Spatio-Temporal Validation of Analysis-Ready PlanetScope Surface Reflectance Data

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CHLOROPHYLL RED-EDGE (CIRE) • Marion County, Illinois, USA • July 7, 2021

Introduction

- Overview of Analysis-Ready PlanetScope (ARPS)
- ARPS Methodology
- Radiometric Validation
  - FORCE
  - RadCalNet
- Geometric Validation
- Conformance to CEOS-ARD Framework

Analysis-Ready PlanetScope Summary

Product Details

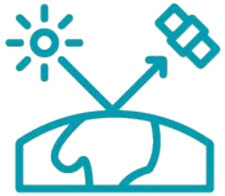
What is it?

- 4 Bands, 3 meter resolution
- Tiled & composited to a common grid
- Near-daily cadence
- Archive from January 1, 2017

What does it enable?

- Change detection across broad areas
- Accurate time series analysis and powerful machine learning

Spatially & temporally consistent timestacks of PlanetScope data.



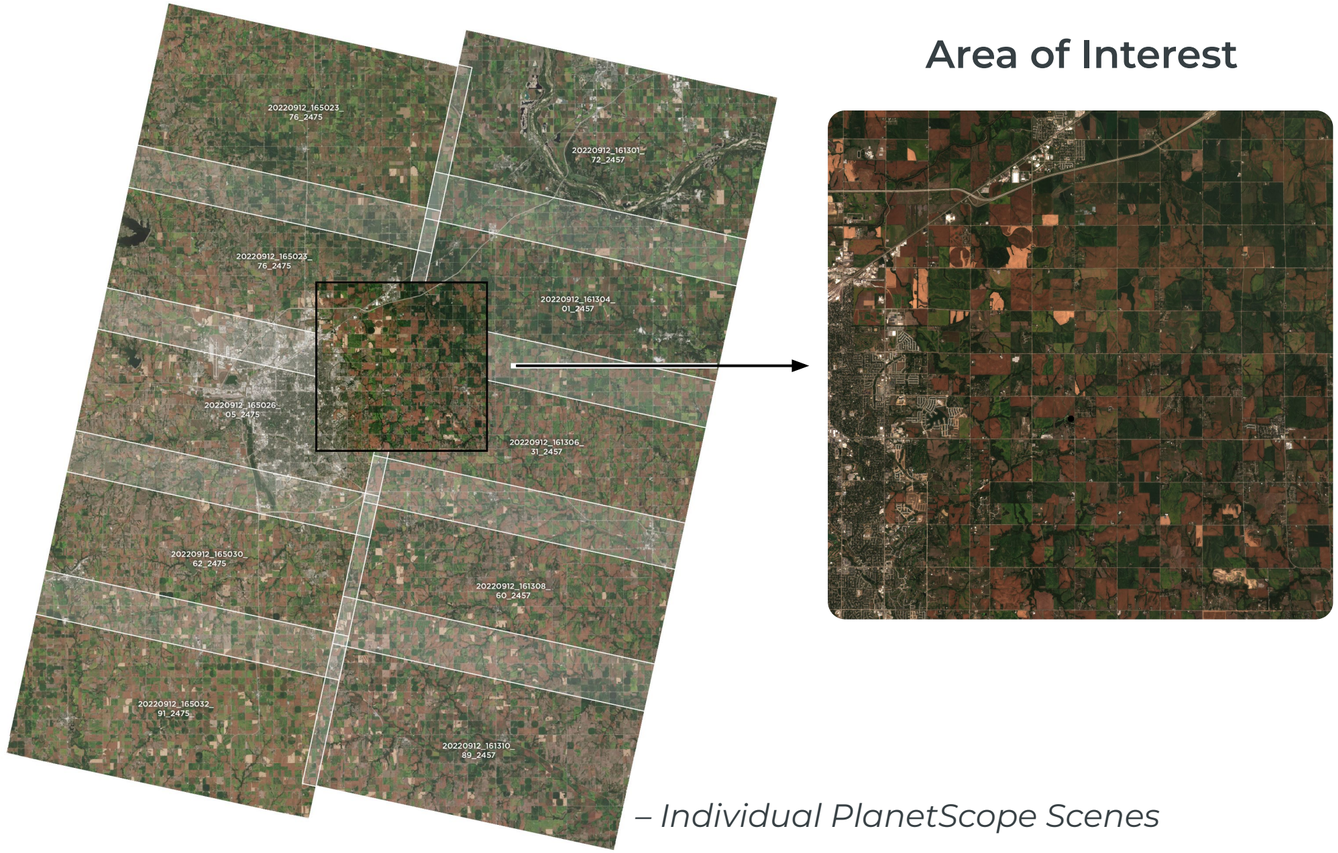
Rigorous geometric registration

Temporally-driven cloud mask

Enhanced radiometric calibration

Enables Spatially Consistent Time-Series Analysis

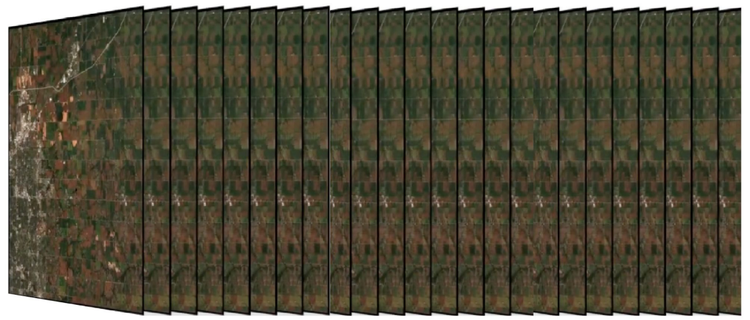
Over a designate AOI, we assemble data that might pull from multiple scenes, removing a painful step of compositing.



