Initial Application of Intra-fleet Simultaneous Crossovers

For Rapid Commissioning of Planet Dove Satellites

Alan Collison, Graham Mills, Hannah Bourne, Arin Jumpasut

Lake Okeechobee, Florida, USA · July 1, 2016

Overview

LONDON ARRAY WIND FARM • United Kingdom • April 17, 2016

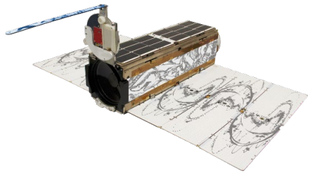
Introduction to Planet's satellites

Singapore Strait • Singapore • July 29, 2016

Agile Aerospace

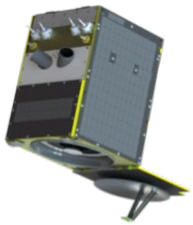
Through our agile aerospace approach, we've created a unique data set

CURRENT CONSTELLATIONS



SuperDove

- ~180 satellites
- Up to 300 million km^2 / day
- 8-band
- Unique scanning



SkySat

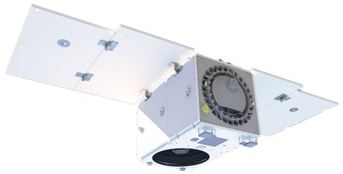
- ~20 satellites
- 50cm resolution
- RGB, NIR, and Pan bands
- Sub-daily tasking

PLANNED HIGH RESOLUTION UPGRADE

PLANNED FUTURE CONSTELLATIONS

Tanager

- 400 - 2500 nm
- ~400 5nm bands
- Technical demo planned to launch in 2024



Pelican

- Initial constellation of up to 30 satellites[1]
- Up to 30cm resolution
- Pan + 6 RGB+NIR bands
- Up to 30 revisits/day

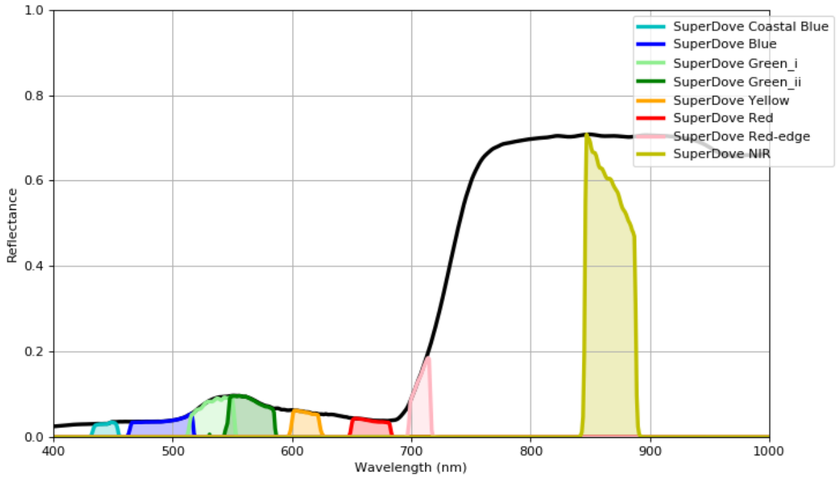
[1] *Does not include initial 2 demonstration satellites planned.*

Effects of Differing Responses

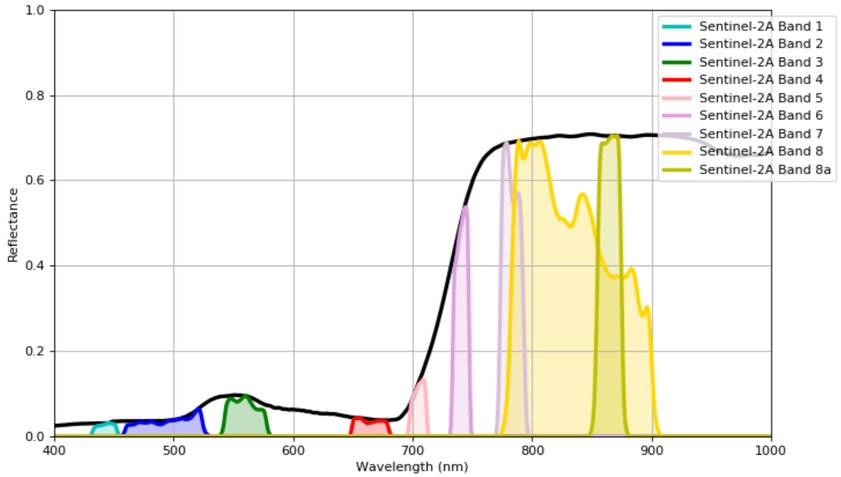
SuperDove

A lawn grass spectrum from a spectral library

SuperDove



Sentinel-2A



SBAF Corrections *SuperDove → Sentinel-2*	Coastal Blue to Band 1	Blue to Band 2	Green_ii to Band 3	Red to Band 4	Red-edge to Band 5	NIR to Band 8a
	0.992	1.019	1.053	0.9524	0.846	1.000

Calibration Methodology

LAKE TUBORG · Canada · May 30, 2015

Overview of Standard Calibration Process

For Commissioning and Bi-yearly Updates

- Calibrations are based on gathering a dataset of near simultaneous crossovers with a reference satellite: **Sentinel-2**
  - A “simultaneous” crossover is when there is less than two hours difference between a reference image and a Planet image for the same location
- **Global** crossovers collected
  - Not limited to calibration sites
- **6-month update interval**
  - Long enough to allow sufficient crossovers
  - Short enough to allow needed updates
  - Updates apply to new collects - ***not retroactive***

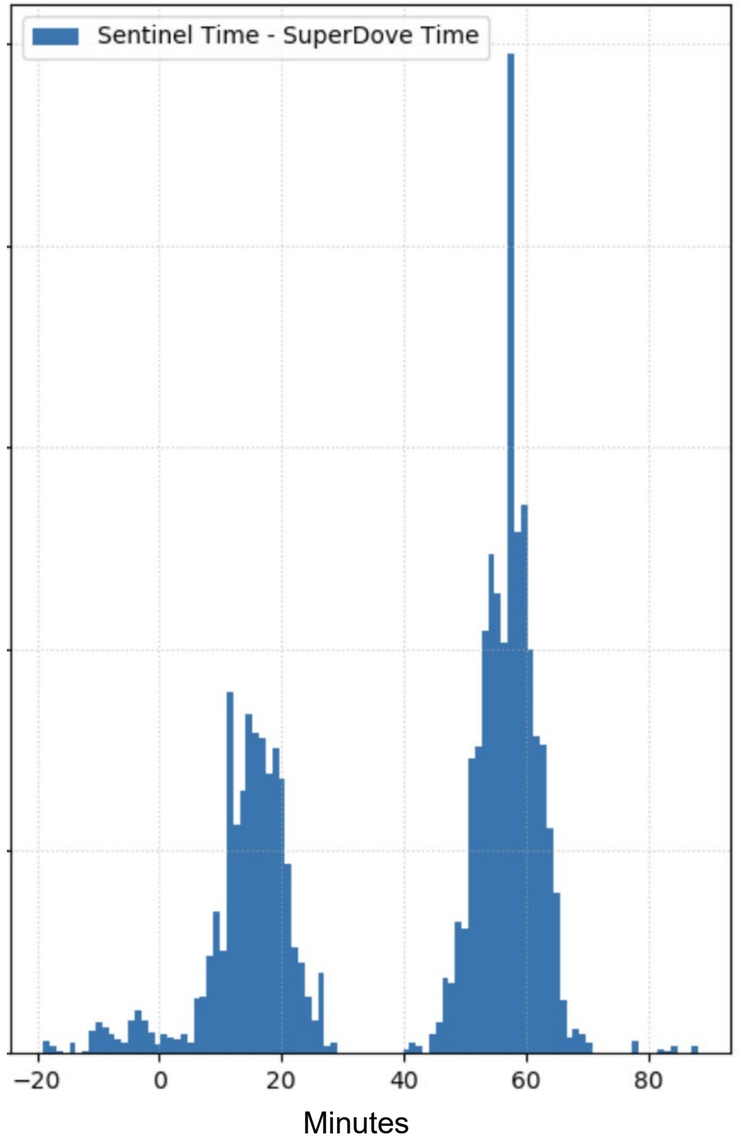
SuperDove / Sentinel-2 Crossovers

Example showing the footprints of SuperDove scene and Sentinel-2 tile products that have near-simultaneous crossovers over any region on Earth.

