CAPELLA SPACE

SAR PRODUCTS FORMAT SPECIFICATION

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DISCLAIMER

DOCUMENT CHANGE LOG

Version	Date	Change Description
1.0	10 April 2020	Initial document version
1.1	6 May 2020	Update STAC metadata to version 0.9.0
1.2	22 January 2021	Added extended metadata fields, such as: Image:calibration, State:direction, CenterPixel:look_angle, Image:peak_nesz, Image:nesz_polynomial. Changed extended metadata fields, such as: Collect:id renamed to collect:collect_id, capella:billable_area. Updated definition of doppler centroid 2D polynomial. Updated SLC and GEO definition and description of internal calibration factor. Beta updated in Beta_nought for SLC products. Reworked PRF object to TimeVaryingParameter
1.3	25 May 2021	New GEC image product type; New SICD product delivery format

		Extended metadata field names 'scale_factor' and 'nesz_peak'. Added extended_metadata fields: Window:broadening_factor, Image:frequency_doppler_centroid_polynomial. Added capella:orbital_plane to STAC metadata.
1.4	18 Aug 2022	Added capella:image_length & capella:image_width to the STAC catalog metadata. Clarified field descriptions for image product name start / stop time, sar:product_type and sar:orbital_plane in STAC catalog metadata, and product_type in extended metadata.
1.5	26 January 2023	Added proj:centroid, proj:shape, proj:transform, locale:datetime, locale:timezone, locale:time, & processing:software to the STAC catalog metadata. Added local_datetime and local_timezone to the extended metadata.
1.6	6 August 2024	Added PFA-specific metadata.
1.7	25 September 2024	Removed capella:product_category.

INTRODUCTION

Capella Space is an information services company that provides on-demand Earth observation imagery. Through a constellation of small satellites, Capella is providing easy access to frequent, timely and quality information affecting several of industries worldwide. Capella's very high-resolution synthetic aperture radar (SAR) satellites are matched with unparalleled infrastructure to deliver reliable global insights that sharpen our understanding of the changing world - improving decisions about commerce, conservation and well-being on Earth.

This document describes the format of the operational basic SAR imagery products generated by Capella's constellation of SAR satellites. Capella's SAR data product portfolio currently includes single look complex (SLC), geocoded ellipsoid corrected (GEC) and geocoded terrain corrected (GEO) image product types. SAR images for all imaging modes and product types are delivered in Capella's TIFF+JSON format. Furthermore, single look complex image data from spotlight and stripmap imaging modes are also made available in the Sensor Independent Complex Data (SICD) format.

This document presents in-depth information on how Capella's SAR imagery products are formatted, packaged, structured and how to access the metadata information. Figure 1 shows the processing steps applied to the raw SAR data to generate the single look complex and geocoded imagery products.

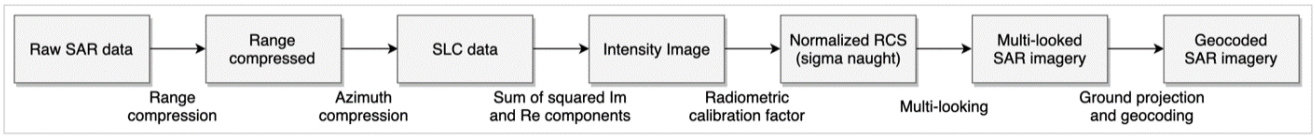


Figure 1: Processing steps to generate Capella's single look complex and geocoded imagery products.

SINGLE LOOK COMPLEX (SLC)

SLC images are single-look, range-compressed and focused SAR data presented in the satellite image acquisition geometry of slant range and azimuth directions (Figure 2). The azimuth direction is along the flight path of the satellite. The slant range direction is perpendicular to the azimuth direction and follows from the satellite to the imaging targets on the ground. Image pixels are processed and projected to zero Doppler SAR coordinates.

SLC images contain both amplitude and phase information. Each image pixel is represented by a complex number with a real (Re) and imaginary (Im) component. SLC images have 32 bits for each pixel sample. The first 16 bits represent the real component of the complex value as a signed 16-bit integer (Int16) and the last 16 bits represent the imaginary component of the complex value as a signed 16-bit integer (Int16). This data type is also known as CInt16.