– Individual PlanetScope Scenes

Area of Interest

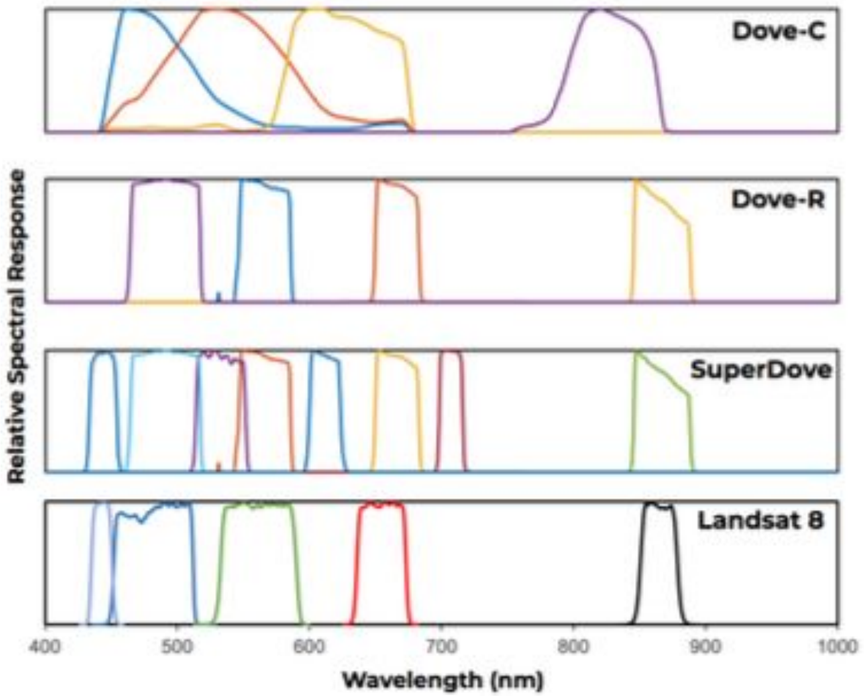
Having a series of images over time over a single AOI is what enables detailed temporal analysis.



Track changes, monitor developments, and gain insights into the dynamics of your selected area.

Harmonization across PlanetScope, Sentinel-2 and Landsat 8/9

- Combines imagery from Dove Classic, Dove-R, and SuperDove sensors.
- Enhances spatial and temporal consistency using trusted references: Landsat, Sentinel-2, MODIS, VIIRS.
- Converts 4-band PlanetScope TOA Reflectance (PS-TOAR) into surface reflectance.
- Ensures radiometric consistency with FORCE-processed Sentinel-2 and Landsat data.
- Matches spectral bands and response functions to Sentinel-2:
    - Blue (B2), Green (B3), Red (B4), Narrow NIR (B8a).



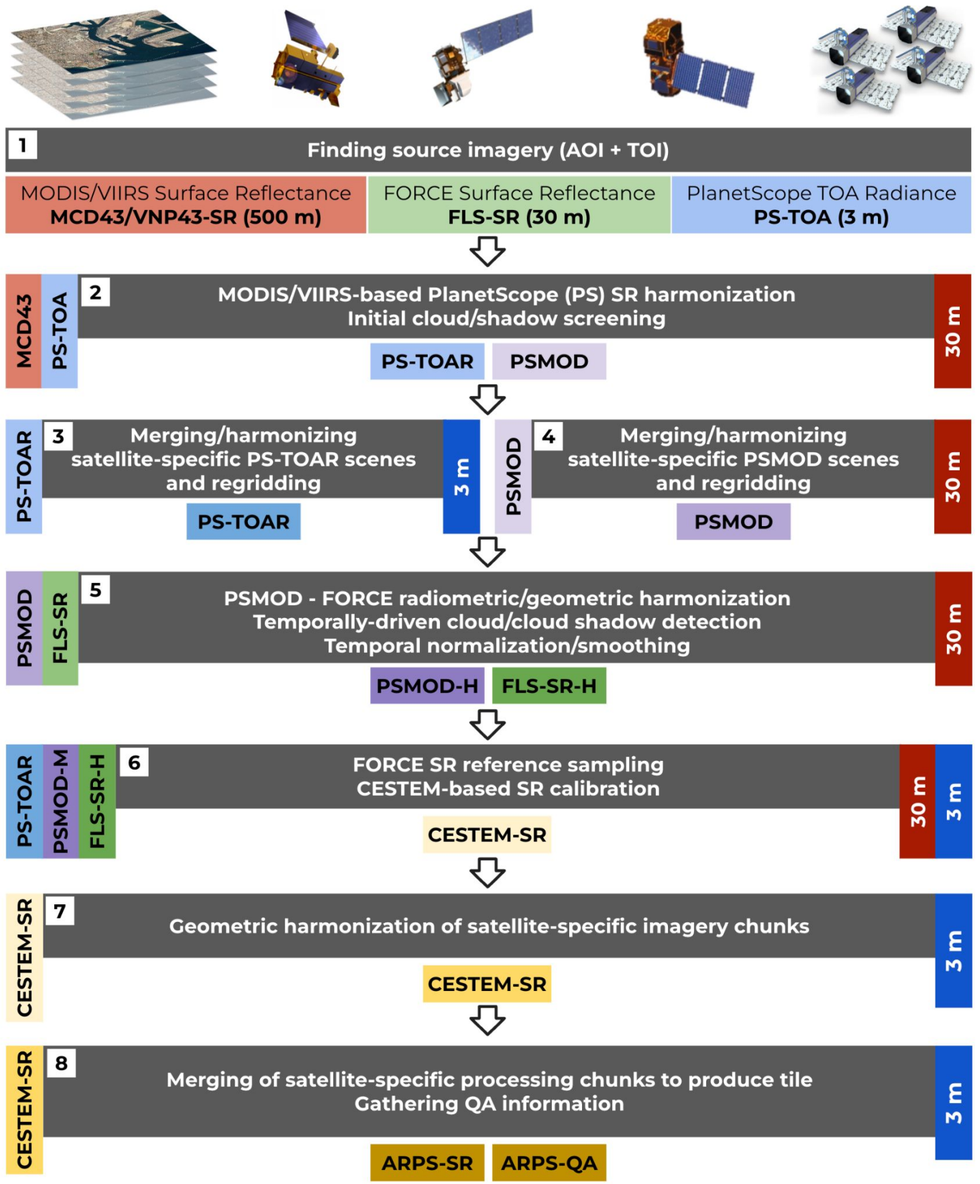
ARPS Methodology

Source Imagery

- Finds associated imagery for Area of Interest (AOI) and Time of interest (TOI) + 1 year calibration window
  - MODIS/VIIRS Surface Reflectance (500 m)
  - LandSat 8/9 and Sentinel 2 Surface Reflectance derived using FORCE (30 m)
  - PlanetScope Top of Atmosphere Radiance (3m)
- Aggregates overlapping PlanetScope images into uniform tiles (UTM-24000).
- Prioritizes images based on quality, cloud cover, and illumination conditions.

