Evaluation of the Radiometric Quality of the Planet Constellation

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Executive Summary

This evaluation assessed the radiometric calibration performance of the PlanetScope constellation, Dove Classic, Dove-R, and SuperDove sensors, against well calibrated reference instruments such as NASA's Terra and Aqua MODIS and ESA's Sentinel2. Across all PlanetScope instrument classes, the analysis shows that the constellation's absolute calibration accuracy and temporal stability remain insufficient for many Earth science applications requiring consistent, low uncertainty surface reflectance measurements. Calibration biases of several percent are observed in all visible and near-infrared (VNIR) bands, with the largest biases in the Blue and Green channels. Temporal stability is also limited: typical variability ranges from ~4–5% in the Red and NIR for Dove-R, to 6–12% in other bands and sensor types, exceeding the ~1% required for scientific studies and achieved by MODIS and Sentinel2.

A primary driver of these limitations is the large number of PlanetScope satellites, each with distinct spectral responses and limited cross calibration opportunities, leading to significant satellite to satellite variation. For example, individual SuperDove satellites exhibit calibration ratios ranging from ~1.0 to 1.13 in the NIR, despite generally strong correlations with MODIS. Long term monitoring from 2020–2024 further reveals pronounced temporal discontinuities—likely linked to periodic recalibration events—causing abrupt shifts in SuperDove radiometry. These changes degrade temporal consistency beyond thresholds typically acceptable for climate, land surface monitoring, or timeseries applications.

Reprocessing experiments demonstrate that improved calibration is feasible. A prototype recalibration of SuperDove NIR reflectance, accounting for distinct temporal epochs, reduced month to month variability by a factor of four (from ±0.04 to ±0.01), highlighting the potential for significant performance gains if Planet adopts more rigorous, documented calibration procedures.

Overall, the findings underscore the need for comprehensive prelaunch sensor characterization, robust and transparent inflight calibration (combining onboard references and established vicarious methods), and peer-reviewed documentation of PlanetScope calibration algorithms and updates. While PlanetScope data can offer valuable high resolution observational capability, especially when aggregated or used qualitatively, substantial improvements in calibration accuracy and stability are required for the constellation to meet the standards necessary for long term scientific analyses, harmonized multi-sensor products, and climate quality applications.

Objectives

The main objective of this project was to evaluate the radiometric calibration of very-high spatial resolution (VHR, stated at 3-4 m) satellite data from the PlanetScope constellation. PlanetScope refers to the Planet Labs constellation that includes Dove Classic (PS2), Dove-R (PS2.SD), and SuperDove (PSB.SD) instruments. Dove Classic is the original Planet sensor, with Dove-R following (both 4 band sensors), and SuperDove being the most recent PlanetScope sensor, with 8 bands. We have analyzed the performance of all three PlanetScope sensor models (see Table below for details). Calibration is a prerequisite to ensure that meaningful downstream products, such as surface reflectance, vegetation indices, and retrieval of surface parameters (using radiative transfer models), can be accurately derived. Both accurate absolute calibration (~ 2% accuracy) and spatio-temporal stability (~1%) are necessary for most scientific studies, especially those aiming at detecting changes of the Earth's surface.

PlanetScope Constellation	Number of Bands	Launch Date	De-commission Date	Observations used	Number of Satellites	Acquisition Period in Analysis
Dove Classic	4	Jul 2014	Apr 2022	129	59	Jun 2019 - Jun 2020
Dove-R	4	Mar 2019	Apr 2022	1500	23	Jun 2019 - Jun 2020
SuperDove	8	Mar 2020	-	41046	281	Jun 2019 - Sep 2025

Methodology

We assess and monitor the calibration in the visible and near-infrared (NIR) spectrum by cross-comparing surface reflectance values from different instruments over a large number of uniform sites distributed globally, the "BELMANIP2" sites (Baret et al., 2006; Villaescusa-Nadal et al., 2019), shown in Figure 1. The reference instrument is NASA's MODerate-resolution Imaging Spectroradiometer (MODIS) aboard the Aqua satellite. The same method was applied also to MODIS aboard the Terra satellite, the Visible Infrared Imaging Radiometer Suite (VIIRS) (Roman et al., 2025), as well as the European Space Agency (ESA) sensor, Sentinel-3, to continuously assess PlanetScope calibration performance. We chose to use as a benchmark the cross-comparison between Terra and Aqua MODIS. Additionally, we include results from ESA's MultiSpectral Instrument (MSI) aboard the Sentinel-2A/B missions that acquire data at 10 m spatial resolution.

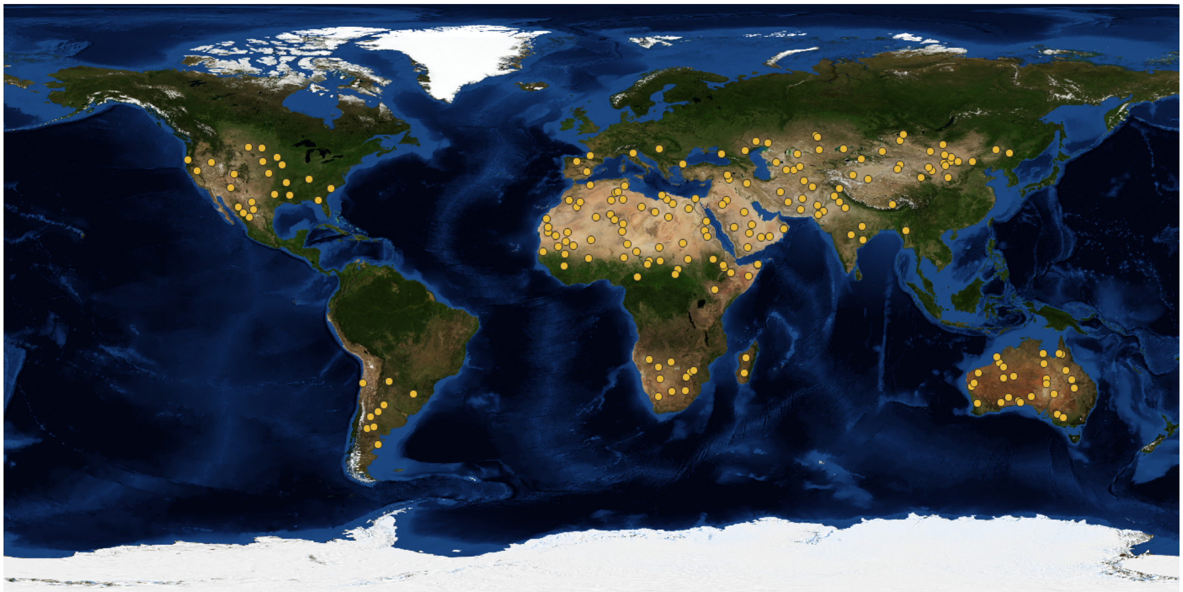


Figure 1: *Geographic distribution of 133 of the BELMANIP2 sites used in the Planet calibration evaluation.*

Findings

The overall conclusion is that PlanetScope calibration is still in need of further improvement; each instrument needs to be characterized prior to launch and calibrated while in flight, and these calibrations should be assessed independently (possibly using methods developed by NASA). In-flight calibration should be achieved by a combination of the onboard system and vicarious calibration methods (Moon, Cloud, Rayleigh Scattering, etc.). Additionally, those calibration tasks need to be documented (e.g., an algorithm theoretical basis document [ATBD], journal article) and peer reviewed.

We attempted to recalibrate the PlanetScope data (SuperDove NIR). The recalibration over the period of September 2021 to July 2024, improved the temporal stability of the SuperDove data by a factor of 4 (from +/- 0.04 to +/-0.01).

Detailed PlanetScope Results

We first analyzed Dove-R because of the amount of data available. Dove-Classic analysis comes after because significantly fewer matchups are available (ten times less), these results should be considered with caution. Finally, the largest dataset both in size and temporal extent is SuperDove, which is the more relevant dataset for the user community.

PlanetScope Dove-R Results

We analyzed 13 months of PlanetScope Dove-R data over 133 of our most stable, in terms of land cover, sites (Figure 1). We acquired 1,500 observations (matchups). The results in this report clearly show that the accuracy of the PlanetScope calibration is not on par with MODIS.

Considering that MODIS meets the calibration and stability requirements for scientific studies mentioned at the outset, we can estimate the "averaged" absolute calibration of PlanetScope to be biased high in the NIR (~3%) and Red (~8%), but more importantly, the stability of the Planetscope record is no better than ~5% in the NIR and Red.

The performance in the Blue and Green bands was also evaluated and found to be worse, which is problematic for deriving surface reflectance through atmospheric correction and some vegetation indices (complementary/alternative to the normalized difference vegetation index [NDVI]). This performance is mainly driven by the fact that there are many different instruments (various physical sensors) that constitute the PlanetScope constellation.

