Tanager Satellite

TANAGER PRODUCT SPECIFICATIONS

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GLOSSARY

The following list defines terms used to describe Planet's satellite imagery products. In the event of any discrepancy of terms defined in other Planet documents, the terms defined herein relate to this Tanager Product Specification only.

Alpha Mask
An alpha mask is an image channel with binary values that can be used to render areas of the image product transparent where no data is available.

Application Programming Interface (API)
A set of routines, protocols, and tools for building software applications.

Atmospheric Correction
The process of correcting Top-of-Atmosphere (TOA) radiance imagery to account for effects related to the intervening atmosphere between the earth's surface and the satellite.

Beta Usable Data Mask
The usable data mask is a raster image having the same dimensions as the image product, comprising 3 bands (Cloud Mask, Cirrus Mask and Surface Water Mask), where each band represents a specific usability class mask.

Blackfill
Non-imaged pixels or pixels outside of the buffered area of interest that are set to black. They may appear as pixels with a value of "0" or as "noData" depending on the viewing software.

Collect
A series of scenes captured in a single overpass by a Tanager satellite.

Circular Error 90th Percentile (CE90)
CE90 indicates that 90% of all positional measurements will fall within a specified radius around the true position.

Digital Elevation Model (DEM)
The representation of continuous elevation values over a topographic surface by a regular array of z-values, referenced to a common datum. DEMs are typically used to represent terrain relief.

GeoJSON
A standard for encoding geospatial data using JSON (see JSON below).

GeoTIFF
An image format with geospatial metadata suitable for use in a GIS or other remote sensing software.

Ground Sample Distance (GSD)
The distance between pixel centers, as measured on the ground. It is mathematically calculated based on optical characteristics of the telescope, the altitude of the satellite.

Graphical User Interface (GUI)
Web based interfaces enable users to interact with Planet's imagery products without needing knowledge of how to use APIs or Application Programming Interfaces.

HDF-EOS5 (HDF5) image format
HDF5 files are self-describing, support partial reading of contents, and contain numerous interrelated datasets within a single file.

Image Support Data (ISD)
Additional metadata or files provided to give context for advanced users.

Integration Time
Refers to the duration during which a sensor collects light or radiation from a target to produce a single measurement or image pixel, which may influence the quality of the captured data.

JavaScript Object Notation (JSON)
Text-based data interchange format used by the Planet API.

Metadata
Data delivered with Planet's imagery products that describes the products content and context and can be used to conduct analysis or further processing.

Nadir
The point on the ground directly below the satellite.

Near-Infrared (NIR)
Near Infrared is a region of the electromagnetic spectrum (780 nm to 1400 nm).

Orthorectification
The process of removing and correcting geometric image distortions introduced by satellite collection geometry, pointing error, and terrain variability.

Pushbroom
A remote sensing technique that uses a linear array of detectors to capture continuous cross-track data along the flight path of a sensor. As the platform moves, the detectors collect spectral and/or spatial information line-by-line, offering efficiency without mechanical scanning components.

Radiometric Correction
The correction of variations in data that are not caused by the object or image being scanned. These include correction for relative radiometric response between detectors, filling non-responsive detectors and scanner inconsistencies.

Scene
A single image captured by a Tanager satellite.

Sensor Correction
The correction of variations in the data that are caused by sensor geometry, attitude, and ephemeris.

Shortwave-Infrared (SWIR)
Shortwave Infrared is a region of the electromagnetic spectrum (1400 nm to 3000 nm).

Sun Azimuth
The angle of the sun as seen by an observer located at the target point, as measured in a clockwise direction from true north.

Sun Elevation
The angle of the sun above the horizon.

Sun Synchronous Orbit (SSO)
A geocentric orbit that combines altitude and inclination in such a way that the satellite passes over any given point of the planet's surface at the same local solar time.

Surface Reflectance (SR)
Surface reflectance is the proportion of light reflected by the surface of the earth. It is a ratio of surface radiance to surface irradiance, and as such is unitless, and typically has values between 0 and 1.

1. OVERVIEW OF DOCUMENT

This document describes Planet's hyperspectral satellite imagery products generated from the current constellation of Tanager satellites. It is intended for users of satellite imagery interested in working with Tanager's product offerings.

1.1. COMPANY OVERVIEW

Planet uses an agile aerospace approach for the design of its satellites, mission control, and operations systems; and the development of its web-based platform for imagery processing and delivery.

Planet was founded with the mission to image the Earth every day and make change visible, accessible, and actionable. Over the past decade with its customers, Planet has revolutionized the Earth observation industry, democratizing access to satellite data beyond the traditional agriculture and defense sectors.

To that end, Planet offers Planet Insights Platform, a cloud-native platform that combines a near-daily scan of the Earth's landmass and strategic waterways with tools for advanced analysis to derive insights and make timely, informed decisions. Planet Insights Platform also provides access to high-resolution imagery, derived data products, and the infrastructure for users to develop web applications, integrate with GIS workflows, and drive data science and machine learning applications.

Businesses, governments, and research institutions leverage Planet's data and platform to scale their operations, increase efficiency, mitigate risk, and develop novel solutions to address their most pressing challenges. This helps them stay ahead in ever-changing global contexts and ultimately capture unforeseen windows of opportunity.

1.2 DATA PRODUCT OVERVIEW

Planet operates the PlanetScope, SkySat, Pelican, and Tanager Earth-imaging constellations. Imagery is collected and processed in a variety of formats to serve different use cases, such as mapping, deep learning, disaster response, precision agriculture, or simple temporal image analytics to create rich information products.

Tanager is an imaging spectrometer that operates as a line scanner collecting approximately 426 bands over the spectral range of 376 to 2500 nm (~0.4 to ~2.5 µm) with a spectral sampling of about ~5 nm. Planet generates calibrated radiance data from raw satellite measurements and further processes radiance to surface reflectance.

Planet offers two geometry types for TanagerScene imagery: Basic and Ortho. Tanager Basic Scene products contain the hyperspectral data (e.g., radiance or surface reflectance) in image space that has been processed to remove distortions caused by terrain and sensor and to provide precise geolocation information in geographic coordinate space. This geolocation information is provided as a separate array (longitude and latitude) to enable users to orthorectify or project the product themselves. An Ortho Scene product is orthorectified and the product was designed for a wide variety of applications that require imagery with an accurate geolocation and cartographic projection. It has been processed to remove distortions caused by terrain and can be used for cartographic purposes. The Ortho Scenes are delivered as visual (RGB), top-of-atmosphere radiance and surface reflectance products. Ortho Scenes are radiometrically-, sensor-, and geometrically-corrected products that are projected to a cartographic map projection. The native file format for both Tanager's Basic and Ortho assets is HDF-EOS5 (HDF5) image format. HDF5 files are self-describing, support partial reading of contents, and contain numerous interrelated datasets within a single file. Inside an HDF5 file, there are groups, datasets, and attributes. Groups are like folders and can hold other groups or datasets. Attributes are details about the groups or datasets. One can add attributes to anything in the file. Datasets are collections of data that are arranged like an array. Users can find the HDF5 documentation here: https://www.hdfgroup.org/solutions/hdf5/.