Cloud and Shadow Masking

- Detects clouds by combining PlanetScope imagery with Sentinel-2/Landsat data.
- Uses multi-temporal analysis to refine cloud/shadow identification.



ARPS Methodology (Cont'd)

Radiometric Harmonization

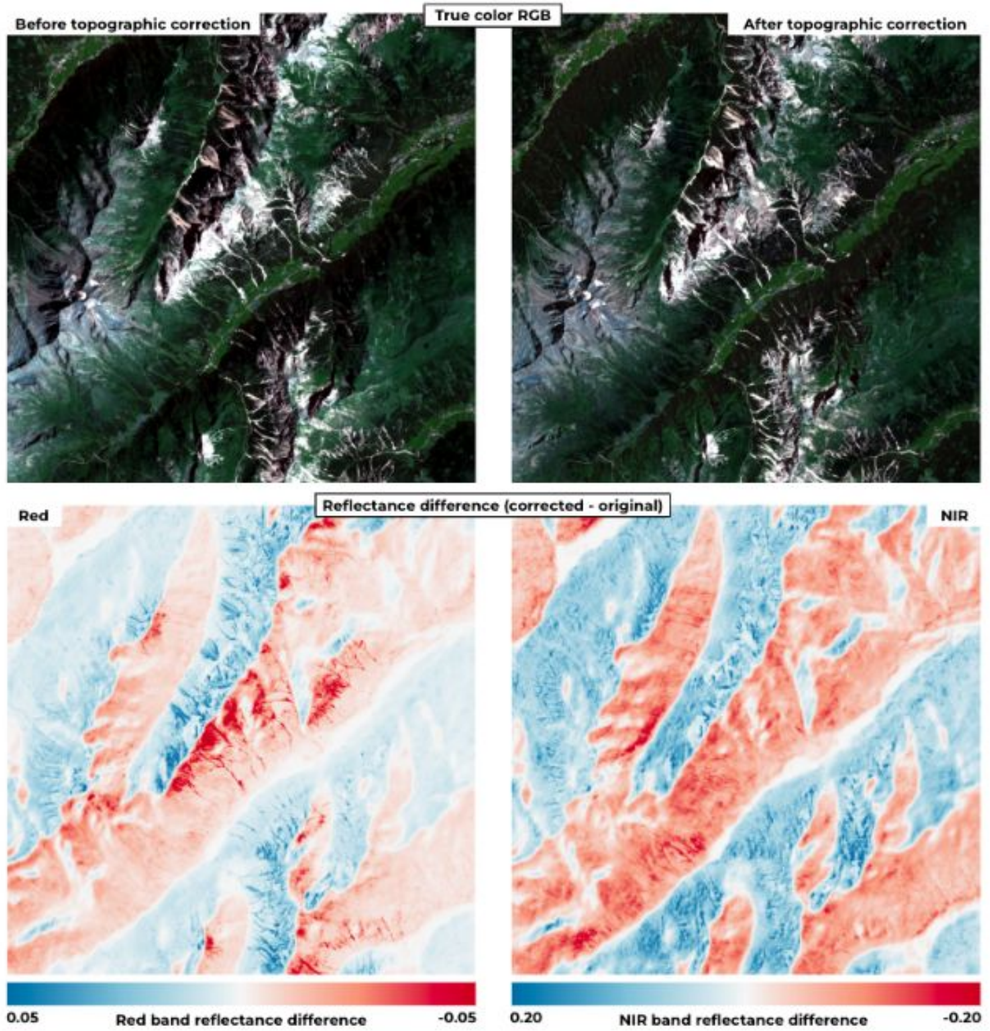
- Uses CESTEM (CubeSat-Enabled Spatio-Temporal Enhancement Method) for radiometric alignment. (Houborg and McCabe 2018a, 2018b)
- Ensures consistency despite temporal and spectral differences.

Topographic Correction

- Adjusts reflectance values for terrain-related distortions.
- Uses Sun-Canopy-Sensor with C-correction method to reduce reflectance inaccuracies in sloped terrain. (Teillet et al. 1982)

