National Aeronautics and Space Administration

OPERA

Observational Products for End-Users from Remote Sensing Analysis

Product Specification Document for Coregistered Single Look Complex Static Layers from Sentinel-1 A/B

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Observational Products for End-users from Remote sensing Analysis (OPERA) project

OPERA Level-2 Coregistered Single Look Complex (CSLC) Static Layers from Sentinel-1 A/B Product Specification

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1 INTRODUCTION

1.1 Purpose

This document provides a description of the Observational Products for End-users from Remote sensing Analysis (OPERA) Level-2 Coregistered Single Look Complex (CSLC) static layers product from Sentinel-1 A/B (S1-A/B) to be generated by the OPERA Science Data System (SDS) and provided to the Alaska Satellite Facility (ASF) NASA's Distributed Active Archive Center (DAAC). Hereafter, this data product is referenced by the short name CSLC-S1-STATIC.

1.2 Document Organization

Section 2 provides an overview of the product including its purpose.

Section 3 provides the structure of the product, including tile definition, file organization, spatial and temporal resolutions, and spatial organization of the product content.

Section 4 provides a qualitative description of the data layers and the metadata provided in the product.

Section 5 provides a detailed description of the individual fields within the CSLC-S1-STATIC product e.g., their units, size, and coordinates.

Appendix A provides further details on the geographical grid and projection systems used to generate the product.

1.3 Applicable and Reference Documents

Applicable documents levy requirements on areas addressed in this document. Reference documents are cited to provide additional information to readers. In cases of conflict between the applicable documents and this document, the OPERA Project shall review the conflict to find the most effective resolution.

Applicable Documents

[AD1] NASA SNWG Cycle 2 – OPERA Program Level (Level 1) Requirements Document, Oct. 15, 2021.

[AD2] OPERA Level 2 Requirements JPL D-107391, Rev. B, Nov. 08, 2022.

[AD3] OPERA Product Description, JPL D-107389, Rev. A, Nov. 30, 2022

[AD4] OPERA CSLC-S1 Product Description, JPL D-108278, Rev. A, Sept. 11, 2023.

[AD5] OPERA CSLC-S1 Algorithm Theoretical Basis Document, JPL D-108752, Sept. 12, 2022.

Reference Documents

[RD1] P. Vincent, M. Bourbigot, H. Johnsen, R. Piantanida, "Sentinel-1 Product Specifications" [Online]. Available: Sentinel Product Specifications.

[RD2] Earth Science Data and Information System (ESDIS) Standards Office (ESO). "HDF5 Data Model, File format and Library-HDF 1.6". Earth data, Jan. 2007. https://www.earthdata.nasa.gov/esdis/esco/standards-and-practices/hdf5. [Accessed 20 May 2021]

[RD3] The HDF5 Library & File Format: [Online]. HDF5 solutions

[RD4] HDF5 documentation at https://portal.hdfgroup.org/display/HDF5/HDF5.

The latest official versions of this document should be obtained from https://www.jpl.nasa.gov/go/opera/about-opera. This document is a 'working version' with the primary purpose of describing the OPERA CSLC-S1-STATIC generated by the OPERA Algorithm Development Team's (ADT) Final release delivery Release 6 (R6) to the OPERA SDS.

1.4 Applicable Software

The software generating the Final version of the CSLC-S1 and CSLC-S1-STATIC products is available on GitHub at COMPASS. The CSLC-S1-STATIC products generated by the Final version of the SAS conform to the product specifications reported in this document. An XML version of the CSLC-S1-STATIC product specifications reported in this document is available on GitHub at https://github.com/opera-adt/Static_Layers_CSLC-S1_Specs/.

2 PRODUCT OVERVIEW

2.1 Product Background

The OPERA Level 2 Coregistered Single Look Complex Static Layers from Sentinel-1 A/B data (CSLC-S1-STATIC) serves as an ancillary product to the OPERA Level 2 Single Look Complex (CSLC-S1) products. The CSLC-S1-STATIC product is distributed separately from the CSLC-S1 products, and it is only produced once (or a limited amount of times) for CSLC-S1 products characterized by the same burst identification string i.e., for all the S1-A/B bursts covering the same geographical area on the ground [AD5].

The CSLC-S1-STATIC product is generated by the same workflow producing CSLC-S1 products by projecting a set of data layers characterizing the acquisition geometry of CSLC-S1 products with the same burst identification string onto a uniformly spaced, north-south, and west-east aligned UTM/WGS84 grid with the same spacing in Easting and Northing directions as the corresponding stack of CSLC-S1 products. For further details on the CSLC-S1 product and on its specifications refer to [AD4].

Figure 2-1 shows the processing workflow used to generate a CSLC-S1 product which includes the functionality to generate the CSLC-S1-STATIC product. The main input to the function generating CSLC-S1-STATIC product is a S1-A/B Standard Archive Format for Europe (SAFE) file containing the SLC bursts to process in a range-Doppler coordinate system and the corresponding metadata in the form of XML annotation files [RD1]. In addition, the function requires the S1-A/B orbit ephemeris and a Digital Elevation Model (DEM) describing the terrain topography for the observed scene.

The spatial coverage of the CSLC-S1-STATIC product is over North America which includes the United States of America (USA) and United States (US) territories within 200 km from the US border, Canada, and all mainland countries from the southern US border down to and including Panama.

