Validation of the WorldView-2 Absolute Radiometric Calibration

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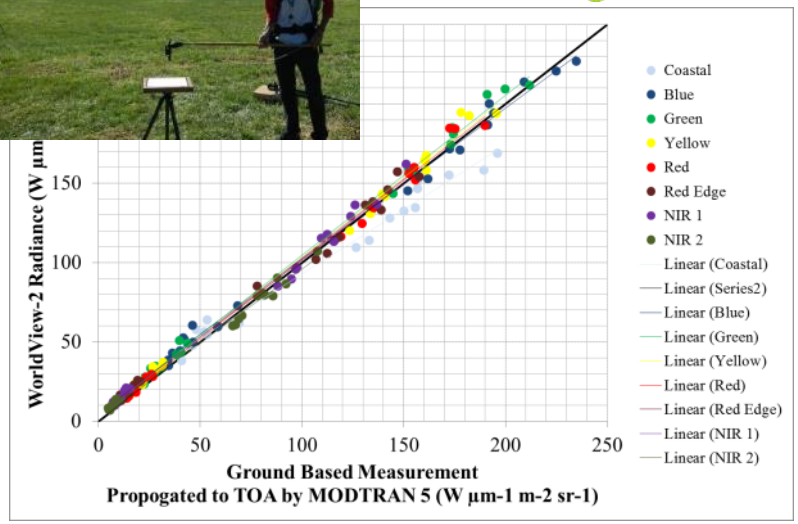
Sanduwa, Democratic Republic of Congo | May 20, 2012 | WorldView-2

Outline of Discussion

- Approach to absolute radiometric calibration
- Development of in-house capabilities
- Comparison to independent resources
- Presentation of WorldView-2 2013 calibration season
- Low reflectance regime – nonlinearity characterization
- Plans for 2014
  - Launch of WorldView-3
  - DigitalGlobe Fleet radiometric performance
  - Cross-calibration to Landsat archive

A thorough approach to absolute radiometric calibration is employed

- Combination of pre-launch and on-orbit methods
  - Vicarious deployments
  - Multiple targets
  - Include more of dynamic range
  - Attention to nonlinearity, BRDF and other items that affect uncertainty
- Implement best practices and international recommended procedures
  - Committee on Earth Observation Satellites
  - NIST traceability
- Partnership and independent validation
  - South Dakota State University (WorldView-2 & WorldView-3)
  - University of Arizona (WorldView-3)

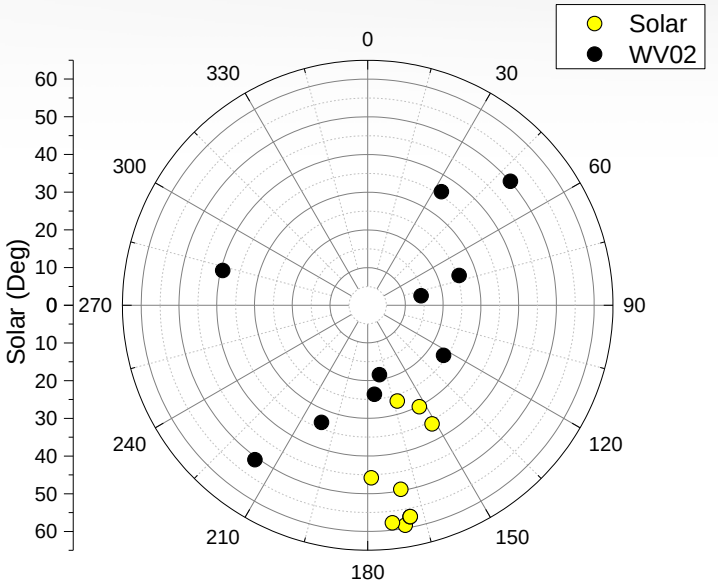


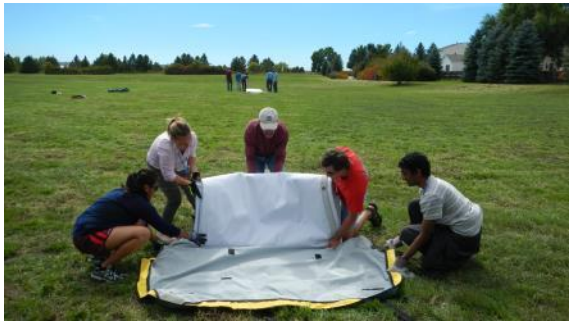
In-house vicarious calibration capabilities

- DigitalGlobe has invested > $250K
  - Full Range Field Spectrometer (VNIR – SWIR)
  - Specialized calibration targets
  - Shadowband radiometer (Local AERONET Station)
  - Weather station
  - Handheld GPS
  - Ancillary Equipment
- Program in place with Colorado Space Grant Consortium
- A full shake-out of the new instrumentation was performed
  - Results comparable to South Dakota State University & a NASA JPL effort in 2010

2013 Calibration Season summary

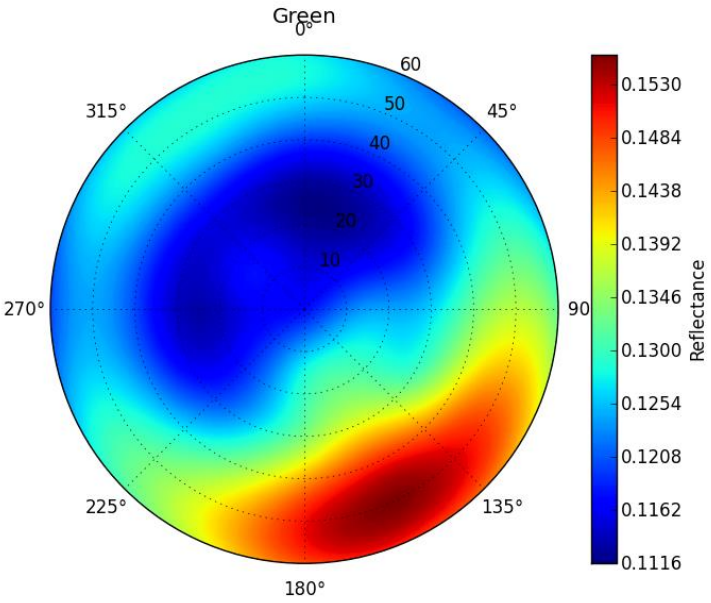
- July - November
- Eleven “good” deploys in Longmont, CO, USA
  - Calibration Tarps (10 days)
  - Sandstone Ranch (grass site)
- Six collects over Libya-4
- Two collects over Brookings vegetated site
- Early part of season suffered from “wet” atmosphere in Longmont and wildfires in Brookings