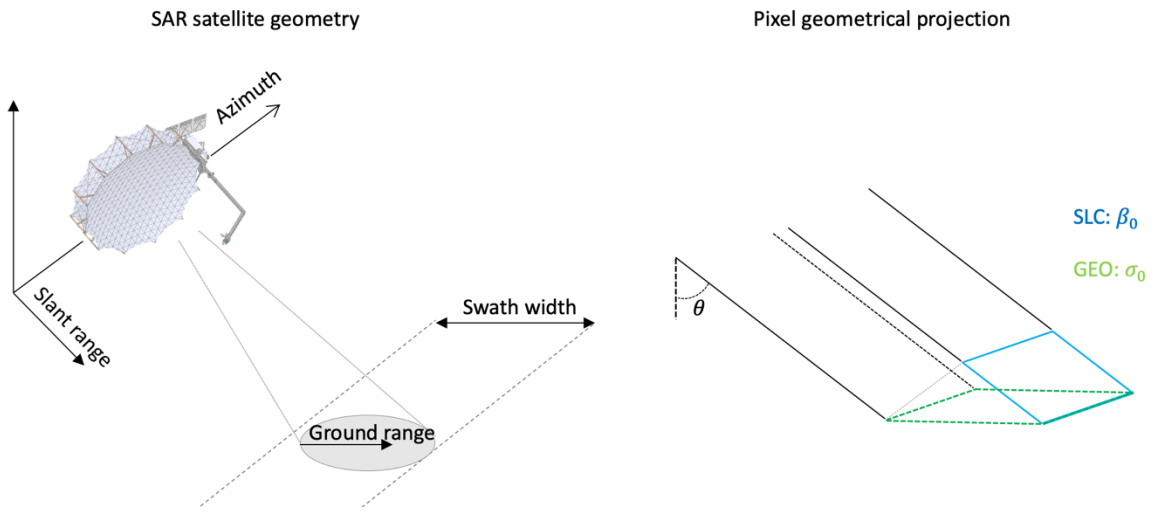


Figure 2: SAR satellite geometry and pixel projection in Capella's SLC and GEO products.

GEOCODED ELLIPSOID CORRECTED (GEC)

GEC images are detected multi-looked dataset which has been geocoded and projected onto the WGS84 ellipsoid. Similar to the SLC image product type a GEC image is range-compressed and focused. The average scene center height is used to generate the GEC image product type and no terrain correction is performed. Consequently, GEC images are ideally suited for users who wish to analyze imagery over areas with significant topographic relief without any DEM correction applied. The pixel values and radiometric calibration process for the GEC image product type is the same as the GEO image described in the following sections below.

GEOCODED TERRAIN CORRECTED (GEO)

GEO images are detected multi-looked dataset which has been geocoded and terrain-corrected using a Digital Elevation Model (DEM). Similar to the SLC image product type a GEO image is range-compressed and focused. The pixel values in the GEO images contain the radiometrically calibrated intensity in linear scale.

A Digital Elevation Model (DEM) is used to improve the geolocation accuracy beyond what is achievable with only considering the ellipsoid. The ground location accuracy for the GEO product depends on the accuracy of the DEM used for map projection and terrain correction.

Spotlight Ultra GEO images are multi-looked 5 times in the azimuth direction to enhance their radiometric resolution, which is a critical quality metric that describes the detection capability of a SAR system. It is a measure of an image's ability to display reflection differences among pixels.

Capella has implemented a multi-look technique obtained by splitting a long synthetic aperture into a set of sub-apertures and then combining them to generate the GEO image product type. For this purpose, five 0.25 m resolution SLC images are generated to make a Spotlight Ultra product.

CALIBRATION: BETA AND SIGMA NOUGHT

The pixel value in GEC and GEO product types contains calibrated amplitude information, in *Sigma Nought* (σ^0) [Ref 3]. In SLC data products, the calibrated pixel values are in represented in the slant range geometry, in *Beta Nought* (see Figure 2).

The σ^0 values are obtained compensating *Beta Nought* (β^0) for the incidence angle computed based on the ellipsoid. Therefore, the *Sigma Nought* can be defined as follows:

$$\sigma^0 = \beta^0 * sin\theta$$

Where θ is the incident angle estimated from the WGS84 ellipsoid on a simple ellipsoid and β^0 is defined as:

$$\beta^0 = \beta / A^\beta$$

where β and A^β are radar backscattering and a reference area defined to be in the slant range plane, respectively (see Figure 2).

The aim of *Sigma Nought* is to minimize the differences in the image radiometry in images obtained from different incidence angles, ascending-descending geometries and/or opposite look directions becomes comparable and can be integrated to obtain derived change maps.

SCALE FACTOR

As part of Capella processing, a calibration factor is applied to take into account the internal calibration of the radar subsystems. The user shall apply only the "scale_factor" (SC) reported in the extended metadata JSON sidecar file for any given SAR imagery product. SC is used to derive the radar brightness from the image pixel values and does not include a separate calibration component.

For SLC the expression for the radar brightness in logarithmic scale reads:

$$\sigma^0_{dB} = 20log_{10}(SC|DN_{slc}|)$$

Where $|DN_{slc}|$ is the absolute value of the radar backscattering β.