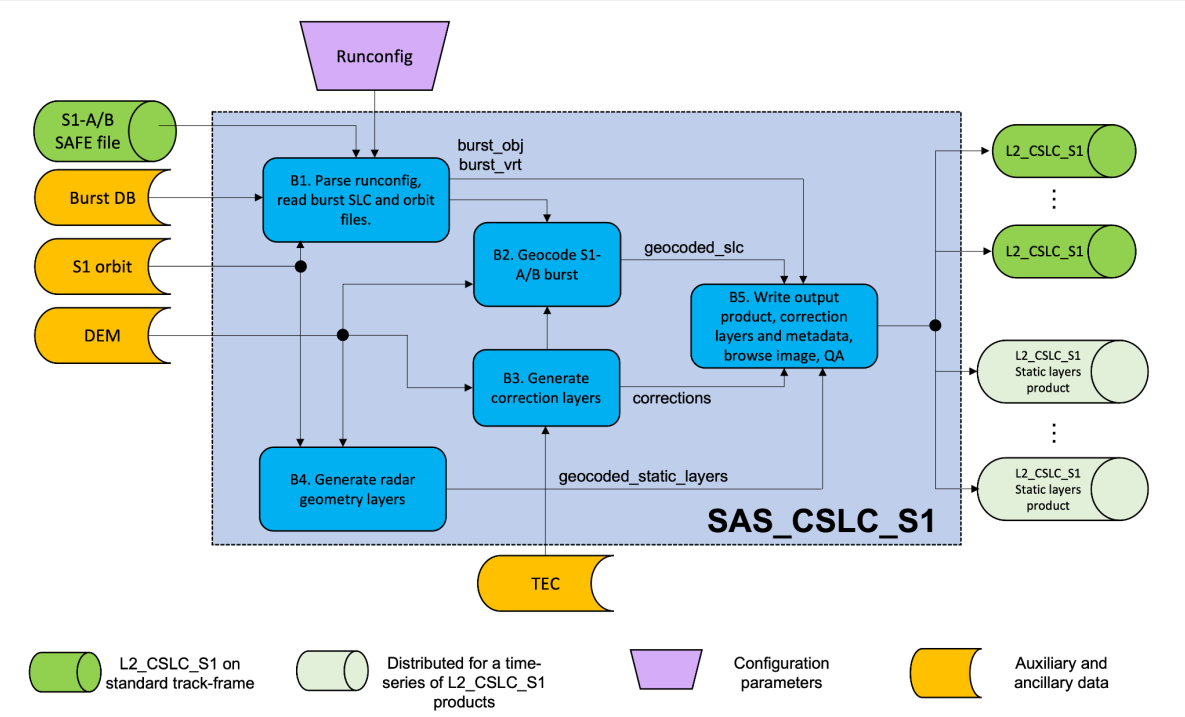

Figure 2-1 OPERA CSLC-S1 workflow diagram.

Input product	Description	Granule Size
S1-A/B SAFE file	The input S1-A/B SAFE file to the OPERA system	Variable
S1-A/B orbit ephemeris	The input S1-A/B orbit ephemeris	Variable
Copernicus DEM	GLO-30 Copernicus Digital Elevation Model	Variable

Table 2-1 Input products for CSLC-S1-STATIC production.

2.2 CSLC-S1-STATIC Product Overview

The CSLC-S1-STATIC products are Level 2 products distributed alongside with CSLC-S1 products.
Each CSLC-S1-STATIC product is distributed as a Hierarchical Data Format version 5 (HDF5) file following the Climate and Forecast (CF)-1.8 convention and it contains both data raster layers (e.g., geocoded geometry layers) and product metadata [RD3].
The pixel spacings of the CSLC-S1-STATIC is identical to the corresponding CSLC-S1 product i.e., 5 and 10 meters in the Easting and Northing direction respectively (see Table 2-2).

Product	Pixel spacing in Northing (m)	Pixel spacing in Easting (m)
CSLC-S1-STATIC	10	5

Table 2-2 Pixel spacing of the CSLC-S1-STATIC product.

3 PRODUCT ORGANIZATION

3.1 File Format - Hierarchical Data Format version 5

Each OPERA CSLC-S1-STATIC product is distributed as a HDF5 file following the CF-1.8 convention [RD3] with separate groups containing the data raster layers and product metadata.

HDF5 is a data model, library, and file format for storing and managing data designed for flexible and efficient I/O, for high volume, and it supports complex data allocation. The National Center for Supercomputing Applications (NCSA) at the University of Illinois developed HDF to help scientists share data more easily. Use of the HDF library enables users to read HDF files regardless of the underlying computing environments. HDF files are equally accessible in Fortran, C/C++, and other high-level computation packages such as Interface Definition Language (IDL), MATLAB or Python. The HDF5 file format enables the storage of compressed images with associated metadata that can be easily read by Geographic Information System (GIS) software including Geospatial Data Abstraction Library (GDAL) and Quantum Geographic Information System (QGIS) if following the CF-1.8 convention.

The HDF Group, a spin-off organization of the NCSA, is responsible for development and maintenance of HDF. Users should refer to the HDF Group website at https://portal.hdfgroup.org/display/HDF5/HDF5 [RD4] to download HDF software and corresponding documentation.

HDF5 represents a significant departure from the conventions of previous versions of HDF. The changes that appear in HDF5 provide flexibility to overcome many of the limitations of previous releases. The basic building blocks have been largely redefined and are more powerful but less numerous. The key concepts of the HDF5 Abstract Data Model are Files, Groups, Datasets,

Datatypes, Attributes and Property Lists. The following subsections provide a brief description of each of these key HDF5 concepts.

3.1.1 HDF5 file

A File is the abstract representation of a physical data file. Files are containers for HDF5 Objects. These Objects include Groups, Datasets, and Datatypes.

3.1.2 HDF5 group

Groups provide a mean to organize the HDF5 Objects in HDF5 Files. Groups are containers for other Objects, including Datasets, named Datatypes and other Groups. Groups are analogous to directories that are used to categorize and classify files in standard operating systems.