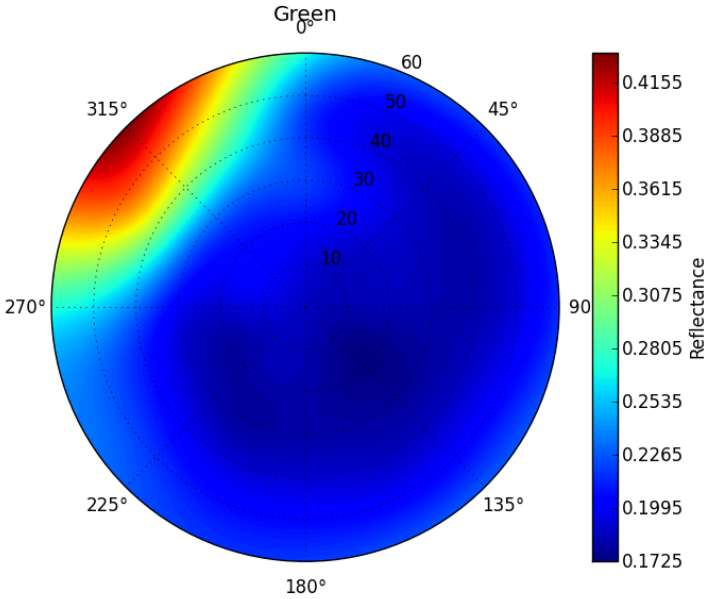


Knowledge of BRDF of targets is critical

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



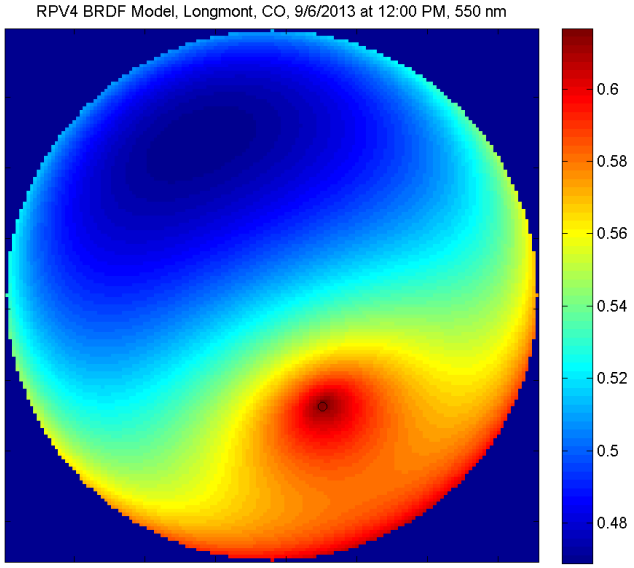
Asphalt



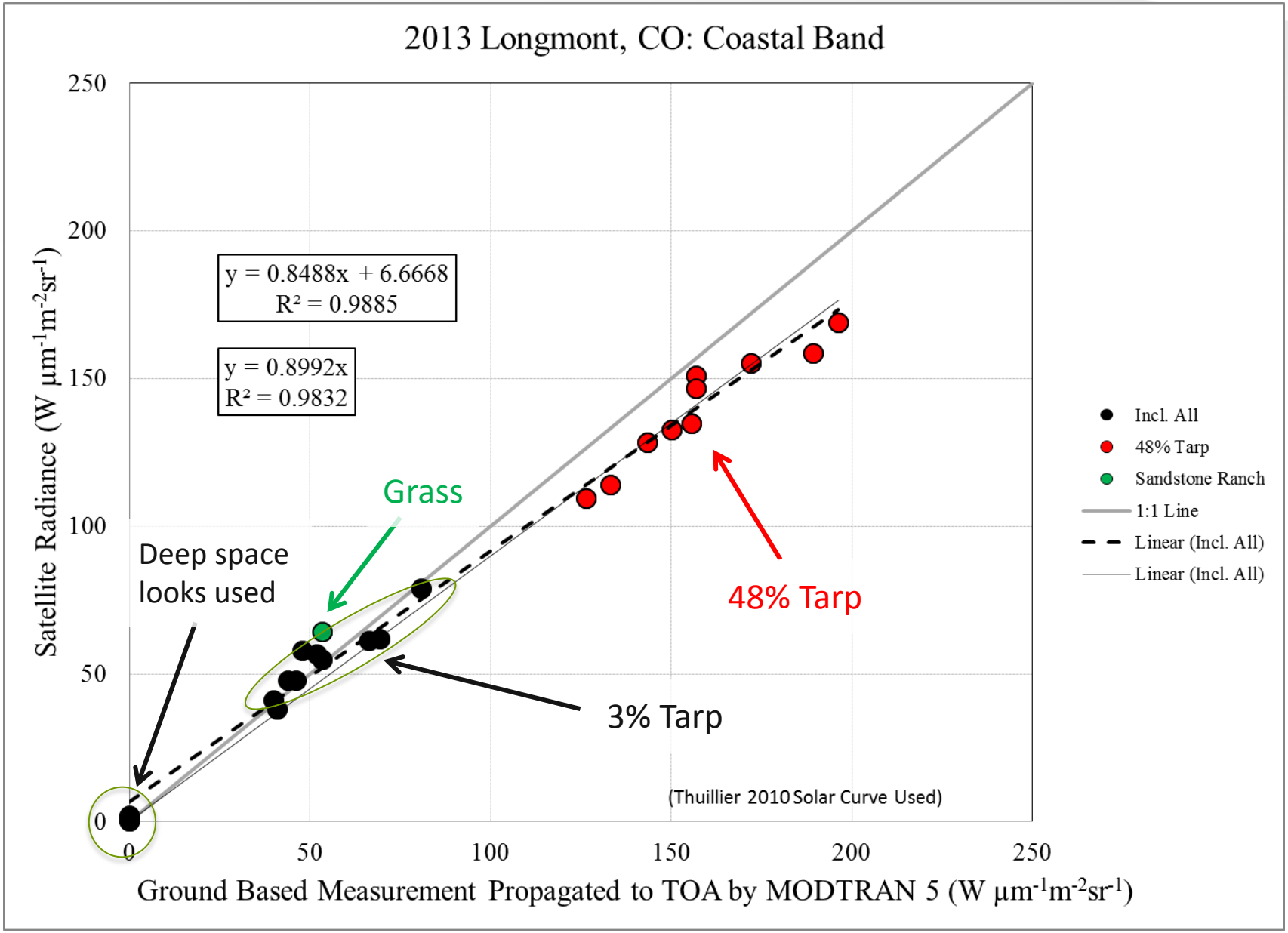
Concrete

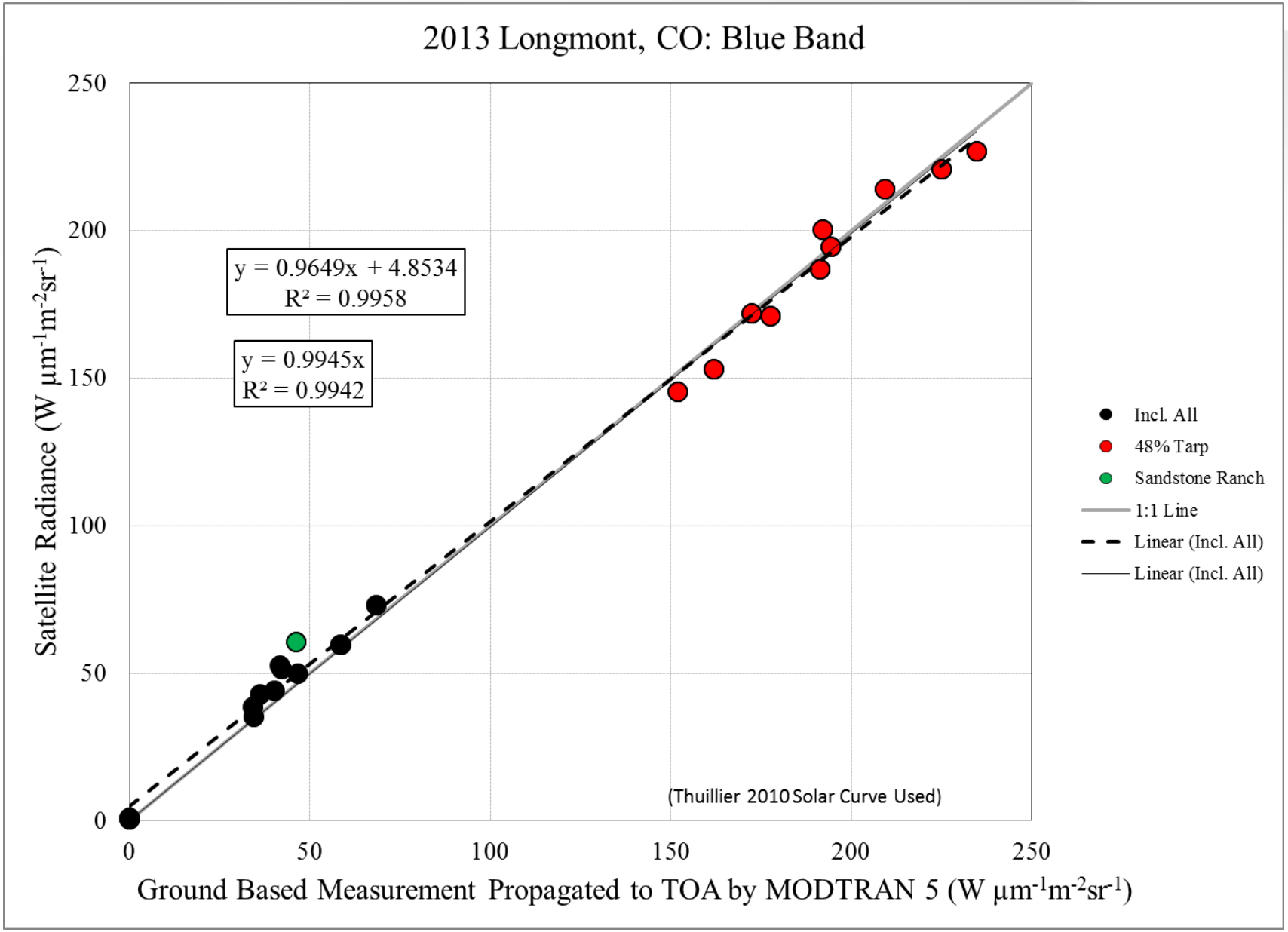
It is essential to understand the BRDF behavior of calibration targets

- Even the most spectrally and physically uniform of tarps have BRDF effects
- Approach:
  - In-situ measurements always!
  - Empirical model under development
  - Frequent measurements of tarp samples outside
  - Continued throughout the year will add solar geometry to the model
  - University of Arizona lab measurements



A look at the Longmont Results


2013 Longmont, CO: Coastal Band
y = 0.8488x + 6.6668
R² = 0.9885
y = 0.8992x
R² = 0.9832
Grass
Deep space looks used
48% Tarp
3% Tarp
(Thuillier 2010 Solar Curve Used)
Satellite Radiance (W µm-1m-2sr-1)
Ground Based Measurement Propagated to TOA by MODTRAN 5 (W µm-1m-2sr-1)
0
50
100
150
200
250
Incl. All
48% Tarp
Sandstone Ranch
1:1 Line
Linear (Incl. All)
Linear (Incl. All)