Similarly, for GEC and GEO products:

$$\sigma^0_{dB} = 20log_{10}(SC\ DN_{gec/geo})$$

SENSOR INDEPENDENT COMPLEX DATA (SICD) FORMAT

For SAR imagery products acquired in the Spot (spotlight) and Strip (stripmap) modes Capella delivers single look complex image data in the Sensor Independent Complex Data (SICD) format aligned with v1.2.1 of the SICD standard specification. SICD formatted imagery products are delivered as a single NITF format file (*.ntf) which contains both the single look complex image data and relevant SAR metadata.

SICD is a U.S. national geospatial-intelligence (GEOINT) standard designed for the storage and dissemination of SAR single look complex (SLC) image data in a sensor-independent manner. The SICD standard leverages the well-established National Imagery Transmission Format (NITF) container format with customized raster segments and metadata tags specifically designed for the storage of SAR complex image products. Capella's SICD format complex image products are compliant with version 1.2.1 of the SICD standard published on 13 December 2018 (NGA.STND.0024-1_1.2.1). Some Capella imagery products are generated with the backprojection algorithm which is supported in the SICD standard by setting ImageFormAlgo="OTHER".

CAPELLA TIFF+JSON FORMAT

Capella delivers SAR data for all image product modes (Spot | Site | Strip) and image product types (SLC | GEC | GEO) in a 3-file bundle package known as the Capella TIFF+JSON format. The Capella TIFF+JSON format bundle package includes one cloud-optimized GeoTIFF format image file along with two JSON metadata sidecar files (STAC & Extended). Each SAR imagery product delivered in Capella's TIFF+JSON format 3-file bundle package includes an Image Data File, a Catalog Metadata File, and an Extended Metadata File.

Image Data File: The Image Data File contains the raster file of processed SAR instrument data.

Naming Convention:

"EEEEEEE_SSS_MM_PPP_HH_SSSSSSSSSSSSSS_EEEEEEEEEEEEEE.tif"

Catalog Metadata File: The Catalog Metadata File contains information about the SAR data collection that allows users to easily search and find relevant data. This metadata is formatted as JSON following the Spatio Temporal Asset Catalog (STAC) specification [ref 2]. STAC simplifies the description of geospatial assets, the exploitation of both data fusion and time series analysis.

Naming Convention:

"EEEEEEE_SSS_MM_PPP_HH_SSSSSSSSSSSSSS_EEEEEEEEEEEEEE.json"

Extended Metadata File: The product extended metadata is a description of the data acquisition, calibration, noise, and product processing. It is formatted as JSON and included in the GeoTIFF TIFFTAG_IMAGEDESCRIPTION TIFF Tag and a plain-text sidecar file.

Naming Convention:

"EEEEEEE_SSS_MM_PPP_HH_SSSSSSSSSSSSSS_EEEEEEEEEEEEEE_extended.json"

Tag	Description	Values
EEEEEEE	Company Name	'CAPELLA'
SSS	Satellite ID	'C01'=CAPELLA-1, 'C02'=CAPELLA-2, etc. 'ARL' for aerial campaign data
MM	Mode of data acquisition	'SP'=Spotlight, 'SM'=Stripmap, 'SL'=Sliding Spotlight
PPP	Product type	'SLC' = Single Look Complex 'GEC' = Geocoded Ellipsoid Corrected 'GEO' = Geocoded Terrain Corrected

HH	Polarization	'HH'=HH polarization, 'VH'=VH polarization, 'HV'=HV polarization, 'VV'=VV polarization.
SSSSSSSSSSSSSS	Acquisition start time	In format YYYYMMDDTHHMMSS
EEEEEEEEEEEEE	Acquisition end time	In format YYYYMMDDTHHMMSS Actual integration time used to generate the SAR product is referenced the Catalog & Extended metadata files.

CAPELLA TIFF+JSON – IMAGE DATA FILE

Capella TIFF+JSON format image data files are provided as Cloud Optimized GeoTIFF (COG). A cloud optimized GeoTIFF is a regular GeoTIFF file, aimed at being hosted in a cloud computing environment, whose internal organization is friendly for consumption by clients issuing HTTP GET range request. It contains at its beginning the metadata of the full resolution imagery, followed by the optional presence of overview metadata, and finally the imagery itself.

More formally, the structure of such a file is:

- TIFF / BigTIFF signature
- Image File Directory of the full resolution image
- Values of TIFF tags that don't fit inline in the IFD directory, such as TileOffsets, TileByteCounts and GeoTIFF keys
- Tile content of full resolution image.

