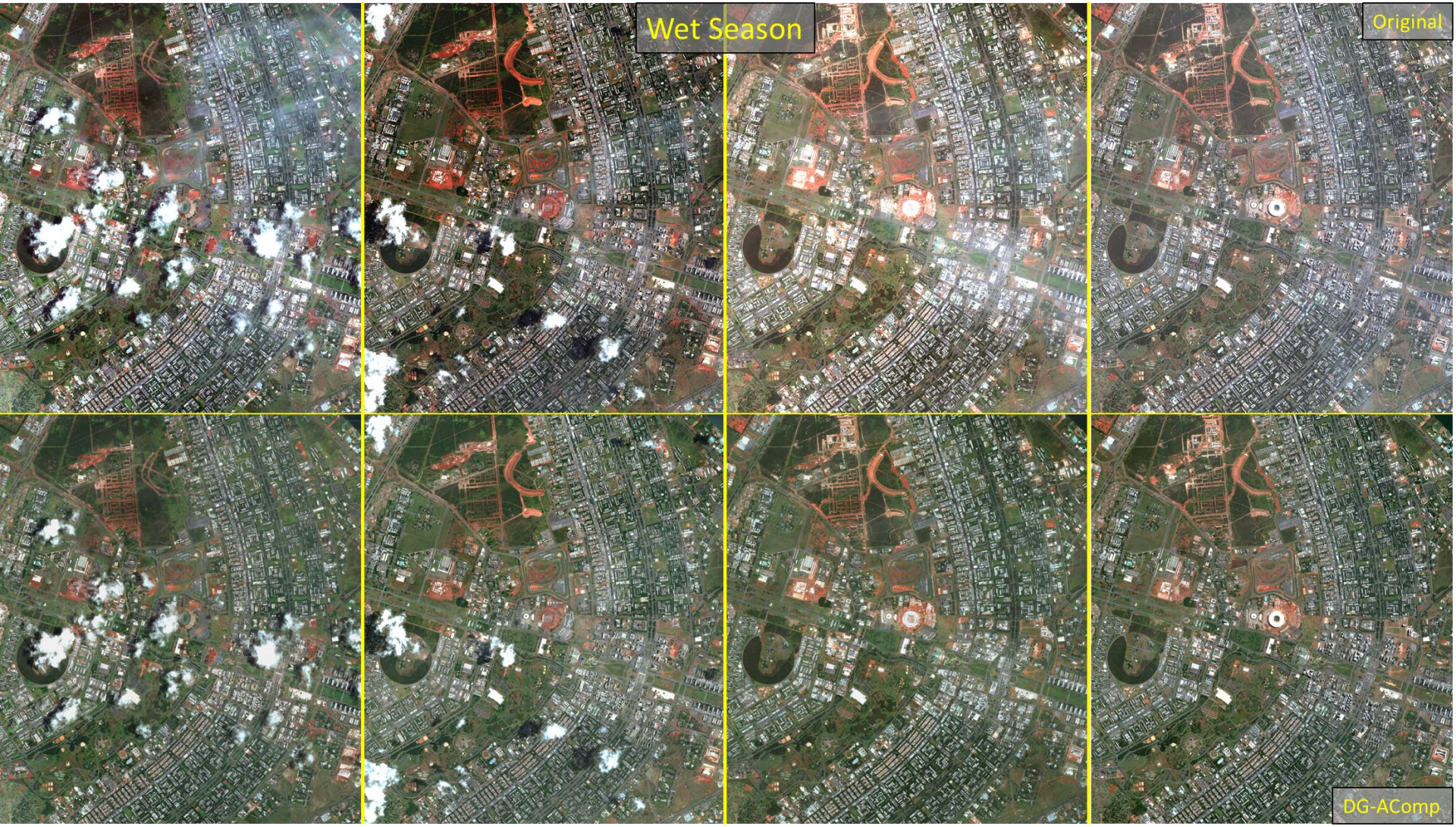
Pixel-based Approach!

Beijing (China) - August 12, 2012: Haze Severity

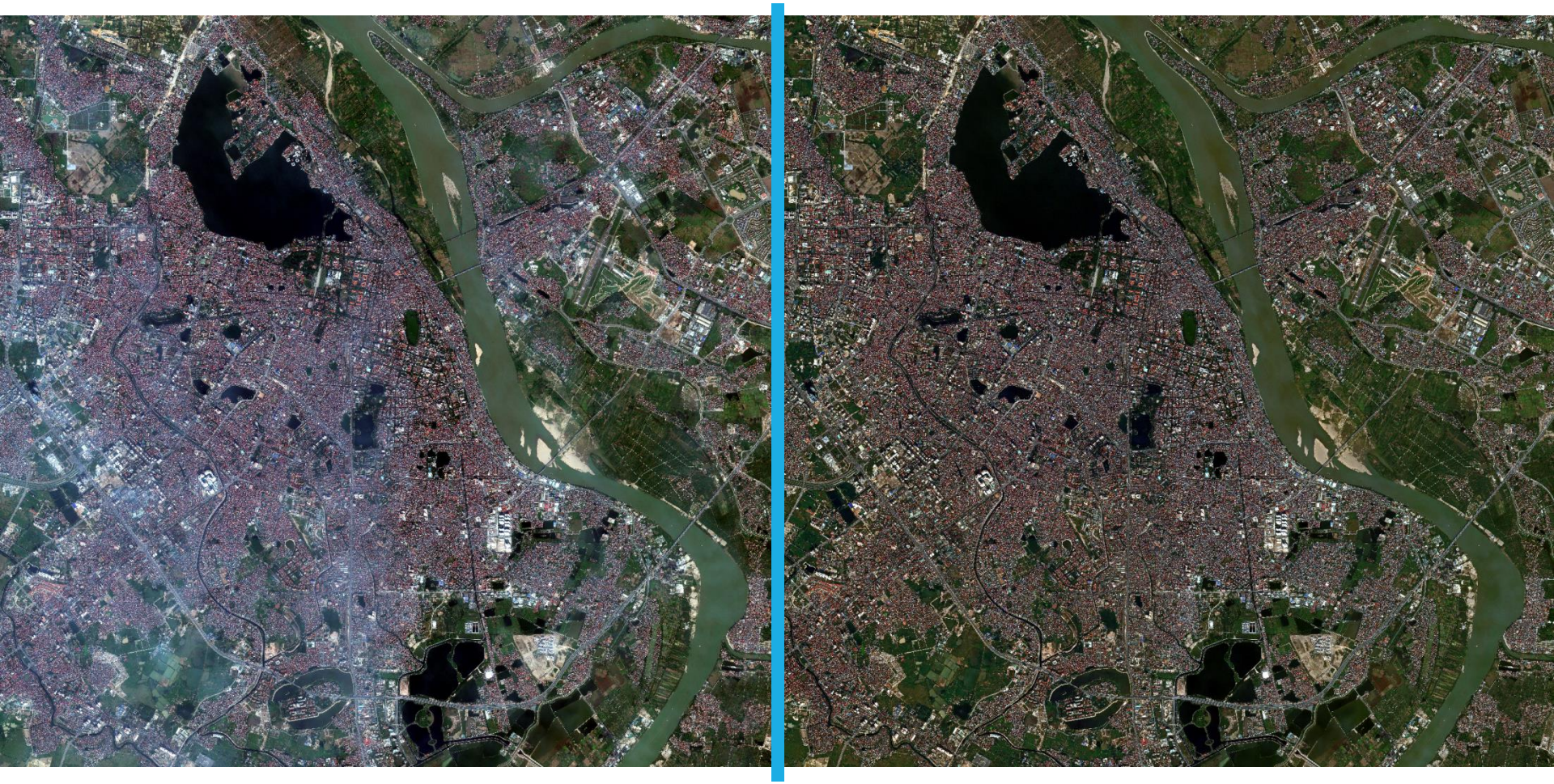


The Consistency of Information

Construction of the National Stadium of Brazil Mané Garrincha (2010-2013)



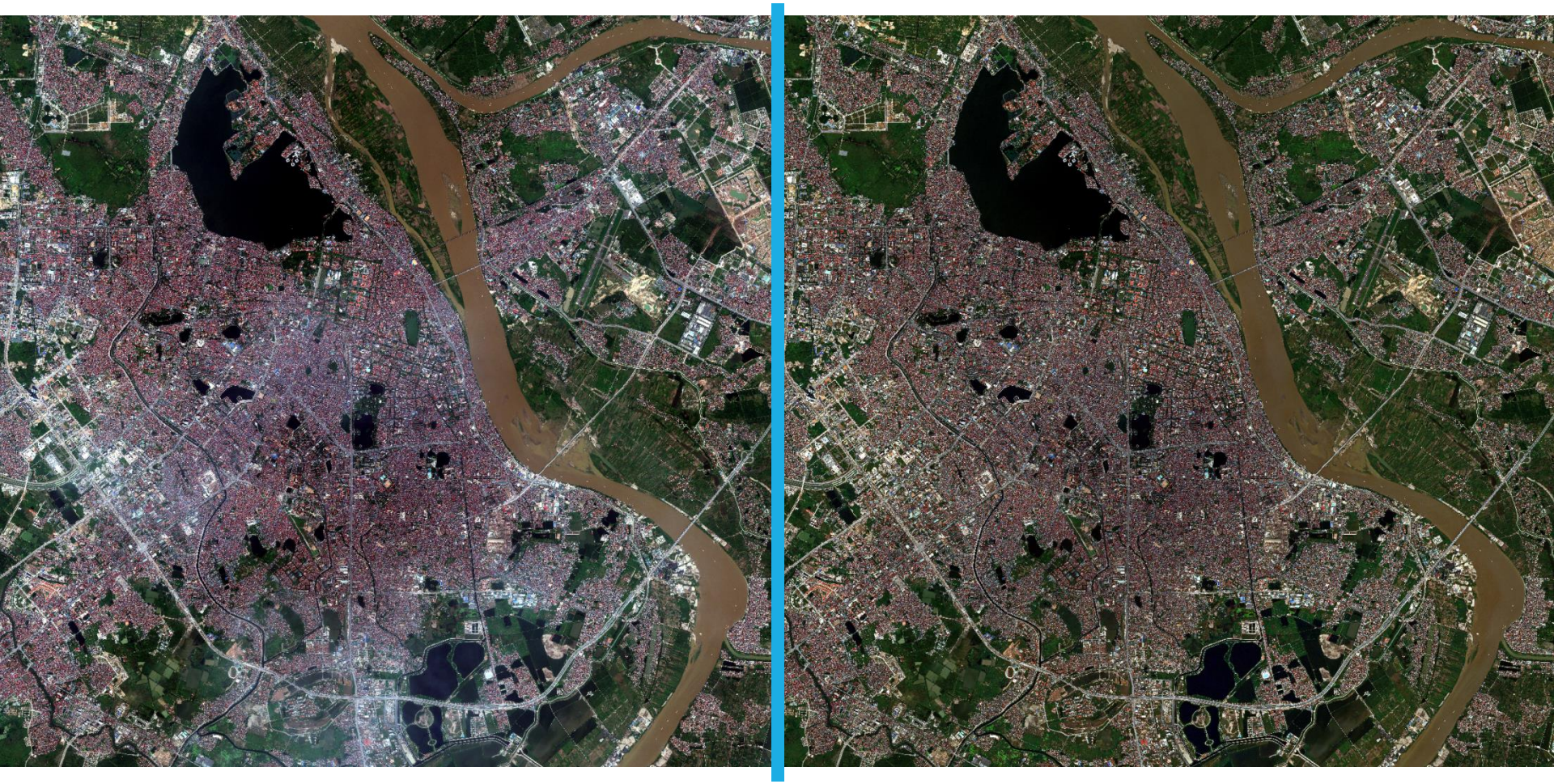
Hanoi (Vietnam) – time series (1/10)



original image

surface reflectance

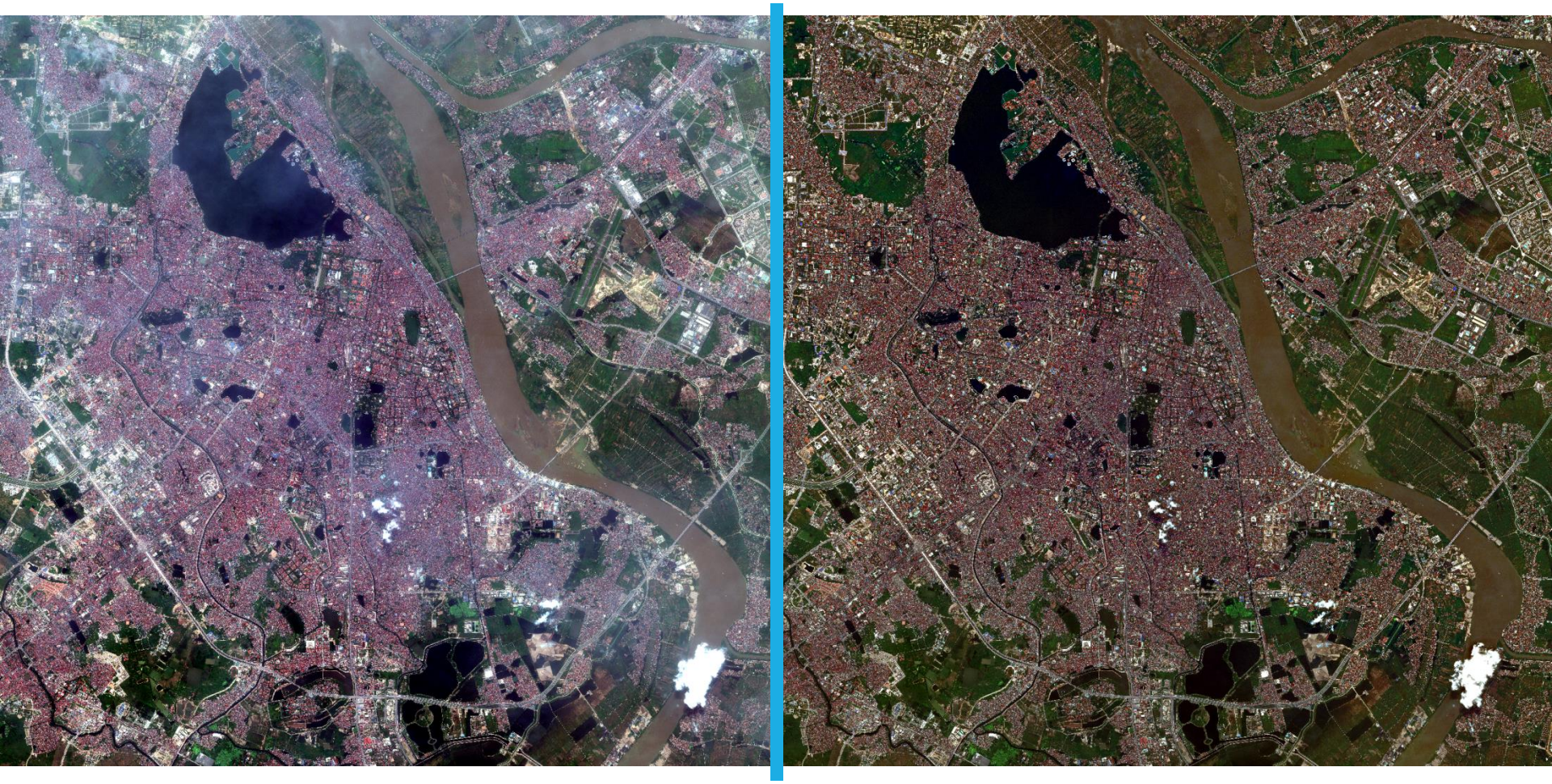
Hanoi (Vietnam) – time series (2/10)



original image

surface reflectance

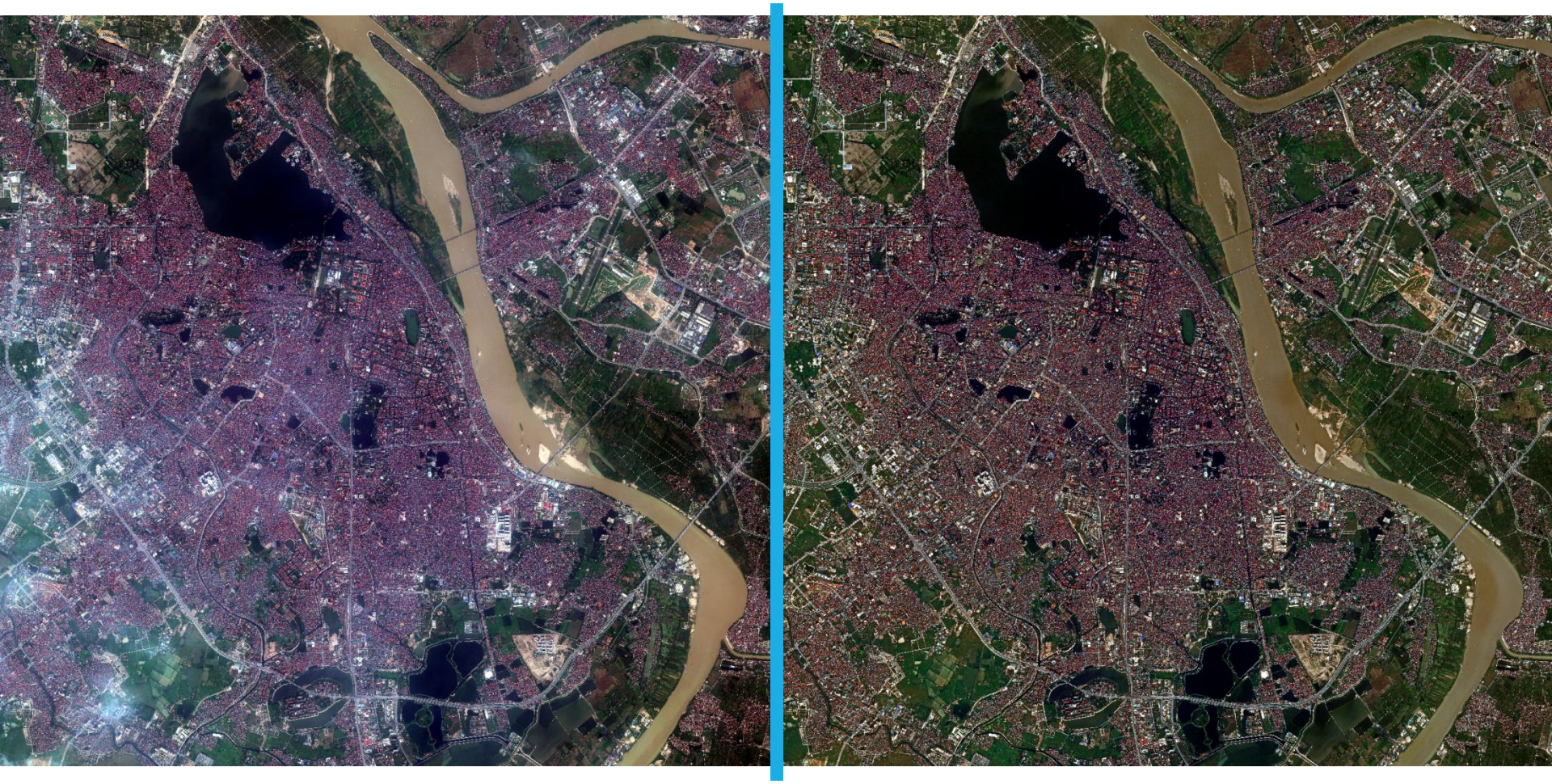
Hanoi (Vietnam) – time series (3/10)



original image

surface reflectance

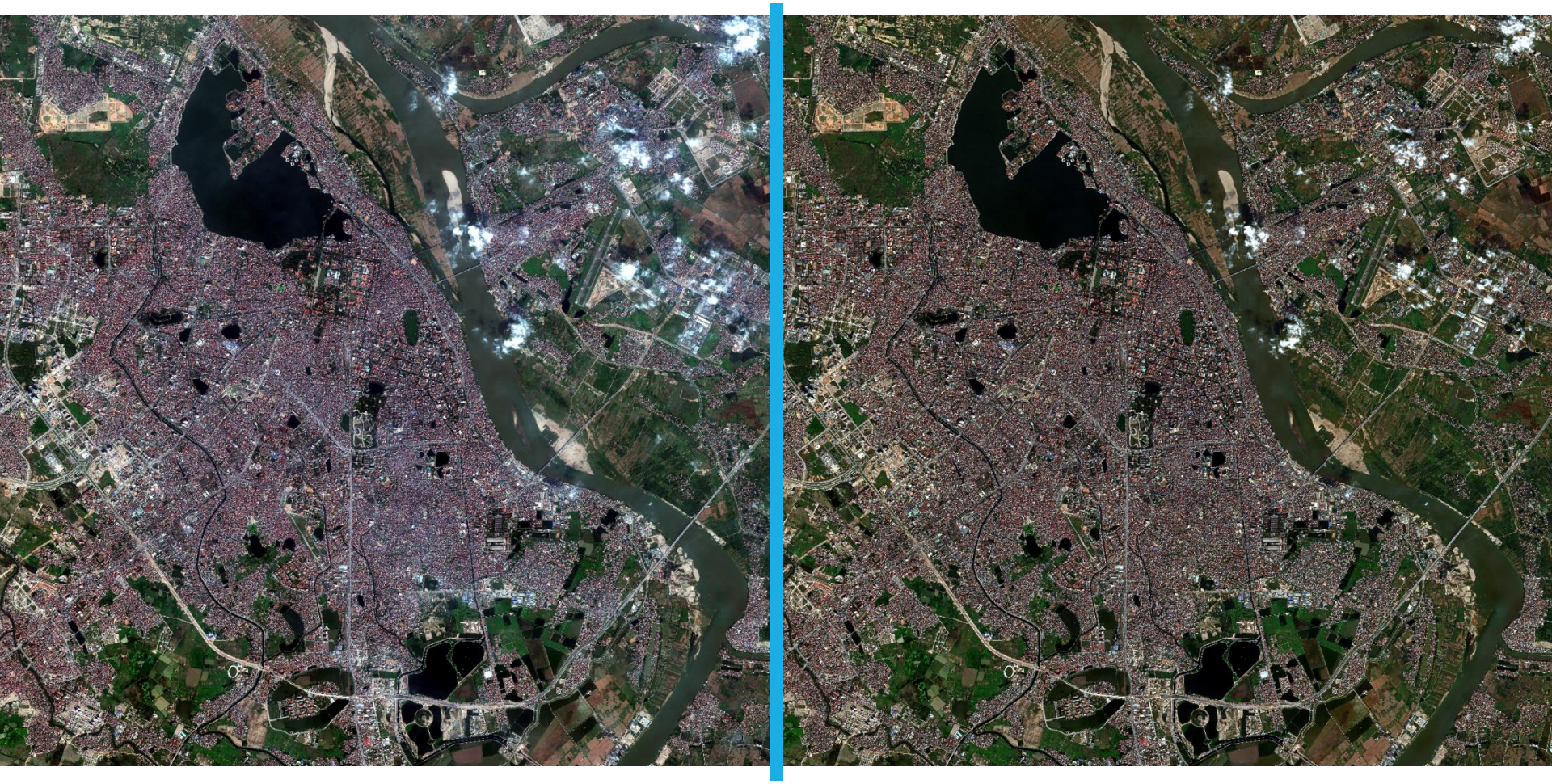
Hanoi (Vietnam) – time series (4/10)



