ICEYE

LEVEL 1 PRODUCT FORMAT SPECIFICATION DOCUMENT

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www.ICEYE.com

TABLE OF CONTENTS

1. INTRODUCTION

INTRODUCTION

ICEYE's SAR Satellite Constellation provides commercial access to timely and reliable Earth observation data. This document is intended to describe the specification for our basic SAR product represented in a Single Look Complex (SLC) format. ICEYE is in the early stages of commercial operations, so we are actively working on refining our product offering. This Early Data Access document contains parameters that will be updated as our products evolve, and we receive valuable customer feedback. Questions and/or comments on this documentation or how to order an ICEYE product should be directed to our Customer Success team at customer@iceye.com

1.1 SCOPE

This document defines the format of Level 1 product components for imagery products generated from the ICEYE SAR constellation. Level 1 products include georeferenced satellite path oriented products, that can be further orthorectified using specialized SAR software tools.

1.2 DOCUMENT STRUCTURE

The document consists of a general rationale for the Level 1 product format and a description of the product delivery package. This is followed by the description of binary image data, annotation parameters detailing product features, and processing modalities.

INTRODUCTION

1.3 LIST OF ACRONYMS

ASCII	American Standard Code for Information Interchange
BSD	Berkeley Software Distribution
CF	Calibration Factor
DC	Doppler Centroid
DN	Digital Number
ECEF	Earth-Centered, Earth-Fixed
GRD	Ground Range Detected
GRSR	Ground Range to Slant Range conversion
HDF	Hierarchical Data Format
PNG	Portal Network Graphics
PRF	Pulse Repetition Frequency
SAR	Synthetic Aperture Radar
SLC	Single Look Complex
UTC	Coordinated Universal Time
VV	Polarization (Vertical transmitted and Vertical received)
XML	eXtensible Markup Language

INTRODUCTION

1.4 LIST OF SYMBOLS

β_0	Radar Brightness
f_{sr}	Range Sampling Rate
θ	Local incidence angle on ground calculated using the ellipsoidal Earth model
σ_0	Radar Backscattering coefficient
t	Range (fast) time

1.5 SAR GLOSSARY

Azimuth - Direction aligned with the relative spaceborne platform velocity vector.

Detection - Processing step in which the phase information is removed and only the signal amplitude is preserved. Normally the detection uses a magnitude squared method and has units of voltage squared per pixel.

Focusing - Data processing finalized to focus the SAR image in range and azimuth through bidimensional signal compression.

Ground range - Projection of the slant range into the ground.

Incidence angle - Local incidence angle on ground calculated using the ellipsoidal Earth model.

Looks - Image obtained using only part of the spectrum to focus the image (subaperture). It can be done in range and in azimuth, and normally is used to reduce the speckle noise from SAR images through incoherent sum (multi-look process).

Range - Direction orthogonal to the satellite velocity.

Slant range vector - Line-Of-Sight distance between the antenna and the target on ground.

Slant range plane - Plane containing the relative sensor velocity vector and the slant range vector for a given target.

2. BASIC (LEVEL 1) SAR PRODUCT FORMAT RATIONALE

BASIC (LEVEL 1) SAR PRODUCT FORMAT RATIONALE

ICEYE products can be differentiated into two major product groups: Level 1 Basic Image Products and Level 2 Enhanced Image Products.

Basic Image Products are satellite path oriented datasets. Basic Image Products correspond to the Committee on Earth Observation Satellites (CEOS) Level 1B processing quality and can be ordered either from archive (previously collected imagery) or as future acquisitions by contacting our ICEYE Customer Success Specialists. Enhanced Image Products are geo-coded and radiometrically corrected imagery, corresponding to CEOS Level 2 quality imagery, and are described in the ICEYE Product Guide.

A basic ICEYE product is represented by a set of SAR image binary data, corresponding image annotation metadata and delivered as a singular product package. Products are characterized by the payload configuration (such as imaging mode and look direction) used by the respective satellite, as well as the level of processing that has been applied to the SAR scene. With respect to the data geometric projection and representation, Basic Image Products are differentiated into two primary product types: geo-referenced Single Look Complex (SLC) and Ground Range Detected (GRD) scenes. SAR image binary data, delivered as digital numbers or quadrature components, can be converted to radar brightness using annotated calibration factor, or further radiometrically calibrated.

