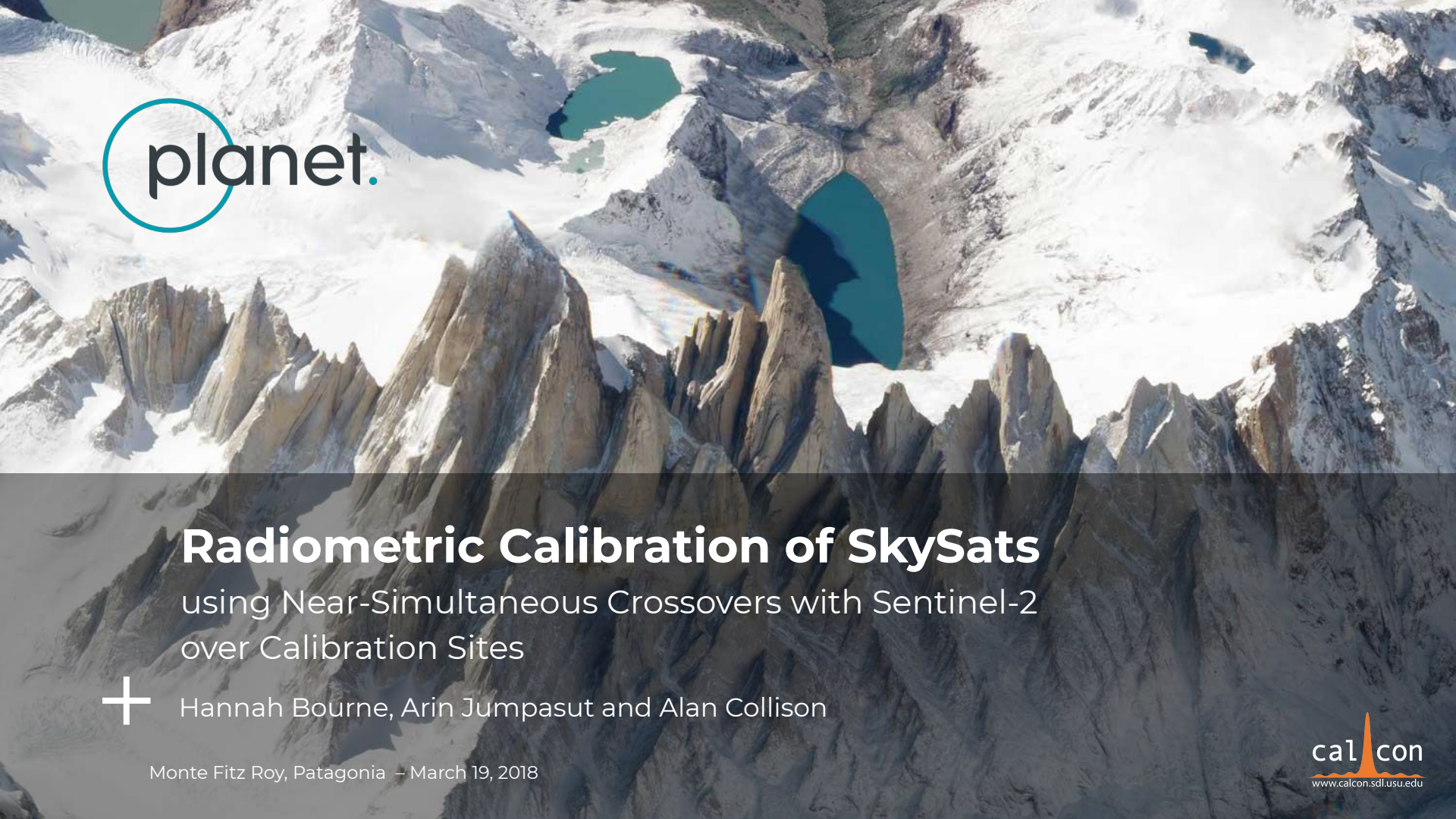

Radiometric Calibration of SkySats

using Near-Simultaneous Crossovers with Sentinel-2 over Calibration Sites

Hannah Bourne, Arin Jumpasut and Alan Collison

Monte Fitz Roy, Patagonia – March 19, 2018

cal con
www.calcon.sdl.usu.edu

Overview

01 | Introduction to Planet SkySats

02 | Interoperability Challenges

03 | Calibration Methodology

04 | Calibration Validation

05 | Summary

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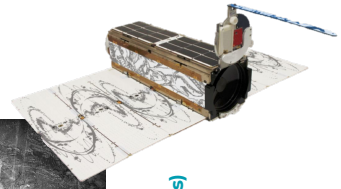
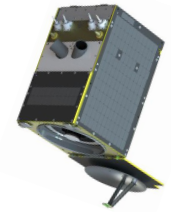
Introduction to Planet SkySats

Singapore Strait, Singapore – July 29, 2016

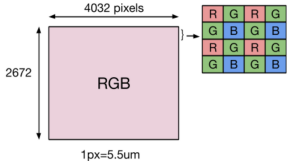
Planet Payloads
Over the Years

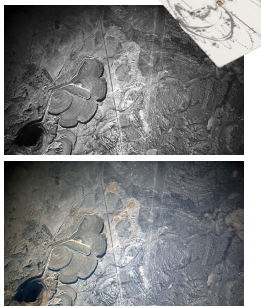




Dove Pilot (~50 satellites)

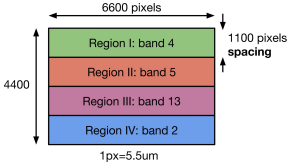
2016

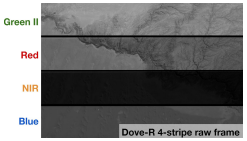


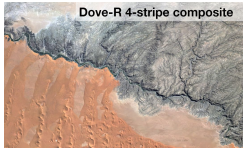


Dove-R (24 satellites)

2018



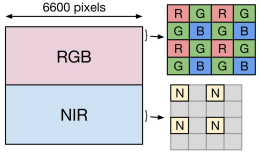


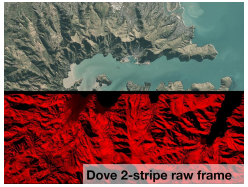


SkySats (21 satellites)

Dove (~150 satellites)

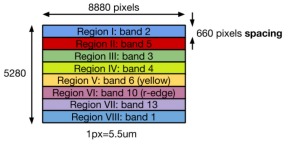
2017

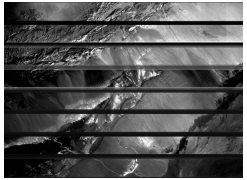


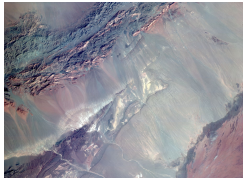


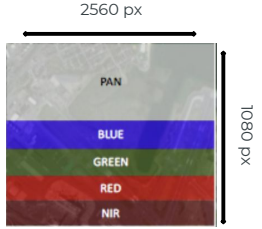
SuperDove (~120 satellites)

2019
2020
2021









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SkySat Collects vs. Scenes

SkySat Scene

SkySat Collect

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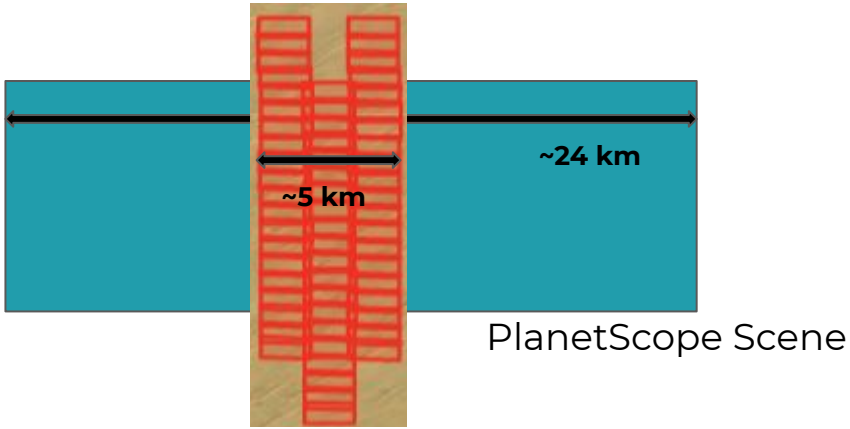
SkySat Scenes vs. PlanetScope Scenes