2013 Longmont, CO: Blue Band
y = 0.9649x + 4.8534
R² = 0.9958
y = 0.9945x
R² = 0.9942
(Thuillier 2010 Solar Curve Used)
Satellite Radiance (W µm-1m-2sr-1)
Ground Based Measurement Propagated to TOA by MODTRAN 5 (W µm-1m-2sr-1)
0
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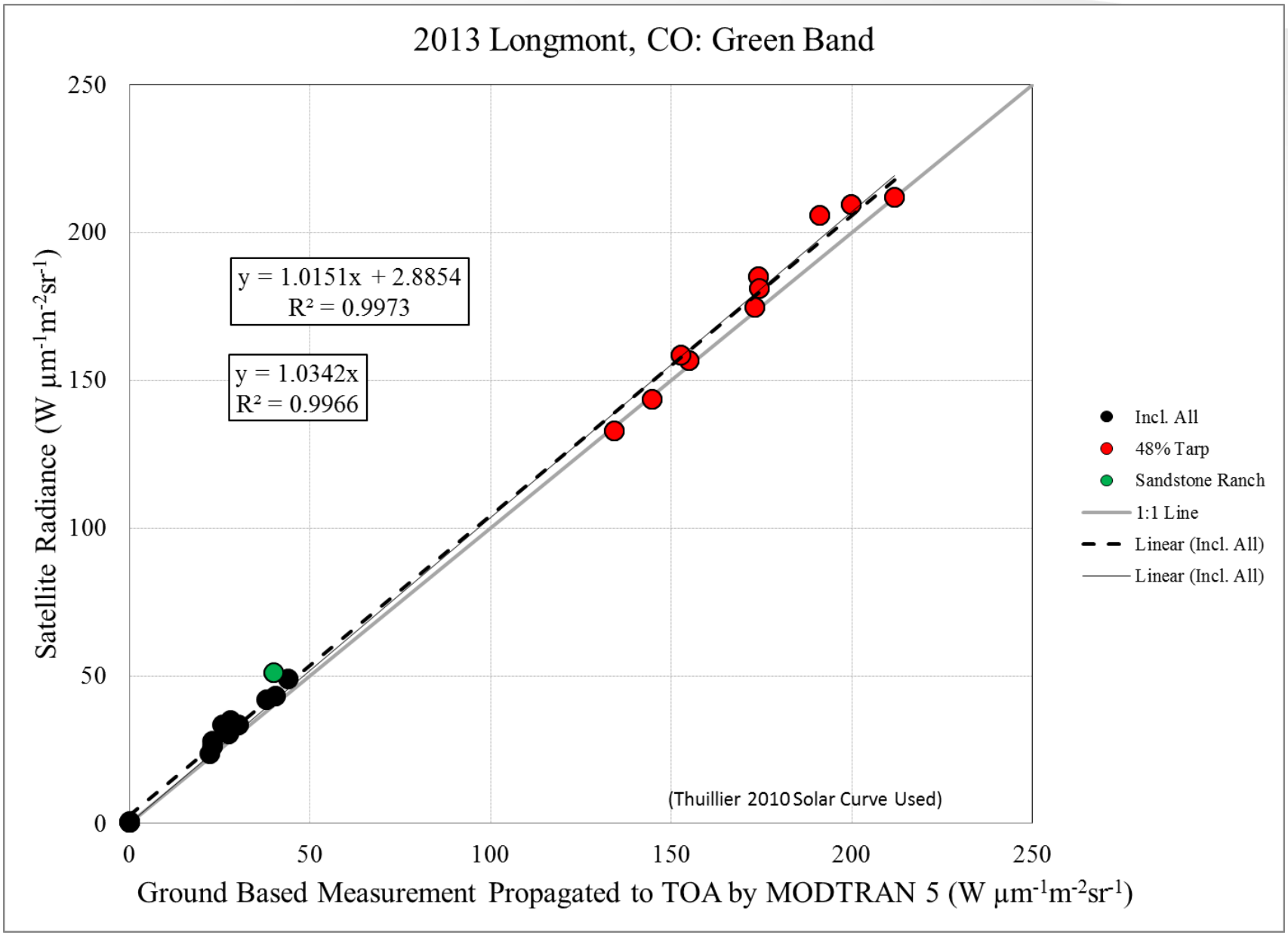