SuperDove / Sentinel-2 Crossover Times

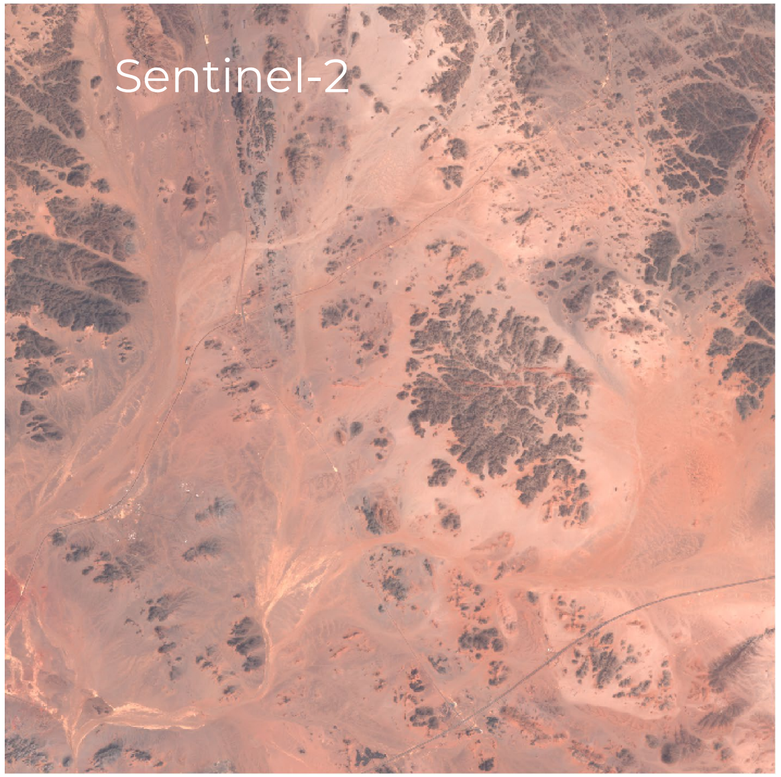
For standard calibration updates, we want to ensure sufficient data that allows reliable comparisons between Sentinel-2 and Planet SuperDoves.

When comparing to Sentinel-2, crossovers are considered for inclusion if they are collected within 2 hours of each other. The majority will ultimately be discarded due to clouds and haze.



SuperDove / Sentinel-2 Crossover Analysis

Tile products are generated from scenes within a strip and compared pixel-by-pixel with corresponding Sentinel-2 tiles at 30m GSD.



NEW: SuperDove Pair Crossovers

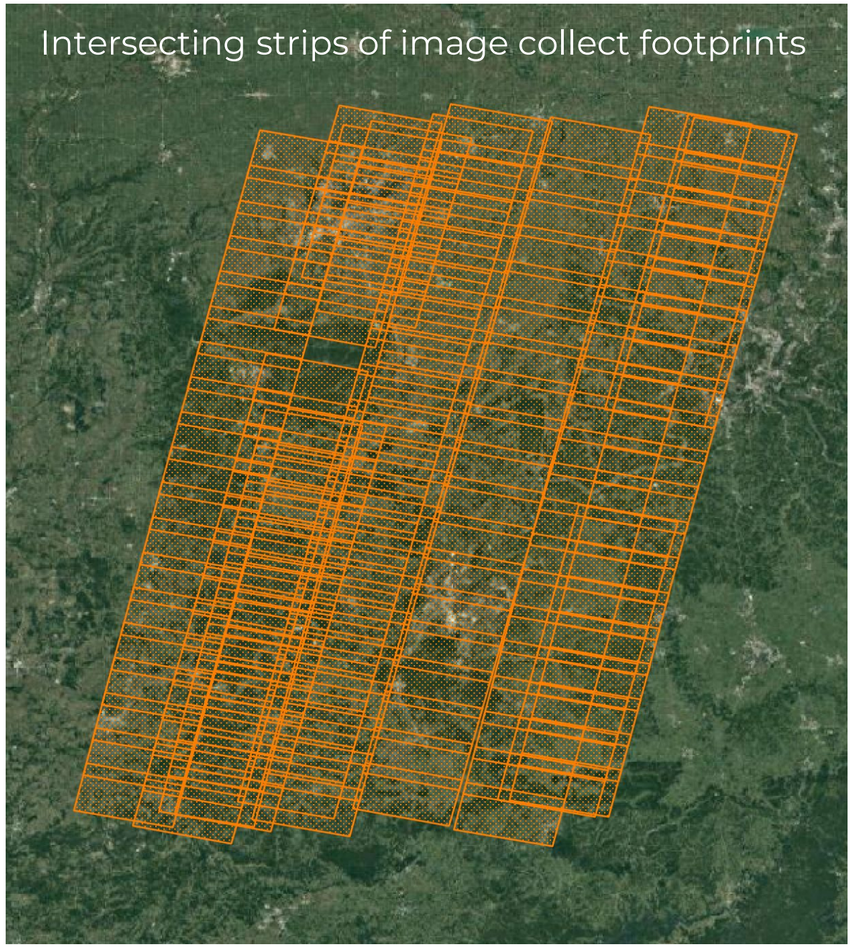
Taking advantage of daily crossover intersections

Image collects for every SuperDove overlap with collects from other SuperDoves to some degree every day.

This provides an opportunity to directly analyze satellite calibrations pairwise, comparing initial calibrations of newly launched satellites with SuperDoves already in orbit.

Advantages:

- Many more crossover pairs to contribute to a calibration update
- Identical sensor in every satellite
- Shorter time difference between collects (< 30 min)



