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

Observational Products for End-users from Remote sensing

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Analysis (OPERA) project

OPERA Level-2 Coregistered Single Look Complex (CSLC) 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) 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.

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 metadata provided in the product.

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

Appendix A provides further details on the geographical grids and the projection systems used to generate the CSLC-S1 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 Static Layers Product Description, JPL D-108762, 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 Specification" [Online]. Available at: S1-A/B 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 Product Solutions.

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

[RD5] ESA Burst Map [Online]. Available at: https://sar-mpc.eu/test-data-sets/.

[RD6] ESA Sentinel-1: Using the RFI Annotations [Online]. Available at ESA-documentation

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 product generated by the OPERA Algorithm Development Team's (ADT) Final release delivery Release (R6) to the OPERA SDS.

1.4 Applicable Software

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

2 PRODUCT OVERVIEW

2.1 Product Background

The OPERA CSLC-S1 product is generated by projecting a S1-A/B Single Look Complex (SLC) image from radar coordinates onto a uniformly spaced, north-south, and west-east aligned UTM/WGS84 grid with a spacing in East and North directions comparable to the full resolution input SLC.

Figure 2-1 shows the processing workflow generating a CSLC-S1 product. The main input dataset to the workflow 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]. Each pixel within an input burst SLC is represented by a complex number and it contains both an amplitude and phase information. The processing workflow requires a set of ancillary input data: the S1-A/B orbit ephemeris, the burst database file containing relevant processing information (e.g., burst identification number, corner coordinates of the CSLC-S1 geographical grid) for all the bursts throughout the S1-A/B mission, a Digital Elevation Model (DEM) describing the terrain topography of the input burst, and an ionosphere Total Electron Content (TEC) file providing a spatial map of the ionosphere vertical TEC content at the time of the S1-A/B acquisition.

The workflow also produces the CSLC-S1 static layers product which is an ancillary product distributed separately from the CSLC-S1 product. The static layers are produced once or a limited number of times to account for changes in the DEM, S1-A/B orbit ephemeris, or changes in the CSLC-S1 static layers algorithm. Each time-series of CSLC-S1 products characterized by the same burst identification number i.e., covering the same geographical area on the ground, shares the same CSLC-S1 static layers product. For further details on the CSLC-S1 static layers product and on its specifications refer to [AD4].

Each S1 satellite can map the global landmasses in the Interferometric Wide (IW) swath mode once every 12 days in a single pass with an ascending or descending orbit direction. The constellation of S1-A/B satellites offers a revisit time of 6 days.
The spatial coverage of the CSLC-S1 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.