Level-1 Single Look Complex (SLC) are basic single look products of the focused SAR signal. Scenes are stored in the satellite image acquisition geometry, in the slant range by azimuth imaging plane in zero-Doppler SAR coordinates. The pixels are spaced equidistant in azimuth (according to the inverse of the pulse repetition frequency) and in slant range (according to the range sampling frequency). Each image pixel is represented by a complex magnitude value (with in-phase I and quadrature Q components) and therefore, contains both amplitude and phase information. Each image pixel is processed to zero Doppler coordinates in range direction, i.e. perpendicular to the flight track.

SLC products are most suitable for advanced users that intend to use phase

BASIC (LEVEL 1) SAR PRODUCT FORMAT RATIONALE

information, primarily in interferometric applications, or prefer lower level processing to implement own processing chains. The SLC product has no radiometric artefacts induced by spatial resampling or geocoding, and can be orthorectified using both commercial and free specialized SAR software tools for instance the European Space Agency (ESA) Sentinel Application Platform (SNAP).

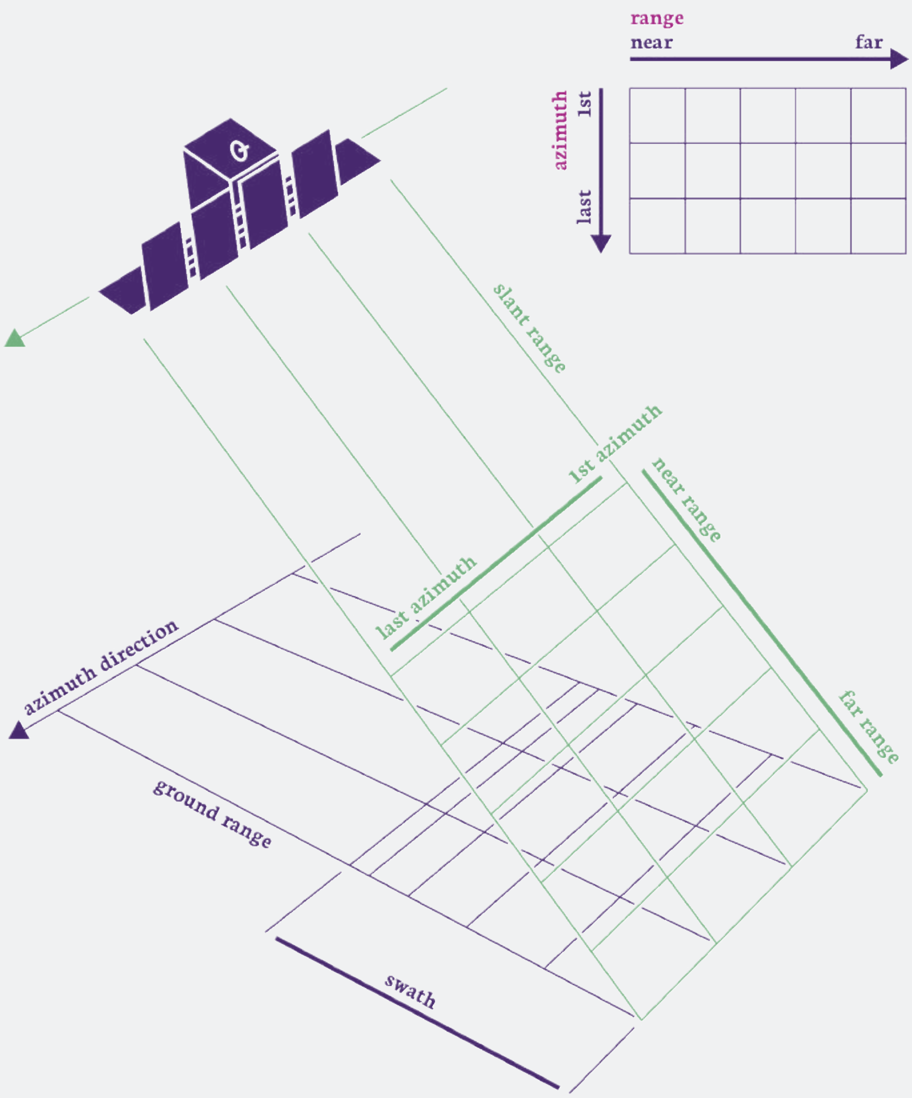

Figure 1. Slant-range and ground range image geometry

BASIC (LEVEL 1) SAR PRODUCT FORMAT RATIONALE

Level-1 Ground Range Detected (GRD) products represent focused SAR data that has been detected and (optionally) multi-look processed and projected to the ground range using an Earth ellipsoid model. The image coordinates are oriented along the flight direction and ground range. The pixel spacing is equidistant in azimuth and in ground range. Ground range coordinates are the slant range coordinates projected onto the ellipsoid of the Earth. For the slant to ground range projection the WGS84 ellipsoid and an averaged fixed value of terrain height is used, annotated in the metadata. Pixel values represent detected amplitude. Phase information is lost. The resulting product has approximately square spatial resolution and square pixel spacing. Additionally, an incidence angle dependence in range calculated using the ellipsoidal Earth model has been readily applied to facilitate the conversion of radar brightness to backscatter intensity. This is explained in more detail in Section 4.2.