4q Commissioning

CORAL REEF • Belize • April 14, 2019

Commissioning of Flock 4q

First use of Dove-Dove crossovers for initial calibration

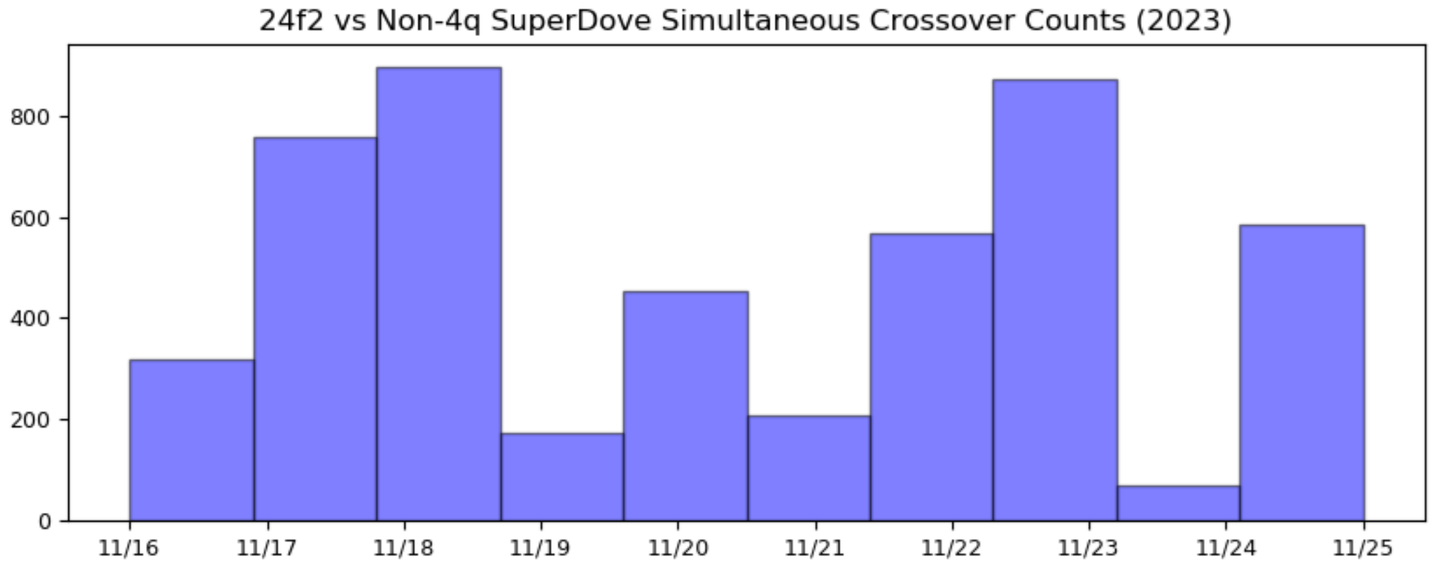
Timeline

Date	Progress
November 11, 2023	36 SuperDoves launched
November 23, 2023	First set of satellites have flat fields completed, radiometric calibration can start
November 25, 2023	First satellite (24f2) radiometric calibration analysis completed
December 2, 2023	28 satellites with updated calibrations ready
December 4, 2023	First satellite (24f2) radiometric validation using Sentinel-2 completed

24f2 – SuperDove Crossovers

November 14th through 25th (2023)

The histogram shows counts of crossover pairs for Flock 4q satellite 24f2 for the two weeks after launch. Only crossovers within 30 minutes of each other were included. In total, 24f2's path intersected the paths of 29 other satellites from three older flocks during the nine day time period shown.

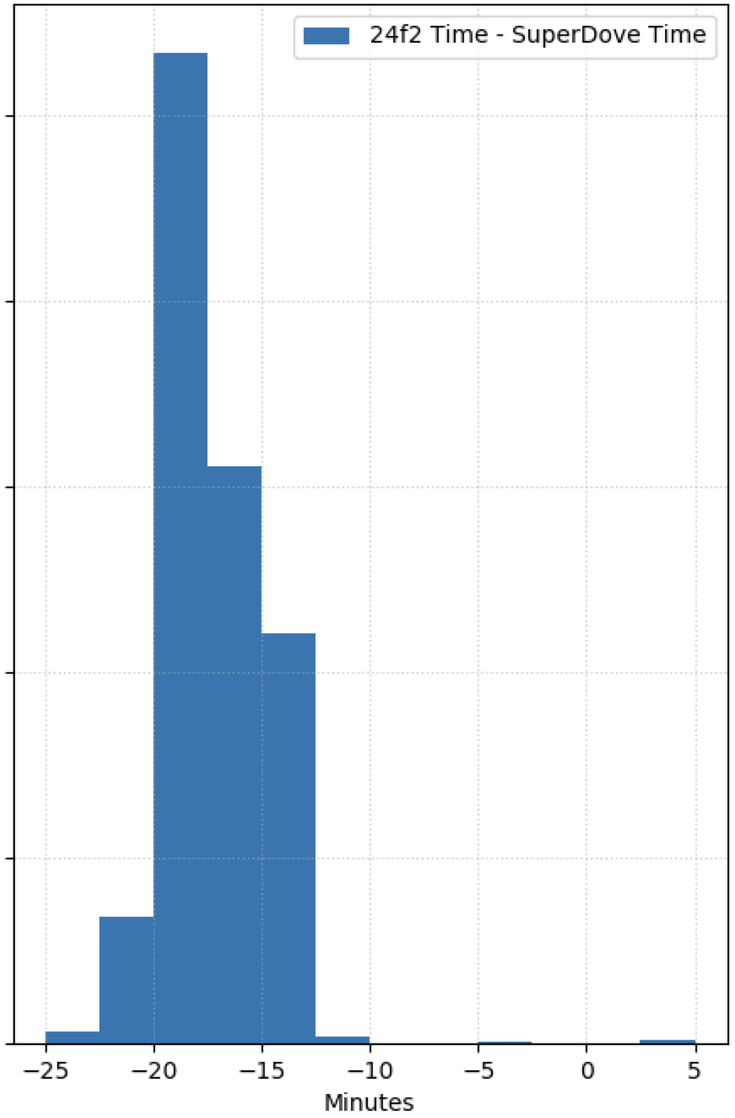


24f2 - SuperDove Crossover Times

November 14th through 25th (2023)

For commissioning, many more near simultaneous crossovers are available each day given the large number of Planet SuperDoves already in active use and their similar orbits.

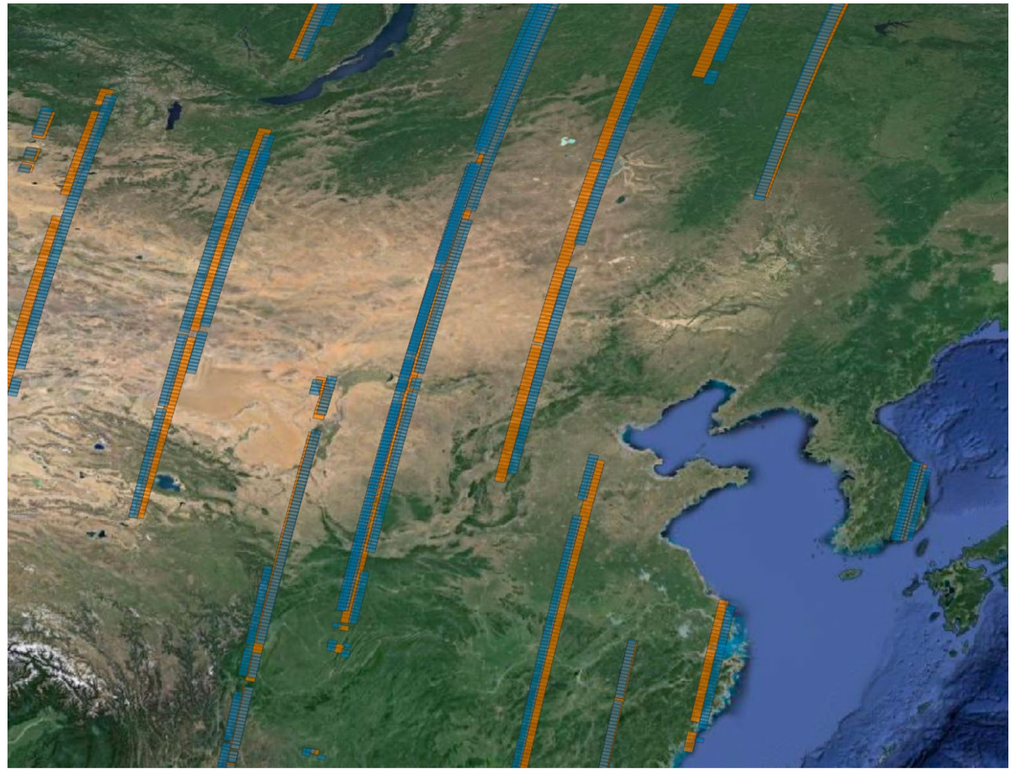
The histogram shows the distribution of crossover pair time differences for 24f2.