We aggregated the PlanetScope Dove-R data for each site to the Climate Modelling Grid resolution (0.05 deg latitude by 0.05 deg longitude) and recorded average and standard deviation for both top of the atmosphere reflectance and the Dove-R surface reflectance product. We then performed in-house atmospheric correction of the Dove-R top of atmosphere data using near-coincident ancillary information from MODIS (aerosol, ozone, and water vapor) by running the 6S radiative transfer code with the Dove-R spectral responses resampled to 2.5 nm. The surface reflectance obtained was compared to the Dove-R surface reflectance product and the agreement was good. Finally, the Dove-R surface reflectance obtained was corrected for bidirectional reflectance distribution function (BRDF) effects using MODIS BRDF information, with standard sun at 45 deg and nadir view geometry.

Although we only selected days when MODIS acquired clear observations (no cloud obstruction or high aerosol cases) for both Aqua and Terra, some residual cloud contamination persists in the PlanetScope Dove-R data, which was mitigated by filtering out cases where the standard deviation of the Dove-R surface reflectance in the Blue was greater than 0.02.

Figure 2 summarizes the results obtained over the 13-month period in the Red and the NIR. The top panel is Terra MODIS versus Aqua MODIS, which is our reference for adequate calibration, and the bottom panel is Planet Dove-Rversus Aqua MODIS.

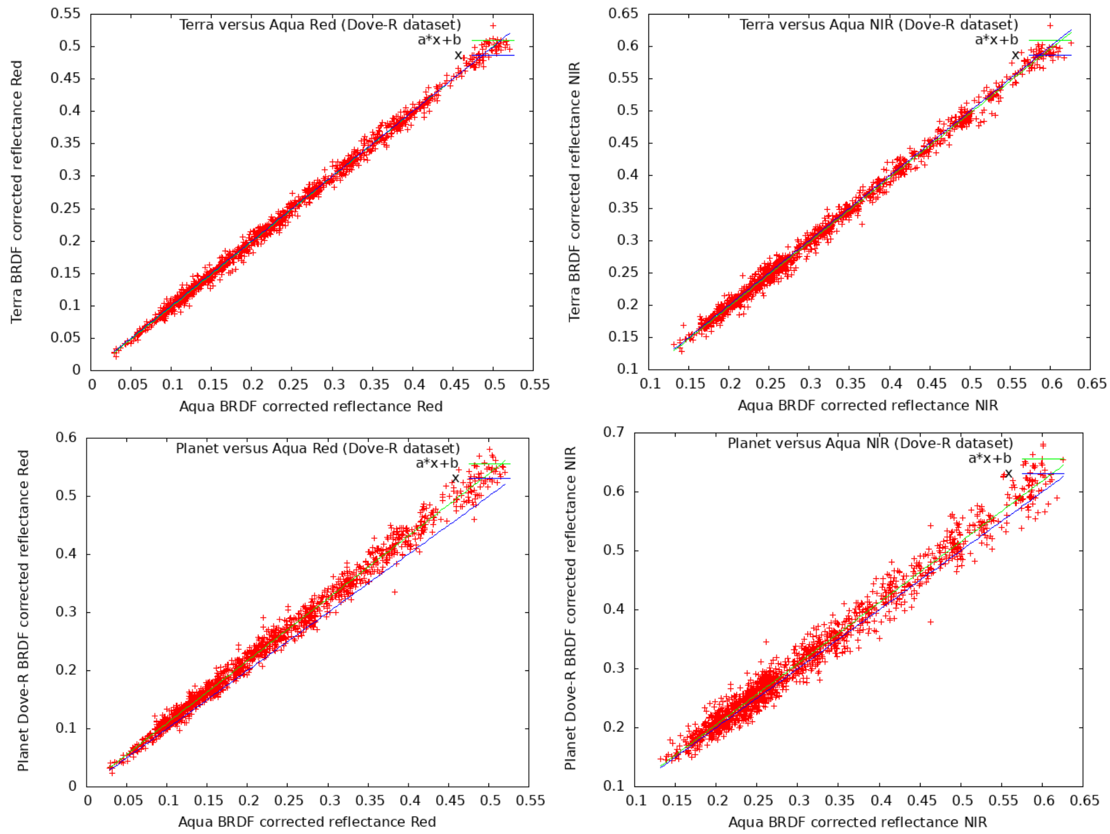
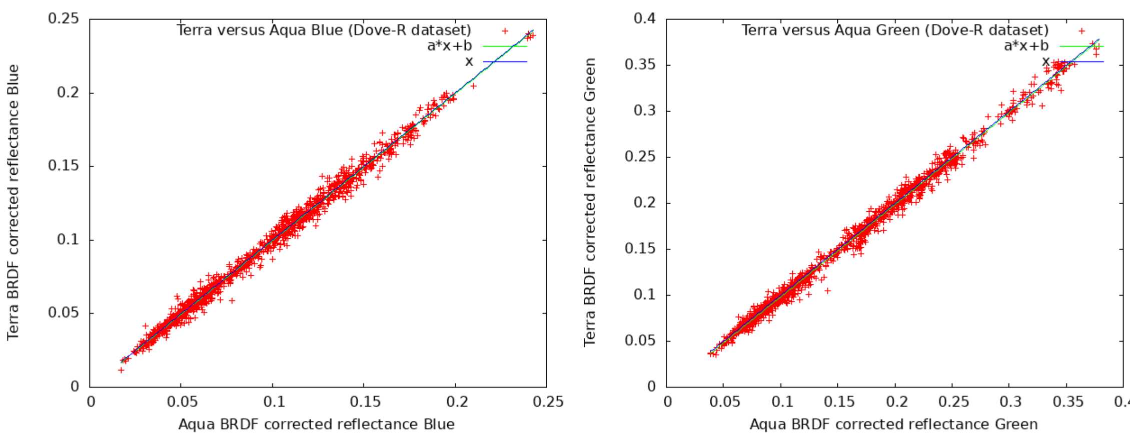


Figure 2: Scatter plots of observations, Terra MODIS vs Aqua MODIS (top) and Planet Dove-R vs Aqua MODIS (bottom) in both Red and NIR bands over the 133 sites in Figure 1, from June 2019 to June 2020 period.

Figure 3 summarizes the results obtained over the 13-month period in the Blue and the Green. Again, the top panel is Terra MODIS versus Aqua MODIS, our reference for calibration, and the bottom panel is Planetscope Dove-R versus Aqua MODIS.



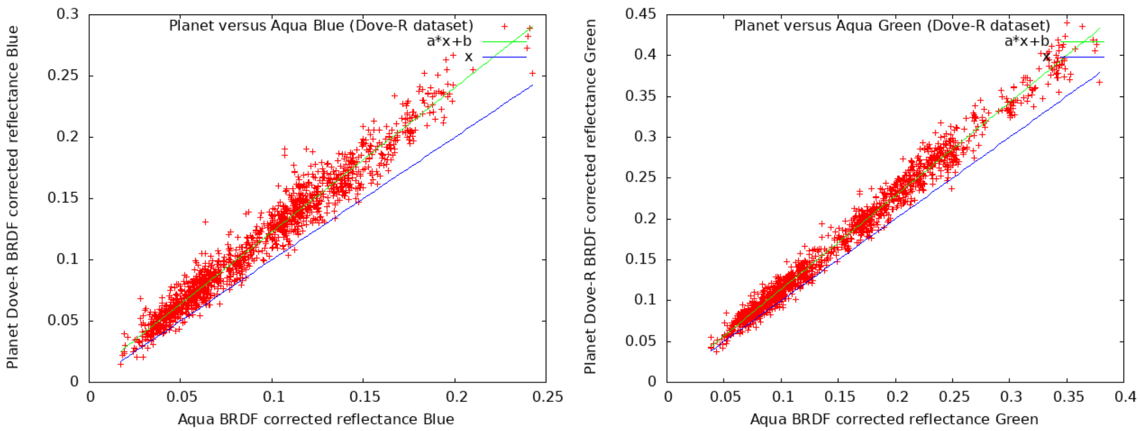


Figure 3: Scatter plots of observations in the Blue and the Green, Terra MODIS vs Aqua MODIS (top) and PlanetScope Dove-R vs Aqua MODIS (bottom) in both Blue and Green over the 133 sites in Figure 1 from June 2019 to June 2020.

Figures 2 and 3 demonstrate the higher dispersion of Dove-R and its lower correlation with Aqua MODIS than that of Terra and Aqua MODIS. This is caused by the large number different instruments that constitute the PlanetScope constellation that require separate calibrations that are also time dependent. The statistics for the Red and NIR bands are summarized in Table 1a, and Table 1b summarizes the Blue and the Green bands.