The advantage of this product is the fact that no image rotation to a map coordinate system has been performed and interpolation artefacts are thus avoided. This product is useful for applications that only require amplitude information and if geocoding or orthorectification is to be applied by the user, or for applications where geocoding is not required.

2.1 FILE FORMAT

Hierarchical Data Format (HDF) is the primary means for storing the image metadata and binary image data of SLC products. The format libraries and associated tools are available under a liberal, BSD-like license for general use. HDF is widely supported by both commercial and non-commercial image processing software and software development platforms.

For GRD products, the format of choice was GeoTiff. This enables quick assessment of SAR imagery using common GIS tools, and the storage of both image metadata and detected amplitude of image data. However, an image orthorectification still needs to be done using specialized SAR software.

In order to simplify access to product annotation, for e.g., for indexing purposes, the key information about the product is also gathered in the **auxiliary XML file.** The chosen format is similar to those implemented for TerraSAR-X/TanDEM-X and RADARSAT-2 missions. ICEYE imagery has several imaging modes, however, annotated metadata contains all the basic information on the delivered product, as uniform as possible for all product types.

3. PRODUCT DELIVERY PACKAGE

▶ PRODUCT DELIVERY PACKAGE

Here, we describe the package directory structure and file naming conventions for Level 1 products.

3.1 PACKAGE STRUCTURE AND FILE NAMES

The Level 1 Product package consists of a primary HDF5/GeoTiff file containing both binary image data and metadata, a secondary XML file containing selected metadata, as well as a set of auxiliary files with variable content agreed with users. The latter always includes a PNG quicklook of the scene.

The structure of the delivery package for the Level 1 Products is shown in Figure 2.

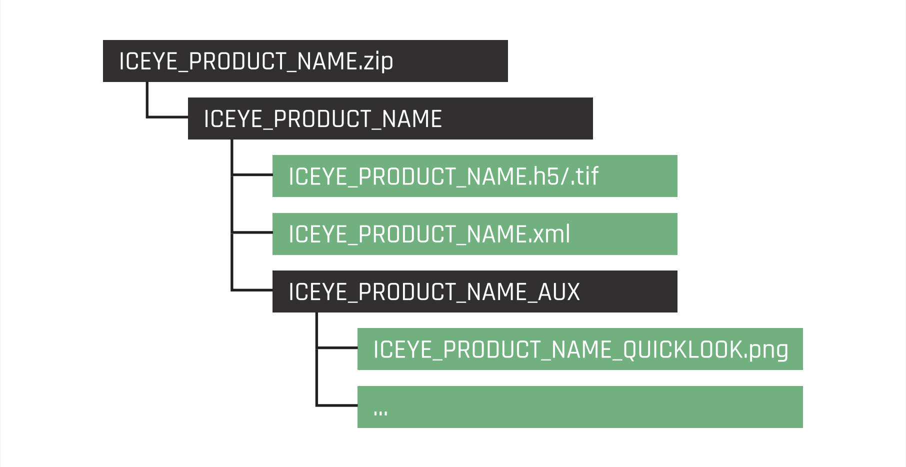

Figure 2. Structure of the Product delivery package for the SLC product

PRODUCT DELIVERY PACKAGE

3.2 FILE NAMING CONVENTIONS

Product file naming is organized to facilitate understanding of the product processing level and key properties at an early stage, without the need to analyze product metadata. The product filename components are shown in Figure 3.