Geometric Harmonization

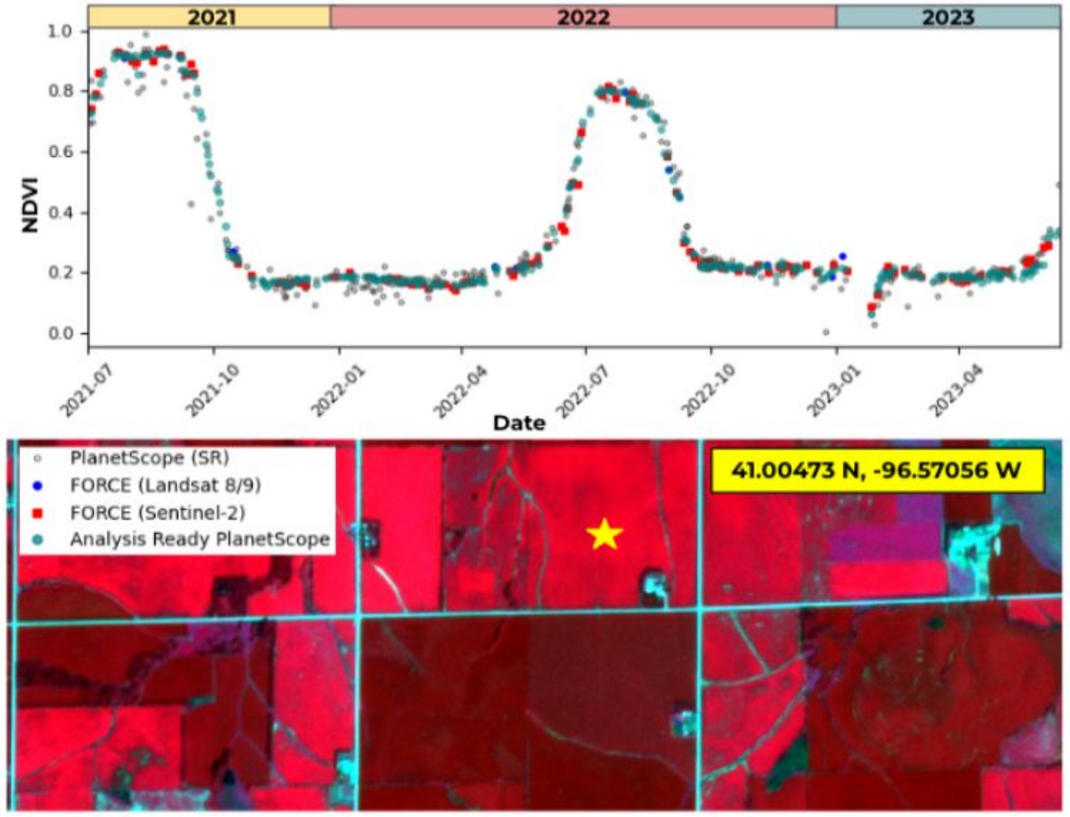
- Employs phase cross-correlation for precise sub-pixel alignment across satellites.
- Ensures accurate spatial alignment for time-series analysis.



Radiometric Validation

FORCE (Framework for Operational Radiometric Correction for Environmental Monitoring)

- **How ARPS Uses FORCE**
  - Radiometric Harmonization – Aligns PlanetScope reflectance with FORCE-derived Landsat 8/9 & Sentinel-2 for spectral consistency.
  - Atmospheric & Topographic Corrections – Uses FORCE's 5S model and terrain correction to normalize reflectance.
  - Cloud & Shadow Masking – Integrates FORCE-refined cloud masks into ARPS's multi-temporal cloud verification.
  - Geometric Alignment – Leverages FORCE's co-registered Sentinel-2/Landsat data for sub-pixel accuracy.
  - Cross-Sensor Interoperability – Ensures CEOS-ARD compliance by aligning PlanetScope with trusted reference datasets.



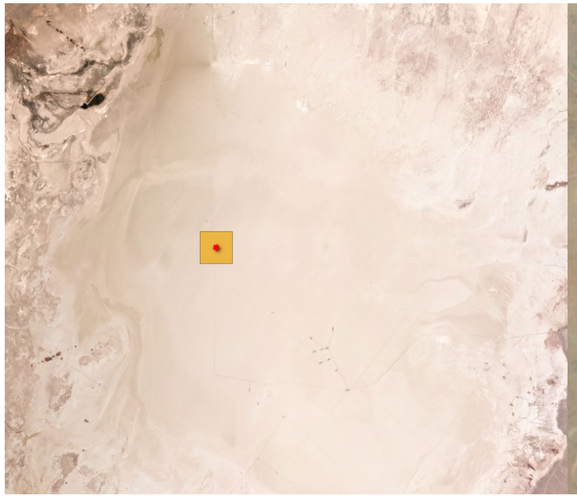
FORCE provides ARPS with a high-accuracy benchmark for radiometric and geometric consistency.

Radiometric Validation

RadCalNet

- Currently consists of **4 sites**
- Provides satellite operators with SI traceable TOA spectrally resolved reflectances to aid in on orbit calibration and validation
- Provide surface and atmosphere measurements used to simulate TOA nadir reflectance at **10 nm** sampling interval
- Provides measurements every **30 minutes**