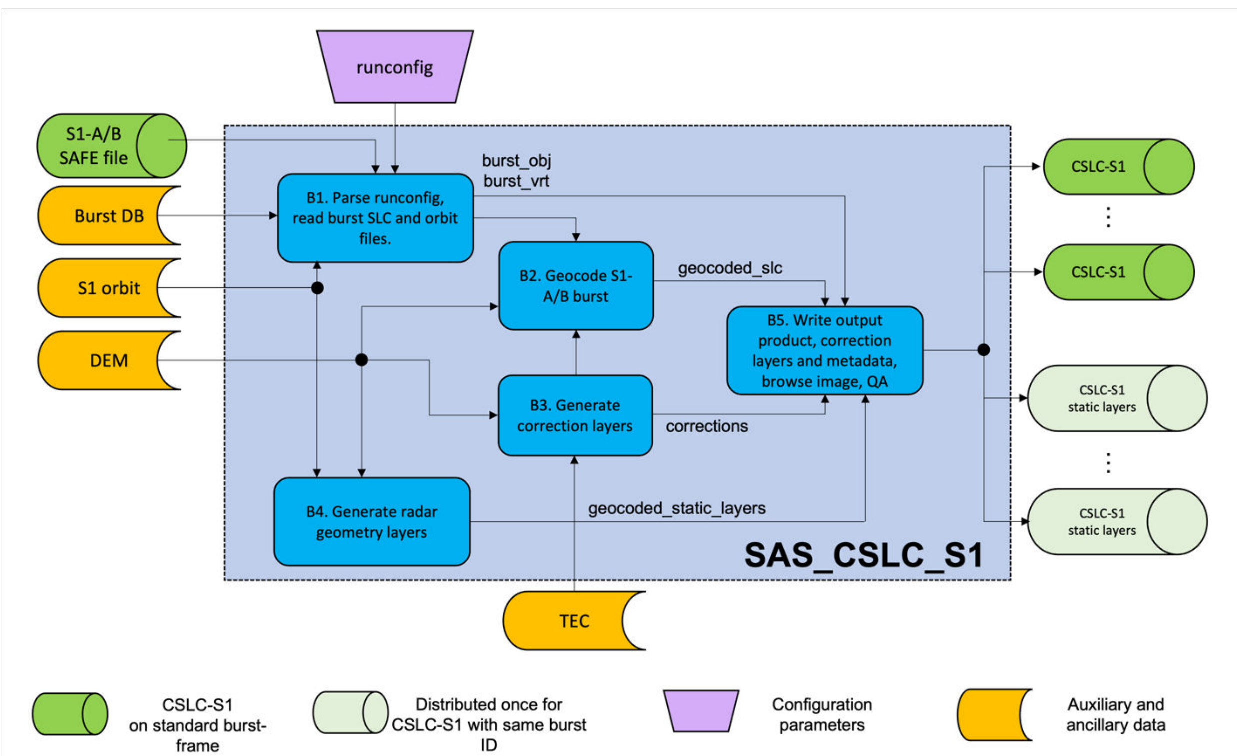

Figure 2-1 OPERA CSLC-S1 workflow diagram.

Input product	Description	Granule Size
S1-A/B SAFE file	S1-A/B SAFE file containing the bursts to process	Variable
S1-A/B orbit ephemeris	The input S1-A/B orbit ephemeris	Variable
Copernicus DEM	GLO-30 Copernicus Digital Elevation Model	Variable
Ionosphere TEC file	Ionosphere TEC map (IONEX format)	Variable
Burst database	SQLite burst database	Fixed

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

2.2 CSLC-S1 Product Overview

CSLC-S1 products are distributed as a Hierarchical Data Format version 5 (HDF5) file following the Climate and Forecast (CF)-1.8 convention and they contain data raster layers (e.g., geocoded complex backscatter) and various product metadata [RD3].
The pixel spacing of a CSLC-S1 product in the Easting and Northing direction is respectively 5 and 10 meters.

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

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

3 PRODUCT ORGANIZATION

3.1 File Format: Hierarchical Data Format version 5

Each OPERA CSLC-S1 product is distributed as a HDF5 file following the CF-1.8 convention [RD3] with separate groups containing the various 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 the development and maintenance of HDF. Users should refer to the HDF Group website at https://portal.hdfgroup.org/display/HDF5/HDF5 [RD4] to download the latest version of the HDF software and the 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 products.

HDF5 Atomic Datatypes	Description
H5T_STD_U8LE	unsigned, 8-bit, little-endian integer
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 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 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, parameters, and 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 the data raster layers and metadata within the product

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

3.2.2 File Level Metadata

Global metadata at the file level are currently given as Global Attributes and are reported 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 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 Specification Document to use as reference for product	JPL-108278
contact	string	Contact information of the agency producing the product	opera-sds-ops@jpl.nasa.gov

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

3.3 CSLC-S1 File Naming Convention

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

Project_Level_ProductType_BurstID_DateTime_ProductGenerationDateTime_Sensor_Pol_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"
- *BurstID*: alphanumerical string uniquely identifying the processed burst. The burst identification string follows the same convention adopted by the ESA burst map [RD5] and it is consistent with the convention *T[TrackNumber]-[BurstIdentificationNumber]-[Swath]* (e.g., "T078-165495-IW3")
- *DateTime*: the acquisition sensing start date and time (format: YYYYMMDDTHHMMSSZ) of the input bust used to generate the product

- *ProductGenerationDateTime*: The date and time (format: YYYYMMDDTHHMMSSZ) at which the product was generated by the OPERA SDS
- *Sensor*: name of the sensor that acquired the input data (e.g., “S1A”)
- *Pol*: two characters indicating the polarization of the burst (e.g., “VV”)
- *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 of a CSLC-S1 product file name:

OPERA_L2_CSLC-S1_ T078-165495-IW3_ 20190906T232711Z_ 20230101T100506Z_S1A_VV_v1.0.h5

3.4 Spatial Organization

CSLC-S1 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 products:

1. All the imagery layers contained in the product are located on the same geographical grid.
2. A time series of CSLC-S1 products with the same burst identification number shares the same geographical grid.
3. 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 temporal sampling matches the temporal sampling of the input S1-A/B burst SLCs. Each S1 satellite can map the global landmasses every 12 days. The constellation of S1-A/B satellites offers a revisit time of 6 days.