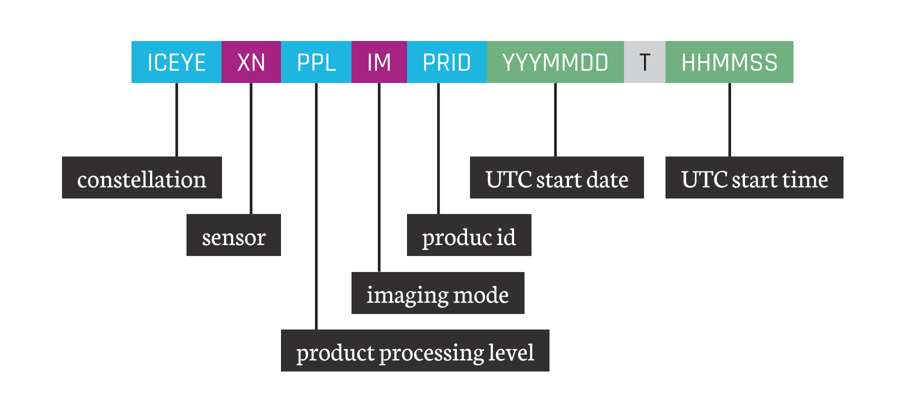

Figure 3. Basic Product filename components

Here, PRID is shown as a unique identifier of acquired scene assigned during scene ordering and acquisition. Other constituent elements are intuitive and explained in more detail in Table 1.

Table 1. Product filename components

CONSTITUENT	NAME	VALUE	NOTES
ICEYE_	constellation	**ICEYE_**	fixed
XN_	sensor	**X2/X4/X5**	specific sensor that has acquired the scene
PPL_	product processing level	**SLC/GRD/ORTHO***	variant of processing level
IM_	imaging mode	**SM/SL/SC***	stripmap, spotlight, scansar*
PRID_	product id	**6403**	data take ID
FFFFFF	UTC start date	**20190211**	YYYYMMDD format
TGGGGGG	UTC start time	**T131415**	Thhmmss format

* Planned product formats and imaging modes

4. SAR IMAGE RASTER FILES

SAR IMAGE RASTER FILES

The image data presently consists of one polarimetric channel (VV) in a separate binary data matrix. In complex products, the individual bursts of each ScanSAR beam are stored together in one individual binary file for each beam. The stripmap and spotlight products are equivalent to a single beam/single burst ScanSAR product in this context. Further, we describe the way these matrices are stored together with the metadata in Basic ICEYE image products.

4.1 COMPLEX SAR PRODUCTS

Single Look Complex (SLC) data are stored as binary matrices in an HDF5 file. Real and imaginary parts are stored separately, using either signed integer 16 bit or single float 32 bit format (annotated in the metadata). It is assumed that all pixels are valid, unless marked with NaN value. The structure of the binary data are shown in Figure 4. Row content are range-lines, and columns contain azimuth samples.

Figure 4. Complex SAR scene geometry in slant range

4.2 DETECTED SAR PRODUCTS

SAR IMAGE RASTER FILES

The image data layer DN_{GRD} of detected SAR products are stored in GeoTIFF file format using unsigned 16 bit representation along with a set of both commonly used and specifically defined GeoTIFF tags. GeoTiff files are readable with standard image processing and GIS software tools.

GRD products are located in the ground range by azimuth surface, with image coordinates oriented along ground range and flight direction. The standard GRD products are detected products with square pixel spacing. Approximately the same pixel resolution for different products (and different incidence angles) is achieved by varying the bandwidth in connection with an acquisition geometry of every planned data take.

Typically, the detection is performed as

$$|DN_{SLC}|^2 = (I^2 + Q^2) ,$$

with I and Q representing the real and imaginary amplitude of the complex backscatter. For GRD scenes, a conversion to sigma-nought has been already applied using incidence angle calculated using the ellipsoidal Earth model:

$$|DN_{GRD}|^2 = |DN_{SLC}|^2 \cdot sin(\theta)$$

If the processing to beta-nought or gamma-nought using local DEM is to be applied, the conversion to radar brightness can be performed using incidence angle information annotated in the product metadata.

5. OTHER PRODUCT COMPONENTS

OTHER PRODUCT COMPONENTS

5.1 QUICKLOOK IMAGES

Quicklooks are stored in the PNG format. A quicklook image is a power averaged and decimated representation of the main product, corresponding to the area within corner-coordinates of given scene. It is assumed, that quicklook images are always present in the deliverable product package. They are stored in a separate AUX-directory of the product.

5.2 XML ANNOTATION METADATA

A subset of parameters describing the acquired product and its processing are available within a separate XML file stored along with the primary SLC/GRD file. XML format is a standard human- and machine-readable text format, and its content can be used for quick indexing or scene screening without a need to open primary image file. As with the quicklook images, XML metadata files are always present in the delivered product package, and stored along the primary HDF5 or GeoTiff file in the root package directory.