2013 Longmont, CO: Green Band
y = 1.0151x + 2.8854
R² = 0.9973
y = 1.0342x
R² = 0.9966
(Thuillier 2010 Solar Curve Used)
Satellite Radiance (W µm-1m-2sr-1)
Ground Based Measurement Propagated to TOA by MODTRAN 5 (W µm-1m-2sr-1)
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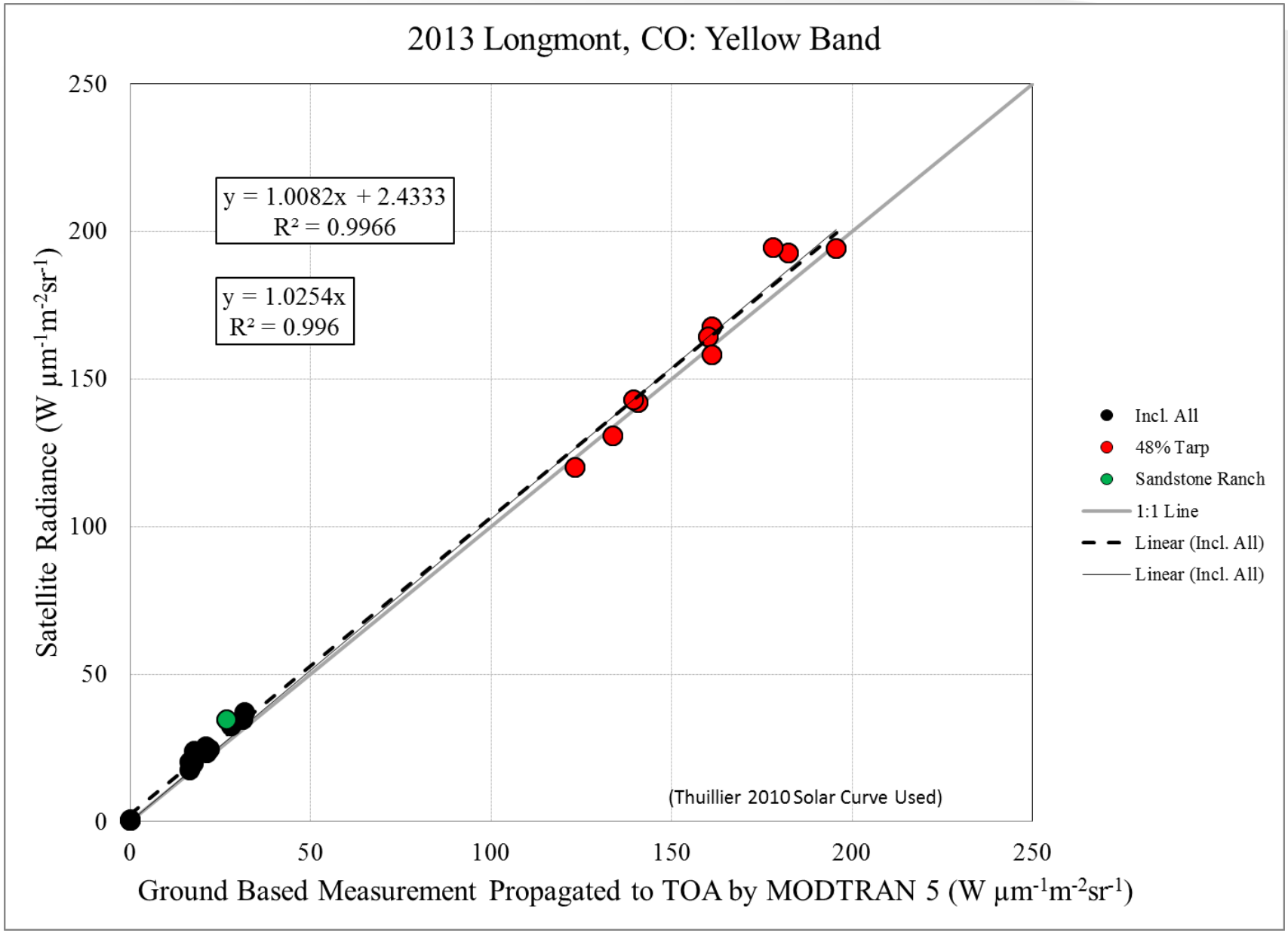
2013 Longmont, CO: Yellow Band
y = 1.0082x + 2.4333
R² = 0.9966
y = 1.0254x
R² = 0.996
(Thuillier 2010 Solar Curve Used)
Satellite Radiance (W µm-1m-2sr-1)
Ground Based Measurement Propagated to TOA by MODTRAN 5 (W µm-1m-2sr-1)