4 OPERA CSLC-S1 PRODUCT

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

4.1 Dimensions and Shapes of Data

The dimensions and shapes of the data layers contained in the CSLC-S1 products are described in Sec 5.1. This information is relevant to downstream workflows using CSLC-S1 products 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 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 for processing. 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 products is synchronized with the release tag number of the GitHub repository https://github.com/opera-adt/CSLC-S1_Specs/ containing an XML version of the CSLC-S1 product specification.

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 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 Radar Imagery

The primary CSLC-S1 data layers are included in the group "/data". A detailed list of the data layers included in this group is reported in Sec. 5.3.

4.3.1 Complex Backscatter

The complex backscatter data layer is produced by projecting a S1-A/B burst SLC from a range/Doppler coordinate system onto a uniformly spaced, north-south, and west-east aligned UTM/WGS84. Each pixel of this dataset is a complex number stored under "/data/polarization" where "polarization" indicates the polarization channel of the input burst for which the corresponding CSLC-S1 product is produced (e.g., VV). For example, the complex backscatter layer corresponding to the VV burst polarization is stored under "/data/VV".

4.3.2 Azimuth Carrier Phase

The electronic steering of the S1-A/B antenna in the along-track direction causes the targets to be illuminated with the same antenna pattern. This effect introduces a linear frequency modulation within the input S1-A/B SLC bursts and, consequently, in the complex backscatter layer of CSLC-S1 products. The removal of this linear frequency modulation (i.e., deramping) is a crucial step to perform prior to basic operations e.g., interpolation, resampling [AD5]. The

CSLC-S1 product provides the phase of this linear ramp under "/data/azimuth_carrier_phase" on the same geographical grid of the complex backscatter layer.

4.3.3 Flattening Phase

The complex backscatter of CSLC-S1 products is flattened with respect to a zero-height ellipsoid (i.e., ellipsoidal flattening) and with respect to the topographic height (i.e., topographic flattening) using a DEM. The phase used to perform flattening is provided under "data/flattening_phase" on the same geographical grid of the complex backscatter layer.

4.4 Radar Metadata

Radar metadata needed to interpret the CSLC-S1 product, as well as the geolocation of its data layers are organized under the Group "/metadata".

4.4.1 Calibration Information

The group "/metadata/calibration_information" (see Sec. 5.4) includes several geocoded low-resolution look-up tables needed to perform the calibration of the complex backscatter layer. These look-up tables include e.g., beta naught, sigma naught, and gamma [RD1].

4.4.2 Noise Information

The group "/metadata/noise_information" (see Sec. 5.5) includes a set of geocoded low-resolution look-up tables to perform the correction of the thermal noise effect.

4.4.3 Processing Information

The group "metadata/processing_information", described in Sec.5.6, stores a set of metadata characterizing the data processing performed to generate the product. The main metadata entry of this group is *runconfig* containing a copy of the run configuration file with all the parameters and the input files used for processing.
The "metadata/processing_information" group is further organized in five 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).
2. *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.
3. *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 a description of the DEM used for processing.

4. *parameters*: includes a list of Boolean flags identifying the type of flattening and the set of timing corrections used to process the product [AD5].
5. *timing corrections*: includes a set of low-resolution look-up tables in range/Doppler coordinates which have been used to correct for the S1 Instrument Processing Facility (IPF) artifacts (i.e., bistatic delay, geometry steering Doppler, and azimuth FM-rate mismatch), atmospheric effects (i.e., ionosphere and static troposphere), and Solid Earth tides [AD5].

4.4.4 Other Radar Metadata

4.4.4.1 Orbit

The orbit ephemeris used for generating the CSLC-S1 product can be found under a subgroup named "metadata/orbit" (see Sec. 5.7). This metadata group includes time-tagged antenna phase center position and velocity vectors in a 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. 5.8, includes a set of metrics characterizing the quality of the data layers included in the CSLC-S1 product. The group is further organized in four main subgroups:

1. *orbit information*: including the type of orbit ephemeris (i.e., restituted or precise) used for processing.
2. *pixel classification*: containing information on the percentage of valid pixels with the complex backscatter layer and the percentage of valid pixels covering land.
3. *rfi information*: containing a set of metadata informing if the input burst is affected by Radio Frequency Interference (RFI) and the type of RFI correction performed. This information is directly migrated from the input S1-A/B burst and it is not available for bursts processed by ESA with a version of the IPF processor lower than 3.40 [RD6].
4. *statistics*: including a series of metrics which statistically characterize the main data layers contained in the "/data" group and the timing corrections LUTs contained in "processing_information/timing_corrections". The main statistical metrics contained within this group are the maximum and the minimum value of each data layer, its mean, and its 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 product.

