



**GDA Corp.**

Geospatial Data Analysis Corporation

*Monitoring The World, For A Better Tomorrow*

# Assessment of the Radiometric Calibration of PlanetScope 2 Dove Imagery

Performed under the CRADA #HM1538-CR-FY16-010

**Dmitry Varlyguin\***, **Luke Roth\***, **Stephanie Hulina\***, **Manuela Rayner\*\***, **James Vrabel\*\***,  
**Frank Avila\*\***, **Paul Bresnahan\*\***, **Luis Henry\*\***

(\*) *GDA Corp., 301 Science Park Road, Suite 112, State College, PA, USA 16803*

(\*\*) *NGA, 7500 GEOINT Drive, Springfield, Virginia, USA 22150*

**Presenter:** Dmitry Varlyguin

*GDA Corp., VP / Chief Scientist*

[dmitry@gdacorp.com](mailto:dmitry@gdacorp.com)

**16<sup>th</sup> JACIE**

**September 19-21, 2017 USGS, Reston, VA**

# Content

- **Goal and Main Result**
- **Imagery**
- **Data Processing**
- **Analysis**
  - ✓ **PlanetScope 2 / Landsat 8**
  - ✓ **Correlations**
  - ✓ **Band Predictions**
  - ✓ **Per-Satellite Effects**
  - ✓ **ISS / SSO Orbit Effects**
- **Conclusions**

# Goal & Main Results

---

## **Goal:**

Assess the radiometric calibration of the PlanetScope 2 TOA imagery by cross-comparing it with "gold" standard Landsat 8 TOA data

## **Main Result:**

PlanetScope 2 imagery exhibits high correlation with co-incident / co-located Landsat 8 imagery. High correlation observed across all analyzed locations, dates, PlanetScope 2 sensors, bands, and LC types

# Acquired Imagery

- **Access:** Planet Data API v1
- **Imagery Dates:** Jan 01, 2016 – Feb 01, 2017
- **AOIs:** 12 Landsat footprints over 3 countries;  
Represent various LCs, both invariant & seasonal
- **LT8 Imagery:** 91 scene; CC<25%
- **Dove Imagery:** PlanetScope 2 generation  
Co-incident / Co-located with LT8 +/-3 hours  
4,577 scenes reported  
4,067 scenes downloaded (which had full meta & UDM\*)

(\*) UDM – Unusable Data Masks; pixel level masks supplied by Planet

# Acquired Imagery

- PlanetScope 2 generation (*i.e.*, operational)
- 31 different PlanetScope 2 satellites
  - Between 14 to 248 scenes were acquired for each satellite ID*
- Level 3B (Ortho Scene) products
  - Radiometrically corrected to top-of-atmosphere (TOA) radiance; orthorectified, projected to a cartographic projection (UTM); 3.0m GSD*
- 2,401 scene: ISS orbit; 1,666 scenes: SSO
  - ISS – International Space Station orbit (altitude: ~420 km; equator crossing time: varies; resolution: ~3m)*
  - SSO -- Sun-Synchronous Orbit (altitude: ~475 km; equator crossing time: 9:30-11:30am; resolution: ~3.7m)*
- ~44 PlanetScope 2 scenes per 1 Landsat scene

# Data Processing

- Converted all imagery to TOA
- Re-projected and down-sampled PlanetScope 2 imagery to match coincident Landsat 8
- Applied data gaps masks (QA+UDM) to each co-incident/co-located Landsat 8 / PlanetScope 2 pair
- Extracted ~5 million cloud-free sample points from co-incident/co-located images (data gaps excluded; random sample)
- Extracted pseudo-invariant points to model variations among PlanetScope 2 satellites
  - Removed non-invariant LC types according to a LC map
  - Removed the effects of LC variation and change between Landsat 8 images over time. Kept only pixels with similar values over time (within 2% reflectance in all bands)
  - Removed points where Landsat 8 and PlanetScope 2 values differed by more than 50% (assumed cloud, atmosphere contaminated)
  - Final set: 40,000 to 60,000 training points per each target spectral profile, representing 32 distinct PlanetScope 2 satellite IDs and both orbits