Table 1a: Linear Regression parameters for Dove-R vs Aqua MODIS and Terra MODIS vs Aqua MODIS.

	R^2	Slope	Intercept	Slope (forced through origin)
Planet NIR	0.978	1.034	-0.001	1.030
Terra NIR	0.995	0.996	-0.002	0.992
Planet Red	0.990	1.074	0.002	1.082
Terra Red	0.997	1.004	-0.002	0.998

Table 1b: Linear Regression parameters for both Dove-R vs Aqua MODIS and Terra MODIS vs Aqua MODIS.

	R^2	Slope	Intercept	Slope (forced through origin)
Planet Blue	0.959	1.177	0.005	1.224
Terra Blue	0.993	0.998	-0.000	0.996
Planet Green	0.983	1.144	-0.000	1.143
Terra Green	0.994	1.001	-0.002	0.991

The inter-comparison was also performed on a monthly timestep, as is done routinely with the Terra MODIS and VIIRS instruments. The results are presented in Figures 4a/4b and Tables 2a/2b showing the slope forced through origin (as ratio on the y-axis, and cal ratio in the tables) for each month.

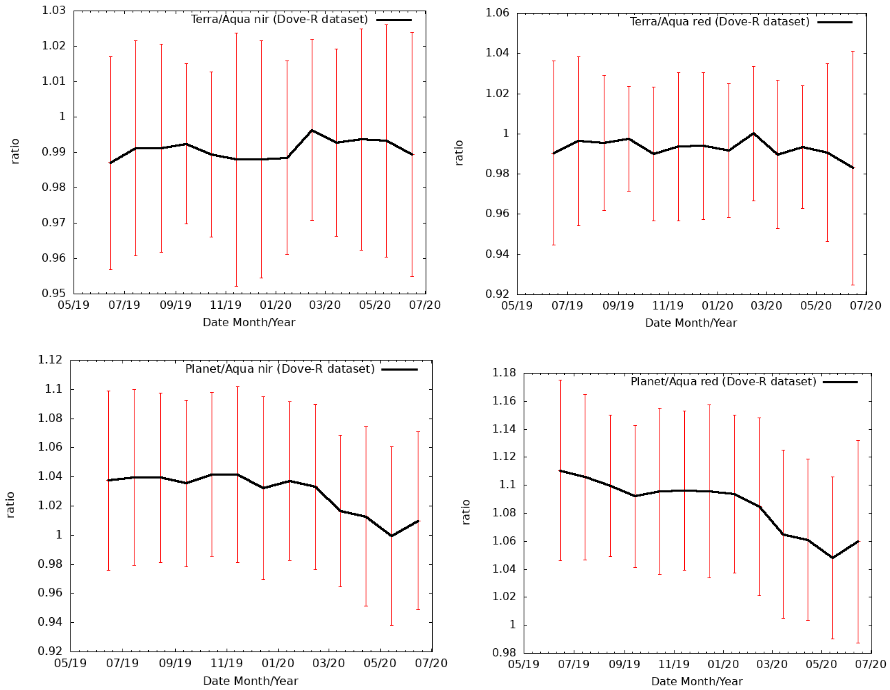


Figure 4a: Cross-Comparison of Terra/Aqua MODIS (top) and Dove-R/Aqua MODIS (bottom) in the Red and near NIR bands over the 133 sites from Figure 1. The error bars are standard deviations over a given month. Note that the range of Y-axis values (min/max) is different on the four plots.

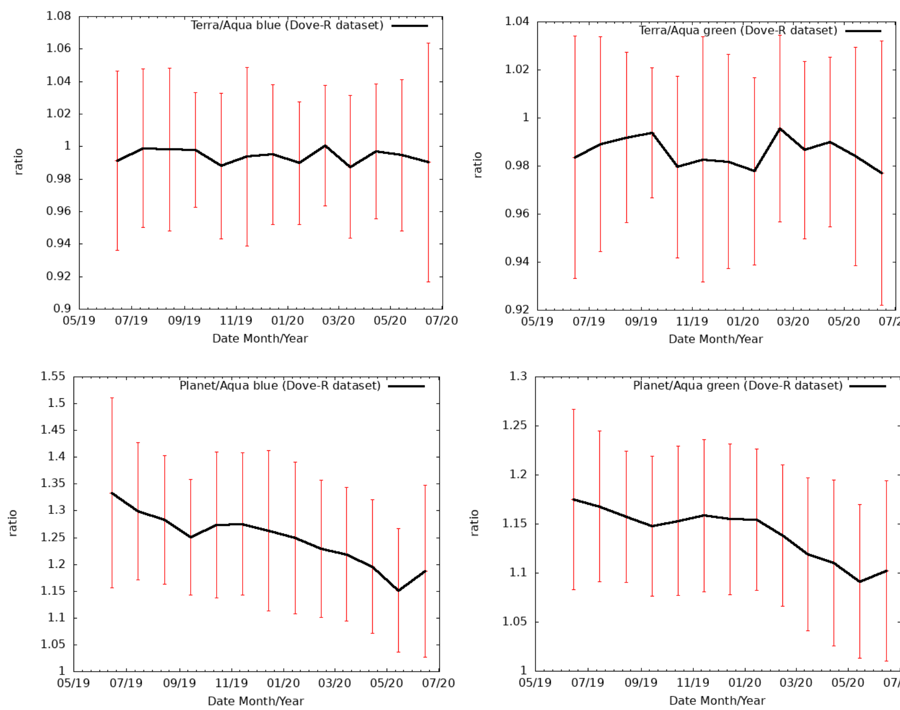


Figure 4b: Cross-Comparison of Terra/Aqua MODIS (top) and Dove R/Aqua MODIS (bottom) in the Blue and Green bands over the 133 sites of Figure 1. The error bars are standard deviations over a given month. Note that the range of Y-axis values (min/max) is different on the four plots.

Table 2a: Statistics for monthly inter-comparison between Terra/Aqua MODIS and between Dove-R /Aqua MODIS in NIR and Red.

	NIR		Red		Number of observations
	Cal Ratio	StDev	Cal Ratio	StDev	
Planet Jun 19	1.037	0.061	1.111	0.064	90
Planet Jul 19	1.040	0.060	1.106	0.059	103
Planet Aug 19	1.040	0.058	1.100	0.051	127
Planet Sep 19	1.036	0.057	1.092	0.051	133
Planet Oct 19	1.041	0.056	1.096	0.059	131
Planet Nov 19	1.042	0.060	1.096	0.057	139
Planet Dec 19	1.032	0.063	1.096	0.062	126
Planet Jan 20	1.037	0.054	1.094	0.056	112
Planet Feb 20	1.033	0.057	1.085	0.063	128
Planet Mar 20	1.017	0.052	1.065	0.060	96
Planet Apr 20	1.013	0.061	1.061	0.058	105
Planet May 20	0.999	0.061	1.048	0.058	110
Planet Jun 20	1.010	0.061	1.060	0.072	100
Terra Jun 19	0.987	0.030	0.990	0.046	90
Terra Jul 19	0.991	0.030	0.996	0.042	103
Terra Aug 19	0.991	0.029	0.995	0.033	127
Terra Sep 19	0.992	0.023	0.998	0.026	133
Terra Oct 19	0.989	0.023	0.990	0.033	131
Terra Nov 19	0.988	0.036	0.994	0.037	139
Terra Dec 19	0.988	0.033	0.994	0.037	126
Terra Jan 20	0.989	0.027	0.992	0.033	112
Terra Feb 20	0.996	0.026	1.000	0.033	128
Terra Mar 20	0.993	0.027	0.990	0.037	96
Terra Apr 20	0.994	0.031	0.994	0.031	105
Terra May 20	0.993	0.033	0.991	0.044	110
Terra Jun 20	0.989	0.034	0.983	0.058	100

Table 2b: Statistics for monthly inter-comparison between Terra/Aqua MODIS and between Dove-R/Aqua MODIS in Blue and Green.