SkySat Collect

- C class - 5 km swath width
- A class - 8 km swath width
- 10 km-100 km length



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Planet Payloads

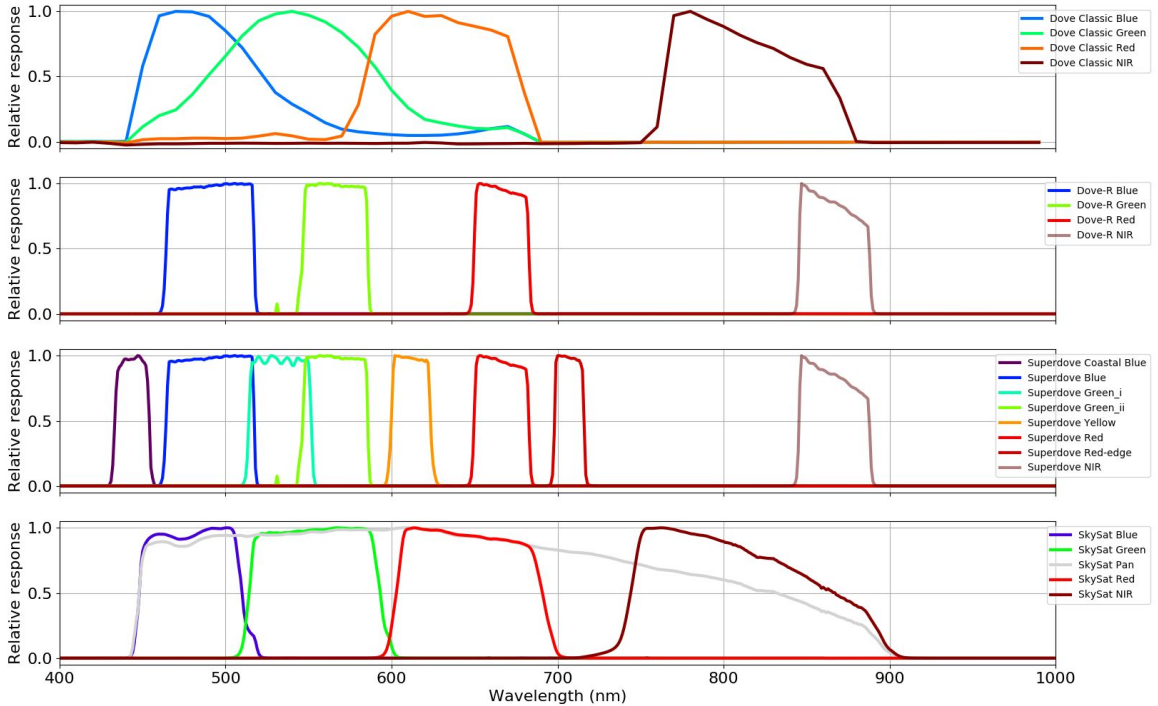
Over the Years

Dove Classic

Dove-R

SuperDove

SkySat



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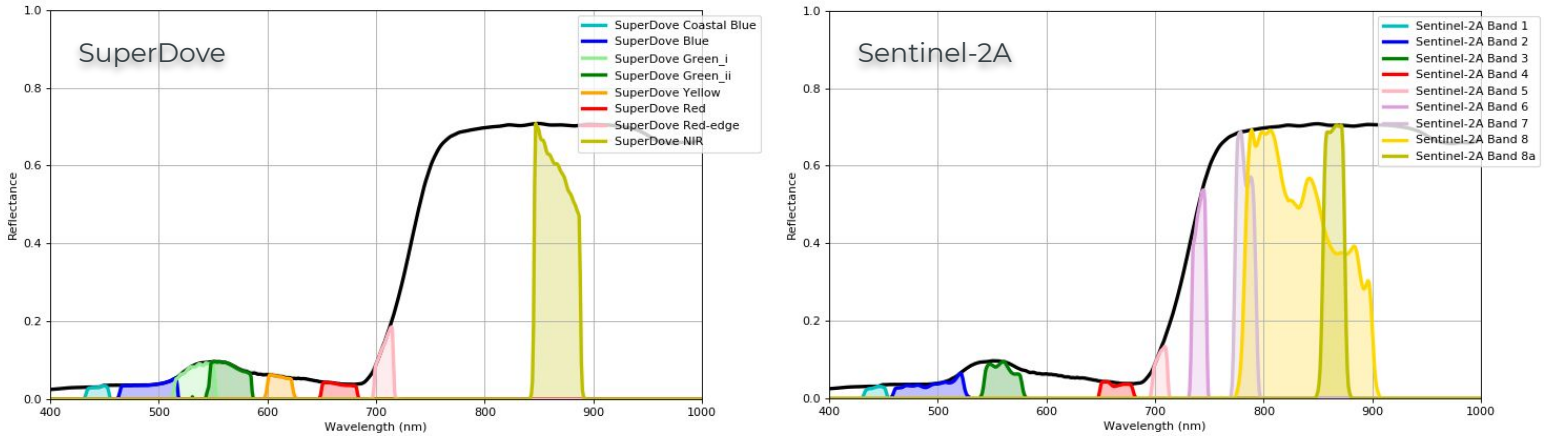
Effects of Differing Responses

SuperDove

A lawn grass spectrum from a spectral library



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

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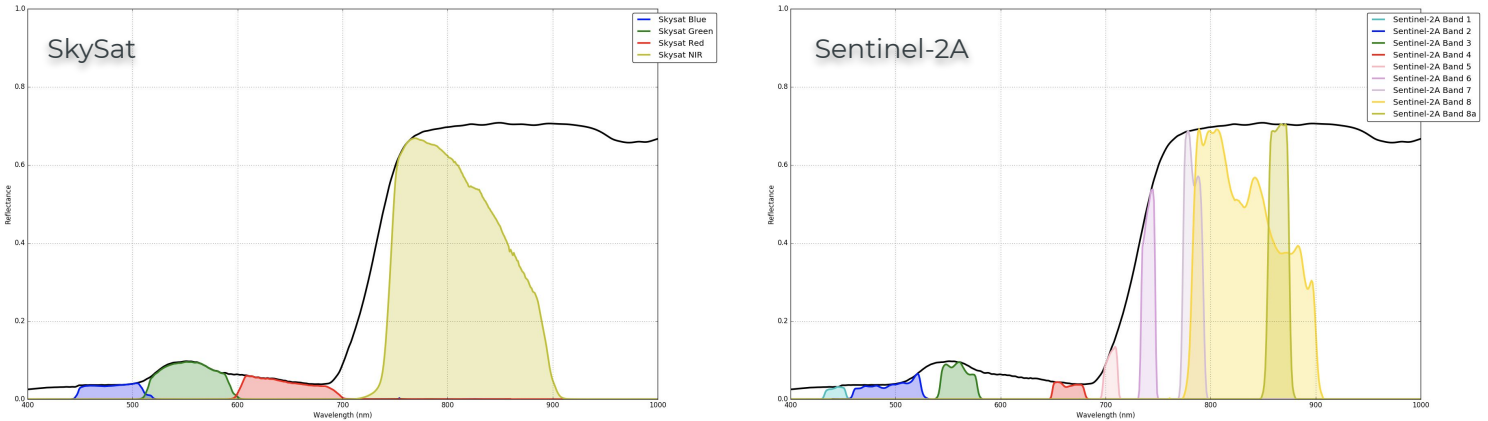
Effects of Differing Responses

SkySat

A lawn grass spectrum from a spectral library



SBAF Corrections *SkySat → Sentinel-2*	Blue to Band 2	Green to Band 3	Red to Band 4	NIR to Band 8
	0.8909	0.8993	1.1940	0.9682

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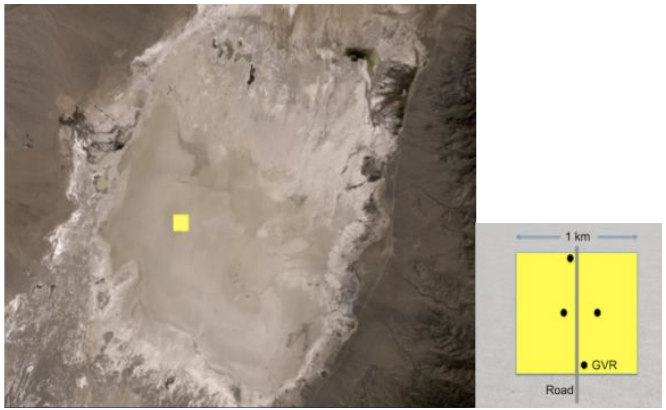
Calibration Methodology

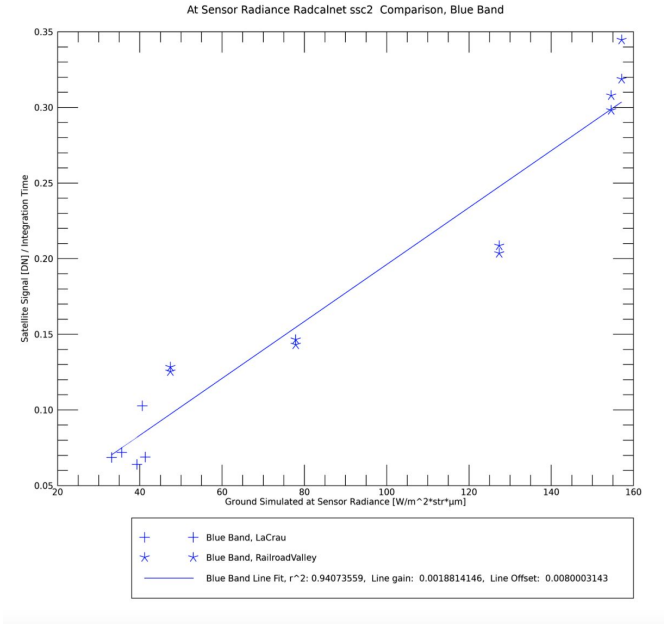
Lake Tuborg, Canada – May 30, 2015

Overview
Original Methodology

Calibrations based on gathering a dataset of **RadCalNet** site crossovers.