1 km x 1 km

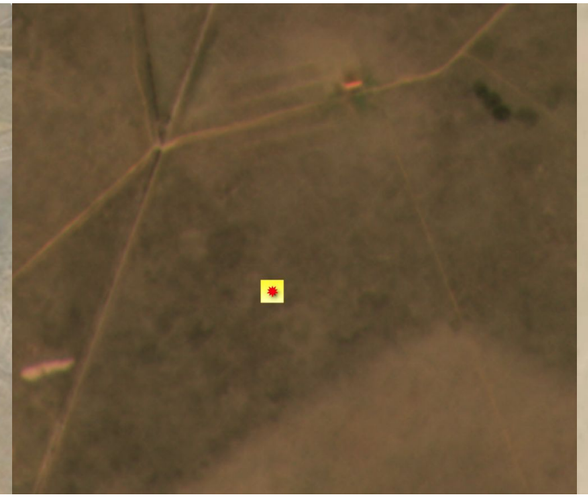


RAILROAD VALLEY

300 m x 300 m

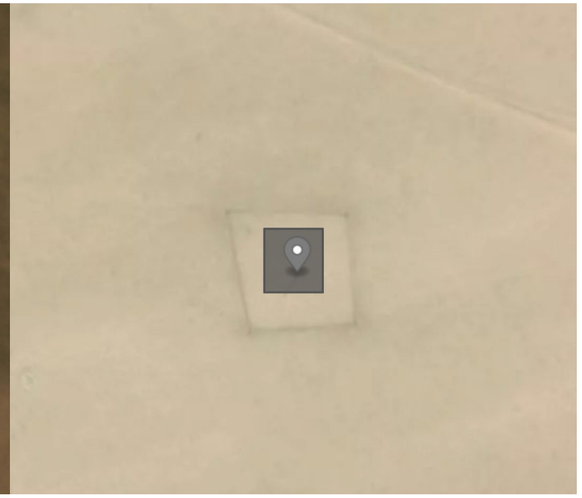
BAOTOU SANDS

100 m x 100 m



LA CRAU

30 m x 30 m

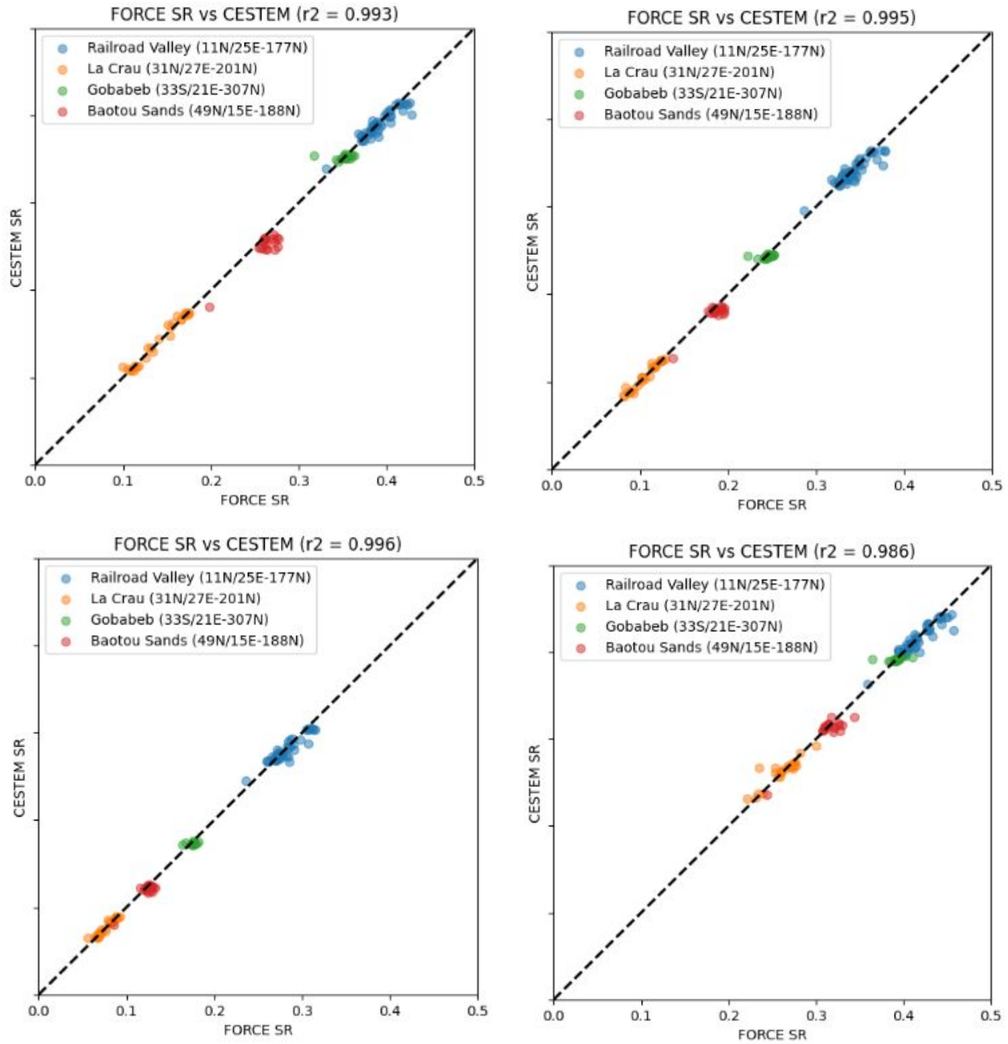


GOBABEB

Radiometric Validation

ARPS vs FORCE

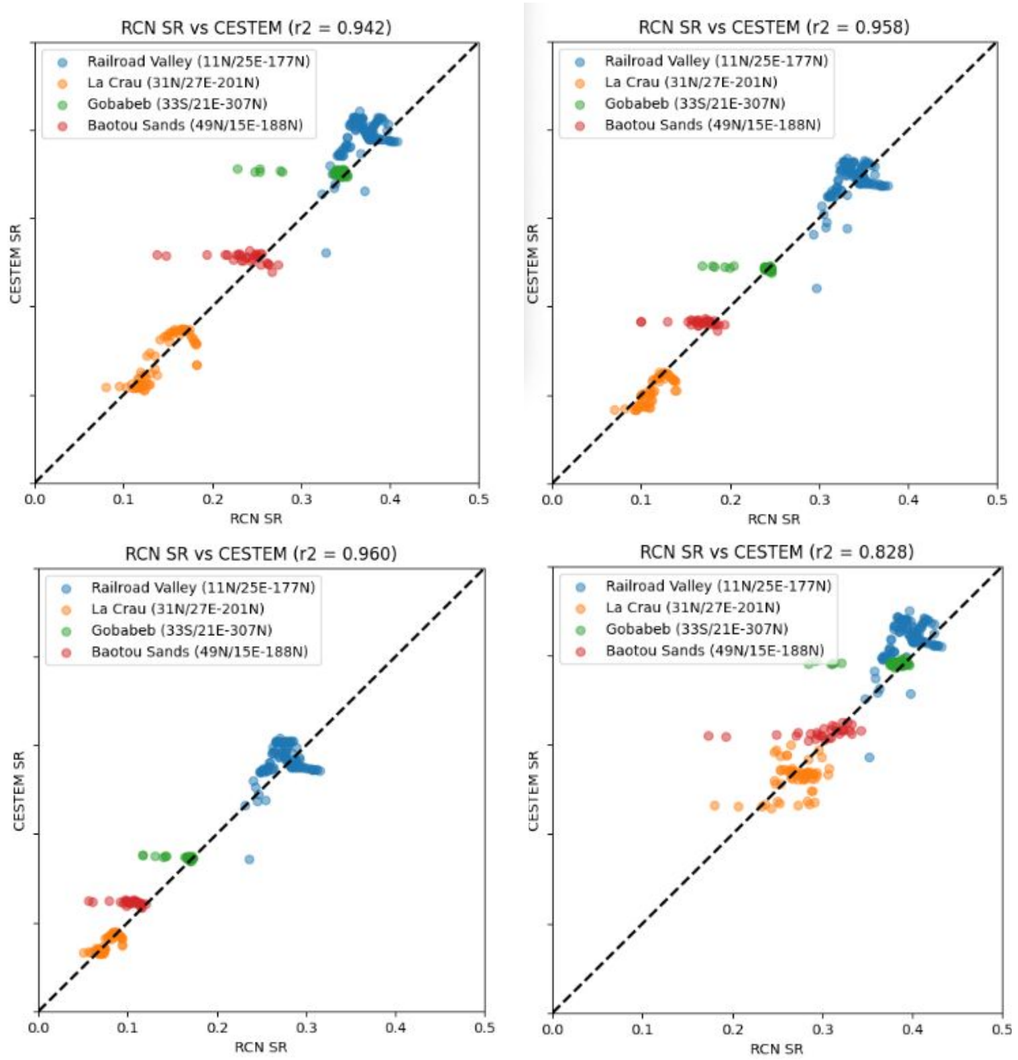
Band	r2	Absolute Accuracy %	Precision %	Uncertainty (1-sigma)
Blue	.996	-0.483	3.45	3.47
Green	.995	-0.573	3.21	3.23
Red	.993	-0.690	3.33	3.34
NIR	.986	-0.174	2.473	2.485