	Blue		Green		Number of observations
	Cal Ratio	StDev	Cal Ratio	StDev	
Planet Jun 19	1.334	0.177	1.175	0.092	90
Planet Jul 19	1.299	0.128	1.168	0.077	103
Planet Aug 19	1.283	0.120	1.157	0.067	127
Planet Sep 19	1.250	0.108	1.148	0.071	133
Planet Oct 19	1.274	0.136	1.153	0.076	131
Planet Nov 19	1.276	0.133	1.159	0.077	139
Planet Dec 19	1.263	0.150	1.155	0.077	126
Planet Jan 20	1.249	0.141	1.155	0.072	112
Planet Feb 20	1.229	0.128	1.138	0.072	128
Planet Mar 20	1.219	0.125	1.119	0.078	96
Planet Apr 20	1.196	0.124	1.110	0.085	105
Planet May 20	1.151	0.116	1.091	0.078	110

Planet Jun 20	1.188	0.161	1.102	0.092	100
Terra Jun 19	0.991	0.055	0.984	0.050	90
Terra Jul 19	0.999	0.049	0.989	0.045	103
Terra Aug 19	0.998	0.050	0.992	0.036	127
Terra Sep 19	0.998	0.035	0.994	0.027	133
Terra Oct 19	0.988	0.045	0.980	0.038	131
Terra Nov 19	0.994	0.055	0.983	0.051	139
Terra Dec 19	0.995	0.043	0.982	0.045	126
Terra Jan 20	0.990	0.038	0.978	0.039	112
Terra Feb 20	1.001	0.037	0.996	0.039	128
Terra Mar 20	0.988	0.044	0.987	0.037	96
Terra Apr 20	0.997	0.041	0.990	0.035	105
Terra May 20	0.995	0.047	0.984	0.045	110
Terra Jun 20	0.990	0.073	0.977	0.055	100

It can be seen in Figures 4a and 4b, and Tables 2a and 2b, PlanetScope Dove-R does not compare as well as Terra MODIS compares with Aqua MODIS.

There is a bias of about 2% in the NIR, 5% in the Red, 15% in the Green, and 18% in the Blue (this may be due in part to relative spectral responses differences). However, there is a month-to-month variability in the Dove-R data, especially after January 2020, that is more marked in the Blue and Green bands. The standard deviation in the Dove-R/Aqua ratio is also higher than for the Terra/Aqua ratio (almost twice as high in the NIR, Red, and Green, and three times as high in the Blue). If we consider the stability of the Terra and Aqua MODIS calibration to be ~1%, and the error in inter-comparison methodology to be the standard deviation of the Terra/Aqua ratio by summing the error quadratically (assuming they are independent), we can estimate the calibration stability in PlanetScope (E_{Planet}) to be:

$$E_{Planet} = \sqrt{{\sigma_{Planet}}^2 - {\sigma_{Terra}}^2}$$

From Tables 1a, using an average standard deviation of 0.06 in the NIR and 0.06 in the Red for Dove-R and 0.03 in the NIR and 0.04 in the Red for MODIS, we estimated that the Planet calibration stability is around 5% in the NIR and 4.5% in the Red. Using the same approach in the Blue and Green (Table 1b), we estimated the Dove-R calibration stability to be 12.5% in the Blue and 6.5% in the Green.

PlanetScope Dove Classic Results

We also performed an analysis of the PlanetScope Dove Classic and SuperDove instruments.

For Dove Classic, we had to eliminate one instrument (ID 1105) that was consistently measuring lower reflectance’s than the rest of the constellation in all bands (see Figure 5).

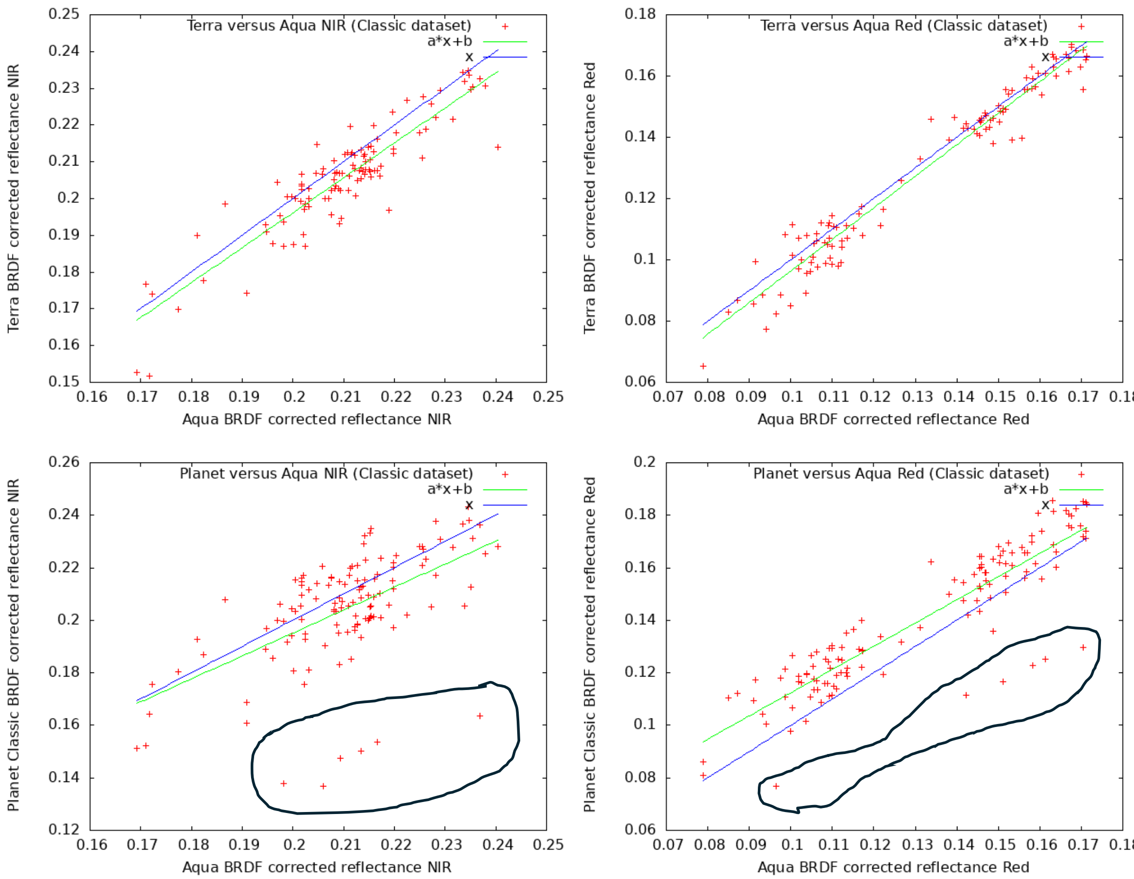


Figure 5: Scatter plots of Red and NIR observations for MODIS Terra vs Aqua (top) and Dove Classic vs Aqua MODIS (bottom) in both Red and NIR bands over the 133 sites during June 2019 to June 2020 period. One Dove Classic instrument, ID 1105, is providing consistently lower measurements in both Red and NIR (outlined in black).

The analysis for Dove Classic is shown in Figures 6a and 6b, and Tables 3a and 3b during the June 2019 to June 2020 period over the test sites. Despite the fact the test dataset is rather small (123 observations), we did not observe any significant improvement from an earlier assessment performed on a January 2019 to June 2019 dataset (reported previously in a separate internal report). We found the results in the Red and NIR were very similar: std dev 0.06 (previous) vs 0.058 (now) in the NIR, and 0.08 (previous) vs 0.073 (now) in the Red. The situation is slightly better in the Blue and Green: 0.21 (previous) vs 0.14 (now) in the Blue, and 0.10 (previous) vs 0.074 (now) in the Green.