The notation for files is identical to the notation used for Unix directories. The root Group is "/". A Group contained within the root Group might be called "/myGroup". Like Unix directories, Objects appear in Groups through "links". Thus, the same Object can simultaneously be in multiple Groups.

3.1.3 HDF5 Dataset

The Dataset is the HDF5 component that stores user data. Each Dataset associates with a Dataspace that describes the data dimensions, as well as a Datatype that describes the basic unit of storage element. A Dataset can also have Attributes.

3.1.4 HDF5 Datatype

A Datatype describes a unit of data storage for Datasets and Attributes. Datatypes are subdivided into Atomic and Composite Types.

Atomic Datatypes are analogous to simple basic types in most programming languages. HDF5 Atomic Datatypes include Time, Bitfield, String, Reference, Opaque, Integer, and Float. Each atomic type has a specific set of properties. Examples of the properties associated with Atomic Datatypes are:

- Integers are assigned size, precision, offset, pad byte order, and are designated as signed or unsigned.
- Strings can be fixed or variable length and may or may not be null terminated.
- References are constructed within HDF5 Files that point to other HDF5 Objects in the same file.

HDF5 provides a large set of predefined Atomic Datatypes. Table 3-1 lists the Atomic Datatypes that are used in OPERA CSLC-S1-STATIC products.

HDF5 Atomic Datatypes	Description
H5T_STD_U8LE	unsigned, 8-bit, little-endian integer

HDF5 Atomic Datatypes	Description
H5T_STD_U16LE	unsigned, 16-bit, little-endian integer
H5T_STD_U32LE	unsigned, 32-bit, little-endian integer
H5T_STD_U64LE	unsigned, 64-bit, little-endian integer
H5T_STD_I8LE	signed, 8-bit, little-endian integer
H5T_STD_I16LE	signed, 16-bit, little-endian integer
H5T_STD_I32LE	signed, 32-bit, little-endian integer
H5T_STD_I64LE	Signed, 64-bit, little-endian integer
H5T_IEEE_F32LE	32-bit, little-endian, IEEE floating point
H5T_IEEE_F64LE	64-bit, little-endian, IEEE floating point
H5T_C_S1	character string made up of one or more bytes

Table 3-1 HDF5 Atomic Datatypes.

3.1.5 HDF5 Attribute

An Attribute is a small aggregate of data that describes Groups or Datasets. Like Datasets, Attributes are also associated with a particular Dataspace and Datatype. Attributes cannot be subsetted or extended. Attributes themselves cannot have Attributes.

3.2 CSLC-S1 Product File Organization

3.2.1 Groups

All OPERA CSLC-S1-STATIC HDF5 files are organized as groups with no actual data at the root ("/") level. Table 3-2 shows the general layout of a CSLC-S1-STATIC HDF5 file generated by the OPERA SDS.

Group Name	Description
/identification	Contains file level metadata for cataloging and archiving the product
/metadata	Contains processing metadata describing the algorithms, the parameters, and the input files used for processing
/data	Contains the main data raster layers and the associated geographical information
/quality_assurance	Contains metrics characterizing the quality of data raster layers and metadata within the product

Table 3-2 Top level organization of the CSLC-S1-STATIC HDF5 file.

3.2.2 File Level Metadata

Global metadata at the file level are currently given as Global Attributes in Table 3-3.

Attribute	Format	Description	Value
conventions	string	Conventions followed in the product. This attribute is set to "CF-1.8" to indicate that the group is compliant with the CF NetCDF conventions.	CF-1.8
title	string	Name of the produced product	OPERA L2_CSLC_S1_STATIC Product
institution	string	Name of the agency producing the product	NASA JPL
project_name	string	Name of the project responsible for the product	OPERA
reference_document	string	Name and version of Product Description Document to use as reference for product	JPL-108762
contact	string	Contact information of the agency producing the product	opera-sds-ops@jpl.nasa.gov

Table 3-3 Global Attributes of the CSLC-S1-STATIC product.

3.3 CSLC-S1 Static Layers File Naming Convention

The file name of CSLC-S1-STATIC products is designed to ensure unique names for OPERA CSLC-S1-STATIC granules. CSLC-S1-STATIC products follow the file naming convention:

Project_Level_ProductType_BurstID_ValidityStartDate_Sensor_ProductVersion.ext

where:

- *Project*: name of the project producing the product i.e., "OPERA"
- *Level*: product level i.e., "L2"
- *ProductType*: product type i.e., "CSLC-S1-STATIC"
- *BurstID*: alphanumeric string uniquely identifying the processed burst. The burst identification string follows the same convention adopted by the ESA burst map and it is consistent with the convention *T[TrackNumber]-[BurstIdentificationNumber]-[Swath]* (e.g., "T078-165495-IW3"*)*
- *ValidityStartDate*: The date and time in the format YYYYMMDDTHHMMSSZ at which the CSLC-S1-STATIC product is intended to be valid.
- *Sensor*: name of the sensor that acquired the input data i.e., "S1A"
- *ProductVersion*: the product version number with four characters, including the letter "v" and two digits indicating the major and minor versions delimited by a period.
- *Ext*: file extension i.e., "h5"

Example:

*OPERA_L2_CSLC-S1-STATIC_*T078-165495-IW3*_20190906_S1A_v1.0.ext*

3.4 Spatial Organization

CSLC-S1-STATIC products are distributed onto a uniformly spaced, north-south, and west-east aligned UTM/WGS84 grid with a pixel spacing in the Easting and Northing direction of 5 meters and 10 meters, respectively.