The entries in this table do not present actual datasets in the HDF5 but are meant to be a guide to identify the relationship between similarly sized datasets.

Name	Shape	Description
scalar	scalar	None
CSLCProductWidth	scalar	Number of pixels in CSLC-S1 product imagery datasets
CSLCProductLength	scalar	Number of lines in CSLC-S1 product imagery datasets
CSLCProductShape	(CSLCProductLength, CSLCProductWidth)	Shape associated with CSLC-S1 imagery datasets
correctionsLUTWidth	scalar	Number of pixels in timing corrections look-up table datasets
correctionsLUTLength	scalar	Number of lines in timing corrections look-up table datasets
correctionsLUTShape	(correctionsLUTLength, correctionsLUTWidth)	Shape associate with timing corrections look-up table datasets
LUTWidth	scalar	Number of pixels in calibration and noise corrections look-up table datasets
LUTLength	scalar	Number of lines in calibration and noise corrections look-up table datasets
LUTShape	(LUTLength, LUTWidth)	Shape associated with calibration and noise corrections look-up table 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 coefficient datasets
polynomialCoefficientsLength	scalar	Number of lines in the polynomial coefficients datasets
polynomialCoefficientsShape	(polynomialCoefficients Length, polynomialCoefficients Width)	Shape associated with the polynomial coefficients datasets

Table 5-1 Table of dimensions and shapes in CSLC-S1 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 product specification version	
/identification/product_type	
Type: string	**Shape: scalar**
Description: Product type	
/identification/product_version	
Type: string	**Shape: scalar**
Description: CSLC-S1 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 product identification variables.

5.3 Radar Imagery

Product Imagery Variables	
/data/VV	
Type: complex64	**Shape: CSLCProductShape**
Description: VV geocoded CSLC image	
/data/azimuth_carrier_phase	
Type: float64	**Shape: CSLCProductShape**
Description: Azimuth carrier phase	
/data/flattening_phase	
Type: float64	**Shape: CSLCProductShape**
Description: Flattening phase	
/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: CSLCProductWidth**
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: CSLCProductLength**
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 SAR imagery variables.

5.4 Calibration Information

Calibration Information Variables	
/metadata/calibration_information/azimuth_time	
Type: string	**Shape: scalar**
Description: Start time (format: YYYY-MM-DD HH:MM:SS.6f)	
/metadata/calibration_information/beta_naught	
Type: float64	**Shape: scalar**
Description: Beta naught	

/metadata/calibration_information/dn	
Type: float32	**Shape: LUTShape**
Description: Geocoded DN	
/metadata/calibration_information/gamma	
Type: float32	**Shape: LUTShape**
Description: Geocoded gamma	
/metadata/calibration_information/sigma_naught	
Type: float32	**Shape: LUTShape**
Description: Geocoded sigma naught	
/metadata/calibration_information/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	
utm_zone_number: UTM zone number	
/metadata/calibration_information/x_coordinates	
Type: float64	**Shape: LUTWidth**
Description: CF compliant dimension associated with the X coordinate	
units	meters
/metadata/calibration_information/x_spacing	
Type: float64	**Shape: scalar**
Description: Spacing of the geographical grid along X-direction	
units	meters
/metadata/calibration_information/y_coordinates	
Type: float64	**Shape: LUTLength**

Description: CF compliant dimension associated with the Y coordinate	
units	meters
/metadata/calibration_information/y_spacing	
Type: float64	**Shape: scalar**
Description: Spacing of the geographical grid along Y-direction	
units	meters

Table 5-4 CSLC-S1 calibration information variables.

5.5 Noise Information

Noise Information Variables	
/metadata/noise_information/range_azimuth_time	
Type: string	**Shape: scalar**
Description: Start time (format: YYYY-MM-DD HH:MM:SS.6f)	
/metadata/noise_information/thermal_noise_lut	
Type: float32	**Shape: LUTShape**
Description: Geocoded thermal noise look-up table	
/metadata/noise_information/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 for ellipsoidal figure	
semi_major_axis: Semi-major axis	
spatial_ref: Spatial reference	
utm_zone_number: UTM zone number	
/metadata/noise_information/x_coordinates	

Type: float64	**Shape: LUTWidth**
Description: CF compliant dimension associated with the X coordinate	
units	meters
/metadata/noise_information/x_spacing	
Type: float64	**Shape: scalar**
Description: Spacing of the geographical grid along X-direction	
units	meters
/metadata/noise_information/y_coordinates	
Type: float64	**Shape: LUTLength**
Description: CF compliant dimension associated with the Y coordinate	
units	meters
/metadata/noise_information/y_spacing	
Type: float64	**Shape: LUTLength**
Description: Spacing of the geographical grid along Y-direction	
units	meters

Table 5-5 CSLC-S1 noise information variables.