6. LEVEL 1B PRODUCT ANNOTATION

LEVEL 1B PRODUCT ANNOTATION

Data types, valid entries and allowed attributes (e.g. units) are defined in detail for each element in the product metadata described therein.

Since both HDF5 and GeoTiff formats are readily readable by many specialized tools and not a binary format, the indicated data types (e.g., strings, integers, doubles) for most of the annotation are the intrinsic default types. The hierarchy level is as flat as possible to facilitate the interpretation of the product annotation.

This product annotation contains information critical for importing to specialized SAR postprocessing software (such as ESA SNAP), as well as some other information that characterizes a given scene. In order to aid cataloguing and facilitating access to product parameters using simpler tools (e.g., browser or text editor), a subset of scene parameters are stored as an XML file.

Additionally, we combine different annotation parameters into thematic groups and explain their specifics, structure, format and values.

6.1 PRODUCT ANNOTATION PARAMETERS

These parameters refer to the product annotation version used during the product generation.

Table 2. Product annotation parameters

FIELD NAME	TYPE	UNIT	DESCRIPTION	VALUE EXAMPLE
product_name	ASCII	Text	ICEYE_datasetID_eventID_(YYYYMMDD)T(HHMMSS)	ICEYE_2457_123123_20191201T056721
spec_version	ASCII	Text	Version of the Level 1 Product Format Specification document	1.0

6.2 PRODUCT PARAMETERS

▶ LEVEL 1B PRODUCT ANNOTATION

In product parameters, general mission, scene and imaging mode related product parameters are specified. Also, basic information on the product content and format is provided along with characterization of the processing modalities of the given product.

Table 3. General product parameters

FIELD NAME	TYPE	UNIT	DESCRIPTION	VALUE EXAMPLE*
product_type	ASCII	text	Product type (if we have product names for different imaging modes)	Stripmap, StripmapWide, Strip-mapHI, Spotlight, ScanSAR
product_level	ASCII	text	Processing level, the SLC product will state SLC	SLC
satellite_name	ASCII	text	Name of the satellite	ICEYE-X2, ICEYE-X4...
acquisition_mode	ASCII	text	Acquisition mode used, basically only 3 options	Stripmap, Spotlight, Scansar
look_side	ASCII	text	Look side of the acquisition, only 2 options LEFT or RIGHT	LEFT
processor_version	float64	number	Version number of the processor used to generate the product	(internal version numbering)
orbit_repeat_cycle	int64	number	Ground track repeat cycle (to be included)	99999
orbit_relative_number	int64	number	Relative number of orbit within the repeat cycle	1447
orbit_absolute_number	int64	number	Absolute number of orbits since launch	1447
orbit_direction	ASCII	text	Specifies whether the orbit is in ascending or descending node at the time of acquisition	ASCENDING or DESCENDING
polarization	ASCII	text	Transmit and receive polarizations used	VV
acquisition_start_utc	ASCII	UTC time	UTC time for when the first pulse of the scene was sent	2019-03-10T18:19:50.316054
acquisition_end_utc	ASCII	UTC time	UTC time for when the last pulse of the scene was sent	2019-03-10T18:20:00.307546
zerodoppler_start_utc	ASCII	UTC time	Time of the first pulse at the start of the scene	2019-03-10T18:19:51.775477
zerodoppler_end_utc	ASCII	UTC time	Time of the last pulse at the end of the scene	2019-03-10T18:20:00.960210

LEVEL 1B PRODUCT ANNOTATION

Table 3. General product parameters (cont.)

FIELD NAME	TYPE	UNIT	DESCRIPTION	VALUE EXAMPLE*
first_pixel_time	float64	seconds	Two-way slant range time origin, corresponding to the near range (1st range sample)	0.004398670017444
geo_ref_system	ASCII	text	Geographic reference frame indicator for scene coordinates and orbit state vectors	WGS84
avg_scene_height	float64	meters	Average elevation over ellipsoid (calculated using SRTM or other low resolution global DEM)	661.0
mean_orbit_altitude	float64	meters	mean sensor altitude above WGS84 ellipsoid	595177.494
mean_earth_radius	float64	meters	mean WGS84 ellipsoid radius over scene	6371346.049
satellite_look_angle	float64	degrees	Satellite look angle	23.5

* satellites and imaging modes listed in the example column also include planned ones

LEVEL 1B PRODUCT ANNOTATION

Scene center and corner coordinates are stored as 4-element vectors containing line and column numbers along with geodetic latitude and longitude values, for each coordinate, as shown below. Indices specify: 0 - line number, 1- column number, 2 - latitude, 3 - longitude.