original image

surface reflectance

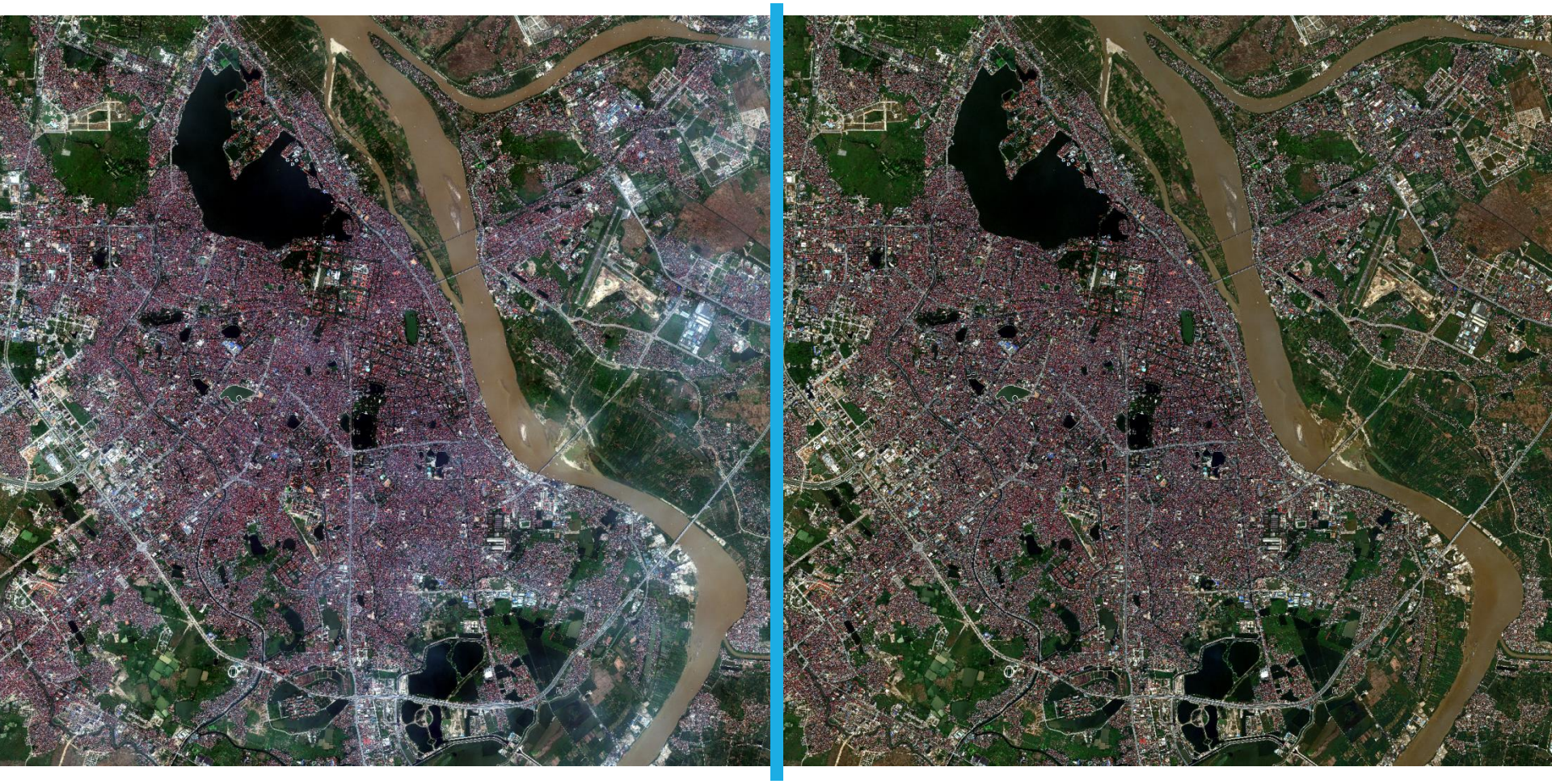
Hanoi (Vietnam) – time series (5/10)



original image

surface reflectance

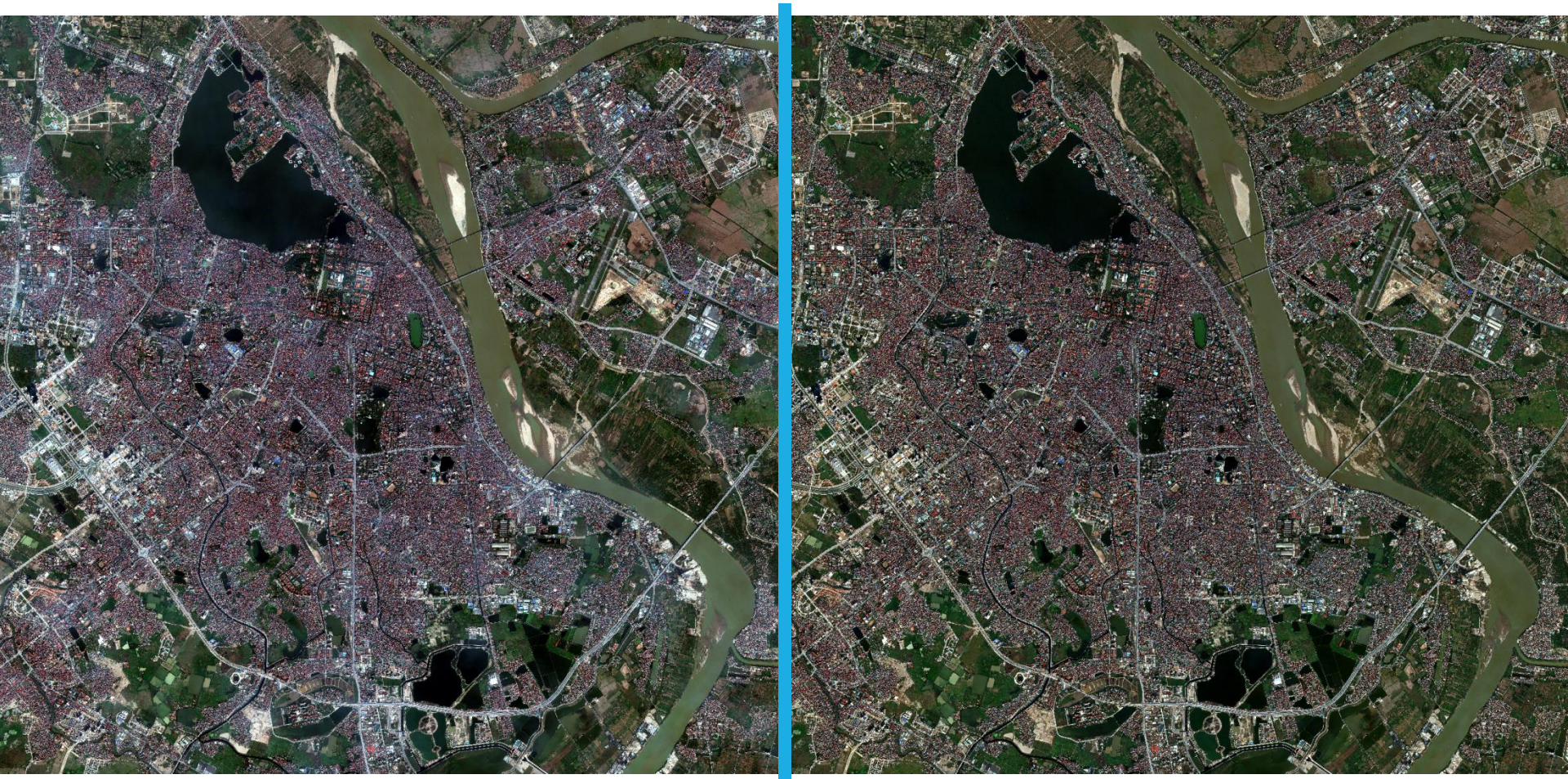
Hanoi (Vietnam) – time series (6/10)



original image

surface reflectance

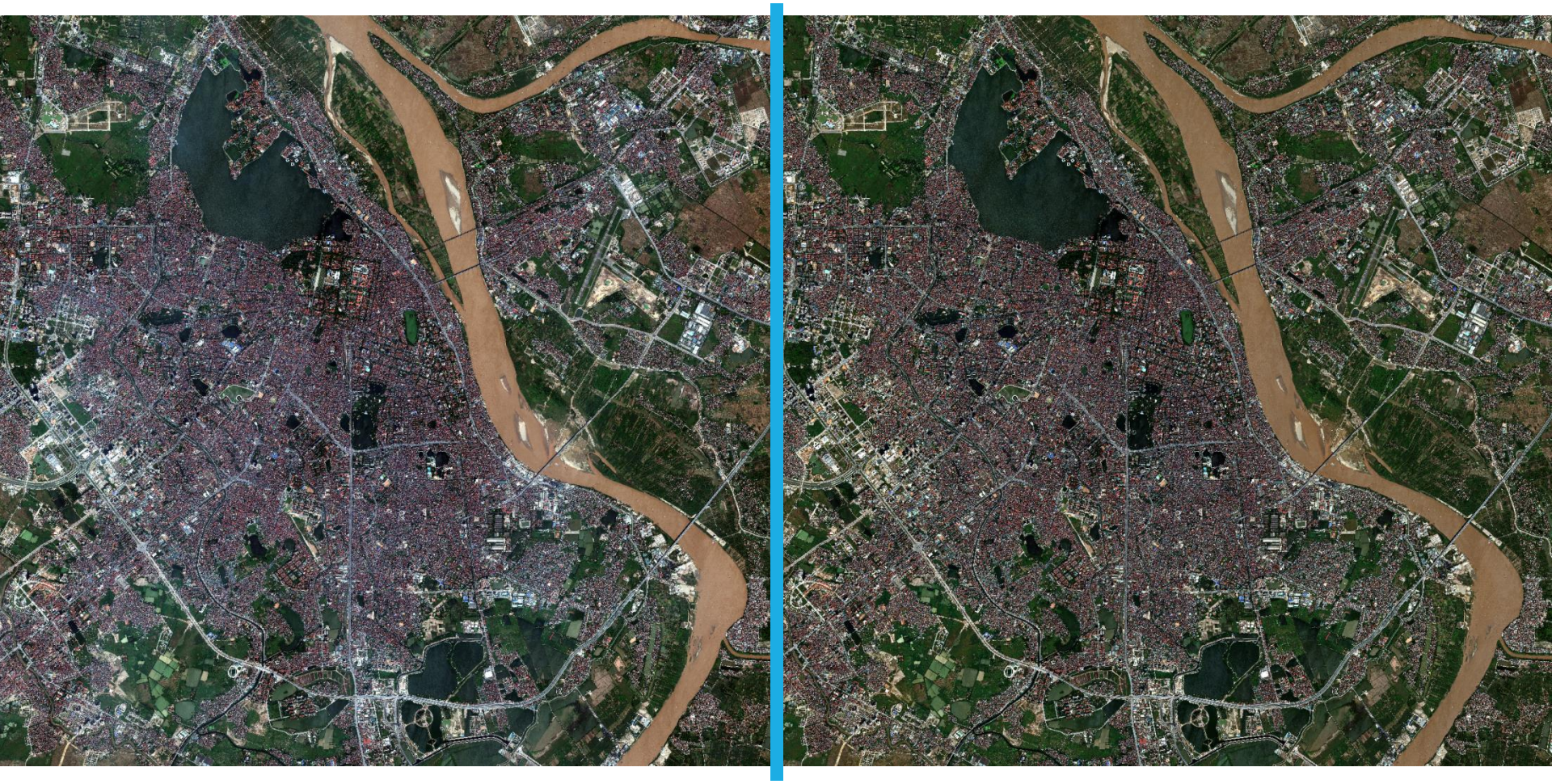
Hanoi (Vietnam) – time series (7/10)



original image

surface reflectance

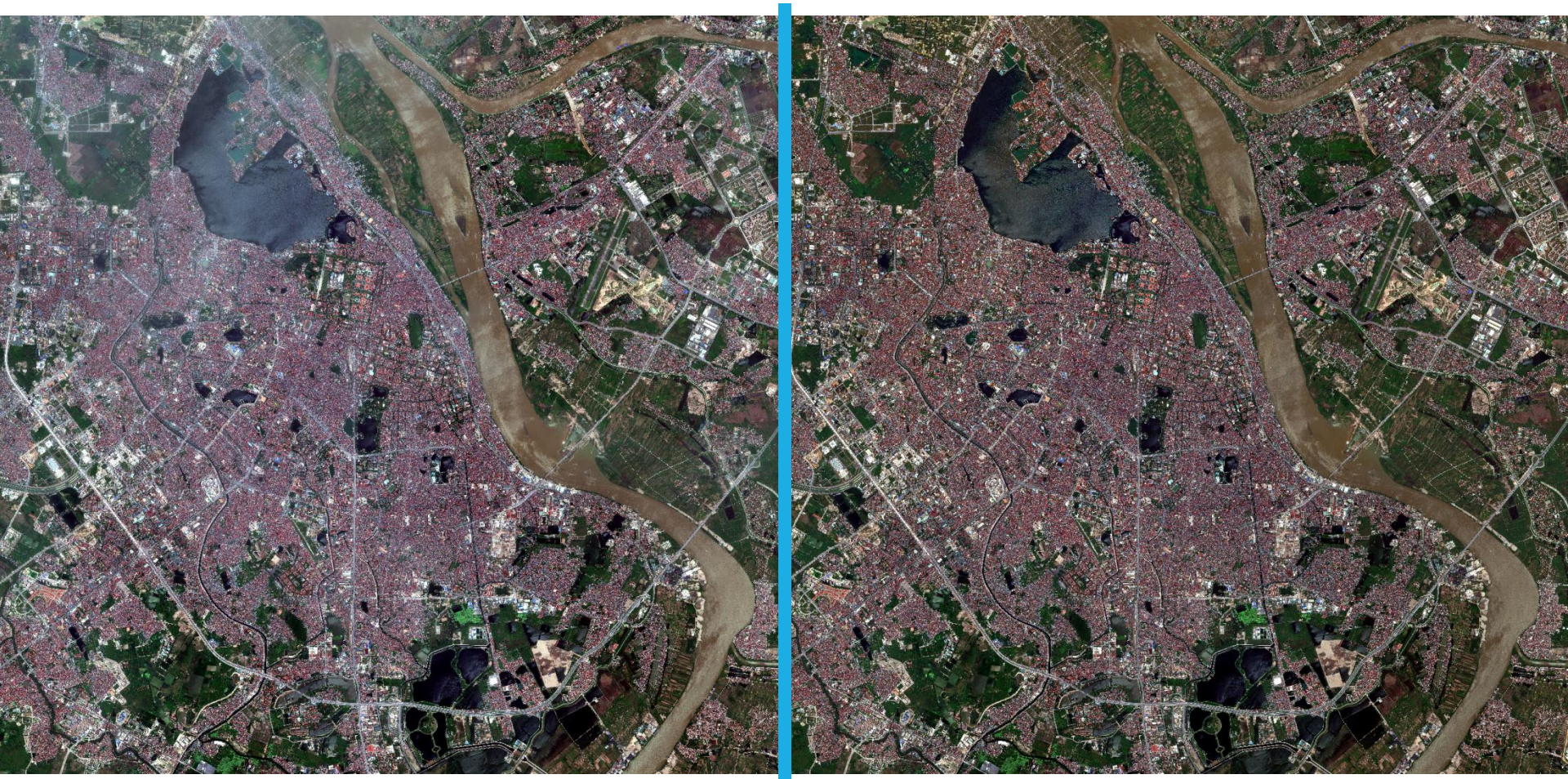
Hanoi (Vietnam) – time series (8/10)



original image

surface reflectance

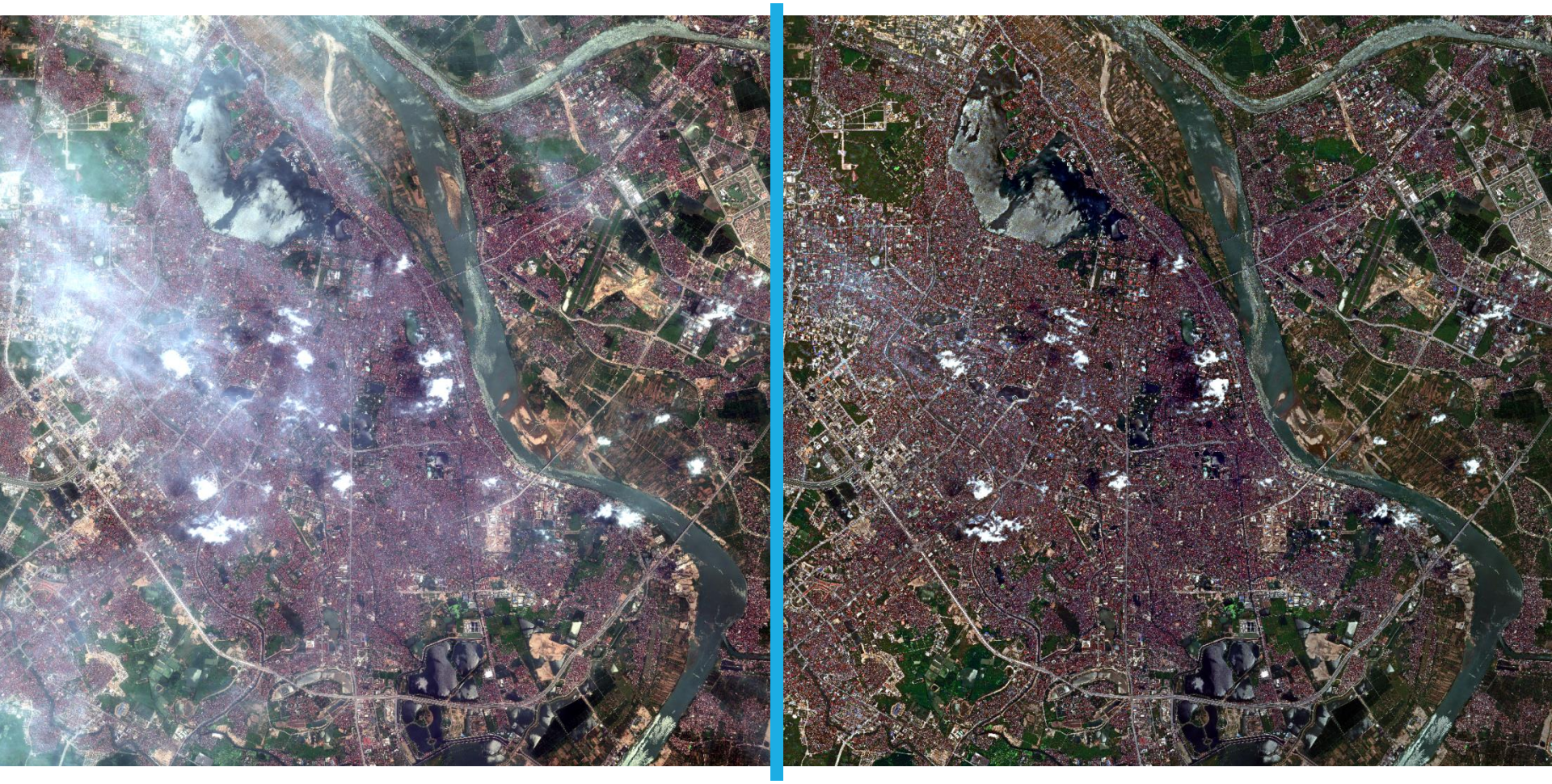
Hanoi (Vietnam) – time series (9/10)



original image

surface reflectance

Hanoi (Vietnam) – time series (10/10)



original image

surface reflectance

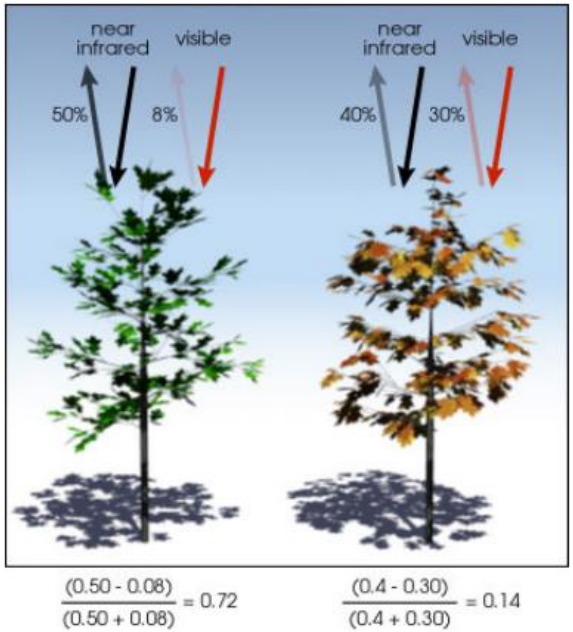
Ag Applications

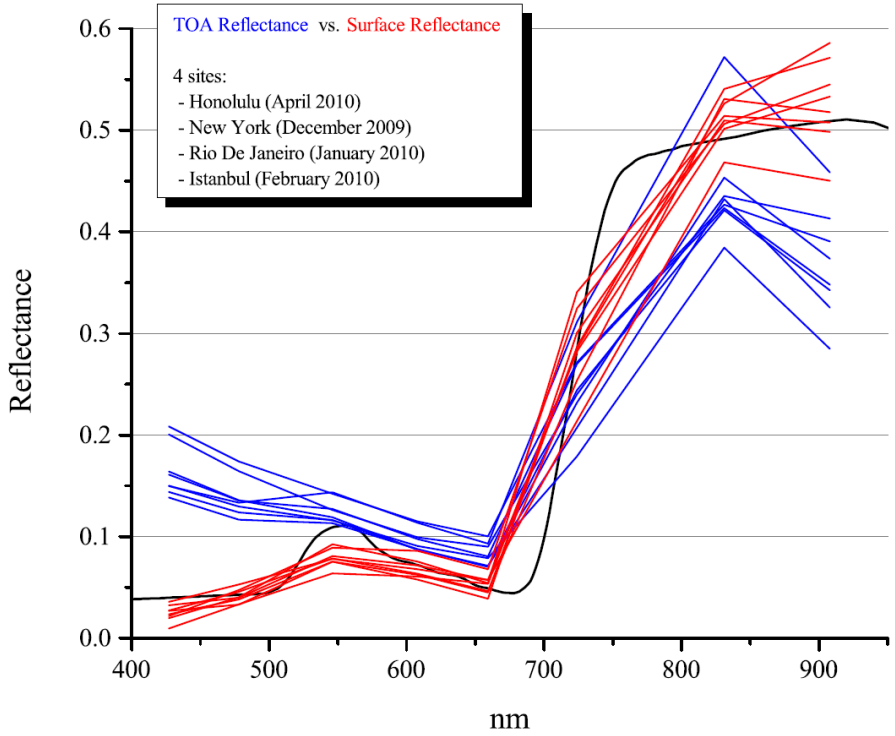
Biophysical Variables

Many biophysical variables such as leaf area index (LAI), canopy roughness, fractional photo-synthetically active radiation (FPAR), and phenology (plant life cycle) are critical inputs to many ecological models.