$$Rad = \frac{DN}{IntTime} \cdot gain + offset$$





Original calibration done in November 2017
Updated every 6 months

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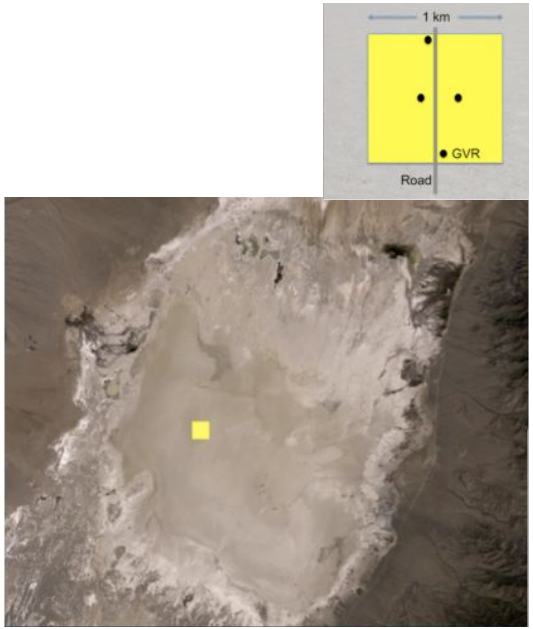
Overview
Original Methodology

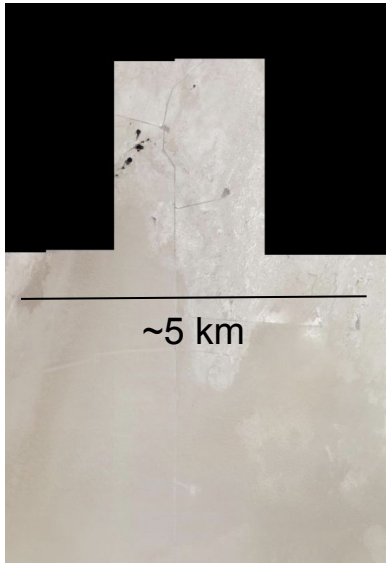
SkySat

- Calibrations are based on gathering a dataset of **RadCalNet** site crossovers.
- As calibration site footprint is so small, calibration is only done for the central detector.
- The other 2 sensors are calibrated relative to the central sensor.



Railroad Valley and target for which RadCalNet TOAR spectra are representative

From radcalnet.org



SkySat Collect over Railroad Valley

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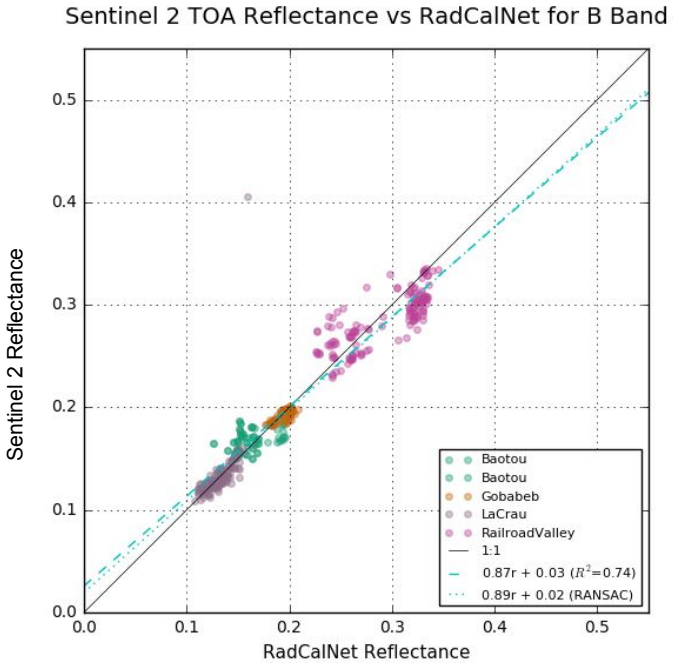
Details

Differences with RadCalNet



- Differences between Sentinel 2 and RadCalNet as a reference
- For consistent **methodology** and **interoperability**, the goal is to use same reference source throughout all payloads

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Overview
New Methodology

- Calibrations are based on gathering a dataset of near **simultaneous crossovers with a reference satellite**
    - A simultaneous crossover is when there is **less than three hours difference** between a reference image and a Planet image for the same point
    - Same reference satellite for all: **Sentinel-2**
- **Dove Classic/SkySat**
    - Standard set of calibration sites, “homogeneous” sample regions
    - **Hyperion spectra** for characterizing the surface reflectance to calculate SBAFs
    - Simultaneous crossovers with Sentinel-2 over standard calibration sites
- **SuperDove/Dove-R**
    - **Global** simultaneous crossovers with Sentinel-2

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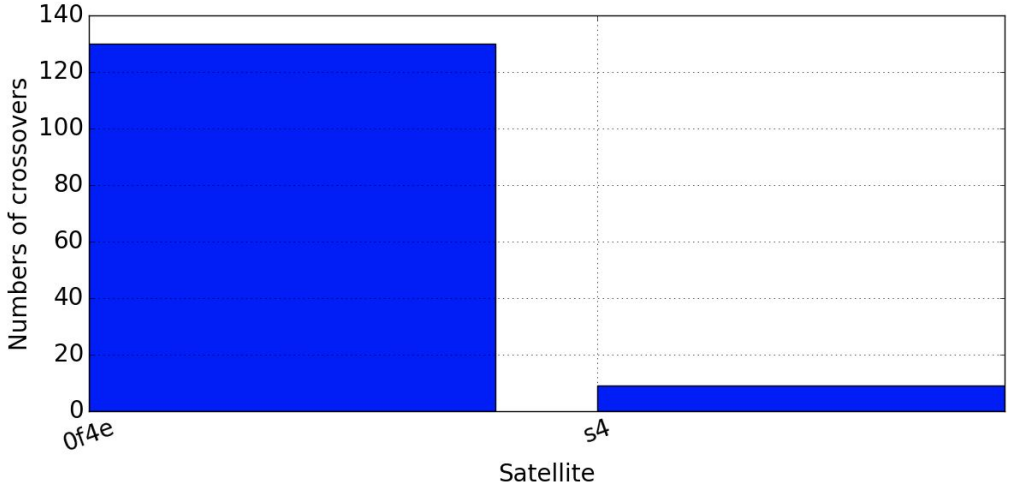
Details

Calibration Challenges



- Number of simultaneous crossovers with Sentinel 2 over calibration sites for a single Dove Classic (0f4e) compared to a single SkySat (s4) over a one month period (July 2021)
- Dove Classics crossover calibration sites regularly
- Even with daily tasking, far fewer SkySat crossovers
- Only use SkySat data taken **<10 degrees** off Nadir

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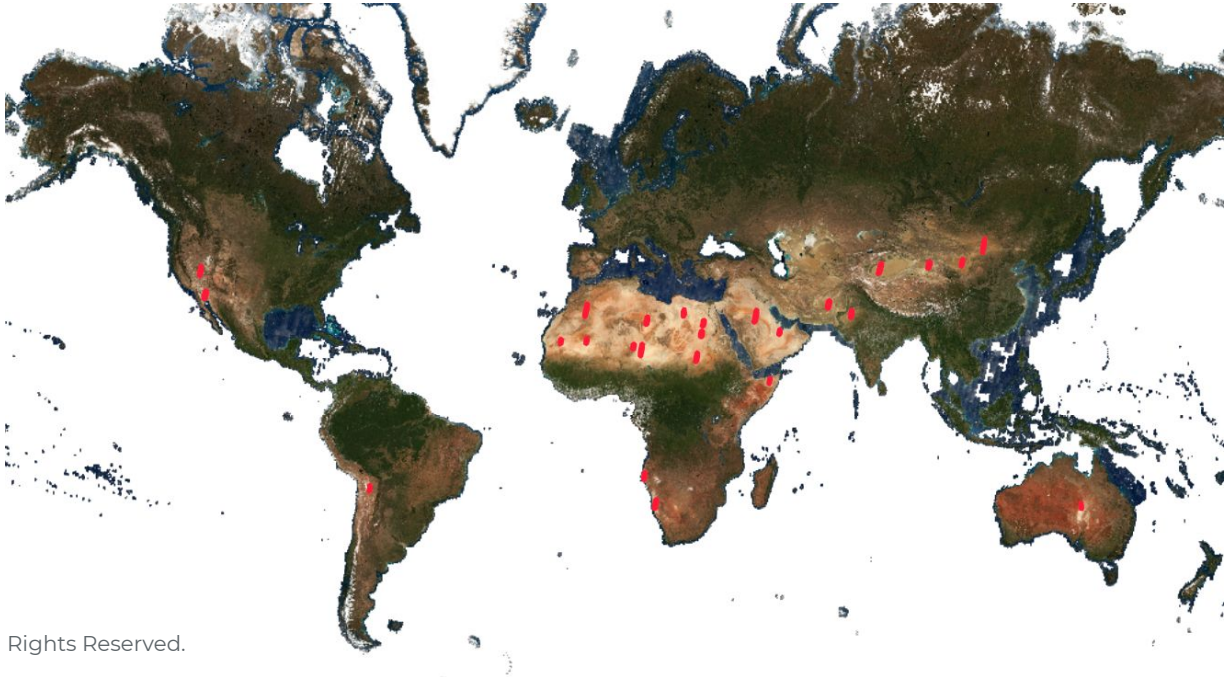
Calibration Sites