5.6 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/complex_data_geocoding_interpolator	

Type: string	**Shape: scalar**
Description: Complex data geocoding interpolation method	
/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/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 file 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	
/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 the SAFE file	
/metadata/processing_information/parameters/azimuth_fm_rate_applied	
Type: bool	**Shape: scalar**
Description: If True, azimuth FM-rate mismatch timing correction has been applied	
/metadata/processing_information/parameters/azimuth_solid_earth_tides_applied	
Type: bool	**Shape: scalar**
Description: If True, solid Earth tides correction has been applied in azimuth direction	
/metadata/processing_information/parameters/bistatic_delay_applied	
Type: bool	**Shape: scalar**
Description: If True, bistatic delay timing correction has been applied	
/metadata/processing_information/parameters/dry_troposphere_weather_model_applied	
Type: bool	**Shape: scalar**
Description: If True, dry troposphere correction based on weather model has been applied	
/metadata/processing_information/parameters/elevation_antenna_pattern_correction_applied	
Type: string	**Shape: scalar**
Description: Elevation antenna pattern correction. OPERA: correction applied by s1-reader and COMPASS. ESA: correction was applied by ESA. None: when the correction was not applied.	
/metadata/processing_information/parameters/ellipsoidal_flattening_applied	
Type: bool	**Shape: scalar**
Description: If True, CSLC-S1 phase has been flattened with respect to a zero-height ellipsoid	
/metadata/processing_information/parameters/geometry_doppler_applied	
Type: bool	**Shape: scalar**

Description: If True, geometry steering doppler timing correction has been applied	
/metadata/processing_information/parameters/ionosphere_tec_applied	
Type: bool	**Shape: scalar**
Description: If True, ionosphere correction based on TEC data has been applied	
/metadata/processing_information/parameters/los_solid_earth_tides_applied	
Type: bool	**Shape: scalar**
Description: If True, solid Earth tides correction has been applied in slant range direction	
/metadata/processing_information/parameters/static_troposphere_applied	
Type: bool	**Shape: scalar**
Description: If True, troposphere correction based on a static model has been applied	
/metadata/processing_information/parameters/topographic_flattening_applied	
Type: bool	**Shape: scalar**
Description: If True, CSLC-S1 phase has been flattened to topographic height using a DEM	
/metadata/processing_information/parameters/wet_troposphere_weather_model_applied	
Type: bool	**Shape: scalar**
Description: If True, wet troposphere correction based on weather model has been applied	
/metadata/processing_information/runconfig	
Type: string	**Shape: scalar**
Description: Run configuration file used to generate the CSLC-S1 product	
/metadata/processing_information/timing_corrections/azimuth_fm_rate_mismatch	
Type: float32	**Shape: correctionsLUTShape**
Description: Azimuth FM-rate mismatch mitigation (azimuth) correction as a function of slant range and azimuth time	
units	seconds
/metadata/processing_information/timing_corrections/azimuth_solid_earth_tides	
Type: float32	**Shape: correctionsLUTShape**
Description: Azimuth solid Earth tides (azimuth) correction as a function of slant range and azimuth time	
units	seconds
/metadata/processing_information/timing_corrections/bistatic_delay	

Type: float32	**Shape: correctionsLUTShape**
Description: Bistatic delay (azimuth) correction as a function of slant range and azimuth time	
units	seconds
/metadata/processing_information/timing_corrections/geometry_steering_doppler	
Type: float32	**Shape: correctionsLUTShape**
Description: Geometry steering Doppler (range) correction as a function of slant range and azimuth time	
units	meters
/metadata/processing_information/timing_corrections/los_ionospheric_delay	
Type: float32	**Shape: correctionsLUTShape**
Description: Ionospheric delay correction (range) as a function of slant range and azimuth time	
units	meters
/metadata/processing_information/timing_corrections/los_solid_earth_tides	
Type: float32	**Shape: correctionsLUTShape**
Description: Solid Earth tides (range) correction as a function of slant range and azimuth time	
units	meters
/metadata/processing_information/timing_corrections/slant_range	
Type: float64	**Shape: correctionsLUTWidth**
Description: Slant range of LUT data	
units	meters
/metadata/processing_information/timing_corrections/slant_range_spacing	
Type: float64	**Shape: scalar**
Description: Spacing of slant range of LUT data	
units	meters
/metadata/processing_information/timing_corrections/zero_doppler_time	
Type: float64	**Shape: correctionsLUTLength**
Description: Azimuth time of LUT data	
units	seconds
/metadata/processing_information/timing_corrections/zero_doppler_time_spacing	
Type: float64	**Shape: scalar**