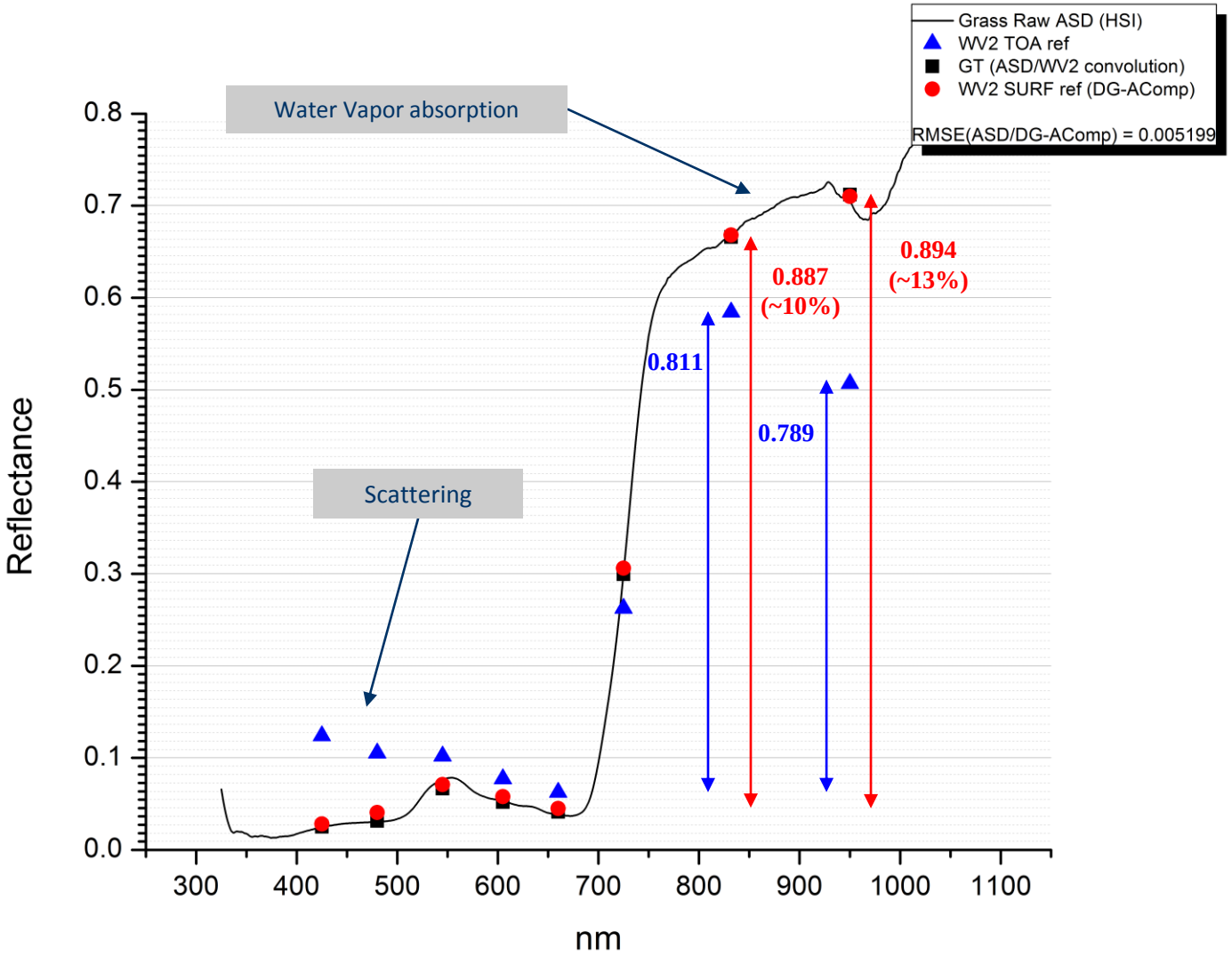
Normalized Difference Vegetation Index (NDVI) is one of the simplest indicator of chlorophyll content:

$$\mathrm{NDVI} = \frac{R_{\mathrm{NIR}} - R_{\mathrm{VIS}}}{R_{\mathrm{NIR}} + R_{\mathrm{VIS}}}$$





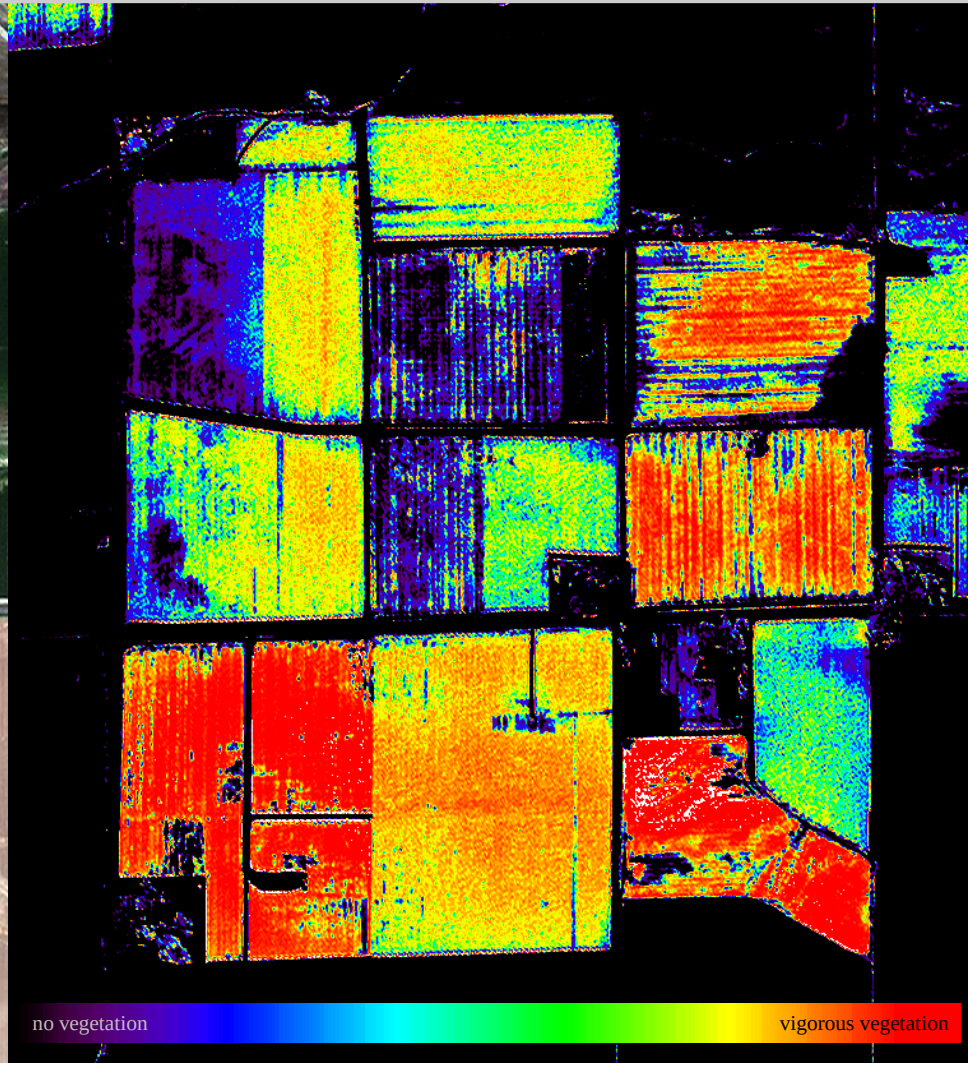
NDVI from TOA and surface reflectance



NDVI from raw data

Longmont (August 10, 2011 – WV2)

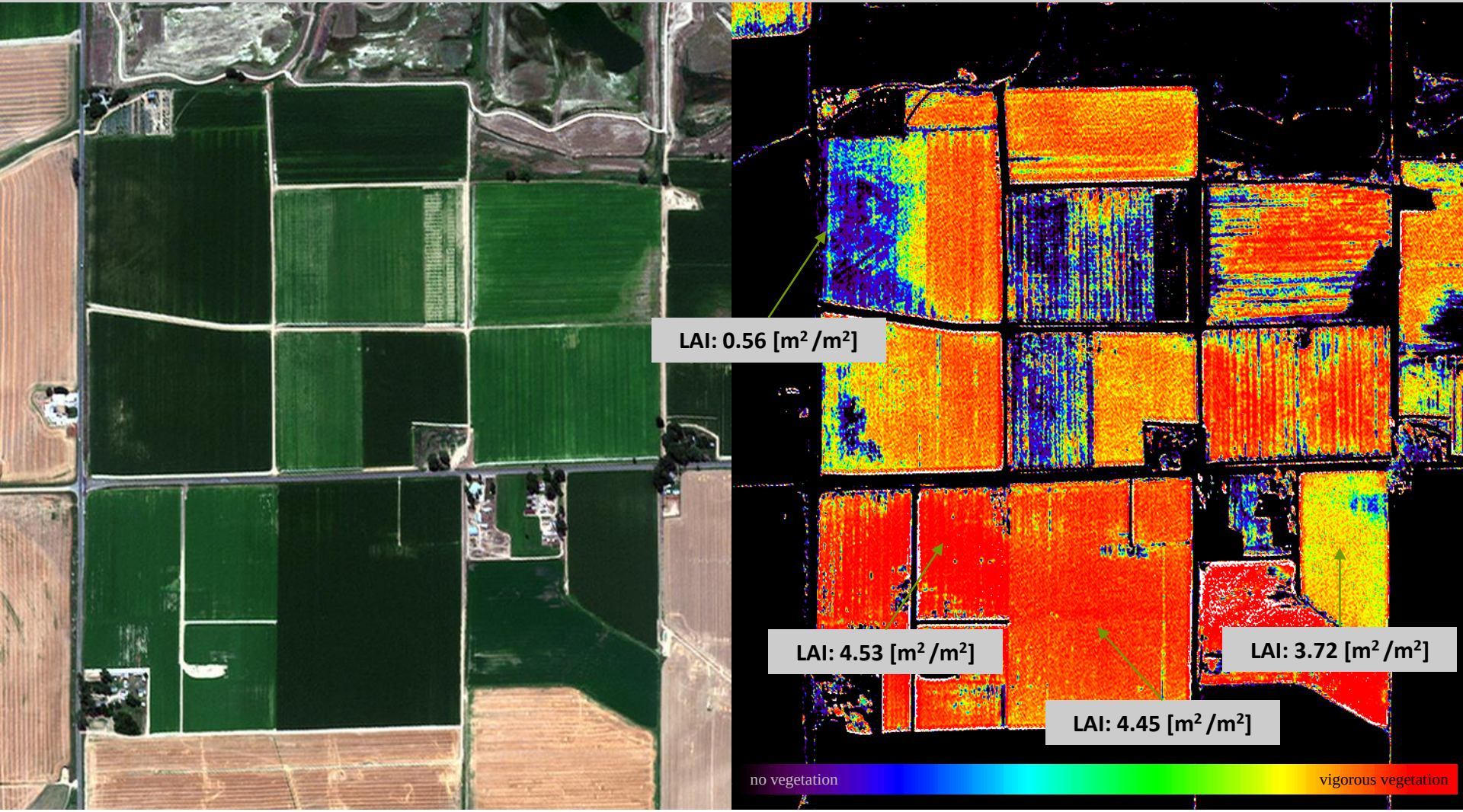
NDVI from raw data



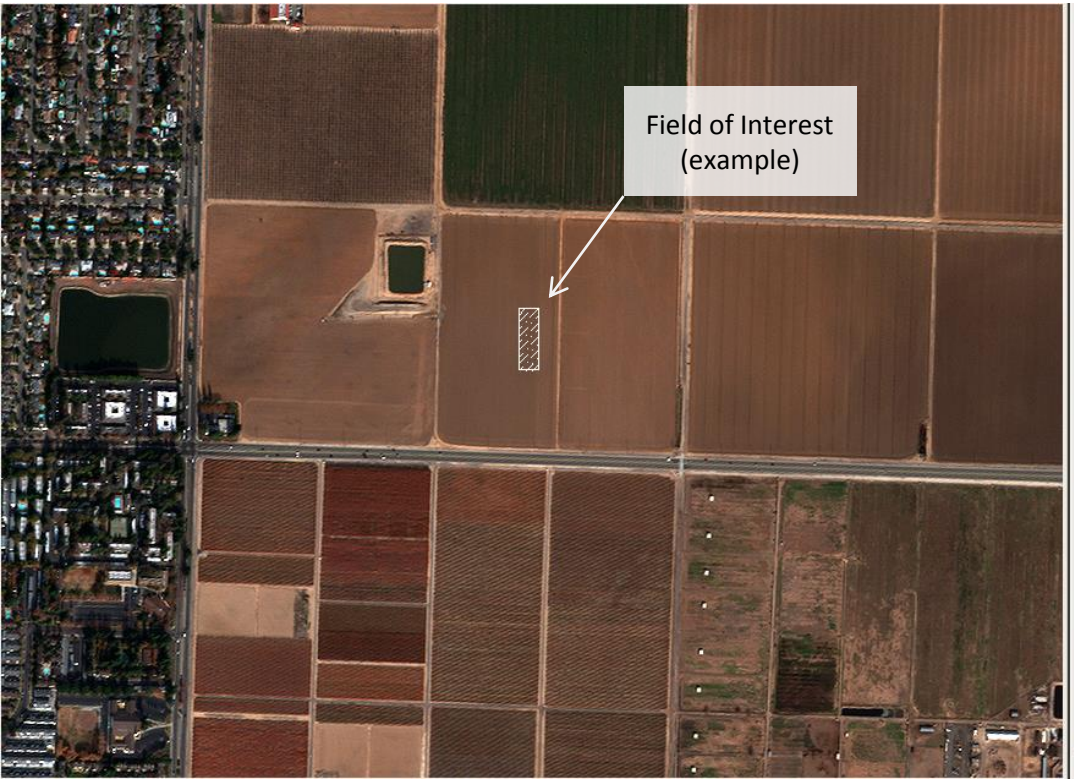
NDVI from Surface Reflectance

Longmont (August 10, 2011 – WV2)