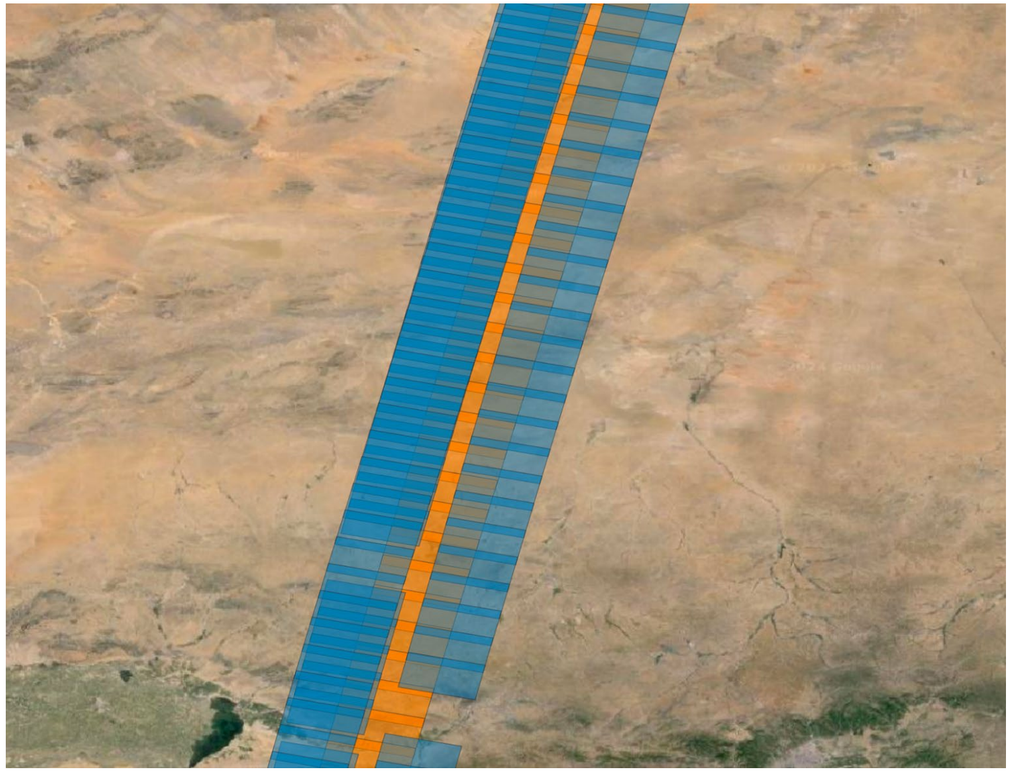


24f2 – SuperDove Crossovers

November 14th through 25th (2023)

Shown are the footprints of image collects involved in near-simultaneous crossovers during the first two weeks after launch for a single Flock 4q satellite (24f2) and all other SuperDoves from older flocks. Left shows a region over East Asia, while the right is a close up of a trio of crossover pairs involving satellites 249c, 2483 and 2488.



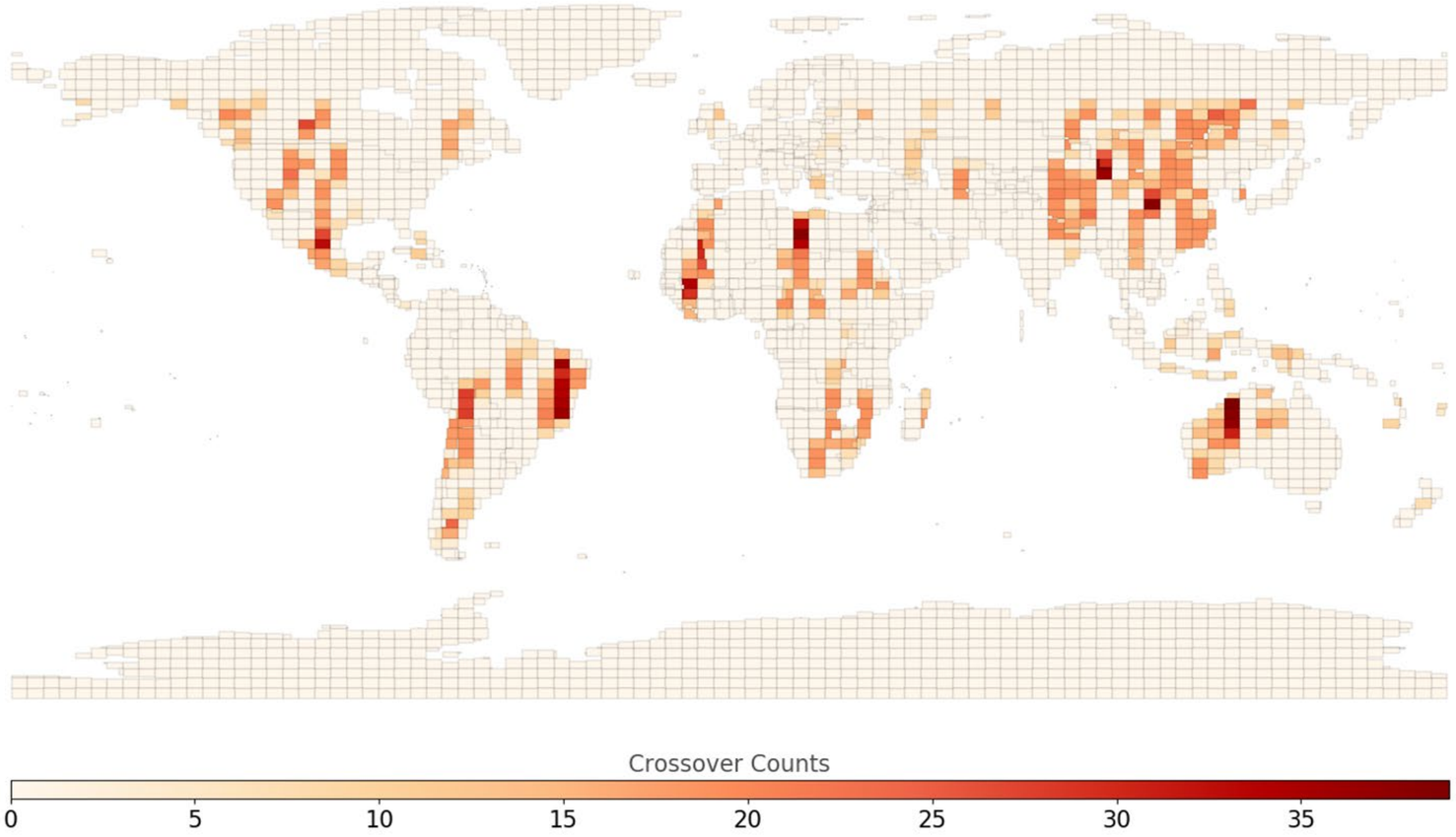


24f2 – SuperDove Crossovers

November 14th through 25th (2023)

The 11 day time period found ~5000 crossover pairs.