Radiometric Validation

ARPS vs RadCalNet

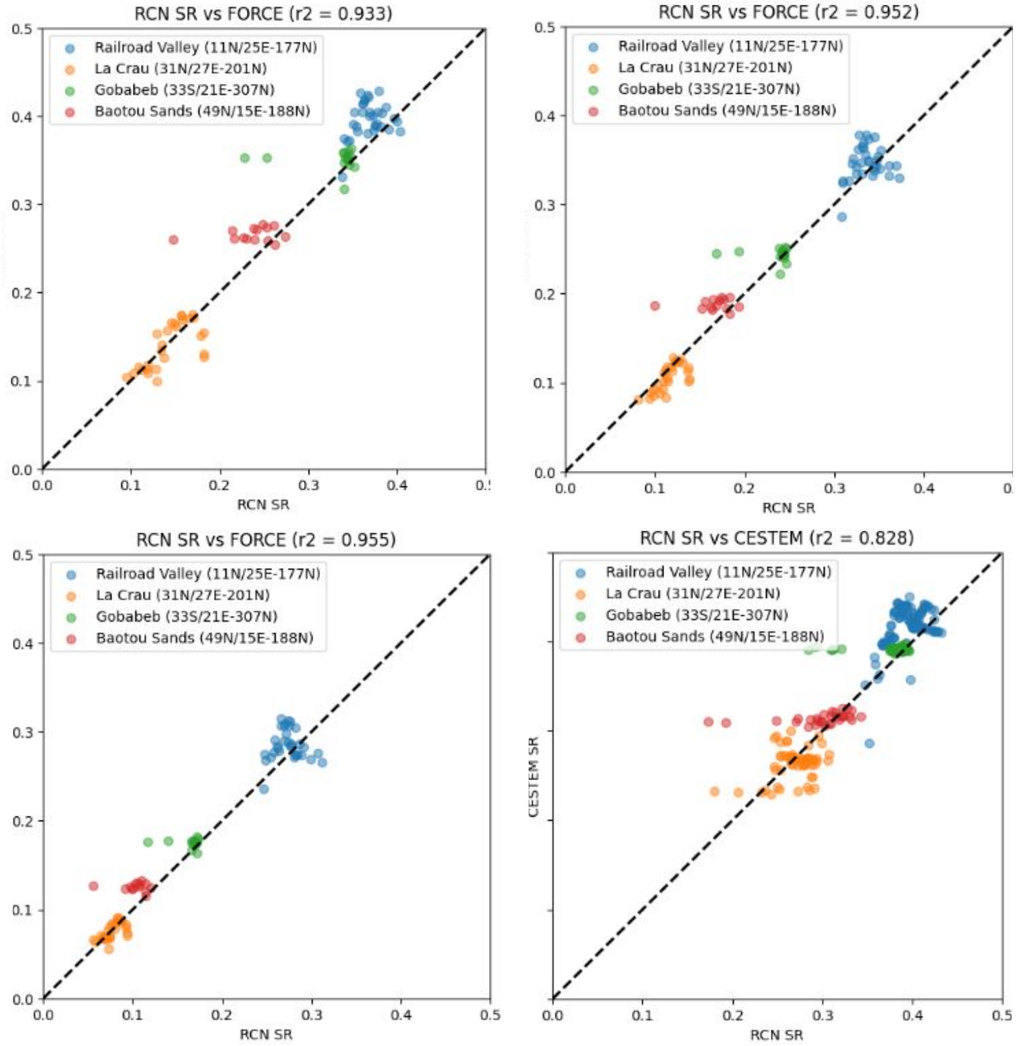
Band	r2	Absolute Accuracy %	Precision %	Uncertainty (1-sigma)
Blue	.960	5.564	13.929	17.418
Green	.958	1.386	11.704	11.727
Red	.942	3.215	8.950	11.703
NIR	.828	3.90	9.903	9.92



Radiometric Validation

FORCE vs RadCalNet

Band	r2	Absolute Accuracy %	Precision %	Uncertainty (1-sigma)
Blue	.955	7.041	17.419	17.418
Green	.952	2.214	14.098	14.177
Red	.933	6.270	13.644	13.720
NIR	.830	3.852	10.301	10.359



Geometric Validation

- ARPS prioritizes Temporal registration consistency above absolution geolocation
- Geometric Validation is done by using a semi-fixed grid and extract matching points between overlapping ortho ARPS images
- Temporal registration is calculated by assessing the overall shifts between image pairs using the first scene in the time-series as the anchor scene

Product:		ARPS	PlanetScope*
Absolute Geolocation	Samples	4,371	10,291
	CE90 (m)	4.55	5.78
	PCTL90 of RMSE (m)	4.74	5.83
Temporal Registration	Samples	6,554	108,400
	PCTL90 of RMSE (m)	3.65	4.48
Band Registration	Samples	33,085	931,795
	PCTL90 of RMSE (m)	0.5	.58