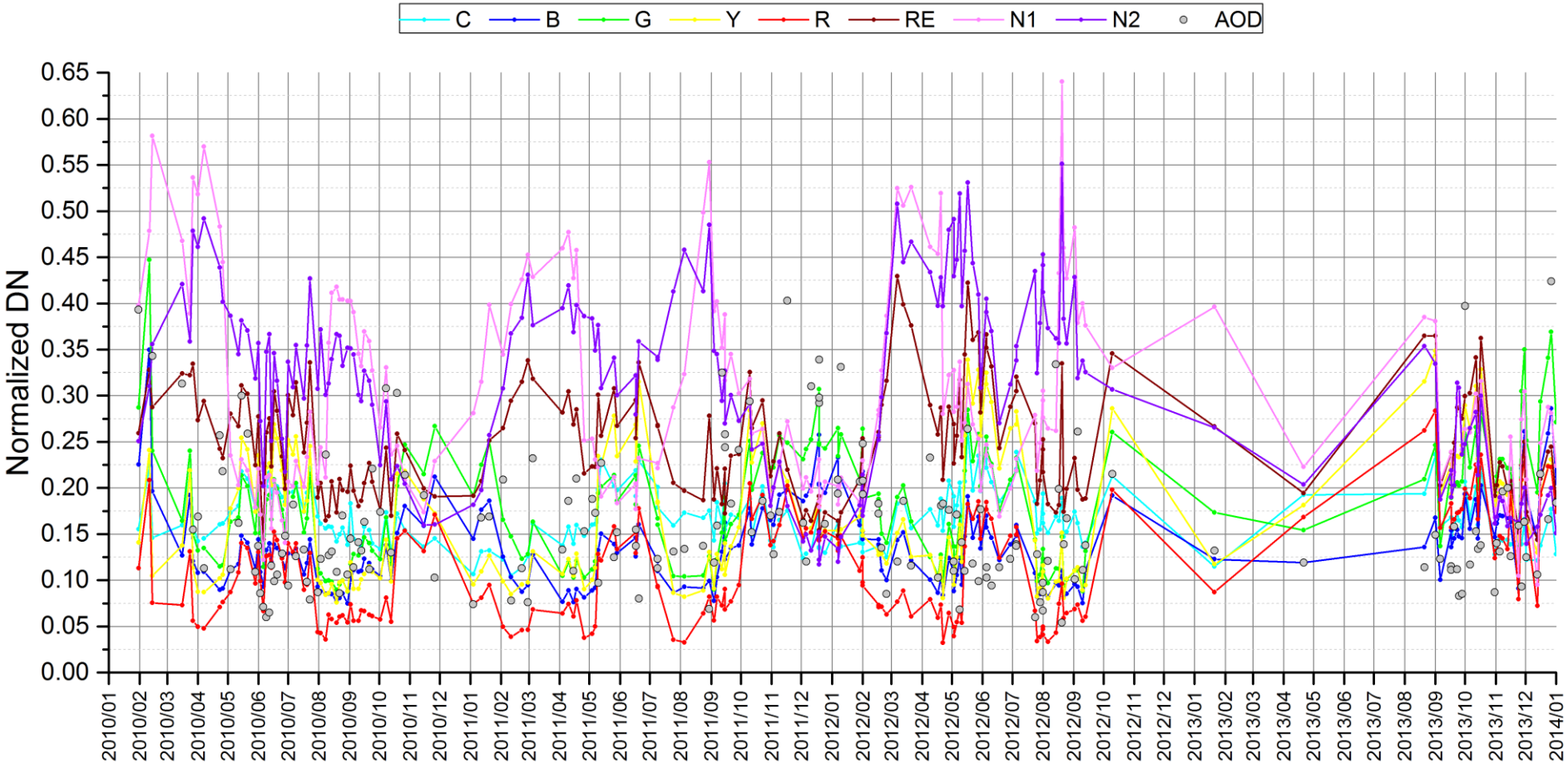
NDVI from surface reflectance



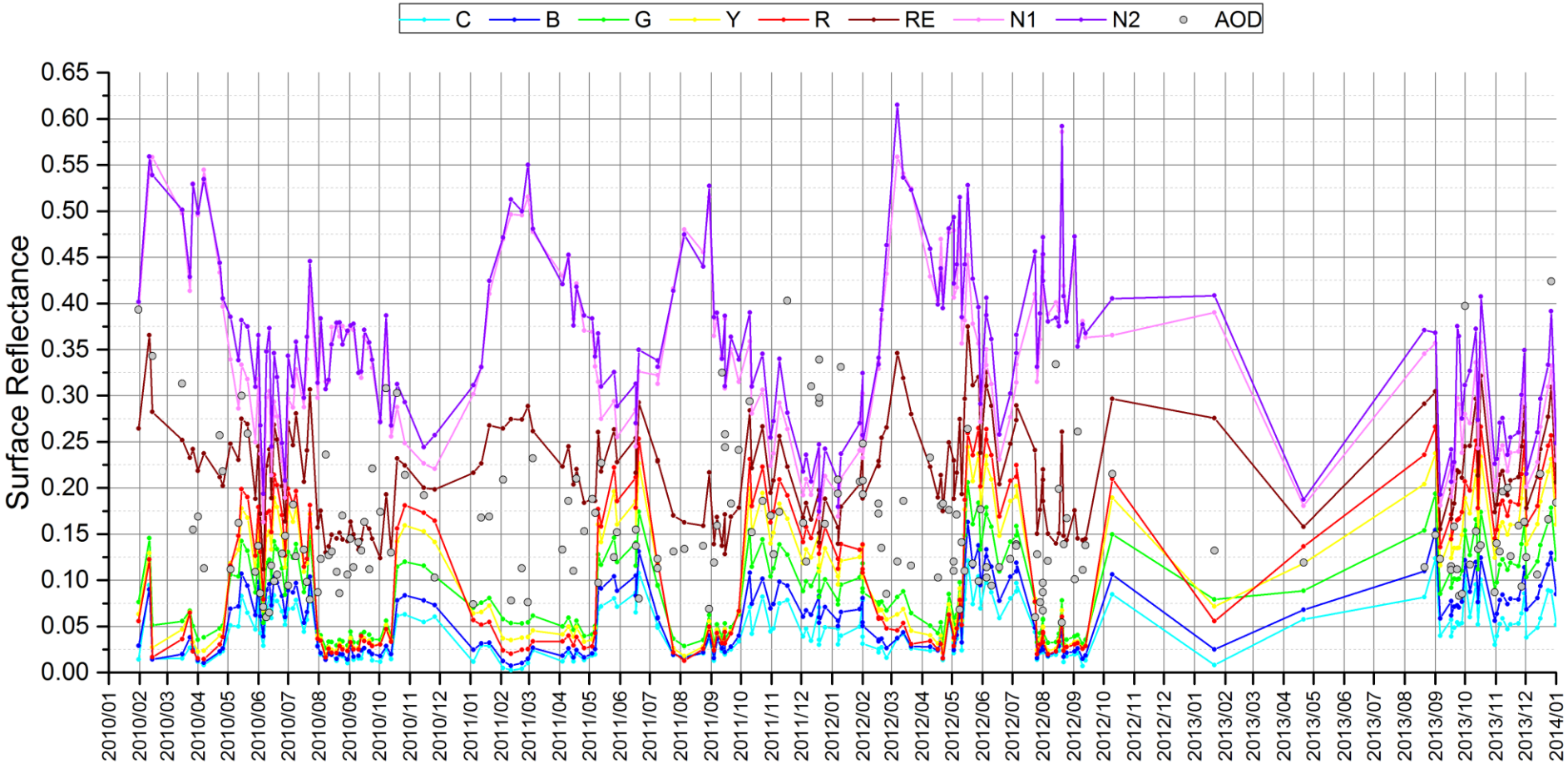
Fresno, CA – 2010/2014 time-series



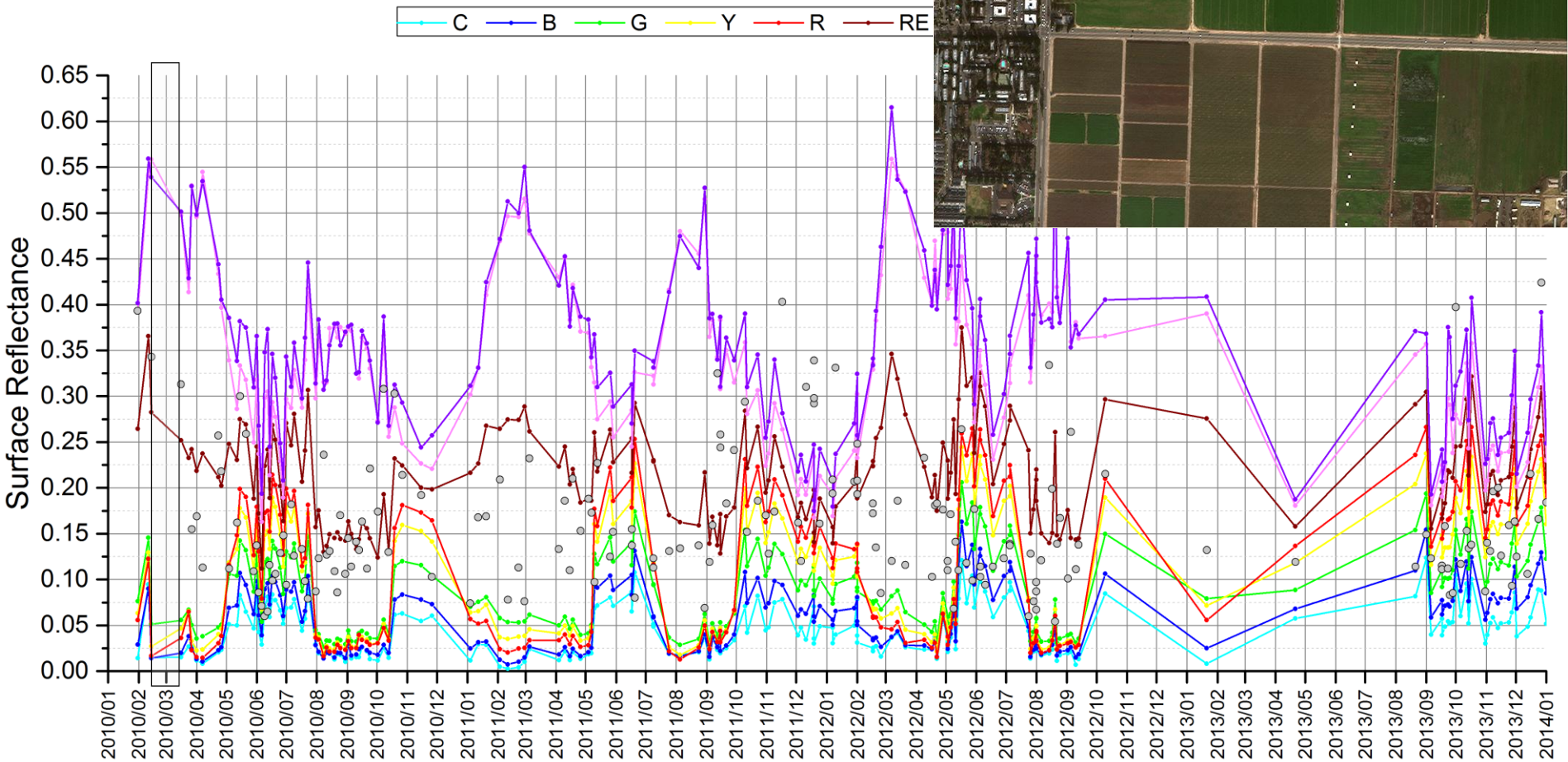
Fresno, CA – 2010/2014 time-series



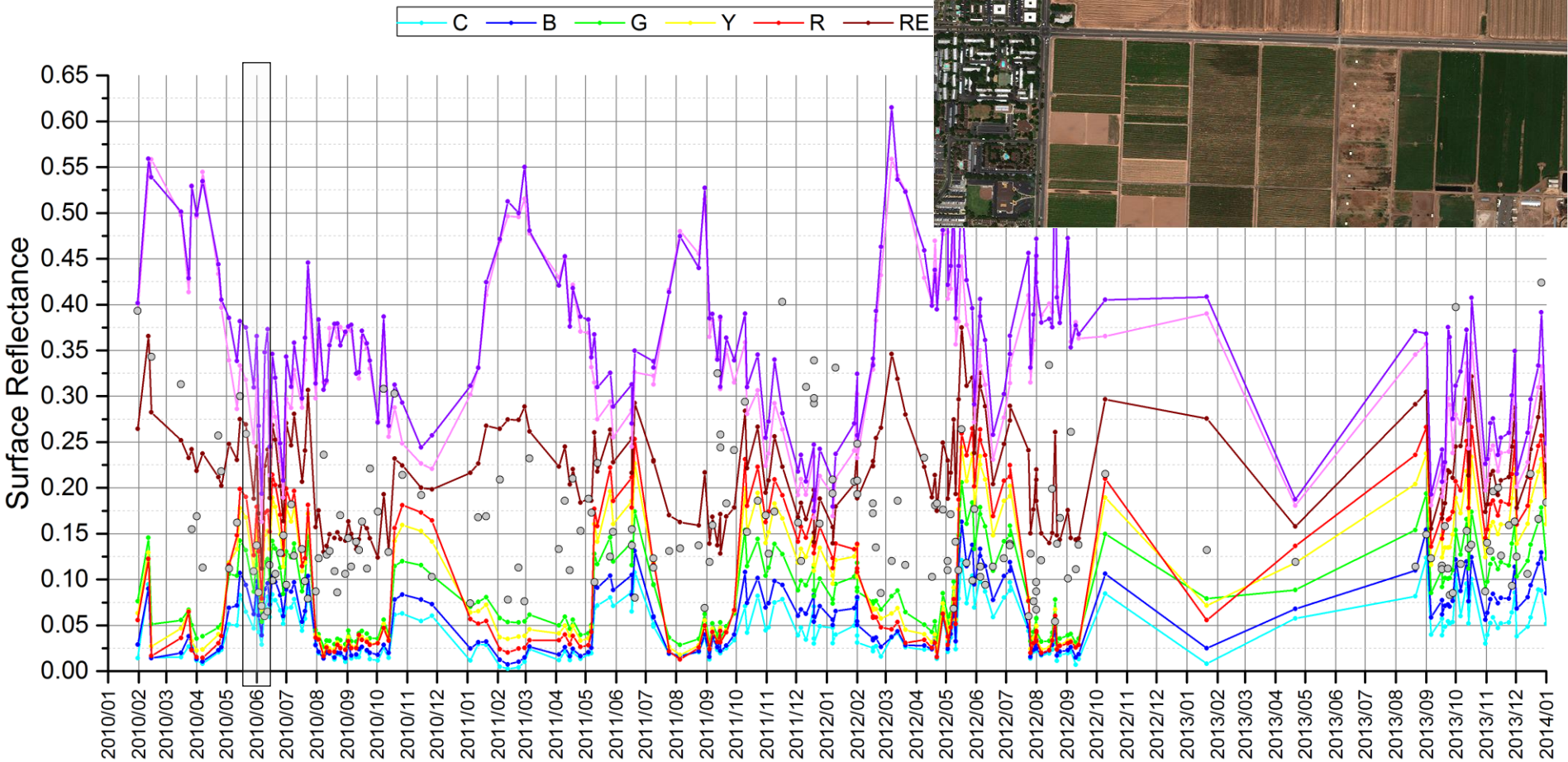
Fresno, CA – 2010/2014 time-series



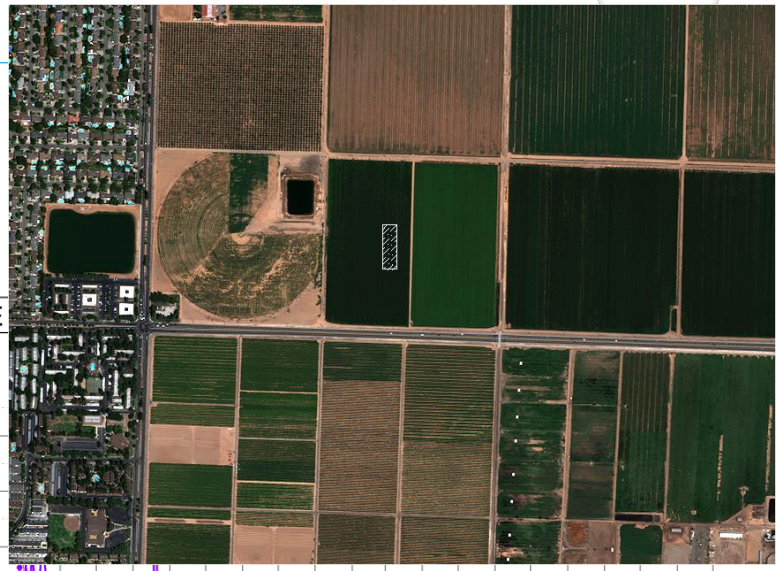
March 2010

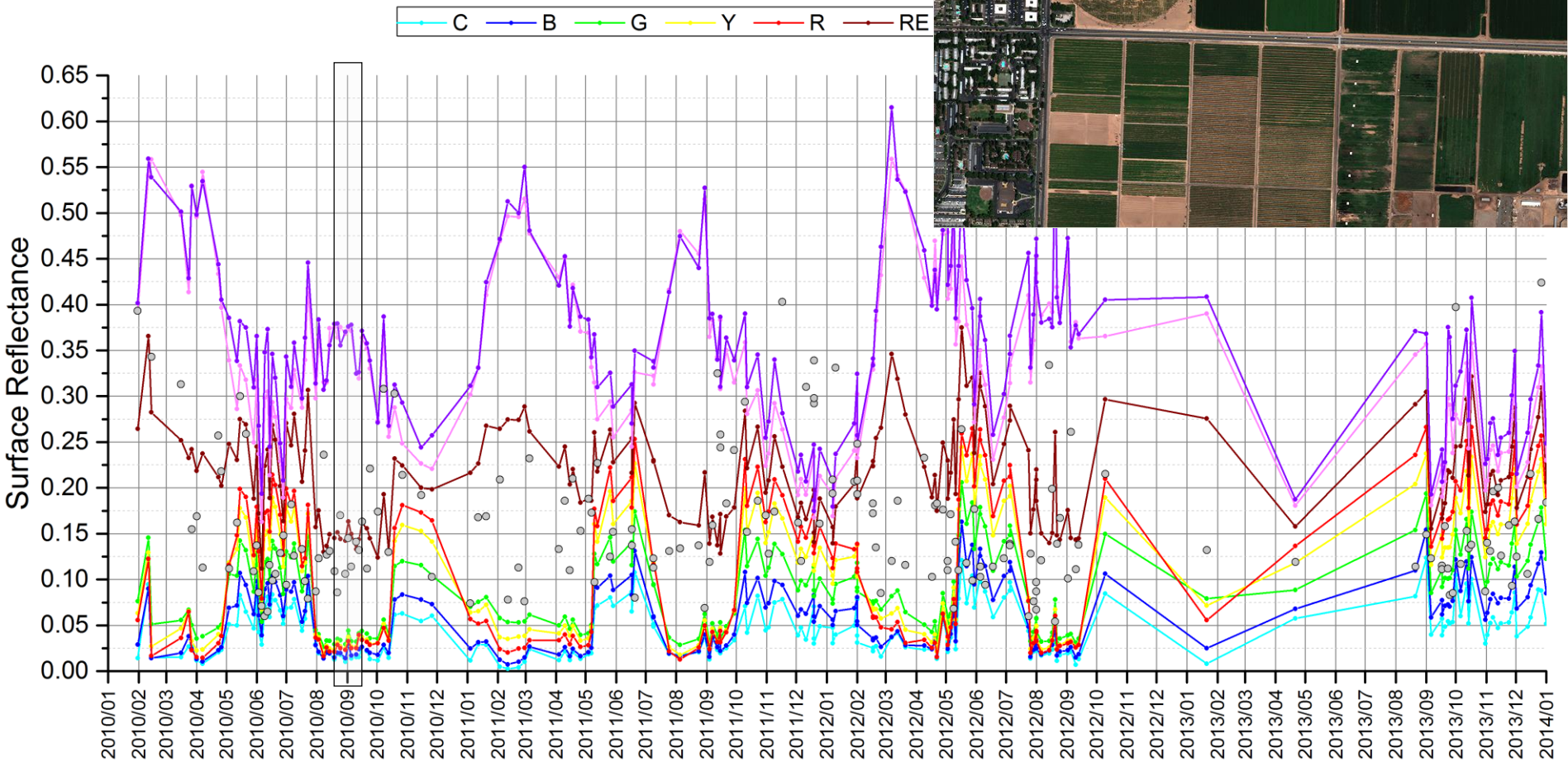


June 2010

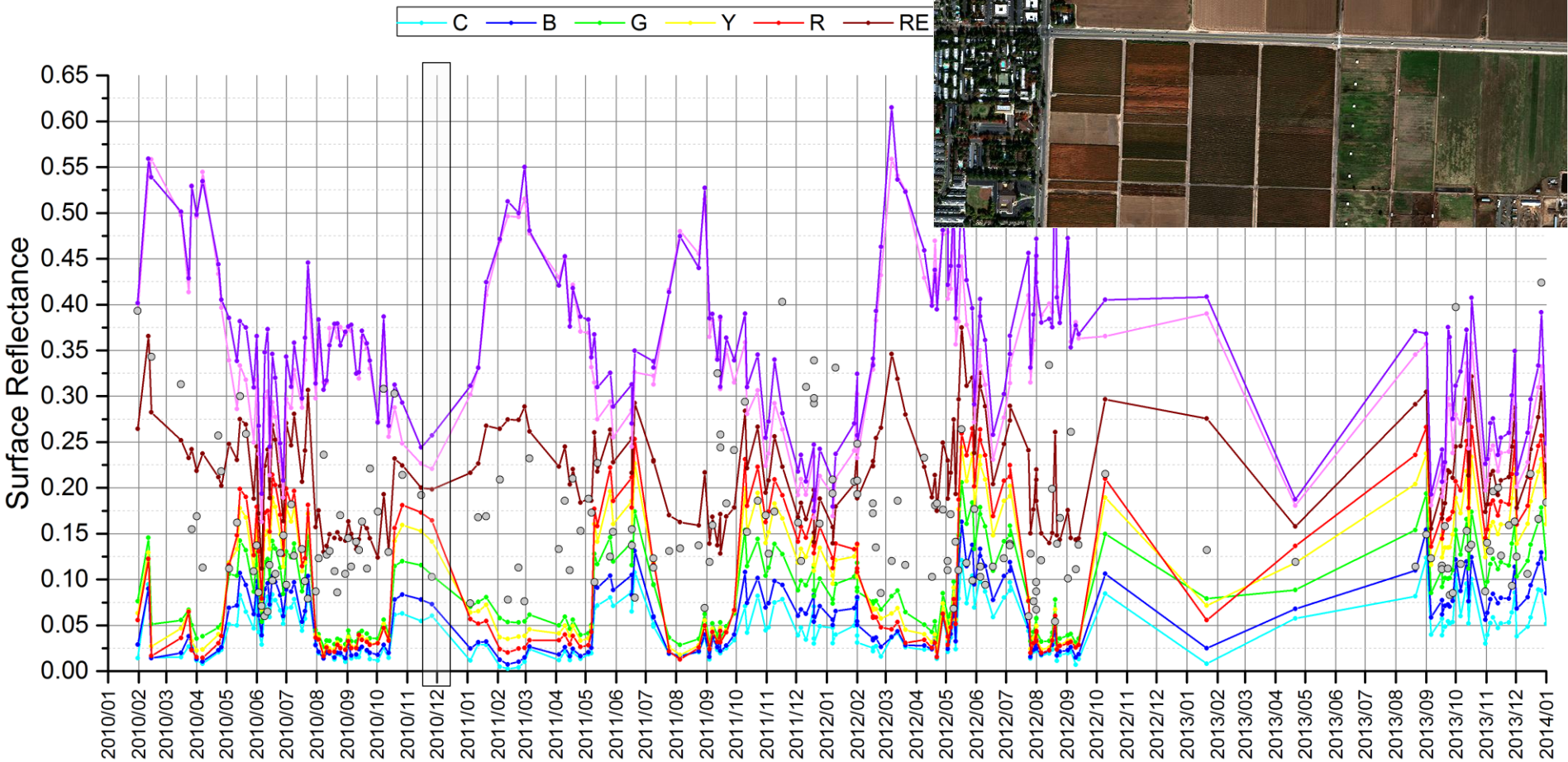


September 2010





December 2010



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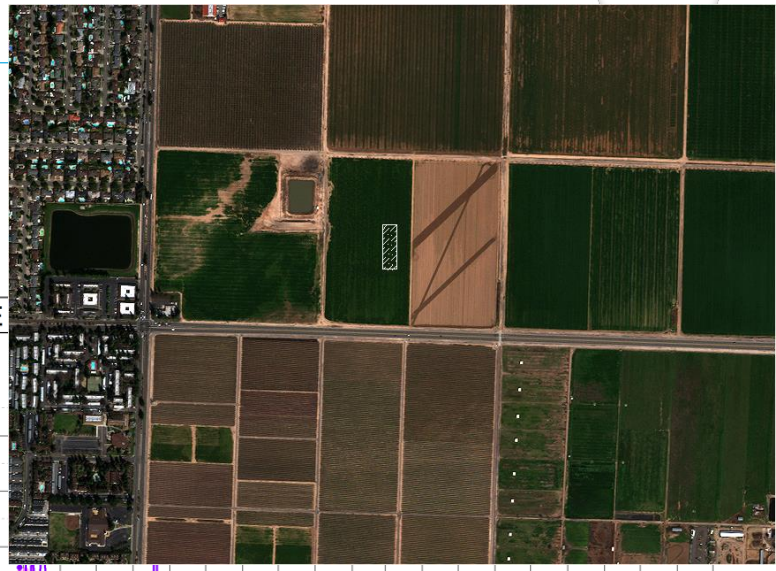
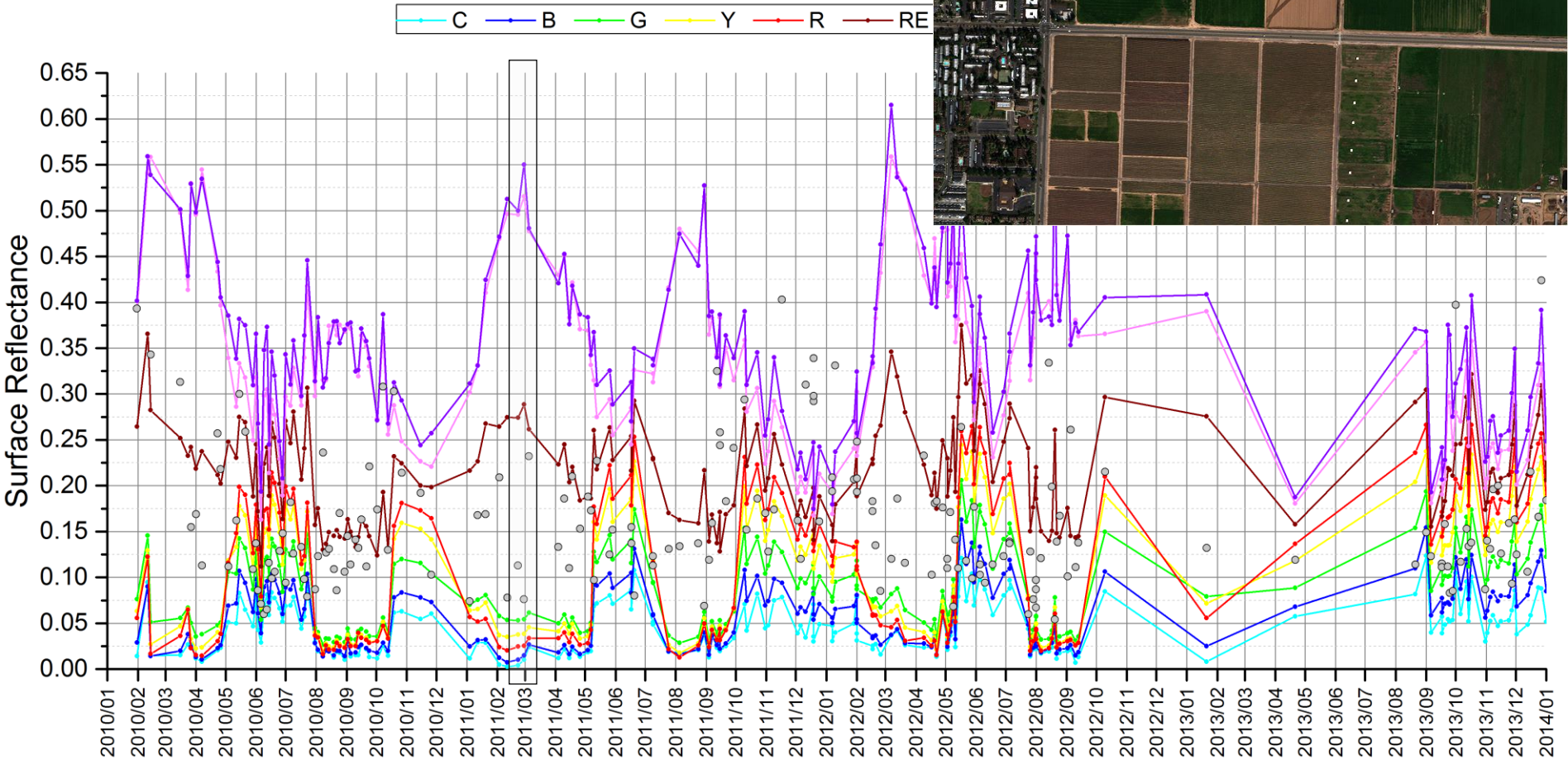
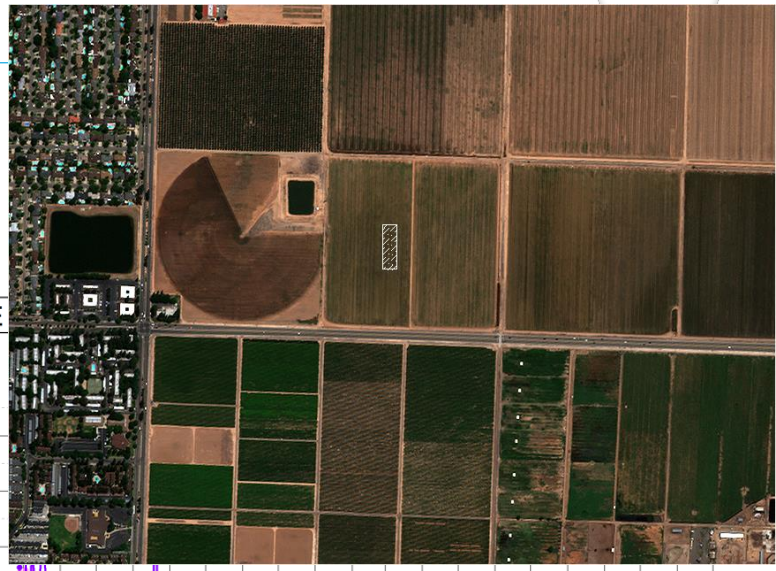
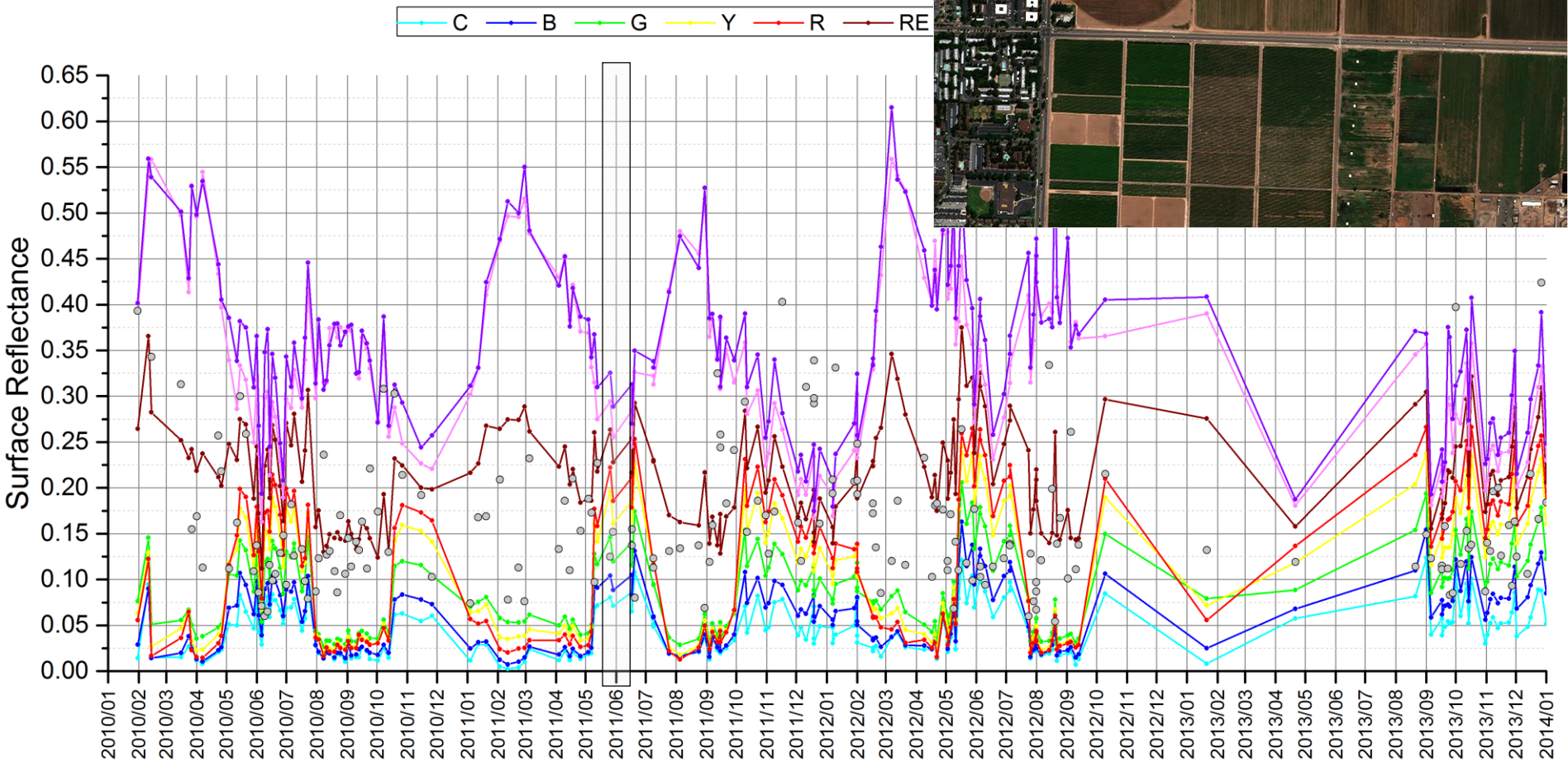