Description: Spacing of azimuth time of LUT data	
units	seconds
/metadata/processing_information/timing_corrections/extended_coefficients/doppler_centroid_azimuth_time	
Type: string	**Shape: polynomialCoefficientsWidth**
Description: Azimuth time for Doppler centroid coefficient data (format: YYYY-MM-DD HH:MM:SS.6f)	
/metadata/processing_information/timing_corrections/extended_coefficients/doppler_centroid_coefficients	
Type: float64	**Shape: polynomialCoefficientsShape**
Description: Doppler centroid coefficients data	
/metadata/processing_information/timing_corrections/extended_coefficients/doppler_centroid_slant_range_time	
Type: float64	**Shape: polynomialCoefficientsWidth**
Description: Slant range time for Doppler centroid coefficient data	
units	seconds
/metadata/processing_information/timing_corrections/extended_coefficients/fm_rate_azimuth_time	
Type: string	**Shape: polynomialCoefficientsWidth**
Description: Azimuth time for FM-rate coefficient data (format: YYYY-MM-DD HH:MM:SS.6f))	
/metadata/processing_information/timing_corrections/extended_coefficients/fm_rate_coefficients	
Type: float64	**Shape: polynomialCoefficientsShape**
Description: FM-rate coefficient data	
/metadata/processing_information/timing_corrections/extended_coefficients/fm_rate_slant_range_time	
Type: float64	**Shape: polynomialCoefficientsWidth**
Description: Slant range time for azimuth FM-rate coefficient data	
units	seconds

Table 5-6 CSLC-S1 processing parameters variables.

5.7 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 5-7 CSLC-S1 orbit metadata variables.

5.8 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_land_pixels	
Type: float64	**Shape: scalar**
Description: Percentage of output pixels labeled as land	
/quality_assurance/pixel_classification/percent_valid_pixels	
Type: float64	**Shape: scalar**
Description: Percentage of output pixels that are valid	
/quality_assurance/rfi_information/VV/is_rfi_info_available[1*]	
Type: bool	**Shape: scalar**
Description: Whether or not RFI information is available	
/quality_assurance/rfi_information/VV/rfi_burst_report/azimuth_time[2*]	

[1*] This metadata field is not present for input S1-A/B granules processed with an IPF version lower than 3.40.
[2]

Type: string	**Shape: scalar**
Description: Azimuth time of the burst report	
/quality_assurance/rfi_information/VV/rfi_burst_report/frequency_domain_rfi_report/isolated_rfi_report/max_percentage_affected_bw[3*]	
Type: float64	**Shape: scalar**
Description: Max percentage of bandwidth affected by isolated RFI in a single line	
/quality_assurance/rfi_information/VV/rfi_burst_report/frequency_domain_rfi_report/isolated_rfi_report/percentage_affected_lines[4*]	
Type: float64	**Shape: scalar**
Description: Percentage of level-0 lines affected by isolated RFI	
/quality_assurance/rfi_information/VV/rfi_burst_report/frequency_domain_rfi_report/max_percentage_bw_affected_persistent_rfi[5*]	
Type: float64	**Shape: scalar**
Description: Max percentage bandwidth affected by persistent RFI in a single processing block	
/quality_assurance/rfi_information/VV/rfi_burst_report/frequency_domain_rfi_report/num_sub_blocks[6*]	
Type: int64	**Shape: scalar**
Description: Number of sub-blocks in the current burst	
/quality_assurance/rfi_information/VV/rfi_burst_report/frequency_domain_rfi_report/percentage_blocks_persistent_rfi*	
Type: float64	**Shape: scalar**
Description: Percentage of processing blocks affected by persistent RFI. In this case, the RFI detection is performed on the mean PSD of each processing block	
/quality_assurance/rfi_information/VV/rfi_burst_report/frequency_domain_rfi_report/sub_block_size*	
Type: int64	**Shape: scalar**
Description: Number of lines in each sub-block[7]	
/quality_assurance/rfi_information/VV/rfi_burst_report/in_band_out_band_power_ratio*	
Type: float64	**Shape: scalar**