In addition to imagery, Planet also provides Derived Products based on Tanager collections. The first Derived Product is a methane detection product, TanagerMethane item-type, that enables leak detection, regulatory enforcement, and emissions inventory applications, among others.

2. SATELLITE CONSTELLATION AND SENSOR OVERVIEW

2.1 TANAGER SATELLITE CONSTELLATION AND SENSOR CHARACTERISTICS

The Tanager satellite is an imaging spectrometer capturing approximately 426 Bands with ~5 nm spacing between an approximate range of 380-2500 nm, with the first launched in August 2024. Planet intends to launch additional Tanager satellites to meet market demands over the coming years.

Each satellite is 3-axis stabilized and agile enough to slew between different targets of interest. Each satellite has a single electric propulsion (EP) thruster for orbital control, along with four reaction wheels and three magnetic torquers for attitude control.

All Tanagers contain three-mirror anastigmat (TMA) telescopes with a focal length of 400 mm and Dyson form spectrometers, with a 640x480 pixel Mercury-Cadmium-Telluride (MCT) detector as the focal plane array.

2.2.1 Collection Modes

Due to the minimum integration time of 8 ms, the lower bound of the along-track length of each pixel is currently at around 58 m when scanning at the orbital rate in pushbroom mode. This along-track elongation of area registered at each sensing element on the focal plane array (FPA) causes pixels in the geometrically corrected images to be rectangular, and for most use cases this pixel stretching is generally an undesirable effect.

In order to overcome this elongation effect and achieve signal-to-noise ratio (SNR) goals, Tanager performs attitude maneuvering, referred to as 'back nodding,' to be able to get a time-prolonged capture over an area compared to what a simple pushbroom scan would allow at the nominal ground scan speed. In other words, the imaging starts before the satellite flies above the starting point of the imaging ground track, and finishes after it has passed over the ending point of the imaging ground track. This strategy allows for more imaging time to be devoted to a potentially smaller area, thus yielding a higher SNR.

Tanager imaging modes. For each mode, the Tanager satellite back-nods with a given angular rate over some distance to provide ground motion compensation.

Standard Sensitivity (1x8ms, 8ms): In this mode, back-nodding is used to slow down the ground scan rate just enough to prevent pixel stretching, maintaining square pixels while maximizing swath length. The primary goal is to avoid elongation without specifically targeting higher SNR.

Medium Sensitivity (2x8ms, 16ms): In this mode, the ground scanning rate is slowed further to provide an effective integration time of approximately 16 ms. The result of this increased effective integration time is an ~1.4x increase in the SNR over Standard Sensitivity mode.

High Sensitivity (3x8ms, 24ms): In this mode, the ground scanning rate is slowed further to provide an effective integration time of approximately 24 ms. The result of this increased effective integration time is an ~1.7x increase in the SNR over Standard Sensitivity mode.

Maximum Sensitivity (4x8ms, 32ms): This mode employs much faster back-nodding to significantly slow the ground scan rate and achieve the highest possible SNR, with an effective integration time of approximately 32 ms. The result of this increased effective integration time is an ~2x increase in SNR over Standard Sensitivity mode.

Glint mode imaging which is in development is essential for monitoring methane plumes over dark ocean surfaces. The strategy in this imaging mode is to maximize the background photon count from the ocean surface, which is usually low, while observing a target of interest on the ocean's surface. The satellite will point towards the sun's specular reflection point on the ocean, where the sunlight reflects off of the surface at the same angle that a satellite is viewing the surface, while the image also contains a target of interest such as an oil rig platform or a large ship. Tanager, the sun's specular reflection point on the ocean, and the Sun itself have to be roughly in the same plane. There is some tolerance on how far out the specular point can be from that ideal plane. For a sun synchronous orbit with LTAN near noon, the sensor will point ahead and then behind in the orbit during each pass.

A notional representation of this imaging mode is shown in the figure below.

Figure 1: Glint Mode

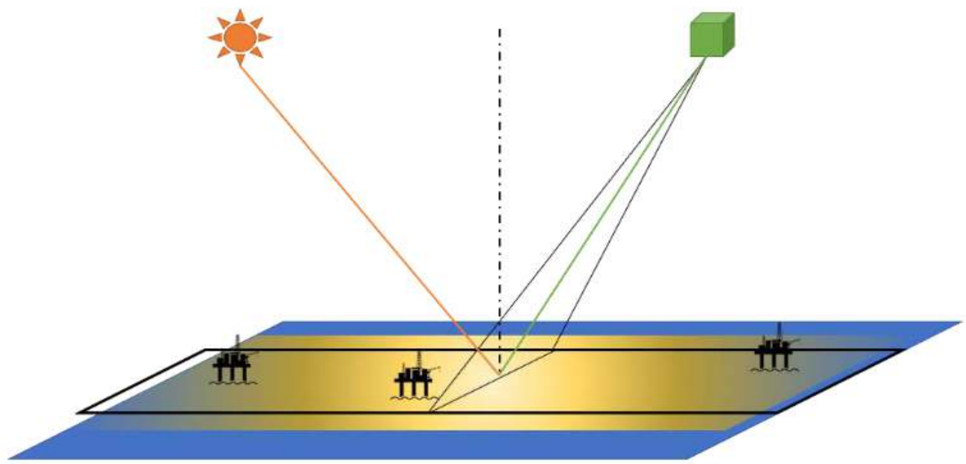


Table 2-A: Tanager Instrumentation & Operations Overview

Attribute	Value
Instrument	Tanager Vehicle
Sensor Type	Dyson-type imaging spectrometer
Telescope	Three-mirror anastigmat (TMA) telescope with a 22 cm aperture
Orbital Parameters (Altitude & Inclination)	Tanager-1: currently 430 km at 97.5°
Min/Max Latitude Coverage	± 90°
Equatorial Crossing (local solar time)	11:00-13:00
Spectral Range	Tanager-1: 376-2500 nm Tanager-1: ~5 nm spacing, 5-7 nm Full Width at Half Maximum
Ground Sample Distance	Tanager-1: ~32 m at nadir (from 430 km altitude)
Off-Nadir Angle	± 30° along track and/or cross-track
Maximum Image Strip per task	Determined based on sensitivity mode: Standard (1x8ms): 390 km Medium (2x8ms): 263 km High (3x8ms): 172 km

	Maximum (4x8ms): 127 km
Revisit Time (per satellite)	Approx. weekly depending on latitude
Instrument Duty Cycle	Approx. 8%
Image Capture Capacity	300,000 km²/day
Geolocation Knowledge	< 1 pixel at CE90
Availability Date (In Operations)	Sept 2024 - Present

3. TANAGER IMAGERY PRODUCTS

Tanager imagery products are available as either individual Basic or Ortho Scenes and radiance or surface reflectance. These products can be obtained from the Planet API through the TanagerScene item type.