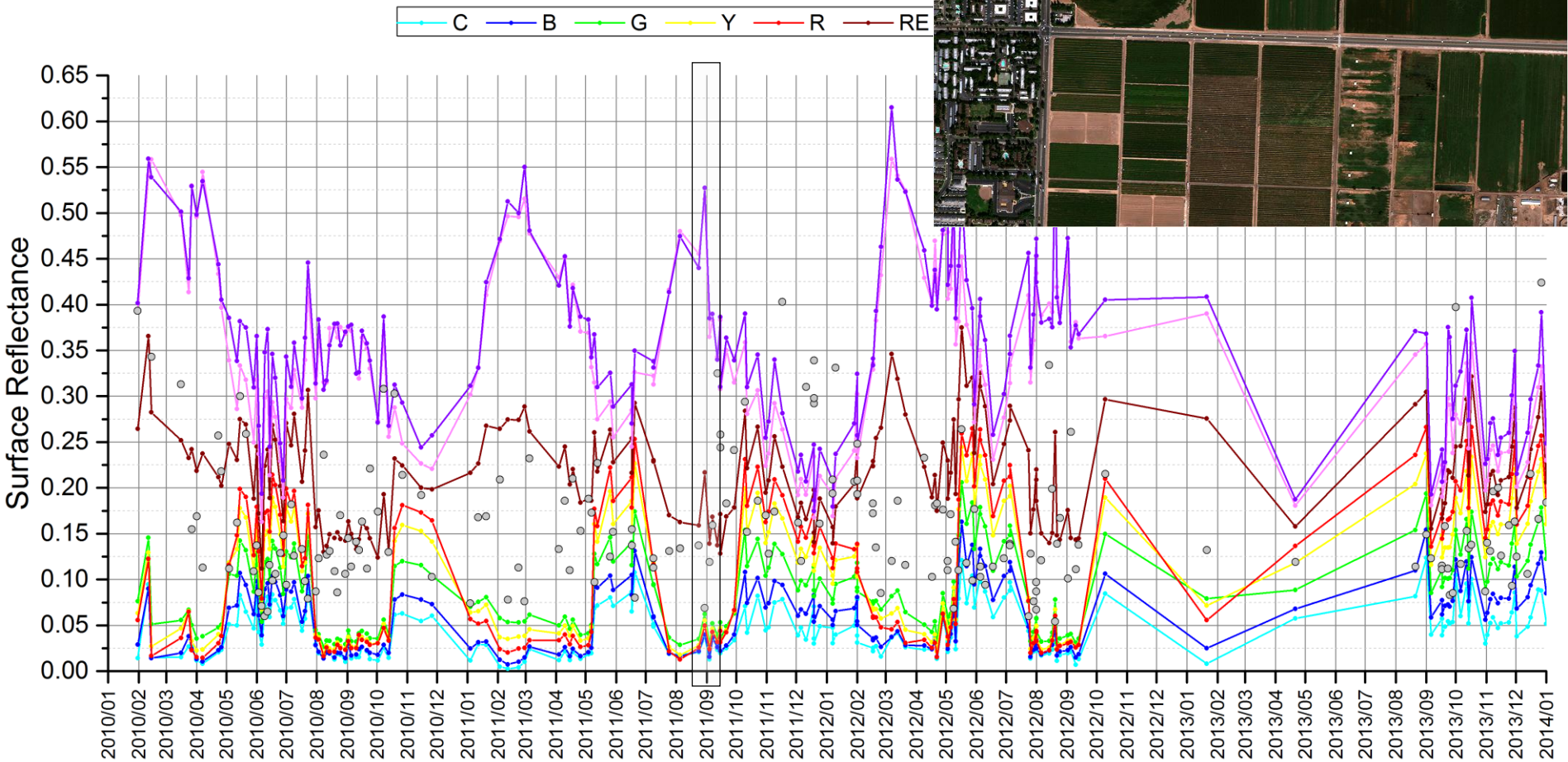


June 2011

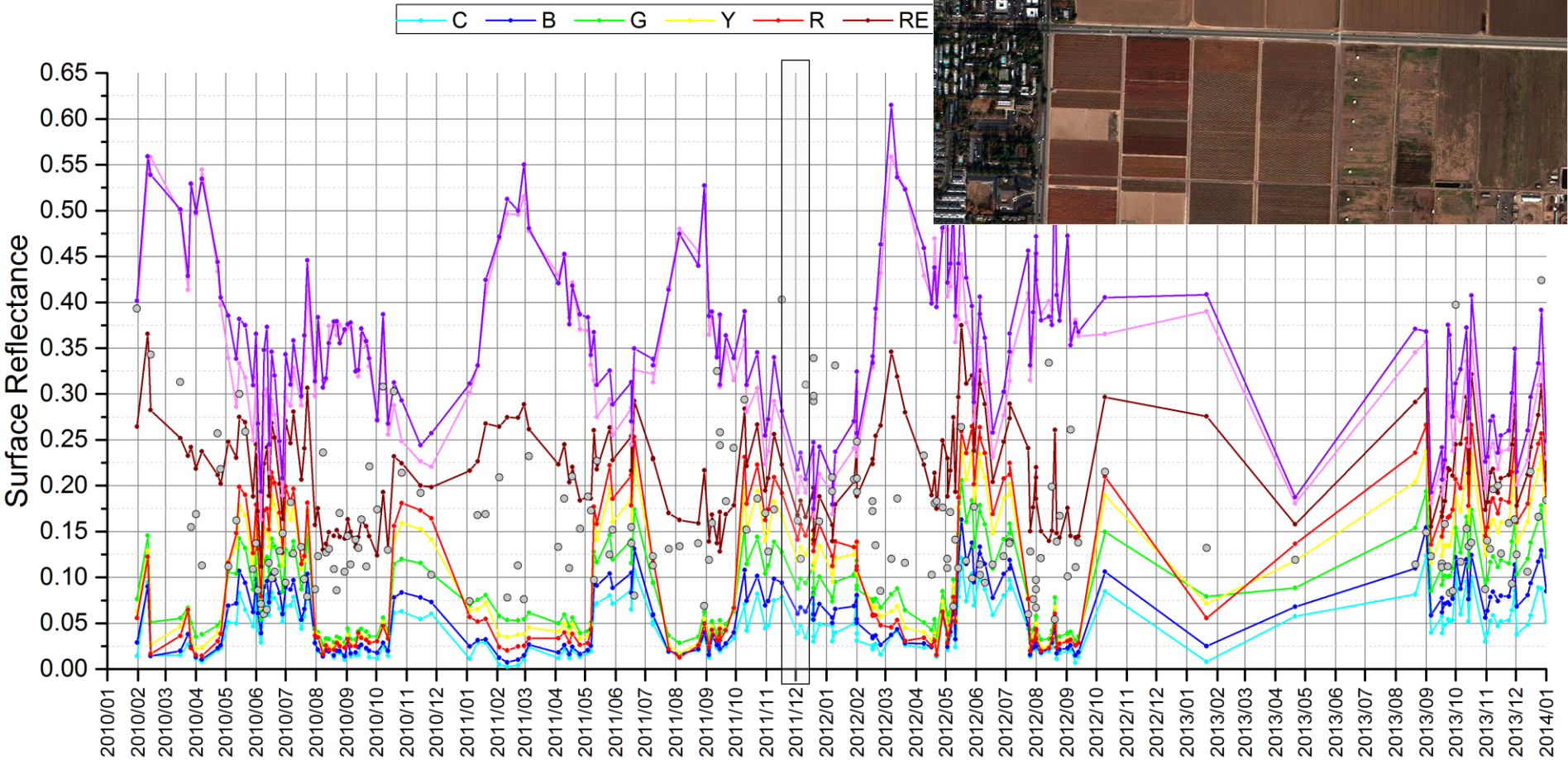




September 2011



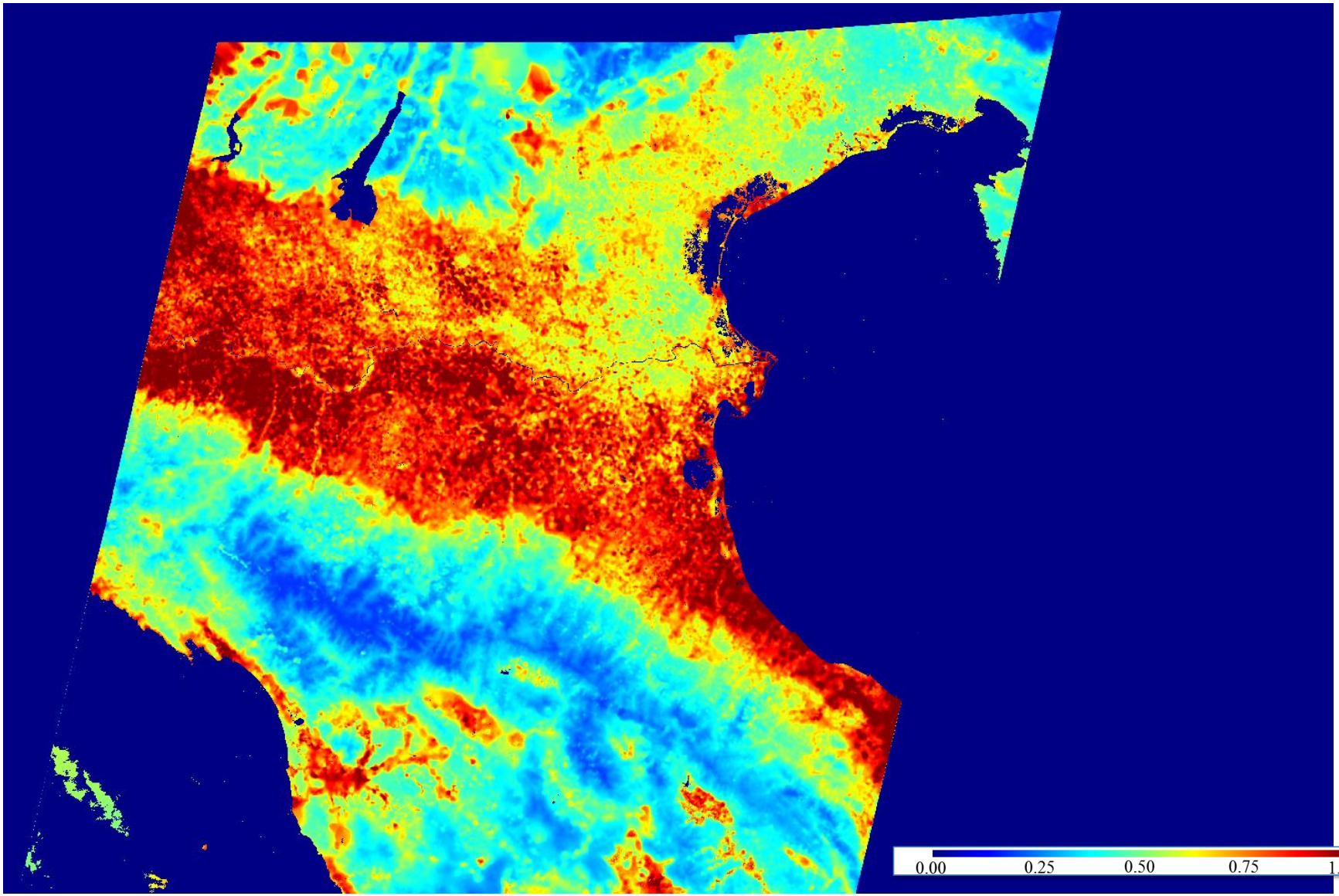
December 2011



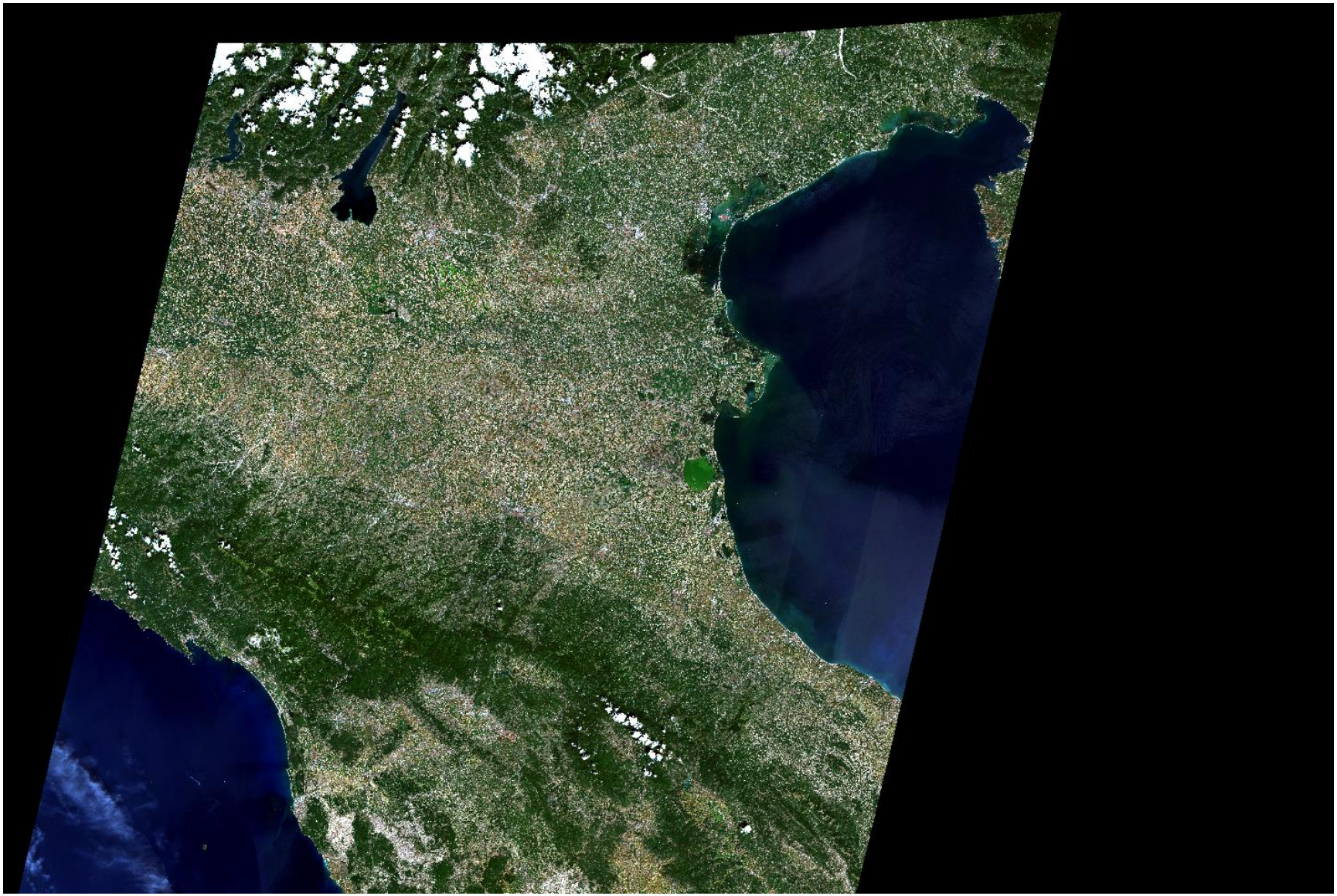
Open Data and Commercial Satellite Platforms: Sentinel-2, Landsat-8, and RapidEye

Sentinel-2: North/East Italy

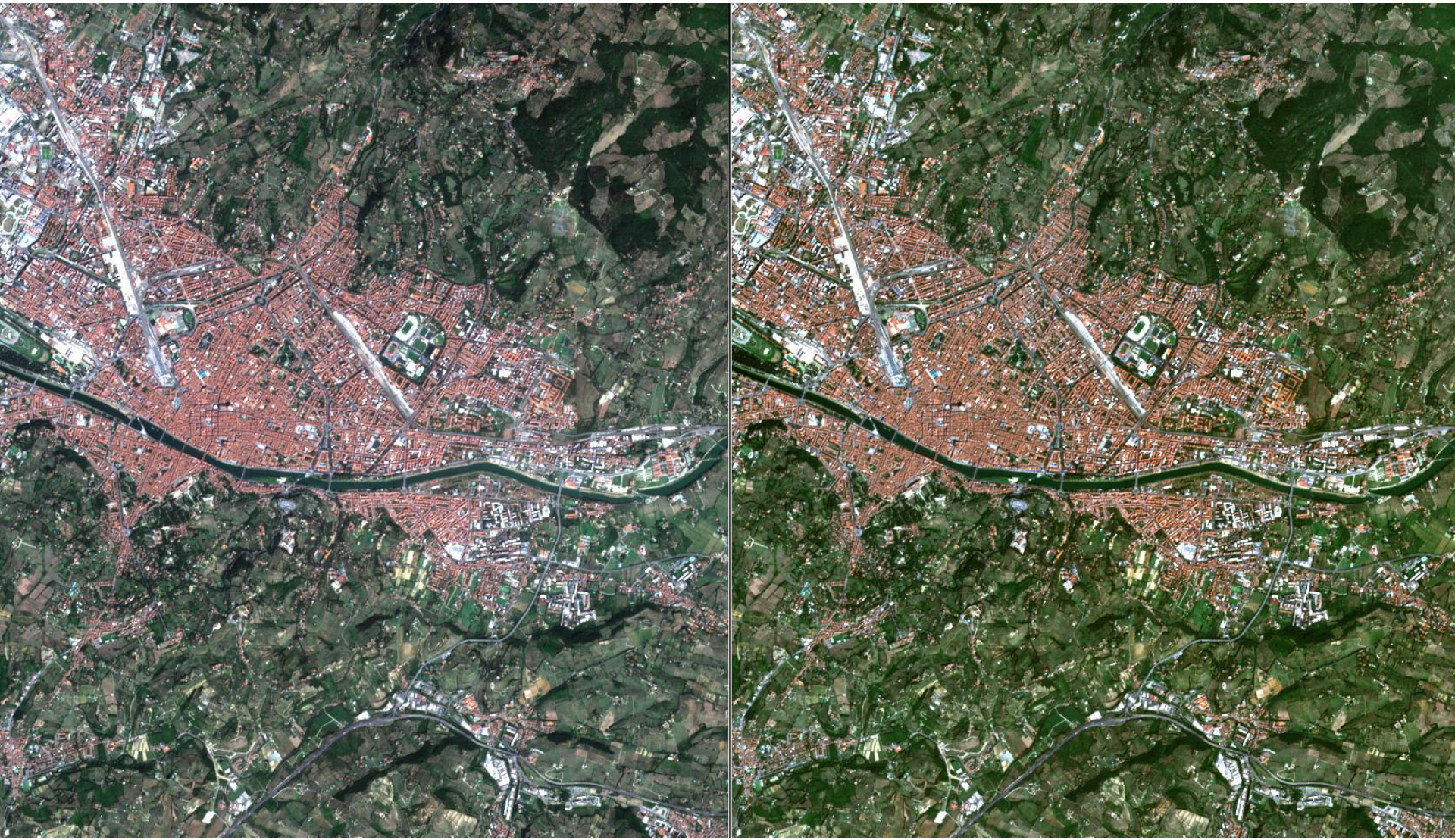
AComp Aerosol Optical Depth (from Sentinel-2)



AComp Sentinel-2: North/East Italy

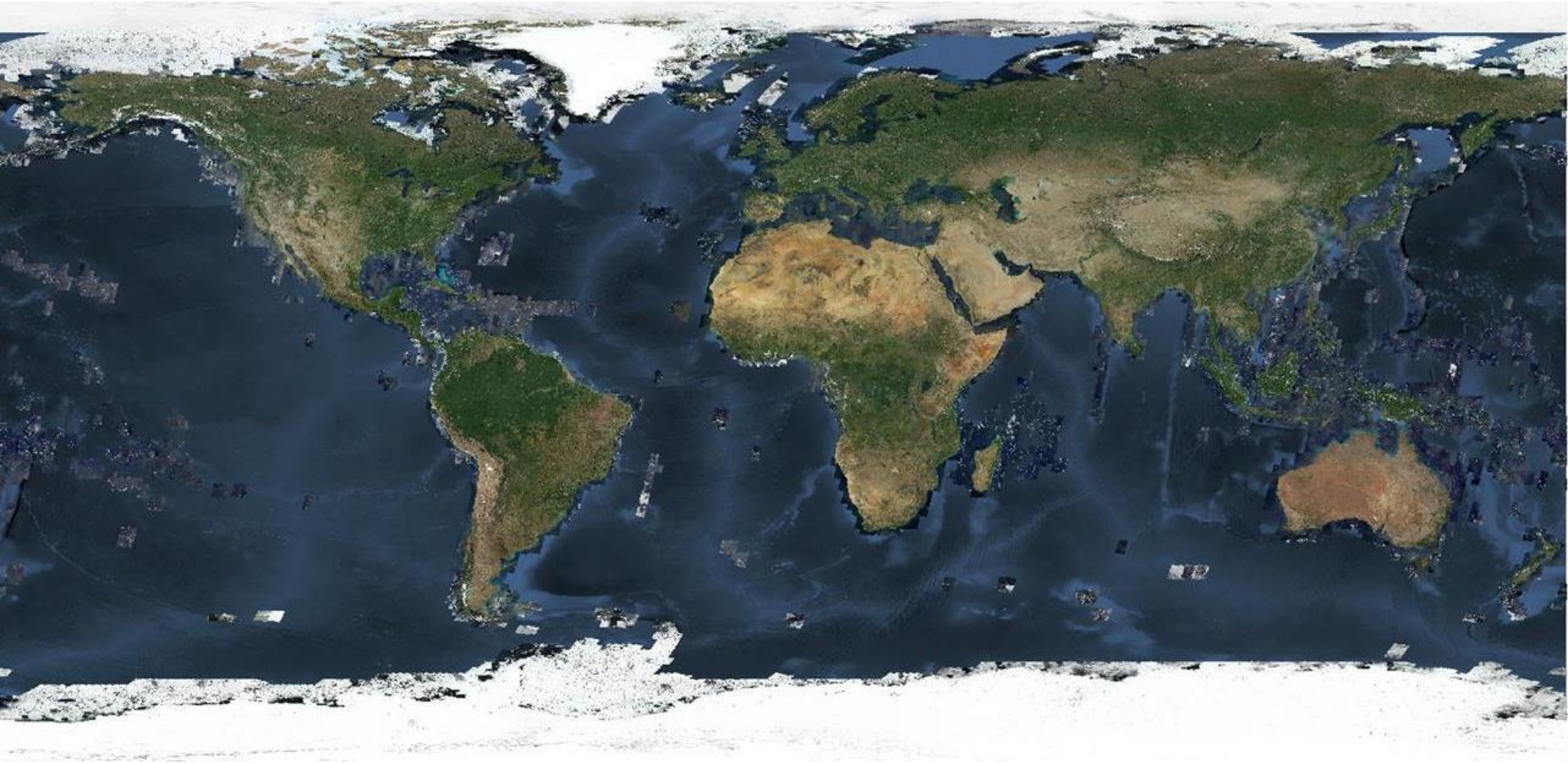


AComp Sentinel-2: North/East Italy (Florence)