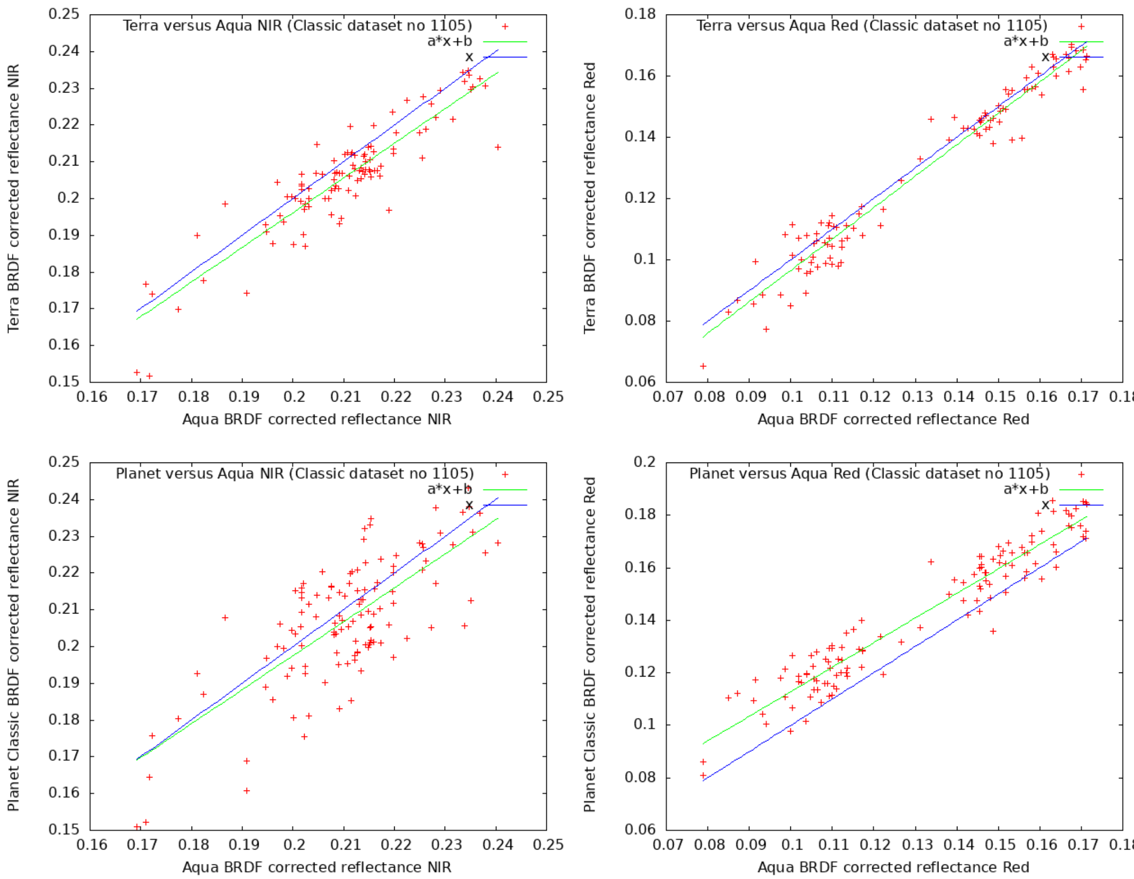


Figure 6a: Scatter plots of Red and NIR observations Terra vs Aqua MODIS (top) and Dove Classic vs Aqua MODIS (bottom) in both Red and NIR bands over the 133 sites during June 2019 to June 2020 period (instrument ID 1105 is excluded).

Table 3a: Linear Regression parameters and noise analysis (stdev) for Dove Classic vs Aqua and for Terra vs Aqua.

	R^2	Slope	Intercept	Slope (forced through origin)	StDev of ratio	Number of observations
Planet NIR	0.529	0.917	0.014	0.985	0.058	123
Terra NIR	0.812	0.944	0.007	0.979	0.031	123
Planet Red	0.910	0.930	0.020	1.078	0.073	123
Terra Red	0.957	1.023	-0.006	0.982	0.052	123

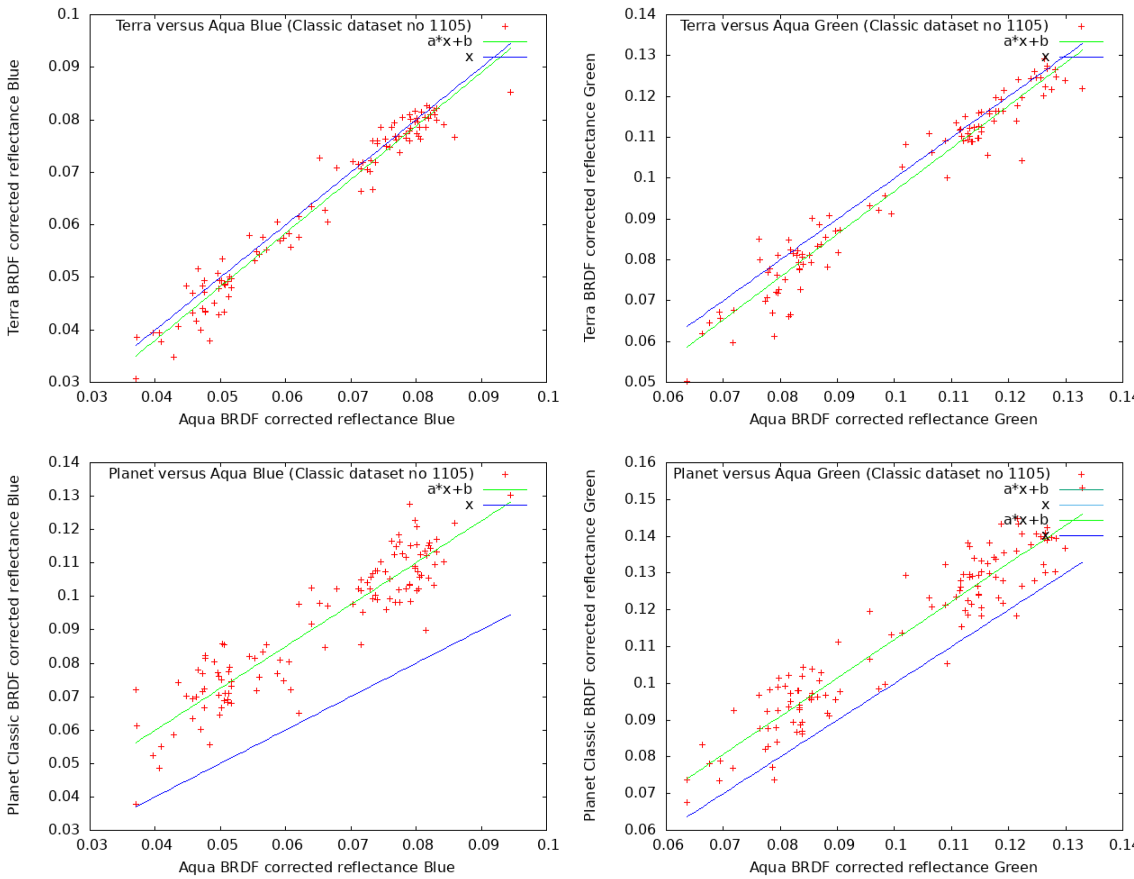


Figure 6b: Scatter plots of observations Terra vs Aqua MODIS (top) and Dove Classic vs Aqua MODIS (bottom) in both Blue and Green bands over the 133 sites during the June 2019 to June 2020 period (instrument ID 1105 is excluded).

Table 3b: Linear Regression parameters and noise analysis (stdev) for Dove Classic vs. Aqua MODIS and MODIS Terra vs Aqua.

	R^2	Slope	Intercept	Slope (forced through origin)	StDev of ratio	Number of observations
Planet Blue	0.849	1.250	0.010	1.399	0.141	123
Terra Blue	0.961	1.018	-0.003	0.980	0.055	123
Planet Green	0.892	1.036	0.008	1.117	0.074	123
Terra Green	0.950	1.048	-0.008	0.972	0.056	123

PlanetScope SuperDove Results

The analysis for SuperDove is shown in Figures 7a and 7b, and Tables 4a and 4b during the June 2019 to June 2020 period over the test sites. With the caveat that the dataset is limited (221 observations), the results are slightly better than for other Dove types (Classic and Dove-R), stdev of ~0.06 in both Red and NIR, 0.076 in the Green, and 0.096 in the Blue. However, all the bands show a high bias, ~10% in Red and NIR and ~16% in the Green and the Blue.