3.1 TANAGER CHUNKING STRATEGY

A single Tanager collection can be quite long and in order to process and deliver Tanager assets with more reasonable file sizes, the collections will be dynamically chunked. Each collect will be separated into TanagerScenes based on a set of rules:

1. A scene is at most 750 lines long.
2. A scene is at least 325 lines long.
3. The strategy seeks to produce square-ish scenes.
4. All scenes within a single collection are approximately the same size. The worst case scenario is that a collect will have only two different scene sizes. These two sizes will vary by only a single line.

Example chunking below. Each [ ] is a TanagerScene.

1700 line collect:

0:567	567:1134	1134:1700

2600 line collect:

0:650	650:1300	1300:1950	1950:2600

3.2 TANAGER IMAGERY NAMING CONVENTION

The name of each acquired Tanager image is designed to be unique and allow for easier recognition and sorting of the imagery. It includes the date and time of capture, as well as the id of the satellite that captured it. The name of each downloaded image product is composed of the following elements:

TanagerScene:

<acquisition date>_<acquisition time>_<hundredths of a second>_<satellite_id>_<asset_type> .<extension>

Example: 20241006_154116_92_4001_ortho_radiance_hdf5.h5
Searchable product in Data API is: TanagerScene 20241006_154116_92_4001

3.3 TANAGER IMAGERY PRODUCT SPECIFICATION

3.3.1 TanagerScene Assets

The following products are generated for each TanagerScene item published to the Planet catalog. Find their asset-type name and description below.

Table 3-A: Tanager Basic and Ortho Scene Product Components

Item-Type	Asset-Type	Description
TanagerScene	Ortho Radiance Scene ortho_radiance_hdf5	Orthorectified, Top of atmosphere radiance (at sensor) calibrated, in HDF5 format.
	Basic Radiance Scene basic_radiance_hdf5	Unorthorectified, Top of atmosphere radiance (at sensor) calibrated, in HDF5 format. Not projected to a cartographic projection.
	Ortho Surface Reflectance Scene ortho_sr_hdf5	Orthorectified, atmospherically corrected surface reflectance product, in HDF5 format.
	Basic Surface Reflectance Scene basic_sr_hdf5	Unorthorectified, atmospherically corrected surface reflectance product, in HDF5 format. Not projected to a cartographic projection.
	Ortho Visual Scene ortho_visual	Orthorectified red, green, blue (RGB) visual image with color-correction, in GeoTIFF format.
	Ortho Beta Usable Data Mask (UDM) ortho_beta_udm	Orthorectified usable data mask (in beta), in GeoTIFF format.
	Basic Beta UDM basic_beta_udm	Unorthorectified usable data mask (in beta), in GeoTIFF format

	Geolocation Array geolocation_array	Longitudes and Latitudes in WGS84 of centers of pixels, in GeoTIFF format.

3.4 TANAGER BASIC SCENE PRODUCT SPECIFICATION

Tanager Basic Scene products contain the hyperspectral data (e.g., radiance or surface reflectance) in image space that has been processed to remove distortions caused by terrain and sensor and to provide precise geolocation information in geographic coordinate space. This geolocation information is provided as a separate array (longitude and latitude) to enable users to orthorectify or project the product themselves. This product line is available in HDF-EOS5 format.

This product line is available in HDF-EOS5 format. Tanager Basic Scene products contain the hyperspectral data (e.g., radiance or surface reflectance) in image space that has been processed to remove distortions caused by terrain and sensor and to provide precise geolocation information in geographic coordinate space. This geolocation information is provided as a separate array (longitude and latitude) to enable users to orthorectify or project the product themselves.

See Section 5.1 - Tanager Processing for more details. The table below describes the attributes for the Tanager Basic Scene product:

Table 3-B: Tanager Basic Scene Product Attributes

TANAGER BASIC SCENE PRODUCT ATTRIBUTES

Information Content	
Image Configurations	Approximately 426 channel radiance product
Product Framing	Scene based, produced by a line scanner. One scene has the nominal dimensions: • Width: approximately 600px • Length: variable by size of collect and Planet chunking. See section 3.1 Tanager Chunking Strategy. • Depth: approximately 426px
Spectral Bands	Approximate range of 376 - 2500 nm with ~5 nm spacing between channels
Ground Sample Distance (GSD)	Tanager-1: ~32 m at nadir (from 430 km altitude)

Processing	
Pixel Size	N/A
Radiometric Corrections	• Dark bias removed

	• Pedestal shift corrected • Flat filed applied • Bad pixels corrected • Spatial/spectral stray light corrected • Optical ghosts corrected • Conversion to absolute radiometric values based on calibration coefficients • Order sorting filter seams interpolated
Geometric Corrections	Sensor-related effects are corrected using sensor telemetry and a sensor model. Orthorectification uses (GCPs) ground control points and fine (DEMs) digital elevation models (10 m to 90 m posting).
Atmospheric Corrections/Estimates	Relevant for surface reflectance products only. • Estimated surface reflectance, water vapor concentration, and aerosol optical thickness at 550 nm and their respective uncertainties derived with the Imaging Spectrometer Optimal FITting (ISOFIT) model that utilizes various radiative transfer models and statistical description of surface, instrument and atmosphere.
Bit Depth	TOA Radiance - W m-2 sr-1 μm-1: 32-bit floating point Surface Reflectance - Unitless: 32-bit floating point
Resampling Kernel	N/A
Map Projection	N/A
Geolocation Accuracy	At 30m GSD <50 m absolute CE90, <25 m relative CE90 where georectification succeeds. In other words, at 30m GSD <2 pixels absolute CE90 and <1 pixel relative CE90 where georectification succeeds.
Horizontal Datum	WGS84

3.5 TANAGER ORTHO SCENES PRODUCT SPECIFICATION

The Tanager Ortho Scene product is orthorectified and the product was designed for a wide variety of applications that require imagery with an accurate geolocation and cartographic projection. It has been processed to remove distortions caused by terrain and can be used for cartographic purposes. The Ortho Scenes are delivered as visual (RGB), top-of-atmosphere radiance and surface reflectance products. Ortho Scenes are radiometrically-, sensor-, and geometrically-corrected products that are projected to a cartographic map projection. The geometric correction uses fine Digital Elevation Models (DEMs) with a post spacing of between 10 and 90 meters.

Ground Control Points (GCPs) are used in the creation of every image and the accuracy of the product will vary from region to region based on available GCPs. Computer vision algorithms are used for extracting feature points such as OpenCV's STAR keypoint detector and FREAK keypoint extractor. The GCP and tiepoint matching is done using a combination of RANSAC, phase correlation and mutual information.