# PS<sub>2</sub> / LT8 Correlations

- High correlation between PlanetScope 2 and Landsat 8 imagery (0.86 to 0.95 in R<sup>2</sup>)
- High correlation observed across all analyzed locations, dates, LC types, and PlanetScope 2 sensors and bands (Red band has the highest correlation)

**PlanetScope 2 Correlation with Landsat 8 (TOA Reflectances, R<sup>2</sup>)**

Model	Blue Band Accuracy	Green Band Accuracy	Red Band Accuracy	NIR Band Accuracy
Ridge Regression	0.866 +/- 0.005	0.910 +/- 0.004	0.924 +/- 0.001	0.880 +/- 0.003
Lasso Regression	0.852 +/- 0.003	0.898 +/- 0.001	0.918 +/- 0.001	0.872 +/- 0.003
Regression Tree	0.915 +/- 0.001	0.943 +/- 0.002	0.948 +/- 0.001	0.921 +/- 0.003
Random Forest	0.923 +/- 0.001	0.948 +/- 0.002	0.951 +/- 0.000	0.927 +/- 0.002



# Band Predictions

- PlanetScope 2 Green, Red, and NIR bands are the most important predictive variables for the corresponding Landsat 8 spectral band
- Landsat 8 Blue band is not predicted well by the PlanetScope 2 Blue band
- Landsat Blue band is more accurately predicted by the PlanetScope 2 Green band
  - ✓ *Due to overlap between the PlanetScope 2 Green band with Landsat Blue band?*
  - ✓ *Due to higher atm contamination of PlanetScope 2 Blue band (vs Landsat Blue band)?*

**Calibration-to-Landsat Coefficients of the Spectral Bands**  
(Ridge Regression Model)

Input Variable	Landsat Blue	Landsat Green	Landsat Red	Landsat NIR
PlanetScope Blue	<b>0.051</b>	-0.602	-0.129	0.278
PlanetScope Green	0.970	<b>1.544</b>	-0.344	-0.196
PlanetScope Red	-0.117	0.122	<b>1.619</b>	-0.089
PlanetScope NIR	-0.135	-0.124	-0.187	<b>0.975</b>

Sensor	Blue Band	Green Band	Red Band	NIR Band
<b>Landsat 8</b>	450-510 nm	530-590 nm	630-670 nm	850-880 nm
<b>PlanetScope 2 Doves</b>	455-515 nm	500-590 nm	590-670 nm	780-860 nm