[3*] This metadata field is not present for input S1-A/B granules processed with an IPF version lower than 3.40.
4
5
6
7

Description: Ratio between the in-band and out-of-band power of the burst	
/quality_assurance/rfi_information/VV/rfi_burst_report/swath[8*]	
Type: string	**Shape: scalar**
Description: Swath of the burst	
/quality_assurance/rfi_information/VV/rfi_burst_report/time_domain_rfi_report/avg_percentage_affected_samples*	
Type: float64	**Shape: scalar**
Description: Average percentage of affected level-0 samples in the lines containing RFI	
/quality_assurance/rfi_information/VV/rfi_burst_report/time_domain_rfi_report/max_percentage_affected_samples*	
Type: float64	**Shape: scalar**
Description: Maximum percentage of level-0 samples affected by RFI in the same line	
/quality_assurance/rfi_information/VV/rfi_burst_report/time_domain_rfi_report/percentage_affected_lines*	
Type: float64	**Shape: scalar**
Description: Percentage of level-0 lines affected by RFI	
/quality_assurance/rfi_information/VV/rfi_mitigation_domain*	
Type: string	**Shape: scalar**
Description: Domain the RFI mitigation step was performed	
/quality_assurance/rfi_information/VV/rfi_mitigation_performed*	
Type: string	**Shape: scalar**
Description: Activation strategy of RFI mitigation [“never”, “BasedOnNoiseMeas”, “always”]	
/quality_assurance/statistics/data/VV/phase/max	
Type: float64	**Shape: scalar**
Description: Max of phase of VV geocoded SLC	
/quality_assurance/statistics/data/VV/phase/mean	
Type: float64	**Shape: scalar**
Description: Mean of phase of VV geocoded SLC	
/quality_assurance/statistics/data/VV/phase/min	
Type: float64	**Shape: scalar**

[8*] This metadata field is not present for input S1-A/B granules processed with an IPF version lower than 3.40.

Description: Min of phase of VV geocoded SLC	
/quality_assurance/statistics/data/VV/phase/std	
Type: float64	**Shape: scalar**
Description: STD of phase of VV geocoded SLC	
/quality_assurance/statistics/data/VV/power/max	
Type: float64	**Shape: scalar**
Description: Max of power of VV geocoded SLC	
/quality_assurance/statistics/data/VV/power/mean	
Type: float64	**Shape: scalar**
Description: Mean of power of VV geocoded SLC	
/quality_assurance/statistics/data/VV/power/min	
Type: float64	**Shape: scalar**
Description: Min of power of VV geocoded SLC	
/quality_assurance/statistics/data/VV/power/std	
Type: float64	**Shape: scalar**
Description: STD of power of VV geocoded SLC	
/quality_assurance/statistics/timing_corrections/azimuth_fm_rate_mismatch/max	
Type: float64	**Shape: scalar**
Description: Max of azimuth FM-rate mismatch	
/quality_assurance/statistics/timing_corrections/azimuth_fm_rate_mismatch/mean	
Type: float64	**Shape: scalar**
Description: Mean of azimuth FM-rate mismatch	
/quality_assurance/statistics/timing_corrections/azimuth_fm_rate_mismatch/min	
Type: float64	**Shape: scalar**
Description: Min of azimuth FM-rate mismatch	
/quality_assurance/statistics/timing_corrections/azimuth_fm_rate_mismatch/std	
Type: float64	**Shape: scalar**
Description: STD of azimuth FM-rate mismatch	
/quality_assurance/statistics/timing_corrections/azimuth_solid_earth_tides/max	

Type: float64	**Shape: scalar**
Description: Max of azimuth Solid Earth tides	
/quality_assurance/statistics/timing_corrections/azimuth_solid_earth_tides/mean	
Type: float64	**Shape: scalar**
Description: Mean of azimuth Solid Earth tides	
/quality_assurance/statistics/timing_corrections/azimuth_solid_earth_tides/min	
Type: float64	**Shape: scalar**
Description: Min of azimuth Solid Earth tides	
/quality_assurance/statistics/timing_corrections/azimuth_solid_earth_tides/std	
Type: float64	**Shape: scalar**
Description: STD of azimuth Solid Earth tides	
/quality_assurance/statistics/timing_corrections/bistatic_delay/max	
Type: float64	**Shape: scalar**
Description: Max of bistatic delay	
/quality_assurance/statistics/timing_corrections/bistatic_delay/mean	
Type: float64	**Shape: scalar**
Description: Mean of bistatic delay	
/quality_assurance/statistics/timing_corrections/bistatic_delay/min	
Type: float64	**Shape: scalar**
Description: Min of bistatic delay	
/quality_assurance/statistics/timing_corrections/bistatic_delay/std	
Type: float64	**Shape: scalar**
Description: STD of bistatic delay	
/quality_assurance/statistics/timing_corrections/geometry_steering_doppler/max	
Type: float64	**Shape: scalar**
Description: Max of geometry steering Doppler	
/quality_assurance/statistics/timing_corrections/geometry_steering_doppler/mean	
Type: float64	**Shape: scalar**
Description: Mean of geometry steering Doppler	