The table below describes the attributes for the Tanager Ortho Scene product:

Table 3-C: Tanager Ortho Scene Product Attributes

TANAGER ORTHO SCENE PRODUCT ATTRIBUTES

Information Content	
Image Configurations	Approximately 426 bands
Product Framing	Scene based, produced by a line scanner. One scene has the nominal dimensions: • Width: approximately 600px • Length: variable by size of collect and Planet chunking. See section 3.1 Tanager Chunking Strategy. • Depth: approximately 426px
Spectral Bands	Approximate range of 376 - 2500 nm with ~5 nm spacing between channels
Ground Sample Distance (GSD)	30m

Processing	
Pixel Size	30m
Radiometric Corrections	• Dark bias removed • Pedestal shift corrected • Flat filed applied • Bad pixels corrected • Spatial/spectral stray light corrected • Optical ghosts corrected • Conversion to absolute radiometric values based on calibration coefficients • Order sorting filter seams interpolated
Geometric Corrections	Sensor-related effects are corrected using sensor telemetry and a sensor model. Orthorectification uses (GCPs) ground control points and fine (DEMs) digital elevation models (10 m to 90 m posting).
Atmospheric Corrections/Estimates	Relevant for surface reflectance products only. • Estimated surface reflectance, water vapor concentration, and aerosol optical thickness at 550 nm and their respective uncertainties derived with the Imaging Spectrometer Optimal FITting (ISOFIT) model that utilizes various radiative transfer models and statistical description of surface, instrument and atmosphere.
Bit Depth	TOA Radiance - W m-2 sr-1 μm-1: 32-bit floating point Surface Reflectance - Unitless: 32-bit floating point
Resampling Kernel	Nearest Neighbor

Map Projection	UTM
Geolocation Accuracy	At 30m GSD <50 m absolute CE90, <25 m relative CE90 where georectification succeeds.
Horizontal Datum	WGS84

3.5.1 Tanager Ortho Visual Scene Product Specification

The Tanager Visual Ortho Scene product is orthorectified and color-corrected. This correction attempts to optimize colors as seen by the human eye providing images as they would look if viewed from the perspective of the satellite. This product has been processed to remove distortions caused by terrain and can be used for cartographic mapping and visualization purposes. This correction also eliminates the perspective effect on the ground (not on buildings), restoring the geometry of a vertical shot.

The Visual Ortho Scene product is optimal for simple and direct use of an image. It is designed and made visually appealing for a wide variety of applications that require imagery with an accurate geolocation and cartographic projection. The product can be used and ingested directly into a Geographic Information System.

Table 3-D: Tanager Visual Ortho Scene Product Attributes

TANAGER VISUAL ORTHO SCENE PRODUCT ATTRIBUTES

Product Attribute	Description
Product Components and Format	Tanager Visual Ortho Scene product consists of the following file components: • Image File – GeoTIFF format
Information Content	
Image Configurations	3-band natural color • red band (665 nm), • green band (565 nm), • blue band (490 nm)
Product Framing	Scene based, produced by a line scanner. One scene has the nominal dimensions: • Width: approximately 600px • Length: variable by size of collect and Planet chunking. See section 3.1 Tanager Chunking Strategy. • Depth: approximately 426px
Ground Sample Distance (GSD)	30m

Processing	
Pixel Size	30m
Geometric Corrections	Sensor-related effects are corrected using sensor telemetry and a sensor model. Orthorectification uses (GCPs) ground control points and fine (DEMs) digital elevation models (10 m to 90 m posting).
Bit Depth	8-bit
Resampling Kernel	Nearest Neighbor
Map Projection	UTM
Geolocation Accuracy	At 30m GSD <50 m absolute CE90, <25 m relative CE90 where georectification succeeds
Horizontal Datum	WGS84

3.6 TANAGER HDF5 PRODUCT COMPONENTS AND FORMAT

The following data is included in the HDF5 file structure. Be sure to notice which products the data is and is not produced for. For example, Atmospheric Estimate data is not included in the radiance product.

Table 3-E: Tanager Basic and Ortho Scene Product Components

Product Attribute	Description
Product Components and Format	The Tanager Basic Scene product provided in HDF5[1] format consists of the following file components: A "HDFEOS" group containing data complying with version 1.1 of the HDF-EOS5[2] spec with the following groups: • HDFEOS/SWATHS/HYP/Data Fields • HDFEOS/SWATHS/HYP/Geolocation Fields • HDFEOS INFORMATION/StructMetadata.0

The *HDFEOS/SWATHS/HYP* and *HDFEOS/GRIDS/HYP* have the attribute *strip_id* to relate the TanagerScene to the strip it was derived from.

[1] https://www.hdfgroup.org/
[2] HDF-EOS5 Data Model, File Format and Library, May, 2016, Version 1.1, https://www.earthdata.nasa.gov/s3fs-public/imported/ESDS-RFC-008-v1.1.pdf https://www.hdfeos.org/

Data Fields

Beta Usable Data Masks

Listed in the *HDFEOS/SWATHS/HYP/Data Fields* group of the HDF-EOS5 files. Also generated as a geoTIFF asset named ortho_beta_udm (see Appendix A). The Tanager beta usable data mask is based on the EMIT codebase (described by Sandford et al. 2020[3] and Thompson et al. 2014[4]).

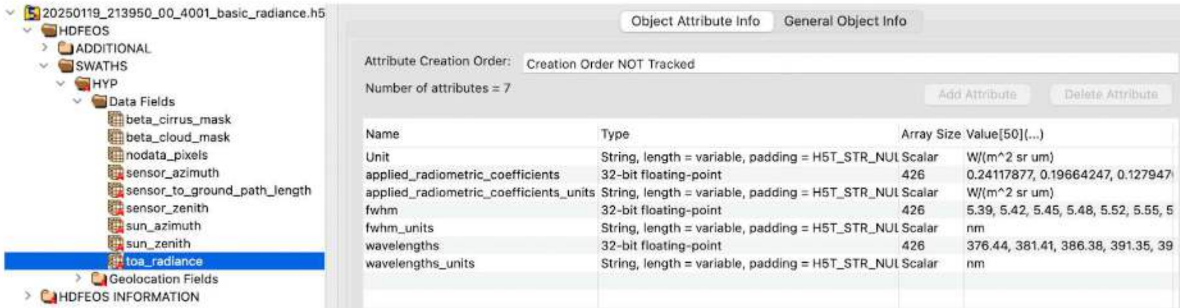
Dataset	Description
beta_cloud_mask	Binary indicating pixels which are clear ("1" indicates cloud)
beta_cirrus_mask	Binary indicating pixels in which cirrus clouds are identified ("1" indicates cirrus)
nodata_pixels	Binary indicating pixels with no data ("1" indicates no data)

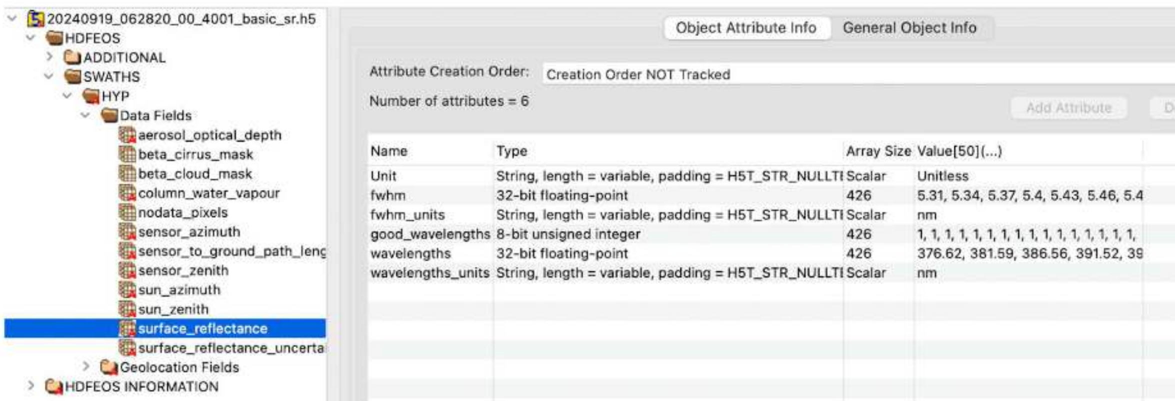
Observation Data

Per-pixel metadata describing observation parameters. Listed in the *HDFEOS/SWATHS/HYP/Data Fields* group of the HDF-EOS5 files.