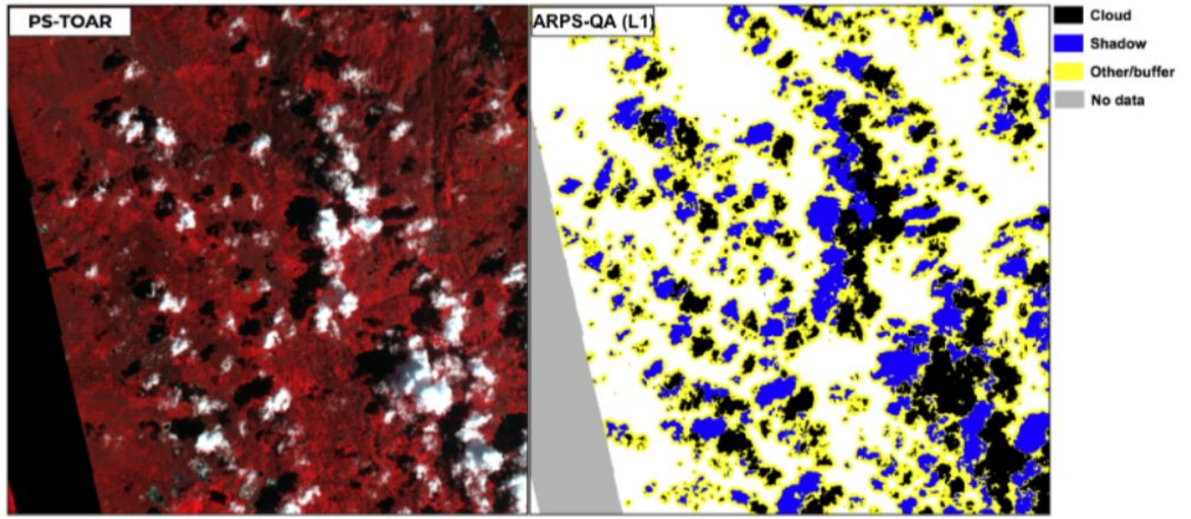
*Planet L1 Data Quality Report Q3 2022

CEOS-ARD Framework

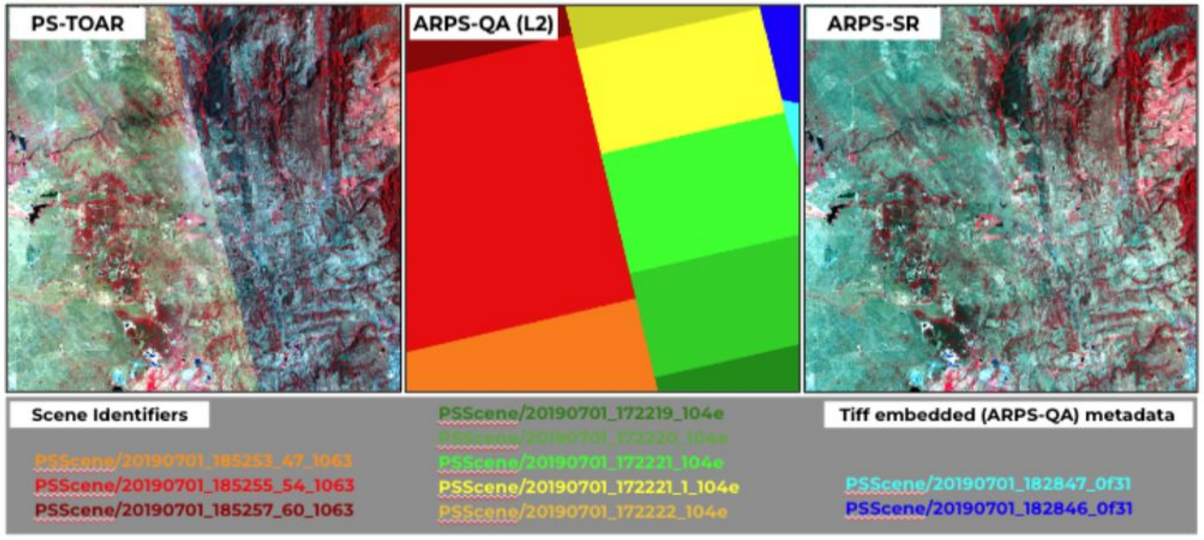
ARPS QA Layer

- **Cloud and Shadow Masking:** It provides detailed pixel-level flags indicating the presence of clouds, cloud shadows, and haze, enabling accurate filtering of unusable data.

- **Traceability:** Includes metadata that allows users to trace back processed pixels to original PlanetScope scenes, ensuring transparency and reliability in data provenance.



Layer	Description	Date Type	Valid range	Scale factor	Offset
Layer 1	Cloud and cloud shadow mask 1 = Clear 2 = Bright Clouds 3 = Cloud shadows 4 = Haze 5 = Adjacent clouds/clouds shadows 6 = Additional cloud/shadow/haze elements based on a cross-scene correlation detection approach 7 = Other contamination, including snow -999 = Scene data not available	16-bit signed integer	1 - 7, and -999	1	0
Layer 2	Pixel traceability/provenance mask (*see embedded metadata for scene IDs*) -999 = Scene data not available	16-bit signed integer	1 - 599, and -999	1	0



CEOS-ARD Framework

ARPS Metadata

- All ARPS products are delivered with a SpatioTemporal Asset Catalog (STAC) file that conforms to the STAC specifications.
- Additional metadata is available in the GeoTiff header.