The GeoTIFF metadata structure for Capella products is:

TIFF Tag	Code	Type	Value	Description
ImageWidth	256	LONG	Variable	Number of pixels per line
ImageLength	257	LONG	Variable	Number of lines in image
BitsPerSample	258	SHORT	32 or 16	*For SLC:* 16 bits I and 16 bits Q *For GEO: 16 bits*
Compression	259	SHORT	1	1=No compression 8=Adobe DEFLATE
PhotometricInterpretation	262	SHORT	1	Color space of the image. 1=minimum value is black.
ImageDescription	270	ASCII	Variable	Full extended metadata in JSON format, identical to the data contained in sidecar JSON file.
SamplesPerPixel	277	SHORT	1	Number of samples per pixel.
PlanarConfiguration	284	SHORT	1	Configuration in which the components (samples) of each pixel are stored. Always set to 1 (contiguous).
Software	305	ASCII	Variable	Processor name and version.
DateTime	306	ASCII	Variable	Date and time of image creation in the format: YYYY:MM:DD HH:MM:SS

Predictor	317	SHORT	1 or 2	A mathematical operator that is applied to the image data before an encoding scheme is applied. 1 = No prediction scheme used before coding. 2 = Horizontal differencing.
TileWidth	322	SHORT	Variable	The tile width in pixels. This is the number of columns in each tile.
TileLength	323	SHORT	Variable	The tile length (height) in pixels. This is the number of rows in each tile.
TileOffsets	324	Array of LONG	Variable	For each tile, the byte offset of that tile, as compressed and stored on disk.
TileByteCounts	325	Array of LONG	Variable	For each tile, the number of (compressed) bytes in that tile.
SampleFormat	339	SHORT	5 or 1	Interpretation of pixel format. Set to 5 (complex signed integer) for SLC products and set to 1 (unsigned integer data) for GEO products
ModelTiepointTag	33922	DOUBLE	Variable	This tag stores raster->model tiepoint pairs in the order ModelTiepointTag = (...,I,J,K, X,Y,Z...) where (I,J,K) is the point at location (I,J) in raster space with pixel-value K, and (X,Y,Z) is a vector in model space. In most cases the model space is only two-dimensional, in which case both K and Z should be set to zero; this third dimension is provided in anticipation of future support for 3D digital elevation models and vertical coordinate systems.
GeoKeyDirectoryTag	34735	SHORT	Variable	Used in interchangeable GeoTIFF files.
GeoDoubleParamsTag	34736	DOUBLE	Variable	Used in interchangeasble GeoTIFF files.
GeoAsciiParamsTag	34737	ASCII	Variable	Used in interchangeable GeoTIFF files.

CAPELLA TIFF+JSON – CATALOG METADATA

The following table presents the fields of the STAC metadata included in the json metadata file.

Element Name	Description	Data Type	Unit
stac_version	The STAC version the Item implements. Currently using the "0.9.0"	String	-
stac_extensions	A list of extensions the Item implements. E.g.: "sar","dtr"	String	-
id	Filename is used as ID	String	-
type	Type of the GeoJSON Object. MUST be set to "Feature"	String	-

bbox		Bounding Box of the asset represented by this item using either 2D or 3D geometries. The length of the array must be 2*n where n is the number of dimensions. The array contains all axes of the southwesterly most extent followed by all axes of the northeasterly most extent specified in Longitude/Latitude or Longitude/Latitude/Elevation based on WGS 84. When using 3D geometries, the elevation of the southwesterly most extent is the minimum depth/height in meters and the elevation of the northeasterly most extent is the maximum. This field enables more naive clients to easily index and search geospatially. STAC compliant APIs are required to compute intersection operations with the item's geometry field, not its bbox.	Numbers	-
geometry		Defines the full footprint of the asset represented by this item, formatted according to RFC 7946, section 3.1. The footprint should be the default GeoJSON geometry, though additional geometries can be included. Coordinates are specified in Longitude/Latitude or Longitude/Latitude/Elevation based on WGS 84.		
	type	Shape type "Polygon"	String	
	coordinates	Longitude/Latitude or Longitude/Latitude/Elevation based on WGS 84.	Number	
properties		A dictionary of additional metadata for the item.		
	proj:centroid	Coordinates representing the centroid of the Item (in lat/long)	Centroid Object	
	proj:shape	Number of pixels in Y and X directions for the default grid	Integer	
	proj:transform	The affine transformation coefficients for the default grid	Number	
	datetime	Date and time of the acquisition E.g., "2019-08-22T06:54:11.00Z"	String	
	start_datetime	Start date and start time of the acquisition E.g., "2019-08-22T06:52:41.000000Z"	String	
	end_datetime	End date and start time of the acquisition E.g., "2019-08-22T06:52:41.000000Z"	String	
	locale:datetime	Local date and time of the acquisition. E.g., "2021-02-2021T02:02:55.149182+0530"	String	
	locale:timezone	Local time zone of the acquisition. E.g., "Asia/Kolkata"	String	
	locale:time	Local time of the acquisition.	String	