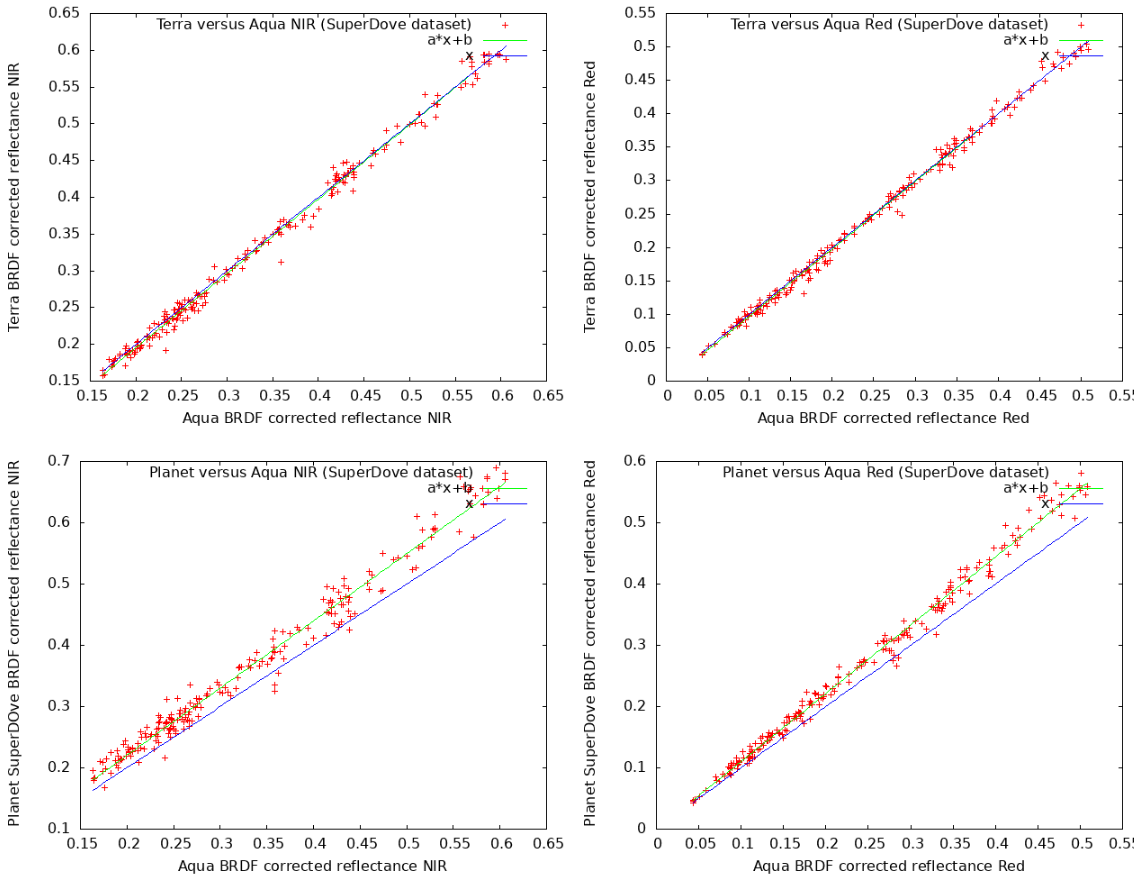


Figure 7a: Scatter plots of observations Terra vs Aqua MODIS (top) and SuperDove vs Aqua MODIS (bottom) in both the NIR and Red bands over the 133 sites during the June 2019 to June 2020 period.

Table 4a: Linear Regression parameters and noise analysis (stdev) for SuperDove vs Aqua MODIS and MODIS Terra vs Aqua.

	R^2	Slope	Intercept	Slope (forced through origin)	StDev of ratio	Number of observations
Planet NIR	0.979	1.100	0.000	1.101	0.060	221
Terra NIR	0.994	1.012	-0.007	0.993	0.033	221
Planet Red	0.991	1.116	-0.002	1.111	0.055	221
Terra Red	0.996	1.009	-0.004	0.996	0.043	221

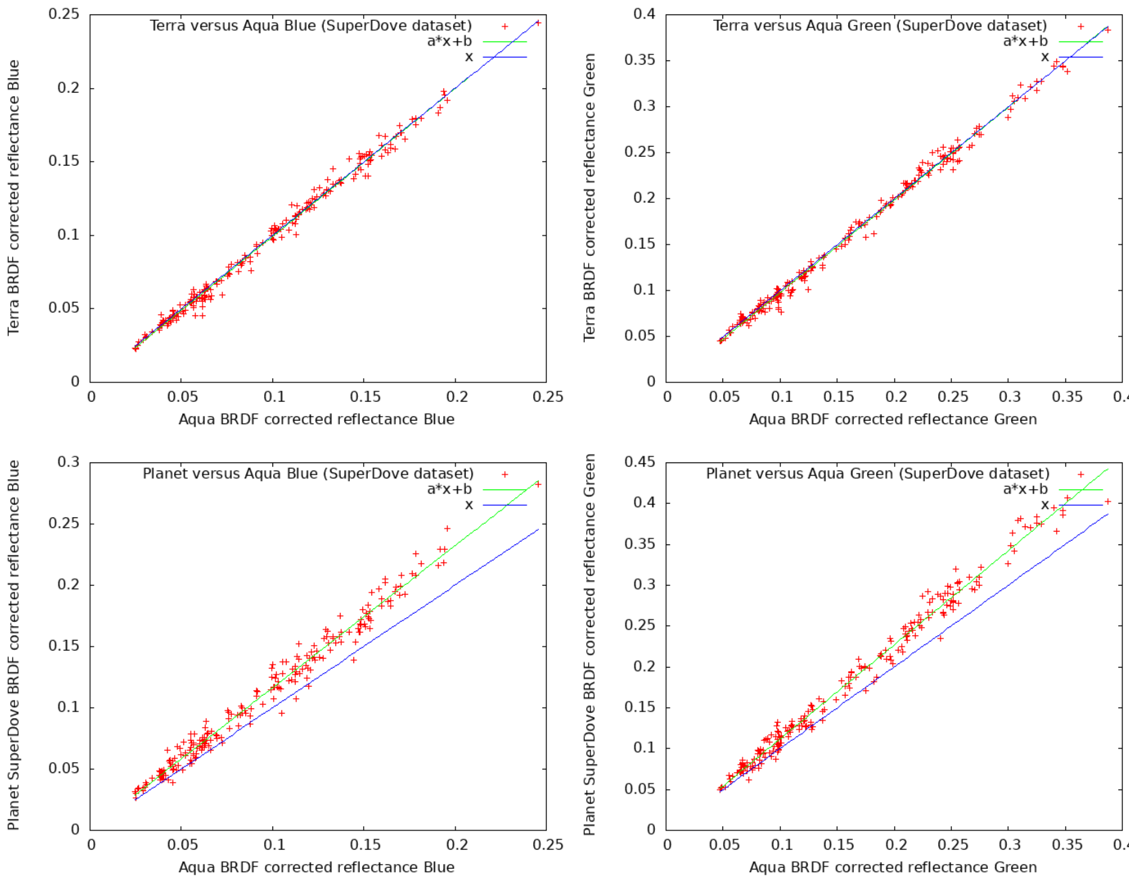


Figure 7b: Scatter plots of observations Terra vs Aqua MODIS (top) and SuperDove vs Aqua MODIS (bottom) in both Blue and Green bands over the 133 sites during June 2019 to June 2020 period.

Table 4b: Linear Regression parameters and noise analysis (stdev) for SuperDove vs Aqua MODIS and MODIS Terra vs Aqua.

	R^2	Slope	Intercept	Slope (forced through origin)	StDev of ratio	Number of observations
Planet Blue	0.978	1.165	-0.000	1.165	0.096	221
Terra Blue	0.992	1.008	-0.001	0.995	0.052	221
Planet Green	0.986	1.156	-0.004	1.138	0.076	221
Terra Green	0.994	1.010	-0.003	0.993	0.048	221

Routine Monitoring of SuperDove (NIR) and Comparison with Sentinel-2

During this phase of the project, we continuously monitored the calibration of SuperDove and applied the same analysis to Sentinel-2A/B (S2). We analyzed more than 30,000 matchups during the 2020-2024 period. The results are presented in Figures 8a-c. Figure 8a shows the SuperDove instrument (red line) exhibits significant temporal variation (1.03 to 1.11) that exceeds the tolerable threshold for NASA/ESA instrument users. As a reference, Terra MODIS ratio (blue line) shows substantially less temporal variation (0.985 to 1.0). The monthly standard deviation of SuperDove ratio (green line) is also substantially higher than that of the reference Terra MODIS (magenta line).

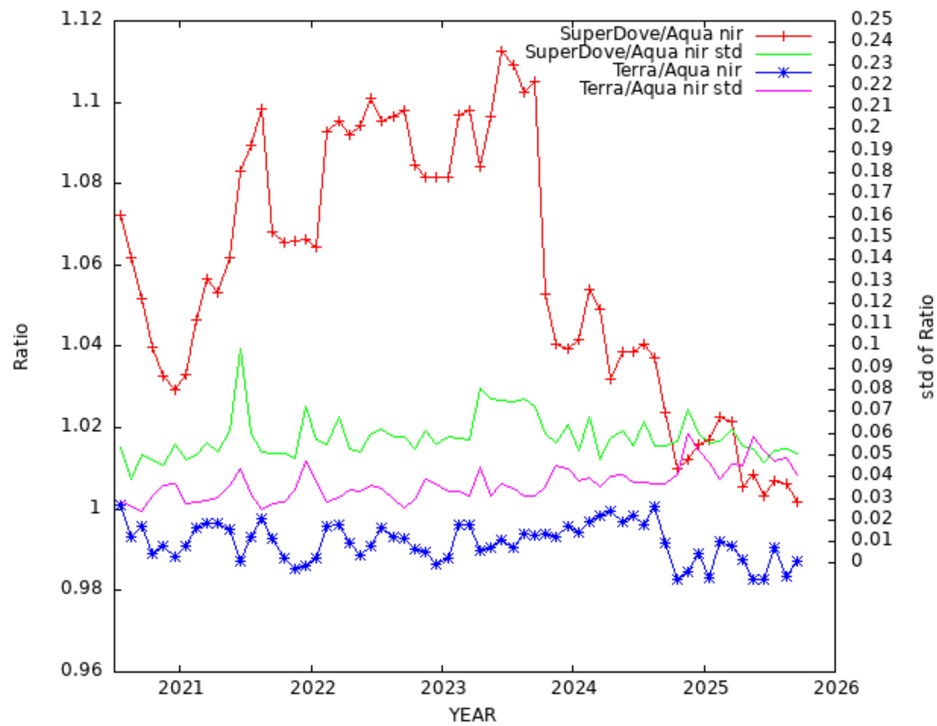


Figure 8a: Averaged monthly ratio between SuperDove and Aqua MODIS NIR band 2 (red line), and between Terra MODIS NIR and Aqua MODIS NIR (blue line) for 40492 matchups over 133 sites. Also shown is the monthly standard deviation of the ratio (shown in green for Planet and magenta for Terra MODIS).