3.5 Spatial Sampling and Resolution

Some salient features of the output grid of CSLC-S1-STATIC products:

3. All the imagery layers contained in the product are located on the same geographical grid.
4. The CSLC-S1-STATIC product shares the same geographical grid of all the CSLC-S1 products characterized by the same burst identification string.
5. The corner coordinates of the geographical grid are multiples of the product pixel spacings in the Easting and Northing directions.

3.6 Temporal Organization

The OPERA CSLC-S1-STATIC serves as an ancillary product to CSLC-S1 products. It is distributed separately from the CSLC-S1 products, and it generated only once or a limited number of times to account for changes in the DEM, S1-A/B orbit ephemeris or in the algorithm producing the product.

4 OPERA CSLC-S1-STATIC PRODUCT

This section describes the CSLC-S1-STATIC product data layers and associated metadata.

4.1 Dimensions and Shapes of Data

The dimensions and shapes of the data layers contained in CSLC-S1-STATIC products are described in Sec 5.1. This information can be used by other downstream workflows to set up further processing i.e., dimensioning arrays.

4.2 Product Identification

The group “/identification” described in Sec. 5.2 provides a collection of metadata to identify the CSLC-S1-STATIC product e.g., the absolute orbit number, the track number, the mission identifier, the radar band, and the orbit pass direction of the burst used to generate the product. The group also includes the name of the processing center producing the product, the processing date and time, and information on the product version and the product specification version. In

particular, the product specification version of CSLC-S1-STATIC products is synchronized with the release tag number of the GitHub repository https://github.com/opera-adt/Static_Layers_CSLC-S1_Specs containing an XML version of the CSLC-S1-STATIC product specifications.
The "/identification" group includes the metadata field "bounding_polygon" which provides the perimeter of the polygon identifying the geographical area covered by the CSLC-S1-STATIC product. The bounding polygon is provided as a set of discrete latitude and longitude coordinates in a Well-Known Text (WKT) format. To avoid geometrical distortions, the bounding polygon of CSLC-S1 granules crossing the anti-meridian is represented by a set of two polygons (i.e., a multi-polygon) bordering one another at the anti-meridian.

4.3 Geometry Layers

The primary data layers of a CSLC-S1-STATIC product are contained in the group "/data" and described in Sec. 5.3. The geometry layers distributed in the "/data" group are:

- *East los*: a floating-point dataset containing the East component of the Line-Of-Sight (LOS) unit vector from the target to the sensor.
- *North los*: a floating-point dataset containing the North component of the LOS unit vector from the target to the sensor.
- *Local incidence angle*: a floating-point raster containing the angle between the LOS vector and the normal to the target local surface.
- *Layover shadow mask*: an unsigned integer layer flagging regions wherein the layover and shadow effect occur. Within this data layer, pixels flagged as "*0":* denote pixels that are not in layover nor shadow; "*1":* denote pixels affected by shadow; "*2":* denote pixels affected by layover; "*3":* denote pixels affected by both layover and shadow.

4.4 Radar Metadata

Radar metadata needed to interpret the CSLC-S1-STATIC product are organized under the group "/metadata".

4.4.1 Processing Information

The group "metadata/processing_information", described in Sec. 5.4, stores a set of metadata characterizing the data processing performed to generate the CSLC-S1-STATIC product. The

main metadata entry of this group is *runconfig* containing a copy of the run configuration file with all the parameters that have been used for processing.
The "metadata/processing_information" group is further organized into three main subgroups:

1. *algorithms*: including the algorithms used to generate the product, the software version of the CSLC-S1 processor and of its main dependencies (e.g., S1 data reader and ISCE3).
1. *input burst metadata*: including a set of metadata describing the input S1-A/B burst in radar coordinates. The metadata in this subgroup can be used to reconstruct the radar grid of the input burst used for processing.
2. *inputs*: including the list of input files used to generate the product i.e., the input SAFE file name, the name of the annotation files (e.g., calibration, noise), the file name of the orbit ephemeris, and of the DEM used for processing.

4.4.2 Other Radar Metadata

4.4.2.1 Orbit

The orbit ephemeris used for generating the CSLC-S1-STATIC are provided under the group "metadata/orbit" (see Sec. 5.5). This metadata group includes time-tagged antenna phase center position and velocity vectors in Earth Centered Earth Fixed (ECEF) cartesian coordinates, the reference epoch, and the orbit direction (i.e., ascending or descending) for the burst used for processing.

4.5 Quality Assurance

The group "/quality_assurance" described in Sec. 5.6 includes a set of metrics characterizing the quality of the data layers included in the CSLC-S1-STATIC product. The group is further organized in three main subgroups:

1. *orbit information*: including the type of orbit ephemeris (e.g., restituted or precise) used for processing.
2. *pixel classification*: containing information on the percentage of pixels labeled as affected by layover, shadow, or both.
3. *statistics*: collecting a set of metrics which statistically characterize the floating-point geometry layers contained within the CSLC-S1-STATIC product. The main statistical metrics contained in this subgroup are the maximum and the minimum value of each data layer, the mean, and the standard deviation.

5 PRODUCT SPECIFICATION

5.1 Dimensions and Shapes

Table 5-1 describes the dimensions and shapes of the datasets included in the CSLC-S1-STATIC product. The entries in this table do not present the shapes of the actual datasets in the HDF5 but are meant to be a guide to identify the relationship between similarly sized data layers.