Dataset	Description
sensor_to_ground_path_length	Distance from the pixel on the sensor to corresponding pixel on the ground in meters
sensor_zenith	Angle from local zenith at the ground pixel to the pixel on the sensor in decimal degrees
sensor_azimuth	Angle from true North at the ground pixel to the pixel on the sensor in decimal degrees
sun_zenith	Angle from local zenith at the ground pixel to the sun in decimal degrees
sun_azimuth	Angle from true North at the ground pixel to the sun in decimal degrees
time	Acquisition time for each pixel in UTC. Time of acquisition is part of the Geolocations Fields for basic products and part of the per-pixel metadata for ortho products.

[3] Sandford, M. W., Thompson, D. R., Green, R. O., Kahn, B. H., Vitulli, R., Chien, S., Yelamanchili, A., and Olson-Duvall, W.: Global cloud property models for real-time triage on board visible–shortwave infrared spectrometers, Atmos. Meas. Tech., 13, 7047–7057, https://doi.org/10.5194/amt-13-7047-2020, 2020.
[4] D. R. Thompson et al., "Rapid Spectral Cloud Screening Onboard Aircraft and Spacecraft," in IEEE Transactions on Geoscience and Remote Sensing, vol. 52, no. 11, pp. 6779-6792, Nov. 2014, doi: 10.1109/TGRS.2014.2302587.





Atmospheric Estimates

Only produced for surface reflectance products. Pixel-level atmospheric estimates as an output of the reflectance retrieval. Listed in the *HDFEOS/SWATHS/HYP/Data Fields* group of the HDF-EOS5 files.

Dataset	Description
column_water_vapor	Column water vapor as estimated during the reflectance retrieval in g/cm².
aerosol_optical_depth	Aerosol optical depth at 550 nm (AOD550) as estimated during the reflectance retrieval (unitless).

Spectral Calibration Data

Per-band metadata describing the spectral calibration data of the sensor. Stored as attributes to *HDFEOS/SWATHS/HYP/Data Fields/toa_radiance* or *HDFEOS/SWATHS/HYP/Data Fields/surface_reflectance* dataset.

Dataset	Description
wavelengths	The center wavelength of the spectral response for each band (nm)

fwhm	The width, in nanometers, of a spectral curve at half the maximum amplitude
good_wavelengths*	Binary to indicate which bands do not accurately represent surface reflectance due to water absorption of other atmospheric features. Good wavelengths are indicated by 1, bad wavelengths are 0. **Only produced for Surface Reflectance products.*

Radiometric Calibration Data

Per-band metadata describing radiometric calibration coefficients used by Planet. Stored as attributes to *HDFEOS/SWATHS/HYP/Data Fields/toa_radiance*.

Dataset	Description
applied_radiometric_coefficients	Radiometric calibration coefficients that were used to convert DNs to TOA Radiance for each band, in units of W/(m²*sr*µm)

Geolocation Fields

Input geometry to be used for georeferencing of the data. The *Geolocation Fields* group has the attribute *Planet_Ortho_Framing*. This is only produced for Basic Products.

Datasets	Description
Latitude	WGS-84 latitude in decimal degrees
Longitude	WGS-84 longitude in decimal degrees
Time	Acquisition time per line in UTC. Unix epoch is the number of seconds that have elapsed since January 1, 1970 midnight UTC/GMT.

A *Planet_Ortho_Framing* attribute is a JSON encoded string containing information about the ortho framing of a TanagerScene. While Planet does not offer a TanagerCollect, customers can use this information to reconstruct ortho collect products.

JavaScript

```
{
 "epsg_code": 32613,
 "rows": 608,
 "cols": 1016,
 "geotransform": [503220.0, 30.0, 0.0, 4410990.0, 0.0, -30.0]
}
```


epsg_code, *rows*, *cols*, and *geotransform* describe framing information for a TanagerScene ortho product. For a given collect, *rows*, *cols*, and *geotransform* may be different for each TanagerScene belonging to that TanagerCollect.

StructMetadata.0

StructMetadata.0 is based on the HDF-EOS5 standards and contains general information about the structure of the file, dataset dimensions, compression, data types and georeferencing information.