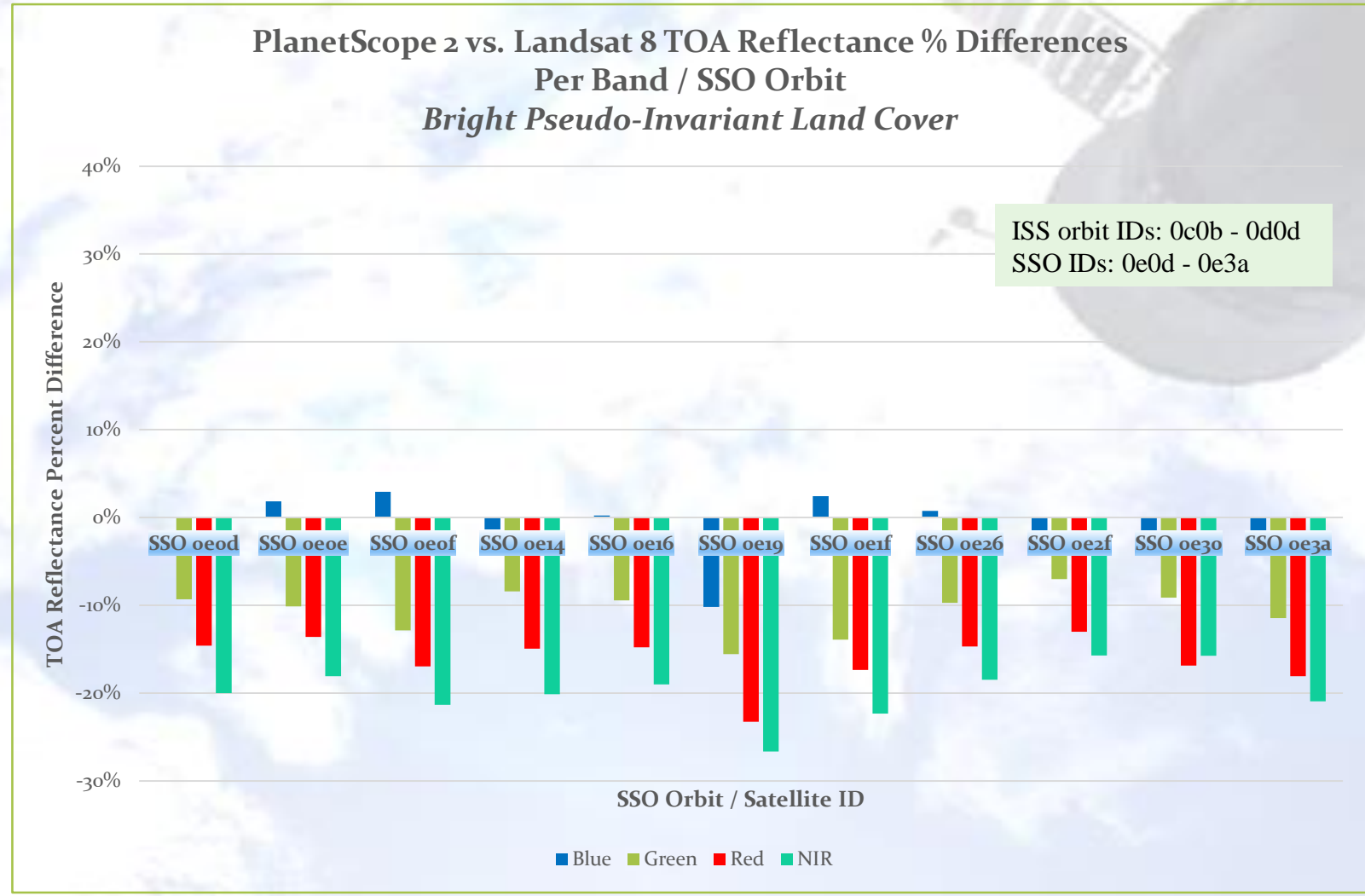


GDA Corp.

# Per Satellite Effects

Small but measurable and repeatable variability in TOA reflectances is observed per PlanetScope 2 orbit, satellite, and spectral band (for bright pseudo-invariant land cover types)

The PlanetScope 2 SSO sensors tend to report lower (vs Landsat 8) TOA reflectances for all bands