		E.g., "02:02:55.149182"		
	platform	Name of the platform	String	
	constellation	Name of the platform	String	
	sar:instrument	Name of the SAR instrument	String	
	sar:instrument_mode	Instrument mode. E.g., "stripmap", "spotlight", "sliding_spotlight"	String	
	sar:frequency_band	SAR band. E.g., "X"	String	
	sar:center_frequency	Center frequency	Number	[GHz]
	sar:polarization	Polarizations. E.g., "HH", "HV", "VH", "VV"	String	
	sat:orbit_state	Orbit state.	String	
	sar:product_type	Imagery product type. E.g.,"SLC", "GEO", "GEC", "SICD", "SIDD", "CPHD"		
	sar:pixel_spacing_range	Pixel spacing in range. The pixel spacing is dependent on what type of image is being processed. For aerial collects a 3D grid (for backprojection processing) is defined. The pixel spacing is the average spacing between each grid point over 100 pixels at the center of the image. For satellite collects, the range doppler geometry is used to calculate the average spacing over 100 pixels at the center of the image.	Number	
	sar:pixel_spacing_azimuth	Pixel spacing in azimuth.	Number	
	sar:looks_range	Number of looks in ground range.	Number	
	sar:looks_azimuth	Number of looks in azimuth.	Number	
	sar:looks_equivalent_number	ENL (defined in a dedicated section below "Multi-looking strategy")	Number	
	sar:resolution_range	Resolution in slant range	Number	
	sar:resolution_azimuth	Resolution in azimuth	Number	[m]
	view:incidence_angle	Incidence angle. Angle is the angle between the vertical (normal) to the intercepting surface and the line of sight back to the satellite at the scene center.	Number	[degree]
	capella:squint_angle	Squint angle. It calculates the squint by looking at the angle between the LOS vector and the velocity vector at the mid-point of the acquisition. The LOS vector is the vector between the scene center pixel and the platform position at the mid-point of the acquisition. A 90 degree squint angle is considered to be no squint.	Number	[degree]
	sar:observation_direction	"right" or "left" looking	String	
	capella:billable_area	Number of squared meters used by Capella billing system.	Number	[m^2]
	capella:collect_id	Unique id for Capella collection. NA for aerial data (i.e., "00000000-0000-0000-0000-000000000000").	String	

	capella:orbital_plane	The orbital plane of the satellite that acquired the image. E.g., 45, 53, 97 NA for aerial data.	Number	
	capella:image_length	Length of image product using the WGS84 ellipsoid projection with no terrain correction.	Number	[m]
	capella:image_width	Width of image product using the WGS84 ellipsoid projection with no terrain correction.	Number	[m]
	processing:software	The version of the processor that created this product.	String	
links		List of link objects to resources and related URLs. A link with the rel set to self is strongly recommended.	String	
assets		Dictionary of asset objects that can be downloaded, each with a unique key. Some pre-defined keys are listed in the chapter 'Asset types'.	String	
collection		The id of the STAC Collection this Item references to (see collection relation type). This field is *required* if such a relation type is present. This field provides an easy way for a user to search for any Items that belong in a specified Collection.	String	

CAPELLA TIFF+JSON – EXTENDED METADATA

The Extended Metadata is provided in the JSON format as part of the image TIFF file in the TIFF tag "TIFFTAG_IMAGEDESCRIPTION". It is also provided in a sidecar JSON file with the product.

Note: time and date fields are ISO8601 formatted and always in UTC.

TOP LEVEL

Name	Type	Definition
collect	Collect	See Collect table
software_version	string	The version of the processor that created this product
software_revision	string	An additional identifier for the software version
product_type	string	Imagery product type. • Single Look Complex (SLC) • Geocoded Terrain Corrected (GEO) • Geocoded Ellipsoid Corrected (GEC)
processing_time	timestamp	The approximate time of product creation
processing_deployment	string	A descriptor of the deployment of the processor used
product_version	string	Describes the version of metadata used

COLLECT

Name	Type	Definition
image	Image	See Image table
radar	Radar	See Radar table
state	State	See State table
pointing	List[Pointing]	See Pointing table
transmit_antenna	Antenna	See Antenna table
receive_antenna	Antenna	See Antenna table
platform	string	The platform of the acquisition
mode	string	The acquisition mode of the radar. One of • stripmap • sliding_spotlight • spotlight
collect_id	string	A unique identifier for the collect
start_timestamp	timestamp	Timestamp for the start of the collection
stop_timestamp	timestamp	Timestamp for the end of the collection
local_datetime	timestamp	Local date and time of the acquisition.
local_timezone	string	Local time zone of the acquisition.