None

```
GROUP=SwathStructure
END_GROUP=SwathStructure
GROUP=GridStructure
	GROUP=GRID_1
		GridName="HYP"
		Band=426
		XDim=846
		YDim=753
		UpperLeftPointMtrs=(570300.00,3555450.00)
		LowerRightMtrs=(595680.00,3532860.00)
		Projection=HE5_GCTP_UTM
		ZoneCode=13
		SphereCode=12
		CompressionType=HE5_HDFE_COMP_DEFLATE
		DeflateLevel=4
		PixelRegistration=HE5_HDFE_CORNER
		GridOrigin=HE5_HDFE_GD_UL
		GROUP=Dimension
			OBJECT=Dimension_1
				DimensionName="Band"
				Size=426
			END_OBJECT=Dimension_1
			OBJECT=Dimension_2
				DimensionName="YDim"
				Size=753
			END_OBJECT=Dimension_2
			OBJECT=Dimension_3
				DimensionName="XDim"
```

```
                Size=846
            END_OBJECT=Dimension_3
        END_GROUP=Dimension
        GROUP=DataField
            OBJECT=DataField_1
                DataFieldName="toa_radiance"
                DataType=H5T_NATIVE_FLOAT
                DimList=("Band","YDim","XDim")
                MaxdimList=("Band","YDim","XDim")
                CompressionType=HE5_HDFE_COMP_DEFLATE
                DeflateLevel=4
            END_OBJECT=DataField_1
            OBJECT=DataField_2
                DataFieldName="sensor_zenith"
                DataType=H5T_NATIVE_FLOAT
                DimList=("YDim","XDim")
                MaxdimList=("YDim","XDim")
                CompressionType=HE5_HDFE_COMP_DEFLATE
                DeflateLevel=4
            END_OBJECT=DataField_2
            OBJECT=DataField_3
                DataFieldName="sensor_azimuth"
                DataType=H5T_NATIVE_FLOAT
                DimList=("YDim","XDim")
                MaxdimList=("YDim","XDim")
                CompressionType=HE5_HDFE_COMP_DEFLATE
                DeflateLevel=4
            END_OBJECT=DataField_3
            OBJECT=DataField_4
                DataFieldName="sensor_to_ground_path_length"
                DataType=H5T_NATIVE_FLOAT
                DimList=("YDim","XDim")
                MaxdimList=("YDim","XDim")
                CompressionType=HE5_HDFE_COMP_DEFLATE
                DeflateLevel=4
            END_OBJECT=DataField_4
            OBJECT=DataField_5
                DataFieldName="sun_zenith"
                DataType=H5T_NATIVE_FLOAT
                DimList=("YDim","XDim")
                MaxdimList=("YDim","XDim")
                CompressionType=HE5_HDFE_COMP_DEFLATE
                DeflateLevel=4
            END_OBJECT=DataField_5
            OBJECT=DataField_6
                DataFieldName="sun_azimuth"
                DataType=H5T_NATIVE_FLOAT
                DimList=("YDim","XDim")
```

```
                                MaxdimList=("YDim","XDim")
                                CompressionType=HE5_HDFE_COMP_DEFLATE
                                DeflateLevel=4
                        END_OBJECT=DataField_6
                        OBJECT=DataField_7
                                DataFieldName="beta_cloud_mask"
                                DataType=H5T_NATIVE_UINT
                                DimList=("YDim","XDim")
                                MaxdimList=("YDim","XDim")
                                CompressionType=HE5_HDFE_COMP_DEFLATE
                                DeflateLevel=4
                        END_OBJECT=DataField_7
                        OBJECT=DataField_8
                                DataFieldName="beta_cirrus_mask"
                                DataType=H5T_NATIVE_UINT
                                DimList=("YDim","XDim")
                                MaxdimList=("YDim","XDim")
                                CompressionType=HE5_HDFE_COMP_DEFLATE
                                DeflateLevel=4
                        END_OBJECT=DataField_8
                        OBJECT=DataField_9
                                DataFieldName="nodata_pixels"
                                DataType=H5T_NATIVE_UINT
                                DimList=("YDim","XDim")
                                MaxdimList=("YDim","XDim")
                                CompressionType=HE5_HDFE_COMP_DEFLATE
                                DeflateLevel=4
                        END_OBJECT=DataField_9
                        OBJECT=DataField_10
                                DataFieldName="time"
                                DataType=H5T_NATIVE_DOUBLE
                                DimList=("YDim","XDim")
                                MaxdimList=("YDim","XDim")
                                CompressionType=HE5_HDFE_COMP_DEFLATE
                                DeflateLevel=4
                        END_OBJECT=DataField_10
                END_GROUP=DataField
        END_GROUP=GRID_1
END_GROUP=GridStructure
GROUP=PointStructure
END_GROUP=PointStructure
GROUP=ZaStructure
END_GROUP=ZaStructure
END
```

4. TANAGER DERIVED PRODUCTS

4.1 TANAGER METHANE NAMING CONVENTION

The name of each detected and quantified methane plume from Tanager imagery is designed to be unique and allow for easier recognition and sorting of the imagery. It includes the date and time of capture, as well as the id of the satellite that captured it providing a unique plume ID for each. The name of each downloaded image product is composed of the following elements:

TanagerMethane:

<item_id>_<asset_type> .<extension>

Example: 20250815_043916_87_4001_ortho_ql_ch4.tif
Searchable product in Data API is: TanagerMethane 20250815_043916_87_4001

4.2 TANAGER METHANE PRODUCT SPECIFICATION

Planet delivers TanagerMethane using the methods described in the Carbon Mapper L3/L4 Algorithm Theoretical Basis Document, including peer-reviewed detection, quantification, and quality-control approaches to ensure scientific rigor across all methane products. Each TanagerMethane item includes plumes that a trained analyst can identify within corresponding TanagerScenes, derived from one or more L2b methane concentration maps.

A visual color ramp will be used that represents the detected concentration of methane within identified plumes, in ppm-m will be in an 8-bit GeoTIFF in order to communicate the spatial distribution of each plume. This representation of methane plumes are designed to illustrate the rough size of a potential emission.

Table 4-A: Tanager Derived Product Asset-Types

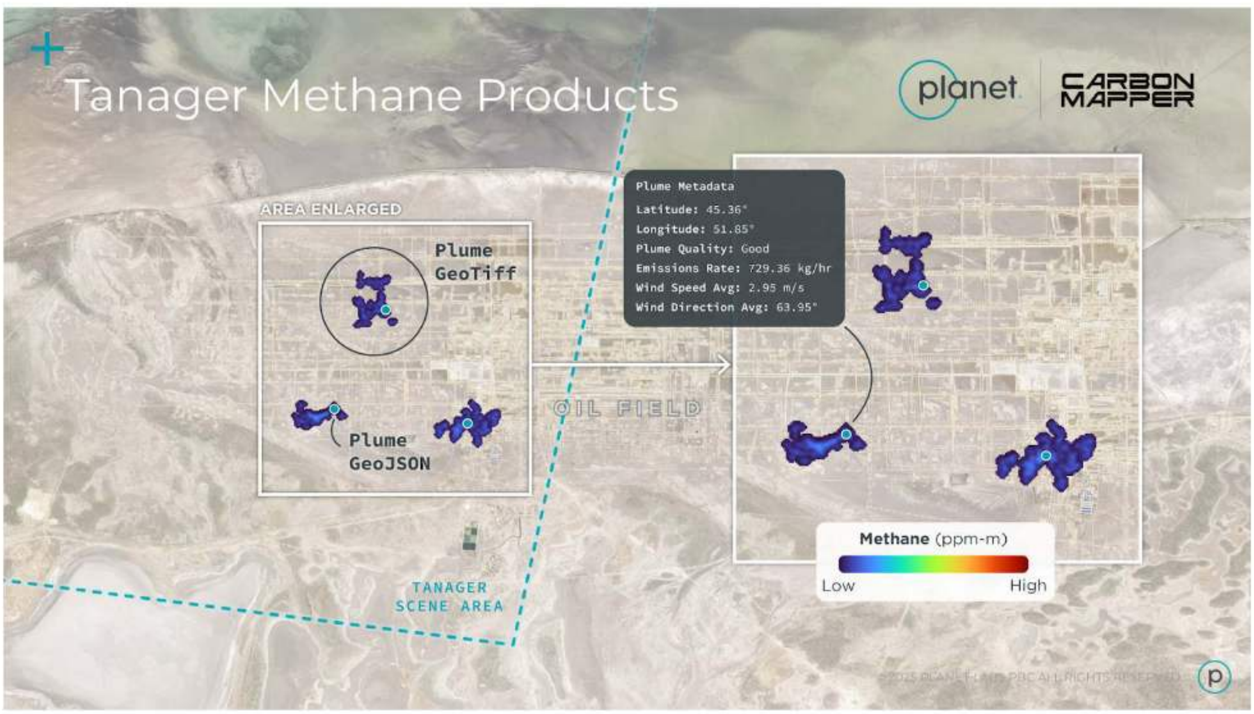
Item-Type	Asset-Type	Description
TanagerMethane	Ortho Methane QuickLook Plume ortho_ql_ch4	Preliminary 8-bit scaled plume intensity in (ppm-m) parts-per-million-meter, in GeoTIFF format. The image will contain an alpha channel indicating pixels with no plume detections. Represents plumes detected within the initial 72 hours after image acquisition.
	Methane QuickLook Plume Metadata ql_ch4_json	Preliminary plume locations, length, size in kg/hr and confidence measure indicating the level of interpretation certainty, in GeoJSON format. Represents plumes detected within the initial 72 hours after image acquisition.