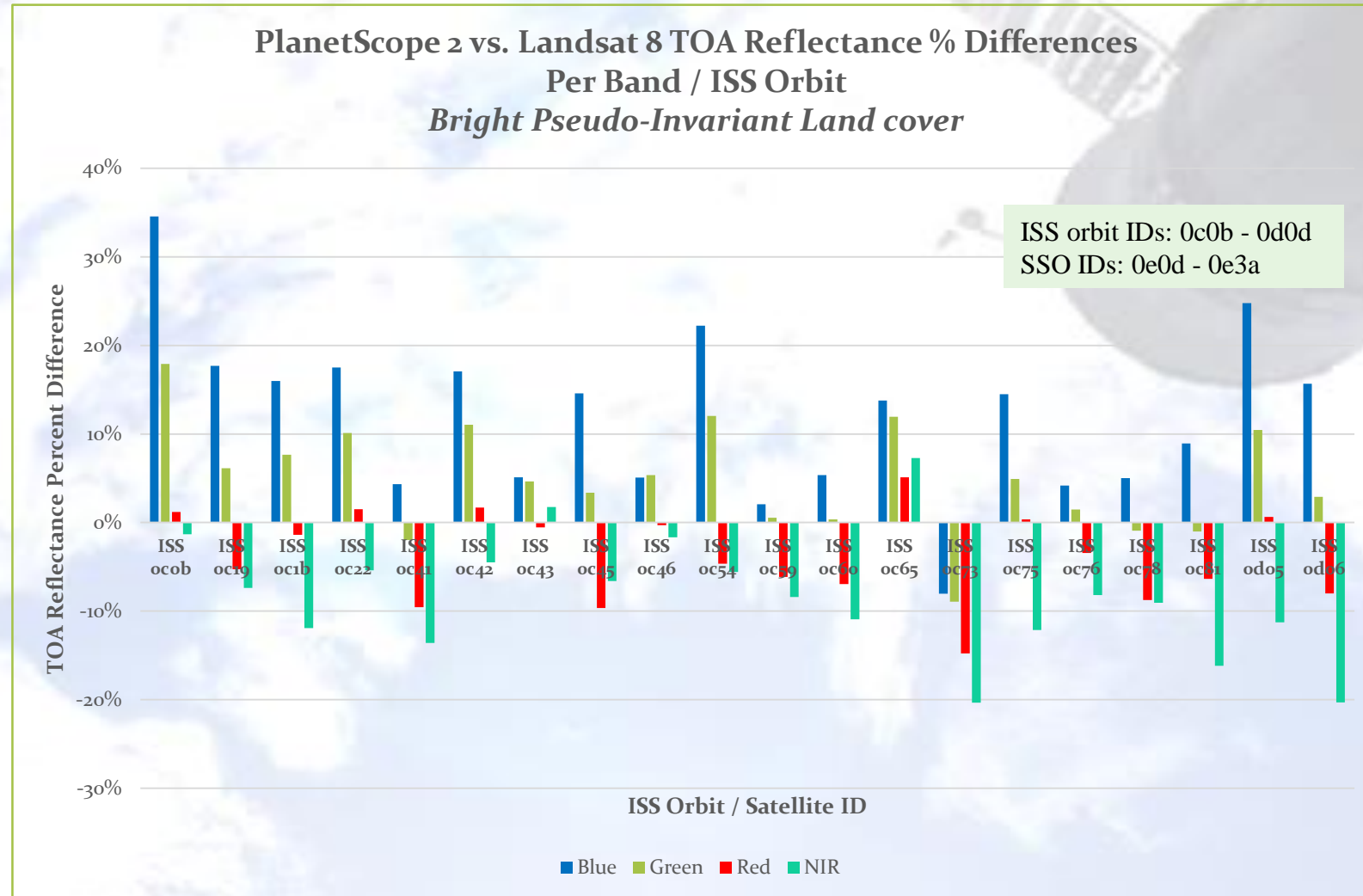


# Per Satellite Effects

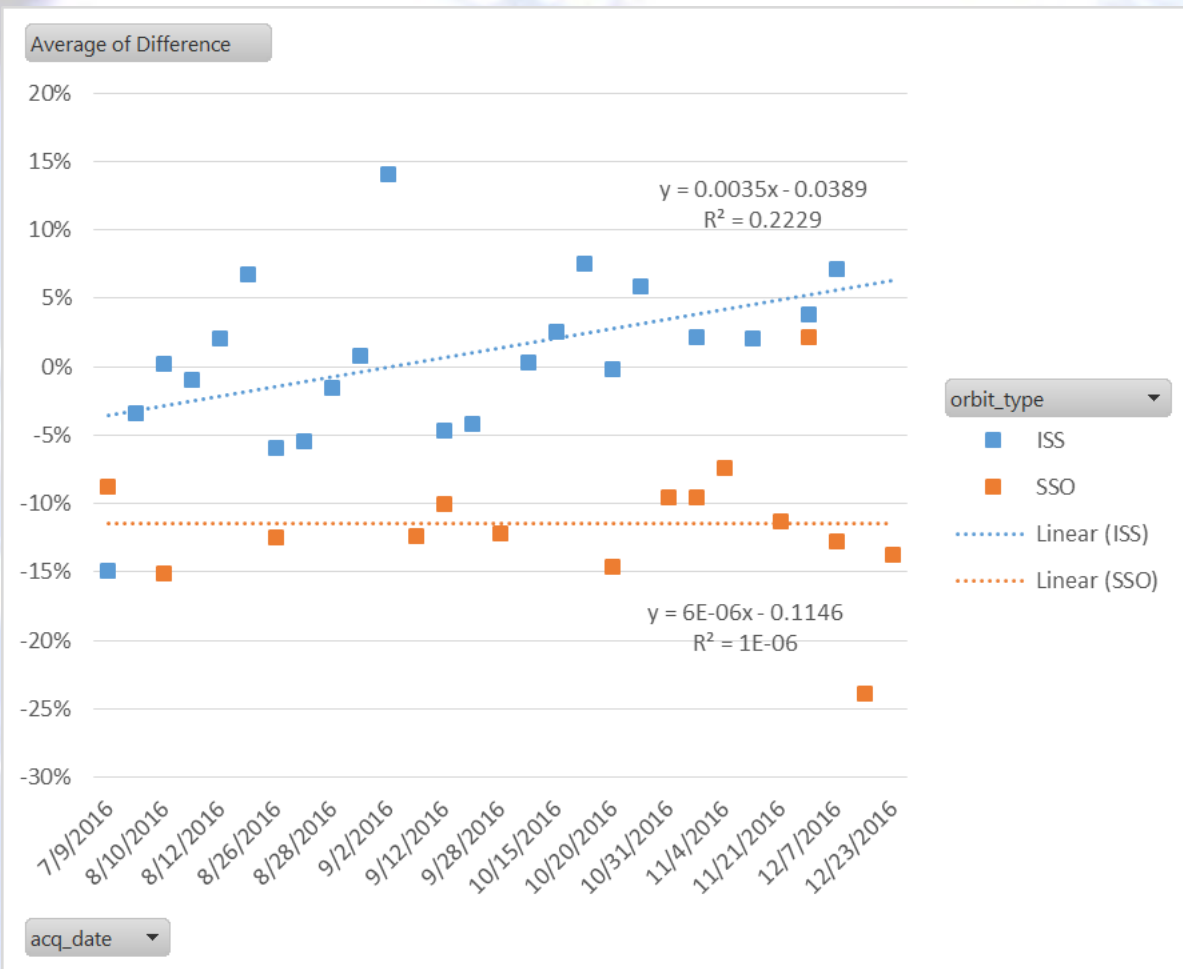


GDA Corp.

The PlanetScope 2 ISS orbit sensors tend to report higher (vs LT8) TOA reflectances in Blue band and lower TOA reflectances in the lower frequencies



## PlanetScope 2 vs Landsat 8 Average % Reflectance Difference (bright pseudo-invariant LC, all AOIs, sensor and band averages)



- PlanetScope 2 ISS scenes seem to be brighter than Landsat 8
- PlanetScope 2 SSO scenes seem to be darker than Landsat 8
- Indications of a temporal trend in PlanetScope 2 imagery overall brightness
  - SSO: Slight decrease? Stable?
  - ISS : Increase?
  - Inconclusive (insufficient repeat imagery)

# Conclusions

- High correlation between co-incident / co-located PlanetScope 2 and Landsat 8 imagery
  - $R^2$ : 0.85 to 0.95
  - Across all analyzed locations, dates, PlanetScope 2 sensors, bands, and LC types
  - Red band has the highest correlation
- PlanetScope 2 Green, Red, and NIR band value is the most important predictor for the corresponding Landsat 8 spectral band
- PlanetScope 2 Green band is the most important predictor for Landsat 8 Blue band

# Conclusions

- For bright pseudo-invariant LC types: A small but measurable and repeatable variability in PlanetScope 2 TOA reflectances per orbit, satellite, and spectral band
  - SSO imagery:
    - Tends to be darker than Landsat 8
    - Tend to report lower values for all bands than Landsat 8
    - Indications of either a stable values or a slight decrease in overall brightness over time
  - ISS imagery :
    - Tends to be brighter than Landsat 8
    - Tend to report higher values in Blue band than Landsat 8
    - Tends to report lower values in Green, Red, and NIR than Landsat 8
    - Indications of a slight increase in overall brightness over time
  
- PlanetScope 2 calibration may be further improved by calibration to the surface reflectances



**GDA Corp.**

**Geospatial Data Analysis Corporation**

*Monitoring The World, For A Better Tomorrow*

---

**THANK YOU!**

**16<sup>th</sup> JACIE**

**September 19-21, 2017 USGS, Reston, VA**