/quality_assurance/statistics/timing_corrections/geometry_steering_doppler/min	
Type: float64	**Shape: scalar**
Description: Min of geometry steering Doppler	
/quality_assurance/statistics/timing_corrections/geometry_steering_doppler/std	
Type: float64	**Shape: scalar**
Description: STD of geometry steering Doppler	
/quality_assurance/statistics/timing_corrections/los_ionospheric_delay/max	
Type: float64	**Shape: scalar**
Description: Max of LOS ionospheric delay	
/quality_assurance/statistics/timing_corrections/los_ionospheric_delay/mean	
Type: float64	**Shape: scalar**
Description: Mean of LOS ionospheric delay	
/quality_assurance/statistics/timing_corrections/los_ionospheric_delay/min	
Type: float64	**Shape: scalar**
Description: Min of LOS ionospheric delay	
/quality_assurance/statistics/timing_corrections/los_ionospheric_delay/std	
Type: float64	**Shape: scalar**
Description: STD of LOS ionospheric delay	
/quality_assurance/statistics/timing_corrections/los_solid_earth_tides/max	
Type: float64	**Shape: scalar**
Description: Max of LOS Solid Earth tides	
/quality_assurance/statistics/timing_corrections/los_solid_earth_tides/mean	
Type: float64	**Shape: scalar**
Description: Mean of LOS Solid Earth tides	
/quality_assurance/statistics/timing_corrections/los_solid_earth_tides/min	
Type: float64	**Shape: scalar**
Description: Min of LOS Solid Earth tides	
/quality_assurance/statistics/timing_corrections/los_solid_earth_tides/std	
Type: float64	**Shape: scalar**

Description: STD of LOS Solid Earth tides

Table 5-8 CSLC-S1 quality assurance variables.

6 CSLC-S1 SAMPLE PRODUCT

Figure 5-1 shows an example of the CSLC-S1 product processed from a S1-A/B burst acquired over Los Angeles (USA) overlaid on a Landsat-8 image.

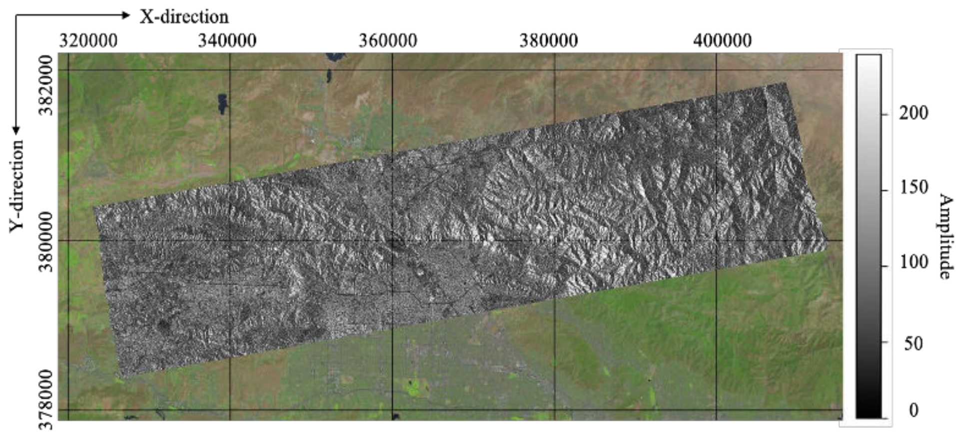

Figure 6-1 CSLC-S1 product amplitude over the Los Angeles area overlaid on a Landsat-8 image.

7 APPENDIX A

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

a. Map Projections

OPERA's SDS is able to ingest any Digital Elevation Model 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 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 products

b. Grid Alignment

OPERA CSLC-S1 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).

8 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
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 Repetion 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