Table 4. Scene coordinates

FIELD NAME	TYPE	UNIT	DESCRIPTION	VALUE EXAMPLE
coord_center [0:3]	vector of float64	coordinates	Central coordinate	[8440,22139,34.86704,-117.99988]
coord_first_near [0:3]	vector of float64	coordinates	First azimuth line near range coordinate.	[1,1,35.12016,-117.74549]
coord_first_far [0:3]	vector of float64	coordinates	First azimuth line far range coordinate.	[16878,1,35.17738,-118,11233]
coord_last_near [0:3]	vector of float64	coordinates	Last azimuth line near range coordinate.	[1,44298,34.55509,-117.88013]
coord_last_far [0:3]	vector of float64	coordinates	Last azimuth line far range coordinate.	[16878,44298,34.61222,-118.24414]

Image data raster specification stores parameters related to the image raster data along with the image data arrays.

LEVEL 1B PRODUCT ANNOTATION

Table 5. Image raster parameters

FIELD NAME	TYPE	UNIT	DESCRIPTION	VALUE EXAMPLE
sample_precision	ASCII	text	Precision used for binary data samples	float32, int16
number_of_azimuth_samples	int64	number	Number of azimuth samples (number of rows in binary data)	44298
number_of_range_samples	int64	number	Number of range samples (number of columns in binary data)	16878
s_i	float32 or int16	number array	Real part of the SLC complex array (only for SLC products)	
s_q	float32 or int16	number array	Imaginary part of the SLC complex array (only for SLC products)	
grd_amplitude (band[0])	int16	number array	Amplitude array (only for GRD products). Sigma-nought conversion factor of sin(inc_angle) applied.	

6.3 PRODUCT SPECIFIC PARAMETERS

LEVEL 1B PRODUCT ANNOTATION

These parameters describe in detail the level and characteristic of the preprocessing applied to the SLC/GRD product.

Table 6. Product specific parameters

FIELD NAME	TYPE	UNIT	DESCRIPTION	VALUE EXAMPLE
azimuth_looks	int64	number	Looks in azimuth direction (for SLC products it is 1)	3
azimuth_look_bandwidth	float64	Hz	Bandwidth of each look in range (only for GRD products)	1157.2
azimuth_look_overlap	float64	Hz	Overlap of adjacent looks in azimuth (only for GRD products)	289.3
range_looks	int64	number	Looks in range direction (for SLC products it is 1)	3
range_look_bandwidth	float64	Hz	Bandwidth of each look in range (only for GRD products)	53600000
range_look_overlap	float64	Hz	Overlap of adjacent looks in range (only for GRD products)	13400000
zerodoppler_start_utc	ASCII	UTC time	Time of the first pulse at the start of the scene	2019-03-10T18:19:51.775477
zerodoppler_end_utc	ASCII	UTC time	Time of the last pulse at the end of the scene	2019-03-10T18:20:00.960210
slant_range_spacing	float64	meters	Spacing between two consecutive slant range samples in meters	0.95172208888
azimuth_ground_spacing	float64	meters	Azimuth sample spacing in meters with the average ground projected velocity	1.44733
range_sampling_rate	float64	Hz	Sampling rate used for digital sampling, defines range sample spacing in time	157500000

LEVEL 1B PRODUCT ANNOTATION

Table 6. Product specific parameters (cont.)

FIELD NAME	TYPE	UNIT	DESCRIPTION	VALUE EXAMPLE
azimuth_time_interval	float64	seconds	Time interval between azimuth samples in the SLC product. (=1/processing_prf)	2.073E-4
chirp_bandwidth	float64	Hz	Bandwidth used for radar pulse (defines achievable radar range resolution)	134000000
chirp_duration	float64	seconds	Duration of chirp	0.000041473
total_processed_bandwidth_azimuth	float64	Hz	Doppler bandwidth used for azimuth compression (defines achievable azimuth resolution)	2893
window_function_range	ASCII	text	Windowing function used over range frequencies	taylor_20_4
window_function_azimuth	ASCII	text	Windowing function used over azimuth frequencies	taylor_20_4
antenna_pattern_compensation	vector of float	numbers	Amplification factor applied for antenna pattern compensation (for each range sample)	[1.8106, 1.8103...1.0956,1.0957]
fsl_compensation	vector of float64	numbers	Amplification factor applied for free space loss compensation (for each range sample)	[1.0457, 1.0457...1.0841,1.0841]
range_spread_comp_flag	int64	flag	Flag indicating if free space loss compensation was applied	1
ant_elev_corr_flag	int64	flag	Flag indicating if antenna elevation pattern compensation was applied	1