Locations of Pseudo-Invariant Calibration (PIC) sites and Rapid Eye Calibration sites



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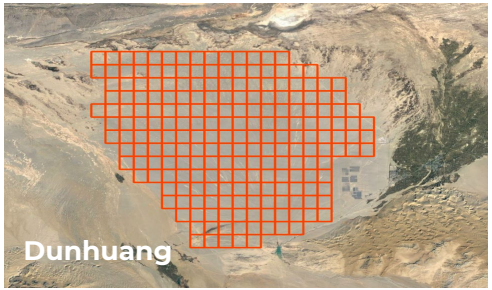
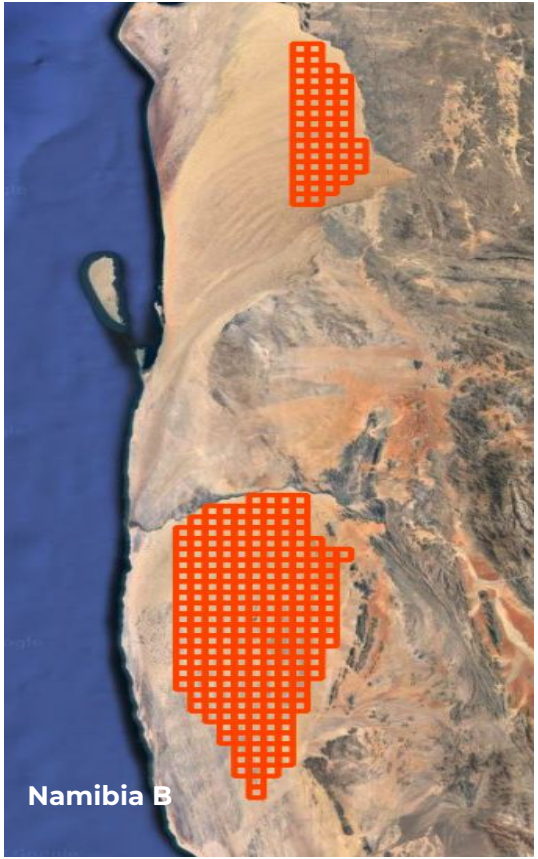
Sample Areas / Details

Dove Classic & SkySat

- Sample size is 1000 x 1000 Pixels (~3.5 km resolution)
- Sampling in spectrally homogenous locations within calibration site
- Spectra is characterized using Hyperion Imagery



Example Calibration Site sample grids



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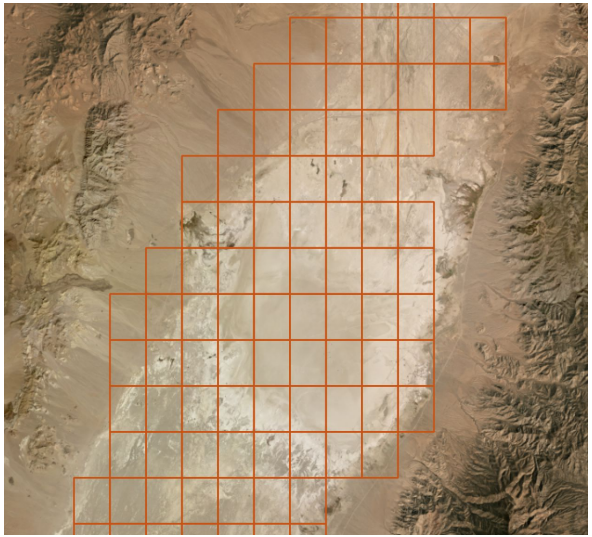
Update Calibration / Details

RadCalNet & SkySat

- Crossovers collected and analyzed for whitelist periods
- **Existing calibrations** updated for time period they fall inside of
- Calculate gain adjustments using crossovers with Sentinel 2 over calibration sites



Railroad Valley Site
Overlain with calibration grid

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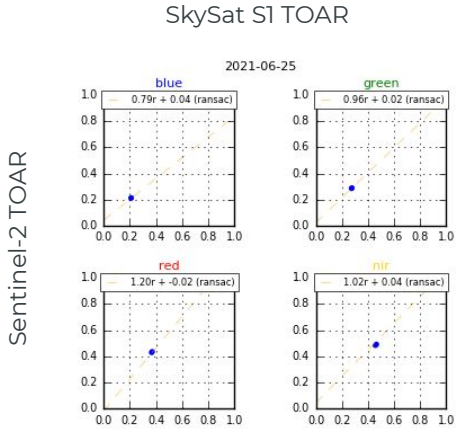
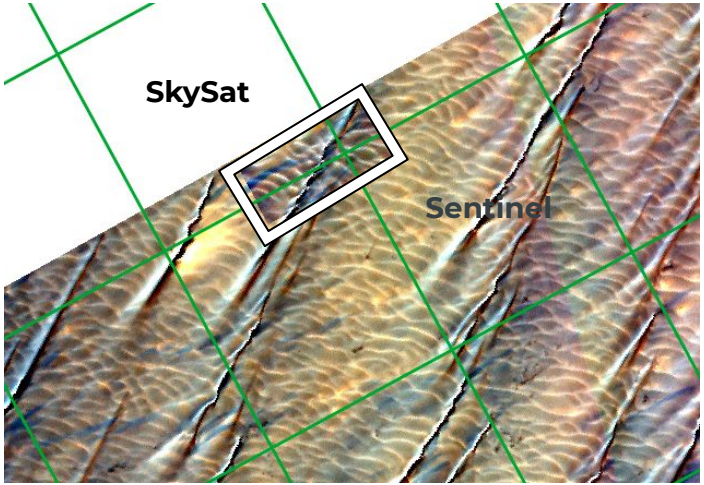
Crossover Analysis / Details

Dove Classic & SkySat

- Sample size is ~3.5 km x 3.5 km resolution
- Sampling in spectrally “homogenous” locations within calibration site
- Sample spectrum is characterized using Hyperion Imagery
- Statistics are gathered and recorded for each crossover, in particular the **joint mode** of the sample reflectance distribution for both the Dove and Sentinel collects.





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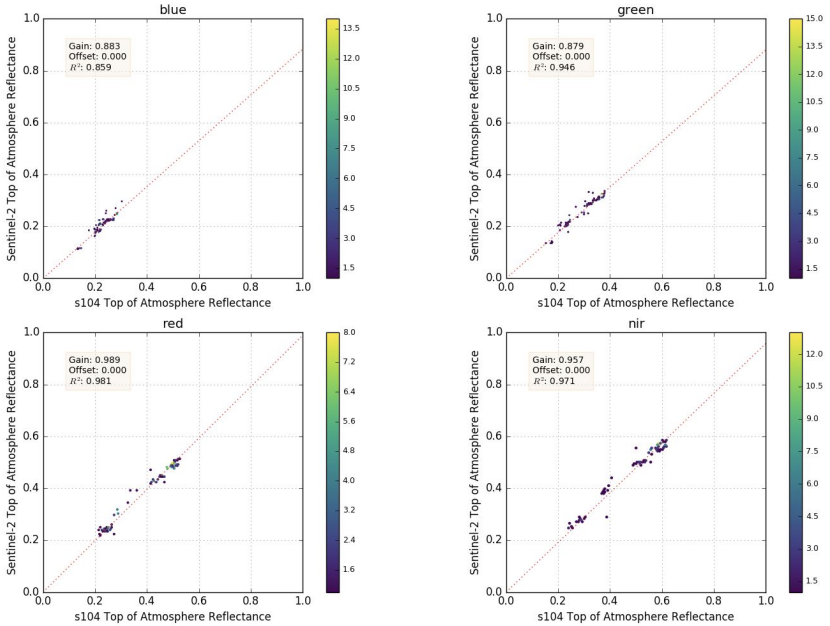
Gain Adjustments / Details

SkySat

Calibration gain adjustment is based on scatter plot fits of the **joint modes** from individual crossovers.

Each plot on the right represents ~130 simultaneous crossovers with Sentinel-2 of one of an individual SkySats.