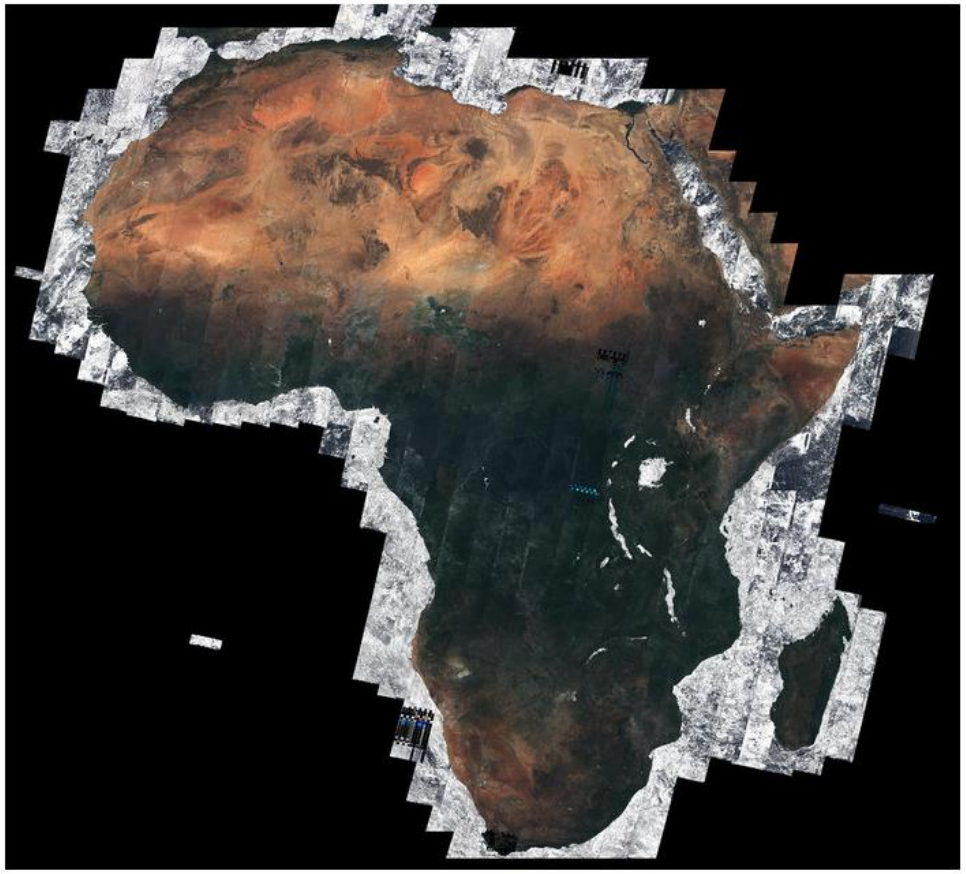
original AComp

AComp/Landsat-8 mosaic of the Globe



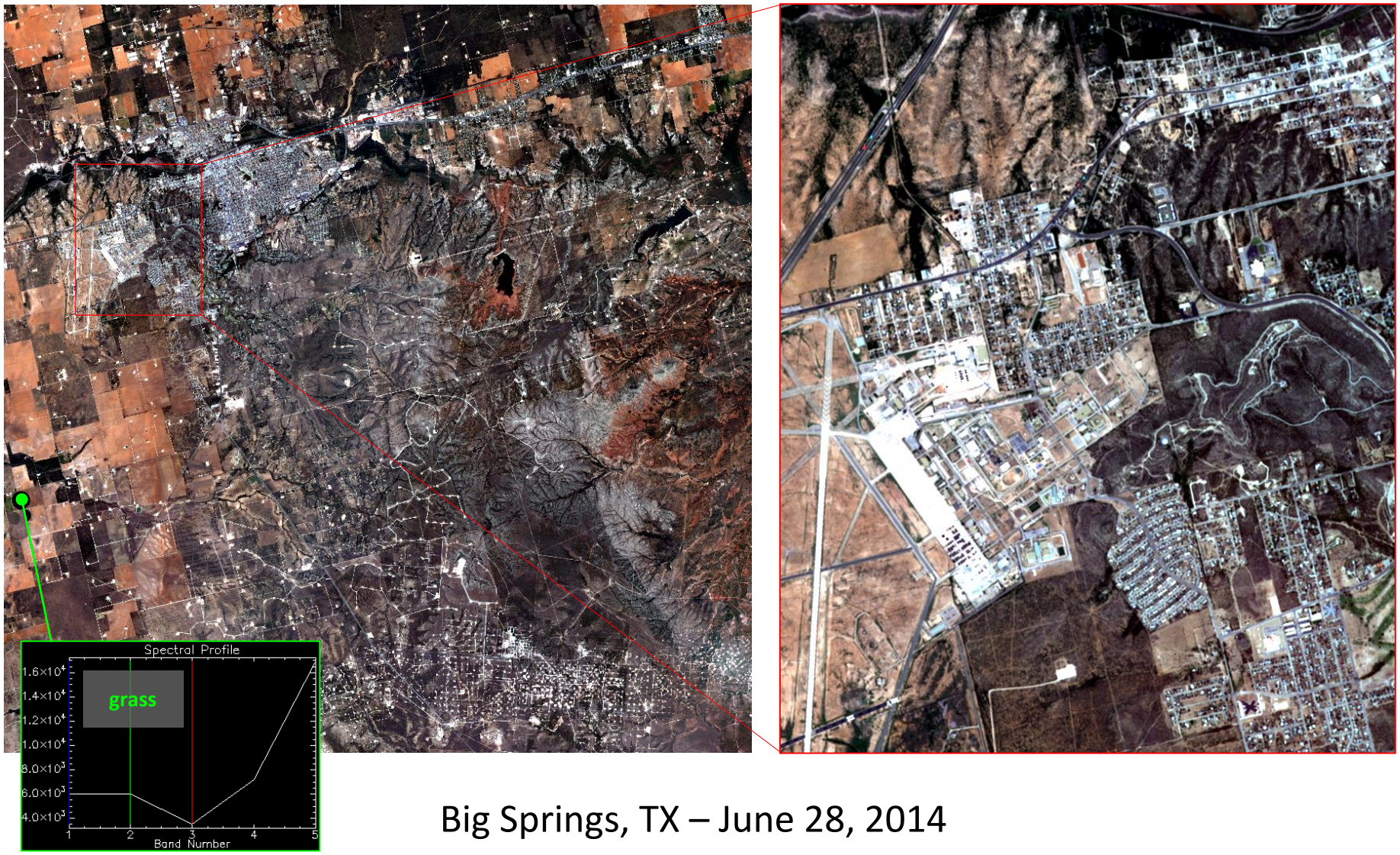
AComp/Landsat-8 vs. Sentinel-2

AComp/Landsat-8



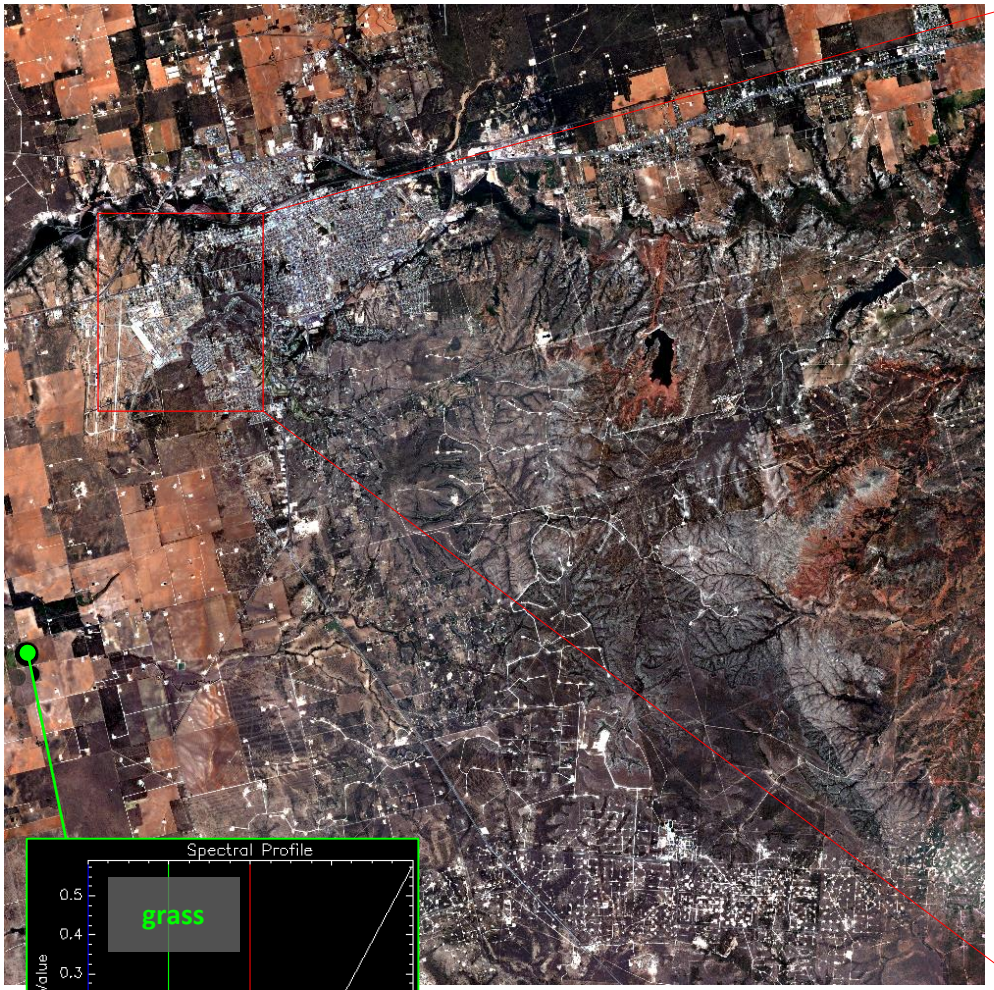
Source: ESA
http://www.esa.int/spaceinimages/Images/2016/05/African_mosaic

RapidEye (original data)



Big Springs, TX – June 28, 2014

AComp RapidEye

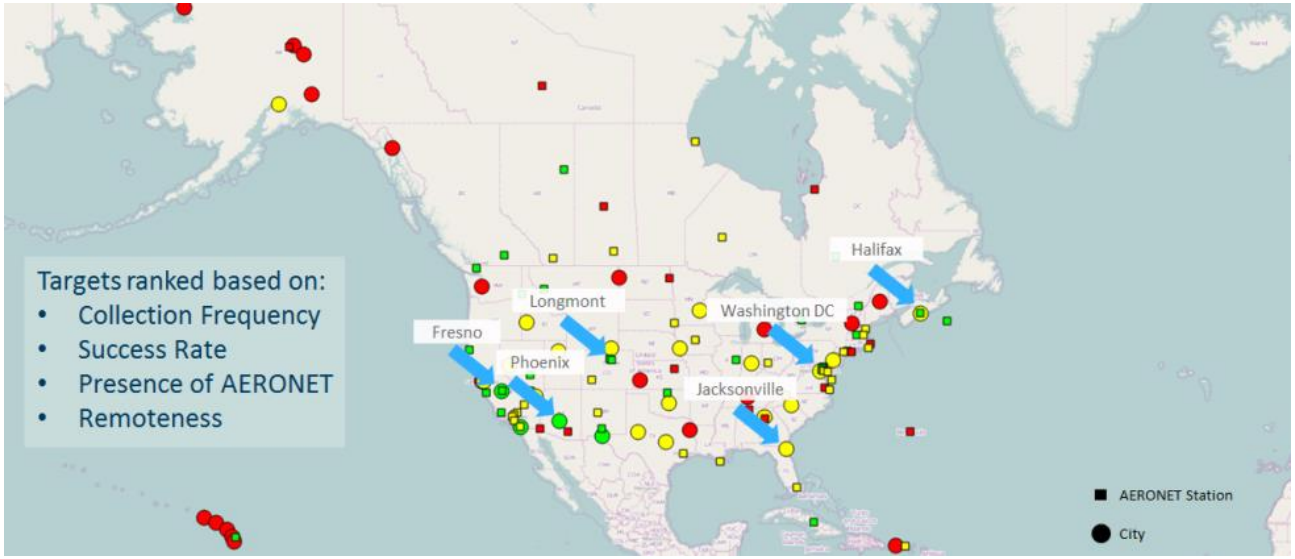


Big Springs, TX – June 28, 2014

Validation Methodology

AComp validation sets

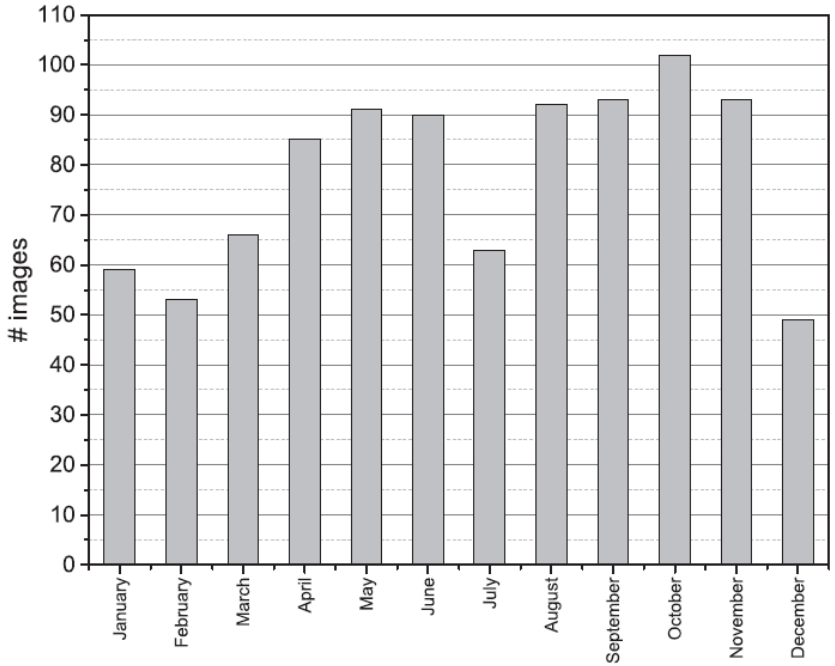
- Aerosol optical depth (AOD) and water vapor (wv) values from **AERONET** stations and **MODIS** were used to measure the accuracy of the AComp retrievals, in addition to **ASD** measurements over 14 different targets
- 6 locations with different climates:
  - rural (Fresno, CA, Longmont, CO, Halifax, Canada)
  - urban (Washington D.C.)
  - semi-arid (Phoenix, AZ)
  - semi-tropical (Jacksonville, FL)

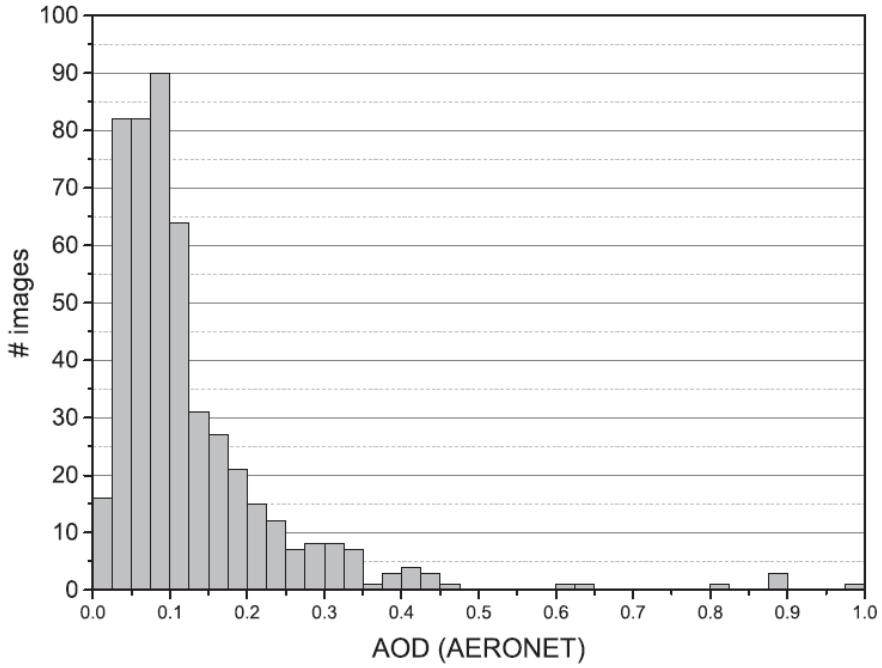


WorldView-2 image set

- 5 years of data: 2010-2014
  - ~1,000 WorldView-2 (WV02) images

Locations	Latitude	Longitude	# images
Fresno (CA)	36.78	-119.78	261
Halifax, Canada	44.65	-63.60	130
Jacksonville (FL)	30.29	-81.64	156
Longmont (CO)	40.14	-105.11	102
Phoenix (AZ)	33.48	-111.99	183
Washington D.C.	38.85	-77.05	104

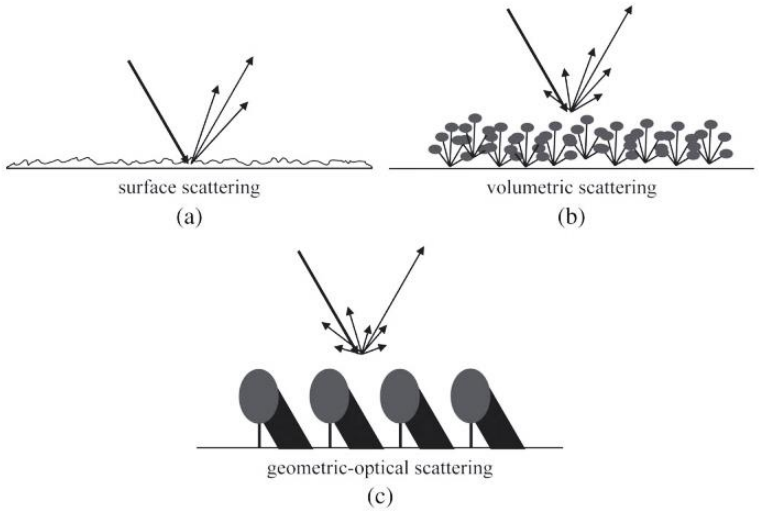


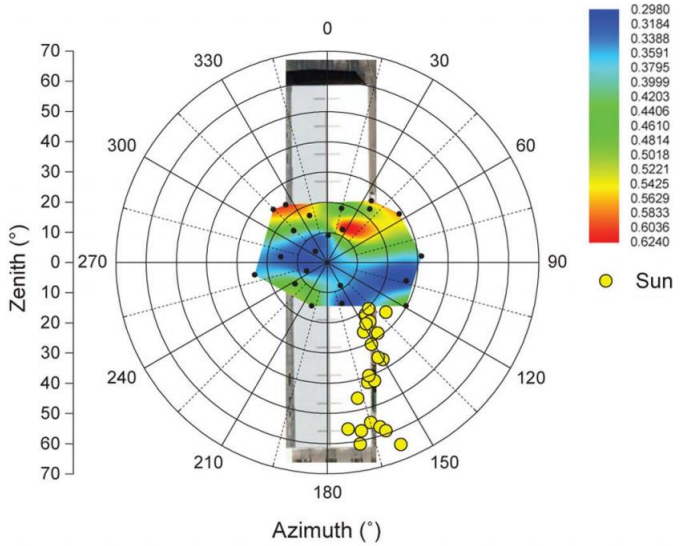


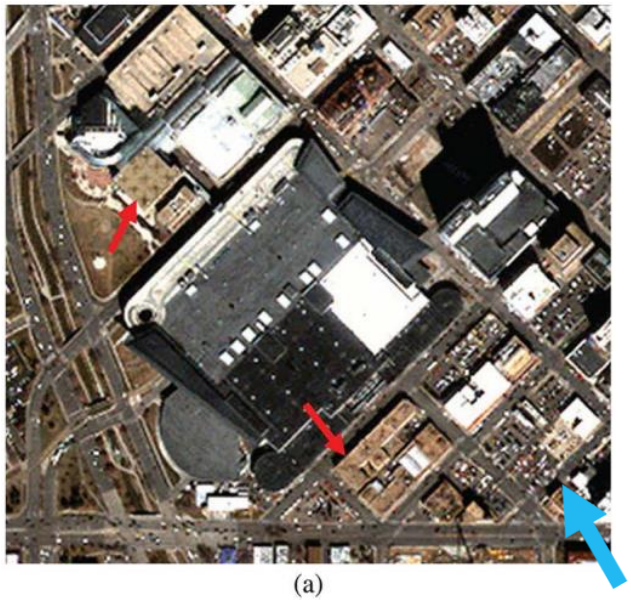
Satellite Agility

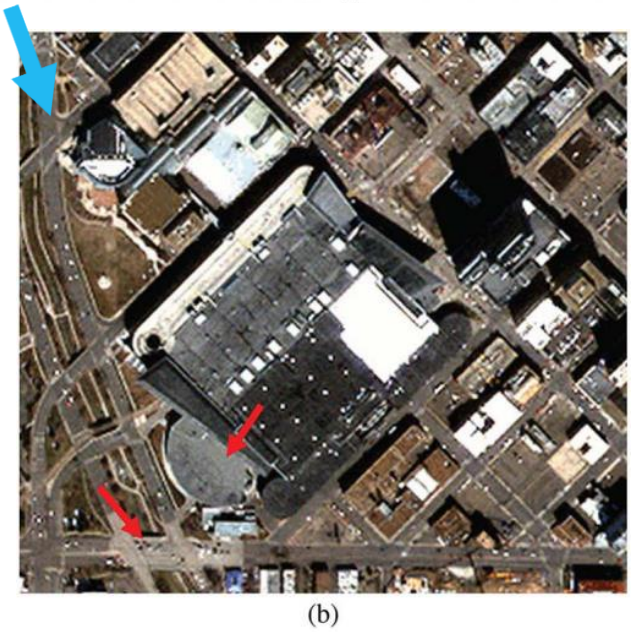
WV02: January 19, 2010 – Rio de Janeiro, Brazil

Satellite Agility = BRDF

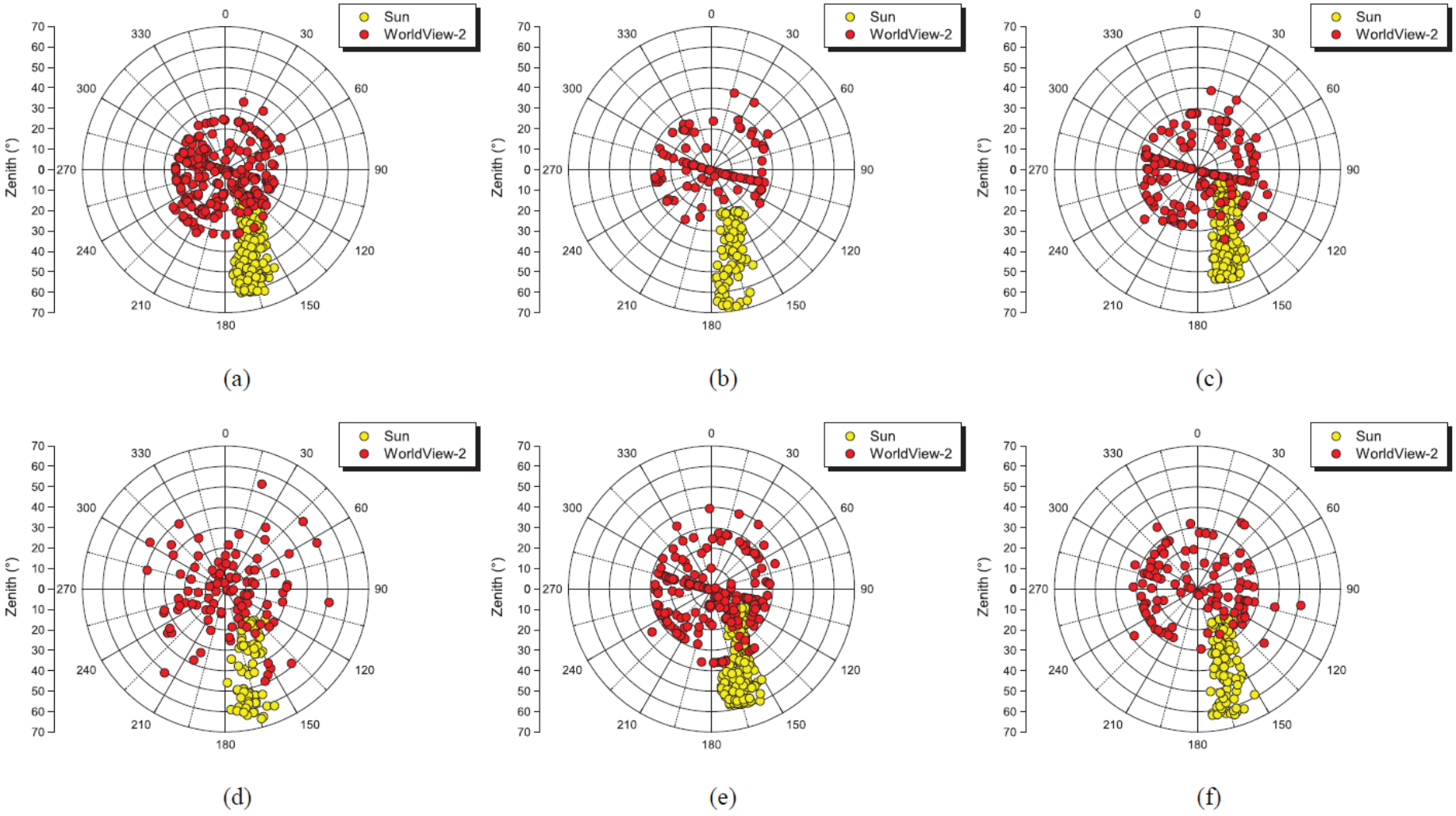





(a)