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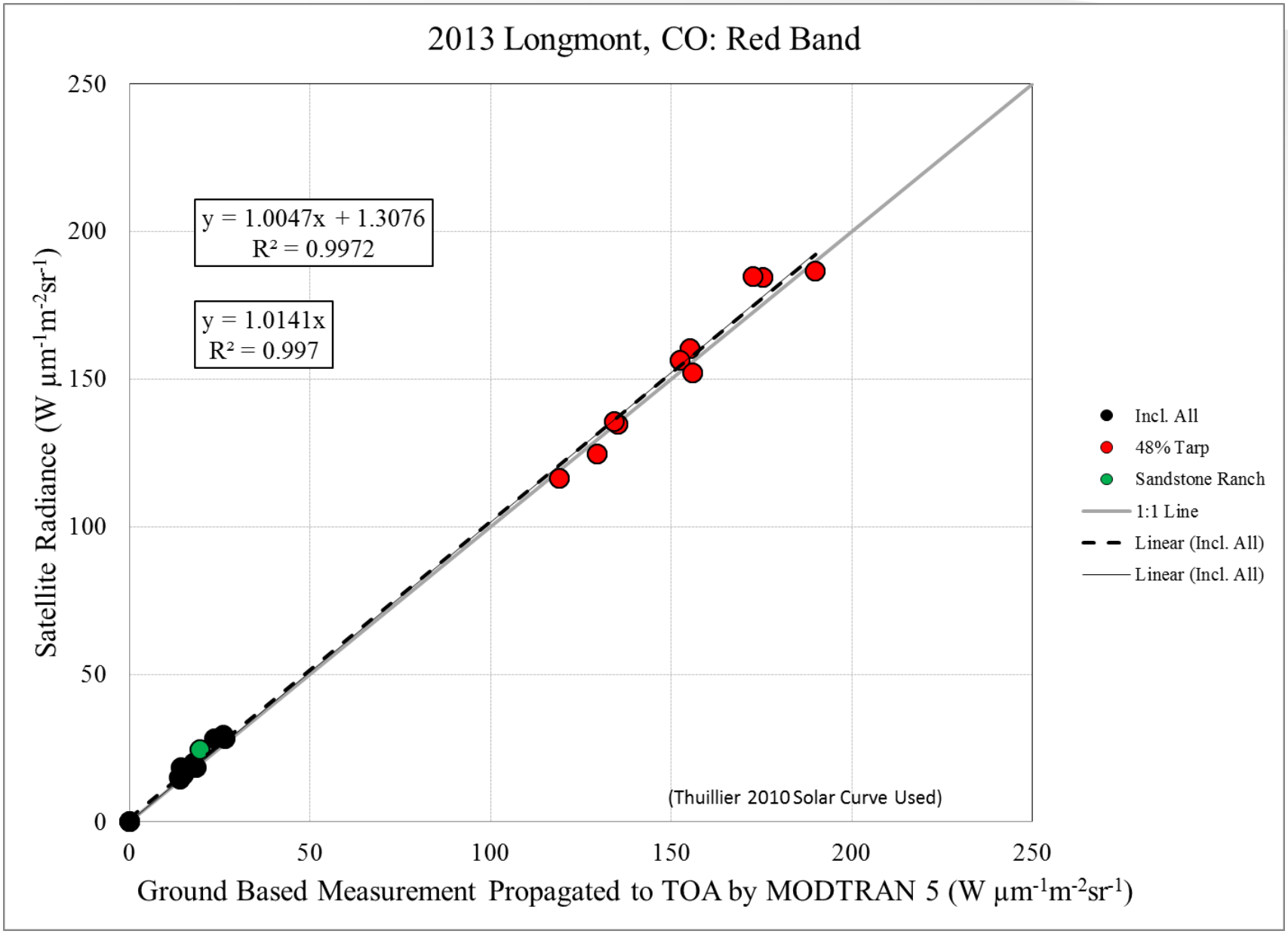
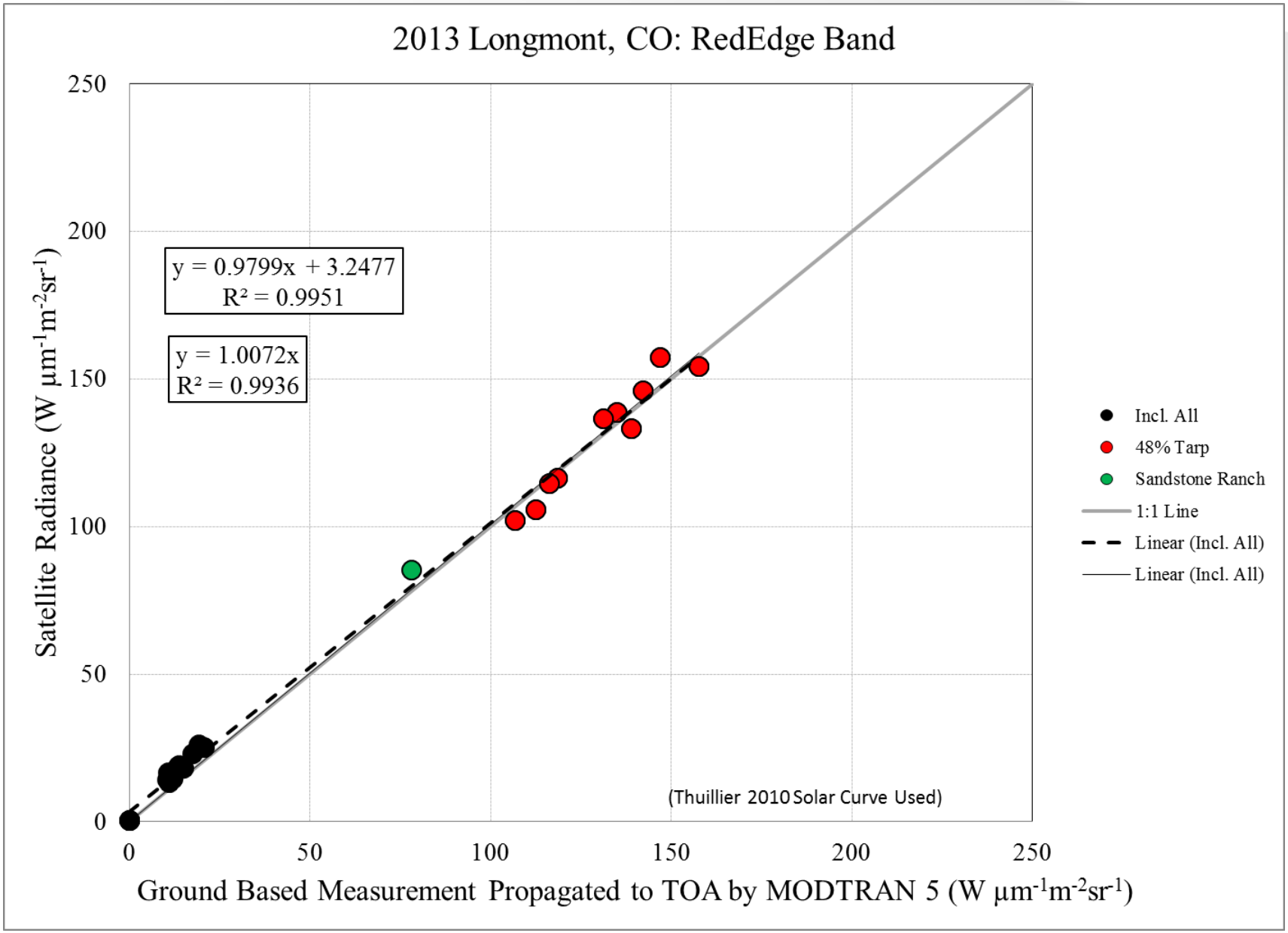
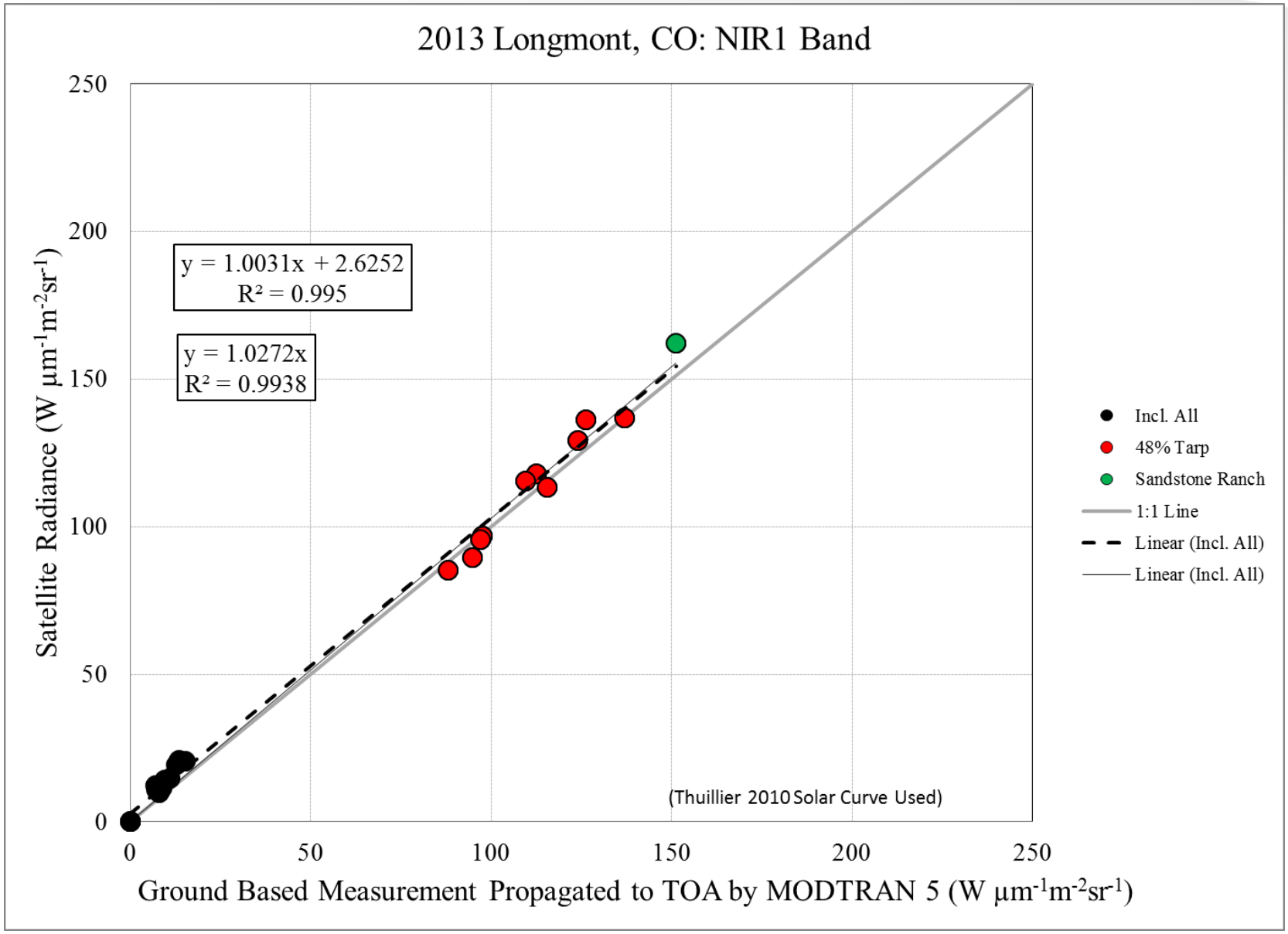
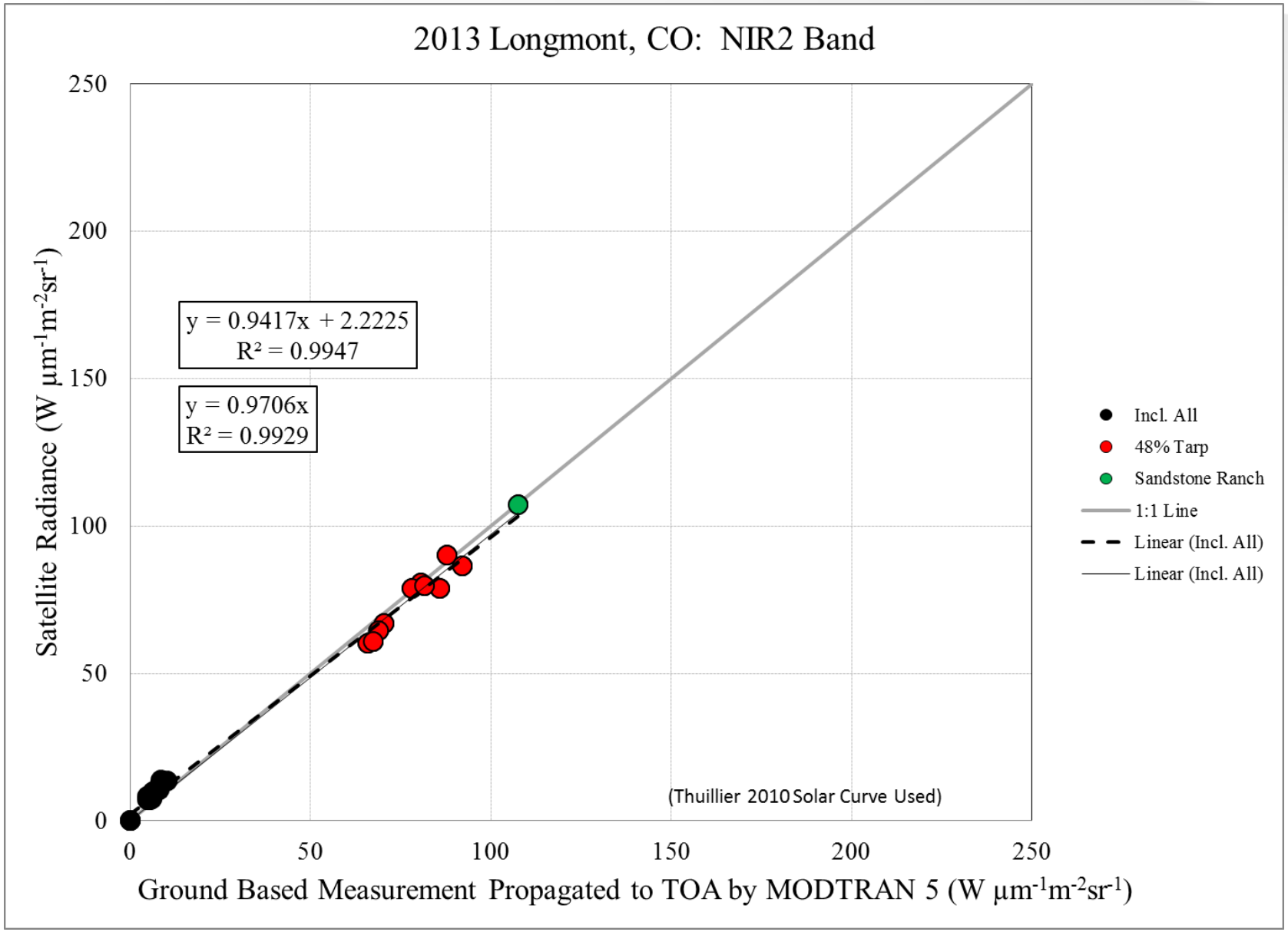
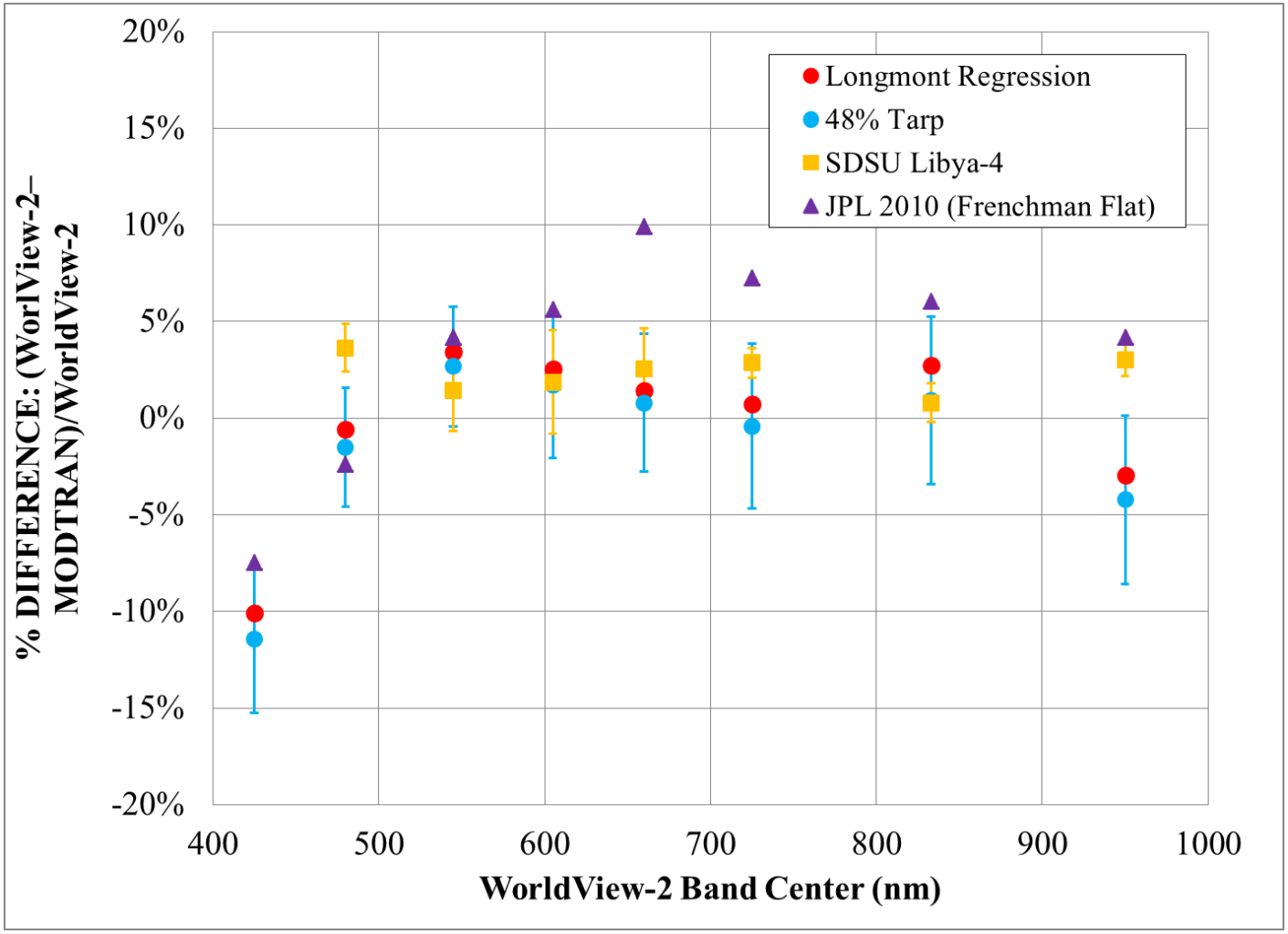