	Recent Monthly Mosaic recent_monthly_mosaic	RGB contextual baselayer from the most recent PlanetScope Global Monthly Mosaic, in GeoTIFF format.

4.2.1 TanagerMethane Bundles

The bundles include Methane QuickLook (MQL) designed for easy interpretation by methane experts with limited remote sensing knowledge. Within this bundle customers will have access to multiple imagery assets, listed below, for their purposes.

- A plume GeoTIFF with a visually interpretable per-pixel plume density in ppm-m (parts per million - meter). This is a description of the amount of methane present in the air column.
- A Plume GeoJSON with the plume location (lat/lon), size (using discrete bins described below), plume length, and visual interpretation confidence measure.



4.2.1.1 Methane QuickLook (MQL) Product

Tanager's Methane QuickLook is a low latency, derived methane product that will reveal point source emission locations and estimates of magnitude in kg/hr for observed plumes This product will be delivered to customers within a 72 hour timeframe after acquisition enabling customers to quickly identify and take action where emissions are detected.

Table 4-B: Tanager Methane QuickLook Assets

Asset Name	Asset-Type	Description
Ortho Methane QuickLook Plume	ortho_ql_ch4	Preliminary 8-bit scaled methane plume intensity in (ppm-m) parts-per-million-meter, in GeoTIFF format. The image will contain an alpha channel indicating pixels with no plume detections.
MethaneQuickLook Plume Metadata	ql_ch4_json	Preliminary plume locations, length, size in kg/hr and confidence measure indicating the level of visual interpretation certainty, in GeoJSON format.

4.2.1.3 Additional Methane Assets

Table 4-D: Additional Methane Assets Available

Asset Name	Asset-Type	Description
Ortho Visual Scene	ortho_visual	Orthorectified red, green, blue (RGB) visual image with color-correction.
Recent Monthly Mosaic	recent_monthly_mosaic	RGB contextual baselayer from the most recent PlanetScope Global Monthly Mosaic at ~4.7 meter resolution in GeoTIFF format.

5. PRODUCT PROCESSING

5.1 TANAGER PROCESSING

Several processing steps are applied to Tanager imagery products, listed in the table below.

Table 5-A: Tanager Processing Steps

TANAGER PROCESSING STEPS

Step	Description

Dark Subtraction	Corrects for sensor bias and dark level to ensure that zero illumination corresponds to zero radiance. The correction is updated frequently by averaging dark frames acquired over the non-sunlit side of Earth.
Pedestal Correction	Subtracts remaining residual error in the zero point after the dark frame is subtracted so that the numerical zero is equivalent to the radiometric zero. This residual is estimated by computing the median value of masked pixels located at the edges of the detector, which are physically blocked from external illumination.
Flat Field Correction	Corrects relative differences in pixel sensitivities to match those in the optimal response area of the sensor. Flat fields are collected for each optical instrument in lab conditions prior to launch, and are routinely updated on-orbit during the satellite lifetime.
Bad Pixel Correction	Fills in defective pixels on the detector following the method described in Chapman et al. (2019), which replaces pixels by linearly interpolating to the most similar spectrum within the frame.
Optical Scatter Correction	Removes stray light artifacts from scatter in the optical elements to bring the spectral response function (SRF) towards a Gaussian distribution. These artifacts are modeled as concentric Gaussians convolved with the original spectrum, so correction involves deconvolving the stray response components from the spectrum with a method outlined in Thompson et al. (2018a).
Optical Ghost Correction	Follows the correction approach of Zandbergen et al. (2020) to remove structured stray light artifacts ("ghosts") that arise due to unwanted reflections within the optics. A ghost image is predicted for each frame and subsequently subtracted to remove the stray signal.
Absolute Radiometric Calibration	Converts the observations from Digital Number (DN) values into physical radiance units (W/(m²*sr*μm)).
Order Sorting Filter (OSF) Seam Correction	Interpolates over the radiometrically suspect rows where the order sorting filter (OSF) seams are located.
Visual Product Processing	Presents the imagery as natural color, as seen by the human eye. Only applied to the ortho_visual asset type.
Orthorectification	The orthorectification process is a method to correct the geographic location of imagery. The orthorectification process depends on the accuracy of the reference imagery, the terrain model, satellite and sensor parameters. OneAtlas Airbus imagery is used as reference images during Tanager orthorectification and the terrain model used for the orthorectification process is derived from multiple sources (SRTM, Intermap, and other local elevation datasets) which are periodically updated. The orthorectification process consists of two key steps. The first step is a feature-based approach for coarse model refinement followed by area-based matching for fine model refinement. The algorithm provides an improved sensor model of the satellite state and sensor, allowing for more accurate georectification.
Atmospheric Correction	Removes atmospheric effects and estimates surface reflectance. Per pixel surface reflectance values are calculated using the ISOFIT (Imaging Spectrometer Optimal

	FITting) python package. This uses an optimal estimation method for simultaneously solving for both the atmospheric composition and surface reflectance values using hyperspectral radiance imagery as the input.

5.2 RADIOMETRIC INTERPRETATION

Radiance products are observed as top of atmosphere radiance. Prior to launch, the instrument calibration uncertainty is required to be ≤ to 15%. After launch, instrument calibration accuracy and uncertainty will be monitored using vicarious collections of Radiometric Calibration Network (RadCalNet) and other calibration sites.

All Tanager satellite images are collected at a bit depth of 16 bits and stored on-board the satellites with a bit depth of up to 16 bits. Radiometric corrections are applied during ground processing and all radiance images are delivered in 32-bit floating point precision with a unit of $W/(m^2*sr*\mu m)$.

5.2.1 Radiance Products

Tanager radiance products are calibrated hyperspectral imagery products that have been processed to enable analysts to derive information products for data science and analytics. The radiance product is optimal for value-added image processing such as land cover classifications. The imagery has radiometric corrections applied to correct for any sensor artifacts and transformation to at-sensor radiance.

The resulting value is the at sensor radiance of that pixel in watts per steradian per square meter per micron ($W/m^2*sr*\mu m$).

5.2.2 Surface Reflectance Products

Tanager's surface reflectance asset corrects for the effects of the Earth's atmosphere, accounting for the molecular composition and variation with altitude along with aerosol content.

Atmospheric Correction

Per pixel surface reflectance values are calculated using the ISOFIT (Imaging Spectrometer Optimal FITting) python package[5]. This uses an optimal estimation method for simultaneously solving for both the atmospheric composition and surface reflectance values using hyperspectral radiance imagery as the input[6].