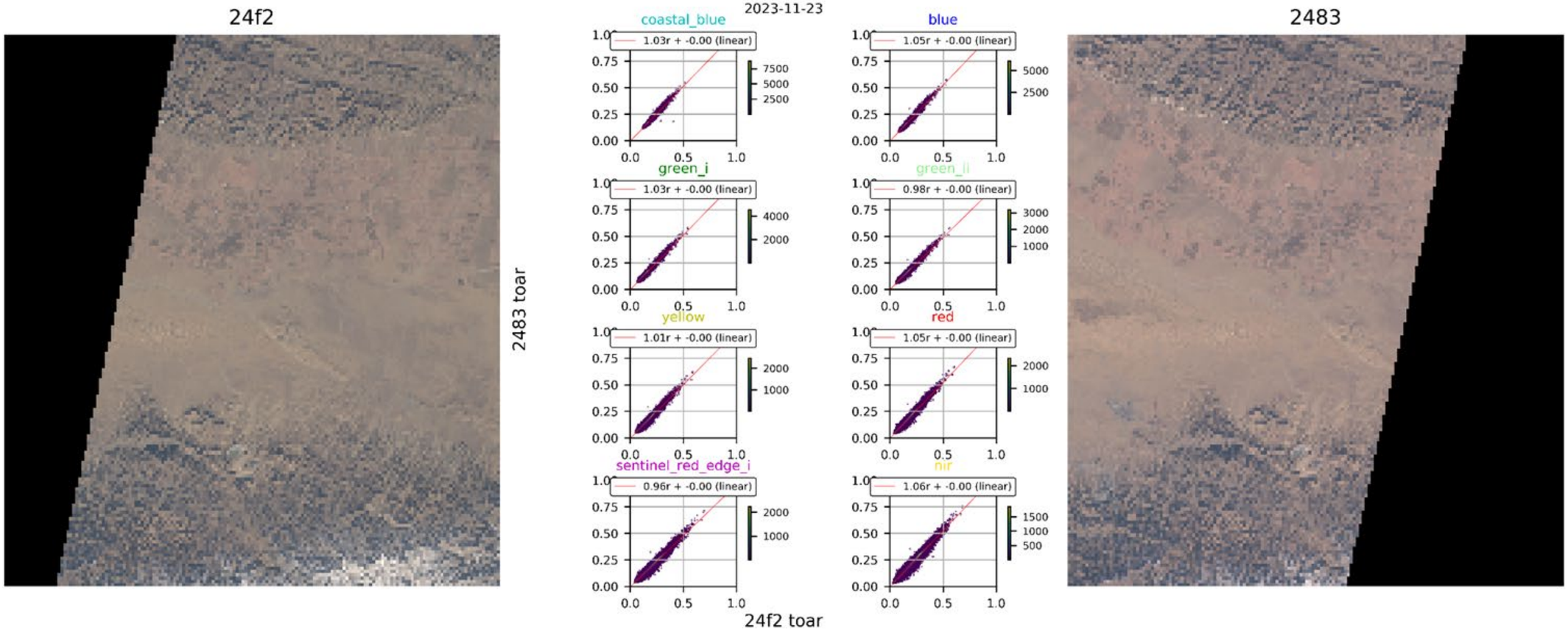
This includes crossovers with 29 other SuperDove satellites.



24f2 - SuperDove Comparisons

Single Crossover Pair example

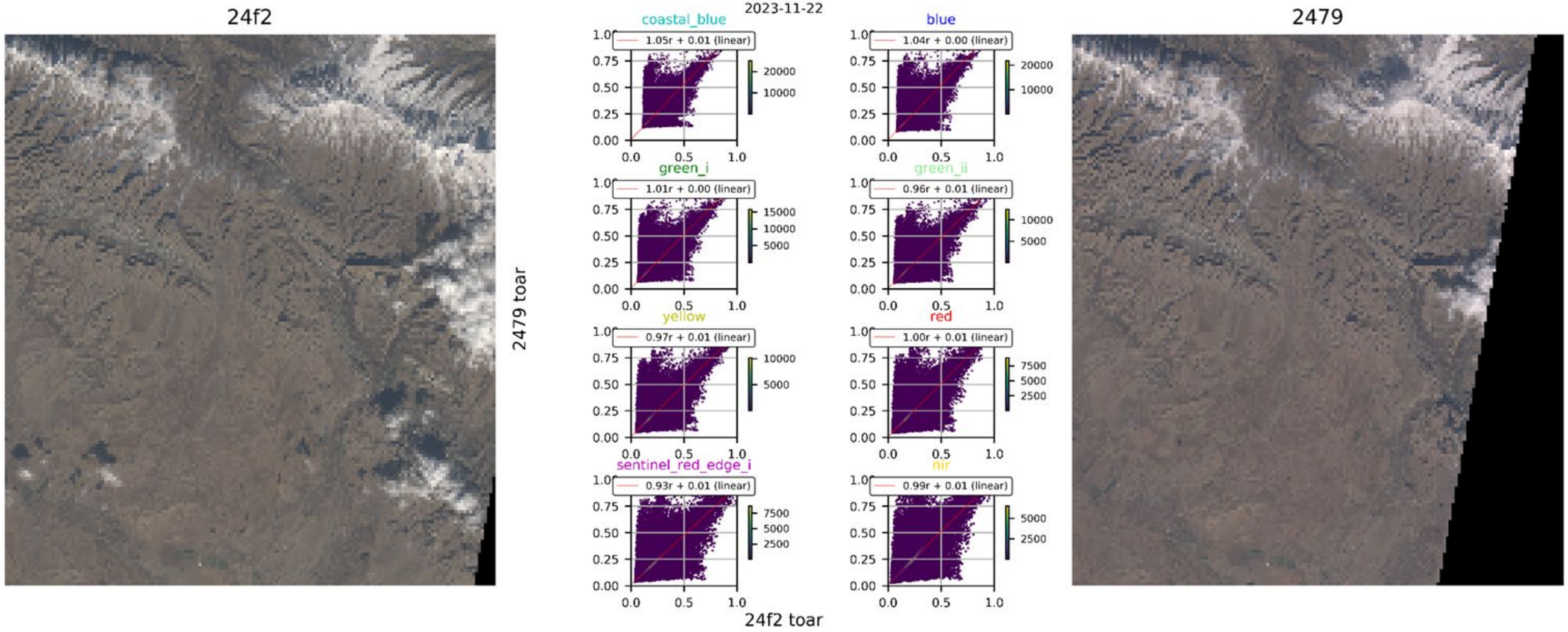
Orthotile products at 30m GSD are compared pixel-by-pixel. The per-band joint mode of each scatter plot distribution is used later for deriving an overall calibration correction.