LEVEL 1B PRODUCT ANNOTATION

6.4 SCENE PROCESSING PARAMETERS

Here we describe processor and product-configuration parameters as well as resulting parameters of the data determined during screening and processing. Doppler Centroid (DC) coefficient estimates are provided every second since the start of image acquisition. For each azimuth location, DC dependence in range is described as a polynomial function. Validity limits are time at near and far range. DC coefficients can be obtained by fitting DC dependence in range from time as:

$$DC(t) = C_0(t - t_{ref})^0 + C_1(t - t_{ref})^1 + C_2(t - t_{ref})^2 + C_3(t - t_{ref})^3 ,$$

where reference point in time t_{ref} corresponds to the mid-range time, and time varies between t_{min} and t_{max} corresponding to near range (first pixel time) and far range, respectively.

The mid- range time is calculated as:

$$t_{ref} = (t_{min} - t_{max}) / 2 = t_{min} + n_{rs} / (2 \cdot f_{sr}) ,$$

where n_{rs} is the number of range samples, and f_{sr} is the range sampling rate.

Overall, the DC coefficient information, for each DC estimate, follows Table 7.

For GRD products, the ground range to slant range (GRSR) conversion can be performed using GRSR polynomial with coefficients stored in the annotated data. Then, the slant range location of specific pixel in the ground range can be calculated as:

$$SR_j = \sum_{k=0}^{p-1} C_k \cdot (GR_0 + (j - 1) \cdot rs)^k , j = [1 , n].$$

where, SR_j and GR_j are the slant and ground range locations for the j-th pixel, respectively; GR_0 is the ground range origin, and rs is ground range spacing.

LEVEL 1B PRODUCT ANNOTATION

Table 7. Scene processing parameters

FIELD NAME	TYPE	UNIT	DESCRIPTION	VALUE EXAMPLE
number_of_dc_estimates	int64	Number	Number of doppler centroid estimates	9
dc_estimate_time_utc [0:end]	ASCII list	Time (UTC)	Timestamp for each doppler centroid estimate	[‘2019-03-10T18:19:51.775477’], [‘2019-03-10T18:19:52.775477’], [‘2019-03-10T18:19:53.775477’], [‘2019-03-10T18:19:54.775477’]]
dc_estimate_poly_order	int64	Number	Order of polynomial describing one doppler centroid estimate	3
dc_estimate_coeffs	2D array of float64, size MxN	Number	Doppler centroid coefficient as a 2D array, size MxN, where M is the number of DC estimates, and N is the DC polynomial order	[[5.417583e+03, 1.130813e+07, -8.125472e+09,7.947223e+12], ... [5.417583e+03, 1.130813e+07, -8.125472e+09,7.947223e+12]]
doppler_rate_poly_order	int64	Number	Order of polynomial describing doppler rate range dependence	3
doppler_rate_coeffs	vector of float64	Number	Coefficients of doppler rate polynomial as a function of range time. Stored as a vector with size corresponding to the order of the doppler rate polynominal	[5.124592968269841e+03; -1.153864338674892e+06; 2.582540352459471e+08; -5.572042961000484e+10]
grsr_poly_order	int64	Number	Order of polynomial describing ground range to slant range projection dependence	4
grsr_coefficients	vector of float64	Number	ground range to slant range polynomial coefficients (only for GRD product)	[6.467483312430216e+05; 0.47388031307797884; 6.685331046296479e-07; -4.928145432555108e-13; 5.0525558404285224e-20]

LEVEL 1B PRODUCT ANNOTATION

Table 7. Scene processing parameters (cont.)