2013 Longmont, CO: Red Band
y = 1.0047x + 1.3076
R² = 0.9972
y = 1.0141x
R² = 0.997
(Thuillier 2010 Solar Curve Used)
Satellite Radiance (W µm-1m-2sr-1)
Ground Based Measurement Propagated to TOA by MODTRAN 5 (W µm-1m-2sr-1)
0
50
100
150
200
250
Incl. All
48% Tarp
Sandstone Ranch
1:1 Line
Linear (Incl. All)
Linear (Incl. All)


2013 Longmont, CO: RedEdge Band
y = 0.9799x + 3.2477
R² = 0.9951
y = 1.0072x
R² = 0.9936
(Thuillier 2010 Solar Curve Used)
Satellite Radiance (W µm-1m-2sr-1)
Ground Based Measurement Propagated to TOA by MODTRAN 5 (W µm-1m-2sr-1)
0
50
100
150
200
250
Incl. All
48% Tarp
Sandstone Ranch
1:1 Line
Linear (Incl. All)
Linear (Incl. All)


2013 Longmont, CO: NIR1 Band
y = 1.0031x + 2.6252
R² = 0.995
y = 1.0272x
R² = 0.9938
(Thuillier 2010 Solar Curve Used)
Satellite Radiance (W µm-1m-2sr-1)
Ground Based Measurement Propagated to TOA by MODTRAN 5 (W µm-1m-2sr-1)
0
50
100
150
200
250
Incl. All
48% Tarp
Sandstone Ranch
1:1 Line
Linear (Incl. All)
Linear (Incl. All)


2013 Longmont, CO: NIR2 Band
Satellite Radiance (W µm-1m-2sr-1)
Ground Based Measurement Propagated to TOA by MODTRAN 5 (W µm-1m-2sr-1)
y = 0.9417x + 2.2225
R² = 0.9947
y = 0.9706x
R² = 0.9929
(Thuillier 2010 Solar Curve Used)
Incl. All
48% Tarp
Sandstone Ranch
1:1 Line
Linear (Incl. All)
Linear (Incl. All)
0
50
100
150
200
250