24f2 - SuperDove Comparisons

Single Crossover Pair example with some clouds and haze

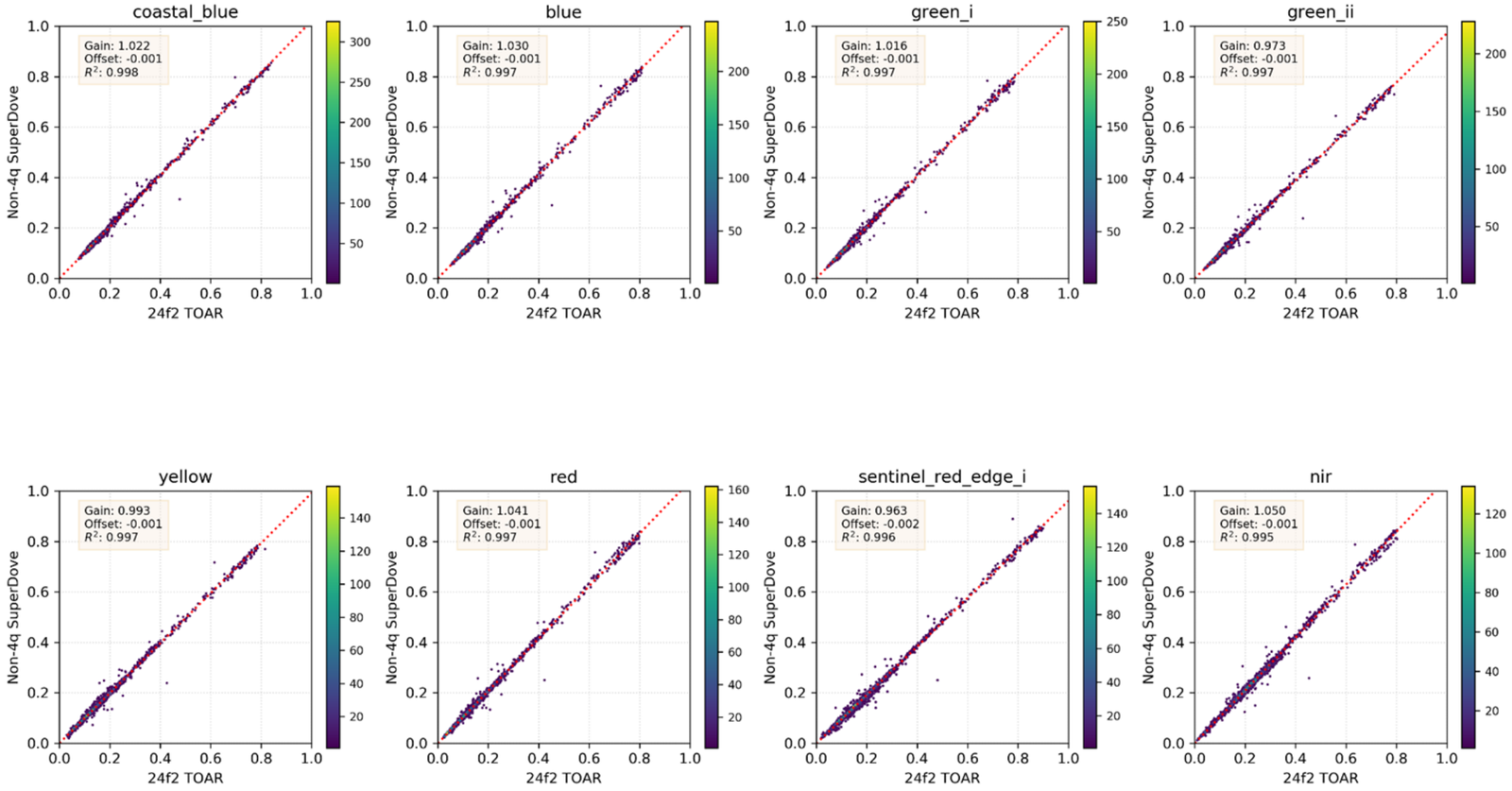
Orthotile products at 30m GSD are compared pixel-by-pixel. The per-band joint mode of each scatter plot distribution is used later for deriving an overall calibration correction.



24f2 Calibration Corrections

November 14th through 25th (2023)

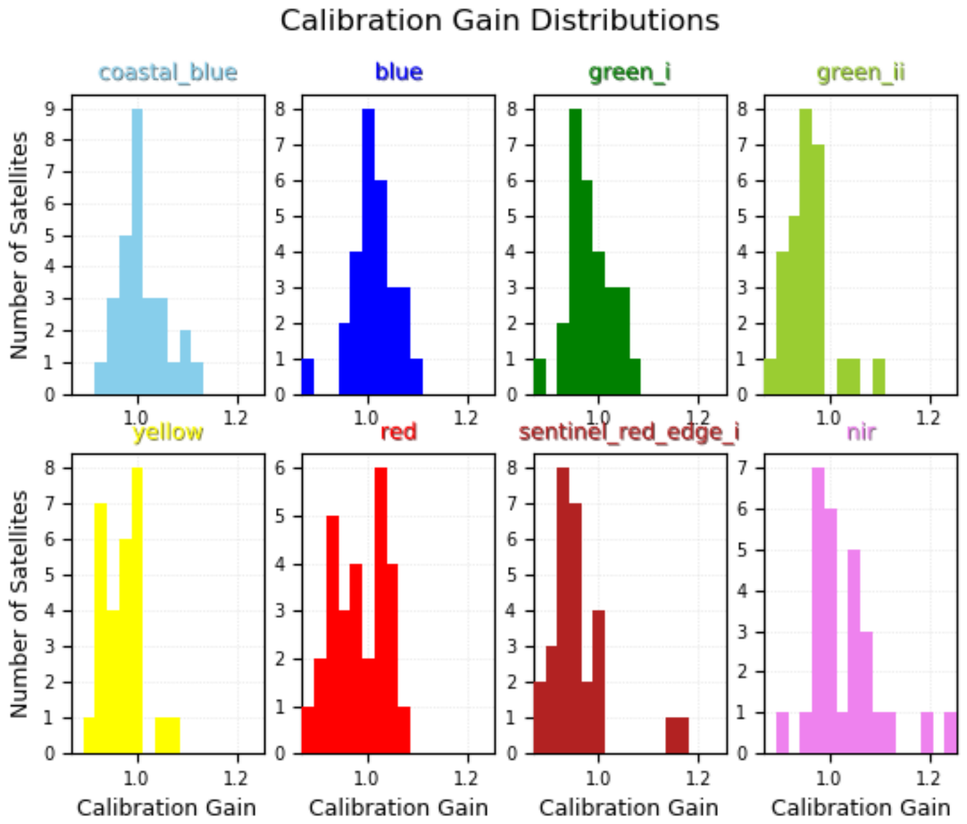
Combining all of the individual crossover comparison results, calibration corrections are derived.



4q Calibration Corrections

Corrections for 28 of the satellites (December 2, 2024)

This shows the distribution of the corrections generated for 28 of the 36 4q satellites.



4q Validation

CORAL REEF • Belize • April 14, 2019

24f2 - Sentinel-2 Validation

Do the corrections provide consistency with Sentinel-2?

To validate updated calibrations we compare to Sentinel-2.

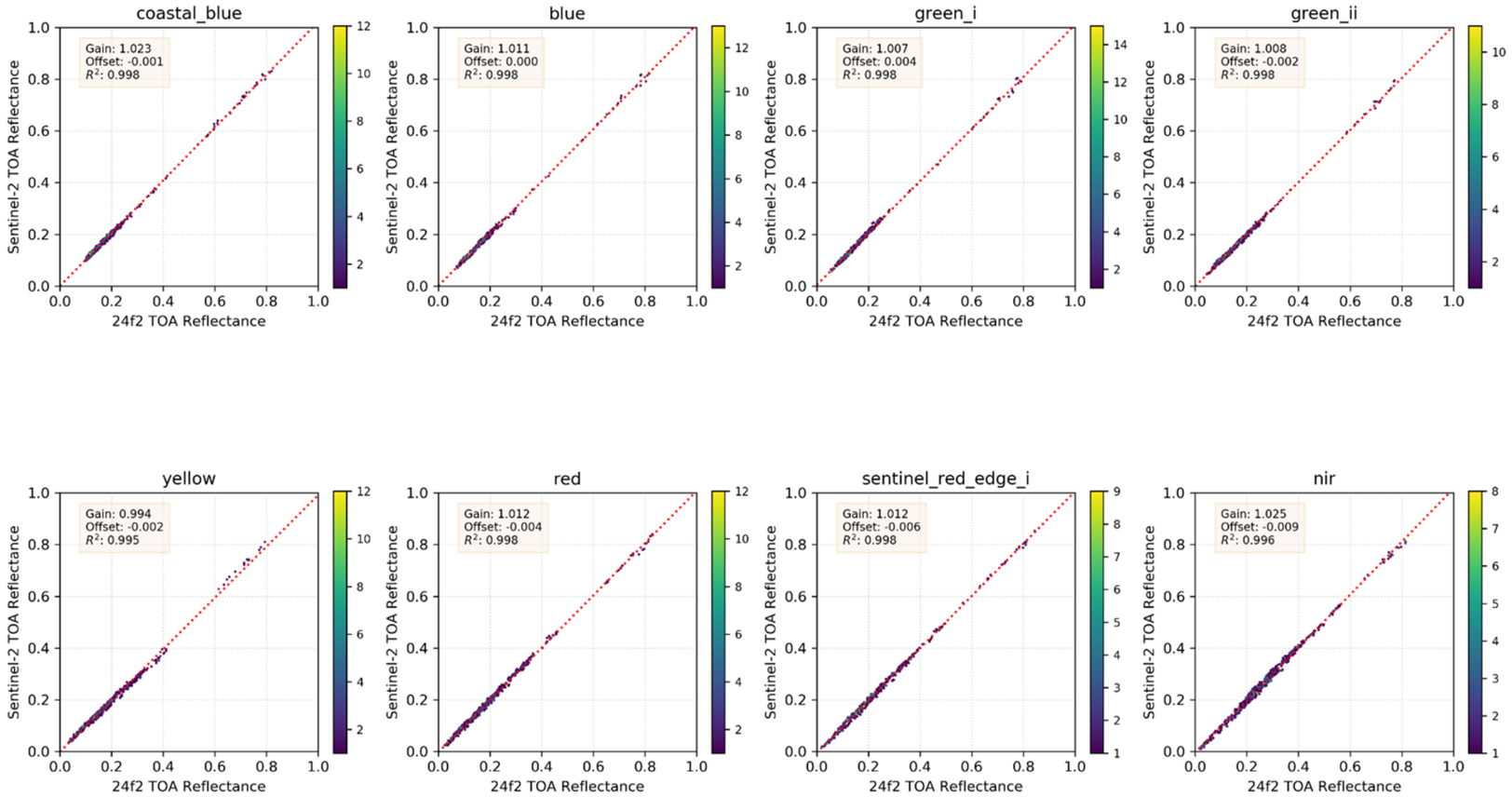
While the validation period starts at the same time as calibration (we can look for crossovers from a few days after launch), there are fewer crossovers between SuperDoves and Sentinel-2 in a given period of time.