The results of a similar analysis using the Sentinel 2 (S2) confirmed the lower quality Planet performance. Figure 8b shows the results for S2 NIR (band 8), a narrow NIR band for which the spectral response is close to the MODIS NIR (band 2). The S2 results (red line) are very stable (1.0 to 1.02) and the monthly standard deviation (Std) of S2 (green line) and Terra MODIS (magenta line) are on average at the same level (0.03 to 0.04).

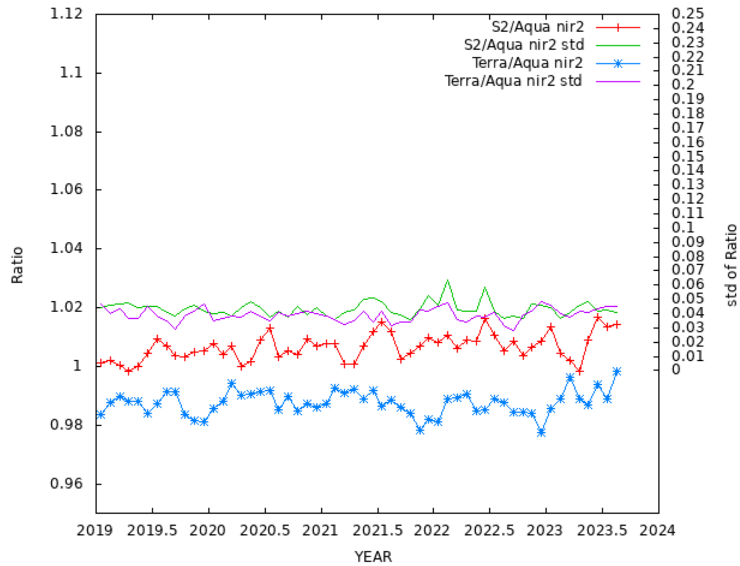


Figure 8b: Averaged monthly ratio between S2 band 8 (narrow NIR) and Aqua MODIS NIR band 2 (red line), and Terra MODIS NIR and Aqua MODIS NIR band 2 (blue line) for 23,054 matchups over 133 sites. Also shown is the monthly standard deviation of the ratio (shown in green for S2 and magenta for Terra MODIS).

We further analyzed S2 by using the other NIR band, band 8A, which is wider than band 8 and not as close to MODIS NIR band 2. The results are presented in Figure 8c. The S2 band 8A (red line) is not as close to 1 as band 8 because of the spectral response differences between MODIS band 2 and S2 band 8A, however, it is temporally stable (0.95 to 0.97). As with band 8, the monthly standard deviation of the ratio for S2 band 8A (green line) and Terra MODIS (magenta line) on average are at the same level (0.03-0.04).

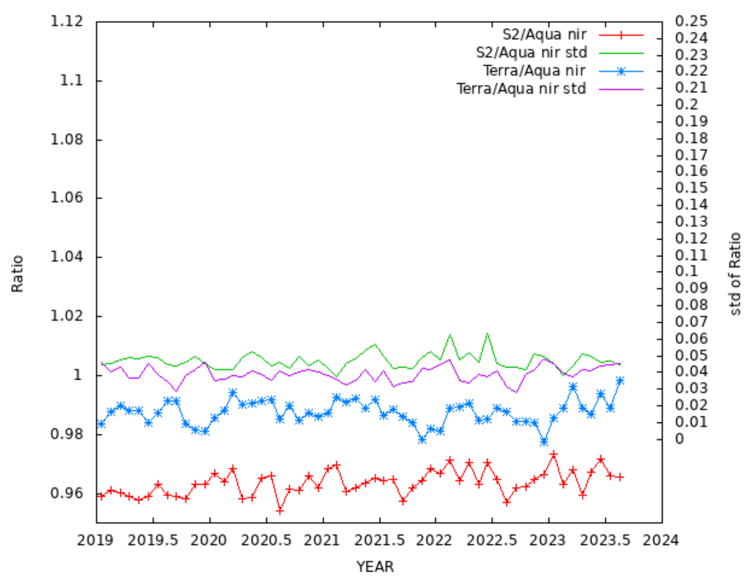


Figure 8c: Averaged monthly ratio between S2 band 8A (wide NIR) and Aqua MODIS NIR band 2 (red line) and Terra MODIS NIR and Aqua MODIS NIR band 2 (blue line) for 23054 matchups over 133 sites. Also shown is the monthly standard deviation of the ratios (in green and magenta, for S2 and Terra MODIS, respectively).

The lower quality calibration performance of PlanetScope SuperDove could be explained by the fact that the constellation is composed of over 270 SuperDove satellites, each of which have a limited amount of data available for calibration against, for example, Sentinel-2 and/or MODIS sensors. For example, Figure 9 shows a comparison of Aqua MODIS with two different Planet SuperDove satellites (ID 2256 and ID 24be) for reflectance in the NIR, corrected for BRDF, over BELMANIP sites with matchups. Despite the limited number of matchups, each SuperDove satellite observation was correlated with MODIS, however, the slope of the relationship is quite different between the two PlanetScope SuperDove sensors (1.02 vs 1.17).

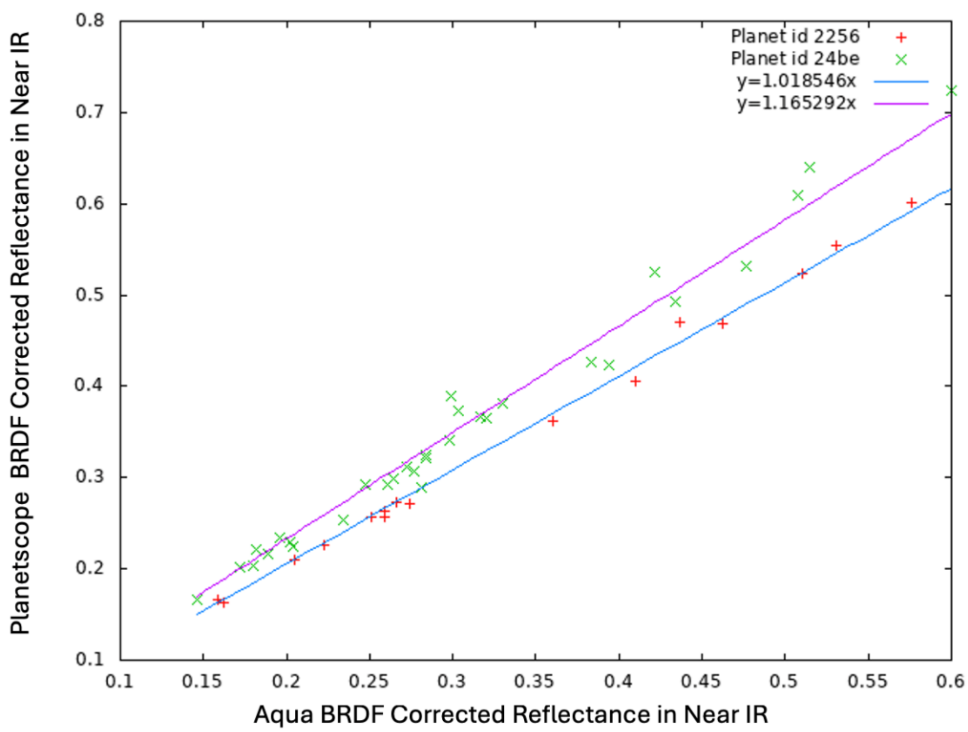


Figure 9: Comparison of Aqua MODIS and Superdove BRDF corrected reflectance in near IR for multiple sites and times for two different SuperDove satellites.

To further investigate this issue, we looked at the calibration of each individual PlanetScope SuperDove satellite processed in this routine monitoring. Figure 10 shows the calibration ratio obtained for each satellite, sorted from the lowest to the highest value, as well as the correlation coefficient (r^2) of the individual SuperDove satellite reflectance with Aqua MODIS reflectance. In general, despite the small number of matchups for each SuperDove satellite, the correlation is quite acceptable (close to 1.0), however, the calibration ratio is quite variable and ranges from 1.0 to 1.13. The variability of the calibration ratio from satellite to satellite explains the poor calibration performance of PlanetScope SuperDove compared to S2.