Name	Shape	Description
scalar	scalar	None
StaticLayersProductWidth	scalar	Number of pixels in CSLC-S1-STATIC product imagery datasets
StaticLayersProductLength	scalar	Number of lines in CSLC-S1-STATIC product imagery datasets
StaticLayersProductShape	(StaticLayersProductLength, StaticLayersProductWidth)	Shape associated with CSLC-S1-STATIC imagery datasets
orbitLength	scalar	Length of orbit state vectors datasets
orbitInputFiles	scalar	Number of orbit input files
2DShape	scalar	Shape of metadata being a vector with two elements
polynomialCoefficientsWidth	scalar	Number of pixels in the polynomial coefficients datasets
polynomialCoefficientsLength	scalar	Number of lines in the polynomial coefficients datasets
polynomialCoefficientsShape	(polynomialCoefficientsLength, polynomialCoefficientsWidth)	Shape associated with the polynomial coefficients datasets

Table 5-1 Table of dimensions and shapes in CSLC-S1-STATIC product.

5.2 Product Identification

Product Identification Variables	
/identification/absolute_orbit_number	
Type: int64	**Shape: scalar**
Description: Absolute orbit number	
/identification/bounding_polygon	
Type: string	**Shape: scalar**
Description: OGR compatible WKT representation of bounding polygon of the image	
units	degrees
/identification/burst_id	
Type: string	**Shape: scalar**
Description: Burst identification string (burst ID)	
/identification/instrument_name	
Type: string	**Shape: scalar**
Description: Instrument name	
/identification/is_geocoded	
Type: string	**Shape: scalar**
Description: Boolean indicating if product is in radar geometry or geocoded	
/identification/look_direction	
Type: string	**Shape: scalar**
Description: Look direction can be left or right	
/identification/mission_id	
Type: string	**Shape: scalar**
Description: Mission identifier	
/identification/orbit_pass_direction	
Type: string	**Shape: scalar**
Description: Orbit pass direction can be ascending or descending	
/identification/processing_center	

Type: string	**Shape: scalar**
Description: Name of the processing center that produced the product	
/identification/processing_date_time	
Type: string	**Shape: scalar**
Description: Data processing date and time	
/identification/product_level	
Type: string	**Shape: scalar**
Description: L0A: Unprocessed instrument data; L0B: Reformatted, unprocessed instrument data; L1: Processed instrument data in radar coordinates system; and L2: Processed instrument data in geocoded coordinates system	
/identification/product_specification_version	
Type: string	**Shape: scalar**
Description: CSLC-S1 static layers product specification version	
/identification/product_type	
Type: string	**Shape: scalar**
Description: Product type	
/identification/product_version	
Type: string	**Shape: scalar**
Description: CSLC-S1 static layers product version	
/identification/radar_band	
Type: string	**Shape: scalar**
Description: Radar band	
/identification/track_number	
Type: int64	**Shape: scalar**
Description: track number	
units	unitless
/identification/zero_doppler_end_time	
Type: string	**Shape: scalar**
Description: Azimuth stop time of product	
/identification/zero_doppler_start_time	

Type: string	**Shape: scalar**
Description: Azimuth start time of product	

Table 5-2 CSLC-S1-STATIC product identification variables.

5.3 Geometry Layers

Product Imagery Variables	
/data/los_east	
Type: float32	**Shape: StaticLayersProductShape**
Description: East component of LOS unit vector from target to sensor	
/data/los_north	
Type: float32	**Shape: StaticLayersProductShape**
Description: North component of LOS unit vector from target to sensor	
/data/layover_shadow_mask	
Type: int8	**Shape: StaticLayersProductShape**
Description: Layover shadow mask. 0=no layover, no shadow; 1=shadow; 2=layover; 3=shadow and layover.	
/data/local_incidence_angle	
Type: float32	**Shape: StaticLayersProductShape**
Description: Local incidence angle in degrees	
/data/projection	
Type: int32	**Shape: scalar**
Description: Projection system	
Ellipsoid: Projection ellipsoid	
epsg_code: Projection EPSG code	
grid_mapping_name: Grid mapping variable name	
inverse_flattening: Inverse flattening of the ellipsoidal figure	
semi_major_axis: Semi-major axis	
spatial_ref: Spatial reference	

utm_zone_number: UTM zone number	
/data/x_coordinates	
Type: float64	**Shape: StaticLayersProductWidth**
Description: CF compliant dimension associated with the X coordinate	
units	meters
/data/x_spacing	
Type: float64	**Shape: scalar**
Description: Spacing of the geographical grid along X-direction	
units	meters
/data/y_coordinates	
Type: float64	**Shape: StaticLayersProductLength**
Description: CF compliant dimension associated with the Y coordinate	
units	meters
/data/y_spacing	
Type: float64	**Shape: scalar**
Description: Spacing of the geographical grid along Y-direction	
units	meters

Table 5-3 CSLC-S1-STATIC geometry layers variables.

5.4 Processing Information

Processing Information Variables	
/metadata/processing_information/algorithms/COMPASS_version	
Type: string	**Shape: scalar**
Description: COMPASS (CSLC-S1 processor) version used for processing	
/metadata/processing_information/algorithms/ISCE3_version	
Type: string	**Shape: scalar**

Description: ISCE3 version used for processing	
/metadata/processing_information/algorithms/dem_interpolation	
Type: string	**Shape: scalar**
Description: DEM interpolation method	
/metadata/processing_information/algorithms/float_data_geocoding_interpolator	
Type: string	**Shape: scalar**
Description: Floating-point data geocoding interpolation method	
/metadata/processing_information/algorithms/s1_reader_version	
Type: string	**Shape: scalar**
Description: S1 reader version used for processing	
/metadata/processing_information/algorithms/topography_algorithm	
Type: string	**Shape: scalar**
Description: Topography generation algorithm	
/metadata/processing_information/algorithms/uint_data_geocoding_interpolator	
Type: string	**Shape: scalar**
Description: Unsigned int geocoding interpolation method	
/metadata/processing_information/input_burst_metadata/azimuth_steering_rate	
Type: float64	**Shape: scalar**
Description: Azimuth steering rate of IW and EW modes	
units	degrees per second
/metadata/processing_information/input_burst_metadata/azimuth_time_interval	
Type: float64	**Shape: scalar**
Description: Time spacing between azimuth lines of the burst	
units	seconds
/metadata/processing_information/input_burst_metadata/center	
Type: float64	**Shape: 2DShape**
Description: Longitude, latitude center of burst	
units	degrees