SkySat s104, sensor 2
Entire whitelist period



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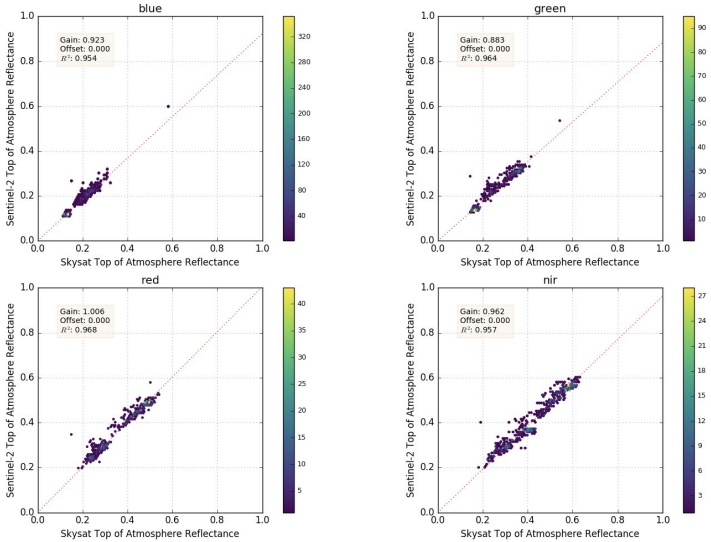
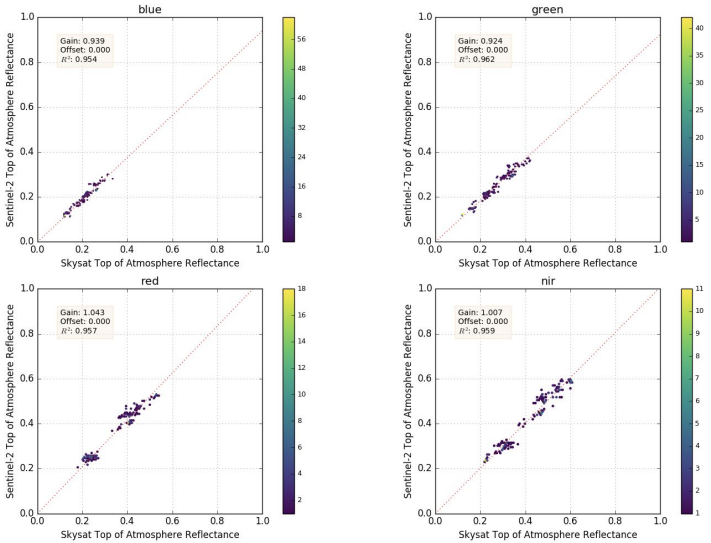
Verification

75/25 split of data

Calibration Data Set



Validation Data Set



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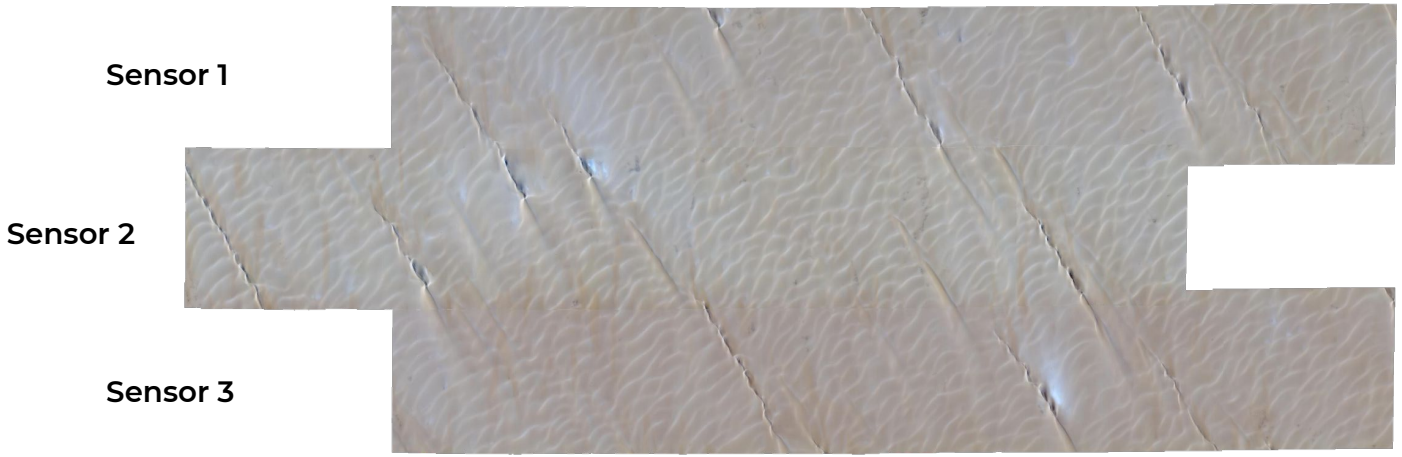
Sensor Differences / Details

SkySat



SkySat s110

- Slight differences between three sensors on a single SkySat
- Some of the difference is due to the different geometry of the camera affecting stray light
- Goal is to remove some of the differences by calibrating each camera individually

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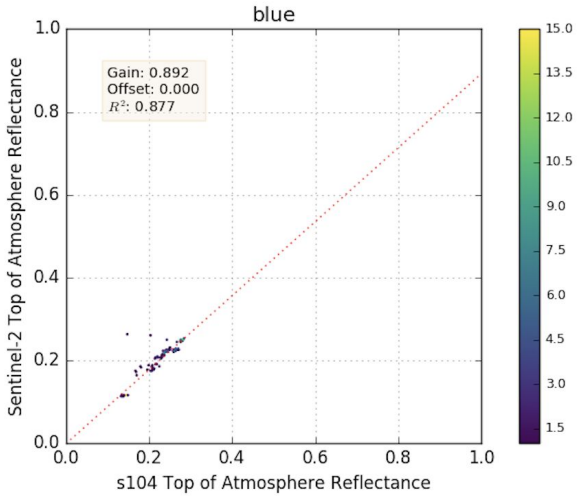
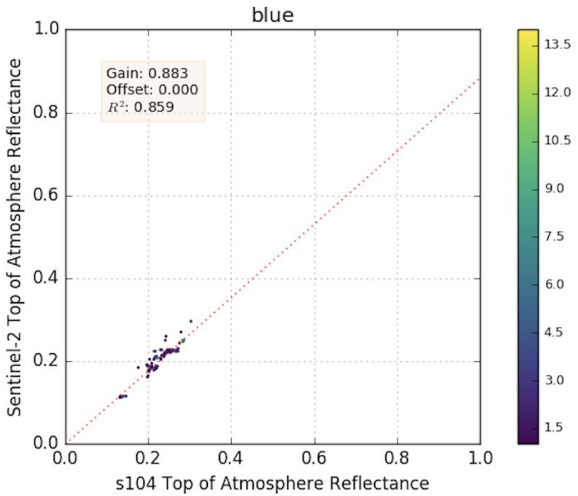
Individual Sensors / Details

SkySat

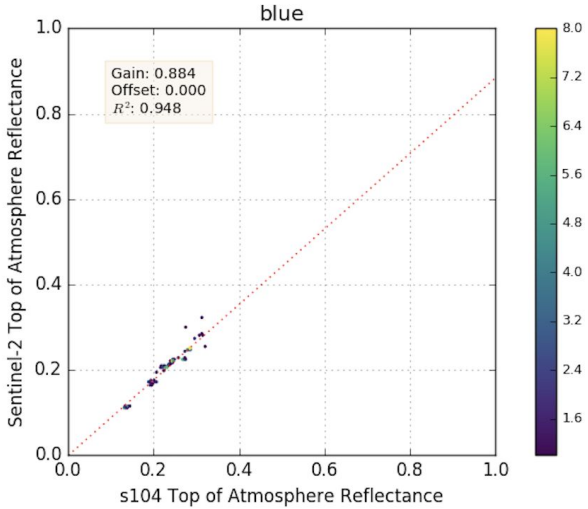
Sensor 1



Sensor 2



Sensor 3



S104 Training Data

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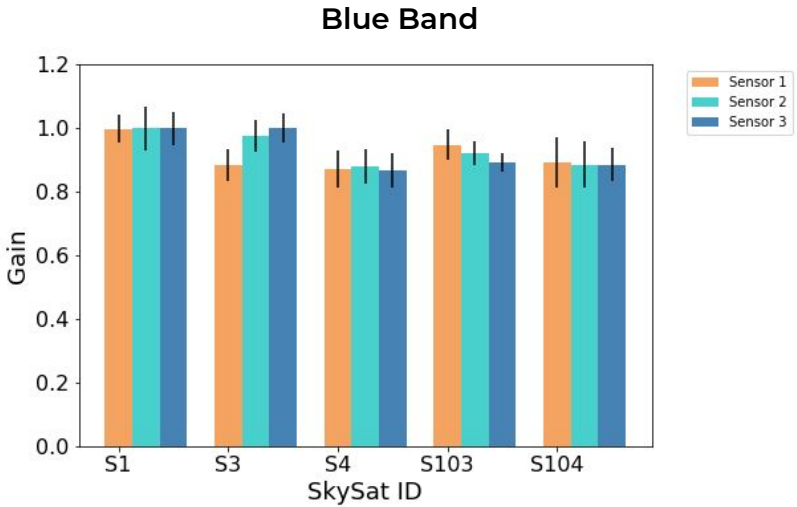
Individual Sensors / Details