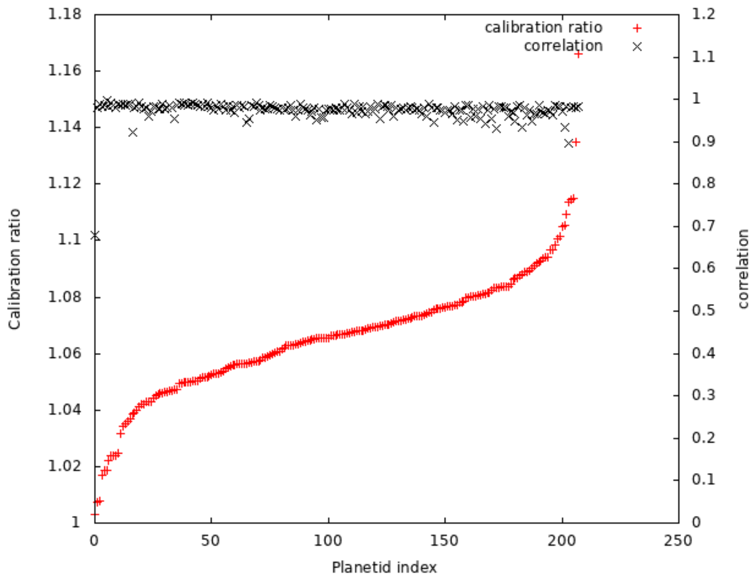


Figure 10: Calibration ratio and correlation (r^2) for individual, SuperDove satellites (each planetid index corresponds to a unique SuperDove satellite).

Possible Recalibration of the PlanetScope SuperDove Data

By carefully analyzing the temporal variation of the SuperDove calibration in the NIR, we have been able to identify three abrupt changes at different dates, indicated by the red arrows in Figure 11. The changes occurred in September 2021, February 2022, and September 2023. There could be more changes that are less pronounced, in September 2022 and February 2023.

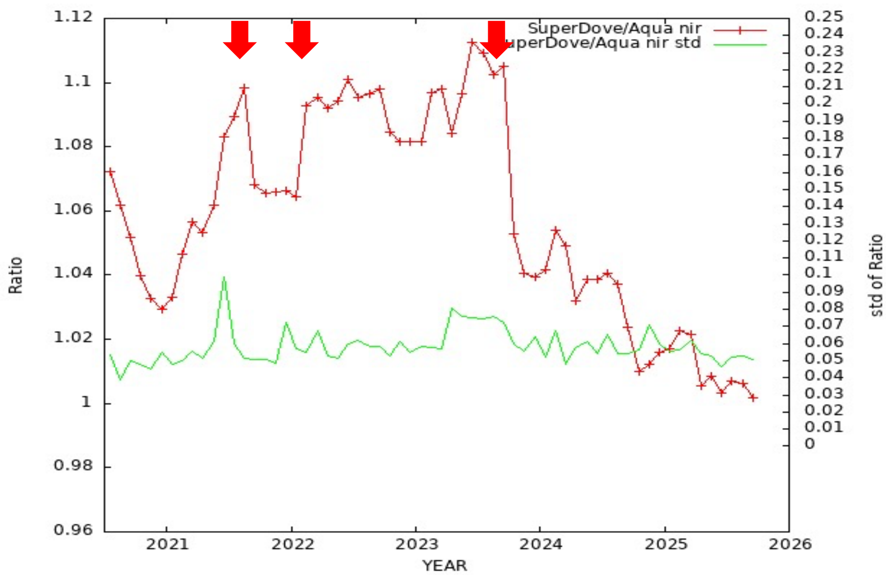


Figure 11: SuperDove monthly calibration ratio derived from Aqua MODIS observations over BELMANIP2 sites.

It is hypothesized that these abrupt changes are a result of Planet's periodic recalibration of their satellite assets. We prototyped the recalibration of SuperDove based on our approach, using four different epochs, to account for those recalibration events. Each asset calibration is derived for

1) beginning of our collection record to August 2021,
2) September 2021 to January 2022,
3) February 2022 to September 2023,
4) from October 2023 till the end of our record.

The evaluation of the resulting recalibrated record is presented in Figure 12. The temporal stability is greatly improved, especially after August 2021, where the ratio for recalibrated data ranges from 0.99 to 1.015 compared to 1.03 to 1.11 for the original data.

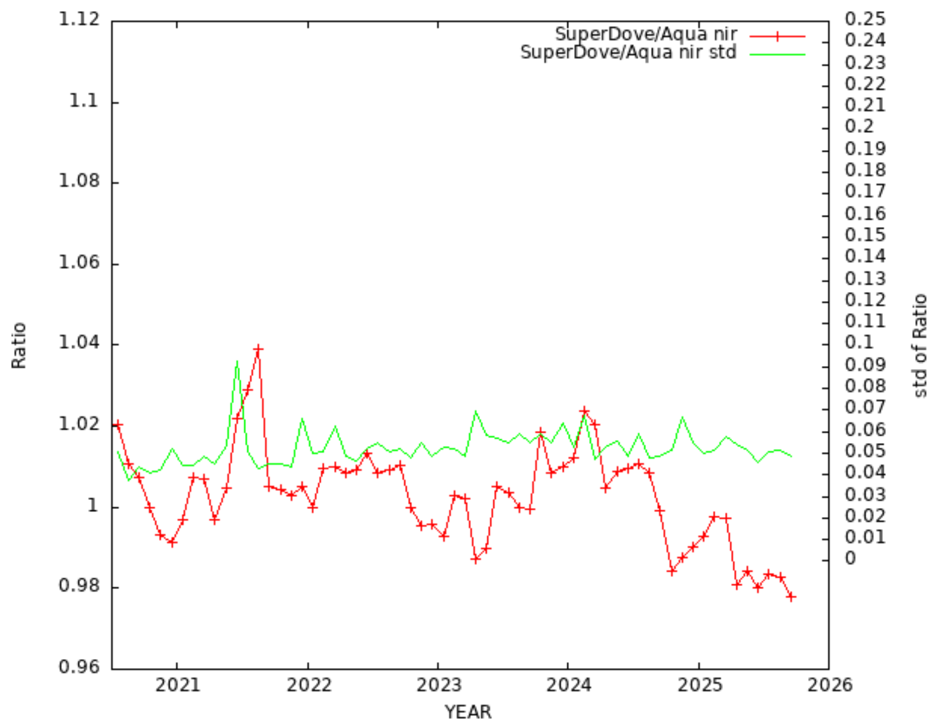


Figure 12: SuperDove recalibrated monthly calibration ratio derived from Aqua observations over BELMANIP2 sites.

Conclusions

The overall radiometric calibration of the PlanetScope constellation (Dove Classic, Dove-R, and SuperDove) currently falls short of the standards required for NASA's long-term scientific Earth observation and climate-quality applications. While PlanetScope provides highly valuable high-spatial-resolution imagery for qualitative use and aggregated monitoring, its absolute calibration accuracy and temporal stability are not yet on par with reference instruments like NASA's MODIS or ESA's Sentinel-2 and users should take note.

The PlanetScope constellation exhibits calibration biases of several percent across all visible and near-infrared (VNIR) bands, with the most significant errors in the Blue and Green region of the spectrum. Temporal stability ranges from 4-5% in the Red and IR regions and 6-12% in other regions, well above the 1% desired stability threshold. The root cause of these limitations is the constellation architecture (over 300 SuperDove satellites).

SuperDove monitoring from 2020–2024 revealed abrupt temporal discontinuities in the data. These abrupt shifts degrade temporal consistency and are highly likely to be caused by the vendor's periodic, undocumented recalibration events.

Improved calibration is very feasible. A prototype recalibration of SuperDove NIR data, accounting for specific temporal epochs, successfully reduced the month-to-month variability by a factor of four (from ±0.04 to ±0.01), bringing it much closer to scientific requirements.

To meet the standards necessary for harmonized multi-sensor products and climate studies, each instrument should be characterized prior to launch and in-flight using a combination of onboard systems and established vicarious methods (e.g., Moon, Cloud, Rayleigh Scattering), with calibration algorithms and updates both documented and peer-reviewed.

References

Baret, F., Morissette, J. T., Fernandes, R. A., Champeaux, J. L., Myneni, R. B., Chen, J., ... & Nickeson, J. E. (2006). Evaluation of the representativeness of networks of sites for the global validation and intercomparison of land biophysical products: Proposition of the CEOS-BELMANIP. *IEEE Transactions on Geoscience and Remote Sensing*, *44*(7), 1794-1803.

Román, Miguel O., Chris Justice, Ian Paynter, Peter B. Boucher, Sadashiva Devadiga, Arthur Endsley, Angela Erb et al. "Continuity between NASA MODIS Collection 6.1 and VIIRS Collection 2 land products." Remote Sensing of Environment 302 (2024): 113963.

Villaescusa-Nadal, J. L., Franch, B., Roger, J. C., Vermote, E. F., Skakun, S., & Justice, C. (2019). Spectral adjustment model's analysis and application to remote sensing data. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, *12*(3), 961-972.