Comparison to other groups



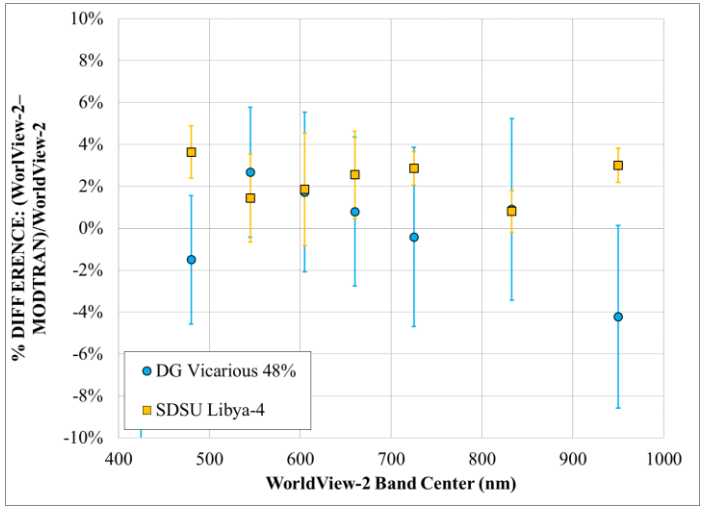
Frenchman Flat, Nevada, USA

Libya-4, Saharan Desert

DigitalGlobe calibration tarps

SDSU empirical absolute calibration model using Pseudo Invariant Calibration Sites (PICS):

- PICS typically used for radiometric stability
- Potential exists for **absolute** calibration
- In particular, Libya-4 Saharan Desert Site
- Promising results, some thoughts
  - Blue band sensitive to AOD
  - RedEdge and NIR2 sensitive to Water Vapor
  - Low signal in NIR2 creates higher uncertainties
  - Surface absorption features in NIR2
  - Even a small bias or offset difference in NIR2 would cause a greater uncertainty than in other bands
- Advantages:
  - Independent verification of vicarious method
  - Data can be collected year round
  - Allows for stability observations over time
- DigitalGlobe fleet observations in 2014 will add to the view angle BRDF model AND view azimuth



WorldView-2 Image of Libya-4 site

Effects amplified in low reflectance regime

- Atmospheric noise (esp @ high ONA)
- More sensitive uncertainties in AOD and water vapor
- Adjacency
- Uncertainties in ground instruments and protocols
- Nonlinear response
- Offset drift
- Grass targets & 3% tarp will help develop understanding of these effects on the entire dynamic range

Brookings Vegetated Site

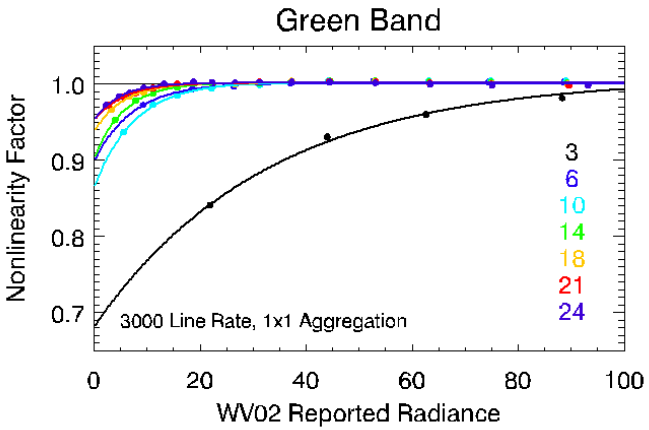
Sandstone Ranch, Longmont

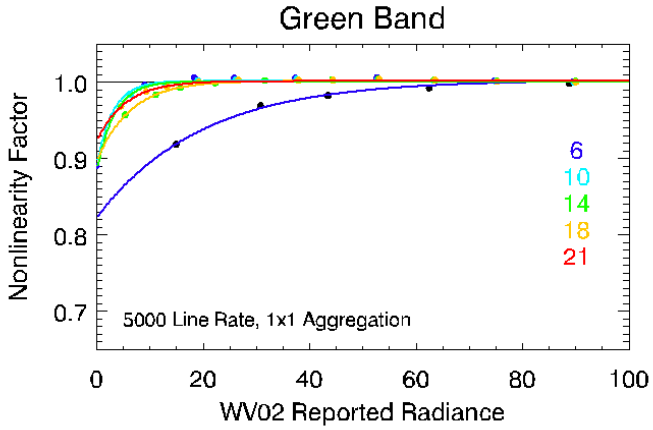
Nonlinear Response in Low Reflectance Pixels

- WorldView-2 is well behaved
- However, science that uses darker pixels (e.g. deep water applications) may require a more rigorous approach
- Pre-launch test data used to create nonlinearity factors
  - Exponential fit to residual nonlinearity in low radiance regime
  - (These results can be made available to interested scientists)

BAND	RADIANCE THRESHOLD*
C	30
B	30
G	30
Y	30
R	40
RE	70
N1	30
N2	40

** Approximate average threshold for each band over TDI 6 - 24*



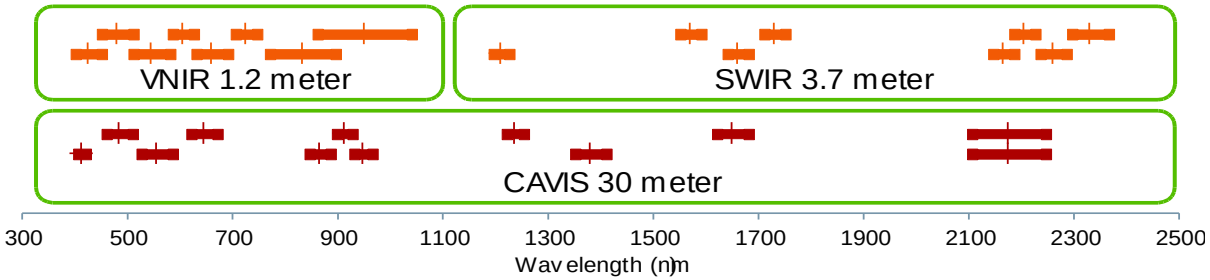


Radiometric Calibration is an ongoing mission

- Preliminary WorldView-2 results show agreement with independent sources
- Continued study of low-reflectance regime
- Improvements for 2014
  - Evolve the BRDF model for tarps
  - In-situ reflectance measurements at every tarp deployment
  - Aerosol and water vapor measurements directly over site (Shadowband install)
  - Focus on high ONA collects
  - We have a full season and should be able to get more data!
  - Fingers crossed for more cooperative skies in 2014
- Validation of entire fleet
  - Continue to refine the WorldView-2
  - GeoEye-1, QuickBird, IKONOS and WorldView-2 & WorldView-3

Ongoing efforts for 2014 include the calibration of three new sensors

- WorldView-3 check-out includes a rigorous absolute calibration effort
- Local tarp deployments in Longmont, CO, USA
- South Dakota State University vegetated site in Brookings, SD, USA
- Side-by-side vicarious campaign with University of Arizona at Lunar Lake/Railroad Valley, NV, USA
  - Effort to validate WorldView-3 coefficients AND DigitalGlobe vicarious approach
- Cross-calibration of DigitalGlobe Fleet with Landsat archive



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