Overall, however, the full time needed to perform calibration during commissioning and validate those calibrations is significantly reduced since both are dominated by the time needed to collect sufficient crossovers and Sentinel-2 crossovers can be searched independently of other activities.

24f2 - Sentinel-2 Validation (commissioning)

November 14th through December 4th (2023)

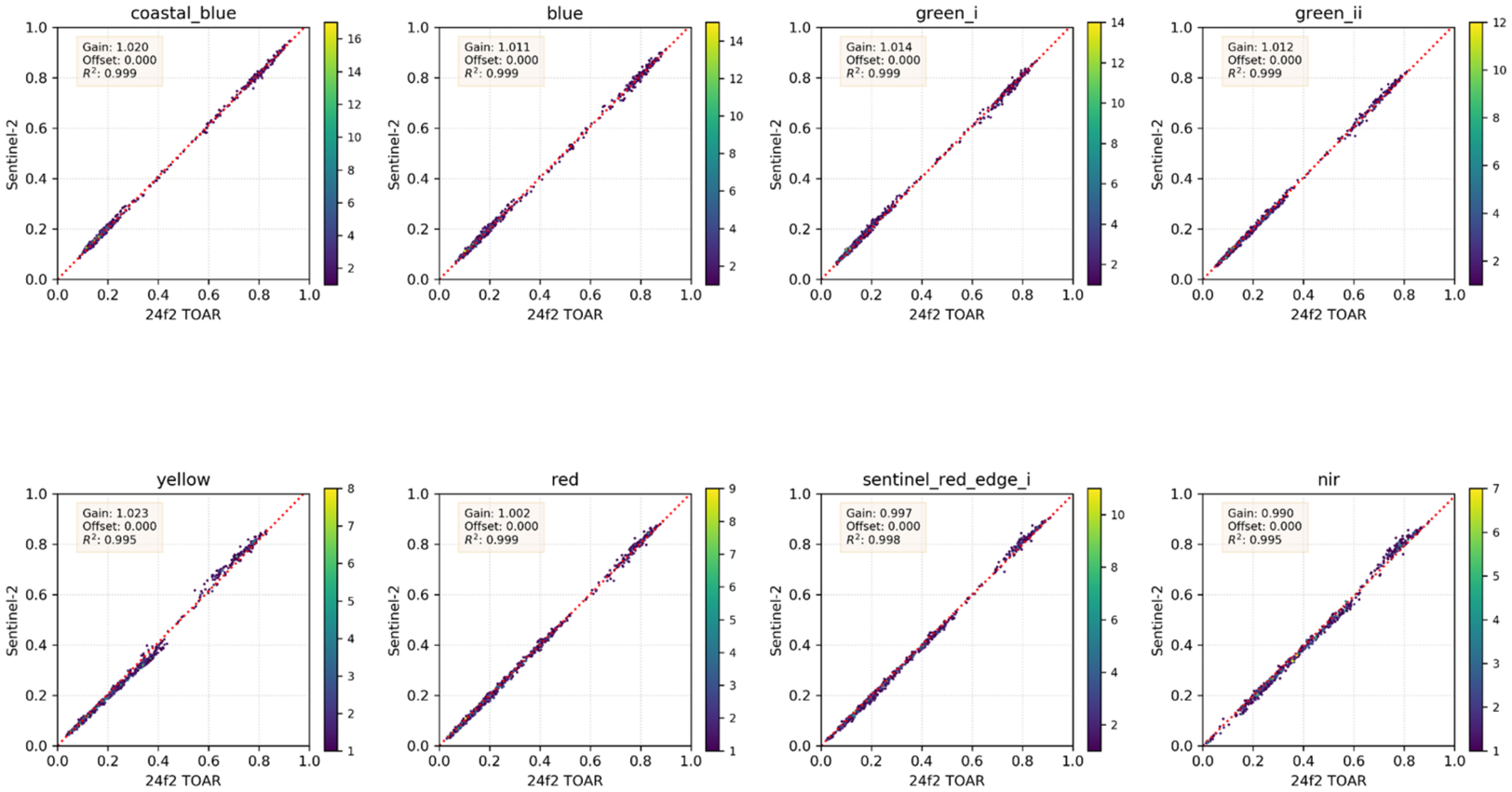
Combining all of the individual crossover comparison results between 24f2 and Sentinel-2 to validate the corrections.



24f2 - Sentinel-2 Validation (operational)

February 1st through May 1st (2024)

This is the same comparison only for data collected over several months in 2024.



4q - Sentinel-2 Validation (operational)

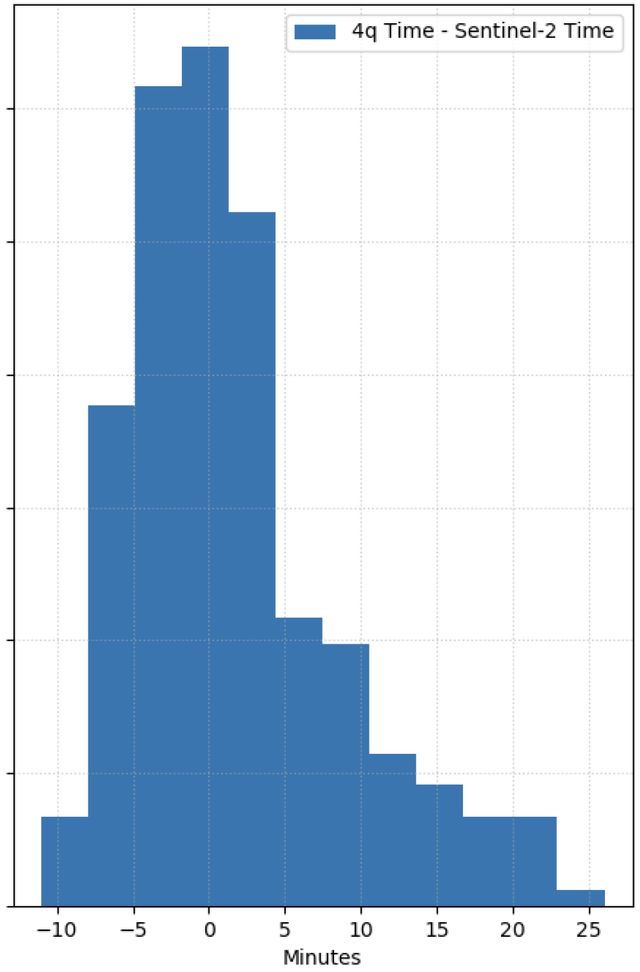
February 1st through May 1st (2024)

Same comparison except now includes a sampling of all 4q data collected during those months.