IMAGE

Name	Type	Definition
data_type	string	The data type of the image • UInt16 • CInt16
rows	int	The number of rows in the image
columns	int	The number of columns in the image
pixel_spacing_row	float	The meters between samples in the row direction at the center of the image.
pixel_spacing_column	float	The meters between samples in the column direction at the center of the image.
range_resolution	float	The resolution in the slant range direction.
azimuth_resolution	float	The resolution in the azimuth direction.
scale_factor	float	The value to multiply the TIFF values by to recover the true science data
center_pixel	CenterPixel	Describes various properties about the scene center pixel

algorithm	string	The algorithm used to transform the raw data to SLC • backprojection • omegak • rda
range_window	Window	The window applied in the range direction
azimuth_window	Window	The window applied in the azimuth direction
processed_azimuth_bandwidth	float	The processed azimuth bandwidth in Hz
image_geometry	ImageGeometry	The image geometry of this image
azimuth_looks	float	The number of looks in the azimuth direction
range_looks	float	The number of looks in the range direction
enl	float	The theoretical ENL of the image
azimuth_beam_pattern_corrected	bool	True if azimuth beam pattern correction was applied
elevation_beam_pattern_corrected	bool	True if the elevation beam pattern correction was applied
radiometry	string	• beta • beta_nought • sigma_nought
calibration	string	• none (no calibration applied) • limited (calibration applied, with no telemetry) • partial (calibration applied, with partial telemetry) • full (calibration applied, with all telemetry)
calibration_id	string	Version of the calibration applied to the data products. Format of string is: <platform>/<start_datetime>-<optional_end_datetime>/<version> For example, the preliminary calibration for products from Capella-2 satellite is: capella-2/2020-09-10T00:00:00Z_/1
nesz_peak	float	Noise equivalent sigma-zero (NESZ) in dB at the peak in the antenna gain pattern (e.g. the minimum NESZ in the image)

nesz_polynomial	Polynomial	A 1D polynomial of Noise equivalent sigma-zero (NESZ) in dB, as a function of absolute range in meters.
frequency_doppler_centroid_polynomial	Polynomial	A 2D polynomial mapping range and azimuth time to doppler centroid frequency in Hz. Notice that the range dependence of the DC polynomial uses range distance. The azimuth variable is seconds since first_line_time.

If range_looks or azimuth_looks are greater than 1, the following fields are also included:

Name	Type	Definition
multilooking_algorithm	string	A description of the multilook algorithm used • boxcar • traditional • improved

IMAGEGEOMETRY

Name	Type	Definition
type	string	Describes the type of the image geometry • slant_plane • surface • geotransform • pfa

For type==geotransform, the following additional fields are specified:

Name	Type	Definition
geotransform	List	6-element affine transform line/pixel → lat/lon
coordinate_system	CoordinateSystem	The coordinate system that the 6-element affine transform transforms to

For type==pfa, the following additional fields are specified

Name	Type	Definition
scene_reference_point_row_col	List[int]	The row and column at the scene reference point in units of pixels
scene_reference_point_ecef	List[float]	The scene reference point in ECEF meters
row_sample_spacing	float	The sample spacing in meters in the row direction

col_sample_spacing	float	The samples spacing in meters in the column direction
row_direction	List[float]	A unit vector in ECEF indicating the row direction
col_direction	List[float]	A unit vector in ECEF indicating the column direction
slant_plane_normal	List[float]	A 3D unit vector in ECEF describing the direction normal to the slant plane
ground_plane_normal	List[float]	A 3D unit vector in ECEF describing the direction normal to the ground plane
polar_angle_polynomial	Polynomial	A 1D polynomial mapping seconds since collect_start to polar angle in radians
spatial_frequency_scale_factor_polynomial	Polynomial	A 1D polynomial mapping polar angle in radians to Spatial Frequency Scale Factor. Used to scale RF frequency to aperture spatial frequency.
›antenna_reference_point_polynomial	Polynomial	3 1D polynomials in X, Y, Z (ECEF) mapping seconds since collect_start to the antenna reference point (in meters)
velocity_antenna_reference_point_polynomial	Polynomial	3 1D polynomial in X, Y, Z (ECEF) mapping seconds since collect_start to the velocity of the antenna reference point (in meters/second)
center_of_aperture	CenterOfAperture	See CenterOfAperture below

For type==slant_plane, the following additional fields are specified:

Name	Type	Definition
doppler_centroid_polynomial	Polynomial	A 2D polynomial mapping range and azimuth time to doppler centroid frequency in Hz used to compute the image geometry. Notice that the range dependence of the DC polynomial uses range distance. The azimuth variable is seconds since first_line_time.
first_line_time	timestamp	The timestamp of the first line
delta_line_time	float	The time difference between successive lines in seconds
range_to_first_sample	float	The slant range distance to the first sample in meters
delta_range_sample	float	The slant range delta distance between each sample in meters

For type==surface, the following additional fields are specified:

Name	Type	Definition
surface_type	string	Describes the type of the surface • affine • equispaced

coordinate_system	CoordinateSystem	Description of the coordinate system of the surface coordinates
z	DEM	The DEM used to compute the z dimension of the surface

For surface_type==affine, the following extra fields are included:

Name	Type	Definition
geotransform	List	6-element affine transform

For surface_type==equispaced, the following fields are also specified:

Name	Type	Definition
x0	float	The initial coordinate in the X direction
dx	float	The spacing the X direction
y0	float	The initial coordinate in the Y direction
dy	float	The spacing in the Y direction

CENTEROFAPERTURE

Name	Type	Definition
time	float	Seconds since collect_start to the time of center of aperture
antenna_reference_point	List[float]	A 3-vector in ECEF meters describing the antenna reference point at center of aperture time
velocity_antenna_reference_point	List[float]	A 3-vector in ECEF meters/second describing the velocity of the antenna reference point at the center of aperture time
polar_angle	float	The polar angle in radians at the center of aperture time
spatial_frequency_scale_factor	float	The Spatial Frequency Scale Factor at the center of aperture time

RADAR

Name	Type	Definition
transmit_polarization	string	The transmit polarization of the radar
receive_polarization	string	The receive polarization of the radar
rank	int	The number of PRIs between transmit and receive
center_frequency	float	The center frequency of the radar (Hz)
time_varying_parameters	List[TimeVaryingParameter]	A list of TimeVaryingParameter objects
pointing	string	• right • left
sampling_frequency	float	The sampling frequency of the ADC in Hz

STATE

Name	Type	Definition
coordinate_system	CoordinateSystem	A CoordinateSystem object describing the spatial coordinates of the orbit
state_vectors	List[StateVector]	A list of StateVectors describing the platform position and velocity
source	string	Orbit product used in processing
direction	string	• ascending • descending • null (if not applicable)

STATEVECTOR

Name	Type	Definition
time	timestamp	The timestamp of the measurement time of the state vector
position	List[float]	A list of 3 floats (x,y,z) describing position in the orbit coordinate system
velocity	List[float]	A list of 3 floats (vx, vy, vz) describing the velocity of the platform in the orbit's coordinate system

POINTING

Name	Type	Definition
time	timestamp	The timestamp of the attitude measurement
attitude	List[float]	A list of 4 floats (w, x, y, z) describing the rotation from the coordinate_system frame to the antenna frame as a quaternion, where w is the scale. The antenna frame is defined as: Z is boresight, and X and Y are the reference azimuth and elevation directions respectively.

ANTENNA

Name	Type	Definition
azimuth_beamwidth	float	The 3dBi azimuth beamwidth in radians
elevation_beamwidth	float	The 3dBi elevation beamwidth in radians
gain	float	The one way gain of the antenna in dBi
beam_pattern	Polynomial	A 2D polynomial that gives normalized (maximum 0dBi) one way beam pattern as a function of offboresight angle in elevation and azimuth in dBi

COORDINATESYSTEM

Name	Type	Definition
type	string	The type of coordinate system, one of • ecef • local_tangent_plane • wkt

If type==local_tangent_plane, the following extra fields are included:

Name	Type	Definition
transform	List[float]	A list of 16 floats describing a 3D homogeneous transformation matrix from ECEF to the local tangent plane coordinate system.

If type==wkt, the following extra fields are included:

Name	Type	Definition
wkt	string	A string representation of the WKT describing the coordinate frame

WINDOW

Name	Type	Definition
name	string	The name of the Window
parameters	object	A free-from object describing the parameters for the window ▪ raised cosine ▪ taylor
broadening_factor	float	The impulse response broadening factor associated with the Window

POLYNOMIAL

Name	Type	Definition
type	string	The type of polynomial • standard • chebyshev • legendre
dimension	int	The dimension of the polynomial
degree	float	Max degree of coefficient
coefficients	List[float]	Array of coefficients ordered so that the coefficient of the term of multi-degree (i_0, i_1 ..., i_n) is contained at index (0, 1, ..., n) where n is the dimension above. The size of the array in each dimension is degree + 1.

TimeVaryingParameter

Name	Type	Definition
start_timestamps	List[timestamp]	A list of timestamps indicating when the specified PRF becomes active
prf	float	The PRF in Hz
pulse_bandwidth	float	The bandwidth of the transmitted pulse in Hz
pulse_duration	float	The time duration of the transmitted pulse in seconds

CENTERPIXEL

Name	Type	Definition
incidence_angle	float	The incidence angle in degrees
squint_angle	float	The squint angle in degrees
look_angle	float	The look ange in degrees
target_position	List[float]	The ECEF coordinates of the center pixel
center_time	timestamp	The timestamp of when the antenna center acquired the pixel