SkySat



Blue			
SkySat id	**Sensor 1**	**Sensor 2**	**Sensor 3**
s1	0.997	0.998	0.998
s2	0.883	0.975	0.999
s4	0.87	0.879	0.867
s103	0.946	0.921	0.892
s104	0.892	0.883	0.884

Individual sensor gains
Error bars represent 1 sigma uncertainty

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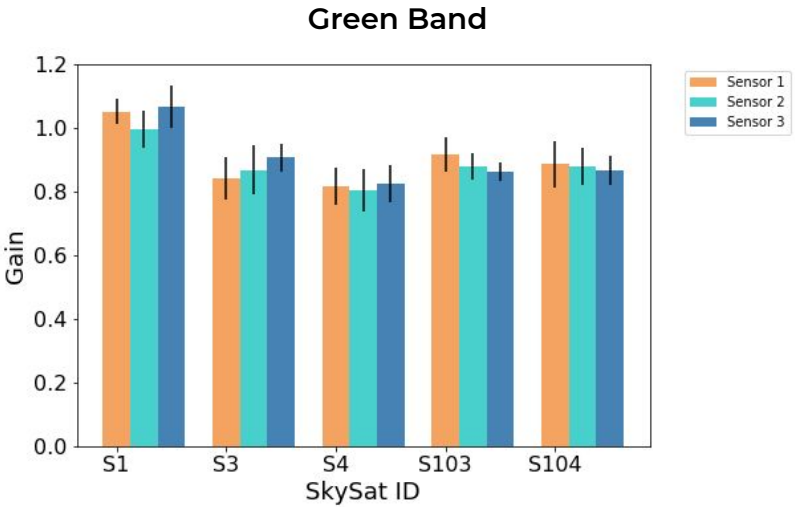
Individual Sensors / Details

SkySat



Green			
SkySat id	**Sensor 1**	**Sensor 2**	**Sensor 3**
s1	1.051	0.996	1.065
s2	0.84	0.867	0.906
s4	0.816	0.803	0.824
s103	0.914	0.877	0.861
s104	0.885	0.879	0.867

Individual sensor gains
Error bars represent 1 sigma uncertainty

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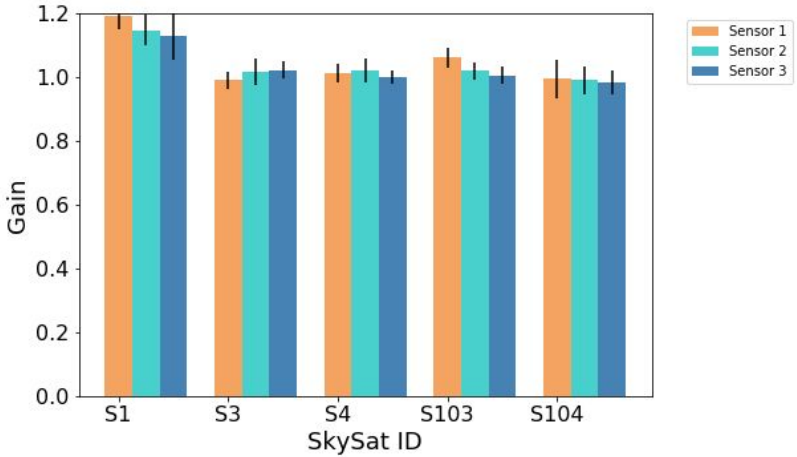
Individual Sensors / Details

SkySat

Red Band



Red			
SkySat id	**Sensor 1**	**Sensor 2**	**Sensor 3**
s1	1.189	1.146	1.127
s2	0.989	1.016	1.022
s4	1.011	1.02	1
s103	1.06	1.019	1.005
s104	0.993	0.989	0.983

Individual sensor gains
Error bars represent 1 sigma uncertainty

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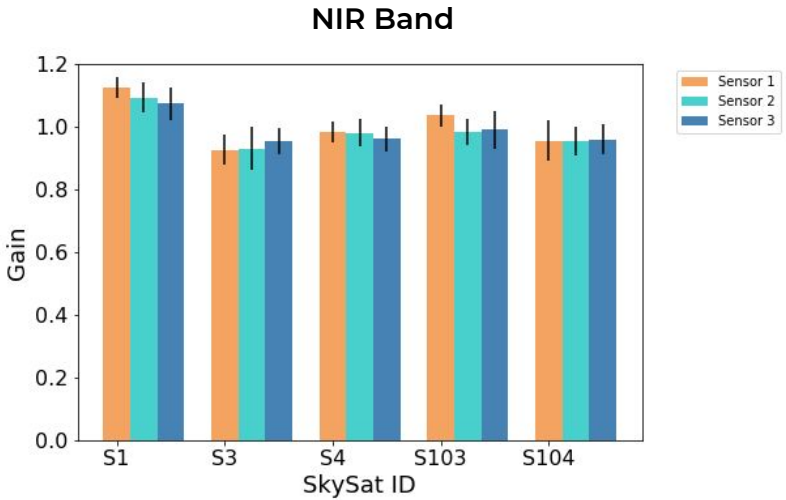
Individual Sensors / Details

SkySat



NIR			
SkySat id	**Sensor 1**	**Sensor 2**	**Sensor 3**
s1	1.124	1.092	1.073
s2	0.926	0.93	0.953
s4	0.982	0.979	0.961
s103	1.035	0.981	0.99
s104	0.955	0.955	0.959

Individual sensor gains
Error bars represent 1 sigma uncertainty

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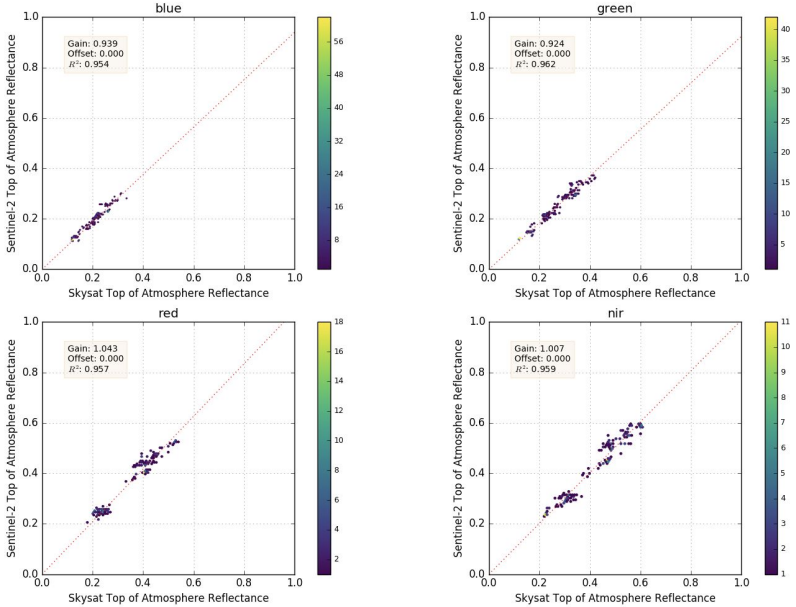
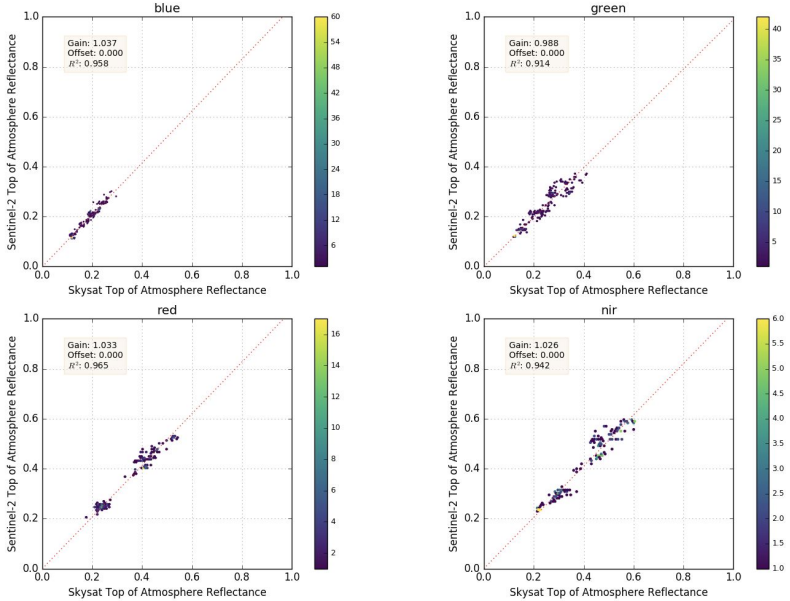
Verification