STAC Extension	Description
Electro-Optical	Specification of the spectral bands contained with the SR product and descriptions of the information bands contained within the QA product
Projection	Coordinates representing the bounding geometry of the tile's footprint
Raster	Properties of the tile pixels

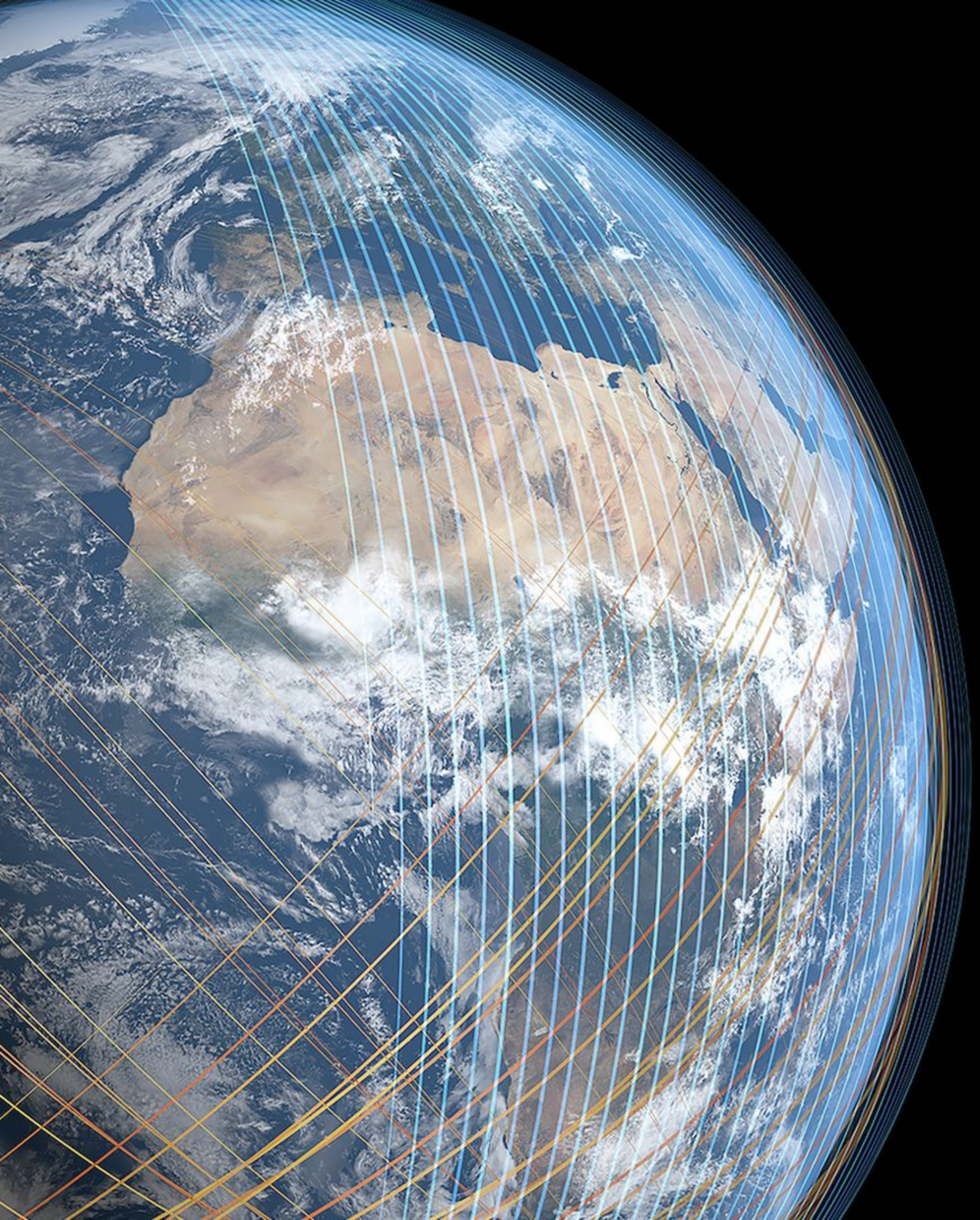
Name	Description	Example
CREATED	Timestamp of the product creation, corresponding to the time at which contributing satellite observations were gathered.	2024-09-20T17:19:27Z
PERCENTAGE_CLEAR	Fraction of pixels in the raster marked as class 1, "clear", in the QA layer 1 cloud mask	86.68
PERCENTAGE_STANDARD_QUALITY	Fraction of observed pixels in the tile which came from "standard" (as opposed to "test" quality PlanetScope images, see Roy et al., 2021)	100
PIPELINE_VERSION	Version identifier for the image processing pipeline used to create that day's data	1.0.0
RUN_TYPE	Designates whether the data were produced in "backfill" or "forwardfill" mode. (See Section 4.6)	backfill
SCENE_IDS[LAYER_2_VALUE]	Newline-separated scene IDs corresponding to integer references numbers in QA layer 2. See the layer 2 description above for more information.	PSScene/20210708_131909_101b[9] PSScene/20210708_131910_101b[10] PSScene/20210708_131911_101b[11] PSScene/20210708_131912_101b[12] PSScene/20210708_134254_06_2406[218] None[-999]
SCENE_SOLAR_AZIMUTH[LAYER_2_VALUE]	The solar azimuth in degrees for each PlanetScope scene in the layer 2 scene provenance raster	40.30[9] 40.20[10] 40.20[11] 40.20[12] 35.00[218] None[-999]
SCENE_SOLAR_ELEVATION[LAYER_2_VALUE]	The solar elevation in degrees for each PlanetScope scene in the layer 2 scene provenance raster	38.60[9] 38.50[10] 38.50[11] 38.40[12] 41.90[218] None[-999]

CEOS-ARD Framework

Closing Gaps with ARPS 1.1.0

- **Radiometric Accuracy:** Moved from Threshold to **Target**. Validated against RadCalNet sites with reported precision and absolute accuracy.
- **Auxiliary Data:** Moved from Below Threshold to **Threshold Met**. Metadata now specifies GLO-30 DEM and FORCE v3.7.10 versioning.
- **Measurement Uncertainty:** Moved from Threshold to **Goal Met**. Uncertainty metrics are now standardized in STAC metadata and product landing pages.

Sections	2025 Status (v1.0)	2026 Status (v1.1)	Key Update
General Metadata	11/17 Target	**14/17 Target**	Improved traceability and aux data disclosure.
Radiometric and Atmospheric Correction	5/6 Target	**6/6 Target**	NBAR and Topographic Correction implemented.



Thank You.

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