/metadata/processing_information/input_burst_metadata/ipf_version	
Type: string	**Shape: scalar**
Description: ESA Instrument Processing Facility software version	
/metadata/processing_information/input_burst_metadata/iw2_mid_range	
Type: float64	**Shape: scalar**
Description: Slant range of the middle of the IW2 swath	
units	meters
/metadata/processing_information/input_burst_metadata/platform_id	
Type: string	**Shape: scalar**
Description: Sensor platform identification string (e.g., S1A or S1B)	
/metadata/processing_information/input_burst_metadata/polarization	
Type: string	**Shape: scalar**
Description: Polarization of the burst	
/metadata/processing_information/input_burst_metadata/prf_raw_data	
Type: float64	**Shape: scalar**
Description: Pulse repetition frequency (PRF) of the raw data	
units	Hertz
/metadata/processing_information/input_burst_metadata/radar_center_frequency	
Type: float64	**Shape: scalar**
Description: Radar center frequency	
units	Hertz
/metadata/processing_information/input_burst_metadata/range_bandwidth	
Type: float64	**Shape: scalar**
Description: Slant range bandwidth of the signal	
units	Hertz
/metadata/processing_information/input_burst_metadata/range_pixel_spacing	
Type: float64	**Shape: scalar**
Description: Pixel spacing between slant range samples in the input burst SLC	

units	meters
/metadata/processing_information/input_burst_metadata/range_chirp_rate	
Type: float64	**Shape: scalar**
Description: Range chirp rate	
units	Hertz
/metadata/processing_information/input_burst_metadata/range_sampling_rate	
Type: float64	**Shape: scalar**
Description: Sampling rate of slant range in the input burst SLC	
units	Hertz
/metadata/processing_information/input_burst_metadata/rank	
Type: int64	**Shape: scalar**
Description: The number of Pulse Repetition Intervals (PRI) between transmitted pulse and return echo	
/metadata/processing_information/input_burst_metadata/range_window_coefficient	
Type: float64	**Shape: scalar**
Description: Value of the weighting window coefficient used during processing	
/metadata/processing_information/input_burst_metadata/range_window_type	
Type: string	**Shape: scalar**
Description: Name of the weighting window type used during processing	
/metadata/processing_information/input_burst_metadata/sensing_start	
Type: string	**Shape: scalar**
Description: Sensing start time of the burst (format: YYYY-MM-DD HH:MM:SS.6f)	
/metadata/processing_information/input_burst_metadata/sensing_stop	
Type: string	**Shape: scalar**
Description: Sensing stop time of the burst (format: YYYY-MM-DD HH:MM:SS.6f)	
/metadata/processing_information/input_burst_metadata/shape	
Type: int64	**Shape: 2Dshape**
Description: Shape (length, width) of the burst in radar coordinates	
units	pixels

/metadata/processing_information/input_burst_metadata/slant_range_time	
Type: float64	**Shape: scalar**
Description: Two-way slant range time of Doppler centroid frequency estimate	
units	seconds
/metadata/processing_information/input_burst_metadata/starting_range	
Type: float64	**Shape: scalar**
Description: Slant range of the first sample of the input burst	
units	meters
/metadata/processing_information/input_burst_metadata/wavelength	
Type: float64	**Shape: scalar**
Description: Wavelength of the transmitted signal	
units	meters
/metadata/processing_information/input_burst_metadata/azimuth_fm_rate/coeffs	
Type: float64	**Shape: polynomialCoefficientsWidth**
Description: Coefficients of the polynomial	
/metadata/processing_information/input_burst_metadata/azimuth_fm_rate/mean	
Type: float64	**Shape: scalar**
Description: Mean of the polynomial	
/metadata/processing_information/input_burst_metadata/azimuth_fm_rate/order	
Type: int64	**Shape: scalar**
Description: Order of the polynomial	
/metadata/processing_information/input_burst_metadata/azimuth_fm_rate/std	
Type: float64	**Shape: scalar**
Description: Standard deviation of the polynomial	
/metadata/processing_information/input_burst_metadata/doppler/coeffs	
Type: float64	**Shape: polynomialCoefficientsWidth**
Description: Coefficients of the polynomial	
/metadata/processing_information/input_burst_metadata/doppler/mean	

Type: float64	**Shape: scalar**
Description: Mean of the polynomial	
/metadata/processing_information/input_burst_metadata/doppler/order	
Type: int64	**Shape: scalar**
Description: Order of the polynomial	
/metadata/processing_information/input_burst_metadata/doppler/std	
Type: float64	**Shape: scalar**
Description: Standard deviation of the polynomial	
/metadata/processing_information/inputs/calibration_files	
Type: string	**Shape: scalar**
Description: List of input calibration files used for processing	
/metadata/processing_information/inputs/dem_source	
Type: string	**Shape: scalar**
Description: Description of the DEM used for processing	
/metadata/processing_information/inputs/l1_slc_files	
Type: string	**Shape: scalar**
Description: List of input L1 RSLC files used for processing	
/metadata/processing_information/inputs/noise_files	
Type: string	**Shape: scalar**
Description: List of input noise files used for processing	
/metadata/processing_information/inputs/orbit_files	
Type: string	**Shape: orbitInputFiles**
Description: List of input orbit files used for processing	
/metadata/processing_information/inputs/burst_location_parameters/burst_index	
Type: int64	**Shape: scalar**
Description: Burst index relative to other bursts in swath	
/metadata/processing_information/inputs/burst_location_parameters/first_valid_line	
Type: int64	**Shape: scalar**