Original vs. Corrected

Validation Data Set Original



Per Sensor Corrections Applied



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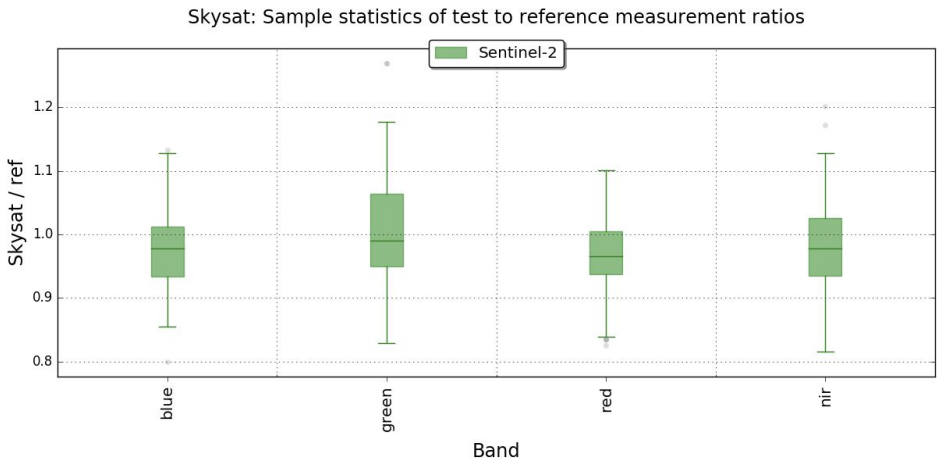
Accuracy



	Accuracy %	Uncertainty %
Blue	-2.919	5.929
Green	0.579	8.772
Red	-2.454	5.213
NIR	-3.610	6.396

Measurements of accuracy and uncertainty for the validation against Sentinel 2 reflectances

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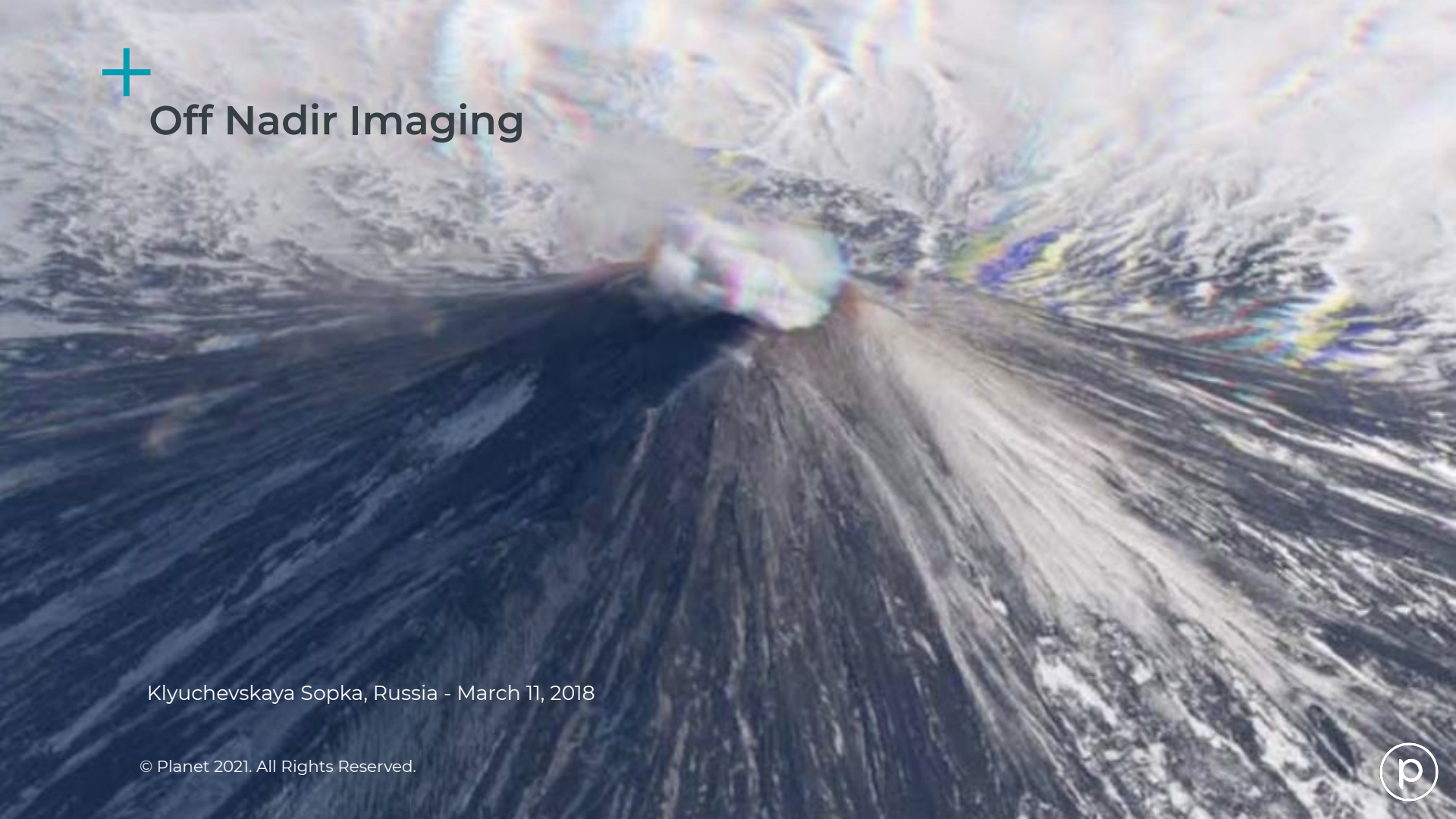
Off Nadir Imaging



Klyuchevskaya Sopka, Russia - March 11, 2018

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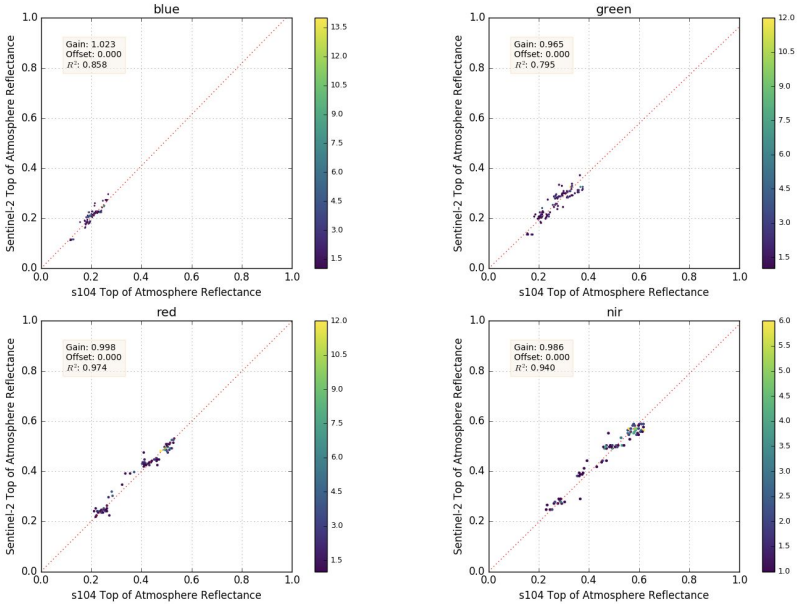
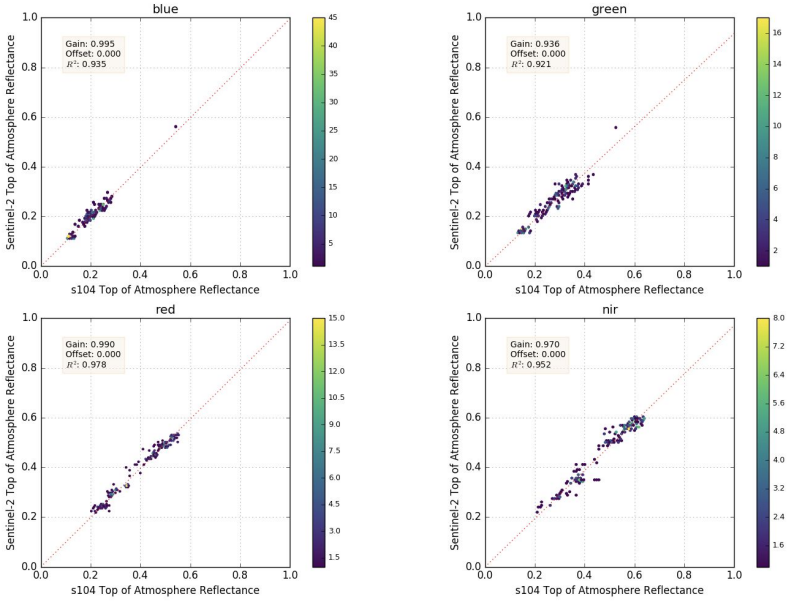
Off Nadir Imaging