FIELD NAME	TYPE	UNIT	DESCRIPTION	VALUE EXAMPLE
grsr_ground_range_origin	float64	Number	ground range origin for GRSR conversion	0.0
grsr_zero_doppler_time	ASCII	UTC time	ground range origin zero Doppler time	2019-04-08T14:50:13.120113
incidence_angle_poly_order	int64	Number	order of the polynomial for calculating the incidence angle dependence in range	4
incidence_angle_coefficients	vector of float64	Number	coefficients of the polynomial for calculating the incidence angle dependence in range	[2.67986035e+01; 8.66207416e-05; -5.61940883e-11; -1.73946139e-17; 8.22003978e-23]
incidence_angle_ground_range_origin	float64	Number	incidence angle origin in ground range, for calculating incidence angle dependence in range	0.0
incidence_angle_zero_doppler_time	ASCII	UTC time	incidence angle origin zero Doppler time	2019-04-08T14:50:13.120113
incidence_center	float64	Degrees	incidence angle in ground at middle range	23.5

LEVEL 1B PRODUCT ANNOTATION

6.5 INSTRUMENT CHARACTERIZATION

Sensor characterization parameters are listed here.

Table 8. Sensor parameters

FIELD NAME	TYPE	UNIT	DESCRIPTION	VALUE EXAMPLE
acquisition_prf	float64	Hz	Pulse Repetition Frequency used for the acquisition	4823.003429691328
processing_prf	float64	Hz	Pulse Repetition Frequency used for the processing, defines azimuth sample spacing in time (can be higher than acquisition in cases where Doppler frequency needs to be unfolded due to high variation of Doppler centroid with range)	9646.006859382656
carrier_frequency	float64	Hz	Carrier frequency of the radar system, static parameter	9650000000

6.6 CALIBRATION PARAMETERS

The calibration factor CF is used to derive the radar brightness β_0 from the binary image pixel values of SLC product. The expression for the radar brightness takes the form:

$$\beta_0 = CF \cdot |DN_{SLC}|^2 \, , \; \beta_{0dB} = 10 \cdot log10(\beta_0).$$

Table 9. Calibration parameters

FIELD NAME	TYPE	UNIT	DESCRIPTION	VALUE EXAMPLE
calibration_factor	float64	Number	Factor to be applied to calibrate detected products to absolute brightness intensity	0.000012341123

LEVEL 1B PRODUCT ANNOTATION

For GRD scenes, a conversion to sigma-nought has been already applied using incidence angle calculated using the ellipsoidal model. This simplifies calculation of radar backscatter to :

$$\sigma^0 = CF \cdot |DN_{GRD}|^2 ,\ \sigma_{0dB} = 10 \cdot log10(\sigma^0),\ |DN_{GRD}|^2 = |DN_{SLC}|^2 \cdot sin(\theta)$$

If the processing to beta-nought is sought for further orthorectification to sigma-nought or gamma-nought using local DEM, the conversion to radar brightness can be performed using incidence angle information annotated in the metadata (Table 7). The incidence angle value for each ground range location can be calculated as:

$$\theta_j = \sum_{k=0}^{p-1} C_k \cdot (IGR_0 + (j - 1) \cdot rs)^k ,\ j = [1 , n].$$

where θ_j is incidence angle for j-th pixel in ground range, IGR_0 is the incidence angle ground range origin, and rs is the ground range spacing.

6.7 PLATFORM PARAMETERS

LEVEL 1B PRODUCT ANNOTATION

Platform parameters are represented by orbit state vectors with time spacing of 0.1 second. For each state vector, their positions, velocity and orientations are provided in agreement with Table 10. ECEF geographic coordinate system is assumed.

Table 10. Orbit state vectors

FIELD NAME	TYPE	UNIT	DESCRIPTION	VALUE EXAMPLE
number_of_state_vectors	int64	number	Total number of orbit state vectors provided for the scene	120
state_vector_time_utc [0:end]	list of ASCII	UTC time	Timestamp for each orbit state vector	[2019-03-10T18:19:48.000000, ...]
posX [0:end]	vector of float64	meters	X-component of state vector position, for each state vector	[-2401162517... -2456350660]
posY[0:end]	vector of float64	meters	Y-component of state vector position, for each state vector	[-5201254993... -5253761907]
posZ [0:end]	vector of float64	meters	Z-component of state vector position, for each state vector	[3963994744... 3859728760]
velX [0:end]	vector of float64	meters	X-component of state vector velocity, for each state vector	[-3285.698...-3245.220]
velY [0:end]	vector of float64	meters	Y-component of state vector velocity, for each state vector	[-3162.667...-3051.016]
velZ [0:end]	vector of float64	meters	Z-component of state vector velocity, for each state vector	[-6130.372...-6208.463]
angX [0:end]	vector of float64		X-component of the antenna pointing orientation	TBP
angY [0:end]	vector of float64		Y-component of the antenna pointing orientation	TBP
angZ [0:end]	vector of float64		Z-component of the antenna pointing orientation	TBP


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