(b)

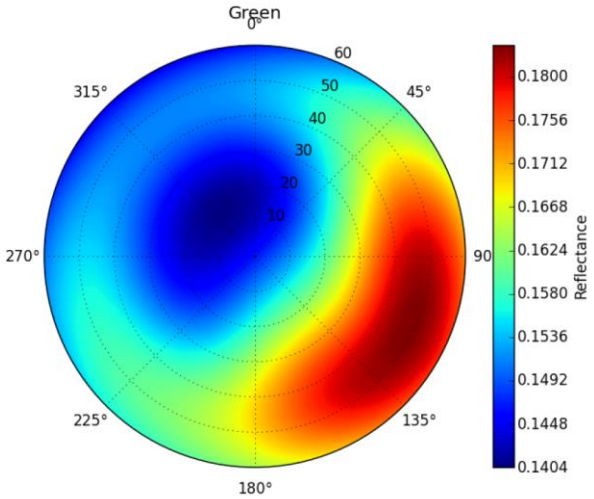
Angular distribution of the Sun and the WV02 acquisitions

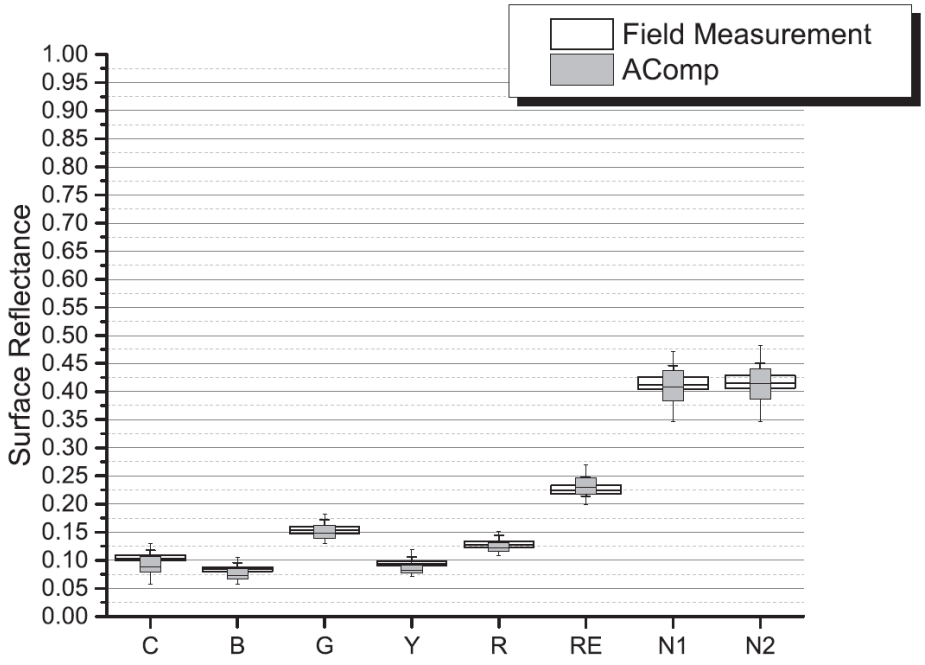


ASD measurements

- 5,000+ ASD measurements
- 14 BRDF targets
- BRDF measurements were taken at the equinoxes to minimize the effects of declination of the Sun
- Targets of interest included:
  - concrete and asphalted surfaces
  - tennis and basketball courts
  - sand

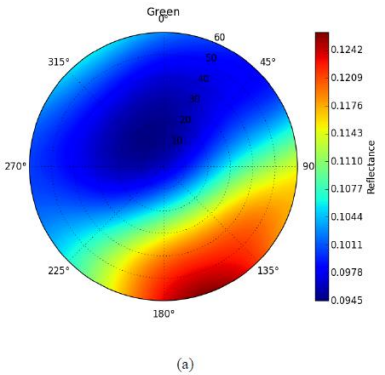
For each target ..



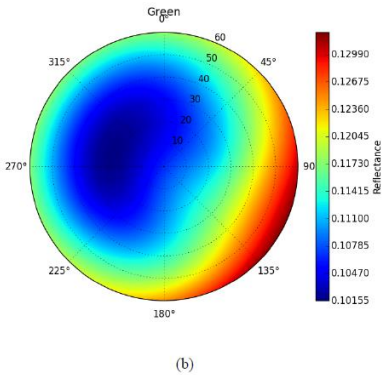


Validation Results

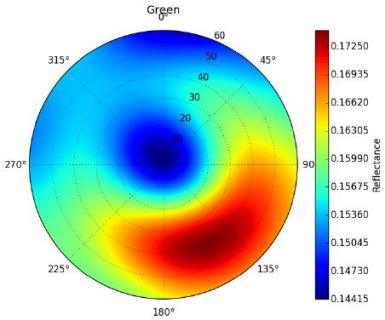
Asphalt



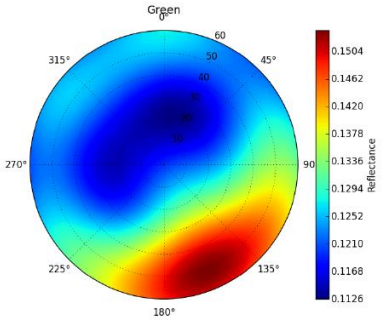
(a)



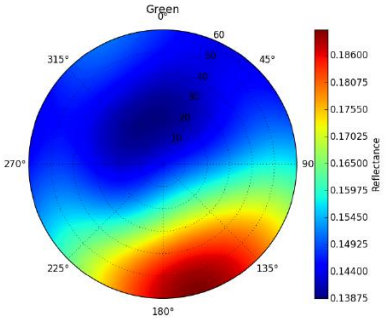
(b)



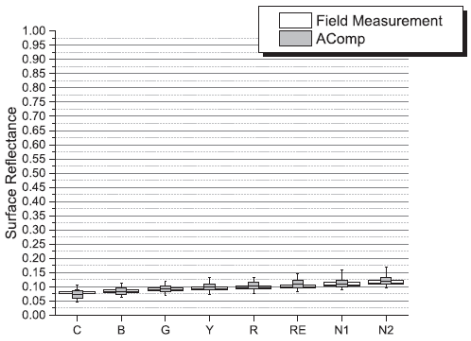
(c)



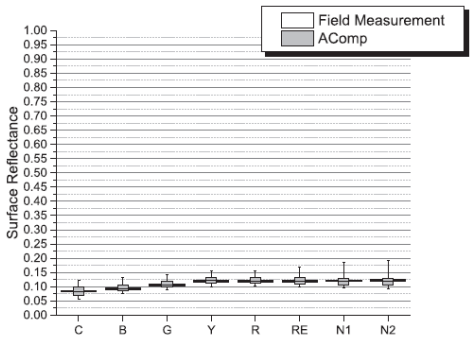
(d)



(e)



(a)



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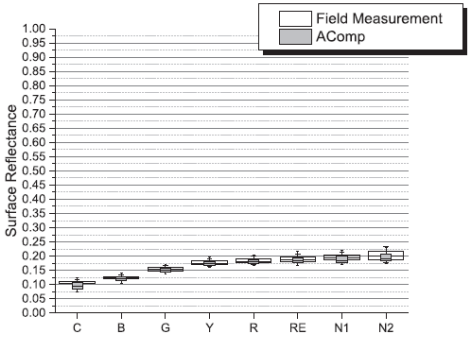
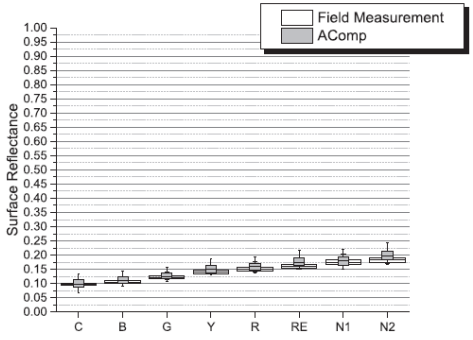
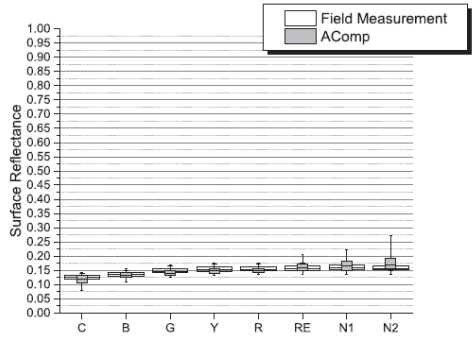


(c)

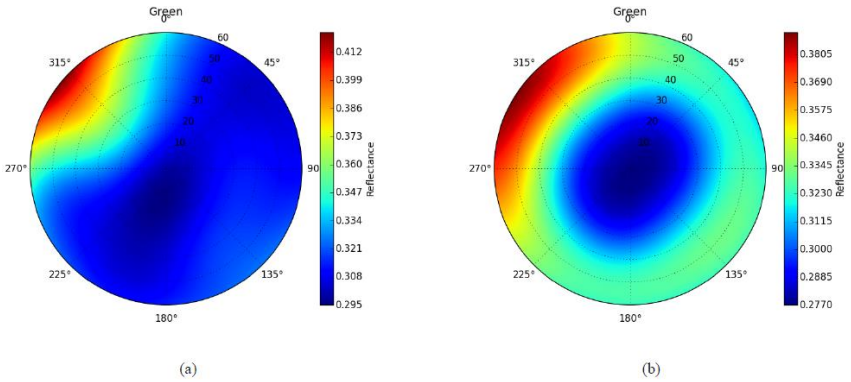


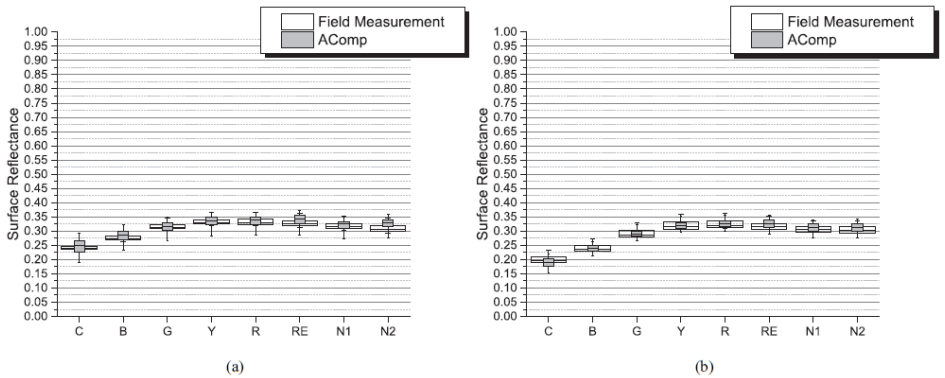
(d)

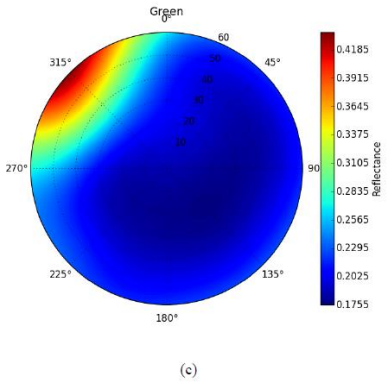


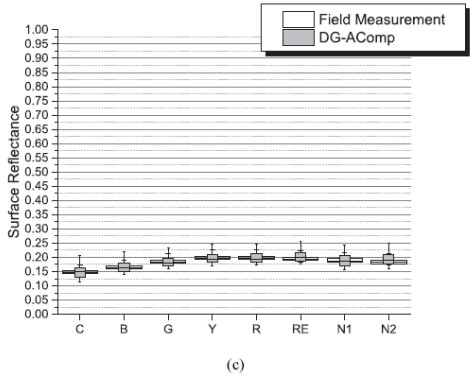
(e)

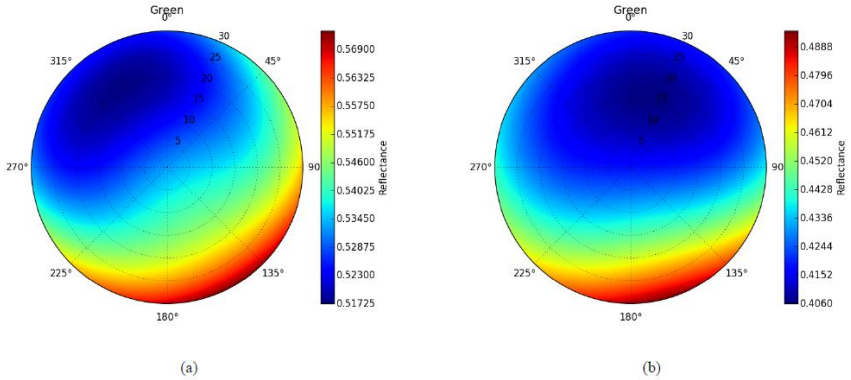
Concrete and Sand

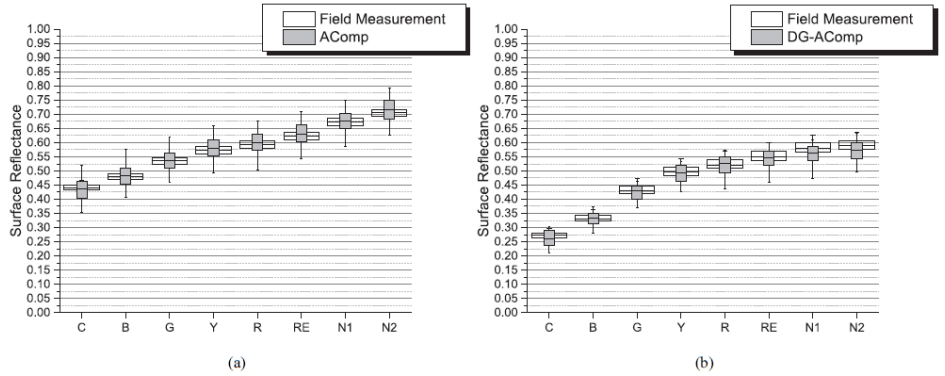




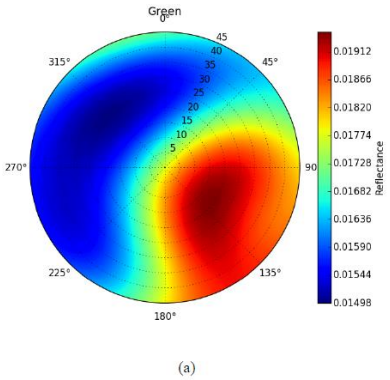


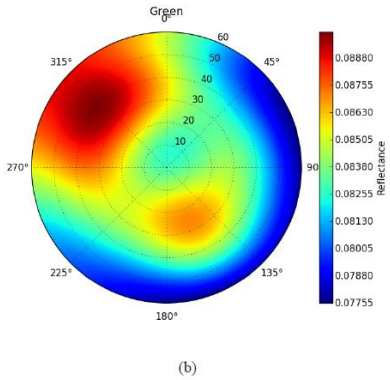


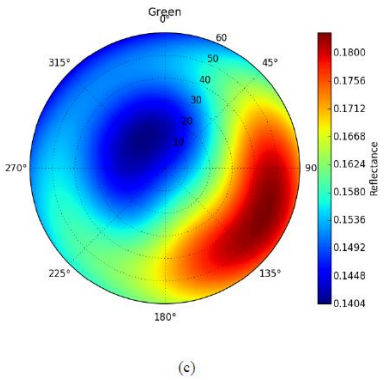


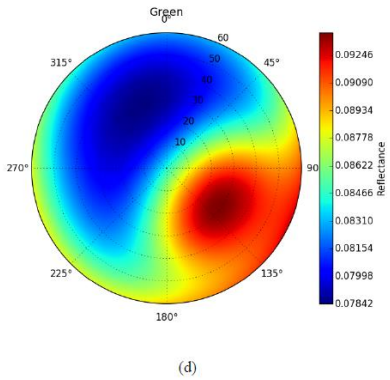


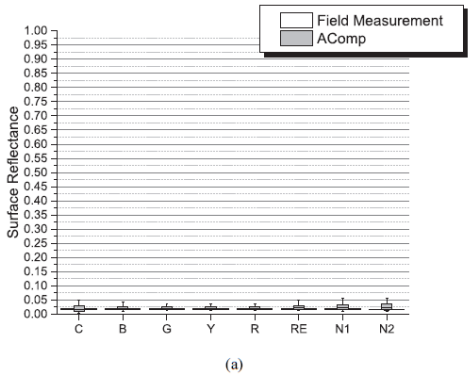
Other targets ..

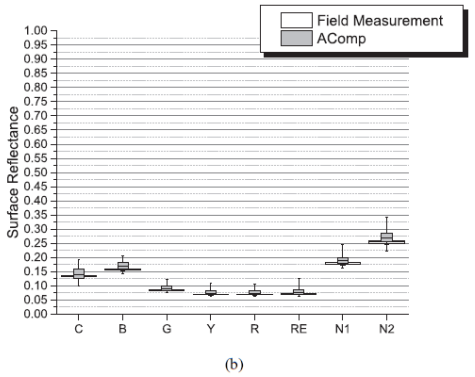


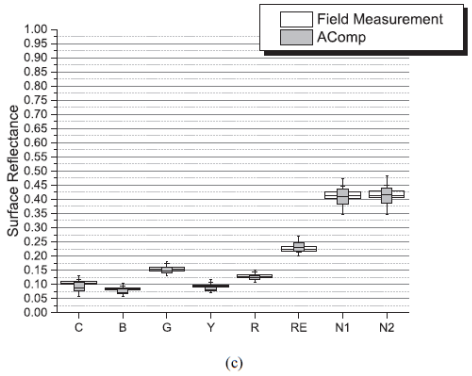


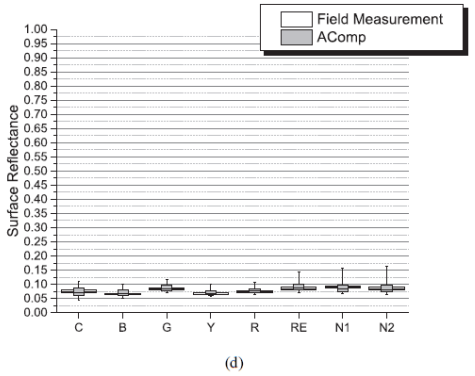


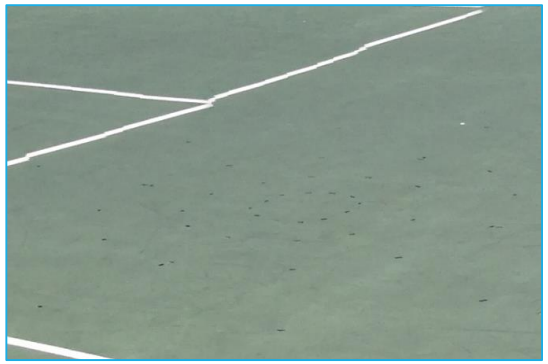




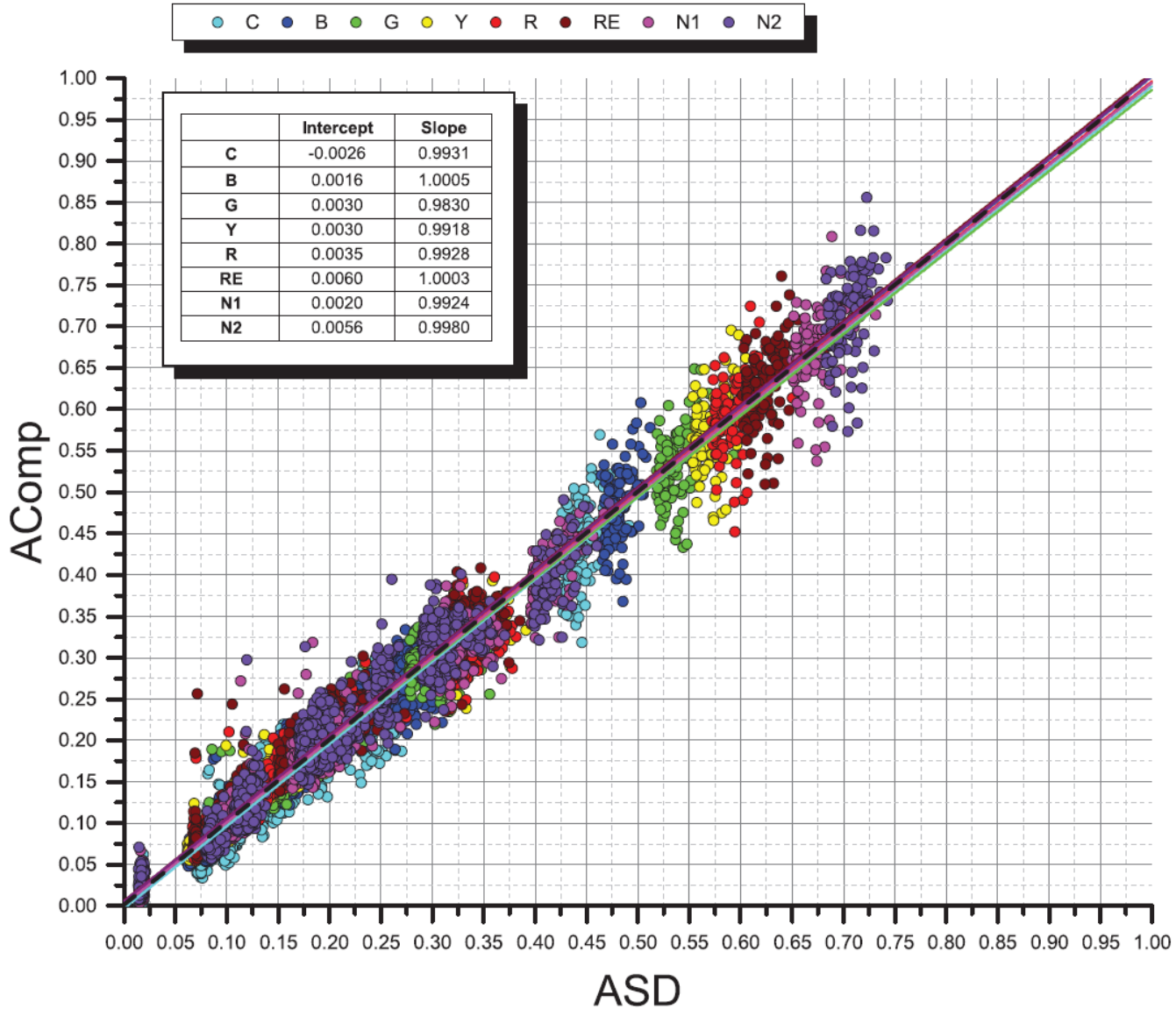






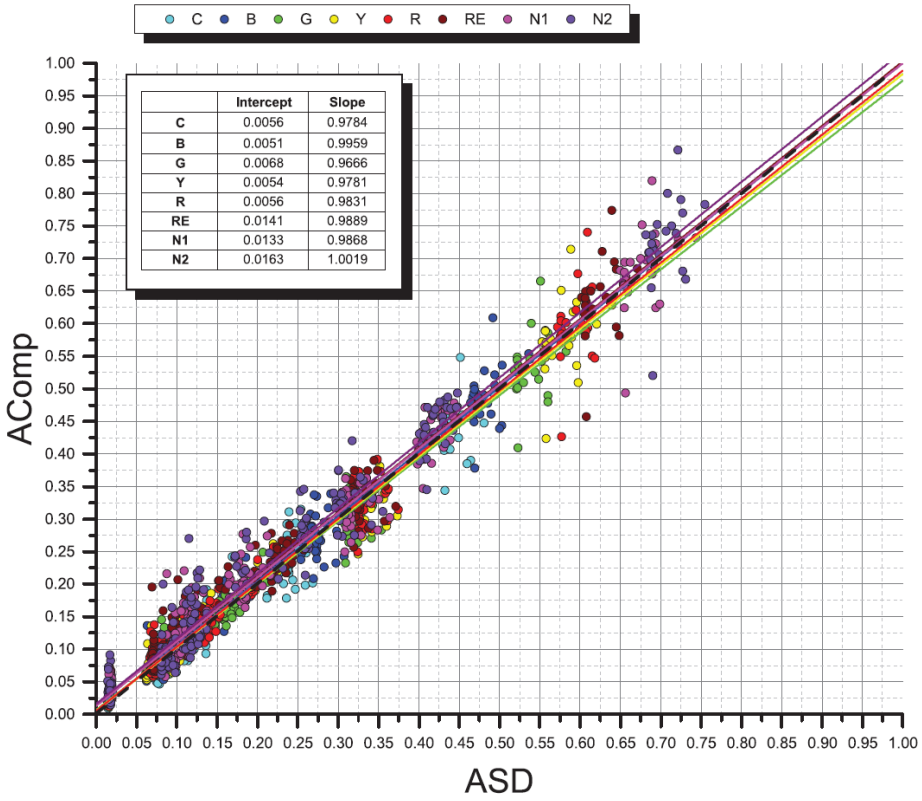


Scatter plot for “clear” images, AOD = [0.00,0.25]