Sentinel-2 Crossover Sites s104

10 Degrees



20 Degrees



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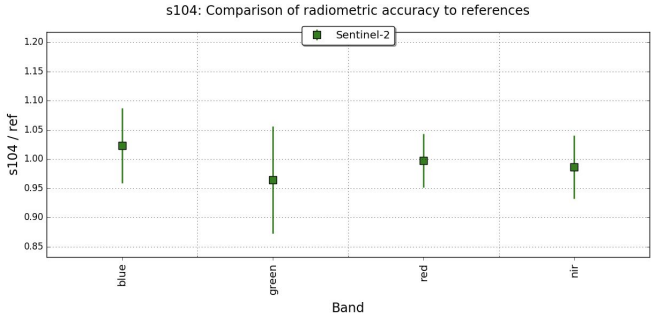
Off Nadir Imaging

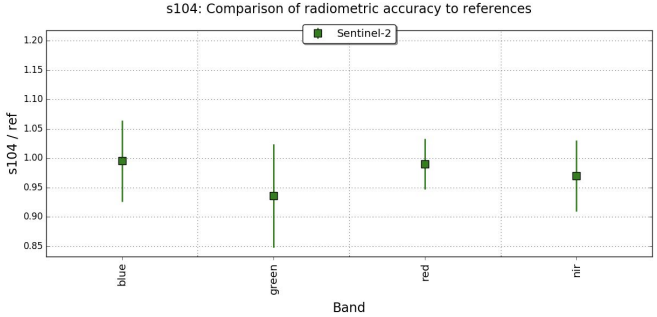
Radiometric Accuracy to References

10 Degrees



	Accuracy %	Uncertainty%
Blue	-2.242	6.399
Green	3.867	9.181
Red	-0.425	4.610
NIR	1.240	5.408

20 Degrees



	Accuracy %	Uncertainty%
Blue	-0.791	6.881
Green	5.594	8.804
Red	0.651	4.300
NIR	3.111	6.028

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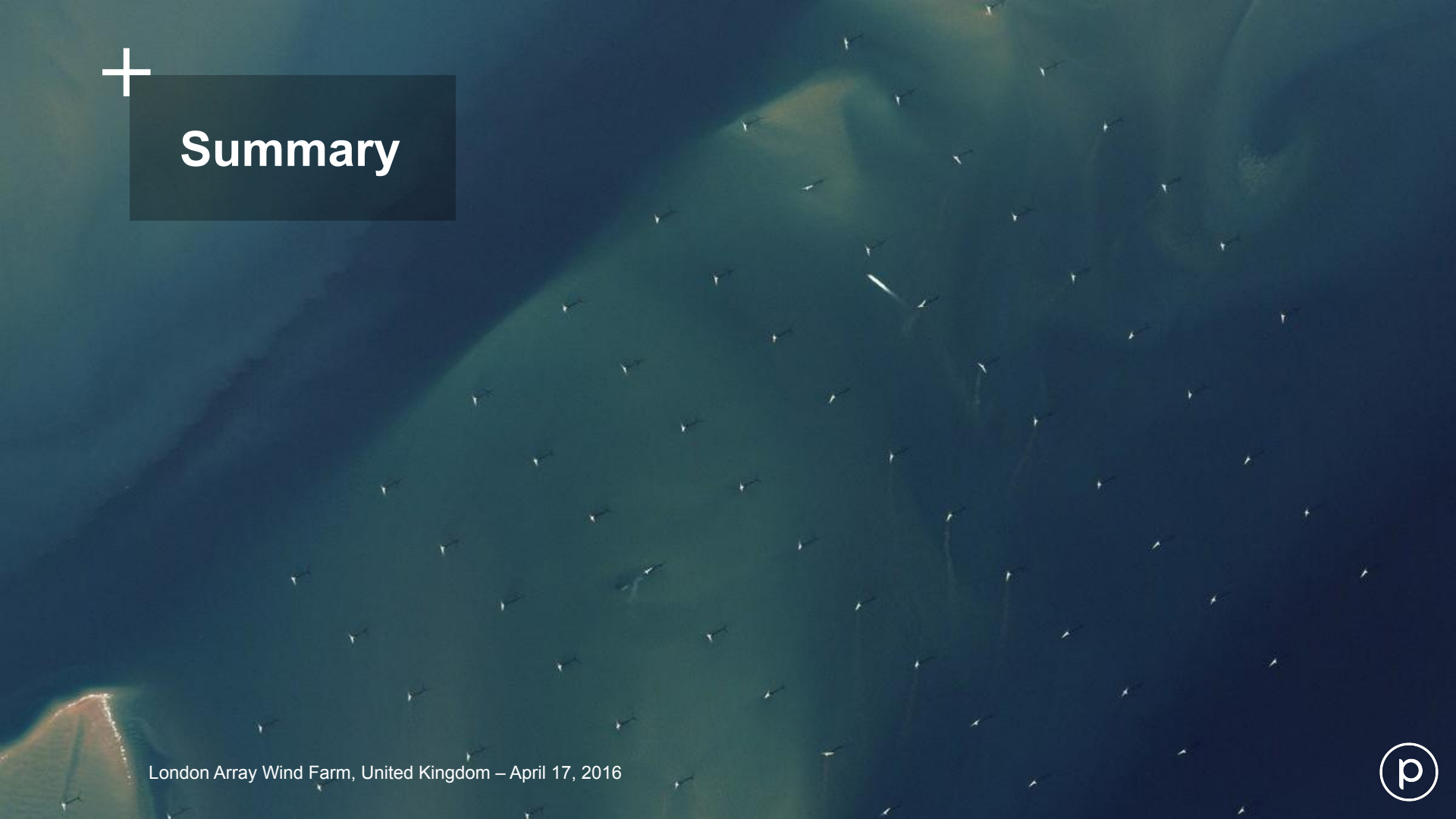
Summary



London Array Wind Farm, United Kingdom – April 17, 2016

Summary

- Update methodology throughout Planet's fleet to use Sentinel 2 as our calibration reference
- Calibrate satellites per sensor
- Radiometric accuracy guaranteed at view angles less than 10 degrees

Future Work

- Further BRDF characterization
- Using Planet's Fusion product as a calibration source where simultaneous crossovers are limited
    - Recently launched Block III satellites
- Further characterization of the three detectors in general imagery

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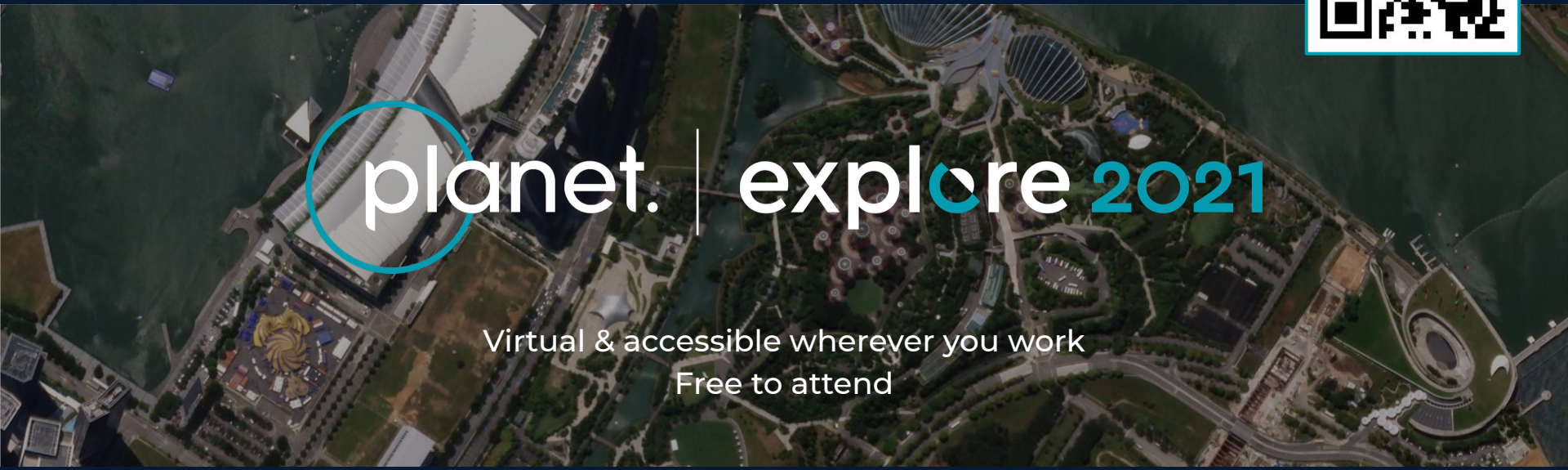
Save the date: October 12-13

Planet Explore 2021 Global Connection

Scan to Register



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Great Barrier Reef, Australia – July 8, 2016