Description: First valid line for burst in measurement tiff	
/metadata/processing_information/inputs/burst_location_parameters/first_valid_sample	
Type: int64	**Shape: scalar**
Description: First valid sample for burst in measurement tiff	
/metadata/processing_information/inputs/burst_location_parameters/last_valid_line	
Type: int64	**Shape: scalar**
Description: Last valid line for burst in measurement tiff	
/metadata/processing_information/inputs/burst_location_parameters/last_valid_sample	
Type: int64	**Shape: scalar**
Description: Last valid sample for burst in measurement tiff	
/metadata/processing_information/inputs/burst_location_parameters/tiff_path	
Type: string	**Shape: scalar**
Description: Path to measurement tiff file inside SAFE file	
/metadata/processing_information/runconfig	
Type: string	**Shape: scalar**
Description: Run configuration file used to generate the CSLC-S1 product	

Table 5-4 CSLC-S1-STATIC processing parameters variables.

5.5 Orbit Metadata

Orbit Metadata Variables	
/metadata/orbit/orbit_direction	
Type: string	**Shape: scalar**
Description: Direction of sensor orbit ephemeris (e.g., ascending, descending)	
/metadata/orbit/orbit_type	
Type: string	**Shape: scalar**
Description: Type of orbit file used for processing. RESORB: restituted orbit ephemeris or POEORB: precise orbit ephemeris.	
/metadata/orbit/position_x	

Type: float64	**Shape: orbitLength**
Description: Platform position along x-direction with respect to the WGS84 G1762 reference frame	
units	meters
/metadata/orbit/position_y	
Type: float64	**Shape: orbitLength**
Description: Platform position along y-direction with respect to the WGS84 G1762 reference frame	
units	meters
/metadata/orbit/position_z	
Type: float64	**Shape: orbitLength**
Description: Platform position along z-direction with respect to the WGS84 G1762 reference frame	
units	meters
/metadata/orbit/reference_epoch	
Type: string	**Shape: scalar**
Description: Reference epoch of the state vectors (format: YYYY-MM-DD HH:MM:SS.6f)	
/metadata/orbit/time	
Type: float64	**Shape: orbitLength**
Description: Time of the orbit state vectors relative to the reference epoch	
units	seconds
/metadata/orbit/velocity_x	
Type: float64	**Shape: orbitLength**
Description: Platform velocity along x-direction with respect to the WGS84 G1762 reference frame	
units	meters per second
/metadata/orbit/velocity_y	
Type: float64	**Shape: orbitLength**
Description: Platform velocity along y-direction with respect to the WGS84 G1762 reference frame	
units	meters per second
/metadata/orbit/velocity_z	
Type: float64	**Shape: orbitLength**
Description: Platform velocity along z-direction with respect to the WGS84 G1762 reference frame	

units	meters per second

Table 5-5 CSLC-S1-STATIC orbit metadata variables.

5.6 Quality Assurance

Quality Assurance Variables	
/quality_assurance/orbit_information/orbit_type	
Type: string	**Shape: scalar**
Description: Type of orbit file used for processing. RESORB: restituted orbit ephemeris or POEORB: precise orbit ephemeris	
/quality_assurance/pixel_classification/percent_combined_pixels	
Type: float64	**Shape: scalar**
Description: Percentage of output pixels labeled layover and shadow	
/quality_assurance/pixel_classification/percent_layover_pixels	
Type: float64	**Shape: scalar**
Description: Percentage of output pixels labeled layover	
/quality_assurance/pixel_classification/percent_shadow_pixels	
Type: float64	**Shape: scalar**
Description: Percentage of output pixels labeled shadow	
/quality_assurance/statistics/static_layers/los_east/max	
Type: float64	**Shape: scalar**
Description: Max of LOS East	
/quality_assurance/statistics/static_layers/los_east/mean	
Type: float64	**Shape: scalar**
Description: Mean of LOS East	
/quality_assurance/statistics/static_layers/los_east/min	
Type: float64	**Shape: scalar**
Description: Min of LOS East	
/quality_assurance/statistics/static_layers/los_east/std	

Type: float64	**Shape: scalar**
Description: STD of LOS East	
/quality_assurance/statistics/static_layers/los_north/max	
Type: float64	**Shape: scalar**
Description: Max of LOS North	
/quality_assurance/statistics/static_layers/los_north/mean	
Type: float64	**Shape: scalar**
Description: Mean of LOS North	
//quality_assurance/statistics/static_layers/los_north/min	
Type: float64	**Shape: scalar**
Description: Min of LOS North	
/quality_assurance/statistics/static_layers/los_north/std	
Type: float64	**Shape: scalar**
Description: STD of LOS North	
/quality_assurance/statistics/static_layers/local_incidence_angle/max	
Type: float64	**Shape: scalar**
Description: Max of local incidence angle	
/quality_assurance/statistics/static_layers/local_incidence_angle/mean	
Type: float64	**Shape: scalar**
Description: Mean of local incidence angle	
/quality_assurance/statistics/static_layers/local_incidence_angle/min	
Type: float64	**Shape: scalar**
Description: Min of local incidence angle	
/quality_assurance/statistics/static_layers/local_incidence_angle/std	
Type: float64	**Shape: scalar**
Description: STD of local incidence angle	

Table 5-6 CSLC-S1-STATIC quality assurance variables.