In this case, all calibrated 4q satellites are compared to Sentinel-2 during the time period.

The total number of crossover pairs included in this sample was limited to 3000 randomly selected crossovers. Otherwise this comparison followed the standard calibration/validation process.

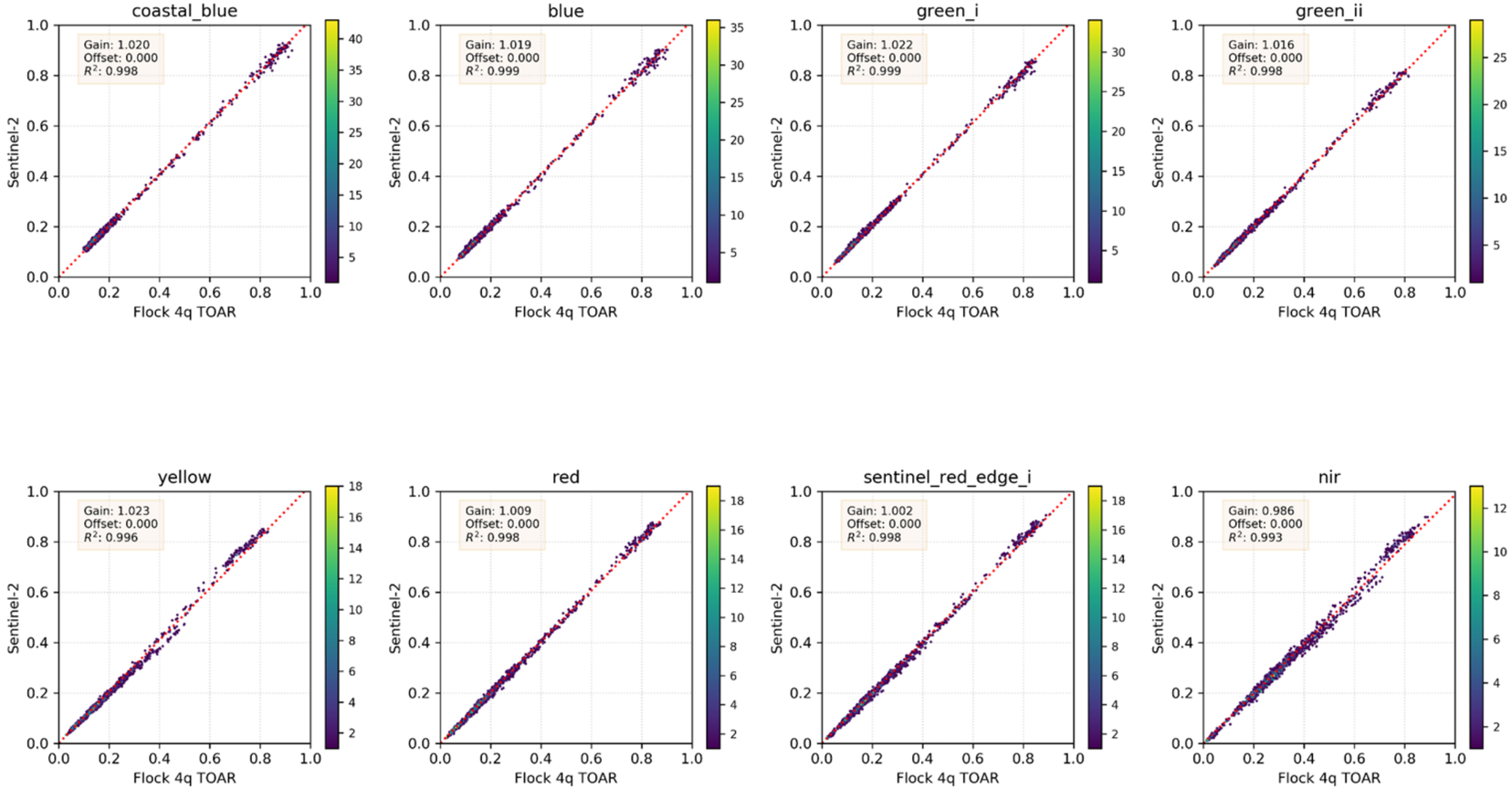
The histogram on the right shows the distribution of crossover time differences that contributed to this dataset.



4q - Sentinel-2 Validation (operational)

February 1st through May 1st (2024)

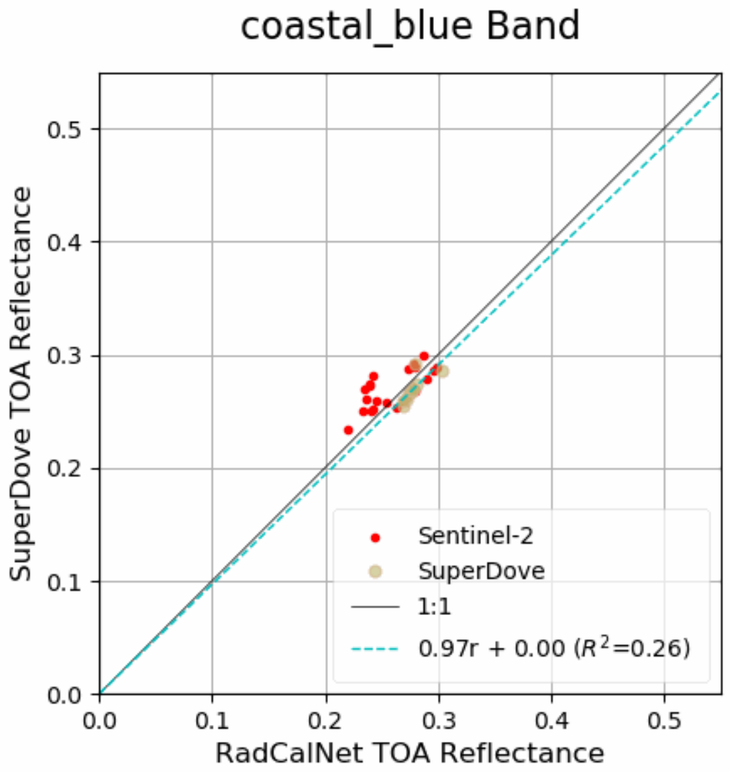
Same comparison except now includes a sampling of all 4q data collected during those months.



4q RadCalNet Validation

January 14th through May 15th (2024)

A comparison to RadCalNet measurements was made for both SuperDoves and Sentinel-2, using data between launch and May 15th. Only Railroad Valley had data during this time period.



Band	Absolute Accuracy %	Uncertainty % (1σ)
coastal blue	-3.02	4.08
blue	-4.36	5.42
green_i	-3.40	4.24
green_ii	-1.19	3.26
yellow	2.90	3.69
red	1.15	2.86
sentinel_ red_edge_i	3.66	4.12
nir	6.26	6.70

Summary

GULF OF OMAN • Iran • June 3, 2021

Summary

Benefits of using Intra-fleet Crossovers for Commissioning

For the first time, Planet has successfully commissioned a new flock of SuperDoves using cross calibration with Planet SuperDoves already in orbit. Using intra-fleet crossovers in this way provides a number of benefits:

- Faster radiometric commissioning by providing more crossover pairs in a shorter time period
- Crossover time differences are up to ~90 minutes shorter than when using Sentinel-2, reducing “noise” from atmospheric changes during that time
- Satellites with nearly identical sensors are being compared
- Sentinel-2 can be used for independent validation, utilizing crossovers from the same time period
- Minimal modifications needed to the existing processing pipeline

For more information, you may find us here:

Official Website

@planet-labs

planet.