[5] https://github.com/isofit/isofit

[6] Thompson, David R., Natraj, Vijay, Green, Robert O., Helmlinger, Mark C., Gao, Bo-Cai, & Eastwood, Michael L. (2018). Optimal estimation for imaging spectrometer atmospheric correction. Remote Sensing of Environment 216, 355-373.

6. PRODUCT METADATA

6.1 TANAGER ITEM LEVEL METADATA

The table below describes the metadata schema for TanagerScene & TanagerMethane items:

Table 6-A: Tanager Metadata Schema

Parameter	Description	Type
_permissions	Assets available for the item which the authenticated user has permission to download.	array
geometry	Geographic boundary of the item's footprint, formatted as a GeoJSON polygon.	json
id	Globally unique item identifier	string
acquired	The RFC 3339 acquisition time of the image.	datetime
cloud_percent	Percent of cloud values in the dataset. Cloud values represent scene content areas (non-blackfilled) that contain opaque clouds which prevent reliable interpretation of the land cover content.	double
collection_mode	Maximum Sensitivity (4x8), Standard Sensitivity (1x8), Glint	string
ground_control	If the image meets the positional accuracy specifications this value will be true. If the image has uncertain positional accuracy, this value will be false.	boolean
gsd	The round sampling distance of the associated Item. Computed for each item to at the center of the scene.	double
item_type	The name of the item type. For example, TanagerScene or TanagerMethane.	string (e.g. TanagerScene)

light_haze_percent	Fraction of the scene affected by high altitude cirrus clouds. The clouds are detected by thresholding Tanager's 1.38 micron cirrus band. False positive detections are common in high-elevation regions.	double
pixel_resolution	Pixel resolution of the ortho products associated with this Item.	double
provider	Name of the imagery provider.	string (e.g. "tanager","planetscope", "skysat")
published	The RFC 3339 timestamp at which this item was added to the API.	datetime
publishing_stage	Stage of publishing for an item. TanagerScene items will be first published and remain in "finalized" stage.	string
quality_category	Metric for image quality. To qualify for "standard" image quality an image must meet a variety of quality standards. If the image does not meet these criteria it is considered "test" quality.	string: "standard" or "test"
satellite_azimuth	Tanager's off track pointing direction, in degrees (0-360) at the center of the scene.	double
satellite_id	Globally unique identifier of the satellite that acquired the underlying imagery. I.E. 4001	string
strip_id	The unique identifier of the image strip that the item came from.	string
sun_azimuth	The angle of the sun, as seen by the observer, measured clockwise from the north (0 - 360) at the center of the scene.	double
sun_elevation	The angle of the sun above the horizon (0 - 90) at the center of the scene.	double
updated	The RFC 3339 timestamp at which this item was updated in the API.	datetime

view_angle	The satellite's off-nadir viewing angle at the center of the scene.	double

6.2 TANAGER DERIVED PRODUCTS

6.2.1 Methane Bundle

The table below describes the GeoJSON metadata schema for TanagerMethane Methane QuickLook (MQL) ql_ch4_json assets:

Table 6-B: Tanager Methane Plume Metadata Schema

Parameter	Description	Type
plume_id	Unique identifier for each plume. The format is <strip_id_<part>. The "part" postfix (e.g., "A", "B", "C") identifies multiple plumes captured in the same image in the order they were detected.	string
plume_provider	Identifies the organization who identified the plume.	string
plume_provider_id	Plume ID according to the `plume_provider`. Planet assigns a new plume ID to match existing naming conventions.	string
plume_provider_version	Plume provenance information. This information is not directly useful to customers, but can be used by Planet and the `plume_provider` to inspect data quality issues.	string
plume_quality	** This field is only used for Methane QuickLook, ql_ch4_json asset-type. ** Qualitative assessment of plume quality captured by a human operator during the plume detection process (good, questionable or bad). More on Plume quality classification below.	string
datetime	Date and time of the acquisition in Coordinated Universal Time (UTC)	datetime
ime	The total kilograms (kg) of methane in a plume above the background concentration at the time of image capture	float
fetch	Plume length, meters (m)	float
emission	Quantified emission rate of a plume in kg/hr, estimated using the Integrated Methane Enhancement method (Duren et al., 2019 - "California's Methane Super-Emitters", Nature)	

emission_uncertainty	The uncertainty in an emission rate, derived from uncertainty in IME and wind speed	
wind_speed_avg	Mean wind speed m/s	float
wind_speed_std	Standard deviation wind speed m/s	float
wind_direction_avg	Wind direction (degrees)	float
wind_direction_std	Wind direction standard deviation (degrees)	float
wind_source	Wind source from reanalysis (e.g. Openmeteo, HRRR, ERA5)	string
strip_id	Strip ID of the Tanager collect that was used for plume detection	string

Plume Quality Classification:

Planet classifies detected plumes into three categories: **Good, Questionable** and **Bad**, based on the following criteria:

- **Good**: The plume is unambiguous, with a well-defined shape and minimal artifacts, making it reliable for further analysis.
- **Questionable**: The plume is clearly present, but there are issues. For example: irregular shape or retrieval artifacts that could affect the accuracy of quantification. A post-emission QC process will also assess whether **Questionable** plumes are suitable for publishing an emission rate or if only the detection will be reported.
- **Bad**: It is unclear whether the detected feature is a plume. However, this is not a final state. After an initial review, a secondary post-emission quality control process is conducted. This review determines whether the detection should be discarded or reclassified as "Questionable."

APPENDIX A – IMAGE SUPPORT DATA

All Tanager imagery products are accompanied by a set of image support data (ISD) files. These ISD files provide important information regarding the image and are useful sources of ancillary data related to the image. The ISD files are:

- Beta usable data mask file
- Geolocation array

Each file is described along with its contents and format in the following sections.

BETA USABLE DATA MASK FILE

The Beta usable data mask information that is stored in the HDF-EOS5 Basic Products (see section Beta Usable Data Mask in section 3.2) can also be accessed through the standalone asset, ortho_beta_udm, in the file format GeoTiff. The usable data mask file provides information on areas of usable data within an image (e.g. clear, cloud, or cirrus).

The pixel size after orthorectification will be 30 m for Tanager ortho_beta_udm. The usable data mask is a raster image having the same dimensions as the image product, comprising 3 bands, where each band represents a specific usability class mask. The usability masks are mutually exclusive, and a value of one indicates that the pixel is assigned to that usability class.

- Band 1: Beta cloud mask (a value of "1" indicates the pixel has clouds, a value of "0" indicates that the pixel does not have clouds)
- Band 2: Beta cirrus mask
- Band 3: NODATA pixel mask

GEOLOCATION ARRAY

The geolocation information that is stored in the HDF-EOS5 Basic Products can also be accessed through the standalone asset, geolocation_array, in the file format GeoTiff. The geolocation arrays have the same dimensions as the basic imagery products (e.g. Basic Radiance Scene or Basic Surface Reflectance Scene) with 2 bands. See also Geolocation Fields in Section 3.2. The metadata of the GeoTiff also contains the *Planet_Ortho_Framing* information explained in Section 3.2.

- Band 1: Longitude in Decimal Degrees
- Band 2: Latitude in Decimal Degrees