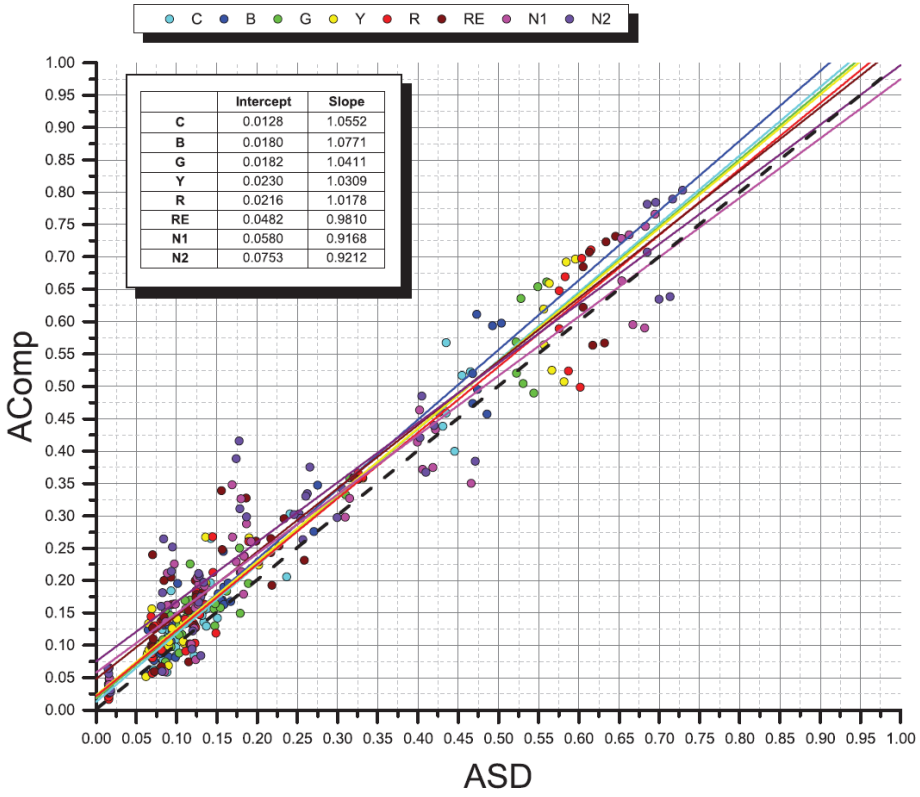


Scatter plots for AOD = [0.25,0.50] and AOD > 0.50

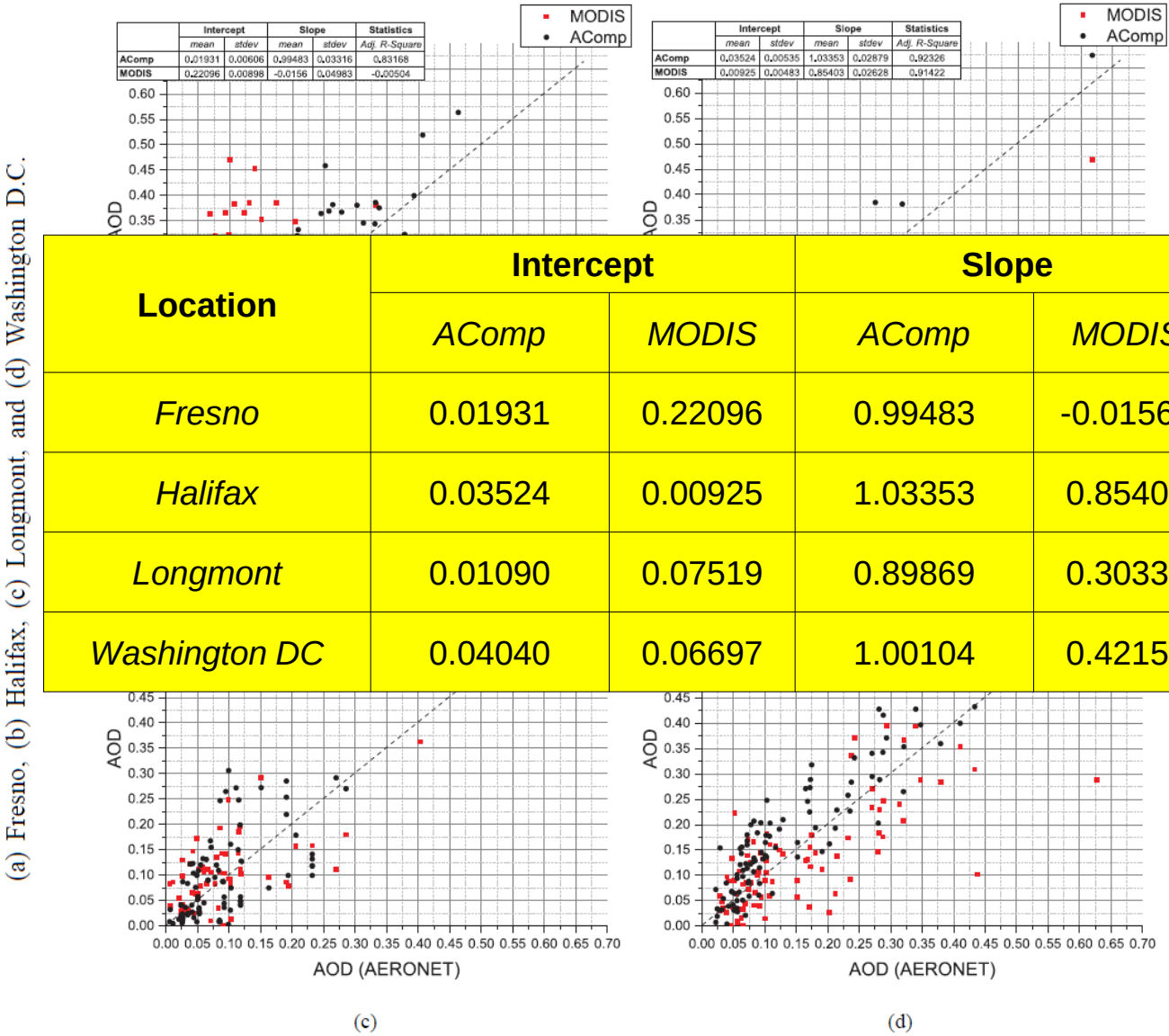
“Moderately Hazy”, AOD = [0.25,0.50]



“Hazy”, AOD > 0.50



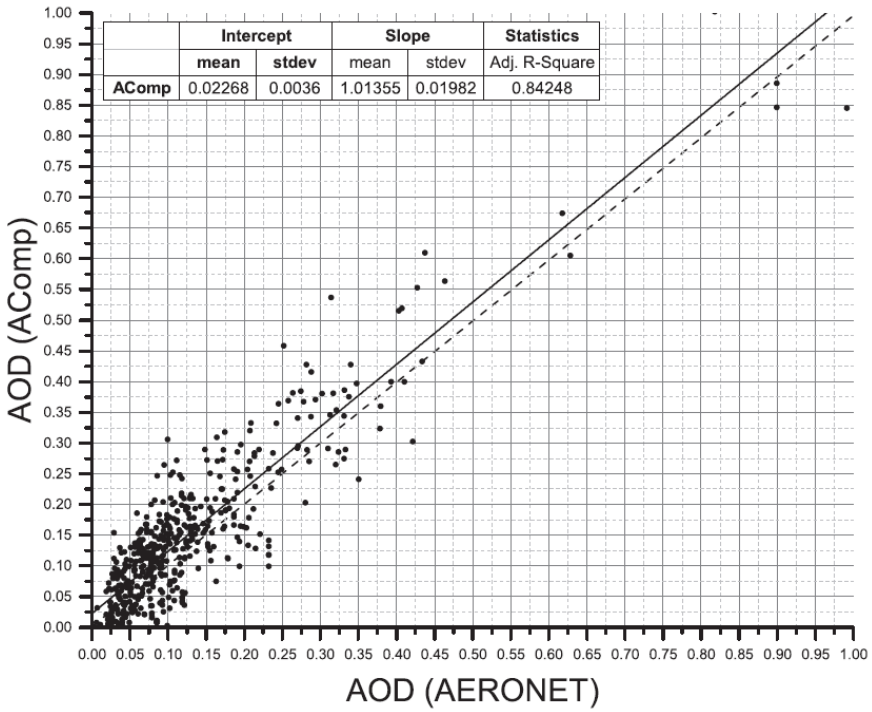
AOD: Comparison to AERONET and MODIS

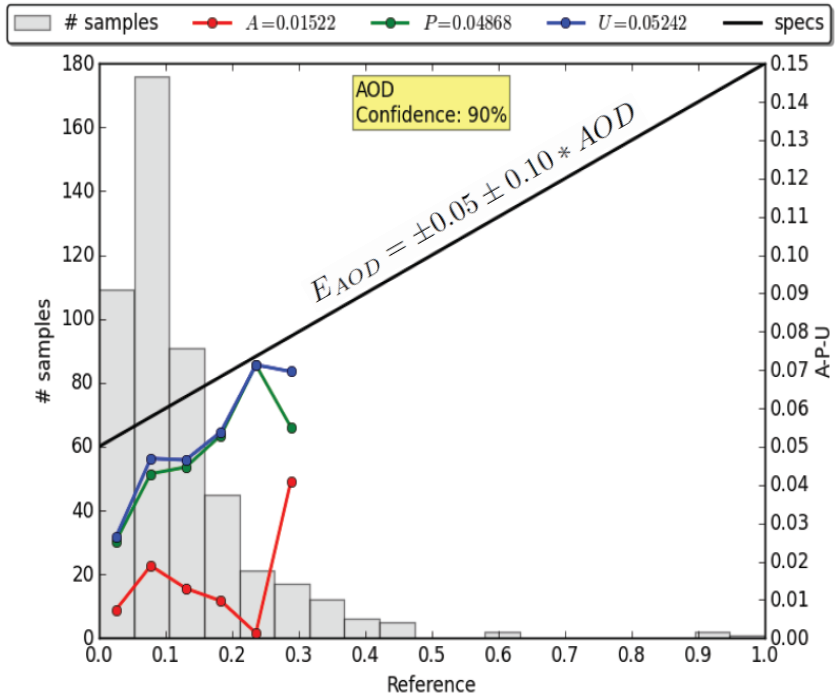


(a) Fresno, (b) Halifax, (c) Longmont, and (d) Washington D.C.

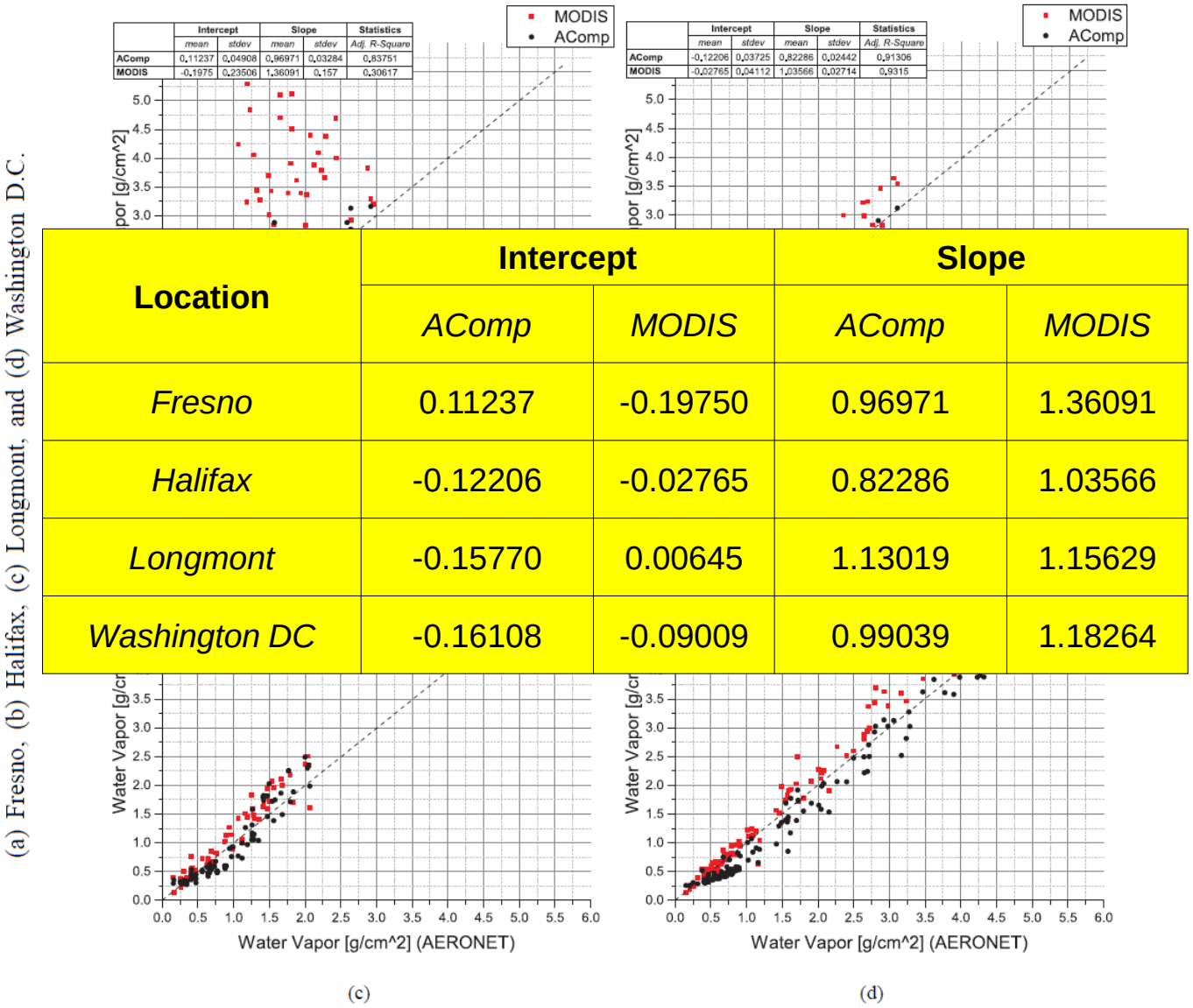
Location	Intercept		Slope	
	AComp	*MODIS*	*AComp*	*MODIS*
Fresno	0.01931	0.22096	0.99483	-0.01560
Halifax	0.03524	0.00925	1.03353	0.85403
Longmont	0.01090	0.07519	0.89869	0.30338
Washington DC	0.04040	0.06697	1.00104	0.42153

AOD: Comparison to AERONET (all measurements)





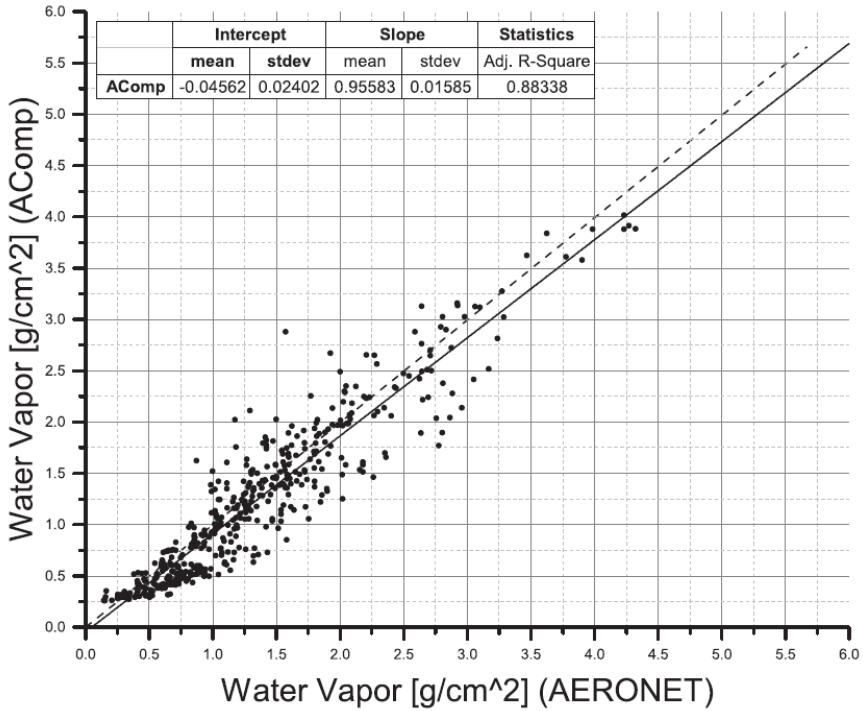
wv: Comparison to AERONET and MODIS

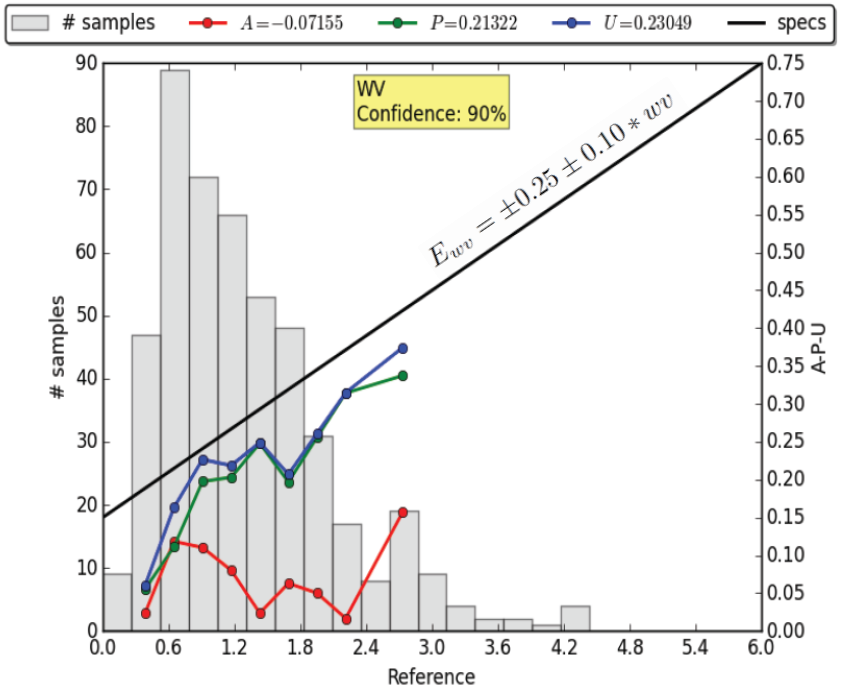


(a) Fresno, (b) Halifax, (c) Longmont, and (d) Washington D.C.

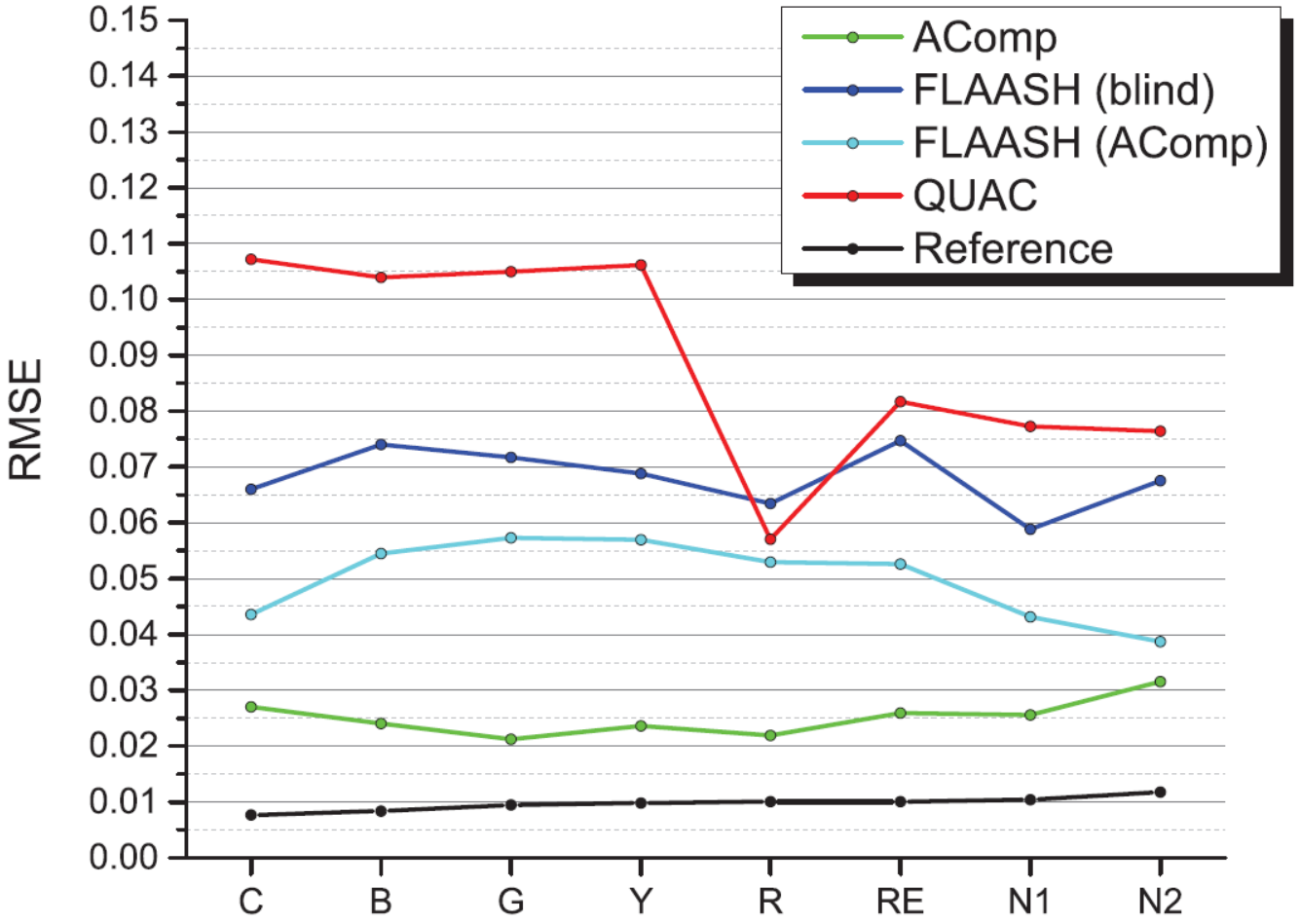
Location	Intercept		Slope	
	AComp	*MODIS*	*AComp*	*MODIS*
Fresno	0.11237	-0.19750	0.96971	1.36091
Halifax	-0.12206	-0.02765	0.82286	1.03566
Longmont	-0.15770	0.00645	1.13019	1.15629
Washington DC	-0.16108	-0.09009	0.99039	1.18264

wv: Comparison to AERONET (all measurements)





Comparison to QUAC and FLAASH



University of Colorado, 2015: http://digitalglobe-marketing.s3.amazonaws.com/files/blog/MichaelSmith_Masters_Report_ACOMP_Assessment.pdf

Conclusions

Conclusions

- Surface reflectance is a foundation technology that is necessary for extracting information from imagery reliably over a large area and with imagery collected over a period of time
- Its applications are countless, including:
  - land use/land cover
  - large-scale mosaics
  - environmental studies (NDVI, LAI, biomass)
  - target detection – species identification