6. APPENDIX A

OPERA CSLC-S1 and CSLC-S1-STATIC products will be generated on a predefined track/burst system. The projection system for a particular burst will be available to the users as a predefined map and will be held constant through the life of the project. Each CSLC-S1 and CSLC-S1-STATIC HDF5 granule itself will include information indicating the projection used for the product.

a. Map Projections

OPERA SDS can ingest any DEM whose vertical datum represents height above the WGS84 Ellipsoid, and the horizontal datum can be represented by a European Petroleum Standards Group (EPSG) code for generating geocoded product. Table 0-1 lists the various projection systems used to output CSLC-S1 and CSLC-S1-STATIC products.

EPSG code	PROJ.4 string	Common Name	Geographical scope
3031	+proj=stere +lat_0=-90 +lat_ts=-71 +lon_0=0 +k=1 +x_0=0 +y_0=0 +datum=WGS84 +units=m +no_defs	Antarctic Polar Stereographic	Antarctica and Southern Hemisphere Sea Ice
3413	+proj=stere +lat_0=90 +lat_ts=70 +lon_0=-45 +k=1 +x_0=0 +y_0=0 +datum=WGS84 +units=m +no_defs	NSIDC Sea Ice Polar Stereographic North	Greenland and Northern Hemisphere Sea Ice
32601-32660	+proj=utm +zone=X-32600 +datum=WGS84 +units=m +no_defs	UTM Zone North	Northern Hemisphere Land except Greenland
32701-32760	+proj=utm +zone=X-32700 +south +datum=WGS84 +units=m +no_defs	UTM Zone South	Southern Hemisphere Land except Antarctica

Table 0-1 Projection systems for CSLC-S1 and CSLC-S1-STATIC products

b. Grid Alignment

OPERA CSLC-S1 and CSLC-S1-STATIC products will use a “pixel is area” convention. The “pixel is area” convention, which is the default, uses northing and easting coordinates Y and X, with (0,0) denoting the upper-left corner of the image, and increasing X to the east, increasing Y to the south. The first pixel value fills the grid cell with the top-left position (0,0) and bottom-right position (1,1).

7. APPENDIX B: ACRONYMS

AD	Applicable Document
ADT	Algorithm Development Team
ASF	Alaska Satellite Facility
ATBD	Algorithm Theoretical Basis Document
Cal/Val	Calibration and Validation
CF	Climate Forecast
CGLS	Copernicus Global Land Service
COMPASS	COregistered Multi-temPorAl Sar Slc (CSLC-S1 processor)
CSLC	Coregistered Single Look Complex
CSLC-S1	Coregistered Single Look Complex from Sentinel-1 A/B data
CSLC-S1-STATIC	Coregistered Single Look Complex Static Layers from Sentinel-1 A/B data
DAAC	Distributed Active Archive Center
DEM	Digital Elevation Model
DN	Digital Number
DOI	Digital Object Identifier
ECEF	Earth-Centered Earth-Fixed
EPSG	European Petroleum Survey Group
ESA	European Space Agency
ESDIS	Earth Science Data Information System
ESO	Earth System Observatory
EW	Extra Wide (S1 transmission mode)
FM	Frequency Modulation
GDAL	Geospatial Data Abstraction Library
GeoTIFF	Georeferenced Tagged Image File Format
GeoJSON	Geographic JavaScript Object Notation (file format)
GIS	Geographic Information System
GLO-30	Global-30 m (refers to the Copernicus DEM)
HDF	Hierarchical Data Format
HDF5	Hierarchical Data Format version 5
IDL	Interface Definition Language
IF	Interface (delivery)
IONEX	Ionosphere Exchange (file format)
IPF	Instrument Processing Facility (Sentinel data processor)
ISCE3	Interferometric Scientific Computing Environment Enhance Edition
IW	Interferometric wide swath (S1-A/B acquisition mode)
JPL	Jet Propulsion Laboratory
L0	Level-0 (data)

L0A	Level-0A (data)
L0B	Level-0B (data)
L1	Level-1 (data)
L2	Level-2 (data)
LRR	Limited Request Release
LRS	Limited Release System
LUT	Look-Up Table
MATLAB	Matrix Laboratory (programming language)
MOE	Medium Orbit Ephemeris
NASA	National Aeronautics and Space Administration
NCSA	National Center for Supercomputing Applications
NetCDF	Network Common Data Format
NetCDF-4	Network Common Data Format version 4
NISAR	NASA-ISRO Synthetic Aperture Radar
OGR	OpenGIS Simple Feature Reference Implementation
OPERA	Observational Products for End-users from Remote-sensing Analysis
POE	Precise Orbit Ephemeris
PRI	Pulse Repetition Interval
PRF	Pulse Repetition Frequency
PSD	Power Spectral Density
QGIS	Quantum Geographic Information System
R5	Release 5 (often as Cal/Val release)
RD	Reference Document
RFI	Radio Frequency Interference
ROE	Restituted Orbit Ephemeris
S1	Sentinel-1
S1A	Sentinel-1A
S1B	Sentinel-1B
S1-A/B	Sentinel-1 A/B
SAFE	Standard Archive Format for Europe (S1-A/B data format specification)
SAR	Synthetic Aperture Radar
SAS	Science Application Software
SDS	Science Data System
SLC	Single Look Complex
STD	Standard Deviation
TBC	To Be Confirmed
TBD	To Be Defined
TEC	Total Electron Content
TIFF	Tagged Image File Format
URS	Unlimited Request System
US	United States

USA	United States of America
UTM	Universal Transverse Mercator
VH	Vertical-receive, Horizontal-transmit (polarization)
VV	Vertical-receive, Vertical-transmit (polarization)
WGS84	World Geodetic System 1984 (often as G1762)
WKT	Well-Known Text (mark-up language)
XML	Extensible Markup Language