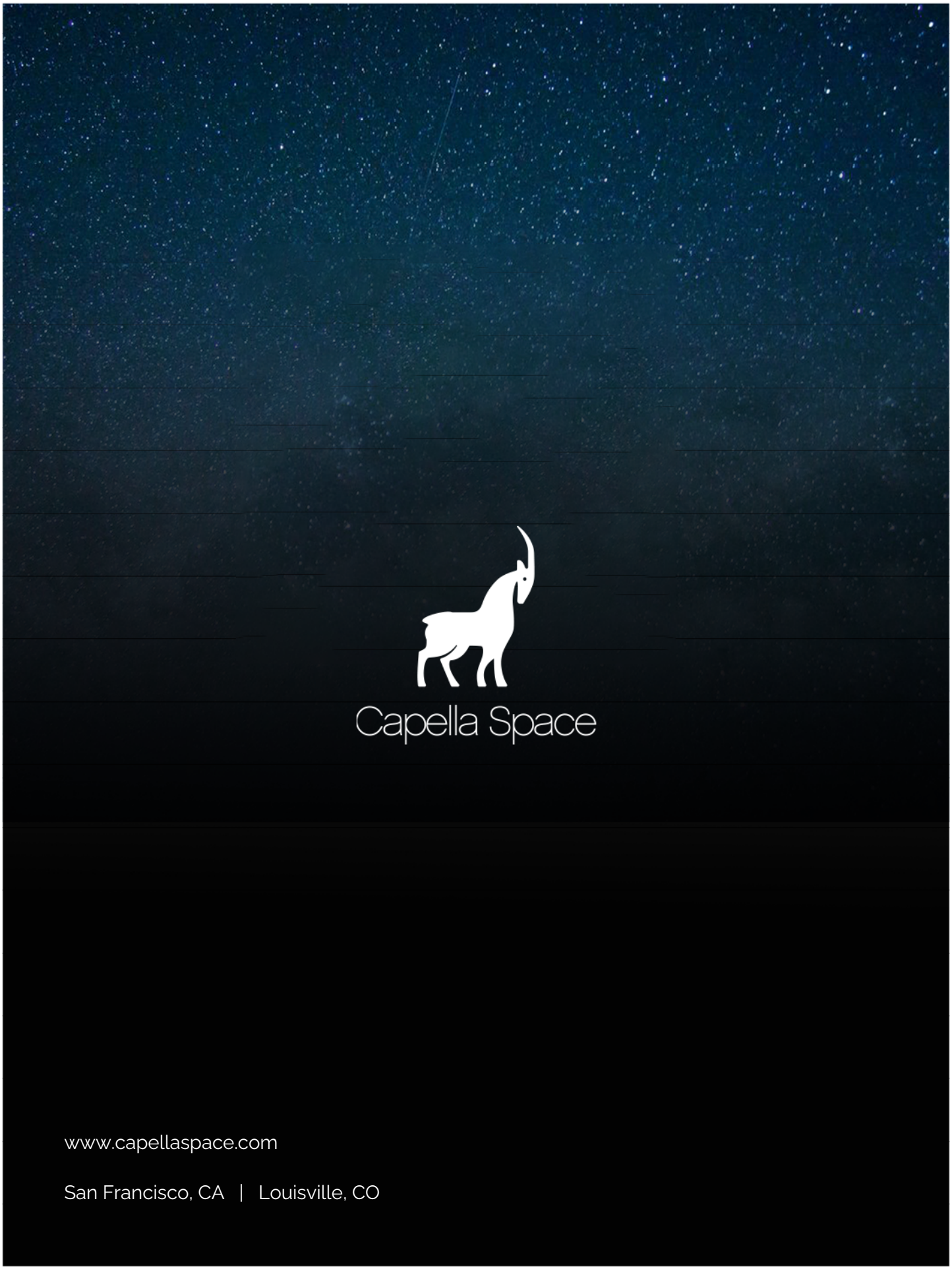
Terrain Models

For SLC product type, we include the terrain model used for focusing during backprojection. For GEC and GEO products, we include the terrain model used for focusing during backprojection and for reprojection during orthorectification.

Name	Type	Definition
link	string	An internal identifier for the terrain model and the link to the source. E.g., "WhiteboxFilter[AW3D30v2012,8,50]+https://www.eorc.jaxa.jp/ALOS/en/aw3d30/index.htm"
name	string	An internal identifier for the terrain model used. E.g., "WhiteboxFilter[AW3D30v2012,8,50]"

REFERENCES

Ref #	Document Title
Ref 1	Capella Space – SAR Imagery Products Guide
Ref 2	Spatio Temporal Asset Catalog: https://stacspec.org/
Ref 3	D. Small, "Flattening Gamma: Radiometric Terrain Correction for SAR Imagery," in *IEEE Transactions on Geoscience and Remote Sensing*, vol. 49, no. 8, pp. 3081-3093, Aug. 2011.



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